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Via E-Mail

Sonoma County Planning Commission
c/o McCall Miller, Department Analyst,
Cannabis Program, County
Administrator's Office
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Re: Sonoma County Cannabis Land Use Ordinance Update and General Plan Amendment and Draft Subsequent Mitigated Negative Declaration

Dear Commissioners:

This firm represents Save Our Sonoma Neighborhoods ("SOSN") in connection with the Sonoma County Cannabis Land Use Ordinance Update and General Plan Amendment ("Project"). This firm concurrently represents the Friends of Mark West Watershed and will submit separate comments on their behalf. SOSN is concerned that allowing ministerial approval of cannabis cultivation and production sites will have substantial negative effects on the character of rural residential areas, damage sensitive resources, and reduce the quality of life for all County residents.

The purpose of this letter is to inform Sonoma County that the Subsequent Mitigated Negative Declaration ("SMND") for the Project fails to comply with the requirements of the California Environmental Quality Act ("CEQA"), Public Resources Code § 21000 et seq., and the CEQA Guidelines, California Code of Regulations, title 14, § 15000 et seq. ("Guidelines"). As detailed below, numerous inadequacies and omissions in the SMND render it insufficient as an environmental review document. The SMND fails to disclose, analyze, and propose adequate mitigation for significant environmental impacts related to air quality, odor, aesthetics, hydrology and water quality, groundwater supply, transportation, greenhouse gas emissions, and loss of agricultural land, and cumulative effects, among others. What analysis the SMND does present is fraught with errors. For example, the SMND's analysis of the Project's odor impacts fails to employ accepted methods of analyzing odor impacts, fails to present a thorough evaluation of impacts, and fails to provide evidence that identified mitigation will be effective. In addition, the countless vague, voluntary, and unenforceable mitigation measures in the SMND fail to comply with CEQA, which requires enforceable, concrete commitments to mitigation. As a result, the SMND fails to describe measures that could avoid or substantially lessen the Project's numerous significant impacts. In addition, the SMND fails to provide any meaningful analysis of allowing events at cannabis cultivation sites. The pervasive flaws in the document demand that the County prepare an Environmental Impact Report ("EIR") and circulate it for review and comment by the public and public agencies.

This letter is submitted along with the report prepared by our expert consultant, Greg Kamman, Senior Ecohydrologist with CBEC Ecoengineering, whose letter dated March 16, 2021 is attached as Exhibit 1 ("Kamman Report").

I. The County may not approve the Project without preparing an environmental impact report under CEQA.

CEQA is designed to ensure that "the long-term protection of the environment shall be the guiding criterion in public decisions." *Friends of College of San Mateo Gardens v. San Mateo County Community College District* (2017) 11 Cal.App.5th 596, 604 [hereinafter "*San Mateo Gardens II*"] (quoting *No Oil, Inc. v. Los Angeles* (1974) 13 Cal.3d 68, 74). Thus, the statute requires an agency evaluating a project to develop an EIR whenever "substantial evidence supports a fair argument that a proposed project 'may have a significant effect on the environment.'" *Committee for Re-Evaluation of T-Line Loop v. San Francisco Municipal Transportation Agency* (2016) 6 Cal.App.5th 1237, 1245-46 (quoting *Laurel Heights Improvement Assn. v. Regents of University of California* (1993) 6 Cal.4th 1112, 1123).

When an agency approves changes to a previously approved project studied in a prior negative declaration, additional subsequent environmental review is required when "whenever there is substantial evidence to support a fair argument that proposed changes 'might have a significant environmental impact not previously considered . . . .'" *San Mateo Gardens II*, 11 Cal.App.5th at 606 (quoting *Friends of College of San Mateo Gardens v. San Mateo County Community College District* (2016) 1 Cal.5th 937, 959 ["*San Mateo Gardens I*"]; *see also San Mateo Gardens I*, 1 Cal.5th at 953. In other words, an agency *must* prepare a subsequent EIR if substantial evidence supports a fair argument that the proposed changes to the project may result in a significant environmental impact. *San Mateo Gardens II*, 11 Cal.App.5th at 606-07. Proposed changes might have a significant impact "when there is some competent evidence to suggest such an impact, even if other evidence suggests otherwise."[1] *Id.* at 607.

The fair argument standard establishes a "low threshold" for requiring a lead agency to prepare an EIR. *Pocket Protectors v. City of Sacramento* (2004) 124 Cal.App.4th 903, 928. Courts "owe no deference to the lead agency's determination," and judicial review must show "*a preference for resolving doubts in favor of environmental review.*" *Id.* (italics in original). Further, where the agency fails to study an entire area of environmental impacts, deficiencies in the record "enlarge the scope of fair argument by lending a logical plausibility to a wider range of inferences." *Sundstrom v. County of Mendocino* (1988) 202 Cal.App.3d 296, 311.

Substantial evidence supporting a fair argument may consist of personal observations of local residents on nontechnical subjects, *Oro Fino Gold Mining Corp. v. Cty. of El Dorado* (1990) 225 Cal.App.3d 872, 882; *Protect Niles v. City of Fremont* (2018) 25 Cal.App.5th 1129, 1152, as well as expert opinion supported by facts—even if that opinion is not based on a specific analysis of the project at issue, *Pocket Protectors*, 124 Cal.App.4th at 928. In marginal cases, where it is not clear whether there is substantial evidence that a project may have a significant impact and there is a disagreement among experts over the significance of the effect on the environment, the agency "must treat the effect as significant" and prepare an EIR. CEQA Guidelines § 15064(g); *City of Carmel-By-The-Sea v. Board of Supervisors*, (1986) 183 Cal.App.3d 229, 245.

As explained further below, ample evidence supports a "fair argument" that the Project may result in significant environmental impacts that were not studied in the 2016

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[1] The relevant analysis under CEQA's subsequent review provisions concerns the changes since the original Medical Cannabis Land Use Ordinance was adopted in 2016, and not only the changes since the 2018 Amendments to allow adult use cannabis. This is because the 2016 Ordinance was studied in a negative declaration, while the Board of Supervisors determined that the 2018 Amendments were exempt from CEQA. *See* Resolution No. 18-0442 (Oct. 16, 2018). CEQA's subsequent review provisions apply only when there has been a prior *environmental review*. *See* Pub. Res. Code § 21166 (applies "[w]hen an environmental impact report has been prepared for a project"); Guidelines § 15162 (applies "[w]hen an EIR has been certified or a negative declaration adopted for a project"). In any event, the development potential allowed by the 2018 Amendments has not been fully realized. *See* SMND at 18. To the extent the Project would facilitate new development in areas opened to cannabis in 2018, that new development potential must be analyzed as a foreseeable effect of this Project.

Negative Declaration. These impacts would include, but not be limited to: air quality, odor, greenhouse gases, aesthetics, hydrology and water quality, groundwater supply, fire safety, transportation, and loss of agricultural land, among others. Because the Project has the potential to result in significant impacts, the County is required to prepare an EIR before it may approve the Project.

II. The descriptions of the Project and the environmental setting are inadequate.

A. The Project description is incomplete, inaccurate, and inconsistent.

In order for a CEQA document to adequately evaluate the environmental ramifications of a project, it must first provide a comprehensive description of the project itself. "An accurate, stable and finite project description is the *sine qua non* of an informative and legally sufficient EIR." *San Joaquin Raptor/Wildlife Rescue Center v. County of Stanislaus*, (1994) 27 Cal.App.4th 713, 730. As a result, courts have found that even if an environmental document is adequate in all other respects, the use of a "truncated project concept" violates CEQA and mandates the conclusion that the lead agency did not proceed in the manner required by law. *Id.* at 729-30. Furthermore, "[a]n accurate project description is necessary for an intelligent evaluation of the potential environmental effects of a proposed activity." *Id*. at 730 (citation omitted). Thus, an inaccurate or incomplete project description renders the analysis of significant environmental impacts inherently unreliable.

As an initial matter, the SMND does not provide a meaningful description of the "development potential"—*i.e.*, the scope and extent of cannabis cultivation and other commercial cannabis activities—that may be permitted by the proposed updates to the cannabis ordinance ("Ordinance"). The CEQA Guidelines define "project" as "the whole of an action" that may result in a direct or reasonably foreseeable indirect change in the environment, and require the lead agency to fully analyze each "project" in a single environmental review document. CEQA Guidelines § 15378(a); *see also* Guidelines §§ 15165, 15168. CEQA further requires environmental review to encompass future actions enabled or permitted by an agency's decision. *Christward Ministry v. Superior County* (1986) 184 Cal.App.3d 180, 194; *City of Redlands v. County of San Bernardino* (2002) 96 Cal.App.4th 398, 409 ("An evaluation of a 'first phase-general plan amendment' must necessarily include a consideration of the larger project, *i.e.*, the future development permitted by the amendment.").

Here, the SMND purports to provide an outer limit on possible development. The SMND states that "a maximum of up to 65,753 acres" could be subject to future cannabis cultivation. SMND at 16,19. This acreage is 10% of the 657,534 acres in the County that are both zoned for agricultural or resource uses and located on parcels larger than 10 acres, likely to reflect the Project's limit on outdoor cannabis cultivation area to 10% of a parcel. *Id.* As explained below, the SMND's description of the Project's development potential is misleading and inadequate to allow the public and decisionmakers to accurately assess the potential effects of the Ordinance.

Troublingly, the SMND omits any analysis of the possible extent of cannabis cultivation in existing permanent structures. The Ordinance itself contains *no limits* on indoor and greenhouse cultivation canopy in existing permanent structures. *See* proposed § 38.12.030(A)(2) ("Indoor cultivation and greenhouse cultivation canopy in an existing permanent structure is not limited."). The SMND should include a description—or at least an estimate—of the number and extent of existing permanent structures in the County that may be converted to cannabis cultivation and their square footage. The base zoning presumably limits the amount of existing permanent structures plus new permanent structures, so the County could accurately calculate the total amount of indoor cultivation allowed using its existing databases. The SMND should also analyze how much cannabis may be grown in such indoor spaces—especially since indoor cultivation can occur on shelved units, potentially *quadrupling* the canopy area possible in an existing structure. *See* Exhibit 2, Borroughs, Vertical Cultivation (website for retailer of horticultural grow shelves for cannabis operations; "Shelves are engineered for single, double, triple, and even quadruple stacks"). In addition, indoor cultivation can have as many as five harvests per year. This existing permanent structure loophole could portend significant impacts on the environment that have not been analyzed. Because the Ordinance allows an unknown, but potentially massive, amount of indoor cannabis cultivation, the corresponding impacts (in terms of increased water usage, energy usage, VMTs, greenhouse gas emissions, etc.) are similarly unknown, and potentially vast.

The Ordinance also apparently allows indoor cultivation in existing permanent structures *in addition to* both (1) indoor cultivation in up to 43,560 square feet of new or expanded permanent structures *and* (2) outdoor cultivation of 10% or less of a parcel. *See* proposed § 38.12.030(B) (limitations on indoor cultivation apply to "all *new* building coverage," not to *total* building coverage). For example, a grower on a 10-acre parcel could have 1 acre of outdoor cannabis cultivation, in addition to 43,560 square feet of cultivation in a new or expanded permanent structure, plus additional indoor cultivation in existing permanent structures currently on the parcel. As a result, the County's assumption that cannabis activities would occur on no more than 10% of the 657,534 eligible acres is incorrect. The Project could result in converting significantly greater acreage to cannabis cultivation.

The County's incomplete and inaccurate estimate of the Project's full development potential could conceal significant potential impacts. For example, the SMND's hydrology analysis concludes that groundwater supply impacts would likely be less than significant because of "the relatively low quantities of water use (from .002 to 1.8 acre-feet per year)."[2] SMND at 69. The SMND then explains that the size limitations—10 percent of a parcel for outdoor grows and no more than one acre of *new* building coverage—would limit water use at individual sites. SMND at 69. This analysis, however, does not take into account the fact that each site can apparently include outdoor cultivation, indoor cultivation in new structures, and additional indoor cultivation in existing structures; or that indoor cultivation can be multi-tiered or stacked for greater growing area in the same building footprint. Greenhouses and hoop houses can harvest three to five crops per year, a fact the SMND neither mentions nor analyzes. Thus, because of the flawed Project description, the SMND's analysis could be significantly underestimating the amount of water demand that could be created by the Project, which could impact both hydrological and biological resources.

In addition to the flaw identified above, and as described at greater length in section IV, below, the SMND incorrectly describes a central feature of the Project as the conversion of commercial cannabis permitting in agricultural and resource zones from a discretionary to a ministerial process. SMND at 5, 8. The SMND further asserts that various proposed provisions in Article 12 of Chapter 38 set forth standards that do not require the exercise of discretion. SMND at 8-13.

The County's description of the "ministerial" nature of the permit review process established by the Ordinance is inaccurate and misleading: the Ordinance establishes a process that *requires* County officials and staff to exercise discretion. For example, the SMND implies that the County does not need to exercise discretion in evaluating biological resources because permit applications must include "a biotic resource assessment prepared by a qualified biologist that demonstrates," among other things, that the activity subject to the permit "will not impact sensitive or special status species habitat." SMND at 39. The Ordinance also requires discretionary review of a permit application if the qualified biologist recommends mitigation measures. *Id.* The Project,

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[2] By the SMND's own explanation of how to convert inches per year to acre-feet, SMND at 69, fn. 1, these figures appear to be incorrect. If cannabis requires 25-35 inches per year of water for outdoor grows and 20-25 inches per year for indoor grows, SMND at 69, then, assuming a cultivation area of one acre, water use should be approximately 2-3 acre feet per year. Of course, this estimate does not account for possible cultivation on areas considerably larger than one acre or multiple crops per year in hoop houses or greenhouses. And, as explained at greater length by hydrologist Greg Kamman, these figures appear to be gross underestimates. *See* Exhibit 1, Kamman Report (March 16, 2021) (citing estimates of water use from cannabis that are 172%-746% higher than those estimates provided in the SMND).

however, does not include any objective standards to guide County officials in determining whether the biologist's assessment is adequate. Thus, County officials will have to exercise their discretion in making these determinations. *People v. Department of Housing & Community Development* (1975) 45 Cal.App.3d 185, 193-94 (holding that a permit process granting officials broad power to determine whether particular elements were sufficient or adequate required the exercise of discretion). The Project contains many similar examples of plans, studies, and reports prepared by experts, see section IV below, each of which suffers from the same defect. *See also* Exhibit 1, Kamman Report (March 16, 2021) (discussing hydrogeologic reports required for cannabis supply wells located in a priority groundwater basin: "It is my opinion that report/plan review is a discretionary process integral to the authorization of a cannabis cultivation permit that can't be done under a ministerial process.").

The SMND also contains an incomplete and inconsistent description of the special events that may be permitted as part of the Project. For example, the SMND states that the Project would no longer prohibit cannabis-related tours and events, SMND at 5, and that such events would "be *subject to existing regulations* in the Zoning Code," SMND at 13 (emphasis added). The SMND also states, however, that the County is developing a "Winery Events Ordinance" that may address cannabis-related special events. SMND at 18. This assertion that events would be governed by regulations currently under development directly contradicts the prior statement that events would be subject to *existing* regulations. Additionally, because the SMND contains no additional details about the planned winery events ordinance, it is impossible for the public or decision makers to determine what events may be permitted, let alone whether those cannabis-related events will cause or contribute to a significant environmental impact (*e.g.*, by increasing noise, traffic, greenhouse gas emissions, wildland fire evacuation issues, or vehicle miles traveled).

The SMND is similarly inconsistent and inaccurate in its description of the relationship between cannabis cultivation and other forms of agriculture. A core feature of the Project is the revision of the General Plan to include cannabis cultivation within the definition of agricultural land use. SMND at 6. To support this change, the SMND asserts that cannabis cultivation "functions similarly to other agricultural operations." SMND at 14. The SMND, however, repeatedly contradicts this conclusion. For example, the SMND states that, "*due to the unique characteristics of cannabis operations*, under the updated Ordinance *provisions applicable to traditional agriculture are expressly not applicable to cannabis cultivation*." SMND at 25 (emphasis added). The SMND also describes the unique impacts cannabis may have on the environment compared to traditional forms of agriculture. For example, the SMND states that cannabis cultivation and processing operations "generate distinctive odors" that can be "reminiscent of skunks, rotting lemons, and sulfur." SMND at 33; *see also* SMND at 34 (acknowledging that cannabis cultivation "can generate particularly strong odors" compared to other agricultural land uses); Exhibit 3, Thomas Fuller, *'Dead Skunk' Stench from Marijuana Farms Outrages Californians*, New York Times (Dec. 19, 2018) (noting that Sonoma County received hundreds of complaints related to cannabis odor in 2018, and quoting an individual living near a cannabis grow: "It's as if a skunk, or multiple skunks in a family, were living under our house. . . . It's beyond anything you would imagine."). Cannabis cultivation also involves different aesthetic, energy, and hazardous materials practices compared to traditional agriculture. *See* SMND at 19 (explaining that cannabis "often involves the use of visible structures"); SMND at 23 (stating that cannabis may include new light sources in otherwise dark areas); SMND at 48 (describing cannabis's uniquely significant energy demands); SMND at 62 (describing hazardous components of high-powered lights used in cannabis operations). Cannabis cultivation is an intensive land use, involving foul odors and energy and other infrastructure demands, that is more similar to industrial uses than to traditional agriculture. *See, e.g.*, Exhibit 4, John W. Bartok, Jr., Cannabis Business Times, *Greenhouse Efficiency Guide: 21 Cannabis Greenhouse Design Considerations* (describing features like conveyors, heating and hot water boiler systems, fan and louver systems for ventilation, and supplemental lighting requirements). The SMND's inconsistent and inaccurate characterization of cannabis as similar to traditional agriculture is misleading to the public and decisionmakers and serves to conceal cannabis's unique features (odor, energy demand, changes in the visual character of rural areas, etc.) that could contribute to the Project's significant environmental impacts.

The Project description is also muddled by the County's adoption of an entirely new Chapter 26 of the Zoning Code on February 9, 2021. While the current Project includes revisions to Chapter 26, the revisions released with the SMND show changes to the *old* Chapter 26, rather than changes to the *new* Chapter 26 adopted on February 9. The competing versions of Chapter 26 make reviewing the Project more complicated and confusing. Furthermore, they hinder the public's ability to conduct a meaningful review of the changes the proposed Project would cause to the County Code text, implementation of the permitting regime and the physical environment. As a result, it is not possible to determine the full scope or extent of the physical impacts that would result from the Project, which violates CEQA. The County must prepare an EIR that shows the changes that would result as applied to the *new* Code, and include an analysis of the cumulative impact of the Project with the Board's recent action to update Chapter 26.

B. The SMND's description of the environmental setting is inadequate.

The SMND also fails to describe the Project setting as required by CEQA and the CEQA Guidelines. An environmental document "must include a description of the physical environmental conditions in the vicinity of the project, as they exist at the time the notice of preparation is published, or if a notice of preparation is not published, at the time environmental analysis is commenced, from both a local and regional perspective." CEQA Guidelines § 15125(a). This description of the environmental setting constitutes the baseline physical conditions by which a lead agency determines the significance of an impact. *Id.* "Knowledge of the regional setting is critical to the assessment of environmental impacts." CEQA Guidelines § 15125(c). Without such an understanding, any impacts analysis or proposed mitigation becomes meaningless.

The environmental setting section of the SMND consists of four paragraphs and a single map describing (1) the location and extent of lands zoned for agriculture, (2) the number of agricultural acres located on parcels larger than 10 acres, (3) the right-to-farm ordinance, and (4) the number of cannabis permits currently issued and in process. SMND at 16-18.

This bare description of land uses falls far short of the description of physical environmental conditions in the vicinity of the project that is required. For example, the environmental setting entirely lacks a description of where the County's water resources are located. Although the SMND later acknowledges that "[o]ver 80% of the county is designated in marginal Class 3 or 4 zones where groundwater supplies are limited and uncertain," SMND at 69, there is no map or overlay showing where these zones are located and whether (and how) they overlap with areas in which cannabis cultivation may be permitted. This omission makes it difficult to assess whether the Project will have a substantial impact on groundwater supplies.

The same flaw is duplicated as to sensitive waterways and riparian habitats. The SMND does not describe how the County's sensitive waterways may overlap with areas that could be subject to cannabis cultivation.[3] This omission conceals what is likely to be a significant impact of the Project. For example, a comparison of maps of the Mark West Watershed and County zoning maps shows that most of the watershed is covered by the LIA, LEA, and RRD zoning designations, in which the Project would ministerially permit cannabis cultivation. *See* Exhibit 5, Integrated Surface and Groundwater Modeling and Flow Availability Analysis for Restoration Prioritization Planning, Upper Mark West Creek Watershed, Sonoma County, CA (Dec. 2020), Figure E1, Page 2. The SMND also fails to consider or describe the likely linkages between surface water features and groundwater. To fully and accurately analyze whether the Project will have an effect on stream flows—and species and habitats dependent on those flows—in sensitive

[3] While the Project includes required setbacks from riparian corridors, SMND at 40, to assess the effectiveness of those setbacks, the public and decisionmakers must know the extent of cannabis cultivation that may be permitted near waterways.

waterways, the County should describe the relationships between the County's groundwater basins, its surface waterways, and the areas where cannabis cultivation may be permitted. *See* Exhibit 6, Letter from Robert Coey, National Marine Fisheries Service (Feb. 26, 2021) (explaining that groundwater use by cannabis cultivators may affect surface streams and their resident threatened and endangered species).

Continuing the pattern of inadequate information provision, the SMND further fails to show the location of sensitive receptors in or near the zones in which cannabis may be permitted. For example, the SMND concludes that "most future cultivation projects that would use hazardous materials . . . would be removed from existing or proposed school sites" because cannabis cultivation would be permitted in districts "which are generally located in more rural areas of the county." SMND at 64. This level of analysis is inadequate and reflects an inadequate description of physical conditions with respect to sensitive receptors. The County surely possesses information on the location of schools in the County (as well as the locations of retirement homes, convalescent homes, hospitals, medical clinics, and drug and alcohol rehabilitation centers, which are relevant to the air quality analysis under CEQA). It should be a simple matter to include a map showing the locations of these sensitive receptors in relation to the zones in which cannabis may be permitted—or, absent a map, a description of the actual numbers of these types of facilities located within a certain distance of the applicable zones. Only with such information can the public and decisionmakers determine whether the Project would have a significant impact on these facilities and whether the County has required sufficient mitigation to reduce those significant impacts.

In addition to these flaws, the SMND's description of the baseline conditions relevant to wildfires and fire risk is inadequate. Wildfire conditions in the State are changing. California is experiencing record-high temperatures: summers are 2.5 degrees warmer than they were several decades ago, and they are likely to get even hotter. *See* Exhibit 7, Susanne Rust et al., *How climate change is fueling record-breaking California wildfires, heat and smog*, Los Angeles Times (Sep. 13, 2020). These high temperatures remove moisture from plants and soils, increasing fire danger and adding combustible fuel to the landscape. *Id.*; *see also* Exhibit 8, Anne Mulkern, *Fast-Moving California Wildfires Boosted by Climate Change*, Scientific American (Aug. 24, 2020) ("Hotter temperatures, less dependable precipitation and snowpack that melts sooner lead to drier soil and parched vegetation," according to UCLA climate scientist Daniel Swain). According to CalFire, the 2020 wildfire season burned over 4.2 million acres—over 4% of the State—in nearly 10,000 incidents; 33 people died; and over 10,000 structures were damaged and destroyed. *See* Exhibit 9, 2020 Incident Archive, CalFire. As of September 13, 2020, that year had already brought six of the 20 largest wildfires in California's history. *See* Exhibit 7, Rust et al.

Sonoma County has acutely experienced the impact of this changing risk profile. As the County is aware, since 2016, about 25 percent of the County's total acreage has burned in a series of devastating wildfires. Each year has brought a steady succession of damaging blazes. The 2017 Sonoma Complex Fires damaged 112,000 acres in the county; the 2019 Kincade Fire, 78,000 acres; and the 2020 wildfires, approximately 125,000 acres.[4] *See* accounts of recent wildfire seasons by the Sonoma County Agricultural Preservation and Open Space District in Exhibits 10 (2017 Sonoma Complex Fire), 11 (2019 Kincade Fire); and 12 (2020 Wildfires). Frequent wildfires also can allow conversion of burned habitats to non-native plants that burn more easily, further increasing wildfire risk for affected areas. *See* Exhibit 13, Tiffany Yap, et al., Center for Biological Diversity, *Built to Burn: California's Wildlands Developments Are Playing With Fire* (Feb. 2021), p. 4.

While the SMND describes recent fires in Sonoma County, (SMND at 98), it does not adequately describe the physical conditions contributing to wildfire risk. In addition to describing the climatic conditions above, the environmental setting should include descriptions of: (1) areas designated by Cal Fire to be at very high risk in which cannabis permits may be issued; (2) areas where cannabis cultivation may be permitted adjacent to "areas with low- to intermediate-housing density," wildland vegetation, and limited emergency access, *see* SMND at 98; and (3) the current state of the County's roadways in areas where cannabis may be permitted. Regarding the first two items, the location of development—particularly developments like indoor cannabis cultivation and hoop houses (which may have associated electrical equipment, § 38.18.020) involving electrical infrastructure—significantly contributes to wildfire risk. *See* Exhibit 13, Tiffany Yap, et al., at 1 ("Almost all contemporary wildfires in California, 95-97%, are caused by human sources such as power lines, car sparks and electrical equipment. Building new developments in highly fire-prone wildlands increases unintentional ignitions and places more people in danger."). Regarding roadways, the third item, the County itself has acknowledged that roadways in RRD zones provide inadequate access for emergency vehicles. *See* Exhibit 14, Discussion Paper: Key Issues and Policy Options, Cannabis Cultivation within Resources and Rural Development (RRD) Lands ("The remote RRD zoned areas are primarily accessed by one lane gravel roads that are remnants of old logging roads. Most cultivation facilities would be required to construct paved, 2-way roads with an 18-foot minimum width, sufficient for emergency vehicle

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[4] This totals 315,000 acres. Sonoma County has 1.32 million acres, so 27.8 percent of the county burned from 2017 to 2020. *See*, https://en.wikipedia.org/wiki/Sonoma_County,_California.

access.").[5] For the public and decisionmakers to accurately assess whether the cannabis activities permitted by the Project will expose individuals to a significant wildfire risk, the environmental setting must fully describe the existing conditions in which those activities would occur.

The environmental setting's discussion of the current status of cannabis cultivation operations in the County is also inadequate. The SMND notes that 78 ministerial permits and 32 conditional use permits have been issued, and 78 ministerial and 55 conditional use permits are in process. SMND at 18. But particularly because, as the SMND notes, these permits may include renewals, they may involve activities other than cultivation, and may include more than one license for the same location, these figures do not convey any meaningful information about the scope of cannabis activity currently permitted in the County. At the very least, the SMND should state the total acreage permitted for cultivation, broken down by the zoning district in which it is located. This data is needed to inform the County's analysis of cumulative impacts, as well as to reveal the scope of potential new development that may be allowed by the Project.[6]

The SMND's discussion of cannabis operations in the County is also inadequate because it almost entirely ignores illegal cultivation, including its extent and its associated impacts. The SMND notes, without further elaboration or detail, that "[m]any cannabis operations have been operating illegally within the RRD land use areas." SMND at 67. It does not provide even an *estimate* of the number, extent, or actual impacts of these illegal cultivation operations. The extent of illegal operations in the County is an important part of the existing environmental baseline. As the SMND itself acknowledges, unregulated cannabis cultivation can be extremely damaging to the environment. Illegal cannabis cultivation: "has been associated with impacts to biological resources," including to sensitive species and their habitats, SMND at 38; has caused negative impacts to waterways, SMND at 55; and creates "high fire risk" related to "inadequate or improper electrical equipment" and explosions "due to the use of volatile chemicals," all located in "high fire hazard areas due to steep slopes, dense vegetation, and insufficient emergency services due to a lack of safe emergency vehicle access," SMND at 67.

Indeed, the conversion of illegal operations to permitted grows and the associated reduction in environmental impacts was a significant assumption underlying the County's

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[5] Available at
http://sonomacounty.ca.gov/WorkArea/DownloadAsset.aspx?id=2147525642.

[6] The county's ArcGIS data indicates 8,289 parcels meet the criteria of being 10 or more acres and have agricultural or resource zoning: RRD (4,015); LIA (1,158); LEA (1,158); DA (1,665).

determinations that (1) the 2016 Ordinance would not have a significant impact and (2) the 2018 Amendments were exempt from CEQA. *See* 2016 Negative Declaration, p. 2 ("This Ordinance would provide a regulatory structure, with operational standards, to allow existing operators to become permitted."); Resolution 18-0442, p. 3 ("[T]he Ordinance expands regulation of the County's cannabis industry to encompass adult-use for the full supply chain, encouraging illegal cannabis cultivators to come into compliance with the environmental protection standards provided for in the Ordinance."). The 2016 Negative Declaration estimated that there were as many as *ten thousand* existing (unregulated) cultivators, the majority of which were located in the RRD zone. 2016 Negative Declaration at 2. According to the 2016 Negative Declaration, "[u]nregulated cannabis cultivation is associated with habitat destruction, pollution of waterways, illegal road construction causing erosion and increased sedimentation, unauthorized use of pesticides, illegal water diversion, large amounts of trash, human waste, non-biodegradable waste, and excessive water and energy use," as well as "offensive odor, security and safety concerns," and "use of hazardous materials." *Id.* An analysis in Bennett Valley found that "[c]ontrary to the ordinance's stated goals, no ongoing operations were legalized in Bennett Valley; all began after the supervisors invited cultivation here." Harrison, Status of Commercial Marijuana Projects in Bennett Valley, Bennett Valley Voice (January 2021), Exhibit 15.

To accurately assess the Project's impacts on the current environment, the County must provide data and analysis concerning current status of illegal operations on the County. The County and the public must be able to determine whether the current regulations have succeeded in converting illegal operations to permitted grows or if, in fact, the legal, regulated regime has grown up alongside and in addition to the prior illegal regime. Indeed, evidence suggests that the latter is more likely. *See* Exhibit 16, Thomas Fuller, The New York Times, *'Getting Worse, Not Better': Illegal Pot Market Booming in California Despite Legalization* (Apr. 27, 2019) (since legalization, "the unlicensed, illegal market is still thriving and in some areas has even expanded."); Exhibit 17, Joseph Detrano, Rutgers Center of Alcohol & Substance Abuse Studies, *Cannabis Black Market Thrives Despite Legalization* (noting that unregulated cannabis may be cheaper than legal product, and thus more attractive, because it is not subject to tax). But without this information, it is impossible for the County and the public to assess the Project's impacts, including (1) whether the Project will reduce impacts of illegal grows by bringing cultivators into compliance, or (2) whether the County's environmental baseline is significantly off because it fails to account for the impacts associated with thousands of illegal operations.

In short, the SMND's incomplete description of the Project and its environmental setting frustrates the core goals of CEQA: to provide a vehicle for intelligent public participation and to provide an adequate environmental impact analysis. See *County of Inyo v. City of Los Angeles*, (1977) 71 Cal.App.3d 185, 197.

III. The SMND's analysis impermissibly focuses solely on the impacts of individual permits and fails to adequately analyze the impacts of the Project as a whole.

The CEQA Guidelines define a "project" as "*the whole of an action*" that may result in a direct or reasonably foreseeable indirect change in the environment. Guidelines § 15378(a). "'Project' is given a broad interpretation in order to maximize protection of the environment." *McQueen v. Bd. of Directors* (1988) 202 Cal.App.3d 1136, 1143 (disapproved on other grounds). The analysis of a project's environmental effects must occur at the earliest discretionary approval. *See, e.g.*, *Laurel Heights Improvement Assn. v. Regents of University of California* (1988) 47 Cal.3d 376, 396 (EIR must analyze future action that is a "reasonably foreseeable consequence" of the initial action that would "likely change the scope or nature" of the effects of the initial action).

A lead agency considering an ordinance or a general plan amendment must analyze the impacts of all the potential activity that may be permitted by or could foreseeably result from those actions. *See Terminal Plaza Corp. v. City and County of San Francisco* (1986) 177 Cal.App.3d 892, 905 (City was required to prepare an EIR to analyze the reasonably foreseeable effects of an ordinance). This analysis is required even though enacting an ordinance or general plan amendment is, in itself, an action that occurs largely on paper. *See* Guidelines § 15378(c) ("The term 'project' refers to the activity which is being approved" and not "each separate governmental approval."). CEQA documents must analyze an ordinance's full potential level of development. As the court in *City of Redlands v. County of San Bernardino* explained, "an evaluation of a 'first phase-general plan amendment' must necessarily include a consideration of the larger project, i.e., the *future development permitted* by the amendment." (2002) 96 Cal.App.4th 398, 409 (emphasis added). Environmental review of the development allowed by a planning enactment must take place regardless of whether that development will actually materialize. *See Bozung v. Local Agency Formation Comm'n of Ventura County* (1975) 13 Cal.3d 263, 279, 282; *Christward Ministry v. Superior Court* (1986) 184 Cal.App.3d 180, 194–95 ("The fact future development is not certain to occur and the fact the environmental consequences of a general plan amendment changing a land use designation are more amorphous does not lead to the conclusion no EIR is required"); *City of Carmel-by-the-Sea v. Board of Supervisors of Monterey County* (1986) 183 Cal.App.3d 229, 235 (EIR for rezoning must be prepared even though "no expanded use of the property was proposed"). The lead agency's obligation to *fully* review an activity's potential environmental effects applies even when the activity is subject to later discretionary approvals. *Laurel Heights*, 47 Cal.3d at 396. That obligation is especially important, however, when the later approvals would be ministerial and would not present an opportunity for further environmental review or mitigation.

Here, the SMND fails to analyze the impacts of the Project as a whole—i.e., whether the sum of all potential activities that may be allowed by the Ordinance would have a significant environmental impact. Instead, the SMND repeatedly bases its analysis of the Project's impacts on whether *each individual permit* that may be issued under the Ordinance would have a significant effect or violate a threshold of significance. This type of analysis is impermissible. *Cf. Bozung v. Local Agency Formation Commission* (1975) 13 Cal.3d 263, 283-84 ("[E]nvironmental considerations do not become submerged by chopping a large project into many little ones—each with a minimal potential impact on the environment—which cumulatively may have disastrous consequences."). The County's analysis is equivalent to determining that a massive shopping center development would not have a significant impact on the environment because the impacts of each individual store would be less than significant. This type of analysis does not inform the public or decisionmakers about the effects of the Project as a whole.

For example, the SMND's analysis of vehicle miles traveled ("VMT") is improperly focused on the impacts of individual permits rather than the Project as a whole. The VMT analysis uses screening criteria applicable to "small projects" that generate fewer than 110 vehicle trips per day. SMND at 89. The SMND then explains that "many, if not most, cannabis cultivation projects" would generate fewer than 110 average daily trips; and that larger projects exceeding 110 average daily trips would have to implement measures to reduce VMT. *Id*. As a result, the SMND concludes that VMT-related impacts would be less than significant. *Id.*

The proper frame for analysis of VMT is not the VMT that would be generated by each individual permit, but the VMT that would be generated by all potential permits allowed by the Project. According to the Office of Planning and Research ("OPR"), general plans or other land use plans "may have a significant impact on transportation if proposed new . . . land uses would *in aggregate* exceed" thresholds of significance recommended by OPR. Exhibit 18, OPR, Technical Advisory: On Evaluating Transportation Impacts in CEQA (December 2018), at p. 18 (emphasis added). OPR's recommended thresholds state, for example, that office projects may have significant impacts if their VMT exceeds the threshold of 15% below existing regional VMT per employee, or retail projects may have significant impacts if they create a net increase in total VMT.[7] *Id.* at pp.15-16. Instead of relying on the aggregate thresholds described by

[7] The same OPR document warns that "isolated rural development" of the sort contemplated in the present Project (which concerns development in RRD districts) lacks

OPR, the SMND's analysis employing the "small project" threshold effectively defines "the Project" as an individual permit, rather than as the Ordinance and General Plan Amendment.[8] This is impermissible. The County must correct this VMT analysis, using an appropriate threshold and frame of analysis that focuses on the Project as a whole. *See* Guidelines § 15378(a); *City of Redlands*, 96 Cal.App.4th 398.

The SMND's analysis of biological resources is similarly flawed. The Project requires each applicant to include a biotic resource assessment that "demonstrates that the cannabis cultivation area and related structures and development will not impact sensitive or special status species habitat." SMND at 39. Each assessment, however, will focus on the impacts from "the cannabis cultivation area" associated with an individual permit, and not the combined potential impacts of all of the cannabis permits allowed by the Project. The SMND concludes that these assessments, combined with exclusions from limited biotic habitat combining zones and setbacks from riparian corridors, would result in a less than significant impact to sensitive species and riparian habitat. SMND at 40-41.

This myopic analysis misses significant potential impacts of the Project as a whole. The SMND acknowledges that cannabis activities will rely on a combination of surface or well water sources. SMND at 69. It then concludes that it is unlikely that cultivators using groundwater would result in overdraft. *Id.* This conclusion, however, is not explained and is based on unsupported estimates of groundwater usage from cannabis cultivators. *See* Exhibit 1, Kamman Report (March 16, 2021) (criticizing the SMND's conclusion). But even assuming that each individual cultivator's water usage is not enough, on its own, to reduce water supplies in a way that threatens sensitive species and

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the VMT benefits present for projects in small towns or cities with access to transit. *Id.* at p. 21.

[8] The SMND briefly gestures toward the threshold addressing 15% reductions below existing VMT levels. SMND at 89. However, the analysis that follows suggests that the Project would *exceed* this threshold, stating that new projects would be "located in rural areas of the County, where existing average trip lengths are higher." *Id.* The SMND also notes that the conversion of existing agriculture to cannabis cultivation would not necessarily result in additional trips, SMND at 89, but this statement is contradicted by the SMND itself and unsupported by any evidence. On the previous page, the SMND states that large greenhouse cultivation operations could result in additional vehicle trips compared to existing uses. SMND at 88 ("[L]arge greenhouse cultivation operations could have 100 to 200 employees commuting to cultivation sites, resulting in additional vehicle trips compared to existing agricultural uses."). Further, the SMND does not appear to assess, let alone to support with evidence, whether cannabis is likely to replace existing agricultural acreage as opposed to adding additional acreage.

riparian habitat, a group of cultivators all drawing water from the same surface water source, from hydrologically-linked surface water sources, or from hydrologically-linked groundwater basins could significantly decrease the water available for in-stream flows despite required setbacks, potentially harming the plant and animal species that rely on those flows. *See also* Letter from Friends of Mark West Watershed to the Planning Commission dated March 18, 2021.

The combined impact of multiple cultivators drawing upon limited groundwater supplies could have significant impacts on biological resources. For example, a recent analysis of streamflow in the Mark West Watershed prepared for the Sonoma Resource Conservation District and California Wildlife Conservation Board emphasized the importance of groundwater to providing habitat for sensitive species. According to the streamflow analysis, groundwater discharge "represents the primary process responsible for generating summer streamflow" in the watershed. Exhibit 5, Jeremy Kobor, et al., Integrated Surface and Groundwater Modeling and Flow Availability Analysis for Restoration Prioritization Planning, Upper Mark West Creek Watershed, Sonoma County, CA (Dec. 2020) at p. 3. The report also showed that human consumption of groundwater threatens streamflow, concluding that groundwater pumping depleted streamflows over the long term. *Id.* at p. 11. The study determined that increased demand for groundwater, combined with other factors, make efforts to sustain or improve streamflows "of paramount importance for coho recovery" in the watershed. *Id.* at p. 25; *see also id.* at 1 ("The Mark West Creek watershed provides critical habitat for threatened and endangered anadromous fish"). Similarly, hydrogeologist Greg Kamman emphasized that one of his "biggest concerns" regarding stewardship of natural resources in Sonoma County is "the increased demand on already stressed groundwater supplies." Exhibit 1, Kamman Report (March 16, 2021).

The biotic resources assessments, with their narrow focus on each individual permit applicant's activities, would not address the combined effects of multiple permittees decreasing groundwater available for streamflows. An EIR for the Project that analyzes these combined potential effects of all potential permits allowed by the Project is the proper place for this analysis, as well as an analysis of feasible mitigation to address such impacts.

IV. The permit approval process contemplated by the Ordinance requires the exercise of discretion by County officials.

The Ordinance purports to allow "ministerial" approvals of commercial cannabis operations throughout the County. Yet, proposed Chapter 38 does not describe ministerial approvals. Per the Ordinance's plain language, every approval of a commercial cannabis operation will necessarily be a discretionary action and thus subject to CEQA. By adopting an ordinance that purports to authorize "ministerial" approvals which in actuality trigger CEQA, the County is heading toward certain litigation from those objecting to future siting decisions for commercial cannabis operations, and from applicants for these projects.

"A project is discretionary when an agency is required to exercise judgment or deliberation in deciding whether to approve an activity. It is distinguished from a ministerial project, for which the agency merely determines whether applicable statutes, ordinances, regulations, or other fixed standards have been satisfied. Ministerial projects are those for which the law requires [an] agency to act ... in a set way without allowing the agency to use its own judgment .... They involve little or no personal judgment by the public official as to the wisdom or manner of carrying out the project. The public official merely applies the law to the facts as presented but uses no special discretion or judgment in reaching a decision." *Protecting Our Water & Env't Res. v. Cty. of Stanislaus* (2020) 10 Cal.5th 479, 489 ("*POWER*") (internal quotations and citations omitted).

Under the proposed Ordinance, the Agriculture Commissioner *must* use his judgment to decide whether to issue permits. Thus, this is different from the situation in *Sierra Club v. County of Sonoma* (2017) 11 Cal.App.5th 11, where the court held that the permit in question did not involve the Commissioner's judgment, even though the County's ordinance might allow for discretion in other instances. *Sierra Club* therefore does not apply here. Instead, a court would hold that the County has improperly classified *all* commercial cannabis permit approvals under the ordinance as ministerial, when in fact the ordinance requires the Commissioner to exercise discretion for each permit. *POWER*, 10 Cal.5th at 499 ("County's blanket classification … enable[d] County to approve some discretionary projects while shielding them from CEQA review").

The Ordinance in many instances requires plans or surveys by qualified professionals to assess impacts, but does not provide standards governing *how* these surveys/plans will be evaluated or deemed sufficient. Thus, County officials will have to exercise discretion to determine whether they are good enough.

For example, every permit application must include a "biotic resource assessment" that "demonstrates" to the Commissioner's satisfaction that the project would not impact sensitive or special status species habitat. Proposed § 38.12.070(A)(1). Whether this plan adequately demonstrates the avoidance of impacts—including whether surveys were properly conducted to determine the presence of sensitive or special status species habitat, and what constitutes an "impact"—is necessarily left to the Commissioner's individual discretion, a task for which he typically lacks expertise.

Similarly, each permit application must include a wastewater management plan that, among other things, "demonstrates" to the Commissioner's satisfaction that the project would have adequate capacity to handle domestic wastewater discharge from employees. Proposed § 38.12.130(A)(5). Each application must also include a storm water management plan and an erosion and sediment control plan that "ensure," again to the Commissioner's satisfaction, that runoff containing sediment or other waste or byproducts does not drain to the storm drain system, waterways or adjacent lands. Proposed § 38.12.130(B). Obviously, whether an applicant's plans sufficiently "demonstrate" the necessary wastewater capacity, or "ensure" that runoff would not drain to waterways, would require the Commissioner's individual judgment. Proposed sections 38.12.070(A)(1), 38.12.130(A)(5) and 38.12.130(B) apply to *all* applications regardless of size or proposed location. Each applicant must submit an energy conservation plan to reduce energy use below the threshold of significance. § 38.12.110. The Commissioner must exercise his personal judgment as to whether the plan is adequate. Thus the Commissioner will have to exercise his discretion for every permit application they process.

Other provisions that require the exercise of discretion to approve or deny a permit include, but are not limited to, proposed sections 38.12.050(B) (historic resource survey), 38.12.050(C) (cultural resource survey), 38.12.130 (wastewater management plan), and 38.12.140 (documentation of water supply).

Furthermore, unlike in *Sierra Club*, here the Commissioner's necessary exercise of discretion under the Ordinance would be directly tied to the mitigation of impacts from individual projects. For instance, the SMND states that "future cannabis projects facilitated by a ministerial permit . . . could result in direct and indirect impacts on sensitive biological resources including sensitive-status species. . . However, to *reduce impacts* to status species and their habitat," applicants would be required to submit the "biotic resource assessment." SMND at 39. As explained above, the Commissioner would have authority to decide whether this assessment adequately demonstrates that no impact would occur—in other words, whether the impact is effectively mitigated.

The Commissioner or County staff would also have discretion to determine the adequacy of the applicant's VMT analysis demonstrating whether a proposed project would add fewer than 110 average daily vehicle trips. SMND at 89, 90. Staff shall "verify[]" that a project complies with applicable County or recommended State thresholds related to VMT and that, "if necessary, [the project] incorporates appropriate VMT-reducing measures consistent with the requirements in Mitigation Measure TRANS-1." *Id.* at 90. With implementation of Mitigation Measure TRANS-1, "[t]his impact would be less than significant with mitigation incorporated." *Id.* at 89. Yet, clearly, staff would need to exercise discretion to "verify" whether the applicant's VMT analysis is adequate and whether a project "incorporates VMT-reducing measures." *Id.* at 90.

CEQA, and not the personal judgment of County staff, governs the discretionary review of projects, including mitigation of impacts. *See Sierra Club*, 11 Cal.App.5th at 22 (ministerial approval process "is one of determining conformity with applicable ordinances and regulations, and the official has no ability to exercise discretion to mitigate environmental impacts"). Here, however, the Commissioner and/or staff would have the authority to deny a proposed project which in their judgment would not avoid biological, vehicle miles traveled, or other environmental impacts. *Id.* at 23 (if agency can deny, or modify, project proposal in ways that would mitigate environmental problems that CEQA compliance might conceivably have identified, then the process is discretionary). Thus, the proposed Ordinance contemplates a discretionary, and not ministerial, approval process.

If adopted, the Ordinance's permit approval regime would be in clear violation of CEQA, and each permit approval would risk a legal challenge and ultimately being overturned by a court. The County must revise the Ordinance and accompanying environmental document to acknowledge that all subsequent permit approvals will necessarily be discretionary decisions subject to review under CEQA.

V. The SMND's analyses of and mitigation for the Project's environmental impacts are legally inadequate.

The evaluation of a proposed project's environmental impacts is the core purpose of an EIR. *See* CEQA Guidelines § 15126.2(a) ("An EIR shall identify and focus on the significant environmental effects of the proposed project"). As explained below, the SMND fails to analyze the Project's numerous environmental impacts, including those affecting land use, transportation and circulation, air quality, biological resources, odor, climate change, public health and safety, and noise. In addition, as discussed above, the SMND never considers the full impacts of the Project—the impacts of the foreseeable impacts of facilitating ministerial approval of cannabis cultivation and production and of events that the proposed Project would allow. In this way, the SMND fails to disclose the extent and severity of the Project's broad-ranging impacts. This approach violates CEQA's requirement that environmental review encompass all of the activity allowed by the proposed Project. The County must analyze all of the aggregated impacts of all of the foreseeable development and activities. Without this analysis, the environmental review will remain incomplete and the Project cannot lawfully be approved.

Below, we discuss several examples of impact areas with particular deficiencies. To ensure that both decision makers and the public have adequate information to consider the effects of the proposed Project, and to comply with CEQA's requirements, the County must prepare an EIR that properly describes the Project, analyzes its impacts, and considers meaningful mitigation measures that would help ameliorate those impacts.

The SMND claims that it is a "programmatic" document and therefore detailed analysis is not within its scope. SMND at 36. Even if it were a programmatic analysis, however, the 'programmatic' nature of this SMND is no excuse for its lack of detailed analysis. CEQA requires that a program EIR provide an in-depth analysis of a large project, looking at effects "as specifically and comprehensively as possible." CEQA Guidelines § 15168(a), (c)(5). Because it looks at the big picture, a program level analysis must provide "more exhaustive consideration" of effects and alternatives than an EIR for an individual action, and must consider "cumulative impacts that might be slighted by a case-by-case analysis." CEQA Guidelines § 15168(b)(1)-(2).

Further, it is only at this early stage that the County can design wide-ranging measures to mitigate County-wide environmental impacts. *See* CEQA Guidelines § 15168(b)(4) (programmatic EIR "[a]llows the lead agency to consider broad policy alternatives and program wide mitigation measures at an early time when the agency has greater flexibility. . . ."). A "program" or "first tier" EIR is expressly not a device to be used for deferring the analysis of significant environmental impacts. *Stanislaus Natural Heritage Project v. County of Stanislaus* (1996) 48 Cal.App.4th 182, 199. It is instead an opportunity to analyze impacts common to a series of smaller projects, in order to avoid repetitious analyses. Thus, it is particularly important that the environmental analysis for this Project analyze the overall impacts for the complete level of development it is authorizing now, rather than when individual specific projects are proposed at a later time.

Deferring analysis to a later stage is unlawful as it leaves the public with no real idea as to the severity and extent of environmental impacts. Where, as here, the environmental review document fails to fully and accurately inform decisionmakers and the public of the environmental consequences of proposed actions, it does not satisfy the basic goals of CEQA and its Guidelines. *See* Pub. Resources Code § 21061 ("The purpose of an environmental impact report is to provide public agencies and the public in general with detailed information about the effect which a proposed project is likely to have on the environment . . . ."). The evaluation of a proposed project's environmental impacts is the core purpose of an EIR. *See* Guidelines § 15126.2(a) ("An EIR shall identify and focus on the significant effects of the proposed project on the environment."). It is well-established that the County cannot defer its assessment of important environmental impacts until after the project is approved. *Sundstrom v. County of Mendocino* (1988) 202 Cal.App.3d 296, 306-07.

The SMND fails to provide the legally required analysis of the extensive growth in cannabis cultivation (from about 50 acres currently to as many as 65,753 acres, a 1,300 fold increase) and operations that the Project allows and promotes. Thus, the County must revise the environmental analysis to accurately disclose the impacts of the maximum amount of cannabis cultivation allowed by the Project. Detailed below are the specific legal inadequacies of the SMND's various impact sections.

A. The SMND fails to adequately analyze and mitigate the Project's air quality and odor emissions

The SMND's analysis of Project-related air quality and odor impacts contains numerous deficiencies that must be remedied in order for the public and decision-makers to fully understand the Project's impacts. Specifically, the evaluation of the Project's air quality impacts must be revised to address: (1) failure to adequately analyze Project operation pollutants; (2) failure to adequately analyze odor emissions; (3) deficient analysis of project-related public health impacts; (4) and failure to identify all feasible mitigation measures for significant impacts. These issues, and other deficiencies, are discussed in greater detail below.

1. The SMND fails to adequately analyze and mitigate the Project's potential to create objectionable odors.

New and expanded cannabis cultivation and production sites facilitated by the proposed Project have the potential to generate significant odors impacting nearby sensitive receptors. As the California Air Resources Board Air Quality makes clear "the types of facilities that can cause odor complaints are varied and can range from small commercial facilities to large industrial facilities…". California Environmental Protection Agency and California Air Resources Board Air Quality and Land Use Handbook: A Community Health Perspective, 2005 at 32 and 33; excerpts attached as Exhibit 19. Odors can cause health symptoms ranging from psychological (e.g., irritation, anger, or anxiety) to physiological (e.g., circulatory and respiratory effects, nausea, vomiting, and headache). *Id*. and BAAQMD CEQA Guidelines at 7-1; excerpts attached as Exhibit 20. As discussed in detail below, the SMND for the Project fails to take seriously the significant odor impacts resulting from cannabis cultivation and processing sites.

a. The SMND fails to follow applicable guidance on methods to evaluate the significance of odor impacts.

The BAAQMD CEQA Guidelines provide guidance for lead agencies evaluating odor impacts. The BAAQMD CEQA Guidelines also provide odor screening distances recommended by agency for a variety of land uses. The guidance specifies that "Projects that would site a new odor source or a new receptor farther than the applicable screening distance shown in Table 3-3 from an existing receptor or odor source, respectively, would not likely result in a significant odor impact."

The BAAQMD CEQA Guidelines also recommend a multi-step process to comprehensively analyze the potential for an odor impact. These include:

- Disclosure of Odor Parameters: this includes information on the type and frequency of the odors, the distance and landscape between the odor sources and sensitive receptors, predominant wind direction and speed, and whether the sensitive receptors would be upwind or downwind from the odor sources. BAAQMD CEQA Guidelines at 7-2.

- Odor Screening Distances: The BAAQMD CEQA Guidelines provide odor screening distances for a variety of land uses. The guidance specifies that Projects that would locate sensitive receptor(s) to odor source(s) closer than the screening distances would be considered to result in a potential significant impact. *Id*. The Guidelines list a variety of land uses known to cause odors. Although cannabis cultivation sites are not specifically included, the list includes such uses as composting facilities, food processing facilities, and green waste and recycling operations. We note that all of the screening distances cited by the BAAQMD range from one to two miles. BAAQMD CEQA Guidelines at 3-4.

- Odor Complaint History: the impact of an existing odor source on surrounding sensitive receptors should also be evaluated by identifying the number of confirmed complaints received for that specific odor source. The Air District recommends that lead agencies take all odor complaints (including ones made to BAAQMD) and evaluate the distance from source to receptor. It also recommends using odor complaints from surrogate odor sources to evaluate if the new source would result in significant odor impacts. BAAQMD CEQA Guidelines at 7-3.

- Significance Determination: lastly, the lead agency should use the information obtained from the steps above to reach a conclusion regarding the significance of the odor impact. *Id*. If an agency concludes there is the potential for significant odor impacts, "BAAQMD considers appropriate land use planning the primary method to mitigate odors." *Id*. The agency recommends that "providing sufficient buffer zones between sensitive

> receptors and odor sources should also be considered prior to analyzing implementation of odor mitigation technology." *Id*.

Here, as discussed below, the SMND pays short shrift to this important issue and entirely fails to apply these established methods of evaluating odor impacts.

b. The SMND presents incomplete and inaccurate analysis of the Project's anticipated odor impacts.

The SMND acknowledges that "[O]dors from cannabis cultivation sites have been described as reminiscent of skunks, rotting lemons, and sulfur..." SMND at 33. The SMND also discloses that "[P]revailing winds carry cannabis odors to downwind residences" and "potentially generate odors that adversely affect a substantial number of people." SMND at 34. However, the SMND's cursory discussion omits any actual analysis of how sources of odorous emissions caused by implementation of the Project would impact sensitive receptors.

Odors from cannabis cultivation sites result from both indoor and outdoor cultivation areas and include odors from manure fertilizer. The molecules that cause most of the foul odors from cannabis cultivation are aromatic volatile organic compounds called terpenes. While the SMND claims that odors are worst during harvesting in the months of September and October, residents living near existing cannabis cultivation sites report experiencing pungent odors from June through November if there is a single harvest, but many cultivators have two or three harvests. (Personal Communication, C. Borg, Urban Planner and members of Save Our Sonoma Neighborhoods, March 8, 2021.) Contradicting the claims by the County that odor is only a 2-month a year problem, a group of neighbors on Abode Road, Petaluma, filed suit in August 2018 after a "strong skunky smell of cannabis cloaked the neighborhood" since spring, causing "significant breathing problems" for a young paraplegic who relies on a breathing tube and was at risk of suffocation. *See* Johnson, Neighbors file federal lawsuit to shut down Sonoma County cannabis grower, Press Democrat August 31, 2018), Exhibit 21; Letter from Stefan and Carol Bokaie, Exhibit 22.

Aside from misrepresenting the extent and duration of odor impacts on nearby sensitive receptors, the SMND fails to provide *any* information on current odor impacts and current odor control systems that may be in place at existing facilities. Such information would inform the public and decisionmakers about anticipated impacts and the efficacy of odor control systems. Notwithstanding the failure of the SMND to provide this rudimentary information about odor sources and odor control systems at existing sites, the SMND is silent with regard to the County's historical record of odor complaints. Had the County undertaken this analysis, it would likely have concluded that the current setbacks have proven to be grossly ineffective, with many area residents suffering from offensive odors as a result of cannabis cultivation operations. County residents indicate that the smell from the such sites can be overwhelming. Individuals also state that they have called the County and the BAAQMD on multiple occasions. It is important to point out that the BAAQMD typically responds to these callers with a perfunctory explanation, stating that nothing can be done since the facility has a permit to operate. Similarly, calls to the County have generally not yielded any change in ameliorating odors despite the fact that the County Code currently considers odor from cannabis a nuisance. *See*, County Code § 26-88-250 (f) (Health and Safety. Medical cannabis uses shall not create a public nuisance or adversely affect the health or safety of the nearby residents or businesses by creating dust, light, glare, heat, noise, noxious gasses, odor, smoke, traffic, vibration, unsafe conditions or other impacts, or be hazardous due to the use or storage of materials, processes, products, runoff or wastes.) Testimonies from residents filing complaints constitute substantial evidence to support a fair argument that the proposed Project may have result in a significant odor impact. In *Oro Fino Gold Mining Co. v. County of EI Dorado* (1990) 225 Cal.App.3d 872,882, (the Court held that personal observations about a previous project constitutes substantial evidence of a potentially significant impact of a new project). See also *Keep Our Mountains Quiet v. County of Santa Clara* (2015) 236 Cal.App.4th 714, 735–736 & fn. 13, 187 Cal.Rptr.3d 96 ("Residents' personal observations of traffic conditions where they live and commute may constitute substantial evidence even if they contradict the conclusions of a professional traffic study."); *Protect Niles v. City of Fremont* (2018) 25 Cal.App.5th 1129, 1152; example letters from Sonoma County residents regarding odor impacts from commercial cannabis cultivation sites, attached as Exhibit 22, (including a letter from Katie Moore regarding odor from a 1-acre outdoor grow in Fulton that presents constant, noxious smells during the growing season at a home 2,000 downwind. When Ms. Moore complained to the county, one official said "this is here to stay. If you don't like it, then move." *Id*.)

Concerning indoor cultivation operations, the SMND foregoes any analysis of these facilities and defers analysis for outdoor cultivation operations to the future requiring a case-by-case review of these facilities if warranted based on the number of complaints. SMND at 35. CEQA requires that impacts be evaluated now, prior to Project approval, not deferred until some later date if complaints are sufficient to trigger an investigation.

By contrast, Yolo County prepared an EIR for its Cannabis Land Use Ordinance. See, https://www.yolocounty.org/government/general-government-departments/community-services/cannabis/cannabis-land-use-ordinance accessed March 1, 2021; excerpted Air Quality and Odor chapter attached as Exhibit 23. The Yolo

County EIR evaluated odor impacts from existing and eligible cannabis cultivation sites and included air dispersion models that simulated atmospheric conditions, such as meteorology and topographical influences to quantify the impact of odors. See also memo from Trinity Consultants to Yolo County, dated August 17, 2020, attached as Exhibit 24. Given that the Project fails to limit the number of cannabis cultivation permits approved by the County, an EIR must evaluate the effects of the whole of the Project, that is, the approval of potentially thousands of outdoor and indoor cultivation sites for up to 65,753 acres of cannabis cultivation. In addition, the County has an obligation to identify effective mitigation as part of this review to ensure that sensitive receptors in the vicinity of cannabis cultivation operations are not significantly impacted by odors.

c. The SMND relies on inadequate mitigation measures that do not reduce odor impacts to less than significant levels.

Instead of providing a thorough analysis of the Project's anticipated odor impacts, the SMND once again relies on unproven mitigation measures to conclude that odor impacts will be reduced to less than significant levels. For example, for indoor cultivation facilities, the Code amendments include a standard that permanent structures that may cultivate or contain cannabis must be equipped with odor control filtration and ventilations systems to control odors. SMND at 33. The standard also states that "odor shall be controlled in a way that prevents cannabis odor from being detected off of the parcel containing the cannabis site." SMND at 33; proposed § 38.12.110. B. The SMND identifies Mitigation Measure AIR-2, which requires daily inspections to verify that air filtration equipment continues to function properly at indoor cultivation sites. However, the SMND fails to provide evidence that the proposed measures will effectively reduce odor impacts to less than significant levels in part because the Project includes no effective means of ensuring that cannabis odor is not detected on adjacent parcels.

With regard to outdoor cannabis cultivation operations, the SMND points to several factors it claims would reduce the exposure of sensitive receptors to odors from outdoor grows. First, the SMND states that "outdoor cannabis cultivation generates the strongest odors in September and October, during the last four to eight weeks of the growing season prior to harvest. This would restrict the timing of the most adverse cannabis odors to no more than two months per year." SMND at 34. While outdoor cultivation may be a single crop per year, hoop houses, which are not controlled for odor, can have three harvests. Thus, the period that odor is problematic can be much longer than the SMND asserts. Real life experience demonstrates the period is much longer that the SMND's estimate. Pungent odors clearly can be a problem throughout the growing season. Even if the cannabis odors were most pungent for only 8 weeks during the year, neighboring property owners would be unable to open their windows or enjoy their homes and backyards during the months of September and October. *See* Fuller, 'Dead

Skunk' Stench from Marijuana Farms Outrages Californians, New York Times, December 22, 2018 attached as Exhibit 3. But in fact, odors adversely impact neighbors for the entire cannabis growing period, including in summer when children are not at school and people tend to spend more time outdoors.

Second, the SMND states that residents in agricultural and resource zones would have limited exposure due to large parcel sizes. SMND at 34. However, many DA, RR, AR and RRD parcels are in non-conforming areas. For example, the cannabis business at 885 Montgomery Road in Sebastopol, is on a 10-acre DA zoned parcel but is surrounded by seven, small, DA and AR/RR zoned parcels with a 3.3-acre average size. See map in Guthrie Letter, Cannabis cultivation should occur in appropriate places, at 13, Exhibit 22. There are many examples of similar non-conforming parcels in the County. An EIR should include a review of existing and eligible cannabis cultivation parcels and analyze how they may impact neighboring residents.

Third, the SMND claims that vegetative screening would buffer sensitive receptors from cannabis odors. *Id*. The SMND appears to base its statement on the United States Department of Agriculture Natural Resource Conservation Service ("NRCS") Publication October 2007- Windbreak Plant Species for Odor Management around Poultry Production Facilities, attached as Exhibit 25. However, while vegetative buffers may be partially effective[9] for reducing poultry and livestock odors (ammonia and hydrogen sulfide), plants are not known to absorb the terpene odor molecules emitted by cannabis. [Personal Communication: C. Borg, Urban Planner, SMW with Dr Deborah Eppstein, Retired Ph.D. in biochemisty, March 10, 2021. In addition, ammonia (NH_3) and hydrogen sulfide (H_2S) are much more volatile than terpenes [ammonia evaporates at -28 degrees Fahrenheit, hydrogen sulfide evaporates at -140 degrees Fahrenheit.] *Id*. The most volatile cannabis terpenes evaporate at +70 degrees Fahrenheit. *Id*. The density of ammonia (0.00089 g/ml) is 1,000 times less than for cannabis terpenes (0.858 g/ml for B-pinene).] *Id*. Thus, the more highly volatile ammonia molecules can disperse much more readily than the heavier terpene molecules. *Id*.

Furthermore, even if planting vegetation were an effective windbreak on flat ground, 20 years growth may be needed, with limited results starting after 5 years. *See*, NRCS Publication October 2007- Windbreak Plant Species for Odor Management around Poultry Production Facilities attached as Exhibit 25. Many cultivation sites in Sonoma

[9] The observed reduction in odor was only 46 percent. NRCS March 2007, p. 2. The reduction probably occurred because "[p]lants have the ability to absorb aerial ammonia." *Id*.

County are located on hillsides facing sensitive receptors where prevailing winds can widely distribute terpene odors.

The SMND fails to evaluate the efficacy of vegetative buffers on cannabis odors and fails to take hillside locations into account. Vegetative buffers do not disperse cannabis terpene odors and prevent them from adversely affecting adjacent parcels. This has been demonstrated by Ortech, a cannabis consulting company with 40 years of odor management experience. It found that “uncontrolled cannabis odors can disperse as far as 1,000 m (3,280 feet or more than 0.6 mile) from outdoor (cannabis) farms and more than 300 m (984 feet) from indoor grow facilities.” Ortech brochure at 2, attached as Exhibit 26. This finding is confirmed through residents’ experiences in recent years, where vegetative screening and thick tree cover does not prevent strong odors from cultivation areas of between 10,000 square feet and one acre from travelling over 600 feet without wind. Prevailing winds extend the odor even further. In another example, the odors from a one-acre cultivation site in Fulton adversely affects people 2,000 feet downwind all summer and fall. *See*, Exhibit 22 at Moore letter; *see also*, “What's it Like to Live 100 feet from 15, 000 Cannabis Plants” North Bay Biz, December 4, 2020, attached as Exhibit 27. These problems would be exacerbated by outdoor cultivations of up to 10 acres.

The SMND acknowledges that the aforementioned factors do not mitigate odor impacts from outdoor cannabis cultivation operations and identifies Mitigation Measure AIR-3, which provides:

“In the case that odors are not adequately diffused and verified odor complaints are received, Mitigation Measure AIR-3 would be required to address odor problems on a case-by-case basis. Where the County finds that a cannabis operation is having a substantial adverse effect on sensitive receptors, the County would review additional measures to reduce outdoor odor generation, including use of engineered solutions such as Vapor-Phase Systems (Fog Systems). Fog systems mix water with an odor-neutralizing chemical, which remains in the air after the water evaporates. With implementation of Mitigation Measure AIR-3, the impact of cannabis odors would be reduced to a less than significant level.”

The SMND fails to explain that vapor phase systems (Fog) are exclusively used for indoor grows. There is no experience for large outdoor grows. The effects of long-term human inhalation of the chemicals in the fog mist and related technologies has not been studied, including potential health problems for pregnant women, babies, children, the elderly, and the acute or chronically ill. It is unlikely that federal or state health authorities would allow its use without much more information.

The SMND then concludes that impacts relating to odorous emissions from outdoor operations would be less than significant with implementation of Mitigation Measure AIR-3. *Id*. However, the SMND itself provides evidence that impacts would be potentially significant when it provides for Permit Sonoma staff to "refer the matter to the Board of Zoning Adjustments for review of additional measures to reduce outdoor odor generation, including use of engineered solutions such as Vapor-Phase Systems (Fog Systems)." *Id*.

In sum, as discussed above, allowing ministerial permits for cannabis cultivation and production is likely to encourage a substantial increase in these facilities. As the SMND admits, cannabis facilities produce strong odors that impact nearby residents and other sensitive receptors, especially where prevailing winds carry cannabis odors downwind. SMND at 34. Sensitive land uses must be protected from these incompatible uses.

The Project, as currently proposed, lacks effective measures to minimize odor-related land use conflicts. A revised environmental analysis in the form of an EIR must assume that the County will have cannabis applications to the greatest degree allowable; that is that all (or at least most) of existing and eligible cannabis cultivation sites will apply for permits. The document must then be revised to include a comprehensive assessment of odors caused by the proposed Project. The analysis should comply with BAAQMD guidance for conducting such analysis as discussed above. Should the analysis determine that the Project's odor impacts are significant, the EIR must identify feasible mitigation measures to avoid and minimize impacts on sensitive receptors. These measures should include overall limits on permit approvals, exclusion zones in the County's sensitive resource areas, and robust setbacks as the primary mitigation to avoid significant odor as well as other impacts. In addition, the EIR should identify additional measures, such as testing with appropriate equipment (*e.g.*, use of field olfactometers; *see* The Nasal Ranger: A Hobbyist Weed Farm's Worst Enemy, attached as Exhibit 28) and engineered solutions as a last resort should odor impacts persist. The only effective mitigation for odor from outdoor grows is distance. At a minimum, because sensitive receptors are known to reside in residences (SMND at 32), the same minimum 1,000-foot setback from sensitive receptors in schools should be applied to residential property lines. Depending upon size of grow and other conditions, in many situations it should be further. See Guthrie, Cannabis cultivation should occur in appropriate places, Exhibit 22.

2. The SMND fails to adequately analyze and mitigate the Project's air quality impacts.

The Project is within the jurisdiction of the Bay Area Air Quality Management District (BAAQMD) and the area is currently designated as a nonattainment area for state and federal ozone standards, the state standard for large particulate matter (PM10), and the state and federal standard for fine particulate matter (PM2.5). SMND at 29. Emissions from cannabis cultivation and production operations include ozone precursors, such as nitrogen oxides (NOx), a substance known to be harmful to people and the environment, and volatile organic compounds ("VOCs"). Ozone is a criteria pollutant under the Clean Air Act, and the BAAQMD is the delegated enforcement agency for the area. Emissions from cannabis cultivation and production operations will contribute to worsening the county's air pollution, which already violates state and federal standards. SMND at 29.

The SMND's discussion of the Project's potential to emit criteria pollutants, such as NOx, is cursory and lacks evidentiary support. While the SMND acknowledges that the Project would generate emissions of particulates and ozone precursors (*i.e.*, NOx), it concludes that "because cannabis cultivation is not an intensive urban land use, it is anticipated that the long-term operation of cannabis cultivation sites would not generate emissions exceeding BAAQMD thresholds." *Id*. at 29 and 30. Based on this rationale, the SMND that the proposed Project would not result in significant Project and cumulative air quality impacts. *Id*. However, the document reaches this conclusion without completing the analysis of the Project's air quality impacts. The SMND fails to calculate NOx emissions and dismisses this potential impact without analysis of any sort and in contradiction to other statements in the document that conclude such exceedance of significance thresholds is possible. SMND at 29 and at Section IV. Summary of Environmental Issues at 15 respectively; staff report to the Planning Commission meeting on March 18, 2021["…it is possible that cannabis operations would generate NOx emissions exceeding the BAAQMD's significance threshold of an average of 52 pounds per day during construction or operation, contributing to regional ozone pollution."]

In fact, cannabis cultivation and production operations emit NOx through use of equipment for cultivation and extraction. Cannabis cultivation and processing also emits VOCs, such as terpenes and butane. Personal communication: C. Borg, Urban Planner and D. Eppstein; also *see e.g.*, https://airqualitynews.com/2019/09/19/cannabis-farms-in-the-us-could-be-causing-chronic-air-pollution/ accessed on 3-12-21 and attached as Exhibit 29 ; https://www.sciencedaily.com/releases/2019/09/190918100230.htm accessed on 3-12-21 and attached as Exhibit 30; and https://science.sciencemag.org/content/363/6425/329.summary accessed on 3-12-21 and attached as Exhibit 31. Studies indicate that cannabis grows contribute substantially to air pollution. *Id*. The SMND fails to quantify the anticipated emissions from ministerial approval of cannabis permits and fails properly evaluate the resulting air impacts. It is well-established that the County cannot defer its assessment of important environmental impacts until after the project is approved. *Sundstrom v. County of Mendocino* (1988) 202 Cal.App.3d 296, 306-07.

Having failed to conduct an adequate analysis of the Project's impacts, the SMND presents Mitigation Measure AIR-1. However, Mitigation Measure AIR-1 exclusively addresses particulate matter or dust. (Mitigation Measure AIR-2 and AIR-3 address odor impacts; *see* comments in section D.2 below.) Thus, the SMND fails to analyze and mitigate the Project's NOx and VOC emissions and the impacts that would result from both. The SMND also fails to adequately analyze the air quality and health and safety impacts associated with significant odor impacts and with the increased fire risk caused by the Project. *See* section D.2 below for additional information on potential health impacts related to odor emissions.

In addition, the SMND fails to evaluate the potential health risks from Project-related increases in fire risk. Fires produce high-risk contaminants, including trace metals, polycyclic aromatic hydrocarbons (PAHs), benzene, carbon monoxide (CO), nitrogen and sulfur oxides, cyanide, volatile organic compounds (VOCs), airborne acids, and particulates. *See* Exhibit 32 (Rahn, M., N. Bryner, R. Swan, C. Brown, T. Edwards, and G. Broyles, Smoke Exposure and Firefighter Risk in the Wildland Urban Interface (2016) FEMA-FP&S Grant, 2013), attached hereto. The increase in fires will deteriorate air quality. Smoke is made up of a complex mixture of gases and fine particles produced when wood and other organic materials burn. The greatest health threat from smoke is from fine particles ($PM_{2.5}$), which are microscopic particles that can penetrate the lungs and cause a range of health problems, from burning eyes and a runny nose to aggravated chronic heart and lung diseases, and even premature death. Exhibit 33 (Airnow, How Smoke from Fires Can Affect Your Health (2018), https://www.airnow.gov/air-quality-and-health/how-smoke-from-fires-can-affect-your-health/ , accessed on March 8, 2021), attached hereto. People with heart or lung diseases, the elderly, children, and pregnant women are especially vulnerable to the effects of PM2.5. *Id*.

B. The SMND fails to adequately analyze and mitigate the Project's impacts on groundwater supply.

CEQA requires that an EIR present decision makers "with sufficient facts to evaluate the pros and cons of supplying the amount of water that the [project] will need." *Vineyard Area Citizens for Responsible Growth, Inc. v. City of Rancho Cordova*, 40 Cal.4th 412, 430-31 (2007). This includes identifying and analyzing water supplies that "bear a likelihood of actually proving available; speculative sources and unrealistic allocations ('paper water') are insufficient bases for decision making under CEQA." *Id.* at 432. The fact that an agency has identified a likely source of water for the Project does not end the inquiry.

The ultimate question under CEQA . . . is not whether an EIR establishes a likely source of water, but whether it adequately addresses the reasonably foreseeable impacts of supplying water to the project. If the uncertainties inherent in long-term land use and water planning make it impossible to confidently identify the future water sources, an EIR may satisfy CEQA if it acknowledges the degree of uncertainty involved, discusses the reasonably foreseeable alternatives—including alternative water sources and the option of curtailing the development if sufficient water is not available for later phases—and discloses the significant foreseeable environmental effects of each alternative, as well as mitigation measures to minimize each adverse impact. *Id*. at 434. This analysis is crucial in light of the drought that has gripped this State for the past several years. This SMND's analysis of impacts to water supply fails to meet CEQA's standards.

As described in section III above, the SMND's failure to consider the impacts of the whole of the project undermines the document's analysis of Project-related impacts, including those impacts related to water supply. The letter prepared by Greg Kamman provides detailed comments on the shortcomings of the SMND's water supply impacts analysis. We incorporate the Kamman Report into these comments. Some of the SMND's most troubling errors identified in the Kamman Report are described below.

The SMND presents unsubstantiated figures on estimated water use by cannabis cultivation and production facilities. The SMND estimates that water use by each cultivator would be less than 2.0 acre-feet of water per year. SMND at 69. However, the SMND fails to disclose how this estimate is derived and seems not to have considered the greatly increased water demand by hoop houses that harvest two to three crops per year. As the Kamman Report explains, the increased demand on the County's already stressed groundwater supplies is a well-documented concern, yet the SMND fails to adequately analyze the impacts of the Project on this limited resource. Kamman Report at 2-4.

Nor does the SMND adequately analyze the impacts of groundwater pumping on creeks, streams, and rivers. Kamman Report at 3-4. Moreover, the methods the County has devised to address potential impacts to surface waters from groundwater pumping do not mitigate potentially significant impacts. *Id*. The 500-foot setback for wells from waterways in Zones 1 and 2 appears to be arbitrary. Similarly, the SMND fails to provide evidence that required well-yield tests for applications in Zone 3 and 4 will prevent impacts to groundwater supplies. *Id*. As the Kamman Report explains, the well-yield test evaluates if the minimum yield will meet irrigation demands, but it does not evaluate if pumping would adversely impact surface water and groundwater resources.

In sum, the SMND fails to adequately evaluate the Project's impacts of groundwater use on the County's groundwater and surface water resources. An EIR for the Project must correct the aforementioned gaps in analysis. In addition, the EIR must evaluate related Project-related impacts associated with water quality and aquatic habitat and biotic resources reliant on that habitat. *See*, Kamman Report at 5-10 and Letter from Friends of Mark West Watershed to Planning Commissioners dated March 18, 2021.

C. The SMND fails to adequately analyze and mitigate the Project's aesthetic impacts.

Sonoma County draws tourists largely based on its rural character, bucolic countryside vistas, and small-town charm. The County proposes allowing up to 65,733 acres of new outdoor cannabis cultivation, together with at least 8,289 acres of greenhouses.[10] Currently about 50 acres of cannabis are being cultivated, so the Project would allow a 1,300-fold increase in the number of cannabis facilities.

The SMND concedes the Project would affect "parcels within scenic vistas." SMND at 19. However, the SMND fails to provide any analysis of the actual impacts. The SMND includes no simulations of views from public viewpoints (such as trails and roadways) of existing and eligible cannabis cultivation sites that may apply for a cannabis cultivation permit. By contrast, the EIR for the Yolo County Cannabis Land Use Ordinance considered views of existing and eligible cannabis cultivation sites from various scenic roadways and public viewpoints and evaluated the impacts of three different alternatives allowing various levels of development. *See*, Yolo County Land Use Ordinance, Draft EIR at 3-1.1 to 3-1.48; excerpts attached as Exhibit 23. Here, the SMND provides no such analysis, and assumes that setbacks and screening alone will be adequate to reduce impacts. However, as discussed further below, the SMND provides no evidence that the mitigation measures will be effective.

Ministerial permits would allow industrial-scale developments without public involvement or consideration of how each project affects the overall landscape. County staff's 2015 Discussion Paper opined on the need to limit indoor cannabis cultivation "because indoor facilities are more industrial in nature…and may not be in keeping visually with the rural character of these lands." See Exhibit 14, Discussion Paper at 4. For this reason, among others, staff recommended that "[A]ll larger sized operations would be required to obtain a conditional use permit, allowing close review of the site on a case by case basis." *Id*. at 5. But here, the proposed Project would conflict with County staff's own recommendations and the SMND fails to adequately study and analyze the impacts of the proposal on aesthetics.

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[10] One acre of new structures for indoor cultivation on parcels 10-20 acres is allowed, and more on larger parcels. Proposed § 38.12.030 (B). The county's ArcGIS data indicates 8,289 parcels meet these criteria: RRD (4,015); LIA (1,158); LEA (1,158); DA (1,665).

The SMND proposes setbacks, screening, and design review to lessen adverse visual effects from cannabis structures. But screening applies only to fences and outdoor canopy, not for hoop houses, greenhouses, or indoor grow facilities. Although they are required to be fenced, the fences will not screen them from view. Setbacks for hoop houses are only 100 feet from a property line of a neighboring residence, and setbacks for greenhouses are as little as 10 feet. SMND at 19; proposed § 38.12.010. The SMND concludes that setbacks reduce impacts to a less than significant level, however the SMND provides no evidence to support this conclusion. SMND at 20-24.

Implementing the Project to allow cannabis cultivation and production on lands designated for traditional agriculture and resource protection will result in significant impacts to scenic views and vistas and changes to the visual character. As described throughout this letter, cannabis cultivation and production differs from traditional agriculture and is more similar to an industrial process. Outdoor cultivation is frequently placed within hoop houses that appear like plastic greenhouses and can add light and glare impacts. *See* photo of hoop houses, attached as Exhibit 34. Indoor facilities look much like multi-story warehouses or self-storage units. See photos of indoor facilities, attached as Exhibit 35. Such facilities would appear out of scale with surrounding community features or unsightly if located in rural environments. These facilities would indisputably have significant visual impacts and degrade the existing visual character of rural communities.

An EIR must include a detailed and thorough analysis of the project's likely aesthetic impacts, as outlined above. It must provide an adequate analysis that would permit informed decisions about the project, effective mitigation measures, and alternatives that could have less intensive impacts. The EIR must also analyze all project components that could impact views. The accepted approach to analyzing visual and aesthetic impacts is to: characterize the existing setting of the area affected by the Project; describe the changes that would result given the proposed changes to the Code; provide photomontages or visual simulations to illustrate examples of the change in character of the affected area before and after project implementation; and identify feasible mitigation measures and alternatives to reduce or eliminate significant impacts. To comply with CEQA, the County must include such an analysis in an EIR for the Project.

D. The SMND fails to analyze all potential direct and indirect impacts, including wildfire safety and emergency access/evacuation.

The SMND includes a description of recent wildfire history in Sonoma County. It describes fires in 2017 and 2019 that burned more than 188,000 acres and destroyed more than 5,600 homes in Sonoma and Napa counties. In 2020, the LNU Lighting Complex fire brought more destruction and devastation to the area. The SMND goes on to state that "extreme wildfire events are anticipated to occur 20 percent more often by 2050 and 50 percent more often by the end of the century." SMND at 98. Given these disclosures, one would expect the County to thoroughly evaluate wildfire impacts from this Project, which would result in development countywide. Instead, the SMND relies on a baseline of conditions of 2016 to evaluate the impacts of the Project. For wildfire risk and other impact areas, this outdated baseline is insufficient. As noted above, since 2017, approximately 25 percent of county land has experienced fire. Personal communication: C. Borg, Urban Planner with SM&W and Dr. D. Eppstein, March 1, 2021. In addition, the mountainous, highly combustible areas in eastern Sonoma County have a Fire Hazard Severity Zone (FHSZ) ranking of "very high" and "high" according to California Department of Forestry and Fire Protection (CAL FIRE 2020) maps, and therefore are the most susceptible to wildland fires. *See* Exhibit 36.

As the climate changes and fire risk grows, Californians and Sonoma County residents and their neighbors are rightfully concerned about the risk of wildfire. With the state still recovering from the disastrous fires of 2020, decisionmakers must consider the role that increased development plays in the proliferation of wildfires, especially when that development encroaches into heavily forested areas with steep hills. CEQA requires environmental documents to analyze the risk of wildfire and the contribution of new projects to the risk of wildfire. In light of the County's history of severe fires, one would expect a thorough evaluation of fire risks associated with changes to allowed land uses.

The SMND here fails at every juncture to provide the legally required analysis of the Project's direct, indirect, and cumulative impacts of a disastrous wildfire. First, the SMND ignores how changes to the climate will impact wildfires in the future. It then provides a legally inadequate analysis of the direct, indirect, and cumulative wildfire hazard impacts associated with easing permit requirements for allowing cannabis cultivation and production in rural undeveloped areas. The SMND exacerbates the failure to identify and analyze the Project's significant impacts by relying on token mitigation measures that do little to reduce the Project's admittedly significant fire hazard impacts, especially in RRD-zoned parcels. SMND, p. 67..

1. The SMND fails to adequately address future changes in precipitation, temperature and wind and their effects on fire hazards.

It is common knowledge that climate change will increase the risk and frequency of wildfire as well as the severity of wildfire events. For example, the intensity of and number of days with Diablo winds is expected to increase. Expected changes in precipitation will result in decreased fuel moisture and increased fire risk. Exhibit 37, A.L. Westerling, H.G. Hidalgo, D.R. Cayan, and T.W. Swetnam, Warming and Earlier

Spring Increase Western U.S. Forest Wildfire Activity, 313 Science 940 (2006); Exhibit 38, D. Cayan, A. L. Luers, M. Hanemann, G. Franco, and B. Croes, Scenario of Climate Change in California: Overview, CEC-500-2005-186-SF (2006).

As discussed in section II.B. above, wildfire season in the western region of the United States, including California, recently has lengthened from a previous average of between five and seven months to a year-round occurrence. The number of large wildfires that burn more than 1,000 acres has increased throughout the western United States. This is occurring as average annual temperature in the Western regions of the United States has risen by nearly two degrees Fahrenheit since the 1970s and the winter snow pack has declined. Union of Concerned Scientists, Infographic: Wildfires and Climate Change, September 8, 2020, https://www.ucsusa.org/resources/infographic-wildfires-and-climate-change, attached as Exhibit 39. The intensity of and number of days with Diablo winds is expected to increase. Expected changes in precipitation will result in decreased fuel moisture and increased fire risk. Exhibit 37 (Westerling, et al.); Exhibit 38 (D. Cayan, et al.) Exhibit 40 (LA Times "How Climate Change is Fueling Record-breaking California Wildfires, Heat and Smog" September 13, 2020) attached hereto.

Despite these known factors, the SMND fails to take them into consideration in its analysis of wildfire impacts, instead assuming that if future grow sites and facilities are built to code and follow minimal guidelines, the risk of fire and the resulting harm they cause will be less than significant. This myopic view of fire risk leaves the public and decision makers unable to fully understand the risk of potentially adding tens of thousands of acres of cannabis cultivation and production facilities in rural areas, in many cases adjacent to open space. The SMND failed to discuss these existing environmental conditions, and as a result, failed to adequately analyze wildfire hazard impacts within this context.

2. The SMND fails to adequately analyze and mitigate the fire hazard impacts of replacing open space land with cannabis cultivation and production facilities.

CEQA requires an analysis of both a project's direct and reasonably foreseeable indirect impacts. Other than acknowledging that the Project could lead to a substantial expansion of cannabis cultivation and associated structures on parcels within high or very high fire severity zones, the SMND provides no analysis of the scope or extent of this impact and fails to identify the foreseeable indirect impacts that will occur as a result of the Project. The SMND cannot just provide bare conclusions, it "must contain facts and analysis" to support and explain such conclusions. *Santiago County Water Dist. v. County of Orange* (1981) 118 Cal.App.3d 818, 831.

The SMND fails to evaluate the potential for the Project to expose people or structures to a significant risk of loss, injury or death involving wildland fires. This is a potentially significant impact inasmuch as the proposed Project would result in more intensive use of rural lands in remote, wildland areas. Studies illustrate the heightened safety risks from development and intensification of land use in areas where fire is a natural part of the ecology and flammable vegetation exists. As development and more intensive land uses encroach on the wildland urban interface, it causes an increase in the number of fires and more loss of life. *See* Land Use and Wildfire: A Review of Local Interactions and Teleconnections, attached as Exhibit 41

A 2017 study that evaluated 1.5 million wildfires in the United States between 1992 and 2012 found that humans were responsible for igniting 84 percent of wildfires, accounting for 44 percent of the acreage burned in wildfires. *See* Exhibit 42 (Balch, Jennifer; Bradley, Bethany; Abatzoglou, John, et. al., Human-Started Wildfires Expand the Fire Niche Across the United States, Proceedings of the National Academy of Sciences: Volume 114 No. 11 (March 14, 2017) https://www.pnas.org/content/pnas/114/11/2946.full.pdf, accessed on August 20, 2020), attached hereto.

The California Office of the Attorney General has noted that locating development in wildfire risk areas "will itself increase the risk of fire" and increase the risk of exposing existing residents to an increased risk of fire, citing a plethora of reports. Letter from Nicole Rinke to Planning Commission on Monterey dated March 20, 2019 at 3-4, attached as Exhibit 43.

Unlike the existing ordinance (*see* Chapter 26 § 26-88-258(a)(3)), the proposed Project would allow the use of volatile compounds on site. Cannabis grown on-site may be processed (dried, trimmed, etc.) on-site by the permittee as well as manufactured using industrial processes to extract the THC oil, and such cannabis products may be transported. See Proposed § 38.14.020 (A)-(C). "Cannabis products" are defined in proposed section 38.18.020, and include edibles, topical products, and concentrated cannabis. Thus, besides volatile compounds, ethanol and high-pressure CO_2 extraction and distillation are allowed. Allowing these chemicals and processes onsite constitutes a serious fire risk that the fire prevention plan (SMND at 85) does not address or mitigate. Personal communication: C. Borg, Urban Planner with SM&W and Dr. D. Eppstein, March 1, 2021. The current cannabis ordinance limits such processes to industrial sites. See SCC Chapter 26, Table 1D.

Other elements of the Project will also increase fire risk and the inevitable resulting fires. Fires are frequently caused by infrastructure, such as roads, power lines, and gas lines. As Sonoma County knows too well from recent experience, power lines ignite wildfires through downed lines, contact with vegetation, colliding conductors, and equipment failures. *See* Exhibit 44 (Texas Wildfire Mitigation Project, How Do Power Lines Cause Wildfires? (2018) https://wildfiremitigation.tees.tamus.edu/faqs/how-power-lines-cause-wildfires, accessed on March 8, 2021), attached hereto. CalFIRE determined that 16 wildfires in northern California in October 2017 were caused by electric power and distribution lines, conductors, and the failure of power poles. *See* Exhibit 45 (California Department of Forestry and Fire Prevention CAL FIRE Investigators Determine Causes of 12 Wildfires in Mendocino, Humboldt, Butte, Sonoma, Lake, and Napa Counties (2018), attached hereto.

Other wildfires are caused by sparks or ignitions from vehicles on roadways. *See* Exhibit 46 (Pacific Biodiversity Institute, Roads and Wildfires (2007) http://www.pacificbio.org/publications/wildfire_studies/Roads_And_Wildfires_2007.pdf, accessed on March 8, 2021), attached hereto. The Project's new roads and additional vehicles on roadways from the Project will exacerbate the fire risk and increase the number of fires—significant environmental impacts unaddressed by the SMND.

The SMND itself acknowledges that commercial cannabis operations "are associated with high fire risk and have been responsible for structure fires in both urban and rural areas." SMND at 67. The SMND also acknowledges that RRD-zoned areas "are known to be high fire hazard areas due to steep slopes, dense vegetation, and insufficient emergency services due to a lack of safe emergency vehicle access." SMND at 67. Easing permit requirements and allowing cannabis grows with only ministerial approval is likely to encourage an influx of permit applications. Intensified land uses like these in remote areas, such as lands designated RRD in the eastern part of the County, increase ignition risk and vastly increase the cost of fighting wildland fires with task forces of urban fire engines needed to protect homes in the urban-wildland interface. At the same time, climate change is making summers hotter and drier, leading to an increase in the frequency and severity of catastrophic wildfire. Moreover, given that many rural parts of the County are accessed by narrow, substandard roads, increasing the intensity of land uses in areas with limited ingress/egress has the potential to degrade safe evacuation of residents as well as impede access for fire fighters and first responders during a fire.

Fire risk is not only a factor on remote parcels zoned RRD. It also affects parcels zoned LEA, LIA, and DA, many of which burned during the four wildland fires in Sonoma County that consumed 25 percent of its acreage since 2017. Much of the burned land is not designated as high or very high fire hazard severity zones. Fires that begin at cannabis cultivation sites can readily spread elsewhere in windy conditions as evidenced by the recent conflagrations in Sonoma County that began in Napa County and progressed into Sonoma during high wind events. For all these reasons, cannabis projects in the wildland-urban interface expose people or structures, directly or indirectly, to a significant risk of loss, injury or death involving wildland fires.

The SMND admits the updated Ordinance could lead to a substantial expansion of cannabis cultivation and associated structures on parcels within very high fire severity zones. SMND at 99 and 100. The SMND even admits that “future cannabis cultivation facilitated by the updated Ordinance would have potentially significant wildfire impacts, as existing codes and regulations cannot fully prevent wildfires from damaging structures or harming occupants. Cannabis cultivation operations in high fire risk areas would increase the exposure of new structures and occupants to risk of loss or damage from wildfire.” SMND at 100. However, the SMND foregoes meaningful analysis of potential impacts to public safety and property loss during a wildfire event. It fails to include an analysis of potential cannabis facilities locating in remote areas with limited access, or locating in close proximity to rural residential development, and how potential fire in different scenarios might spread under different weather, fuel, wind and ignition point scenarios.

3. The SMND fails to analyze impacts related to emergency response and evacuation.

Concerning emergency response and evacuation, the SMND merely asserts that the Project would not affect emergency response routes or response times and concludes that impacts related to emergency evacuation would be less than significant. SMND at 98. The SMND provides no support for its conclusion. Despite the document’s admission that the Project would allow for expansion of cannabis cultivation within designated high fire risk areas in remote mountainous areas, and that the Project would result in potentially significant wildfire impacts, the SMND defers analysis and mitigation of this important issue.

Instead, the SMND relies on a project element requiring a site security plan that includes emergency access in compliance with fire safe standards. SMND at 99. The SMND also imposes two mitigation measures. The first addresses construction activities; it prohibits construction activities, such as welding and grinding outdoors during National Weather Service red-flag warnings and requires fire extinguishers and spark arresters on construction vehicles. The second addresses new structure locations; it requires compliance with existing regulations prohibiting cultivation on slopes greater than 15%, includes grading limits and ridgetop protections, and adds criteria for siting new structures including avoidance of landslide-susceptible areas and sloped hillsides. SMND at 101.

The SMND's approach to mitigation is inadequate under CEQA for multiple reasons. First, many of the potential sites that could be used for cannabis cultivation are located on substandard, narrow, dead-end, rural roads. *See e.g.*, photos of typical roads leading to existing cannabis cultivation sites in Sonoma County, attached as Exhibit 48. These roads fail to meet State Fire Safe Regulations as discussed further below. Secondly, even if emergency vehicles could traverse such roads, there is no space to allow for vehicles of evacuating residents that share those roads. Whether or not the County has adopted an emergency response plan to address these deficiencies, under CEQA the County has an obligation to evaluate the extent and severity of these public safety risks. The SMND bypasses the required step of analyzing the potential impacts of implementing the Project. For example, it fails to evaluate the potential for Project-related increased truck and automobile traffic to hinder evacuations on narrow rural roads and steep private roads. Consequently, the EIR lacks evidentiary support for its conclusion that the Project's impacts relating to evacuation and emergency response would not be significant.

The SMND's approach is particularly egregious given that a 2015 staff-prepared discussion paper on "Cannabis Cultivation Within Resources and Rural Development (RRD) Lands ("Discussion Paper"), addressed the inadequacy of rural roads in RRD areas and includes the following paragraph related to 'Emergency Services':

"The remote RRD zoned areas are primarily accessed by one lane gravel roads that are remnants of old logging roads. Most cultivation facilities would be required to construct paved, 2-way roads with an 18 foot minimum width, sufficient for emergency vehicle access. Water for fire suppression may also be required. Emergency response in these areas are handled by volunteer fire departments and response times vary."

Discussion Paper at 1, available at http://sonomacounty.ca.gov/WorkArea/DownloadAsset.aspx?id=2147525642 accessed on March 8, 2021, attached as Exhibit 14. The Discussion Paper indicates that the County has data about rural roadways that should have been incorporated into this environmental documentation, yet the SMND is silent regarding safety issues resulting from substandard roadways in remote areas.

Moreover, State Fire Safety Regulations require a "minimum of two ten (10) foot traffic lanes" for emergency access and egress. See, California Code of Regulations, Title 14 Natural Resources, §1273.01. The California Board of Forestry and Fire Protection ("Board") has expressed its concerns regarding the County's standards for fire safe roads both because they omit standards included in the State's Fire Safe Regulations and because the County's standards on their face appear to be less stringent than the Fire Safe Standards. See, October 23, 2020 letter from Jeff Slaton, Senior Board Counsel for the

Board of Forestry and Fire Protection, to the Board of Supervisors, Exhibit 47. The Board expressed "particular concern" about standards for existing roads and for ingress/egress that allows concurrent civilian evacuation. Notwithstanding the County's recent failed request for certification of its fire safe ordinance, the County has an obligation to evaluate the impacts of implementing the proposed Project and to identify mitigation measures to minimize significant impacts related to public safety.

The SMND should have prepared an evacuation analyses to identify areas that would have evacuation impacts. These analyses would have: (1) identified the locations of existing facilities that would experience increased events; (2) identified the locations of reasonably foreseeable new facilities; (3) identified the expected number of workers and total estimated amount of operational traffic at each of these facilities[11]; (4) evaluated the capacity of roadways near the existing and new facilities and determined whether these roadways would be able to accommodate added traffic during evacuations; (5) modeled the various scenarios of wildland fire that could occur near each facility's vicinity; and (6) determined whether (a) area residents and facility visitors would have adequate time to escape and (b) emergency service providers would be able to access the sites' in a timely manner, consistent with emergency service response time goals. It is imperative that such analyses be conducted for the proposed Project given the wildfire crisis that is plaguing the West and given the potential for cannabis cultivation and production facilities to locate in a "Very High Fire Hazard Severity" and "High Fire Hazard Severity" zones. *See* Exhibit 36 CalFire Fire Sonoma County Hazard Severity Zones December 2020 and Exhibit 49 Wildland Fire Hazard Areas Map, Public Safety Element, Sonoma County General Plan 2020.

In addition, it has come to our attention that the County Board of Supervisors' tentative calendar for 2021 includes a two-hour item scheduled for August 17, 2021 to review and adopt the County's plan for preparing and conducting large-scale community emergency evacuations. This planning process for community evacuations during emergencies should precede and inform the County's consideration of this proposed Project. Once the County has a better understanding of the areas of vulnerability and requirements for safely evacuating residents during emergencies, that valuable information can be incorporated into an EIR for this Project to comprehensively evaluate potential public safety issues for the community.

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[11] For example, if the Project were implemented on Matanzas Creek Lane, a 1-mile dead-end road that is only 11 feet wide, 720 people could be employed that would have to be evacuated. Comments by Bill Burns and Sherilyn Burns, Exhibit 22. This is an enormous increase from evacuating residents of 17 parcels.

Nor does the EIR consider in any meaningful way post-fire condition hazards associated with unstable slopes, such as landslides, erosion, and gullying. *See* Exhibit 50 (US Geological Survey, New Post-Wildfire Resource Guide now Available to Help Communities Cope with Flood and Debris Flow Danger (2018), https://www.usgs.gov/center-news/post-wildfire-playbook?qt-news_science_products=1#qt-news_science_products, accessed on March 8, 2021), attached hereto. After a fire, landslide hazards, including fast-moving, highly destructive debris flows, can occur because fires destroy vegetation that slows and absorbs rainfall and harm roots that stabilize soil. *Id*. The burning of vegetation and soil on slopes more than doubles the rate that water will run off into watercourses. *See* Exhibit 51 (California Department of Conservation, Post-Fire Debris Flow Facts, 2019, https://www.conservation.ca.gov/index/Pages/Fact-sheets/Post-Fire-Debris-Flow-Facts.aspx#:~:text=The%20January%202018%20Montecito%20debris,Geological%20Survey%20scientists%20estimated%20the, accessed on March 8, 2021). Post-fire debris flows are particularly hazardous because they can occur with little warning, damage objects in their paths, strip vegetation, block drainage ways, damage structures, and endanger human life. *Id*. An EIR must include this analysis.

4. The proposed mitigation will not reduce wildfire hazard impacts to a less than significant level.

Despite the obvious severity of potential impacts resulting from proliferating cannabis facilities countywide, the SMND relies on impotent mitigation measures that do not actually mitigate anything. The minimal mitigation the SMND proposes fails to reduce fire hazard impacts to a less-than-significant level.

The SMND largely relies on consistency with Fire Code requirements and required preparation of a "fire prevention plan" as part of the application process. SMND at 99. The fire prevention plan is to demonstrate compliance with the Fire Code and applicable local and state standards. *Id*. As discussed in more detail below, CEQA directly forbids an assumption, without underlying analysis, that simply complying with a regulatory standard is adequate to mitigate a potentially significant impact. *See*, *e.g.*, *Californians for Alternatives to Toxics v. Department of Food & Agriculture* (2005) 136 Cal.App.4th 1, 16-17 (compliance with regulation alone not a basis for finding impact less than significant); *Protect the Historic Amador Waterways v. Amador Water Agency* (2004) 116 Cal.App.4th 1099, 1108-09 (environmental effect may be significant despite compliance with such requirements).

Moreover, any proposed facilities are already required to comply with fire regulations. Merely requiring compliance with existing agency regulations does not conclusively indicate that a proposed project would not have a significant and adverse impact. *See Kings County Farm Bureau v. City of Hanford* (1990) 221 Cal.App.3d at 716. Furthermore, the SMND indicates that the Project's wildfire impacts would be significant notwithstanding the Project's compliance with the Fire Code and local and state standards. SMND at 99. Thus, there is no substantial evidence to support the SMND's conclusion that the Project's fire hazard impacts will be less-than-significant.

This blatant failure to mitigate wildfire risks is especially problematic in light of California's recent spate of deadly wildfires; it is unfathomable that the County could even consider approving potentially tens of thousands of acres of cannabis facilities on rugged terrain without first paying adequate consideration to fire and emergency response. As such, the County cannot approve the Project unless it recirculates a EIR that adequately mitigates the aforementioned wildfire impacts.

In sum, the Project would encourage development of new cannabis cultivation and production facilities by making the permits easier to obtain and making the facilities more profitable by allowing events. As the SMND acknowledges, most lands zoned RRD and DA are located in more remote areas of the County. The SMND is legally inadequate due to its failure to address the threat posed by an increase in land use intensity and traffic in rugged, remote areas of the County. Until this issue is examined thoroughly in an EIR, the County may not approve the proposed Zoning Code and General Plan amendments.

E. The SMND fails to adequately analyze and mitigate the Project's traffic impacts related to an increase in Vehicle Miles Travelled.

The SMND presents a deficient traffic analysis which fails to address the true impacts of the Project. First, as discussed in Section III of this letter above, because the SMND focuses solely on the impacts of individual permits, it fails to adequately analyze the impacts of the Project as a whole. With regarding to traffic related impacts, the SMND fails to analyze impacts associated with a significant increase in VMT from the aggregate increase generated from all potential permits allowed by the Project. Instead, it limits its comments to the potential effects of traffic trips from each separate facility. As discussed above, this approach is inappropriate under CEQA. The proposed Project is not an end in itself. It is the prelude to development of additional cannabis cultivation and production sites and additional events at these facilities.

Breaking the Project into parts by leaving out the future activity of having multiple applications annually is illegal segmentation and leads to inadequate environmental review. *See*, e.g., *Bozung v. Local Agency Formation Comm'n* (1975) 13 Cal.3d 263, 283-84 (CEQA mandates that "environmental considerations do not become submerged by chopping a large project into many little ones"). A lead agency, moreover, may not segment a project by reviewing entitlements one at a time, waiting for each new approval to consider the specific development proposed. Instead, an agency must provide environmental review of an entire project at the time of the first approval. See, *e.g.*, *City of Carmel-By-the-Sea* (1986) 183 Cal.App.3d 229, 233-35, 244 (city must analyze full environmental consequences of rezone because it "was a necessary first step to approval of a specific development project"); *Koster v. County of San Joaquin* (1996) 47 Cal.App.4th 29, 31, 34, 39-40 (County EIR must analyze General Plan amendment that was the "first step" toward developing new towns).

Second, what analysis the SMND does include is incomplete, inconsistent, and unsupported. For instance, the SMND states that "cultivation operations could have 100 to 200 employees commuting to the sites. SMND at 88. It then states that cannabis cultivation projects would generate a net increase of fewer than 110 average daily trips. The SMND fails to present any data to support either figure. Nevertheless, the number of trips and vehicle miles travelled that should have been considered are those from the expected *total* number of applications annually, not from each facility separately.

The County's own documents provide evidence that trips and VMT are likely to be higher than this SMND presents. For example, the 2016 Negative Declaration for the Medical Cannabis Ordinance indicates that a one-acre cultivation site or a 0.25-acre indoor operation can each require 12-15 employees during peak periods and fifteen employees average 30-60 trips a day. Sonoma County 2016 Negative Declaration for the Medical Cannabis Ordinance at 44. A 2020 permit application for a 1-acre cannabis operation in Glen Ellen employs 12 full-time and five part-time staff during peak fire season. See Draft Mitigated Negative Declaration for UPC19-0002, Gordenker Ranch Cannabis at 6, attached as Exhibit 52. Using the County's method of estimating daily trips from the number of employees in its 2016 Negative Declaration, 100 to 200 employees would result in 400 to 800 daily trips for a single large greenhouse project. This amount of increased traffic would result in adverse impacts related to public safety on narrow, rural roads, particularly during emergency evacuations.

The County can easily calculate an estimate of trips from all facilities together by estimating the number of applications based on the applications received in the past few years since cannabis cultivation has been allowed in the County and extrapolating from that number. *See e.g.*, Yolo County Cannabis Land Use Ordinance Environmental Impact Report dated September 1, 2020 available at https://www.yolocounty.org/government/general-government-departments/community-services/cannabis/cannabis-land-use-ordinance , accessed on March 1, 2021; excerpts attached as Exhibit 23. Such estimates must differentiate between indoor and outdoor cultivation and size of projects to estimate the number of employees per acre, which would allow an estimate of the number of daily trips.

Moreover, the SMND's identified Mitigation Measures providing that individual cannabis cultivation project applicants provide analysis of the amount of average daily trips and vehicle miles travelled does not excuse the County from analyzing the impacts of implementing the Project now. Inasmuch as the proposed Code and General Plan amendments are the first discretionary approval that will ultimately result in development activity countywide, this environmental document must analyze the environmental impacts from these activities in as detailed a manner as possible. *Koster v. County of San Joaquin* (1996) 47 Cal.App.4th 29, 31, 34, 39-40.

Finally, the SMND's failure to properly evaluate Project's trips and VMT, implicates the SMND's analysis of greenhouse gases. An EIR for the Project must address this flaw.

F. The SMND fails to adequately analyze and mitigate the Project's greenhouse gas emissions.

The SMND acknowledges that cannabis cultivation is a land use that generates substantial greenhouse gas ("GHG") emissions from energy use. SMND at 61. It also discloses that new cannabis operations permitted under the proposed Project could contribute to an exceedance of California's statewide targets. *Id*. But again, the SMND foregoes the necessary analysis of estimating the amount of GHG emissions that would be emitted from implementation of the Project. Instead, the SMND assumes that Project elements would reduce GHG emissions to a less-than-significant level.

This approach fails under CEQA for multiple reasons. First, the SMND's perfunctory "analysis" of the Project's GHG impacts does not comply with CEQA. Rather than study the environmental implications of the Project's GHG emissions, the SMND takes the legally impermissible easy route: it simply labels impacts as significant, without offering any information on the nature or scope of the problem. It is not sufficient to simply assert that an impact is significant and then move on. This approach does not allow decision makers and the public to understand the severity and extent of the Project's environmental impacts. *See, e.g., Berkeley Keep Jets Over the Bay Com. v. Bd. of Port Comrs*. (2001) 91 Cal.App.4th 1344, 1370-71; *Galante Vineyards v. Monterey Peninsula Water management Dist*. (1997) 60 Cal.App.4th 1109, 1123; *Santiago County Water Dist. v. County of Orange* (1981) 118 Cal.App.3d 818, 831 (a lead agency may not simply jump to the conclusion that impacts would be significant without disclosing to the public and decision makers information about how adverse the impacts would be).

The SMND should have calculated the amount of GHG emissions from the project based on the Ordinance requirements and limitations. *See*, Estimating Adequate Licensed Square Footage for Production, BOTEC Analysis Corporation, 2014, attached as Exhibit

53 and available at https://www.cannabisbusinessexecutive.com/wp-content/uploads/2014/11/5a_Cannabis_Yields-Final.pdf accessed March 16, 2021. For example, based on the assumption that indoor grows can yield .04 kg per square foot of cannabis per harvest, and that indoor grows can yield 4-6 harvests per year. An indoor grow of 20,000 square feet, with four harvests per year, would thus produce 3,200 kg of cannabis annually. Converting that to ounces, you get 112,876.7 ounces, which would generate 16,141,368 pounds, or about 7,300 metric tons per year of carbon emissions, which would be the equivalent of adding 1,460 cars to the road. This estimate would be for a single indoor grow of approximately 20,000 square feet. The Ordinance does not contain a limit on existing permanent indoor structures, and limits new structures (on parcels of 10-20 acres) to 43,560 square feet.

Second, the SMND relies on the proposed Ordinance's requirement that greenhouse and indoor cultivation sites reduce GHG emissions either by using 100 percent renewable energy sources or by offsetting emissions from non-renewable sources by purchasing carbon credits. SMND at 61. However, the SMND cannot simply assume that the purchase of GHG offsets will eliminate the Project's GHG emission impacts. Until the SMND's provides a comprehensive analysis of the Project's impacts, it is not possible to formulate effective mitigation. Moreover, even if offsets were potentially feasible mitigation, the SMND must demonstrate their effectiveness in reducing the Project's climate change impacts. When a lead agency relies on mitigation measures to find that project impacts will be reduced to a level of insignificance, there must be substantial evidence in the record demonstrating that the measures are feasible and will be effective. *Sacramento Old City Assn. v. City Council of Sacramento*, 229 Cal.App 3d 1011, 1027 (1991); *Kings County*, 221 Cal.App. 3d at 726-29. As discussed further below, we can find no such evidence here.

The proposed Ordinance provision related to the offset requirement states that "any offsets shall be generated in California pursuant to protocol accepted by the County…", but neither the Ordinance nor the SMND specify what this protocol will entail. SMND at 61 and draft Ordinance at § 38.12.110.C. Moreover, the SMND confers complete discretion in County staff to determine whether the purchased carbon offsets meet the unspecified protocol and whether the offsets are adequate to reduce impacts. *Id*. Courts have found mitigation fees inadequate where the amount to be paid for mitigation was unspecified and not "part of a reasonable, enforceable program." *Anderson First Coalition v. City of Anderson (2005) 130 Cal.App.4th* 1189; see also *Cal. Clean Energy Com. v. City of Woodland* (2014) 225 Cal.App.4th 173, 198.

In practice, even the most sophisticated offset programs have failed. A 2016 report prepared for the EU Directorate General for Climate Action concluded that nearly 75% of the potential certified offset projects had a low likelihood of actually contributing additive GHG reductions, and less than 10% of such projects had a high likelihood of additive reductions. Exhibit 54 (Institute of Applied Ecology, *How additional is the Clean Development Mechanism? Analysis of the application of current tools and proposed alternative*s, March, 2016) at 11; *see* also Exhibit 55 (*Carbon Credits Likely Worthless in Reducing Emissions, Study Says*, Inside Climate News, April 19, 2017.) Partly in recognition of these flaws, offsets are typically permitted to constitute only a very small part of an overall emission reduction program—for example, California's cap and trade program allows no more than 8 percent reductions come from offsets. There is simply no evidence that the undefined, unenforceable offsets proposed by the SMND will cause any meaningful reduction to mitigate the permanent increase in GHG caused by the proposed development. Protocols adopted by voluntary market registries may not meet standards necessary to ensure that Project emissions actually will be reduced to a less than significant level. *See Golden Door Properties, LLC v. County of San Diego* (2020) 50 Cal.App.5th 467 at 511-12.

An EIR on the Project must address the aforementioned flaws by providing a detailed analysis of GHG emission impacts and mitigation to minimize those impacts.

G. The SMND fails to adequately address the Project's related impacts on energy use, wildfire safety, and utility services.

1. Energy use under the Ordinance would vastly exceed the County's threshold, such that the proposed mitigation measure is woefully inadequate.

CEQA requires that a lead agency analyze the energy impacts of a proposed project, specifically, whether the project would "result in potentially significant environmental impact due to wasteful, inefficient, or unnecessary consumption of energy resources, during project construction or operation." CEQA Guidelines, Appendix G, § VI(a); *see* also Pub. Resources Code § 21100(b)(3); CEQA Guidelines § 15126.2(b). This analysis must include the project's energy use "for all phases and components." CEQA Guidelines § 15126.2(b). If this analysis indicates that a project would result in wasteful or inefficient energy use, the agency "shall mitigate" this significant impact. *Id.* Related to this requirement, the lead agency must also analyze whether the proposed project would "require or result in the relocation or construction of new or expanded. . . electric power [or] natural gas . . . facilities, the construction or relocation of which could cause significant environmental effects." CEQA Guidelines, Appendix G, § XIX(a).

According to the California Public Utilities Commission, cannabis is an energy-intensive crop when grown indoors. *See Energy Impacts of Cannabis Cultivation*, Cal.

Pub. Utils. Com., April 2017, attached as Exhibit 56.[12] "According to a recent study … Seattle Light and Power estimates a 3% increase in overall electric demand as a result of legal cannabis production, and a utility interviewee from Colorado estimated that the total load growth for the state attributable to cannabis production since 2013 was between 0.5% and 1%. In 2015, Bloomberg researchers estimated that cannabis grow facilities made up almost 50% of the new power demand in Colorado." J. Remillard & N. Collins, *Trends and Observations of Energy Use in the Cannabis Industry*, Alliance for an Energy Efficient Economy (2017) (internal citations omitted), attached as Exhibit 57.[13] *See also* "Nearly 4 Percent of Denver's Electricity Is Now Devoted to Marijuana," CPR News, published Feb. 19, 2018[14]; "3 Big Questions About Energy Use in Legal Cannabis Cultivation," Midwest Energy Efficiency Alliance, published August 27, 2019 ("Oregon has experienced localized blackouts due to the added strain on the electric grid from indoor cannabis facilities.")[15]; "Electricity Use in Marijuana Production," Nat'l. Conference of State Legislatures, published August 2016 ("The electricity consumption of growhouses is staggering when compared to business and residential use.")[16]; "Most states legalizing marijuana have yet to grapple with energy demand", Energy News Network, published July 27, 2019 ("[S]tates legalizing cannabis so far have done little to limit or even track the huge amounts of energy needed to grow it indoors.")[17].

The SMND's analysis of these issues is cursory and violates CEQA. First, rather than cite to the copious literature on the energy intensity of commercial cannabis operations, the SMND merely states that "indoor and mixed-light operations can require a relatively large amount of electricity" due to the various energy-intensive activities

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[12] Available at: https://www.cpuc.ca.gov/uploadedFiles/CPUC_Public_Website/Content/About_Us/Organization/Divisions/Policy_and_Planning/PPD_Work/PPD_Work_Products_(2014_forward)/PPD%20-%20Prop%2064%20Workshop%20Report%20FINAL.pdf (last visited March 11, 2021).
[13] Available at: https://www.aceee.org/files/proceedings/2017/data/polopoly_fs/1.3687880.1501159058!/fileserver/file/790266/filename/0036_0053_000046.pdf (last visited March 11, 2021).
[14] Available at: https://www.cpr.org/2018/02/19/nearly-4-percent-of-denvers-electricity-is-now-devoted-to-marijuana/ (last visited March 11, 2021).
[15] Available at: https://www.mwalliance.org/blog/3-big-questions-about-energy-use-legal-cannabis-cultivation (last visited March 11, 2021).
[16] Available at: https://www.ncsl.org/research/energy/electricity-use-in-marijuana-production.aspx (last visited March 11, 2021).
[17] Available at: https://energynews.us/2019/06/27/most-states-legalizing-marijuana-have-yet-to-grapple-with-energy-demand/ (last visited March 11, 2021)

involved in cultivation, including but not limited to building lighting and heating and cooling systems, and other energy usage for cultivation, processing and distribution. SMND at 49. Nor does the SMND attempt to identify existing energy supplies and energy use patterns in the region and locality. CEQA Guidelines § 15126.2(b). Instead, the SMND includes a table showing the total electricity and natural gas demand in PG&E's entire service area of Northern California. SMND at 48. This information serves no purpose for determining the impact of the project on existing energy supplies in Sonoma County. Consequently, the SMND does not include a baseline against which the project's energy intensity can be measured. CEQA Guidelines § 15125(a) (physical environmental conditions "in the vicinity of the project" will normally constitute the baseline physical conditions by which the lead agency determines whether an impact is significant).

The SMND establishes a threshold of significance for the project's impact on inefficient or wasteful energy use. A significant impact due to the wasteful or inefficient use of energy would occur if a cannabis operation uses more than 25.5 kWh/square foot annually. SMND at 49. Yet, the SMND makes no effort to identify the "[t]otal energy requirements of the project by fuel type and end use," or the "[t]otal estimated daily vehicle trips to be generated by the project and the additional energy consumed per trip by mode." CEQA Guidelines, Appendix F. Instead, the SMND states that indoor cultivation *generally* uses 200 kWh/square foot annually and that mixed-light cultivation uses 110 kWh/square foot annually. SMND at 48. However, the SMND also states that energy use "can vary widely as a result of factors such as plant spacing, layout and the surrounding climate." *Id.* Rather than use a generic range for the energy intensity of indoor operations, the County should have used a modeling tool, such as CalEEMod, to estimate the maximum potential energy intensity of the proposed project, assuming all properties currently or foreseeably eligible for cultivation under the Ordinance were to construct growing facilities to the maximum extent permitted. *See Christward Ministry v. Superior Court* (1986) 184 Cal.App.3d 180, 194 (evaluation of action must include analysis of all activities permitted by the action). This tool also should take into account the unique climatic conditions of Sonoma County.[18]

[18] The SMND furthermore errs in estimating the project's energy use from transportation modes associated with workers, by assuming that "the number of employees working …[is] likely similar to existing and planned" agricultural facilities in the County. SMND at 50. Whether the average number of workers per existing or planned agricultural operation would be "similar" under the proposed Ordinance is not the point; rather, for purposes of estimating energy impacts, the SMND must look at the *absolute* number of

Even omitting a discussion of factors which may result in higher energy uses by cannabis operations in Sonoma County, the SMND thus indicates that indoor operations could use *eight times* more energy than the County's threshold of significance for determining whether energy use is wasteful or inefficient. The SMND therefore finds that the Project would result in a significant impact. SMND at 50. However, the SMND asserts that, with implementation of Mitigation Measure ENERGY-1, the Ordinance "would not result in wasteful or unnecessary energy consumption in Sonoma County, and impacts would be less than significant with mitigation incorporated." *Id.*

The County's proposed mitigation measure for this significant impact is woefully insufficient to reduce this impact to below the threshold of significance. The measure would merely require that, before receiving a building permit, an applicant must submit an "energy conservation plan" to reduce energy use below the threshold of significance (25.5 kWh/square foot per year). This plan must contain (1) a detailed inventory of the proposed project's energy demand, and (2) a program for reducing or "offsetting" the project's energy use such that it does not exceed the threshold, including but not limited to "[e]vidence that the project will permanently source project energy demands from renewable energy sources (*i.e.*, solar, wind, hydro)," or reduce energy use through energy efficiency measures. SMND at 51.

There are numerous legal problems with MM ENERGY-1. First, the mitigation measure is duplicative of the Ordinance itself, and thus would not actually "mitigate" anything. Per section 38.12.110 of the proposed Ordinance, indoor and greenhouse projects would *already* be required to be fully powered by renewable energy, or else offset by carbon credits determined by the County to be verifiable and enforceable. SMND at 49. The SMND finds that notwithstanding this requirement of the Ordinance, impacts would still be significant; hence the proposal of MM-ENERGY-1. Yet, the mitigation measure would merely require what the Ordinance already requires—that projects be powered by renewable energy.

Second, the SMND provides no evidence that any combination of either grid-tied, or on-site renewable generation, or energy efficiency, would be sufficient to power the types of cannabis operations the Ordinance would allow throughout the County, whether individually or cumulatively. Under CEQA, mitigation measures' efficacy must be apparent and there must be evidence in the record showing they will be effective in remedying the identified environmental problem. *See Sierra Club v. County of San Diego* (2014) 231 Cal.App.4th 1152, 1168. MM ENERGY-1 does not come close to meeting

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new workers/truck trips that would result. Thus, the SMND lacks any evidence to conclude that worker-associated transportation would not result in significant energy impacts.

this standard. Similarly, allowing applicants to "offset" their energy use by buying carbon credits does not actually address the issue of whether there is sufficient energy *supply* to support the projects the Ordinance would allow. *See also* Section V.C, *supra*, discussing requirement that mitigation relying on carbon "offsets" be verifiable, enforceable and non-duplicative.

Third, by its own terms, MM-ENERGY-1 would only apply to cannabis operations in new buildings; it would not apply to cannabis operations newly allowed by the Ordinance in existing buildings. As explained in proposed section 38.12.030 – Limitation on Canopy and Structures, the Ordinance does not limit the square footage of indoor cannabis operations in existing structures. Thus, despite the fact that the wasteful use of energy from indoor cannabis operations allowed under the Ordinance could exceed the County's threshold by eight times, MM-ENERGY-1 would only attempt to address wasteful energy use in new structures.

2. The SMND fails to analyze whether the Project would require new or expanded electric distribution facilities, the construction of which could cause significant impacts.

Given that the SMND indicates that the types of projects the Ordinance would allow could massively exceed the County's threshold of significance, the County should have analyzed whether the current distribution system—as distinct from current energy *supply*—has sufficient capacity to serve these projects, both individually and cumulatively. Under CEQA, the lead agency must analyze whether the proposed project would "result in the relocation or construction of new or expanded. . . electric power [or] natural gas . . . facilities, the construction or relocation of which could cause significant environmental effects." CEQA Guidelines, Appendix G, § XIX(a). Among other things, new electric wires create an increased risk of wildfire, which is a significant environmental impact under CEQA. *See, e.g.,* Pub. Resources Code § 8386(b) (each utility shall submit annual wildfire mitigation plan, including a "description of the preventive strategies and programs to be adopted by the [utility] to minimize the risk of its electrical lines and equipment causing catastrophic wildfires."); *see also* SMND at 99-100 (concluding that "the updated Ordinance would not require the installation of new power line infrastructure, and therefore would not exacerbate fire risk.").

The SMND completely fails to do this. The SMND's discussion of this potential impact cross-references the aforementioned finding that "because the updated Ordinance would allow for larger cannabis operations . . . large-scale new cannabis uses could potentially exceed energy supply during operation." SMND at 96. Yet, instead of analyzing whether the project would require the "relocation or construction of new or expanded. . . electric power [or] natural gas . . . facilities," the SMND concludes *without* *evidence* that aforementioned MM-ENERGY-1 would avoid having to construct new distribution facilities. The SMND fails to recognize that even if sufficient generation were available to serve the projects that will be allowed by the Ordinance, substantial upgrades to the distribution system would likely be necessary in order to supply this energy to individual projects, often in remote rural areas where distribution systems are already marginal.

In fact, there is substantial evidence that PG&E's current distribution system in Sonoma County would not support the type and scale of projects the Ordinance would allow, even if sufficient renewable generation were available to supply these projects. As just one example of an existing and proposed project that together would likely exceed the current distribution line capacity, there is an existing grow and adjacent proposed cultivation both on Palmer Creek Road, Healdsburg (permit nos. UPC17-0067 and UPC18-0046, respectively). PG&E's Integration Capacity Analysis ("ICA") map shows the feeder nearest these two sites, which indicates zero capacity for additional load and also zero capacity for additional distributed generation. This map suggests, first, that an upgrade to the distribution system would be needed to support the considerable additional electricity demand (or load) associated with cannabis production at these locations; and second, that it would not be possible for an applicant simply to install their own on-site renewable generation to meet their new demand. *See* Exhibit 58 (ICA map screenshot showing feeder nearest Palmer Creek Road).[19] The County must use all available tools to evaluate whether buildout of cannabis operations under the proposed Ordinance would exceed the available capacity of the distribution system, particularly in areas where the Ordinance would actually or foreseeably allow cultivation operations.

[19] "Load ICA" is defined as the "[a]mount of load that can be installed at that location without any thermal or voltage violations at the time the integration capacity analysis was performed." *See* Exhibit 59, PG&E's instruction manual for ICA maps, at 10. Although PG&E's data does not prove conclusively that upgrades to electric infrastructure would be necessary (*see, e.g*., recent order from an Administrative Law Judge in the California Public Utilities Commission's ICA proceeding, requiring the Investor Owned Utilities ("IOUs"), including PG&E, to clean up their messy data; the order is available at https://docs.cpuc.ca.gov/PublishedDocs/Efile/G000/M361/K810/361810169.PDF), it is the best data publicly available at this time, and it demonstrates that the County must do a more in-depth investigation before proceeding. Alternatively, the County must require a permit-by-permit discretionary review to determine, at the time of permitting, whether significant impacts would occur.

H. The SMND fails to adequately analyze and mitigate the Project's noise impacts.

The proposed Project would result in a significant increase in cannabis cultivation operations in the County. The SMND acknowledges that these facilities, particularly mixed light and indoor cultivation structures use HVAC units, and other noise producing equipment that operates 24 hours per day. SMND at 80. Hoop houses can have electrical and mechanical equipment (§ 38.18.020) and could produce noise from fans and HVAC. Unshielded HVAC equipment located within 1,000 feet of an offsite receptor could generate noise exceeding the "nighttime standard of 45 dBA L50." SMND at 80. The SMND discloses that even with shielding, HVAC "equipment could still exceed the nighttime standard within a distance of 300 feet from sensitive receptors." *Id*. The SMND concedes it "is necessary to require a sufficient setback between HVAC equipment and sensitive receptors." *Id*.

The noise resulting from implementation of the Project will detrimentally affect rural communities and residents living near cannabis cultivation sites. Despite the SMND's disclosure of the Project's anticipated exceedance of the County's noise standards, the SMND fails to provide a complete evaluation of the Project's noise impacts. As an initial matter, given that the SMND's traffic analysis underestimates Project-related traffic, operational noise impacts at adjacent residential areas are likely to be even higher than the SMND discloses. Once the County calculates a more accurate estimate of truck and vehicle traffic associated with cannabis cultivation and associated special events, the revised analysis can be used to estimate noise impacts.

In addition, a revised analysis must calculate anticipated noise from various types of facilities using typical equipment. The analysis should take into account the potential for multiple facilities to locate near each other and/or along one roadway. Concerning noise from special events, the County must calculate the number of events that can take place at facilities based on any limits imposed by the relevant Code section on such events rather than assuming that such events "would occur infrequently." SMND at 81. Without such an analysis, the SMND provides no evidence that the amount of noise reduction provided through identified best management practices will be sufficient to reduce noise to less-than-significant levels. SMND at 82.

I. The SMND fails to analyze significant impacts associated with loss of farmland.

The SMND fails to adequately analyze or mitigate the effects of the Project on agricultural land conversions in the foothills and mountainous areas of the County. Implementation of the Project would allow the avoidable conversion of thousands of acres of lands currently designated for grapes and other food crops to cultivation and production of cannabis. Despite this potential loss of farmland, the SMND includes virtually no analysis of the Project's impacts on the loss of agricultural land for cultivation of food crops. As explained in section VIII below, cannabis cultivation is qualitatively different from other forms of agriculture, particularly in terms of its environmental impacts, and thus should not be redefined as "agriculture" in the County's General Plan.

The lucrative business of growing cannabis provides financial incentives to convert traditional agricultural land to cannabis uses. An increase in cannabis facilities in remote, rural areas will in turn add more pressure for even more conversion of rural agricultural lands used for food production. The SMND acknowledges this potential conversion of land when it states: "Expanded cannabis operations under the updated Ordinance also would displace other types of agricultural cultivation (*e.g.*, vegetables, grapes, and plant nurseries)…." SMND at 61. Nonetheless, the SMND fails to evaluate the impacts of displacing traditional agricultural activities.

The Sonoma County General Plan Agricultural Element (Agricultural Element) indicates that supporting cultivation of the food system is considered a priority. For instance, the Agricultural Element states that the purpose of the general plans is "to establish policies to insure the stability and productivity of the County's agricultural lands and industries." Agricultural Element at AR-1. The Agricultural Element at section 2.10, where it indicates that aquaculture and fishing should be considered along with land based agricultural practices, does so because those businesses produce a food source. The Agricultural Element specifies :

"Aquaculture and the fishing industry produce a food source and have needs similar to land based agricultural operations. Policy is needed to treat the support facilities of the fishing industry that relate to food production or harvesting in the same manner as those of other agricultural production."

Agricultural Element at AR-2. Similarly, Agricultural Element Policy AR-1e states:

"Encourage and support farms and ranches, both large and small, that are seeking to implement programs that increase the sustainability of resources, conserve energy, and protect water and soil *in order to bolster the local food economy*, increase the viability of diverse family farms and improve the opportunities for farm workers."

Agricultural Element at AR-3; emphasis added.

In light of the fact that agriculture is an important land use in Sonoma County, that the County is known for its vineyards and sustainable agriculture, and that it has long been a high priority of the County to provide for the conservation of its agriculture, the avoidable loss of thousands of acres of productive farmland to the cannabis industry resulting from the Project is significant. Thus, the County must include analysis of this significant impact in an Environmental Impact Report for the Project.

Finally, it is important to note that the permanent protection of agricultural and open space areas has become an urgent need throughout the state. California statutory and case law have long recognized open space as a valuable environmental resource. Accordingly, the California Legislature has declared that "open-space land is a limited and valuable resource which must be conserved wherever possible." Gov't Code § 65562(a). Nearly fifty years ago the California Supreme Court recognized that "[t]he elimination of open space in California is a melancholy aspect of the unprecedented population increase which has characterized our state . . . ." *Associated Home Builders of the Greater East Bay, Inc. v. City of Walnut Creek*, 4 Cal.3d 633,638 (1971), cert. denied, 404 U.S. 87S (1971). Of course, the problem has become ever more serious since the Court's prescient statement.

J. The SMND fails to adequately analyze and mitigate the Project's impacts on specific and area plans.

The SMND fails to analyze conflicts with any of the County's eight specific and area plans. Policy LU-1a of the General Plan emphasizes that:

> A Specific or Area Plan may establish more detailed policies affecting proposed development, but may not include policies that are in conflict with the General Plan. In any case where there appears to be a conflict between the General Plan and any Specific or Area Plan, the more restrictive policy or standard shall apply.

In particular, the Project conflicts with policies in the Bennett Valley Area Plan and possibly other specific and area plans. Land Use Policy 2 in the Bennett Valley Area Plan provides "Commercial development is not considered appropriate to the rural character of Bennett Valley." Both Chapter 26 and Chapter 38 permit *commercial* cannabis activity, and Sonoma County Counsel has concluded that discretionary approvals under Chapter 26, building permits issued under chapter 7, and grading permits issued under chapter 7 are "development."[20]

[20] *See*, Comments submitted by Bennett Valley Citizens for Safe Development, Exhibit 22.

Land Use Policy 3 provides "[d]evelopment shall be coordinated with the public's ability to provide schools, fire, police and other needed services." Emphasis added. Crime is a major concern with cannabis cultivation, and it can take 30 to 45 minutes for a sheriff to respond to a call in Bennett Valley. The Proposal would allow 600 acres of commercial marijuana cultivation in Bennett Valley and fails to discuss or mitigate this issue. Possible mitigations include establishing a sheriff's substation in Bennett Valley; banning permits on properties located on shared access roads to minimize home invasions of innocent non-growers; and banning marijuana grows adjacent to parcels that are zoned residential to limit home invasions of neighbors not involved with marijuana cultivation.[21]

VI. The SMND fails to provide any analysis of the Project's potentially significant cumulative impacts.

CEQA requires lead agencies to disclose and analyze a project's "cumulative impacts," defined as "two or more individual effects which, when considered together, are considerable or which compound or increase other environmental impacts." Guidelines § 15355. Cumulative impacts may result from a number of separate projects, and occur when "results from the incremental impact of the project [are] added to other closely related past, present, and reasonably foreseeable probable future projects," even if each project contributes only "individually minor" environmental effects. Guidelines §§ 15355(a)-(b). A lead agency must prepare an EIR if a project's possible impacts, though "individually limited," prove "cumulatively considerable." Pub. Res. Code § 21083(b); Guidelines § 15064(i).

Extensive case authority highlights the importance of a thorough cumulative impacts analysis. In *San Bernardino Valley Audubon Society v. Metropolitan Water Dist. of Southern Cal.* (1999) 71 Cal.App.4th 382, 386, 399, for example, the court invalidated a negative declaration and required an EIR be prepared for the adoption of a habitat conservation plan and natural community conservation plan. The court specifically held that the negative declaration's "summary discussion of cumulative impacts is inadequate," and that "it is at least potentially possible that there will be incremental impacts. . . that will have a cumulative effect." *See* also *Kings County Farm Bureau v. City of Hanford* (1990) 221 Cal.App.3d at 728-729 [EIR's treatment of cumulative impacts on water resources was inadequate where the document contained "no list of the projects considered, no information regarding their expected impacts on groundwater resources and no analysis of the cumulative impacts"].

In contravention of the above authorities, the SMND provides no discussion or analysis whatsoever of the Project's cumulative impacts. SMND at section 21 at 103.

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[21] *Id*.

Instead the SMND makes conclusory statements regarding the Project's cumulative impacts. For example, the SMND claims that the Project "would not adversely affect biological, cultural, or other physical resources outside of the project sites." *Id*. As discussed throughout this letter, this statement is incorrect. First, the SMND's purported analyses on these topics focuses only on potential impacts from each individual facility (as opposed to impacts from all possible facilities under the Project), thus failing to evaluate the impacts from the whole of the project. Second, the SMND fail to consider other potential Projects or the cumulative effects of the whole project along with other projects. Impacts related to hydrology, water quality, and groundwater will result in cumulative impacts to area rivers and streams that support sensitive fish species. *See also*, Letter from Robert Coey, National Marine Fisheries Service dated February 26, 2021 attached as Exhibit 6. The SMND fails to evaluate these impacts.

The SMND's cumulative impact analysis refers the reader to the individual resource section for a discussion of the Project's cumulative air quality and greenhouse gas impacts. *Id*. Again, the SMND purported analyses on these topics focuses only on potential impacts from each individual facility. SMND at 30. While the SMND asserts that "[A]ir pollutant emissions from individual projects can contribute to cumulative air pollution in a regional air basin," no actual analysis is included. *Id*. Moreover, as discussed above the SMND fails to provide evidence that the identified mitigation measures will be enforceable and effective. The SMND then states that other issues, including aesthetics "are site-specific by nature, and impacts at one location do not add to impacts at other locations or create additive impacts." SMND at 103. The document provides no evidence to support this statement. The SMND fails to consider the effects of this Project along with other projects in the County (*e.g.*, the County's Winery Events Ordinance currently under consideration). The SMND thus completely ignores the cumulative effects of all the potential development that may take place pursuant to the new zoning provisions and general plan amendments combined with other development. These impacts must be analyzed in an EIR on the Project.

VII. The mitigation proposed by the SMND is inadequate.

Because, as discussed above, the SMND fails to thoroughly examine and analyze the Project's impacts, it also fails to adequately mitigate for the related impacts. Moreover, the SMND relies on insufficient mitigation and fails to consider and adopt all feasible mitigation.

The County cannot approve projects with significant environmental impacts if any feasible mitigation measure or alternative is available that will substantially lessen the severity of any impact. Pub. Res. Code § 21002; CEQA Guidelines § 15126(a). The County is legally required to mitigate or avoid the significant impacts of the projects it approves whenever it is feasible to do so. Pub. Res. Code § 21002.1(b). An EIR is inadequate if it fails to suggest feasible mitigation measures, or if its suggested mitigation measures are so undefined that it is impossible to evaluate their effectiveness. *San Franciscans for Reasonable Growth v. City and County of San Francisco* (1984) 151 Cal.App.3d 61, 79. Of course, the County may not use the inadequacy of its impacts review to avoid mitigation: "The agency should not be allowed to hide behind its own failure to collect data." *Sundstrom v. County of Mendocino* (1988) 202 Cal.App.3d 296, 36. Nor may the City use vague mitigation measures to avoid disclosing impacts. *Stanislaus Natural Heritage Project*, 48 Cal.App.4th at 195. Put another way, an EIR must set forth specific mitigation measures or set forth performance standards that such measures would achieve by various, specified approaches. *See* CEQA Guidelines § 15126.4; *see* also *Sacramento Old City Assn. v. City Council of Sacramento* (1991) 229 Cal.App.3d 1011, 1034; *see* also *Communities for a Better Environment' v. City of Richmond* (2010) 184 Cal.App.4th 70, 93-95 (agency may not approve a vague mitigation measure that contains no performance standards and criteria to guide its later implementation). Without performance standards and an explanation of why mitigation cannot be developed now, the SMND cannot insist the impact will be insignificant and defer the development of specific mitigation measures to some future time. Guidelines § 15126.4 (a)(1)(B). The SMND failed to comply with this bedrock CEQA requirement.

"In the case of the adoption of a plan, policy, regulation, or other public project [such as the proposed Code and General Plan amendments], mitigation measures can be incorporated into the plan, policy, regulation, or project design." CEQA Guidelines § 15126.4(a)(2). Mitigation is defined by CEQA to include "[m]inimizing impacts by limiting the degree or magnitude of the action and its implementation." CEQA Guidelines § 15370(b). In addition to proposing new "policies" as mitigation, mitigation should include changes in where development is planned, what kind is planned, and how dense or intense that development is planned to be.

Here, there is no indication that the SMND considered additional policies or modifications to the proposed amendments to mitigate the impacts of the Project. For example, as described above, the Project would exacerbate risks from wildfire hazards to existing residents and introduce new hazards in terms of providing inadequate emergency evacuation routes. These increased risks and hazards constitute a significant impact requiring the County to identify feasible mitigation measures and alternatives to minimize them. Instead of fully evaluating the Project's wildfire-related impacts, the SMND effectively assumes that no such impacts are possible because future applicants will be required to comply with applicable (unspecified) regulations. SMND at 99.

The County incorrectly conflates code compliance with the CEQA process. CEQA directly forbids an assumption, without underlying analysis, that simply complying with a regulatory standard is adequate to mitigate a potentially significant impact. Under well-established case law, compliance with existing policies and regulations does not excuse the agency from describing project activities or from analyzing resulting impacts. See, *e.g.*, *Californians for Alternatives to Toxics v. Department of Food & Agriculture* (2005) 136 Cal.App.4th 1, 16-17 (compliance with regulation alone not a basis for finding impact less than significant); *Protect the Historic Amador Waterways v. Amador Water Agency* (2004) 116 Cal.App.4th 1099, 1108-09 (environmental effect may be significant despite compliance with such requirements). A revised environmental document must identify feasible mitigation measures for such impacts (*e.g.*, limiting the number of cannabis facilities within high fire risk zones, limiting the total number of permits approved, and/or limiting cannabis facilities to areas with access via roads that meet State standards for fire safety).

Concerning Project impacts related to odors, the SMND fares no better. Despite acknowledging that odor impacts from cannabis cultivation sites are potentially significant (SMND at 33 and 34), the SMND provides virtually no analysis of odor impacts from indoor cultivation sites. Instead, as described in detail in section V.D.2 above, the SMND relies on measures requiring odor control filtration and ventilation systems to control odors for indoor cultivation. But because the SMND fails to impose quantifiable performance standards, it fails to provide evidence that the measure will reduce impacts to less-than-significant levels.

For outdoor cultivation sites, the SMND relies on established setbacks to minimize odor impacts and a single mitigation measure that impermissibly defers analysis of odors until after the cultivation permit is approved and implemented. SMND at 35. Buffers and setbacks can be effective ways to minimize odors since distance reduces the strength and concentration of odors through atmospheric dispersion. However, the minimal buffers proposed by the SMND are inadequate to reduce odor impacts to adjacent residents. As shown by cannabis consulting firm Ortech, setbacks of at 3,000 feet or more are necessary to minimize odors from outdoor cannabis cultivation sites. Ortech brochure at 2, attached as Exhibit 26. In fact, many counties (i.e., Napa and Marin) forbid outdoor cultivation recognizing the significant negative impacts on health and safety of residents, citing both odor and crime. Other counties, such as Yolo County, require larger minimum setbacks of 1,000 feet for outdoor cultivation of up to one acre of cultivation.

A revised environmental document must identify feasible mitigation measures for odor impacts, particularly for outdoor cultivation areas (*e.g.*, limit or exclude cannabis cultivation sites adjacent to RR-, AR- and RRD-designated areas of the County; increase setbacks from residential property lines to a minimum of 1,000 feet to 3,000 feet from residences depending on site specific location, topography, and prevailing winds; require cultivation of less odorous plant strains; and/or limiting cultivation to smaller grow areas). In cases where mitigation efforts of cannabis operators repeatedly fall short of effectiveness (as measured by three or more complaints from neighbors), modification of the operator's cannabis cultivation permit should be required to address the impact. This can include either increasing the setback, relocation of outdoor activities indoors or in a greenhouse or, if odor impacts persist, revoking the permit.

In another example, the SMND acknowledges significant aesthetic impacts related to degradation of existing visual character. SMND at 21 and 22. Here similar to its approach for mitigating odor impacts, the SMND relies on setbacks and screening to minimize impacts to views and visual character. However, the SMND provides no evidence that these measures will be effective to reduce impacts to less than significant levels. Especially for larger indoor facilities that include industrial-sized warehouse buildings, planting vegetation and minimal setbacks are not likely to effectively screen these facilities from public viewpoints.

Compliance with CEQA would involve acknowledging and describing the anticipated effects of the Project. To this end, an EIR must quantify the Project's effects on area residents (including loss of agricultural land, odor and air pollution, transportation impacts, increased wildfire risk, increased noise, and impacts to views) and natural resources (including impacts on water supply, watershed water quality, and on biological resources dependent on water quality) and the efficacy of the proposed mitigation, so that the public and decision makers may reach their own conclusions. *Save Our Peninsula Committee v. Monterey County Board of Supervisors* (2001) 87 Cal.App.4th 99, 130. The current proposal to allow cannabis cultivation sites with ministerial review and minimal setbacks of 100 feet from the property line and 300 feet from the residences of sensitive receptors would result in significant impacts that have neither been adequately analyzed nor adequately mitigated.

VIII. Cannabis is associated with uniquely problematic nuisance conditions and should not be included under the County's Right-to-Farm Ordinance.

The proposed project would amend the General Plan (2020) to redefine agricultural land use as inclusive of cannabis cultivation, thus potentially making commercial cannabis operations subject to the County's Right to Farm Ordinance (Sonoma County Code, ch. 30). In addition, the proposed Chapter 38 lacks the Health and Safety clause that is in the current chapter 26 cannabis ordinance (§ 26.88.250(f)) that forbids commercial cannabis activity from creating a public nuisance or adversely affect the health or safety of the nearby residents. As explained throughout this letter, cannabis is associated with uniquely problematic nuisance conditions and thus should not be defined as, and receive the same protections as, traditional agriculture.

In 2016, the Board of Supervisors found that cannabis should be treated differently from other agriculture because its classification under the Federal Controlled Substances Act. The Board of Supervisors distinguished cannabis from other agriculture because of its "federal classification as a Schedule I drug, the security concerns associated with a high value crop, and the unique characteristics of the cannabis cultivation operations." December 20, 2016 Board of Supervisors Resolution Approving an Amendment to Uniform Rules 2.0, 4.0, 7.0 and 8.0 of the Sonoma County Uniform Rules for Agricultural Preserves and Farmland Security Zones. See Exhibit 60 Board of Supervisors 2016 Proposed Ordinance. The Resolution cited the FCSA for its classification of cannabis as a Schedule I drug. The Resolution further stated "that excluding cannabis cultivation from the Uniform Rules' definition of 'agricultural use,' is desirable and will appropriately tailor Sonoma County's agricultural preserve program to meet local, regional, state, and national needs for assuring adequate, healthful and nutritious food for future residences." *Id.*

Although the SMND states that "the County has since found that despite this federal classification, cannabis cultivation functions similarly to other agricultural operations and that it fits within the plain language and intent of the term 'agriculture,'" none of the considerations that went into the Board's 2016 reasoning have changed. Cannabis cultivation is an intensive land use involving odors and energy and other infrastructure demands more similar to industrial uses than to traditional agriculture. *See*, *e.g.*, Exhibit 4, John W. Bartok, Jr., Cannabis Business Times, Greenhouse Efficiency Guide: 21 Cannabis Greenhouse Design Considerations (describing features like conveyors, heating and hot water boiler systems, fan and louver systems for ventilation, and supplemental lighting requirements). Furthermore, the SMND itself contradicts any finding that cannabis cultivation is "similar" to other agricultural operations.

The SMND concludes that the proposed project would require extensive mitigation in order to reduce cannabis operations' impact on surrounding agricultural uses. In describing this mitigation, the SMND explicitly differentiates cannabis cultivation from other forms of agriculture. For instance, although agricultural land uses often generate odors, "cannabis cultivation can generate particularly strong odors that adversely affect people." SMND at 34; *see also id.* at 33 (cannabis cultivation and processing operations "generate distinctive odors" that can be "reminiscent of skunks, rotting lemons, and sulfur.").

Similarly, although it is common for agricultural operations to include visible structures such as barns and silos, "the updated Ordinance could allow for additional cannabis structures (especially light-reflective greenhouses and hoop houses) that could contrast with the general form, scale, and bulk of other agricultural structures or vegetation in rural areas." SMND at 22; *see also id.* at 24 ("cannabis cultivation can cause distinct glare impacts in comparison to typical agricultural practices. Greenhouses and hoop houses used for cannabis cultivation can have highly visible light-reflective materials."). Cannabis cultivation also involves different energy and hazardous materials practices compared to traditional agriculture. *See* SMND at 48 (describing cannabis's uniquely significant energy demands); SMND at 62 (describing hazardous components of high-powered lights used in cannabis operations).

Other counties, including Alameda, Humboldt, and Mendocino, have declined to expand the definition of agriculture in their general plans to include cannabis for these very reasons. They also cite the fact that cultivation of cannabis raises health, safety and welfare concerns not raised by other traditional agricultural products. Given the status of cannabis as a controlled substance, which is illegal under federal law, cannabis cultivation involves potential adverse effects that differ from the cultivation of other types of crops (*e.g.*, criminal activity and impacts on children and sensitive populations). State cannabis regulations include a number of development standards and permitting requirements to avoid or mitigate these adverse effects, which are not required for the cultivation of other types of crops on agricultural lands. Cannabis cultivation and cannabis operations are therefore excluded from the State and these counties' definitions of agriculture.

IX. Conclusion

As set forth above, the Project does not come close to satisfying CEQA's requirements. The SMND fails to describe the Project and its setting, and fails to provide a complete analysis of Project impacts, cumulative impacts, and feasible mitigation measures. At the same time, ample evidence demonstrates that a fair argument exists that the Project may have significant environmental impacts. In light of this evidence, CEQA requires that an EIR be prepared. For this reason, SOSN respectfully requests that the Project be denied.

Very truly yours,

SHUTE, MIHALY & WEINBERGER LLP

Joseph "Seph" Petta

Aaron M. Stanton

Carmen J. Borg, AICP
Urban Planner

Exhibits

1. Letter from Greg Kamman, Senior Ecohydrologist with CBEC Ecoengineering, dated March 16, 2021

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4. John W. Bartok, Jr., Cannabis Business Times, *Greenhouse Efficiency Guide: 21 Cannabis Greenhouse Design Considerations*

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6. Letter from Robert Coey, National Marine Fisheries Service (Feb. 26, 2021)

7. Susanne Rust et al., *How climate change is fueling record-breaking California wildfires, heat and smog*, Los Angeles Times (Sep. 13, 2020)

8. Anne Mulkern, *Fast-Moving California Wildfires Boosted by Climate Change*, Scientific American (Aug. 24, 2020)

9. 2020 Incident Archive, CalFire

10. Sonoma County Agricultural Preservation and Open Space District – Sonoma Complex Fire

11. Sonoma County Agricultural Preservation and Open Space District – Kincade Fire

12. Sonoma County Agricultural Preservation and Open Space District – 2020 Wildfires

13. Tiffany Yap, et al., Center for Biological Diversity, *Built to Burn: California's Wildlands Developments Are Playing With Fire* (Feb. 2021)

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EXHIBIT 1

cbec eco engineering
Hydrology | Hydraulics | Geomorphology | Design | Field Services

March 16, 2021

Ms. Carmen Borg
Shute, Mihaly & Weinberger LLP
396 Hayes Street
San Francisco, CA 94102-4421

Subject: Review of Draft Subsequent Mitigated Negative Declaration
Permit Sonoma File No: ORD20-0005
Sonoma County Cannabis Land Use Ordinance Update and General Plan Amendment

Dear Ms. Borg:

I am a state licensed Professional Geologist and Certified Hydrogeologist with over thirty years of technical and consulting experience in the fields of geology, hydrology, and hydrogeology. I have been providing professional hydrology and hydrogeology services throughout California since 1989 and routinely manage and lead projects in the areas of surface- and groundwater hydrology, water supply, water quality assessments, water resources management, and geomorphology. A copy of my resume is provided as Attachment A.

I have been retained by Shute, Mihaly & Weinberger LLP (SMW) to review and evaluate the Draft Subsequent Mitigated Negative Declaration (SMND) for the Sonoma County Cannabis Land Use Ordinance Update and General Plan Amendment. Based on my review of this document, it is my professional opinion that the SMND is inadequate in evaluating and mitigating the potential significant impacts of Project actions on hydrology, groundwater supply and biological resources, especially in the upper Mark West Creek watershed (MWW)[1].

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[1] For purposes of this letter, the upper Mark West watershed is defined as the Critical Habitat Area of the Porter Creek-Mark West Creek drainage indicated on the County's Groundwater Availability map, dated December 6, 2016 and contained in Policy and Procedure Number 8-1-14, "Procedures for Groundwater Analysis and Hydrogeologic Reports" (PRMD, 2017).

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In addition, as written, I don't agree that authorization of permits for cannabis cultivation can be done under a ministerial process, but rather will require some discretion on the part of the County. The rationale for these opinions is based on the findings presented below.

1. Potentially underestimated and undocumented water use estimates

The SMND (pg. 69) state that water use requirements for outdoor cannabis production ranges from 25- to 35-inches per year[2]. The origin and/or derivation of these water use rates are not presented in the SMND. Water use estimates presented in Table 1 (Projected Water Use for Cannabis) of the County's 2015 Discussion Paper (Cannabis Cultivation RRD Zone, ORD15-0005)[3] translate to much higher water use rates, ranging from 43- to 261-inches per year, values that are 172% to 746% higher than those presented in the SMND. The potential impact on water resources due to cannabis cultivation center on the volume of water use required. The unsubstantiated and significant divergence in water use estimates presented in County documents calls into question the validity of analysis and conclusions based on these estimates. The SMND does not disclose any information regarding the source, accuracy or validity of water use estimates. Therefore, they should be considered arbitrary and unsupported in their use in impact analysis.

2. Unsubstantiated impact assessment of water use

The SMND states (pg. 71) that the ordinance would result in less than significant impact to groundwater supplies, recharge and sustainable management. A key premise of this finding is based on the stated low quantities of anticipated groundwater use for cannabis cultivation. The analysis to support this finding is omitted and unsupported for the following reasons.

- Page 69 of the SMND contains the following sentence, "*Based on the relatively low quantities of water use (from 0.002 to 1.8 acre-feet per year), the likelihood that an individual cultivator or group of cultivators using groundwater from an alluvial aquifer would, by themselves, cause substantial groundwater overdraft is unlikely*." There is no discussion or explanation on how the water use estimate of 0.002 to 1.8 acre-feet per year is derived. Without substantiating how these estimates are derived, they are just arbitrary numbers. Nor is there any analysis or justification to support the claim that one or more cultivators using groundwater will not deplete groundwater resources.

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[2] The volumes listed in the last sentence of Footnote 1 in the SMND is incorrect. It should read: For example, 12 inches (1 foot) per year applied over an area of 1 acre would be a volume of 1 acre-foot; 12 inches per year applied over an area of 10,000 square feet would be a volume of **10,000** cubic feet (approximately **74,805** gallons), or **0.23** acre-feet.

[3] Discussion Paper – Key Issues and Policy Options, Cannabis Cultivation within Resources and Rural Development (RRD) Lands, ORD15-0005.

- Page 69 of the SMND states, "*Future cannabis facilities in rural areas would rely on either surface (river, lakes and springs) or well water sources. Accordingly, the introduction of cannabis cultivation in these areas could increase the use of groundwater*." This statement echoes one of my biggest concerns regarding responsible stewardship of Sonoma County natural resources, which is the increased demand on already stressed groundwater supplies. The SNMD does not analyze the potential impact of increased groundwater demand. Statements that, "*The size limitations for cultivation sites under the updated ordinance would limit water use*" (pg. 69) and *"… cannabis cultivation would not use more water than other crops that could grow under existing regulatory setting without permit*" (pg. 69) fail to address the fact that increase the number of sites initiating cannabis cultivation will increase cumulative demands on surface- and ground-water resources; resources the County already knows are stressed in groundwater scarce and over draft basins (Kleinfelder, 2003; Santa Rosa Plain Basin Advisory Panel, 2014; and Woolfenden and Nishikawa, 2014).

3. Net zero water plan for wells located in a Priority Groundwater Basin

The SMND (pg. 70) indicates that for cannabis irrigation supply wells located in a Priority Groundwater Basin, the permittee must provide a hydrogeologic report prepared by a qualified professional demonstrating and concluding that the commercial cannabis use will not result in or exacerbate conditions of a basin or aquifer, consistent with the requirements for sustainable groundwater management plans under the California Sustainable Groundwater Management Act (SGMA). Having reviewed and assisted in the preparation of Groundwater Sustainability Plans (GSP) under SGMA, I know that preparing these reports requires considerable technical analysis, interpretation and professional judgement. It is also my experience, that data gaps are a frequent impediment. The reports will determine whether groundwater pumping will impart potential significant impacts on the environment.

The SMND does not identify who will review the analyses and conclusions presented in these reports/plans. Regardless, report/plan review will require a decision maker to determine if the report/plan conforms to standard practices and federal/state/County codes and policies. It may also require the decision maker to place limitations and conditions on the permittee to avoid environmental impacts. It is my opinion that report/plan review is a discretionary process integral to the authorization of a cannabis cultivation permit that can't be done under a ministerial process.

4. Potential impacts to interconnected surface water in Groundwater Availability Zone 1 or 2

Subdivision b. on page 70 of the SMND appears focused on ensuring groundwater pumping within 500 feet of a blue-line stream does not deplete interconnected surface waters. Under Subdivision b., there are three options to demonstrate this impact will not occur. Option 2) implies that wells within 500 feet of the Russian River and Dry Creek will not deplete interconnected surface water. Option 3) implies that wells within 500 feet of a blue-line stream and located in Groundwater Availability Zone 1 or 2 will not deplete interconnected surface water. However, the SMND does not present any analysis or justification for these determinations. Similar to the concerns raised by NMFS in their comment letter to this section of the Ordinance (see page 2 of Attachment B), it is my opinion and experience that it is possible for wells to deplete interconnected surface waters along any stream or creek depending on the well proximity, pumping rate and hydrogeologic properties of the aquifer and stream substrate. In short, the potential to deplete interconnected surface water is based on localized conditions, not a broad characterization of aquifer type. Therefore, the SMND is incomplete as it does not present any analysis to demonstrate that Options 2) and 3) will not potentially deplete interconnected surface water and adversely impact the beneficial uses of surface waters.

5. Potential impacts to interconnected surface water in Groundwater Availability Zone 3 or 4

The purpose of Subdivision c. on page 70 of the SMND is to demonstrate that there is enough yield (i.e., minimum yield) from the well to meet irrigation demands. A well yield test determines what is the maximum sustainable pumping rate from the well. However, the SMND does not evaluate or demonstrate that pumping at the "minimum yield" rate will not potentially deplete groundwater volumes, lower groundwater levels, or deplete interconnected surface waters[4]. The well yield test requirements listed under Subdivision c. evaluates if the minimum yield will meet irrigation demands but does not evaluate if pumping adversely impacts surface water and groundwater resources. Thus, it is my opinion that complying with Subdivision c. on page 70 of the SMND does not evaluate if well pumping results in potentially adverse impacts to water resources.

6. Groundwater level monitoring and annual reporting

Page 71 of the SMND indicates the updated Ordinance places monitoring and reporting conditions on the permit, including: equipping groundwater wells with a calibrated water meter and sounding tube (to measure water levels); submission of annual report including quarterly data on water meter readings and total quantity of water pumped; static water level readings; and providing a recorded easement to provide County personnel access to the well to collect water meter readings and groundwater level measurements. The SMND does not provide an explanation for how the annual reports will be evaluated or what the triggers will be for remedial actions. However, these reports are a condition placed on the permit, which will be evaluated to likely inform a discretionary decision or action. Thus, like the net zero water plan discussed under

[4] An analogy: if a car can sustain a 100-mph speed, driving it at this speed will exceed the speed limit.

item 3. above, annual reporting is a condition requiring discretionary action to the administration of a cannabis cultivation permit.

7. Upper MWW should be excluded from the Cannabis Ordinance due to the presence of sensitive biotic resources

The Mark West Creek watershed is unique to Sonoma County in that it hosts critical aquatic and riparian habitat and endangered and sensitive aquatic species. Because of its unique physical and biological characteristics, the watershed has been identified in numerous natural resource planning efforts for protection and enhancement, including the following.

- Upper Mark West Creek provides habitat for the following listed species under the U.S. Endangered Species Act (ESA): CCC steelhead listed as threatened in 1997; CC Chinook Salmon listed as threatened in 1999; CCC Coho Salmon listed as endangered in 2005. Coho in the Russian River watershed have also been listed as endangered under the California Endangered Species Act (CESA) in 2005 and were nearly extirpated from the watershed in the late 1990s (CDFW, 2018). Other aquatic species of special concern found in the upper watershed include California Roach (*Lavinia symmetricus*), Northwestern Pond Turtle (*Actinemys marmorata*), and Foothill Yellow-Legged Frog (*Rana boylii*) (Ibid).
- Mark West Creek is ranked as critical habitat for steelhead and coho salmon and assigned as a Phase 1 (highest priority) stream for coho recovery in National Marine Fisheries Service's (NMFS) Central California Coast Evolutionary Significant Unit (CCC ESU) Coho Recovery Plan (NMFS, 2012).
- The Mark West Creek watershed was selected in 2014 as one of only five watersheds under the California Water Action Plan (CWAP) to receive coordinated efforts by the SWRCB and California Department of Fish and Wildlife (CDFW) to enhance stream flows in systems that support critical habitat for anadromous fish (CDFW, 2018; OEI, 2020).
- In response to the CWAP, the CDFW has recently begun a Habitat and Instream Flow Study in the upper Mark West Creek. Goals and objectives of the study are to identify and develop relationships between stream flow and available salmonid habitat and determine the flows and water quality conditions needed to maintain rearing habitat and connectivity for juvenile salmonids and their food sources (CDFW, 2018).
- The upper Mark West Creek watershed was designated a "Natural Landscape"[5] Priority Conservation Area (PCA) by ABAG in 2008 (ABAG, 2021). Priority Conservation Areas (PCAs) are open spaces that provide agricultural, natural resource, scenic, recreational, and/or ecological values and ecosystem functions. These areas are identified through

[5] PCAs are categorized by four designations: Natural Landscapes, Agricultural Lands, Urban Greening and Regional Recreation.

consensus by local jurisdictions and park/open space districts as lands in need of protection due to pressure from urban development or other factors.

- The majority of the upper Mark West Creek watershed that falls within the jurisdiction of the Franz Valley Specific Plan study area (2012) and has been assigned a “resource conservation” designation, recognizing the resource suitability, environmental and public service constraints, and natural sensitivities of the area[6]. Because the majority of the Plan area occurs within areas of marginal (or less) groundwater availability, the Plan recommends that construction activities, creation of impervious surfaces and changes in drainage should be avoided through the Planning Division’s discretionary actions. The Plan also recommends, “Maintain a low intensity of residential development in the Mark West Creek area to maintain future County preserve options; especially observe riparian setbacks along this creek”.
- In 2008, with funding from the Sonoma County Water Agency through the Cooperative Russian River Watershed Program, Sotoyome Resource Conservation District initiated the Upper Mark West Watershed Management Plan. The goals of the Plan are to meet water quality standards for sediment, support aquatic life and restore aquatic habitat, protect and enhance wetland habitat, promote native biodiversity in upland habitats and improve water conservation.

As demonstrated in the planning and study efforts listed above, the Mark West Creek watershed is an area with sensitive biotic resources or significant environmental sensitivity and should be excluded from the added water demands associated with cannabis cultivation.

8. Upper MWW should be excluded from the Cannabis Ordinance because local groundwater aquifers are in overdraft

The County funded a study by Kleinfelder, Inc. in 2003 to explore the factors affecting the availability of groundwater in three water scarce areas experiencing concentrated building and well construction (Kleinfelder, 2003). One area, the Mark West Study Area, is a 7.5 square mile intermountain valley located just north of Santa Rosa lying within the Mark West Springs Creek watershed[7]. The aquifer underlying the Study Area is primarily fractured bedrock of the Sonoma Volcanics, though thick deposits of the Glen Ellen formation occur in the northwest portion of the area where there is relatively little development. Kleinfelder states that the availability of groundwater in these formations is not predictable, but where groundwater is found, it is generally sufficient to supply current demand.

As part of their study, Kleinfelder quantified changes in residential and urban water demands between 1950 and 1997 along with construction depth and water levels of numerous wells. They found that the

[6] The 1979 Plan contains substantial description and analysis of natural resources in the study area. This original background language was deleted from all subsequent modified versions (1993, 2008 and 2012) of the Plan. The landuse designations cited here are from the 1979 Plan.

[7] The other two study areas included the Joy Road and Bennett Valley Areas.

mean depth to water in new wells trends downward in each study area over time; the trend in Mark West Study Area drops from 90 feet in 1950 to about 175 feet in 1997. They conclude that the downward trend in depth-to-water in new wells corresponds to the trend of overall development. They also found a clear trend of increasing average well depths over time. They attribute the trend of increasing well depths to the need for drillers to reach groundwater levels that are lowering over time.

Kleinfelder's analysis of the annual average depth to water in new wells shows a trend of decreasing water levels over time in the three Study Areas. They conclude the decline in water levels is most likely explained by increased groundwater extraction over time. The trend analysis of depth to water in new wells together with reports of dropping water levels, seasonal well failures, and complete well failures all suggest groundwater overdraft[8] conditions. Additional development beyond the 1997 levels will likely increase overdraft as indicated in the following excerpt from the Kleinfelder report (pg. 40).

> *There is a potential for further residential and agricultural development in the Study Areas because they have not been developed to the maximum density allowed by existing zoning ordinances. New homes and vineyards require water and more wells would be needed to meet demand. Additional groundwater extraction is likely to increase the rate of overdraft and result in further decline of groundwater levels. In fact, if an overdraft condition currently exists, groundwater levels may continue to decline even if no additional extraction occurs. Levels will continue to drop as long as extraction exceeds recharge.*

In response to the expansion of vineyards and rural residences in rural Sonoma County over the recent decades, CEMAR (Center for Ecosystem Management and Restoration) completed a study on how human development has effected hydrologic conditions and salmonid habitat in the upper Mark West Creek watershed[9] (CEMAR, 2015). CEMAR states that in the Mark West Creek watershed irrigated agriculture and rural residences are the two most evident forms of water use, with vineyards being the most prevalent agricultural cover type. As part of their study, CEMAR quantified annual water demands for human uses in the upper watershed for comparison to summer streamflow data collected at several locations along the main stem Mark West Creek. Key findings and conclusions from the CEMAR report include the following.

- The upper watershed is geologically and topographically diverse. The majority of the watershed is underlain by Sonoma Volcanics and a large portion is Franciscan Complex.
- The source of summer base flows in Mark West Creek come from springs and groundwater seepage from the Sonoma Volcanics[10]. Although flow rates are low (ranging from around 0.5 to

[8] Groundwater overdraft occurs when groundwater use exceeds the amount of recharge into an aquifer, which leads to a decline in groundwater level.
[9] The CEMAR report focuses specifically on the area upstream of the confluence with Humbug Creek with Mark West Creek (near the west end of St. Helena Road).
[10] The 1979 Franz Valley Specific Plan corroborates this conclusion in the following statements, "In addition to the valley recharge in the alluvial soils and the stream gravels of the Franz and Knight Valleys, the more permeable and fractured areas of the Sonoma Volcanics are of major importance for groundwater recharge. Two areas along the

0.03 ft^3/s, the creek exhibits consistent stable low flow through summer months, especially in headwaters.

- Study estimates indicate that residential and agricultural summer water demands exceed creek flow rates throughout the dry season May-October.
- Though there may be very few surface water diversions directly from Mark West Creek, water needs satisfied through pumping groundwater or from spring boxes likely remove water that would otherwise become base flow.
- Base flow in late summer could increase substantially if human water needs met through pumping groundwater or diverting from streams during the dry season were reduced.
- The potential for groundwater pumping to deplete streamflow is much greater for Sonoma Volcanic geology than Franciscan bedrock, even if Franciscan bedrock is thicker and closer in proximity to the stream.
- The data describing depth to water in well completion reports indicates an overall trend of greater depth to water among those wells located within the entire study region, as well as those wells within one-quarter mile of Mark West Creek for the period 1965-2014[11].
- Summer base flows are lower or recede into subsurface alluvium in portions of the main stem Mark West Creek and North Fork Mark West Creek due to excessive sediment accumulation and channel aggradation.
- Groundwater pumping likely results in reduced creek base flow, especially if wells are located in bedrock fractures that would otherwise provide base flow in summer.
- Given the range of possible scenarios for describing surface water-groundwater relationships in fractured bedrock, it is not possible to know how pumping groundwater from fractured bedrock may affect streamflow without conducting a test of well operation and streamflow response to see whether and how streamflow patterns deviate from baseline conditions when water is pumped.

In 2016, a notably dry year, the State Water Resources Control Board (SWRCB) submitted an Emergency Regulatory Action regarding enhanced water conservation and additional reporting requirements for the protection of specific fisheries in the Mark West Creek watershed (OAL, 2016). The SWRCB has authority to ensure the protection and preservation of streams and to limit diversions to protect critical flows for species, including for state- and federally-threatened and endangered salmon and steelhead species. An important and relevant statement in this emergency order is the acknowledged role groundwater plays in sustaining

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upper reaches of Mark West Creek are responsible for maintaining summer flow and the high quality of the riparian vegetation and the fishery habitat of the creek".

[11] Although not stated in the CEMAR report, similar to the Kleinfelder study, the long-term trend of declining (lowering) groundwater levels suggest groundwater overdraft.

creek flows. The order states, "*Due to the known hydraulic connection between sub-surface water and surface streams in the Russian River watershed, as well as the limited water use information in the area, additional information on diversions, whether surface or subsurface, and use of water is needed to better assess impacts on surface stream flows*". The emergency regulatory action was effective from 3/30/2016 to 12/28/16.

Based on available technical studies, groundwater supplies in the upper Mark West Creek Watershed have steadily declined over the past 70 years and several local aquifers are in overdraft condition. It is acknowledged that groundwater sustains summer creek base flows. Existing creek base flow rate in upper Mark West Creek are very low during summer and is reduced to a level that threatens salmonids and other aquatic species during dry year-types (OEI, 2020). The increased water demands associated with expanded cannabis cultivation will only further exacerbate existing cumulative impacts on water/aquatic resources in upper Mark West Creek. Because of the documented trend in decreased groundwater availability and strong linkage between groundwater and creek summer base flow, I agree with NMFS comments to the Ordinance (see Attachment B), that the potential for adverse impacts from unrestricted groundwater pumping for cannabis irrigation are high. Therefore, I recommended that the upper Mark West Creek be excluded from the Cannabis Ordinance.

9. Upper MWW should be excluded from the Cannabis Ordinance due to existing water quality impacts in the watershed

The RWQCB has listed Mark West Creek and its tributaries upstream and downstream of the confluence with the Laguna de Santa Rosa as 303(d) impaired water bodies for sedimentation/siltation and temperature (RWQCB, 2018). Downstream of the confluence with the Laguna, Mark West Creek is also listed as impaired for aluminum, dissolved oxygen, phosphorous, and manganese. Cannabis cultivation typically requires earth disturbance that generates potential sediment discharge to nearby water bodies, especially in steep or unstable terrain or where in close proximity to drainages. Given the existing upper watershed is impacted by sediment delivery to the creek, even small and unintentional sediment loading will add to existing cumulative adverse impacts to the creek. Therefore, it is recommended that the upper Mark West Creek watershed should be excluded from the Cannabis Ordinance to avoid this impact.

10. Upper MWW should be excluded from the Cannabis Ordinance due to reduced recharge to the Santa Rosa Plain Groundwater Basin

The County is developing a Groundwater Management Plan (GMP) for the Santa Rosa Plain Watershed (Santa Rosa Plain Basin Advisory Panel, 2014) pursuant to the state Sustainable Groundwater Management Act (SGMA). As stated in the GMP, groundwater levels have decreased in response to groundwater pumping in the Santa Rosa Plain groundwater basin.

SGMA requires governments and water agencies of medium priority basins[12] to halt overdraft and bring groundwater basins into balanced levels of pumping and recharge.

The GMP indicates that seepage from streams flowing onto the Santa Rosa Plain, including Mark West Creek, are a major source of recharge to the groundwater basin. Thus, any incremental increase in groundwater pumping within the upper Mark West Creek watershed would not only exacerbate overdraft of local aquifers but would reduce streamflow in Mark West Creek and associated downstream recharge, additionally exacerbating overdraft in the Santa Rosa Plain groundwater basin. Any future increases in groundwater pumping due to cannabis cultivation in the upper Mark West Creek watershed would also exacerbate groundwater overdraft in the Santa Rosa Plain basin. Therefore, it is recommended that the upper Mark West Creek watershed should be excluded from the Cannabis Ordinance to avoid this impact.

11. Further amendments to the Ordinance are needed to provide consistency with state law and regulations

Stream flow monitoring requirement: CEMAR (2014) concludes that the complex geology and surface water-groundwater interaction of the upper Mark West Creek watershed render standard County "hydrogeologic investigations" insufficient to evaluate the impacts of groundwater pumping on creek flow. This scenario likely exists in many other County watersheds. CEMAR recommends that coordinated well operation (pumping) observations and creek flow monitoring is required to identify and quantify groundwater-surface water interaction. The Counties Cannabis Ordinance [Sec. 26-88-254, (g), (10)] includes the requirement for the preparation of a net zero water plan, hydrogeologic report and/or water yield test to certify that operation of an onsite groundwater supply does not exacerbate an overdraft condition in basin or aquifer or result in reduction of critical flow in nearby streams. However, the following section of the ordinance [Sec. 26-88-254, (g), (11)] only discusses groundwater monitoring and reporting protocols. As indicated above, stream flow monitoring is also required to definitively assess potential impacts on instream flows from groundwater withdrawals. Therefore, I recommend that an additional stream flow monitoring requirement be added to the ordinance for sites located within Groundwater Availability Zone 3 or 4, consistent with surface water flow monitoring requirements contained in the RWQCB Cannabis Cultivation Policy.

Instream flow requirements: A stated purpose of the County's ordinance amendment is to "harmonize" and "align" the ordinance with state law. Numerous requirements under the

[12] The Santa Rosa Plain groundwater sub-basin (defined in DWR's Bulletin 118) is currently identified as a medium priority basin/subbasin and is, therefore, subject to the requirements of SGMA.

RWQCB Cannabis Cultivation Policy are triggers and/or mitigations in response to impacts on water and aquatic resources that are clearly anticipated (and articulated) from increased cannabis cultivation (e.g., minimum instream flow requirements). The State regulations clearly identify/anticipate and address potential adverse impacts from the legalization of cannabis cultivation. The County's ordinance should do likewise.

Please feel free to contact me with any questions regarding the material and conclusions contained in this letter.

Sincerely,

Greg Kamman, PG, CHG
Senior Ecohydrologist

REGISTERED GEOLOGIST
GREGORY R. KAMMAN
NO. 360
CERTIFIED HYDROGEOLOGIST
12/31/22
STATE OF CALIFORNIA

REFERENCES

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ATTACHMENT A

Greg Kamman, PG, CHG
Senior Ecohydrologist

Education

MS, 1989, Geology, Sedimentology and Hydrogeology, Miami University, Oxford, OH

BA, 1985, Geology, Miami University, Oxford, OH

Professional Registration

1993, Professional Geologist, California, #5737

1995, Certified Hydrogeologist, California, #360

Professional Experience

cbec, inc., eco-engineering, West Sacramento, CA, Senior Ecohydrologist, 2020-present

Kamman Hydrology & Engineering, Inc., San Rafael, CA, Principal Hydrologist/Vice President, 1997-2020

Balance Hydrologics, Inc., Berkeley, CA , Sr. Hydrologist/ Vice President, 1994-1997

Geomatrix Consultants, Inc., San Francisco, CA, Project Geologist/Hydrogeologist, 1991-1994

Environ International Corporation, Princeton, NJ, Sr. Staff Geologist/Hydrogeologist, 1989-1991

Miami University, Oxford, OH, Field Camp Instructor and Research Assistant, 1986-1989

Greg Kamman is a professional geologist and certified hydrogeologist with over 30 years of technical and consulting experience in the fields of geology, hydrology, and hydrogeology. He specializes in directing and managing projects in the areas of surface and groundwater hydrology, stream and tidal wetland habitat restoration, water supply and water quality assessments, water resources management, and geomorphology. Mr. Kamman has worked extensively throughout California's coastal watersheds and estuaries, and on multiple projects in Oregon and Hawaii.

Mr. Kamman's experience and expertise includes evaluating surface and groundwater resources and their interaction, stream and wetland habitat restoration assessments and design, characterizing and modeling basin-scale hydrologic and geologic processes, assessing watershed hydraulic and geomorphic responses to land-use change , and designing and conducting field investigations characterizing surface and subsurface hydrologic and water quality conditions. Greg commonly works on projects that revolve around sensitive fishery, wetland, wildlife, and/or riparian habitat enhancement within urban and rural environments. Mr. Kamman performs many of these projects in response to local, state (CEQA) and federal statutes (NEPA, ESA), and other regulatory frameworks. Mr. Kamman frequently applies this knowledge to the review and expert testimony on state and federal water operation plan EIR/EIS reports, Groundwater Sustainability Plans, Habitat Conservation Plans, and biological assessments.

Mr. Kamman is accustomed to working multi-objective projects as part of an interdisciplinary team including biologists, engineers, planners, architects, lawyers, and resource and regulatory agency staff. Mr. Kamman is a prime or contributing author to over 360 technical publications and reports in the discipline of hydrology, the majority pertaining to the protection and enhancement of aquatic resources. Mr. Kamman has taught the following courses: stream restoration through U.C. Berkeley Extension (2001-2008); wetland hydrology through San Francisco State University's Romberg Tiburon Center (2007 and 2012-2014); and presented webinars (2020) to California Water Boards staff on hydrologic and hydraulic modeling. He has devoted his career to the protection, enhancement and sustainable management of water resources and associated ecosystems.

SELECTED EXPERIENCE

Floodplain Management Projects

Flood Reduction, Mitigation Planning, and Design on Yreka Creek, Siskiyou County, CA
City of Yreka as subcontractor to WRA, Inc., 2008-2010

Mr. Kamman completed a series of field and hydraulic model investigations for restoration planning and design along Yreka Creek to reduce flood hazards and potential damage to the City's water treatment plant and disposal field infrastructure. This work also addresses and satisfies dike repair mitigation conditions stipulated by state resource agencies. While achieving these goals, Mr. Kamman tailored analyses and study objectives to assist the City in: enhancing the ecological floodplain restoration along Yreka Creek; providing opportunities for expanded public access and trail planning consistent with the goals of the Yreka Creek Greenway Project; and improving the water quality of Yreka Creek.

Key elements of this work included: review and synthesize existing information; identify and analyze the feasibility for three conceptual alternatives; and conceptual design and report preparation. Funding for implementation of restoration work over such a large area was a significant concern to the City. Therefore, designs identify and define phasing in a fashion that gives the City flexibility in implementation.

SELECTED EXPERIENCE *(CONTINUED)*

West Creek Drainage Improvement Assessment, Marin County, CA
Marin County Flood Control, 2006-2008

Mr. Kamman prepared a study focused on characterizing existing flood conditions and developing and evaluating flood reduction measures along West Creek in Tiburon. The work was completed through the implementation of hydrologic and hydraulic feasibility and design assessments. The conceptual design and analysis of potential flood reduction strategies (alternatives) was completed through the development of a HEC-RAS hydraulic model that simulates historic, existing and proposed project flood conditions. It was intended that the conceptual design developed under this scope of work would be of sufficient detail and quality to initiate project permitting and the environmental compliance process and documentation. Opportunities for riparian corridor and aquatic habitat enhancement were also considered and integrated into the conceptual design. Mr. Kamman also developed and assessed six alternative flood hazard reduction measures. The hydraulic model results for each alternative were compared against baseline conditions in order to evaluate their ability to alleviate flood hazards.

Gallinas Creek Restoration Feasibility Assessment, Marin County, CA
San Francisco Bay Institute, 2003-2005

Mr. Kamman completed a feasibility assessment for restoration of Gallinas Creek in northern San Rafael. Restoration will require removal of a concrete trapezoidal flood control channel and replacement with an earthen channel and floodplain in a "green belt" type corridor. Work included the collection of field data and development of a HEC-RAS hydraulic model to evaluate and compare existing and proposed project conditions. Designs must continue to provide adequate flood protection to the surrounding community. The study also includes and evaluation of existing habitat values, potential habitat values, and restoration opportunities and constraints.

Hydrologic and Hydraulic Evaluation for Trinity County Bridge Replacement, Trinity County, CA
Trinity County Planning Department, 2002

Mr. Kamman completed technical peer review of peak flow estimates and hydraulic design parameters associated with the replacement of 4 bridges across the upper Trinity River in Trinity County, California. A primary study component was accurately predicting the magnitude and frequency of flood releases from Trinity Dam. Numerous flood frequency analytical approaches were evaluated and used throughout this study.

Restoration of Lower Redwood Creek Floodway and Estuary, Humboldt County, CA
California State Coastal Conservancy and Humboldt County DPW, 2002-2003

Mr. Kamman provided technical review for the development of a hydraulic model to evaluate river and estuary restoration alternatives along the lower portions of Redwood Creek between Orrick (Highway 1) and the Pacific Ocean. This work was completed to evaluate the feasibility for creek/estuary restoration alternatives developed by the County, and effects on flood hazards along this flood-prone reach.

In order to better address and evaluate the current flood hazards along the entire floodway and identify potential flood hazard reduction measures, Mr. Kamman was retained to update HEC-2 models previously prepared by the Army Corps, and to evaluate the impacts of vegetation encroachment (increased roughness) and sediment deposition on floodway conveyance. Mr. Kamman expanded the Corps hydraulic model with newly completed channel surveys and channel roughness observations. The impetus for this work was to assist the County in identifying mutually beneficial strategies for ecosystem restoration and flood hazard reduction. Technical work was completed under close coordination and communication with county engineers. Study results and findings were presented at public meetings of local area landowners and stakeholders.

Tembladero Slough Small Community Flood Assessment, Monterey County, CA
Phillip Williams & Associates, Ltd., 1997

Mr. Kamman completed a flood information study of Tembladero Slough near Castroville on behalf of the San Francisco District Corps of Engineers. The purpose of this work was to identify and document local flood risks existing in the community and propose potential floodplain management solutions as part of the Corps 1995/1997-flood recovery process. Work centered on conducting a field reconnaissance, reviewing available historical data, and conducting discussions/interviews with local landowners and agency personnel.

Fluvial Projects

Muir Woods National Monument Bank Stabilization Plan for Conlon Creek, Marin County, CA
Golden Gate National Parks Conservancy (GGNPC), 2018-present

Mr. Kamman developed a grading and drainage plan for the Conlon Avenue Parking Lot, located adjacent to Redwood Creek and sensitive Coho salmon habitat. More recently, he has assisted GGNPC and the NPS in assessing the planning and design for creek bank stabilization and ecological enhancement at a failed culvert on a tributary channel at the project site. This work includes constructing a HEC-RAS model to evaluate: culvert removal and channel design; fish passage; and water quality impacts. Work is currently in development of 50% engineering design.

Hydrology and Hydraulic Assessments for Design of Butte Sink Mitigation Bank Project, Colusa County, CA
WRA, Inc., 2017-2018

Mr. Kamman was retained to provide hydrology and hydraulic modeling support in the development of design and Draft Prospectus for the Butte Sink Mitigation Bank (Bank). This work entailed developing the necessary hydrology information, hydraulic model and documentation to support further design, environmental compliance and agency approvals/permitting of the Bank. The main objective of work was to develop a design that provides the necessary ecological conditions and functions for successful establishment and operation of the Bank.

Lagunitas Creek Salmonid Winter Habitat Enhancement Project, Marin County, CA
Marin Municipal Water District, 2013-2018

Mr. Kamman designed and led a study to evaluate opportunities to enhance winter habitat for coho and other salmonids in Lagunitas Creek and its largest tributary - Olema Creek. This work was done as a two-phase assessment and design effort. The first phase (completed in 2013) included a winter habitat assessment to evaluate existing juvenile salmonid winter habitat in Lagunitas Creek and lower Olema Creek. The results of this assessment were used to prioritize winter habitat needs, and identify opportunities for winter habitat enhancement to increase

SELECTED EXPERIENCE *(CONTINUED)*

the winter carrying capacity of coho salmon and steelhead. The second phase (completed in 2017) consisted of a designing winter habitat enhancements. These enhancements focused on restoring floodplain and in-channel habitat structures. Winter habitat enhancement work also needed to consider potential impacts to or benefits for California freshwater shrimp (Syncaris pacifica), a federally endangered species.

This work included field reconnaissance, topographic surveys and the preparation of final design drawings at nine different project sites. An overall self-maintaining design approach was developed to guide individual project plan, with minimal earthwork and disturbance to existing riparian and wetland habitat. Self-sustained, natural evolution of a multi-thread channel within a more active floodplain is a desired outcome of project actions. Design elements and structures are intended to enhance or restore natural hydrologic processes to promote geomorphic evolution of more active high flow (side) channels and floodplain. Design elements include construction of 24 individual log structures.

Lower Miller Creek Management and Channel Maintenance, Marin County, CA
Las Gallinas Valley Sanitary District, 2013-2015

Mr. Kamman was commissioned to formulate and implement a plan for sediment removal and improved flood flow conveyance in the Lower Miller Creek channel. The need for improved flood and sediment conveyance is driven by the following factors. Progressive accumulation of course sediment in the project reach had reduced area wide discharge efficiencies along Miller Creek and at District outfalls. The District had an immediate need to dredge Lower Miller Creek to protect existing operations and facilities. Miller Creek supports a population of federally listed Steelhead, and adjacent wetland areas potentially support other state and federally listed special status species. Therefore, permitting requirements and cost efficiency required minimizing the extent and frequency of channel excavation/maintenance that may adversely impact habitats in the wetland and riparian corridor.

The design objective of the project was to define and optimize an integrated channel maintenance, flood, and sediment management plan, that protects existing facilities from stream and coastal flood hazards. The plan's objective was to minimize costs and ecological impacts of future anticipated and designed maintenance activities required under District operations. Working with District Staff, Mr. Kamman developed a suite of potential project alternatives and identified a preferred approach. Mr. Kamman completed all CEQA compliance (IS/MND) and permitting. Mr. Kamman also managed and directed development of engineered drawings and assisted in bid document preparation.

Mr. Kamman provided site assessment, long term management planning and channel maintenance support to the Sanitary District to maintain flood conveyance, manage sediment aggrading at District outfalls, and improve ecological values in the intertidal Bayland reaches of Miller Creek. The creek supports multiple federal and state listed endangered species. Initial work included completing hydraulic and geomorphic assessments to characterize causes of channel aggradation, and quantify sediment yields. Assessments included evaluation of climate change impacts on habitat and flood hazards, and water quality modeling of District outfalls to quantify tidal exchange and dilution. Based on this analysis and supporting biological resource assessments, Mr. Kamman identified alternatives for channel maintenance, performed a cost benefit assessment of dredging alternatives, and is assisted the District in developing short and long term management objectives. Mr.Kamman also led a multidisciplinary design team in the preparation of engineering plans and specifications as well as permits and environmental compliance documents.

Vineyard Creek Channel Enhancement Project, Marin County, CA
Marin County Department of Public Works, 2007-2013

Mr. Kamman managed the preparation of designs and specifications for a flood conveyance and fish habitat and passage improvement project on Vineyard Creek. Creek corridor modifications included replacing the box culvert at the Center Road crossing with a free span bridge or bottomless arch culvert (civil and structural design by others), providing modifications to the bed and bank to eliminate erosion risks to adjacent properties and improve water quality, promoting active channel conveyance of both water and sediment, and providing improved low and highflow fish passage, improved low flow channel form and enhanced in-stream habitat, repairing eroding banks, and expanding/enhancing adjacent channel floodplains. The riparian corridor was replanted to provide a low-density native understory, "soft" bank erosion protection, and increased tree canopy along the tops of banks. Mr. Kamman prepared the JARPA for the project and conducted permit compliance and negotiations with all participating resource agencies. Designs and permitting also address the known presence of Native American artifacts. This work was contracted under an expedited design schedule and phased construction was initiated the summer of 2008 and continued the summer of 2009.

Bear Valley Creek Watershed and Fish Passage Enhancement Project, Marin County, CA
The National Park Service and Point Reyes National Seashore Association, 2005-2013

Working on behalf of the NPS and PRNSA, Mr. Kamman completed a watershed assessment and fish passage inventory and assessment for Bear Valley Creek. Work included a geomorphic watershed assessment and completing field surveys and hydraulic modeling (including flood simulations) of ten road/trail crossings to identify and prioritize creek and watershed restoration efforts while considering and addressing current flooding problems at Park Headquarters – a major constraint to channel restoration efforts that would likely exacerbate flooding. Mr. Kamman also completed a suite of conceptual restoration designs (Phase 1) including: the replacement of two county road culvert crossings with bridges; channel creation through a ponded freshwater marsh (former tidal marsh); and replacement of 4 trail culverts with prefabricated bridges; and associated in-channel grade control and fishway structures. Engineered drawings and specifications were also developed for some of these sites to assist PORE with emergency culvert replacements after damages sustained during the New Year's Eve flood of 2005. Mr. Kamman also directed geotechnical, structural and civil design of project components.

Two projects were completed in 2006 on emergency repair basis resulting from flood damages suffered during the New Year's Eve storm of 2005. The two most recent projects were constructed in 2013, consisting of a large bank repair and adjacent to main access road/trail and culvert replacement further upstream on same road. The bank repair utilized bioengineering approaches including engineered log revetments and log diversion vanes.

SELECTED EXPERIENCE *(CONTINUED)*

Kellogg Creek Restoration Project, Contra Costa County, CA
Olberding Environmental on behalf of the Contra Costa County Water District, 2012-2013

Mr. Kamman led the development of PS&E to restore 3,000 linear feet of riparian and associated creek corridor habitat. Project was designed as compensatory mitigation for direct and indirect impacts to jurisdictional waters from the Los Vaqueros Reservoir Expansion Project that Contra Costa Water District. Work included field investigations and data analysis to characterize hydrologic/ geomorphic conditions and numerical modeling to optimize desired inundation and hydroperiods. Work was completed under subcontract to.

Miller Creek Sanitary Sewer Easement Restoration, Marin County, CA
Las Gallinas Valley Sanitary District, 2010

Working on behalf of the District, Mr. Kamman completed field surveys and technical feasibility studies to develop engineering plans and specifications for a stream bank restoration project to protect an exposed sanitary sewer pipeline, stabilize incised banks, and promote an ecologically healthy stream corridor along an approximately 50 linear foot damaged reach of Miller Creek. The design includes backfill and materials to accommodate construction of a vegetated stabilized slope. The eroded bank repair included design of a 1:1 Envirolok vegetated slope with geogrid reinforced soil lifts extending eight to ten feet back from the slope face. One-quarter-ton rock will be placed in front of the Envirolok wall at the toe of the reconstructed bank to provide added scour protection. In order to perform the work, the project site will be dewatered. An existing felled tree perpendicular to the creek flow will be relocated and secured into the right creek bank with root wad remaining in active channel. All work on the bank and within the creek bed must be completed pursuant to project permits due to presence of steelhead trout.

California Coastal Trail Planning and Design at Fitzgerald Marine Reserve, San Mateo County, CA
WRA, Inc., 2008-2009

Mr. Kamman provided hydrology and hydraulics expertise in the planning and design for the 0.25-mile segment of the California Coastal Trail at the Fitzgerald Marine Reserve. The project was overseen by the San Mateo County Parks Department. This segment of Coastal Trail provides improved access from the trailhead to the beach as well as a free span bride over Vicente Creek. Greg completed the field surveys and hydraulic modeling to assist an interdisciplinary team to design the project. Understanding the hydrology of Vicente Creek and quantifying flood conditions was critical to successfully designing and constructing the free span bridge. He also evaluated how creek hydrology and coastal wave processes interact at the beach outfall in order to identify opportunities and constraints to beach access improvements (which will include crossing the creek on the beach) during both wet and dry season conditions in order to evaluate both permanent and seasonal crossing design alternatives.

Hydrologic Assessment and Conceptual Design for Conservation and Wetland Mitigation Bank Project, Stanislaus County, CA
WRA, Inc., 2009

Working as a subcontractor to WRA, Inc., Mr. Kamman provided hydrology, geomorphology and engineering support for the planning and design for a Conservation and Wetland Mitigation Bank on the San Joaquin River, in the Central Valley near Newman, California. The property is currently owned by the Borba Dairy Farms. The primary objective of the study was to characterize the hydrologic and geomorphic controls on the spatial distribution of habitat types. To meet this objective, Mr. Kamman's assessment included: (1) collecting and synthesizing hydrologic data to characterize existing and historic streamflow, geomorphic and shallow groundwater conditions; (2) filling a data gap by collecting topographic data of hydrologic features; (3) developing a hydraulic model capable of predicting water surface profiles for a range of design flows; and (4) quantifying the linkage between surface water/groundwater conditions and specific vegetation communities and habitat types through implementation of reference site assessments. Mr. Kamman also provided conceptual design and permitting support in evaluating habitat enhancement and creation opportunities on the site.

Redwood Creek Floodplain and Salmonid Habitat Restoration, Marin County, CA
Golden Gate National Recreation Area and Golden Gate Parks Conservancy, 2005-2008

Mr. Kamman lead development of a preferred project alternative and final project design drawings and specifications for a floodplain and creek restoration and riparian corridor enhancement effort on lower Redwood Creek above Muir Beach at the Banducci Site. A primary objectives of the project was to: improve salmonid passage/rearing/refugia habitat; riparian corridor development to host breeding by migratory song birds; and wetland/pond construction to host endangered red-legged frog. The preferred design includes: excavation along the creek banks to create an incised flood terrace; engineered log deflector vanes; removing and setting back (constructing) approximately 400-feet of levee; creating in- and off-channel salmonid rearing and refugia habitat; reconnecting tributary channels to the floodplain; and creating California red-legged frog breeding ponds. Designs were completed in 2007 and the project constructed in the summer of 2007.

Considerable hydraulic modeling was completed to evaluate and develop means to help reduce chronic flood hazards to surrounding roadways and properties. Alternatives that included set-back levees and road raising were developed and evaluated. Detailed and careful hydraulic (force-balance) analyses and computations were completed as part of engineered log deflector designs. These were unique and custom designed structures, building on past project efforts and in consultation with other design professionals.

This project demonstrates Mr. Kamman's ability to work closely with the project stakeholders to develop a preferred restoration alternative in a focused, cost-effective and expedited fashion. This was achieved through close coordination with the NPS and the effective and timely use of design charrette-type meetings to reach consensus with participating stakeholders. Conceptual through full PS&E were completed on-time and on-budget in 2007 and was project constructed in the fall of 2007. Mr. Kamman worked closely with NPS staff to "field fit" the project, by modifying grading plans to protect existing riparian habitat. Mr. Kamman also provided construction management and oversight to floodplain grading and installation of engineered log structures. Based on field observations, the project is performing and functioning as desired.

Pilarcitos Creek Bank Stabilization Project, San Mateo County, CA
TRC Essex, 2006-2007

Mr. Kamman directed field surveys and technical modeling analyses to develop restoration design alternatives for a Bank Stabilization Project on Pilarcitos Creek

SELECTED EXPERIENCE *(CONTINUED)*

in unincorporated San Mateo County, California. This work included hydrology and hydraulic design and preparation of plan sheets and technical specifications as well as a revegetation plan. Due to the importance of protecting an existing gas mainline, the design package will be completed in close coordination with TRC Essex geotechnical staff and revegetation subcontractor and PG&E civil staff. Design feasibility analyses focused on developing hydraulic design criteria for the project, including: estimates of design flood flow magnitudes (2-, 5-, 10-, 25-, 50- and 100-year floods); water surface elevation estimates for a suite of design floods; associated average channel velocities and shear stresses; and estimates for riprap sizing for channel bank toe protection. Plan sheets, technical specifications and cost estimates were provided for review and approval.

Watershed Assessments

Evaluation of Project Impacts on Oregon Spotted Frog, Klamath County, OR
Oregon Water Watch and Earthjustice, 2016-2019

Mr. Kamman designed a suite of hydrologic, hydraulic and geomorphic studies to evaluate proposed change operations of the Crane Prairie, Wickiup and Crescent Lake dams and reservoirs as related to harm to Oregon spotted frogs. Work began with analyzing impacts associated with proposed water delivery operations and developing a proposed alternative prioritizing protection and enhancement of frog habitat. This work followed with a technical review and critique of the USFWS's Biological Assessment. Work included preparation of four declarations for the clients.

Tennessee Hollow Creek Riparian Corridor Restoration, San Francisco County, CA
Presidio Trust, 2001-present

Mr. Kamman has been leading and assisting the Trust and Golden Gate National Recreation Area (GGNRA) in the planning and design on over a dozen multi-objective riparian corridor restoration and watershed management projects in the Tennessee Hollow/Crissy Marsh watershed since 2001. Specific project objectives include: daylighting creeks; riparian corridor restoration; expanding Crissy Marsh; enhancing recreation, education, archeological, and cultural resource opportunities; improving water quality discharges to San Francisco Bay; and remediation of numerous landfills within the watershed. Typical initial phases of work focus on characterizing surface and groundwater conditions within each project area and identifying opportunities and constraints to restoration of natural wetlands and creek/riparian corridors. Notable challenges of this work include restoring heavily disturbed natural resources in an urban setting while integrating designs with recreation, archeology/cultural resources, education and remediation programs. Mr. Kamman has acted as lead hydrologist and designer on eight separate reaches in the 271-acre Tennessee Hollow Creek watershed and several other projects within and in the vicinity of Mountain Lake.

All task authorizations under these on-call and individual design contracts and included hydrology and water quality assessments and conceptual restoration planning and design. The project areas overlapped both the Presidio Trust and NPS-GGNRA management areas. Preliminary construction cost estimates for project alternatives within the Tennessee Hollow watershed range from $10- to $20- million. Several restoration projects are also tied to providing mitigation for the current San Francisco Airport expansion and Doyle Drive Seismic Improvement projects. Several projects have been constructed since 2012 (Thompson's Reach, El Polin Loop), two projects (East Arm Mtn. Lake and YMCA Reach) were constructed in 2014, and MacArthur Meadow restoration in 2016.

This work illustrates the Mr. Kamman's ability to complete a broad variety of hydrologic analyses, including: multiple years of rigorous and thorough surface water and groundwater hydrologic and water quality monitoring throughout the entire watershed to characterize and quantify existing hydrologic conditions; development of a detailed watershed-scale water budget for existing and proposed land-used conditions (capturing existing and proposed vegetation cover types and land use activities) to calculate groundwater recharge estimates input into the numerical watershed model; preparation of EA sections on water resources and water quality (NEPA compliance) regarding Environmental Conditions, proposed Impacts, and Proposed Mitigations associated with the project; preparing detailed alternative plans; and coordination and preparation of engineered plans/specifications for construction. All work was completed on budget and in a timely fashion.

Mountain Lake Water Budget, San Francisco County, CA
Presidio Trust, 2012-2017

Mr. Kamman was retained to develop a water balance model for Mountain Lake in the Presidio of San Francisco. Through development of a water balance model, the Trust seeks to understand: the major source(s) of inflow to both Mountain Lake; anticipated seasonal (monthly) changes in water level relative to various outflow assumptions; and the relationship of surface and groundwater interaction. This information gained from this study will be used to: 1) better understand and manage lake levels for ecological habitats; 2) identify flood storage capacity of Mountain Lake and fluctuations in lake level under various storm conditions; 3) better understand and maintain wetland habitat in the east arm; and 4) complete mass balance calculations to assess water quality in and feeding into the lake.

To implement this study, Mr. Kamman developed a water budget model to identify and quantify the primary water inputs and outputs to the lake and determine major controls over water storage. Primary water budget variables analyzed includes: precipitation; evaporation/evapotranspiration; groundwater exchange; and surface runoff. This study also included a long-term field investigation completed between 2012 and 2016 to: identify all point source inputs such as culverts and drainage outlets; identify diffused surface runoff inputs from surrounding lands, including a golf course; better characterizing the function and performance of the primary lake outfall structure; monitor groundwater levels surrounding the lake; and continuously monitor lake water level and storage over a mult9i-year period. These data were used to quantify water budget variables used to build the water budget model. Precipitation and barometric pressure data used in the model was provided by the Trust maintained weather station. Model daily evaporation estimates came from a variety of local area gauges maintained by state agencies.

The water budget model developed for this study is successful in accurately simulating historic water level conditions. The model using a daily time-step appears more accurate than model using a weekly time-step, but both provide reasonable agreement with observed conditions. The model is highly sensitive to groundwater exchange with the lake. The water budget is also a proven useful tool for the design and analysis of improvements to the lake outfall structure and establishing flood storage needs to protect the adjacent highway.

SELECTED EXPERIENCE *(CONTINUED)*

Cordilleras Creek Hydrologic Assessment, San Mateo County, CA
City of Redwood City, 2002-2003

Mr. Kamman assisted the Cordilleras Creek Watershed Coordinator in planning, seeking funding, and implementing a hydrologic and biologic assessment of the Cordilleras Creek watershed. Work completed included completing a full creek reconnaissance and channel stability assessment, preparation of a watershed assessment work plan, presentations at public meetings, and study/review of flooding issues in the watershed. Challenges faced in this predominantly privately owned watershed include removal of numerous fish passage barriers and educating/coordinating property owners.

Capay Valley Hydrologic and Geomorphic Watershed Assessment, Yolo County, CA
Yolo County RCD, 2008-2010

Mr. Kamman designed and supervised a hydrologic, geomorphic watershed assessment, and conceptual restoration design for the Capay Valley segment of Lower Cache Creek . Funding for the project was from a CALFED Watershed Program grant. The Capay Valley reach of Cache Creek experiences considerable stream bank erosion, which contributes to downstream sedimentation. The channel instability also threatens adjacent homes and can negatively impact the riparian habitat along the creek that functions as an important wildlife corridor from the Western Coastal Range to the Yolo Bypass. Additionally, a significant proportion of methylmercury transported into the Bay-Delta originates from the Cache Creek watershed. The main goal of this proposed study is to address both the causes and the aforementioned consequences of bank erosion.

The assessment was designed to evaluate and quantify changes in hydrologic and geomorphic conditions in response to historical changes in land-use and water development (e.g., diversions, reservoir construction, groundwater pumping, etc.). This assessment also evaluated how historic human induced changes in hydrologic and geomorphic conditions affect riparian ecology in terms of the lost or altered floodplain area, character, and inundation frequency. A key product of this assessment was to distinguish between “natural” and “accelerated” bank erosion, and to identify the underlying causes (both natural and anthropogenic) so that appropriate solutions can be developed. Desired outcomes of the study included: reduce bank erosion by developing restoration designs for typical trouble sites; produce a ranking system to prioritize sites for stabilization and restoration; contribute to community education through watershed science education and the Yolo STREAM Project outreach program; improve water quality through reduction in accelerated erosion; and contribute to riparian corridor restoration and support the RCD’s Wildlife Conservation Board funded efforts to remove non-native tamarisk and around from the creek corridor. Work was completed through a broad spectrum of field and analytical investigations that received close review by the RCD, stakeholders, and a Technical Advisory Committee.

Ventura River Unimpaired Flow and Habitat Assessment, Ventura County, CA
City of Buenaventura and Nautilus Environmental, 2006-2007

Mr. Kamman completed a hydrology feasibility assessments as part of evaluating the reuse of Ojai Valley Sanitary District (OVSD) effluent for other beneficial uses. Currently, OVSD discharges treatment plant effluent to the lower Ventura River. The City and OVSD recognize that the reduction in the discharge of treated effluent to the Ventura River could have an environmental effect on sensitive and endangered species. In light of these concerns, this study was conducted to determine if a reuse project is feasible without significant environmental harm.

The assessment included hydrologic and geomorphic field and analytical assessments of past (unimpaired), current and proposed surface and groundwater flow conditions over a wide range of dry- through wet water year-types. The main objective if these analyses was to determine the linkage to water quality and aquatic habitat conditions including: flow durations; extent of gaining vs. losing reaches; low flow inundation/wetted area; and influence on barrier beach dynamics. Mr. Kamman collaborated with a team of other professionals to prepare a facility plan documenting the analyses and conclusions of respective water recycling investigations.

Hydrologic Analysis of FERC Minimum Flows on Conway Ranch Water Rights, Mono County, CA
Law Office of Donald Mooney, 2001-2002

Mr. Kamman completed a hydrologic analysis to evaluate if FERC’s proposed Minimum Flow Plan for Mill Creek would interfere with the exercise of the Conway Ranch’s water rights from Mill Creek. The approach to this analysis was to quantify the duration of time the Conway Water right was met under historic gaged and simulated proposed Minimum Flow Plan conditions. The primary objective of the analysis was to evaluate impacts during the winter period when flows are typically limited due to water storage as snow pack. Minimum Flow Plan conditions were simulated by developing a spreadsheet model that redistributes actual (historic) Lundy Lake releases in a fashion that maintains a minimum flow of 4 cfs to Mill Creek to accommodate the downstream Southern California Edison’s (SCE) power plant. The analysis period for both historic and simulated Minimum Flow Plan conditions consisted of water years (WY) 1990 through 1998 to capture an exceptionally diverse range of wet and dry year-types.

The primary method used to quantify changes in flow between historical and simulated Minimum Flow Plan conditions was to prepare and compare flow duration curves for each condition during both the winter and summer periods during a variety of water year types. Model results were tabulated for each conditions to determine the differences in the percentage of time target flows were equaled or exceeded. Based on these findings, Greg was contracted to complete more in-depth monthly modeling.

Groundwater Management Projects

Assessments of Groundwater-Surface Water Interaction, Stanislaus County, CA
The Law Offices of Thomas N. Lippe, APC and California Sportfishing Protection Alliance, 2015-present

Since 2015, Mr. Kamman has been assessing groundwater conditions within Stanislaus County and evaluating potential impacts of groundwater pumping on surface water flow and aquatic habitat of the Stanislaus, Tuolumne and San Joaquin Rivers. Mr. Kamman completed a comprehensive review and synthesis report of available groundwater and interconnected surface water (ISW) reports and data. Using available soils, geology and hydrology information, Mr. Kamman also delineated and mapped subterranean streams and Potential Stream Depletion Areas (PSDAs) to identify stream corridors susceptible to adverse impacts from groundwater pumping. This information is intended to help Groundwater Sustainability Agencies identify potential impacts to ISW.

SELECTED EXPERIENCE *(CONTINUED)*

Most recently, Mr. Kamman has been retained to review and comment on 7 Groundwater Sustainability Plans (GSPs) for critically overdraft groundwater subbasins within or adjacent to Stanislaus County. This review focused on how GSPs address Groundwater Dependent Ecosystems (GDE) and ISW. Comments included recommendations on monitoring and study plans to identify and quantify impacts of groundwater pumping on stream flow rates and associated ecological habitats.

Assessment of Surface Water-Groundwater Interaction, Humboldt County, CA
Friends of the Eel River (FOER), 2020-present

Mr. Kamman is currently providing technical assistance in understanding surface water-groundwater interactions in the Lower Eel River Valley. Work includes reviewing and synthesizing available reports and hydrologic data and providing a science-based opinion on the role groundwater plays in supporting stream flow and aquatic habitats. This analysis addresses conditions and changes associated with seasonal and long-term wet-dry cycles. Data gaps will be identified and documented during the analysis.

This work is being completed to support FOER efforts at protecting aquatic resources within the framework of current water management practices and the public trust doctrine under California law. Additionally, this work includes providing hydrologic and hydrogeologic review, comment and recommendations during development of the basin's Groundwater Sustainability Plan (GSP) under the California Sustainable Groundwater Management Act (SGMA).

Scott Valley Subbasin Technical Hydrogeologist Assistance, Siskiyou County, CA
Klamath Tribal Water Quality Consortium and Quartz Valley Indian Reservation, 2019-present

Mr. Kamman is providing technical review and comment on the groundwater models and associated studies in the Scott Valley groundwater subbasin under the Sustainable Groundwater Management Act (SGMA) process. Work includes: review of groundwater models; synthesis and review of available groundwater quality data; assisting to identify constituents of concern; and review of the planning and technical studies being used to develop a basin Groundwater Sustainability Plan (GSP).

Middle Russian River Valley Shallow Groundwater Storage Enhancement Study, Sonoma County, CA
Friends of the Eel River, 2016

Working on behalf of Friends of the Eel River, Mr. Kamman completed a study to identify and quantify the volume of recoverable aquifer storage along two independent 6-mile reaches within the alluvial fill valley of the Russian River. The approach to this study was to quantify how channel incision has reduced shallow groundwater levels and quantify how much aquifer storage can be increased if channel bed elevations are restored to historic levels. The goal of this investigation was to identify feasible approaches to increase groundwater storage that would off-set losses associated with the termination of out-of-basin diversions from the Eel River. This work was completed through: intensive review and mapping of available groundwater level data; quantification of aquifer hydraulic properties; and calculating the shallow aquifer storage volume. In total, reclaiming the shallow aquifers within these two areas yield a total added storage volume of over 20,000 AF.

Green Gulch Farm (GGF)/Zen Center Water Resources Investigation, Marin County, CA
Green Gulch Farm, 1998-2019

Mr. Kamman completed a multi-phase study to evaluate the short- and long-term water uses and resources at GGF. Work was initiated by developing comprehensive water usage/consumption estimates and assessing available water resources, including spring, surface water, and ground water sources. Water demand estimates included quantifying potable and agricultural water usage/demands. Once reliable water supplies were identified and water usage/demand figures calculated, Mr. Kamman provided recommendation for improvements to water storage and distribution systems, land-use practices, conservation measures, treatment methods, waste disposal, and stream and habitat restoration. The initial phase of work included: in-depth review of available reports and data; review of geology maps and aerial photography; review of water rights and historic land use records; field reconnaissance including year-round spring flow monitoring; mapping and quantifying existing runoff storage ponds; and surface water peak- and base-flow estimates.

The second phase of work included identification of possible groundwater sources and siting and installation of production wells. This included sighting three drilling locations, obtaining County and State well drilling permits for a domestic water supply; coordination and oversight of driller; and directing final well construction. Upon completion of a well, Mr. Kamman directed a well pumping yield test and the collection and analysis of water quality samples (including Title 22) for small water supply system use. The final phase of work included assisting GGF with water treatment system options at the well head and integration of the groundwater supply into an existing ultra-violet light treatment system servicing spring water sources. Work was completed in 2000 with a budget of approximately $25,000, including all driller and laboratory subcontracting fees.

Stanford Groundwater Assessments, Santa Clara County, CA
Stanford University Real Estate Division, 2012-2016

Mr. Kamman provided technical hydrogeologic services to evaluate groundwater conditions and drainage requirements associated with the construction of several new facilities on or near Page Mill Road. The main objective of this study is to determine the seasonal depth to groundwater beneath the project site under existing and potential future conditions and provide an opinion on if the project is required to comply with the City of Palo Alto, Public Works Engineering Basement Exterior Drainage Policy (effective October 1, 2006). This work included obtaining and reviewing available technical reports, maps and literature pertaining to groundwater conditions in the project vicinity. Based on this review, we have prepared a letter report of findings and recommendations.

Bodega Bay Wetland Water Supply, Sonoma County, CA
Friends of Bodega Bay, 2007

Mr. Kamman Conducted an evaluation of the groundwater underflow feeding a large coastal wetland in Bodega Bay and recommended mitigation measures for potential losses in supply associated with proposed residential development in recharge areas. Work included: long-term monitoring of ground water quality and supply; monitoring surface water and spring flow and water quality; assessing and characterizing the interaction between surface and subsurface water sources during different seasons and water year-types; developing a detailed water budget for the site to assess impacts to recharge areas; and developing a number of physical solutions to mitigate for recharge losses.

SELECTED EXPERIENCE *(CONTINUED)*

L.A. Department of Water and Power, Groundwater Recharge Facility Operation Study, Los Angeles County, CA
ICF Consulting, 2006

Working as a subcontractor to ICF Consulting of Laguna Niguel, California, Mr. Kamman provided technical assistance in the hydraulic modeling of sediment accumulation in selected spreading ground facilities owned and operated by the Los Angeles Department of Public Works. The object of this work is to evaluate changes in infiltration and groundwater recharge rates over time within the spreading grounds in association with sediment accumulation from turbid waters.

Corde Valle Golf Club Surface-Groundwater Interaction Study, Santa Clara County, CA
LSA Associates, 2004

On behalf of LSA Associates of Pt. Richmond, CA, Mr. Kamman completed a 3rd party independent review of available reports and data sets (boring logs, well water levels, groundwater quality, aquifer pump-test, and surface water monitoring) to evaluate if pumping of the Corde Valle irrigation well is adversely impacting flow in West Llagas Creek. This investigation was implemented in response to a concern expressed by California Department of Fish and Game staff regarding the potential for differential drying of the West Branch of Llagas Creek along Highland Avenue. The analysis was also complicated by the likely effects of pumping from surrounding off-site wells.

Aquifer Testing for Tennessee Hollow Watershed Project, San Francisco County, CA
Presidio Trust, 2002

The Mr. Kamman assisted in the design and implementation of an aquifer test at the Presidio of San Francisco. We prepared an aquifer test work plan and conducted step-drawdown and constant-rate aquifer tests at the site using both manual and electronic data collection methods. This work included interpretation of the aquifer test results using software-based solution methods and prepared a written summary of methods and findings. In addition, Mr. Kamman located, coordinated and managed a drilling effort for the logging and installation of several groundwater monitoring wells in the project area to address identified data gaps.

San Joaquin River Riparian Corridor Restoration Project, San Joaquin Valley, CA
McBain-Trush, 2002

Mr. Kamman completed an assessment of historic and existing shallow groundwater conditions beneath and adjacent to the San Joaquin River between Friant Dam and the Merced River. This work focused on reviewing available reports and flow/groundwater- level data to characterize surface water and groundwater interaction and implications for riparian vegetation, water quality and fishery habitat restoration. Hydrologic analyses were performed to identify the location and seasonal evolution of losing and gaining reaches an implication on future restoration planning and design efforts. The main deliverable for this analysis was a report section focused on describing the historical changes in regional and local groundwater conditions in the San Joaquin Valley and evolution of anthropogenic activities (e.g., groundwater withdrawals, irrigation drainage systems and return flows, development of diversion structures, changes in land-use; and introduction of CVP/State Water Project deliveries) and associated impacts on deep/shallow groundwater levels, surface water flows, and surface and groundwater quality.

Tidal, Estuarine & Coastal Projects

Quartermaster Reach Wetland Restoration Project, San Francisco County, CA
Presidio Trust, 2006-present

Mr. Kamman was retained in 2006 as part of a multi-disciplinary team to develop restoration alternative designs for a 10-acre filled and paved site marking the historic confluence of Tennessee Hollow Creek and Crissy Marsh adjacent to San Francisco Bay. The Trust's planning documents define the main objectives for Tennessee Hollow restoration as: a) "Restoration [of Tennessee Hollow] will expand riparian habitat and allow for an integrated system of freshwater streams and freshwater, brackish, and tidal marsh, re-establishing a connection to Crissy Marsh" and b) "Restore and protect Tennessee Hollow as a vibrant ecological corridor". The project is located within the setting of a National Park and a National Historic Landmark District. Thus, another goal for the project is to protect the area's historic buildings and sensitive cultural and archeological resources to the extent possible, to enhance visitor experience to the area, and to integrate creek restoration with other urban land uses.

Mr. Kamman provided H&H technical input and consultation to the design team to develop a restoration project consisting of a creek-brackish marsh-salt marsh interface and associated upland habitats. His work included evaluating surface water, groundwater and tidal sources. In addition, the development of a hydrodynamic model has informed and guided a preferred project design, including evaluation of storm surge, road crossing and Tsunami impacts to the project. A technical challenge addressed with the use of the model included predicting and quantifying salt/brackish marsh habitat zones within the restored wetland in response to periodically but prolonged closed-inlet conditions to Crissy Marsh - a water body that serves as the downstream connection to the proposed project.

Another unique challenge to this project includes integrating restoration planning and design efforts with the replacement and retrofit of Doyle Drive, the main on/off-ramp for the Golden Gate Bridge, being replaced along the entire northern boundary of the Presidio. Mr. Kamman is providing long-term technical review of this project to the Trust with respect to impacts to water resources and associated existing ecological habitats. The Quartermaster project also falls within the managerial jurisdiction of both the Presidio Trust and NPS-GGNRA, requiring work in close cooperation with both Presidio Trust and National Park Service (NPS) staff.

Salt River Ecosystem Restoration Project, Humboldt County, CA
Humboldt County RCD, 2005-2019

Mr. Kamman provided hydrology, engineering and environmental compliance services towards the planning and design of river and tidal wetland restoration on the Salt River (Eel River Delta plain) near Ferndale, California, in Humboldt County. The purpose of the Salt River Ecosystem Restoration Project (SRERP) is to restore historic processes and functions to the Salt River watershed. These processes and functions are necessary for re-establishing a functioning riverine, riparian, wetland and estuarine ecosystem as part of a land use, flood alleviation, and watershed management program. The Salt River Project has three components: 1) dredging the lower Salt River and lower Francis Creek from near the Wastewater Treatment Plant downstream for 2.5 miles; 2) restoring 247 acres of wetland estuary habitat in the lower Salt River within the 440-acre former

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dairy; and 3) reducing sediment inputs from tributary watersheds. The Salt River Project was designed using an "ecosystem approach" to address hydrology, sedimentation, and fish and wildlife habitat.

As part of project feasibility assessment, Mr. Kamman completed a hydrologic and water quality monitoring program, and developed a MIKE11 hydrodynamic model of the lower Salt River and Eel River estuary in Humboldt County, for the Humboldt County RCD. The purpose of this work was to complete a hydrologic, geomorphic, and hydraulic modeling assessments of the character and dominant physical processes controlling flow of water and sediment through the lower Salt River. Land use changes in the area have caused significant aggradation and infilling of the Salt River, significantly reducing tidal exchange, fish passage, and exacerbating flooding in upland areas. A primary goal of this study is to evaluate the feasibility of proposed restoration elements intended to increase tidal prism and exchange and in-channel sediment scour and transport. The desired outcome is a sustained increase in river conveyance capacity to improve drainage of surrounding flood-prone lands and improve aquatic, wetland, and riparian habitat.

As part of project development and feasibility assessment, Mr. Kamman completed a hydrologic and water quality monitoring program and MIKE11 hydrodynamic model development of the lower Salt River and Eel River estuary in Humboldt County for the Humboldt County RCD. The purpose of this work is to complete a hydrologic, geomorphic, and hydraulic modeling assessments of the character and dominant physical processes controlling flow of water and sediment through the lower Salt River. Land use changes in the area have caused significant aggradation and infilling of the Salt River, significantly reducing tidal exchange, fish passage, and exacerbating flooding in upland areas. A primary goal of this study is to evaluate the feasibility of proposed restoration elements intended to increase tidal prism and exchange and in-channel sediment scour and transport. The desired outcome is a sustained increase in river conveyance capacity to improve drainage of surrounding flood-prone lands and improve aquatic, wetland and riparian habitat.

Western Stege Marsh Restoration Project, Contra Costa County, CA
Tetra Tech, 2008-2010

Mr. Kamman provided technical hydrology and wetland hydraulics support to post-project monitoring of the Western Stege Marsh Restoration Project. His involvement began by providing an independent technical review of previous year's hydrologic monitoring results to evaluate the proposed monitoring success criteria and the rationale used to develop these criteria. This work entailed reviewing historic monitoring data and available natural slough channel geometry data-sets for San Francisco Bay area marshes. Mr. Kamman's study approach was to independently develop desired and sustainable channel geometry relationships for natural, healthy San Francisco Bay salt-marshes and compare them to the published success criteria. Greg was also retained to implement the Year 4 post-project hydrologic monitoring, with modifications to aid in better linking hydrologic processes to ecological conditions and function within the restored marsh. This work consisted of completing more targeted water level monitoring and channel geometry surveys in reference marsh areas containing desired physical and ecological attributes. These data were used to develop geomorphic success criteria (target channel geometry) more tailored to the project marsh and augment the criteria provided in available literature. Working closely with the project team of scientists, Mr. Kamman compared these hydrologic monitoring results to available vegetation surveys to better assess the overall success and evolutionary trend of the marsh.

Giacomini Wetland Restoration Project, Marin County, CA
The National Park Service and Point Reyes National Seashore Association, 2003-2012

Mr. Kamman managed a multi-year project for the NPS in the design and feasibility analysis of a tidal wetland, riparian, and freshwater marsh complex, on the 500-acre Giacomini Dairy Ranch, at the south end of Tomales Bay. The project began in 2003 and included hydraulic, hydrologic, and geomorphic assessments to characterize existing physical conditions, developing restoration alternatives, and completing hydrologic feasibility analyses. Restoration alternatives evaluated creation of a mosaic of subtidal through upland wetland and riparian habitat zones, as well as improvements to salmonid passage, red-legged frog habitat, tidewater goby habitat, and clapper-rail habitat. Emphasis was placed on completing detailed studies to quantify project-induced changes in flood frequency, magnitude and duration, impacts on water quality to local groundwater supply wells, and changes in sediment and water quality conditions in Tomales Bay.

Beginning in 2006, Mr. Kamman managed and assisted design engineers, preparing plans, specification, and cost estimates for a three phased construction schedule, that was completed in the summer of 2008. This project illustrates Mr. Kamman's ability to complete a broad variety of hydrologic feasibility analyses, including flood frequency analyses for contributing watersheds, reproducing historic flood events through numerical modeling, flow duration analysis and evaluation of environmental flow regimes, development of a water budget for created freshwater marsh and frog breeding ponds, sediment yield estimates, completing field monitoring (flow, water level, groundwater level, sediment, and water quality monitoring) to characterize existing site hydrologic and geomorphic conditions (fluvial and tidal), wind-wave setup and run-up for levee stability determination and construction design, coordinating and performing topographic and hydrographic surveys, performing hydrodynamic and water quality modeling of existing and alternative conditions, developing detailed construction cost estimates preparation of technical reports and design drawings and specifications in support of NEPA/CEQA environmental compliance, and public meeting presentation and participation. In addition, Mr. Kamman managed staff in the generation of DEM and TIN models of the existing site and all action alternatives. All work was completed on budget and in a timely fashion, despite repeated expansions to the project boundary and last minute changes driven by endangered species issues.

Critical Dune Habitat Restoration to Protect Threatened and Endangered Species, Marin County, CA
The National Park Service, 2009-2010

Mr. Kamman provided and managed engineering, design, and implementation planning support for the restoration of 300 acres of critical dune habitat at Abbots Lagoon within the NPS Point Reyes National Seashore. He developed engineered drawings, technical specifications and engineer's cost estimates, and assisted NPS in defining a range of methodologies suitable to local conditions and sensitive flora and fauna. This area of the park supports the best remaining intact dune habitat, including some of the largest remaining expanses of two rare native plant communities: American dune grass (Leymus mollis) foredunes, and beach pea (Lathyrus littoralis). European beach grass and iceplant were removed from

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the project site using mechanical removal and hand removal techniques. The project goal was to remove these invasive species from approximately 135 acres of prime dune habitat in the 300-acre project site, while not impacting sensitive species and habitats. The intended result was to remobilize this historic dune field and restore their natural form and migratory processes.

This project illustrates Mr. Kamman's ability to work closely with NPS staff to balance habitat protection and restoration across the landscape. As part of project design, he developed grading plans, and specified work flow, equipment movement and access routes which minimize impacts to special status species. Extensive fencing and exclusions zone planning was required to protect existing native habitats, and minimize tracking of plant stock to or through restored sties. In addition work elements had to be structured and prioritized to maximize ground work subject to budgetary constraints and work flow uncertainties. All work has been completed on budget and in a timely fashion, even with repeated expansions to the project boundary and affected area and last minute changes driven by endangered species issues.

Lower Gualala River and Estuary Assessment and Management Plan, Mendocino County, CA
California State Coastal Conservancy and Gualala River Watershed Council, and Sotoyome RCD, 2002-2005

Mr. Kamman worked with fisheries biologists to evaluate the hydrologic and water quality conditions in the lower Gualala River and estuary and identify and evaluate potential impacts to summer rearing habitat for salmonids and other aquatic organisms. This work included: assessing how the impacts of upstream land use (logging and water diversions) have altered water delivery and water quality to the Lower River and estuary over time; characterizing the physical coastal and riverine processes controlling opening and closure of the estuary inlet and lagoon morphology; monitoring and characterizing real-time and seasonal changes in lagoon water level and water quality; and evaluating the sediment transport capacity and geomorphic condition of the lower river and estuary. Mr. Kamman took the lead in developing and editing a management plan for the lagoon, prescribing actions to preserve, protect and enhance ecological habitats (with emphasis on salmonids) within the lagoon and lower Gualala River.

This project was completed on-time and on-budget and demonstrates Mr. Kamman's ability to integrate physical, water quality and biological data and information into a coherent and understandable description of the interrelated processes controlling the aquatic ecology of a lagoon system. A big challenge on this project was completing a high-quality and defensible field monitoring program on a "shoe-string" budget. The outcome of this study provides important understanding on how and why steelhead are surviving in a heavily logged (95% private ownership) watershed. The management plan prescribes recommendations to preserve and protect the lagoon as primary rearing habitat for steelhead.

Suisun Bay Tidal Wetland Restoration Design, Contra Costa County, CA
East Bay Regional Park District and LSA Associates, 1999-2005

Mr. Kamman provided hydrologic design services to the restoration of a 55-acre tidal wetland on Suisun Bay. The design will maximize habitat for special status fish species, and (to the extent possible) habitat for other special status animal and plant species. Working with a multi-disciplinary design team, Mr. Kamman assisted in developing a design based on analysis of habitat needs, tidal hydrodynamic and geomorphic processes, sedimentation rates and soil characteristics. Project tasks included: a site analysis defining existing ecological and hydrologic conditions; a hydrologic and biological restoration opportunities and constraints analysis to define restoration and management objectives; and hydrodynamic and sedimentation modeling to evaluate design alternatives. The final restoration and management plan included a grading plan, landscape revegetation plan and monitoring and maintenance plans. This work again illustrates his capabilities in the characterization of physical site conditions, development and feasibility analysis of project alternatives, and preparation of preliminary designs of sufficient detail to allow for environmental compliance through the CEQA/NEPA process.

Santa Clara River Estuary and Lower River Assessment, Ventura County, CA
Nautilus Environmental on behalf of the City of Ventura, Public Works Department, 2003-2004

Mr. Kamman directed a hydrologic and geomorphic assessment of the lower Santa Clara River and estuary. This work was completed for prime contractor in an effort to assist with re-permitting of treated effluent discharges to the estuary. The proposed study entailed characterizing existing and historic hydrologic and physiographic conditions and an assessment of historic changes in inflow to the estuary. This task included a comprehensive review and evaluation of available hydrologic reports and flow data within the watershed to characterize changes in flow associated with development of numerous water projects within the Santa Clara River basin. The main deliverable from this analysis was the development of a historic unimpaired flow record to the estuary based on regional regression analyses and water operations modeling. Within the estuary, Mr. Kamman designed and conducted a multi-year monitoring program of water levels, water quality (temperature, dissolved oxygen, salinity, and pH), and sand-spit morphology in order to evaluate inlet opening/closure frequency and associated changes in aquatic habitat (esp. tidewater goby) and other ecologic communities. A considerable portion of this subtask included detailed coastal process analysis (including wave power analyses and littoral sand transport), which, considered with the inflow analysis, provides a basis to evaluate the seasonal cycle of barrier beach buildup and destruction.

This project illustrates Mr. Kamman's ability to complete a broad variety of hydrologic and coastal process analyses under strict regulatory oversight. A premier study completed on this project was the development of a detailed water and salinity budget model for the estuary to evaluate the impacts of a wide variety of proposed and modified estuary inflow regimes to determine potential future water level and salinity conditions in the lagoon and impact on frequency of inlet breaching. In addition to coordinating and implementing a variety field monitoring and surveys, Mr. Kamman also provided real-time information and input to informational and negotiation meetings with state resource and regulatory agencies.

Eden Landing Ecological Reserve Restoration, Alameda County, CA
East Bay Regional Park District, 2000-2003

Mr. Kamman developed and completed hydraulic and hydrodynamic modeling assessments for the design of an approximately 1000-acre tidal marsh restoration in former Cargil salt manufacturing ponds, located a mile inland of San Francisco Bay. The restoration goals required balancing the desires to restore tidal marsh conditions to the site, while maintaining and enhancing the open water and salt

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panne habitats preferred by resident and migratory shorebirds. The restoration plan also needed to incorporate restoration objectives with remediation of high soil salinities resulting from past salt production, subsided ground elevations, dredging of new channels to the bay, existing infrastructure constraints, public access for the San Francisco Bay Trail, and preservation of several important cultural and historical sites. Hydraulic design objectives include maximizing both interior circulation and tidal exchange between the restoration parcel and the bay. A series of one-dimensional unsteady hydrodynamic models (MIKE11) were used to design the channel network, identify high velocity areas requiring erosion protection, and characterize expected habitat conditions. An important component of this design and feasibility assessment was to translate desired ecological habitat conditions identified in the EIR into specific hydrologic design criteria, considering channel velocities, scour, sediment transport, tidal water inundation frequencies and seasonality of ponding. Mr. Kamman worked closely with EBRPD civil engineers, assisting with the translation of hydraulic design criteria into final engineered drawings and specifications.

Wetland & Pond Projects

Design of California Red-Legged Frog Breeding Ponds, San Francisco Bay Area (various), CA
The National Park Service and Golden Gate National Parks Conservancy, 1997-present

Mr. Kamman has lead or provided hydrologic and engineering design assistance to the sighting and design of nearly two dozen breeding ponds for California red-legged frog throughout the San Francisco Bay Area. Work has been completed in Marin, Sonoma, Solano, Contra Costa, Alameda, and Santa Clara Counties under the auspices of numerous federal, state, and local county/city agencies. A common study approach consists of an initial site reconnaissance of watershed conditions and identification of potential sites. The reconnaissance is followed by a surface water hydrologic sufficiency analysis using available meteorologic and stream flow information. An important variable sought during pond sighting is the presence of migration corridors between known breeding areas and/or perennial water sources. Based on in-depth research and post-project monitoring, Mr. Kamman has refined or developed site-specific evapotranspiration estimates, which commonly do not match standard applied values. Accurate evapotranspiration rates are necessary if ponds are intended to periodically dry-down as a means to preclude undesired species such as bullfrog or mosquito fish. In many instances, a seasonal groundwater-monitoring program is implemented in order to better investigate and quantify potential and seasonal groundwater contributions. Other design challenges we commonly experience include: design of impermeable liners for ponds located in upland areas or highly permeable soils; hydraulic analyses and design of outfalls/spillways; sedimentation management/maintenance approaches; and requirements of inoculum and water used to line and fill the pond, respectively.

Hydrologic Feasibility Assessment for Mana Plain Wetland Restoration Project, Kauai, HI
State of Hawaii Department of Land and Natural Resources, 2010-2019

Working on behalf of the Mana Plain Wetland Restoration Partnership, Mr. Kamman completed a hydrologic feasibility assessment for the Mana Plain Wetland Restoration Project proposed by the State of Hawaii Department of Land and Natural Resources (DLNR), Division of Forestry and Wildlife (DOFAW) on the island of Kauai. The Mana Plain Wetland Restoration Project site is approximately 105 acres of low-lying abandoned sugarcane fields immediately north of the Kawaiele Waterbird Sanctuary and east of the Pacific Missile Range Facility. The purpose of the Mana Plain Wetland Restoration Project is to maximize the area of constructed wetlands within the restoration site. Palustrine emergent wetlands within the project will create habitat for four species of endangered Hawaiian waterbirds and other sensitive species, including: Hawaiian stilts; Hawaiian ducks; Hawaiian coots; Hawaiian moorhen; migratory waterfowl; and migratory shorebirds. The Mana Plain is of vital importance for the recovery of endangered waterbirds species. This restoration project will be designed to provide important breeding and feeding wetland habitats on an island where; 1) wetlands have been severely degraded, and 2) mongoose, an introduced predator, have not been established.

Mr. Kamman's work on this project included technical assessments and development of proposed restoration alternatives. Analyses completed included: a synthesis of the physical site setting (topography, geology, hydrogeology and soil); reviewing available data to characterize site meteorology, surface water drainage, water quality, and groundwater conditions; preparing a detailed water budget to describe the characteristics and processes of surface water and groundwater movement into and through the project area; evaluating project feasibility, water supply alternatives and costs; and completing a flood hazard impact assessment to evaluate potential project benefits and impacts to local area flooding. Working with the project partners, Mr. Kamman developed a preferred project alternative and supported in preparation of the project Environmental Assessment document. Mr. Kamman's firm was also retained by the State of Hawaii to develop engineering designs of the project.

MacArthur Meadow Wetland Restoration, San Francisco County, CA
Presidio Trust, 2013-2016

Mr. Kamman has been working on over a dozen independent wetland and creek restoration planning and design efforts within the Presidio of San Francisco since 2001. Most recently (2016), he developed a wetland restoration grading plan for the MacArthur Meadow Wetland Restoration Project in the central portion of the Tennessee Hollow watershed. As part of the site assessment, Greg characterized and modeled surface and groundwater interactions and identified a unique opportunity to restore 4 acres of mixed meadow, natural wetlands and creek/riparian corridor. This was possible due to the discovery of shallow groundwater conditions beneath this historically disturbed landscape. Various design components were integrated into the grading plan in order to enhance groundwater recharge and storage in the Meadow, while retarding runoff and drainage out of the wetland, including: daylighting storm drain runoff into the Meadow; reconfiguring internal channel alignments to enhance channel habitat and groundwater recharge; creation of wetland depressions to retain and recharge surface water; and removal of fill material to decrease the depth to the water table. Notable challenges of this work include restoring heavily disturbed natural resources in an urban setting while integrating designs with archeology/cultural resources, education and remediation programs.

Dragonfly Creek Restoration Project, San Francisco County, CA
Presidio Trust, 2007-2011

Mr. Kamman designed and managed hydrologic monitoring and analysis studies in support of planning and design for riparian and wetland habitat restoration along approximately 500-linear feet of the Dragonfly Creek corridor near Fort Scott of the Presidio of San Francisco. Work has included completing subsurface

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investigations including the installation of shallow wells and a sharp-crested weir with recorder to gauge creek flows. Mr. Kamman assisted in the development and selection of a preferred project alternative, considering on-site cultural resource protection, education and resource management issues (including flood control). Mr. Kamman prepared permit applications. Major components of the project included removal of significant fill and building foundations and installation of a new creek road crossing that will maintain the historical alignment, function and architectural character of a culturally significant roadway. Mr. Kamman oversaw development of PS&E for this project, which will create mitigation wetlands for a highway earthquake retrofit project that passes through the Park.

This project illustrates Mr. Kamman's ability to complete a broad variety of hydrologic analyses, including: surface water and groundwater hydrologic monitoring to characterize and quantify existing hydrologic conditions; rainfall-runoff modeling; hydraulic modeling of flood and scour conditions (including road crossing); preservation of existing wetland habitat and vegetation communities; integration with other Presidio Trust programs; and contracting flexibility to assist in conceptual planning and environmental compliance without increasing project design costs.

Mori Point Sensitive Species Habitat Enhancement Project, San Mateo County, CA
Golden Gate National Recreation Area and Golden Gate National Parks Conservancy, 2005-2011

Mr. Kamman provided hydrologic analyses, sighting and engineering design (PS&E) for three California red-legged frog breading ponds within the 105-acre Mori Point area. These efforts were completed in association and collaboration with a larger Coastal Trail improvement and ecosystem restoration effort. Quarrying and off-road vehicle use have left this site heavily scarred. The focus of restoration work was to protect the endangered San Francisco garter snake and the threatened red-legged frog. Most of this work will be focused on invasive species removal and enhancing endangered species habitat. As part of species habitat improvement, Mr. Kamman worked with project ecologists to design the ponds to optimize breeding habitat for California red-legged frog.

Work started with an initial site reconnaissance and study of watershed conditions and identification of potential sites. The reconnaissance was followed by a surface water hydrologic sufficiency analysis using available meteorological and stream flow information and installation and monitoring of shallow piezometers to quantify the proximity and seasonal variability in depth to water table. An important variable sought during pond sighting was the presence of migration corridors between known breeding areas and/or perennial water sources. Based on in-depth research and post-project monitoring for other ponds they created in the San Francisco Bay area, Mr. Kamman refined site-specific evapotranspiration estimates. Accurate evapotranspiration rates are necessary if ponds are intended to periodically dry-down as a means to preclude undesired species such as bullfrog or mosquito fish.

Other design challenges experienced included: design of impermeable liners for ponds located in upland areas or highly permeable soils; hydraulic analysis and design of outfalls/spillways; sedimentation management/maintenance approaches; and requirements of inoculum and water used to line and fill the pond, respectively. Mr. Kamman has designed numerous ponds for the NPS and affiliates within the Bay Area, including Mori Point (constructed 2007), Banducci (constructed 2007) and Giacomini (Phase I and Phase II constructed in 2007 and 2008) project sites.

Hydrologic Assessment and Restoration Feasibility Study for Shadow Cliffs Regional Recreation Area, Alameda County, CA
East Bay Regional Park District, 2009-2010

Mr. Kamman developed and implemented an assessment to identify groundwater levels and supplemental water supplies that will sustain seasonal wetland restoration areas and riparian habitats under an altered future hydrologic regime. This work will inform a forthcoming Land Use Plan Amendment for park occupying a series of former gravel quarry pits. Work included: obtaining and synthesizing available surface water and groundwater data to characterize existing hydrologic and water supply conditions and seasonal variability; quantifying the likely changes in groundwater conditions and quarry pit lake levels in association with changes in regional water transmission and groundwater recharge operations; and identifying, developing and evaluating a suite of ecosystem restoration alternatives. Other important project objectives include: improving habitat for waterfowl and wildlife; broadening recreational use; enhancing visitor education and wildlife interpretation; improve park aesthetics. Mr. Kamman evaluated a preferred park and ecosystem enhancement alternative that involves diverting high winter flows from an adjacent arroyo. This project demonstrates Greg's ability to characterize hydrologic conditions and quantify the relationship between groundwater, surface water and wetland habitat conditions, both under existing conditions and in predicting future hydrologic and ecologic conditions under an altered hydrologic regime (i.e., lower groundwater table).

Laguna Salada Marsh and Horse Stable Pond Restoration Project, San Mateo County, CA
Tetra Tech, 2007-2009

Mr. Kamman provided technical hydrology and hydraulics support to the planning and conceptual restoration design of Laguna Salada marsh and Horse Stable Pond, located adjacent to Sharp Park Golf Course in the town of Pacifica, California. The primary objectives of the project are: to reduce flood impacts within the project vicinity; improve sustainable ecological habitat for the endangered San Francisco garter snake and the threatened California red-legged frog; better understand and characterize the hydrologic and water quality conditions/processes affecting flood and ecological habitat conditions within the project vicinity; provide an effective pumping operation plan to meet ecological objectives; and develop appropriate hydrologic analytical approaches and models to assist Tetra Tech and the San Francisco Recreation and Park Department in the planning and design for marsh, pond, and creek restoration. The project is also a unique opportunity to connect this resource with the California Coastal Trail, the Bay Area Ridge Trail, and the surrounding GGNRA lands.

Mr. Kamman's work included completing a comprehensive review of available hydrologic and site information and implementing selected field investigations to develop and calibrate an integrated hydrology-flood routing-pond water operations model that will quantify the volume and depth of water moving through the project system. The investigation will also further characterize shallow groundwater conditions and water quality with respect to effects on Laguna Salada and Horse Stable Pond. Analytical and numerical modeling tools are being used to better characterize existing hydrologic and water quality conditions and to assist in identifying project opportunities and constraints as well as evaluate potential restoration design components - all necessary to inform a sustainable

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and successful restoration design.

Tolay Lake Restoration Feasibility Assessment, Sonoma County, CA
Sonoma County Agricultural Preservation and Open Space District, 2003

Mr. Kamman completed a detailed hydrologic feasibility analysis to evaluate a suite of potential freshwater lake and wetland restoration alternatives. Sites were evaluated under existing watershed land-use practices and under existing and forecasted water demands (in the form of existing water rights/applications). Analysis consisted of developing a detailed water budget model to simulate alternative restored lake inundation areas and depths under median and dry year conditions, as well as a 50-year historic period (1947-1997) displaying highly variable rainfall and runoff supplies. Three lake restoration alternatives were evaluated based on existing topography and likely historic lake configurations. The restoration alternatives include lakes with storage volumes equivalent to 136-, 1100-, and 2550-acre feet.

Haypress Pond Decommissioning and Riparian and Channel Restoration, Marin County, CA
Golden Gate National Recreation Area (GGNRA), 2001-2002

This project restored 170 meters of historic creek and riparian habitat through removal of Haypress Pond dam in Tennessee Valley within GGNRA. The goals of the project were to alleviate long-term maintenance needs and eliminate non-native bullfrog habitat threatening native California red-legged frog habitat in adjacent watersheds.

Working with the Park biologist, Mr. Kamman developed designs to decommission the dam and restore natural riparian and meadow habitat. This work included: characterization of existing topographic conditions; design of a channel profile through the proposed restoration project reach; preparation of a grading plan for the restoration project; and hydrologic and hydraulic analyses to evaluate the performance of the creek channel and flood plain below the former dam during a variety of flows. Challenges of this work included integrating sediment reuse into plans and construction phasing.

Damon Slough Site Seasonal Wetland Design, Alameda County, CA
Port of Oakland, 1999-2001

Working on behalf of the Port of Oakland, Mr. Kamman completed extensive surface and groundwater monitoring and data analyses to develop a detailed water budget to assist in the evaluation and design of a 7.5 acre seasonal freshwater wetland. Primary project objectives included a design that would provide shorebird/waterfowl roosting habitat, minimize impacts to existing seasonal wetland areas, and lengthen the duration of ponding through the end of April to promote use by migratory birds. In addition to developing hydrologic design criteria, responsibilities included development of grading plans to accommodate a local extension of the Bay Trail and wetland outlet works.

Water Quality Projects

Chicken Ranch Beach Soil and Groundwater Quality Investigation and Restoration Planning, Marin County, CA
Tomales Bay Watershed Council, 2007-present

Mr. Kamman is leading scientific and engineering efforts for a wetland and riparian corridor restoration project on Third Valley Creek and Chicken Ranch Beach in Inverness, California. The main project goals are to create a self-sustaining riparian and wetland system (requiring minimal operation and maintenance) and eliminate public exposure to high levels of bacteria that exist in a site drainage ditch discharging to the beach. The design will likely include establishing a blend of habitats, including: riparian stream corridor, seasonal/perennial freshwater marsh, and tidal/saltwater marsh.

Current efforts have included the development and implementation of a soil and groundwater quality investigation to delineate the source of elevated bacteria levels. This work includes: the collection and testing of depth-discrete soil samples; groundwater well installation, sampling and testing; and surface water sampling and testing; analysis of laboratory results; and reporting, including recommendations for further/expanded investigations. Mr. Kamman coordinated this time-sensitive sampling and analysis (six hour hold times) with Brulje and Race Laboratories in Santa Rosa.

Lower Miller Creek Channel Maintenance and Material Reuse Sampling Analysis Plan, Marin County, CA
Las Gallinas Valley Sanitary District, 2015

Mr. Kamman was commissioned to formulate and implement a plan for sediment removal and improved flood flow conveyance in the Lower Miller Creek channel. Accumulation of course sediment in the project reach had reduced discharge efficiencies at District outfalls. Miller Creek supports a population of federally listed Steelhead and adjacent wetland/marsh areas potentially support other state and federally listed special status species. Working with District Staff, Greg developed a suite of potential project alternatives and identified a preferred approach. Mr. Kamman completed all CEQA compliance (IS/MND), permitting and oversaw development of engineered plans and specifications.

In order to evaluate if reuse of excavated material from 2,655 feet of creek corridor in upland areas was feasible, Mr. Kamman developed and implemented a Sampling Analysis Plan (SAP) pursuant to U.S. Army Corps Guidance for Dredging Projects within the San Francisco District. Sample collection, sample handling, and analysis were performed in accordance with the SAP. Results for analytes were compared to a variety of screening criteria to determine the material's suitability for reuse in aquatic environments. A full suite of chemical and physical analyses were performed on soil samples collected from 16 locations, including: metals, PAHs, PCBs, pesticides, TOC, specific conductance, pH, sulfides, percent moisture and grain-size. Mr. Kamman managed all aspects of this effort including reporting and presentations/negotiations at multi-agency meetings through the Corps Dredge Materials Management Office (DMMO).

Lower Pitkin Marsh Hydrologic and Water Quality Monitoring, Sonoma County, CA
Sonoma Land Trust, 2008-2010

Mr. Kamman was retained to develop and implement a hydrologic and water quality monitoring program at Lower Pitkin Marsh outside of Forestville, California. The Pitkin Marsh area is one of the most valuable complexes of mixed riparian woodland and thicket, freshwater marsh, wet meadow, oak woodland and grassland in Sonoma County. The complex interaction of surface water, ground water, and scattered seeps and springs on the site creates unusual hydrologic conditions that promote a rare assemblage of plant species which includes several endemics. The primary objective of the hydrologic monitoring program was to understand the annual and season sources of both surface and ground water supplying wetlands. Hydrologic and water quality monitoring was

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initiated during the winter wet season of 2008/09 and will be conducted for a 12-month period through the ensuing summer dry-down and into the following wet season. Understanding how groundwater levels, spring flow and creek flow rates recede from winter wet to summer dry conditions will provide an important understanding and quantification of the seasonal variability in water supplies feeding selected wetland types. General water quality parameters (temperature, pH, specific conductance, and ORP) are measured at all monitoring locations during each visit. Nutrients (N and P) are measured in selected surface water and groundwater samples collected during at least three monitoring events, including a winter high flow, spring high base flow and summer low baseflow.

Pescadero Lagoon Restoration and Enhancement, San Mateo County, CA
California State Coastal Conservancy, 2005-2006

Mr. Kamman was retained to support restoration and water quality enhancement planning efforts in Pescadero Lagoon. In 2005-2006, he completed a synthesis of available hydrologic and water quality information in responding to requests for development of a hydrodynamic and water quality model of the lagoon. This model was considered as a means to identify causes for repeated fish-kills in the lagoon that occurred during initial breaching of the inlet. Mr. Kamman assisted in preparing a synthesis and model development feasibility report from this effort.

Water Temperature Simulations for Trinity River Fish and Wildlife Restoration Project, Trinity County, CA
Trinity County Planning Department, 1994-2004

For over a decade, Mr. Kamman completed a number of hydrology and water quality investigations in support of alternative feasibility studies on the Trinity River Fish and Wildlife Restoration Project in direct support of the Trinity River Restoration EIR/EIS. Studies involve assessing the effects of proposed flow alternatives on water temperature within and downstream of Lewiston Reservoir. Mr. Kamman was responsible for data collection, processing, and flow/temperature modeling of Lewiston Reservoir as part of a coordinated evaluation including other Trinity River system models. Another study included evaluating how project operations could be implemented or modified to optimize Lewiston Lake release temperatures to meet downstream temperature criteria and compensate for increased warming of the river associated with side channel and feather edge restoration activities. Mr. Kamman continues to evaluate how more recent water projects (raising Shasta Dam, Sites Reservoir, and the Waterfix tunnels) consider and integrate with the Trinity Restoration Project.

Upper Eel River Unimpaired Flow and Water Temperature Assessments, Humboldt County, CA
CalTrout, 1997-1999

Mr. Kamman evaluated changes in the natural flow regime of the upper Eel River, and developed an Upper Eel River proposed release schedule to enhance downstream Chinook and Steelhead spawning and rearing habitat. This work was triggered by proposals set forth by PG&E as part of their Potter Valley Project FERC relicensing process. Work consisted of two main investigations. The first included reviewing results of a ten year PG&E study and development of multivariate regression and stream reach (SSTEMP) temperature models to assess the effects proposed flow alternatives would have on downstream temperatures. The second investigation consisted of characterizing unimpaired flow conditions and developing a daily unimpaired flow record for use in project operation models.

Selected Litigation Support Projects

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Chartrand, A.B., and Kamman, G.R., 2019, Comments to Central Coast Regional Water Quality Control Board Ag. Order 4.0 regulatory requirement options and proposed Requirement Options Tables. Prepared for: The Otter Project and Monterey Coastkeeper, January 22, (8p.), 5 tables and Monitoring Reporting Plan (MRP; 26p.).

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Kamman, G.R., 2018, Oral Testimony of Greg Kamman for Part 2 of the California Waterfix Change of Diversion Hearing before the State Water Resources Control Board at Joe Serna Jr.-CalEPA Building, Sacramento, CA, April 16.

Kamman, G.R., 2017, Review Comments: PAD and SD1, FERC Relicensing of Potter Valley Project (PVP). Professional declaration prepared for: Friends of Eel River, July 31, 8p.

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Kamman, G.R., 2016, Review of Draft General Waste Discharge Requirements for Vineyard Dischargers in the Napa River and Sonoma Creek Watersheds. Prepared for: Law Offices of Thomas N. Lippe APC, December 12, 4p.

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Kamman, G.R., 2016, Declaration of Greg Kamman Plaintiff's Joint Motion for Preliminary Injunction, Prepared for Center for Biological Diversity (Plaintiff) v. U.S. Bureau of Reclamation, Case No. 6:16-cv-00035-TC (Recovery for Oregon Spotted Frog, Upper Deschutes Basin, Oregon) , February 4, 8p.

Kamman, G.R., 2015, Sharp Park Project Impacts to Laguna Salada. Prepared for National Parks Conservation Association and Wild Equity Institute, April 14, 1p.

Kamman, G.R., 2014, Review of Middle Green Valley Specific Plan Project, Revised Recirculated Draft Environmental Impact Report, Solano County, CA, Sch# 2009062048. Professional Declaration Prepared for: Law Offices of Amber Kemble, August 11, 11p.

Kamman, G.R., 2012, Deposition of Gregory Richard Kamman, R.G., C.H.G., Schaefer vs. City of Larkspur, CA, Superior Court of the State on California, County of Marin. August 23, 2012.

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ATTACHMENT B

UNITED STATES DEPARTMENT OF COMMERCE
National Oceanic and Atmospheric Administration
NATIONAL MARINE FISHERIES SERVICE
West Coast Region
777 Sonoma Avenue, Room 325
Santa Rosa, California 95404-4731

February 26, 2021

Tennis Wick, Director
County of Sonoma
Permit and Resource Management Department
2550 Ventura Avenue
Santa Rosa, California 95403

Dear Mr. Wick:

This letter communicates NOAA's National Marine Fisheries Service's (NMFS) concerns regarding the proposed Mitigated Negative Declaration (MND) addressing the Sonoma County Cannabis Land Use Ordinance Update and General Plan Amendment (Update) for cannabis cultivation in Sonoma County, California. NMFS is responsible for conserving threatened and endangered marine species under the federal Endangered Species Act (ESA), and ESA-listed Central California Coast (CCC) coho salmon (*Oncorhynchus kisutch*), CCC steelhead (*O. mykiss*), and California Coastal Chinook salmon (*O. tshawytscha*) reside within many rivers and streams throughout the County. Our concerns stem from the proposed requirements for cultivators using groundwater as their water source, and how these requirements will likely be inadequate in preventing impacts to ESA-listed salmonids and their habitat.

Surface water and underlying groundwater are likely hydraulically linked throughout much of Sonoma County, and this linkage is critically important in creating seasonal habitat for juvenile salmonids. Where the groundwater aquifer supplements streamflow, the influx of cold, clean water is critically important for maintaining temperature and flow volume during summer months. Pumping from these aquifer-stream complexes can adversely affect instream habitat by lowering groundwater levels and interrupting the hyporheic flow between the aquifer and stream.

Groundwater is the predominant source of water for cannabis cultivation operations within Sonoma County. State Water Board regulations concerning surface water diversions for cannabis cultivation contain required best management practices (BMP's) highly protective of instream flow volume and fish habitat, such as requiring summer forbearance, winter diversions, and fish friendly bypass flows. However, similar BMP's are not required by the State Water Board for cultivation sites utilizing groundwater wells as a source for cannabis cultivation. Because of this discrepancy under state law, the vast majority of cannabis cultivation applications throughout the County are opting for groundwater wells as their water source. We are concerned in particular, that wells are being drilled and pumped without appropriate analysis regarding their potential impact to surface water, especially near-stream wells that may also impact groundwater/surface water dynamics and result in streamflow depletion. With those concerns in mind, we offer the following comments.

Re Page 70, Section 10(b): The MND states the following: *Future cannabis facilities in rural areas would rely on either surface (rivers, lakes, and springs) or well water sources. Accordingly, the introduction of cannabis cultivation in these areas could increase the use of groundwater.* As explained above, very few rural cultivation sites are currently using surface water diversions as a water source, likely to work around the required BMP's mandated by the State Water Board for surface water diversions. NMFS is concerned about both surface water and groundwater diversions, as they are linked, and we believe the potential for impacts from unrestricted groundwater use is high.

Re Page 71, Section 10(b)(4)(b): This section addresses near-stream wells (e.g., "well is within 500 feet of blue line stream"), and is intended to minimize streamflow depletion impacts. According to the MND, if a well is within 500 feet of a blue line stream, the applicant must document one of three things: 1) prepare a "net zero water plan", 2) document the well is near the Russian River or Dry Creek, or 3) document the well is within the Groundwater Availability Zone 1 or 2. By including the third option, the authors of the MND seem to assume that streamflow depletion impacts are unlikely in Groundwater Availability Zones 1 and 2. However, streamflow depletion can occur within any of the groundwater zones in Sonoma County, and is largely influenced by well distance from the waterway, the pumping intensity, and the transmissivity of the underlying geology, not groundwater availability zones. Thus, the current standards and requirements appear unlikely to adequately mitigate the potential impact of streamflow depletion, making a MND inappropriate. NMFS recommends the Update require either a net zero water plan, or a hydrogeologic analysis confirming streamflow depletion impacts are unlikely, before any cannabis operation utilizing a near-stream well is approved, regardless of which Groundwater Availability zone it may occur in.

Furthermore, while we understand that the current Update applies only to cannabis cultivation, NMFS recommends the County also update their well ordinance and permitting procedures to apply this requirement (i.e., require a net zero water plan, or a hydrogeologic analysis confirming streamflow depletion impacts are unlikely) to all permit applications for near-stream wells.

NMFS appreciates the opportunity to comment regarding the proposed Mitigated Negative Declaration addressing the Sonoma County Cannabis Land Use Ordinance Update and General Plan Amendment for cannabis cultivation If you have any comments or questions regarding this letter, please contact Mr. Rick Rogers at rick.rogers@noaa.gov, or 707-578-8552.

Sincerely,

RMCoey

Robert Coey
North Coast Branch Supervisor
North-Central Coast Office

cc: (via email)
Bryan McFadin, North Coast Regional Water Quality Control Board
(Bryan.McFadin@waterboards.ca.gov)
Wes Stokes, California Department of Fish and Wildlife (Wes.Stokes@wildlife.ca.gov)
David Hines, California Department of Fish and Wildlife (David.Hines@wildlife.ca.gov)
Daniel Schultz, State Water Board (Daniel.Schultz@waterboards.ca.gov)
Jessica Maxfield, California Department of Fish and Wildlife
(Jessica.Maxfield@wildlife.ca.gov)

EXHIBIT 2

Borroughs has products for every stage of the growth cycle, and each system is easily configurable to meet your cultivation needs. Our products are designed to reduce your nursery footprint, optimize your space, and help increase your yield. Through years of manufacturing and design expertise, Borroughs can get the most out of your vertical space.

Horticultural grow shelves replace single layer tables which waste vertical space. These systems are designed for commercial cannabis grow operations and indoor farming, these systems are perfect for top feed irrigation systems. Wire decking options are available for flood and drain trays, as well.

Shelves are engineered for single, double, triple and even quadruple stacks (level of shelves/racks). Take advantage of your vertical space and reduce your working footprint.

Go higher.

Many warehouses have high ceilings that are ideal for a 2-story system. Borroughs has the expertise to design high-rise, multi-level grow facilities and increase your cultivation space.

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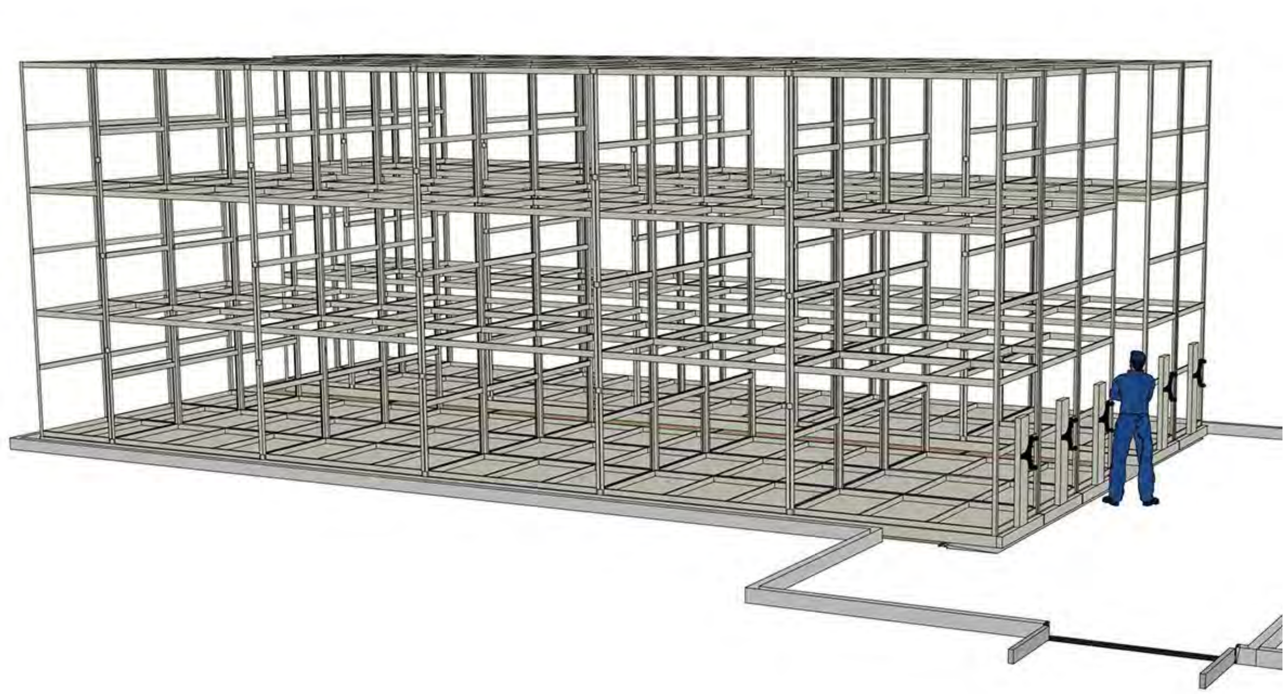
Are you looking to double your grow space? Our Aisle-Saver System is a high-density mobile system available for your cultivation facilities. The shelves ride on a carriage and rail system, allowing open access to only the aisle you need to work in. This increases usable space by 50%, or reduces the room footprint by half.



For more information regarding our vertical grow products and to talk to an expert call 800-748-0227 or click on the link below.

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EXHIBIT 3

The New York Times

'Dead Skunk' Stench From Marijuana Farms Outrages Californians

By Thomas Fuller

Dec. 19, 2018

CARPINTERIA, Calif. — They call it fresh skunk, the odor cloud or sometimes just the stink.

Mike Wondolowski often finds himself in the middle of it. He may be on the chaise longue on his patio, at his computer in the house, or tending to his orange and lemon trees in the garden when the powerful, nauseating stench descends on him.

Mr. Wondolowski lives a half-mile away from greenhouses that were originally built to grow daisies and chrysanthemums but now house thousands of marijuana plants, part of a booming — and pungent — business seeking to cash in on recreational cannabis, which has been legal in California since January.

"If someone is saying, 'Is it really that bad?' I'll go find a bunch of skunks and every evening I'll put them outside your window," Mr. Wondolowski said. "It's just brutal."

When Californians voted to legalize recreational marijuana in 2016, there were debates about driving under the influence and keeping it away from children. But lawmakers did not anticipate the uproar that would be generated by the funk of millions of flowering cannabis plants.

As a result of the stench, residents in Sonoma County, north of San Francisco, are suing to ban cannabis operations from their neighborhoods. Mendocino County, farther north, recently created zones banning cannabis cultivation — the sheriff's deputy there says the stink is the No. 1 complaint.

Cannabis buds on plants at New Family Farm in Sebastopol, Calif. Jim Wilson/The New York Times

In Santa Barbara County, cannabis growers confronting the rage of neighbors are spending hundreds of thousands of dollars installing odor-control systems that were designed for garbage dumps.

The smell from commercial cannabis farms, which brings to mind a mixture of rotting lemons and sulfur, is nothing like the wafting cloud that might hover over a Phish show, pot farm detractors say.

"It's as if a skunk, or multiple skunks in a family, were living under our house," said Grace Guthrie, whose home sits on the site of a former apple orchard outside the town of Sebastopol. Her neighbors grow pot commercially. "It doesn't dissipate," Ms. Guthrie said. "It's beyond anything you would imagine."

When cannabis odors are at their peak, she and her husband, Robert, sometimes wear respirators, the kind one might put on to handle dangerous chemicals. During Labor Day weekend, relatives came to stay at the house, but cut short their visit because they couldn't stand the smell.

"I can't be outside more than 30 minutes," Mr. Guthrie said of peak odor times, when the cannabis buds are flowering and the wind sweeps the smell onto his property. "The windows are constantly closed. We are trapped inside. There's no escape."

Britt Christiansen and her neighbors in Sonoma County banded together and sued the operators of a local pot business over the smell. Jim Wilson/The New York Times

After nearly one year of recreational sales in California, much of the cannabis industry remains underground. Stung by taxes and voluminous paperwork, only around 5 percent of marijuana farmers in the state have licenses, according to Hezekiah Allen, the executive director of the California Growers Association, a marijuana advocacy group. Sales of legal cannabis are expected to exceed $3 billion this year, only slightly higher than medical marijuana sales from last year. Tax revenues have been lower than expected, and only about one-fifth of California cities allow sales of recreational cannabis. The dream of a fully regulated market seems years off.

The ballot measure legalizing recreational marijuana passed in 2016 with a comfortable majority of 57 percent. Many of those complaining about cannabis odors say they were among those who supported it. They just don't want it stinking up their property, they say.

"Just because you like bacon doesn't mean you want to live next to a pig farm," said Lynda Hopkins, a member of the Sonoma County Board of Supervisors, whose office has been inundated with complaints about the smell.

The odor question is also roiling local politics.

Marijuana businesses in Carpinteria recently donated $28,000 worth of lab equipment to Carpinteria High School, according to Philip Greene, the chief of operations for Ever-Bloom, a cannabis producer that helped coordinate the donation. The high school is flanked by cannabis greenhouses that have sent odors wafting in. In the past two years, students have complained of headaches, parents have grown angry and the high school has had to warn visiting sports teams that they might encounter the odor.

The donation has not yet been made public, but is seen by some as an effort to offset the damage done by the stench. In an interview, Maureen Foley Claffey, a member of the Carpinteria School Board, said it would send a "confusing and problematic" message to students to accept it. Ms. Claffey lashed out at the superintendent, Diana Rigby, for soliciting donations from the cannabis industry at a time when members of the community are battling the stink.

A Nasal Ranger, a device that measures the odors in the air. It is in use in Colorado, the first state to legalize recreational marijuana.
Dave Kolpack/Associated Press

"Are we that desperate for cash that we are willing to take it from anyone without regard to the source and the message?" she said. "I guess money talks."

Ms. Rigby, the superintendent, did not return phone calls or email requesting comment.

In Sonoma County, hearings on cannabis ordinances at the board of supervisors overflow with representatives from the cannabis industry, who wear green, and angry residents, who wear red.

Of the more than 730 complaints Sonoma County has received about cannabis this year, around 65 percent are related to odor, according to Tim Ricard, the county's cannabis program manager.

"There's been a tremendous amount of tension in the community," said Ms. Hopkins, the Sonoma supervisor. "If I had to name an ice-cream flavor for cannabis implementation it would definitely be rocky road."

Cannabis executives recognize that pot grows can be odorous, but say their industry is no different from others that produce smells.

Dennis Hunter, right, a co-founder of CannaCraft, a marijuana business in Santa Rosa in Sonoma County, watching Matt Kulczycki filling a mold with cannabis-infused dark chocolate. Jim Wilson/The New York Times

"You have a smell issue that sometimes can't be completely mitigated," said Dennis Hunter, a co-founder of CannaCraft, a large marijuana business based in Santa Rosa in Sonoma County. "But we have dairy farms here in the area or crush season for the vineyards — there's agricultural crops, and a lot of them have smells."

Britt Christiansen, a registered nurse who lives among the dairy farms of Sonoma County, acknowledges that her neighborhood smells of manure, known locally as the Sonoma aroma.

But she says she made the choice to live next to a dairy farm and prefers that smell to the odor that drifted over from the marijuana farm next door to her house.

"We opened the door and the smell kicked us in the face," Ms. Christiansen said. Her neighbors banded together in October and sued the operators of the pot business; the case is ongoing.

One problem for local governments trying to legislate cannabis odors is that there is no objective standard for smells. A company in Minnesota, St. Croix Sensory, has developed a device called the Nasal Ranger, which looks like a cross between a hair dryer and a radar gun. Users place the instrument on their nose and turn a filter dial to rate the potency on a numerical scale. Charles McGinley, the inventor of the device, says a Level 7 is the equivalent of "sniffing someone's armpit without the deodorant — or maybe someone's feet — a nuisance certainly."

Lawmakers did not anticipate the uproar that would be generated by the funk of millions of flowering cannabis plants. Jim Wilson/The New York Times

A Level 4, he said, is the equivalent of a neighbor's freshly cut grass. "It could still be a nuisance, but it wouldn't drive you away from your front porch," Mr. McGinley said.

Standing next to a flowering cannabis bud, the smell would easily be a Level 7, Mr. McGinley said.

The Nasal Ranger is in use in Colorado, the first state to legalize recreational marijuana, but California counties and cities are still struggling with the notion that smells are subjective.

Ever-Bloom in Carpinteria is one of a number of marijuana businesses that have invested hundreds of thousands of dollars to mitigate the stink. Two previous systems failed, but the current one, modeled on devices used to mask the smell of garbage dumps, sprays a curtain of vapor around the perimeter of the greenhouses. The vapor, which is made up of essential oils, gives off a menthol smell resembling Bengay.

Dennis Bozanich, a Santa Barbara County official charged with cannabis implementation who has become known as the cannabis czar, says the essential oil odor control has been largely successful. But not every grower can afford to install it.

On weekends, Mr. Bozanich becomes a cannabis odor sleuth, riding his bicycle through Carpinteria sniffing the air for pot plants. He recently drove through the area with a reporter, rolling down the windows on a stretch of road with cannabis greenhouses. He slowed the car and puzzled over where a cannabis odor was coming from.

"I've got one stinky location right here and I can't quite figure it out," he said.

His description of the stink?

"Dead skunk."

EXHIBIT 4

GREENHOUSE EFFICIENCY GUIDE

21 Cannabis Greenhouse Design Considerations

John W. Bartok, Jr.

Greenhouses are becoming popular structural options for cannabis production due to lower facilities costs, easy expansion potential, ability to capture more uniform light from the sun and reduced production costs, as compared to indoor warehouse facilities. However, there are many important design elements you need to consider once you have developed a business plan and selected a site.

Planning should be your first step in developing a framework for an orderly greenhouse build-out. Start with a facilities master plan that looks at topography and drainage, the building locations, parking for customers and staff, access for vehicles and equipment, and utilities (including water supply and electricity).

Facilities Layout

1. Because materials handling is one of the largest costs in a greenhouse operation, **major consideration should be given to placement of a new greenhouse and its relation to the headhouse.** A headhouse is the key nerve center that houses the work area, office, germination and growth rooms, utility area, processing, shipping and storage. Typically, a headhouse makes up 10 percent to 20 percent of the total greenhouse space.

2. **The selection of a plant-moving system is important** in relation to the plants grown, distance moved and elevation differences. Conveyors, carts and pallet trays have advantages and disadvantages that you should evaluate.

3. **A master plan can also help in obtaining zoning, wetlands and building permits.** You should submit the master plan with the initial phase of any multiphase build-out or expansion. This then becomes part of the approval process. If commission membership and sentiments change, the expansion phases are already on file.

4. **Expansion space should be planned for all areas.** It is best to create the plan on paper so that several alternatives can be evaluated. Greenhouses are large, modular erector sets, and expansion is easy if planned in advance. Fuel supply, electricity, water service and headhouse layout should be sized with expansion in mind.

Greenhouse Style

5. **A free-standing greenhouse can have a quonset (hoop), Gothic or gable roof shape.** Gothic designs are the most popular as they provide higher light transmission and shed snow more easily. A-frame design is standard when glass will be used for glazing. The free-standing design is usually the best choice for the small grower planning on less than 10,000 square feet of growing space. It is easy to build additional greenhouses as more space is needed. A separate growing environment can be provided in each house. Individual greenhouses can also be shut down when not in use. Free-standing greenhouses are generally less expensive to build, as site preparation and erection costs are less.

6. **Growing space greater than 10,000 square feet is best provided by a gutter-connected greenhouse.** Individual bays vary in width from 12 feet to 30 feet and have a clearance of 12 feet to 20 feet at the gutter. Bays can be constructed to achieve the desired width. The greenhouse can also be built in modular sections when more growing area is needed. Lengths up to 300 feet are available. A gutter-connected greenhouse offers the greatest flexibility. A taller gutter height is better as it provides an air buffer and room for an energy truss and energy/shade screen. Heat can be centralized, and heating costs are as much as 25 percent less than an equal area in free-standing greenhouses. Utilities are centralized and easier to install.

7. **Glass glazing will give the highest light transmission** (about 90 percent), but has the greatest heat loss. When the greenhouse is fitted with one or two energy screens, the heat loss is about the same as double-poly (two layers of 6-mil film plastic separated by air from a small blower) or twin-wall polycarbonate (a rigid

material that has ribs between two layers of rigid plastic). Taxes on a greenhouse covered with low-cost, four-year poly are generally less than one with more permanent material. A glazing that diffuses the light will provide more uniform coverage and deeper penetration into the plant canopy.

Space Utilization

8. **A peninsula-style bench arrangement will allow for more growing space than the traditional long benches.** It also allows separation of individual plant varieties. The main aisle down the center of the greenhouse or bay should be wide enough to allow two carts to pass (usually 5 feet to 6 feet wide, but may be up to 10 feet wide in a gutter-connected greenhouse). Perpendicular side aisles can be 18 inches to 24 inches wide.

9. **Movable benches can increase usable growing space to as much as 90 percent of your total greenhouse space.** These can be set up near the floor to give maximum plant height area or at 30 inches above the floor to give convenient working height. One 20-inch to 24-inch work aisle is all that is needed.

10. To save valuable greenhouse growing space, **mother plants and early vegetative growth can be done in separate rooms in the headhouse.** Good temperature, humidity and lighting control can provide the ideal environment.

Hoop roof structure

Heating

11. With energy being one of the largest cost items in production, **installing high-efficiency heating is extremely important.**

12. **Compare heating fuels on a cost per million-BTU (British thermal unit) basis.** Natural gas is usually the least expensive, but can cost more when the demand charge for the summer months is added in. Some growers have found that installing propane heaters to handle peak demand will lower total heating cost.

13. **A hot water boiler is the best choice for a heating system.** Water temperature can be modulated to meet the needs of air or root-zone systems at different times of the year. Distribution can be low-cost, water-to-air unit heaters or fin pipe radiation. Hot air unit heaters and furnaces work well for greenhouses that may be closed for winter.

14. **Heating the bottom of pots, the floor or under the benches can provide uniform root-zone temperature, allowing air temperature to be lower.** This saves fuel. A natural gas- or propane-fired domestic hot-water heater or an instantaneous in-line water heater works well for small greenhouses. Distribution can be performed with cross-linked polyethylene (PEX) or ethylene propylene diene monomer rubber (EPDM) tubing, or low-output fin radiation under the benches. It is best to limit this type of heat to no more than 25 BTU/sq. ft., as excessive drying of the growing mix can occur otherwise. Water temperature should not exceed 110°F. In cold climates, air heat provides the difference.

Energy/Shade Screens

15. A reduction of up to 50 percent in fuel costs can be achieved with **the installation of an energy/shade screen.** This movable screen is closed at night to retain heat. During the summer, it provides shade to lower plant-leaf temperature and save electricity from less fan operation. A 40-percent to 60-percent shade with 50-percent energy savings is a common material used for cannabis production.

Gothic roof structure

Cooling

16. **A fan and louver system will provide the most positive ventilation.** Although more expensive to operate than a natural ventilation system, it will provide better temperature control. The system should be designed to give a ventilation rate of about 2 cubic feet per minute (cfm)/sq. ft. of floor area during the winter and 8 cfm/sq. ft. during the summer. Several stages of ventilation capacity with multiple fans are best. Select the largest diameter fans with the smallest motors to get the lowest electricity consumption (cfm/watt). Evaporative cooling, either fan-and-pad or fog can lower inside temperature by up to 20°F during the summer.

17. **Natural ventilation through side and roof vents can be effective if sized properly.** Side vents should measure between 15 percent and 25 percent of the floor area. The same applies for roof vents. If insect screening is required, a larger area is needed in side and roof vents, as screening will reduce airflow.

18. **A horizontal air flow (HAF) system provides good air movement,** uniform temperatures and reduces disease potential. Use 1/10 horsepower 12-inch- to 20-inch-diameter fans. Spacing depends on fan design, but fans should provide a minimum air-mass speed of 100 feet/minute for adequate air circulation.

Controls

19. **If individual thermostats are used** for the heating and cooling systems, **select those that have a +/-1ºF differential** (meaning the temperature can only swing 1 degree from the setpoint). This will give better temperature control and save energy. A better choice is to use an electronic controller that will integrate the heaters, fans, evaporative cooling system, irrigation system and supplemental lights. Many controllers also have temperature and power alarm features to warn cultivators of problems within the grow environment. Computer control is best for multiple greenhouses or several sections in a gutter-connect greenhouse.

Supplemental Lighting

20. To overcome variable weather conditions and still meet a production schedule, some supplemental lighting is usually needed. **High pressure sodium (HPS) and light-emitting diode (LED) fixtures are the most efficient.** As cannabis is a short-day plan—with a total daily light integral (DLI) of 30 to 40 moles of sunlight plus supplemental light that has to be accumulated within 12 hours—you may have to install 500 μmols to 600 μmols of supplemental lighting to achieve this. Have the lighting-equipment supplier design the fixture layout using its computer program to get adequate intensity and uniform coverage for your location.

Irrigation

21. Automated watering can save considerable labor. **The system should be designed to provide uniform watering.** Drip systems, either individual emitters for container crops or tape for crops grown in beds, are usually the best choice. (More water is wasted with overhead sprinklers as water goes between the containers and also runs off the leaves.) A large number of plants can be irrigated at one time on a small water supply due to the low flow rate. Adding one or more injectors can provide fertigation. This can be either a portable unit with integral concentrate tank or a central location in the headhouse with storage for the mixing tanks and fertilizer.

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2018/greenhouse-efficiency-guide.aspx) | 2018/structurally-sound.aspx)

EXHIBIT 5

Integrated Surface and Groundwater Modeling and Flow Availability Analysis for Restoration Prioritization Planning, Upper Mark West Creek Watershed, Sonoma County, CA

Wildlife Conservation Board Grant Agreement No. WC-1996AP
Project ID: 2020018

December 2020

Prepared for:

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Dedication

In recognition of those many residents of the Mark West Creek watershed that have suffered losses in the past few years to the Tubbs Fire and the Glass Fire, we dedicate this report in their honor. Many of the citizen contributors to this effort have been working for many years to advance the consciousness of the community with respect to wildfire hazards, fuel management and fire safe communities, and it is an unfortunate truth that there remains much to be done. We dedicate this report in the spirit of community service and the example that has been set by these citizens, families, friends, and communities.

Acknowledgements

Many individuals and organizations contributed to the successful completion of this project including the various members of the project team from the Sonoma Resource Conservation District, Coast Range Watershed Institute, O'Connor Environmental Inc., Friends of Mark West Watershed, the Pepperwood Foundation, and Sonoma County Regional Parks. Many individual landowners graciously provided access for field reconnaissance and streamflow and groundwater monitoring work. Other agencies and organizations including California Sea Grant, California Department of Fish and Wildlife, National Marine Fisheries Service, Sonoma Water, Trout Unlimited, Permit Sonoma, and Sonoma Water also contributed significantly to the project by sharing data and providing input through three Technical Working Group meetings.

Limitations

The descriptions of watershed and streamflow conditions described in this report are based on numerical model simulations which were developed using best available data and hydrologic practices. Available model input data varied widely in its resolution and accuracy, and while the model was calibrated successfully to available streamflow and groundwater monitoring data, the extent of available calibration data is relatively limited. All model scenarios represent hypothetical actions on the landscape and do not imply any interest or commitment on the part of landowners to implement them. Both the existing condition and scenario results represent approximations of real-world conditions that contain uncertainty and should be interpreted as a guide for understanding watershed hydrology and the effects of potential management actions rather than as precise quantitative predictions of actual or future conditions.

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Executive Summary

Introduction

The Mark West Creek watershed provides critical habitat for threatened and endangered anadromous fish and was recently identified in the California Water Action Plan as one of five streams statewide for targeted flow enhancement efforts. Effective implementation of a flow enhancement program requires a detailed understanding of the natural and man-made controls on spring and summer streamflows. The primary goal of this project is to provide a comprehensive hydrologic analysis of streamflow conditions and the relative effectiveness of various potential flow enhancement actions in upper Mark West Creek watershed relative to salmonid habitat requirements. The project provides a framework for prioritizing restoration efforts and developing effective strategies and projects to protect and enhance streamflows.

This study evaluates the upper 40 mi^2 of Mark West Creek watershed upstream of the Santa Rosa Plain (Figure E1) identified as critical salmonid summer rearing habitat in the State Water Resources Control Board Emergency Order WR 2015-0026-DWR (SWRCB, 2015). The study was conducted over a three year period and was completed by the Coast Range Watershed Institute (CRWI) in cooperation with the Sonoma Resource Conservation District (SRCD), Friends of Mark West Watershed, Sonoma County Regional Parks, and the Pepperwood Foundation. Assistance was also provided by local staff of California Department of Fish & Wildlife (CDFW). Funding for the project was provided by a Streamflow Enhancement Program grant from the California Wildlife Conservation Board (WCB).

O'Connor Environmental, Inc., completed the modeling analysis under contract with CRWI. The completed model is intended to serve as a tool to help evaluate the hydrologic consequences of future project proposals. The principal mission of CRWI as a tax-exempt scientific not-for-profit organization in this regard is to provide a virtual "home" for the model and to make it available for future use and updates as new management questions arise and new data become available. In this way, CRWI seeks to extend the benefits to the public of this grant-funded project beyond the immediate utility of its findings.

Approach and Methods

The principal element of the project was development and calibration of a distributed hydrologic model using the computer model code MIKE SHE. Inputs included a wide variety of climate, topographic, land cover, soils, water use, and hydrogeologic data. Outputs included estimates of the annual and seasonal water balance, streamflow hydrographs, and groundwater levels throughout the watershed. The model was constructed using 0.5-acre square grid cells to represent the landscape and stream channel cross sections spaced at 100-ft intervals to represent major stream channels. The model simulates continuous daily hydrologic conditions over a 10-yr period from water year 2009 to 2019. The model was calibrated to streamflow data at three locations and groundwater elevation data at nine locations supplemented by observations of flow conditions (wet vs. dry) on the main stem of Mark West Creek and mapped locations of seeps and springs.

A wide variety of existing and new data sources were used to construct the model. Topographic inputs were derived primarily from the Sonoma County LiDAR Digital Elevation Model (DEM). Climate inputs were derived from monitoring data collected by various entities as well as distributed climate estimates from the U.S. Geological Survey. Land cover data and vegetation properties were based on detailed mapping of vegetation communities provided by Sonoma County Agricultural Preservation and Open Space District in combination with LiDAR-derived Leaf Area Index data and literature-based rooting depth estimates. Soil properties were based on the U.S. Department of Agriculture's Soil Survey Geographic Database (SSURGO) and adjusted during model calibration.

Hydrogeologic inputs were based primarily on new analyses performed for this study which included interpretation of the distribution and thickness of geologic materials from more than

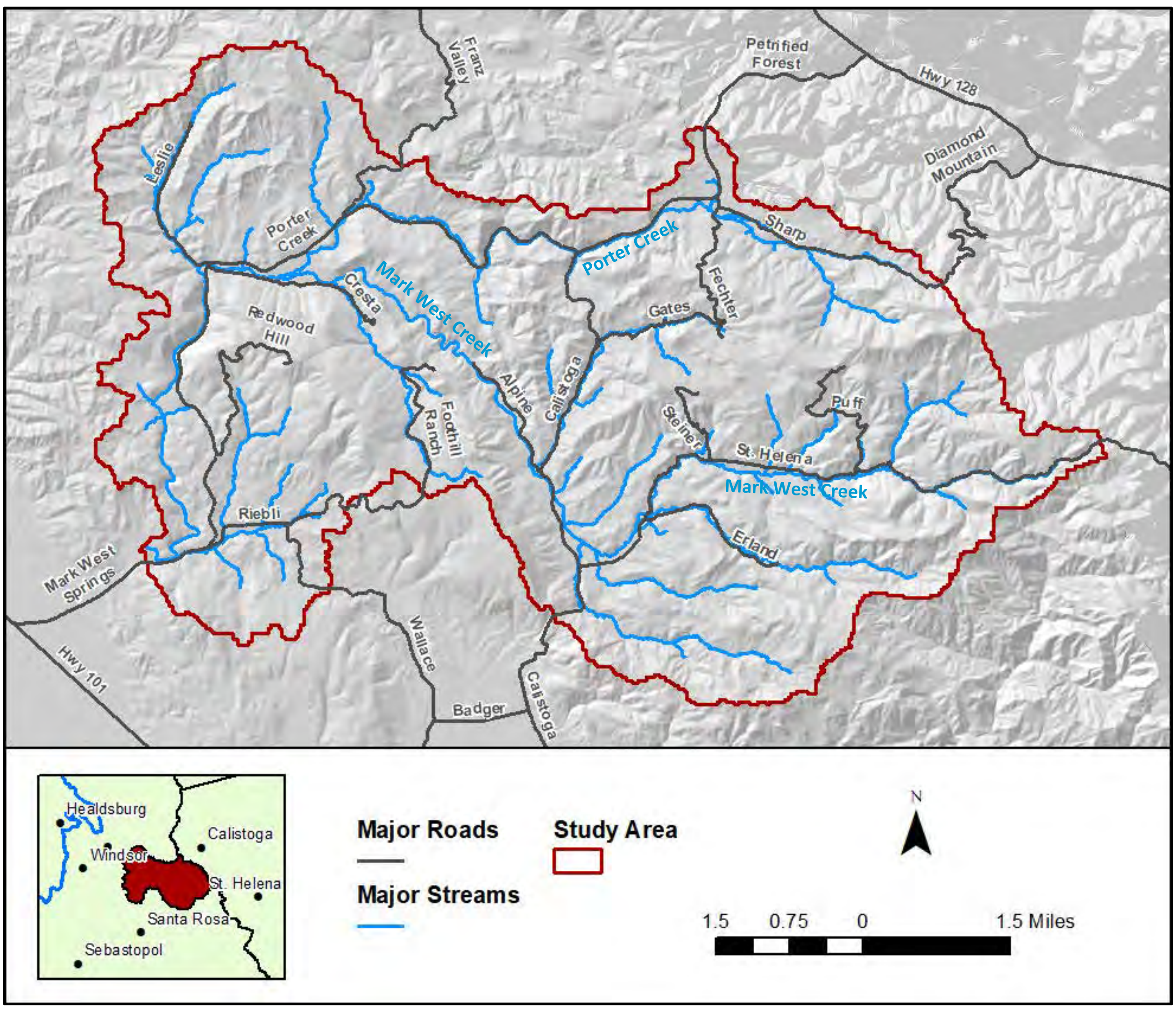


Figure E1: Map of the study area showing major roads and streams.

150 subsurface geologic logs obtained from Well Completion Reports and estimation of aquifer properties from analysis of pump tests completed for Sonoma County Well Yield Certifications at 23 wells. Estimates of the volumes, rates, and sources of water use were based on data from a variety of sources including the State Water Resources Control Board Emergency Order (Order WR 2015-0026-DWR) and Water Rights Database, available Well Completion Reports, spatial mapping of water uses (including vineyards, cannabis farms, wineries, and residences), literature values and other official estimates of water use for various purposes including data from the Town of Windsor and the City of Healdsburg.

Existing Hydrology and Streamflow

Annual precipitation varied widely over the 10-yr study period from 19.5 inches in 2014 to 61.2 inches in 2017, a pattern typical of streams in the California Coast Range (Table E1). Annual streamflow also varied widely from 8.3 to 32.8 inches, largely in response to precipitation patterns. Simulated Actual Evapotranspiration (AET), representing water use by vegetation plus evaporation, accounted for the largest outflow from the watershed over the long-term, ranging from 14.1 to 24.1 inches per year largely in proportion to annual precipitation (Table E1). Simulated annual infiltration recharge to groundwater varied substantially as a function of precipitation from 0.8 inches in the drought year 2014 to 10.1 inches in 2017, an unusually wet year (Table E1).

The simulated groundwater recharge rates indicate large spatial variability, with much of the watershed generating less than 2 in/yr and some portions of the upper watershed generating more than 20 in/yr (Figure E2). Numerous factors affect recharge rates; however, the spatial variations in recharge appear to be primarily controlled by soil properties, topographic position, and the west to east precipitation gradient. Recharge is concentrated in the upper Mark West Creek watershed upstream of and including the Van Buren Creek watershed, as well as in the upper Humbug Creek watershed (Figure E2).

The Climatic Water Deficit (CWD) provides a measure of the seasonal moisture stress and may be indicative of vegetation health and associated fire risk. This metric varied widely across the watershed from 15 to 40 in/yr except locally where lower rates occur due to availability of shallow groundwater (Figure E2). Topographic aspect appears to be a primary control on the spatial variability of CWD with north-facing slopes characterized by lower PET having significantly lower CWD values relative to south-facing slopes.

Groundwater discharge by seeps and springs represents the primary process responsible for generating summer streamflow in the watershed. This discharge is highly concentrated in the upper watershed with the watershed area upstream of Van Buren Creek generating 55% of the total springflow in the watershed despite representing only 17% of the total watershed area. Much of this discharge occurs along steep incised stream banks comprised of bedrock of the Sonoma Volcanics exposed in the upper watershed. Surface water-groundwater interaction through the streambed is relatively limited in most reaches owing to the limited depth and distribution of alluvium overlying bedrock in narrow valley bottoms. The exception to this occurs

Table E1: Annual watershed (top) and groundwater (bottom) water budgets simulated with the hydrologic model, units are inches of water per year.

	Inflows		Outflows			
Water Year	**Precipitation**	**Irrigation**	**AET**	**Streamflow**	**Groundwater Pumping**	**Change in Storage**
2010	42.51	0.07	24.06	17.14	0.15	1.23
2011	43.97	0.07	23.13	17.92	0.15	2.84
2012	28.07	0.07	20.07	10.67	0.15	-2.76
2013	28.87	0.07	17.58	12.83	0.15	-1.62
2014	19.46	0.07	14.06	8.30	0.15	-2.97
2015	26.57	0.07	14.94	12.74	0.15	-1.19
2016	33.30	0.07	17.30	13.83	0.15	2.09
2017	61.18	0.07	21.47	32.75	0.15	6.88
2018	26.59	0.07	18.93	9.07	0.15	-1.49
2019	49.77	0.07	21.63	23.44	0.15	4.62
Average	**36.03**	**0.07**	**19.32**	**15.87**	**0.15**	**0.76**

	Inflows		Outflows					
Water Year	**Infiltration Recharge**	**Streambed Recharge**	**Interflow**	**Baseflow**	**Springflow**	**ET from Groundwater**	**Groundwater Pumping**	**Change in Storage**
2010	6.05	0.71	4.29	0.76	0.58	0.82	0.15	0.16
2011	7.49	0.70	4.00	0.80	0.62	0.89	0.15	1.73
2012	2.22	0.57	1.72	0.63	0.84	1.08	0.15	-1.63
2013	2.39	0.58	2.19	0.60	0.68	0.98	0.15	-1.62
2014	0.84	0.52	1.09	0.50	0.76	1.06	0.15	-2.19
2015	2.10	0.66	1.53	0.59	0.67	1.02	0.15	-1.20
2016	4.44	0.60	2.55	0.67	0.48	0.75	0.15	0.44
2017	10.12	1.03	3.39	0.86	0.97	1.07	0.15	4.72
2018	2.87	0.53	1.91	0.62	0.72	1.06	0.15	-1.05
2019	8.17	1.03	3.48	0.83	0.99	0.99	0.15	2.76
Average	**4.67**	**0.69**	**2.61**	**0.69**	**0.73**	**0.97**	**0.15**	**0.21**

in a short reach of Mark West Creek immediately upstream of the Porter Creek confluence where relatively thick and broad alluvial deposits create losing conditions and local disconnection of surface flow in drier water years. Across the entire study area, the volume of water that recharges from streams to groundwater is approximately balanced by the volume that discharges to streams through the streambed (Table E1).

In wet years the average summer streamflow in Mark West Creek was about 0.7 cubic feet per second (cfs) below Van Buren Creek and 1.5 cfs below Porter Creek, whereas in dry years these flows declined to about 0.3 and 0.7 cfs, respectively (Figure E3 shows 10-yr average conditions). Except for the reach upstream of Porter Creek that experiences local surface flow disconnection during drier years, most reaches retain small but consistent streamflows even under drought conditions. Year to year variations in springtime streamflows were substantially larger than the variations in summer flows with average springtime flows below Van Buren Creek ranging from 2 to 8 cfs and below Porter Creek from 6 to 30 cfs.

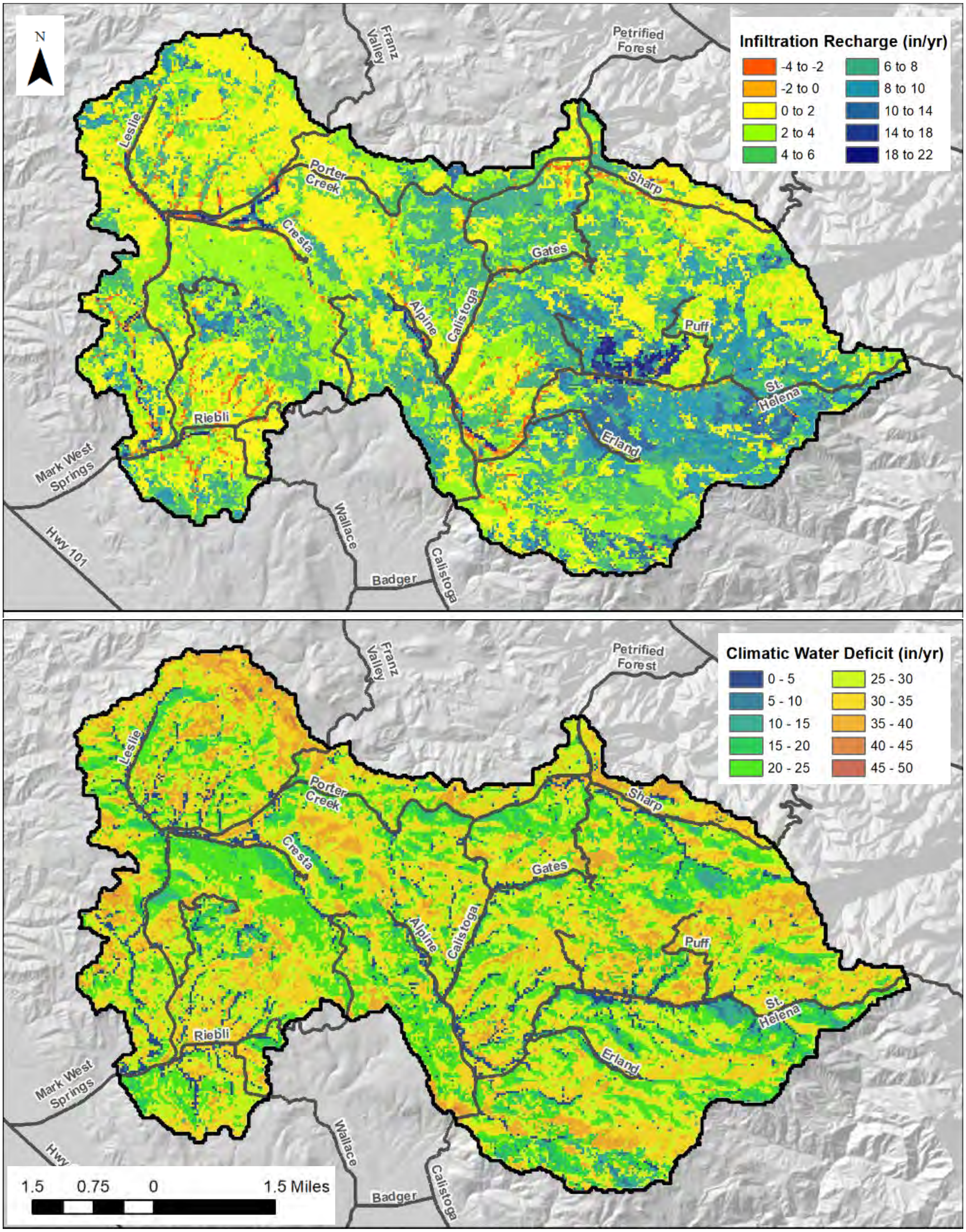
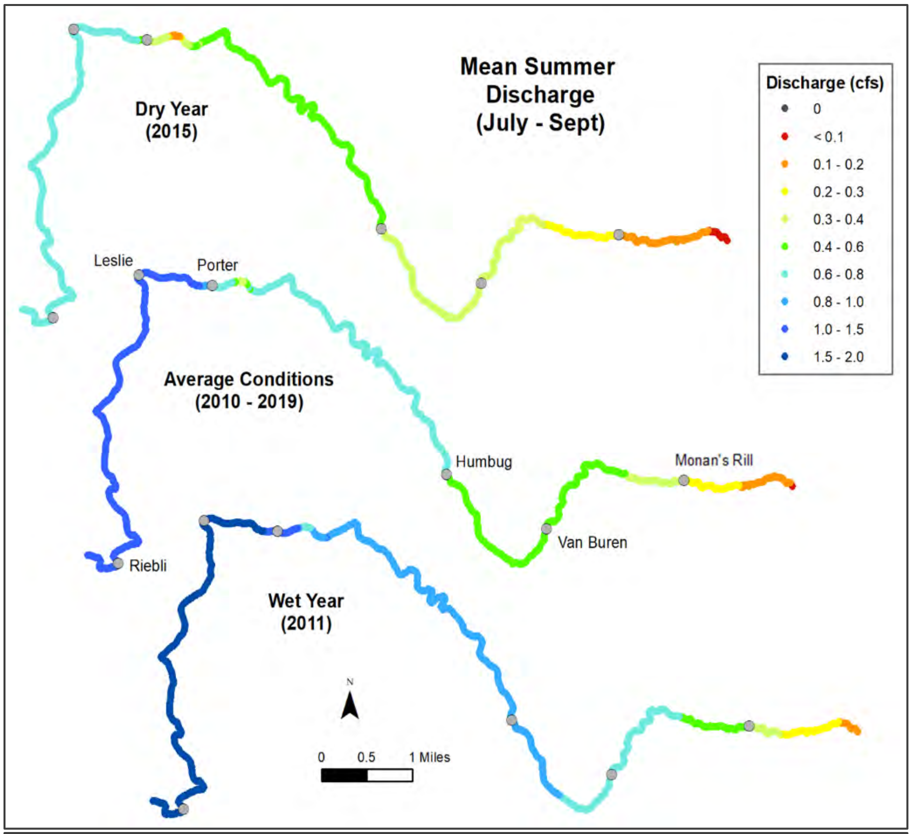


Figure E2: Mean annual infiltration recharge (top) and climatic water deficit (bottom) simulated with the hydrologic model of the upper Mark West Creek watershed.



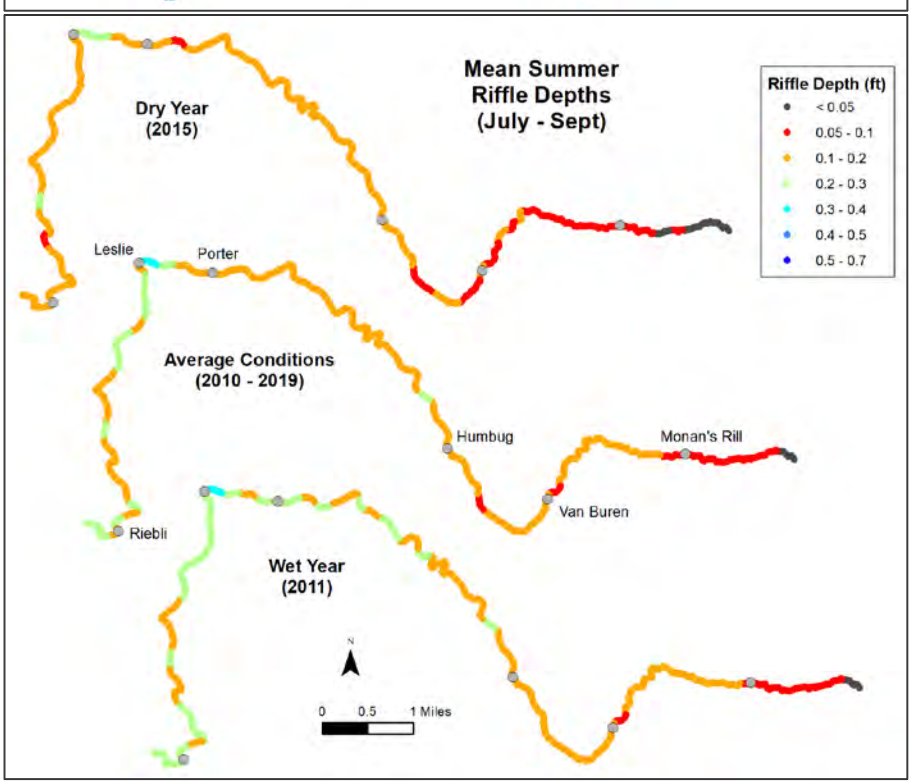


Figure E3: Mean summer streamflows (top) and riffle depths (bottom) in mainstem Mark West Creek simulated by the hydrologic model.

In most water years, average summer riffle depths remain above 0.1-ft in most locations downstream of Monan's Rill, and below Porter Creek depths reach 0.2 - 0.3 ft in many locations (Figure E3). Minimum flow depth in riffles are of interest as an indicator of fish habitat conditions. Average springtime riffle depths vary substantially between years. During the drought conditions of 2014, depths were less than 0.2-ft upstream of Van Buren Creek and between 0.2-0.4 ft below Porter Creek. In the wet water year 2017, riffle depths remained above 0.2-ft as far upstream as one river mile above Monan's Rill and were above 0.5-ft in portions of the lower watershed. The simulated spatial distributions of riffle depths reflect both reaches where riffle depths are limited by reduced streamflows (most notably the reach upstream of Porter Creek which loses flow to the alluvium) as well as where depths are limited by geomorphic controls such as the reaches about 1-mile upstream of Riebli Creek (Figure E3).

Existing Water Use

Total water use in the watershed was estimated to be approximately 430 ac-ft/yr, equivalent to about 0.5% of the mean annual precipitation. The largest uses are residential and vineyard irrigation which account for about 48% and 33% of the total water use respectively (Figure E4). Industrial uses account for the next largest fraction at about 9%. The remaining 10% consists of irrigation for pasture and other crops (6%), irrigation of cannabis (3%), winery use (<1%), and vineyard frost protection (<1%) (Figure E4). About 85% (367.1 ac-ft/yr) of the total use in the watershed is from groundwater with the remaining 15% (63.6 ac-ft/yr) coming from surface water sources. About 81% (51.5 ac-ft/yr) of the total surface water use is direct diversion to pond storage, 10% (6.7 ac-ft/yr) is direct stream diversions, and 9% (5.4 ac-ft/yr) is diversion at springs.

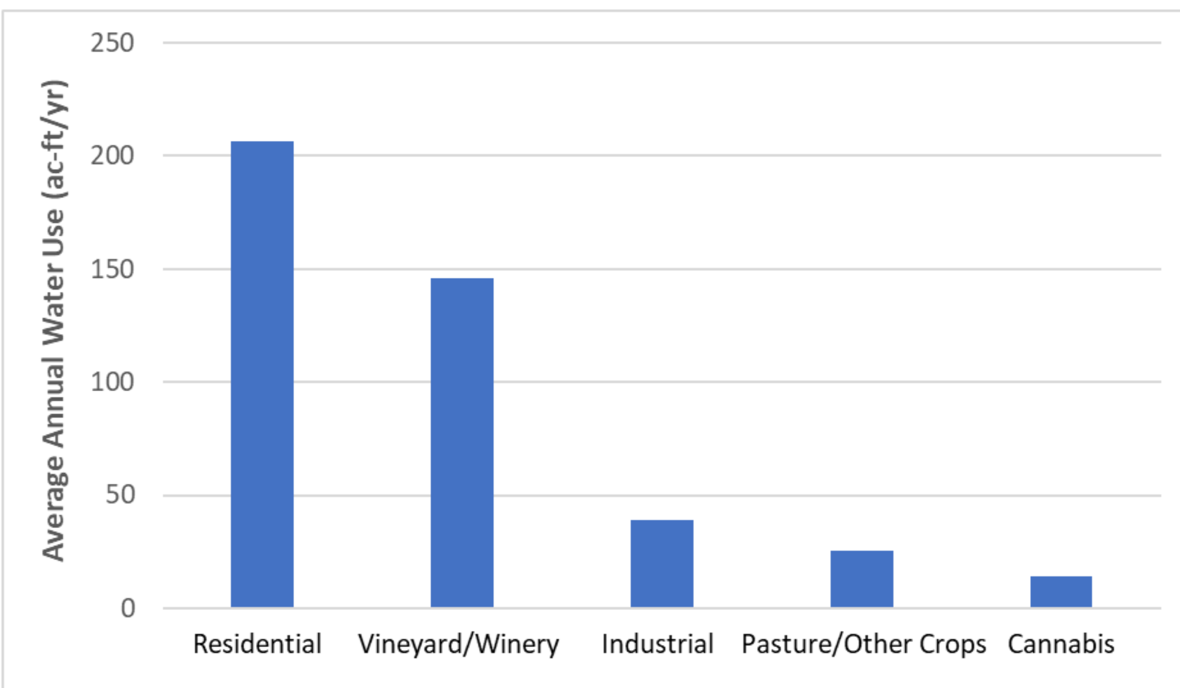


Figure E4: Water use in the Mark West Creek watershed study area by major water use category.

Fish Habitat Characterization

We developed two streamflow classifications based on the simulation results to represent habitat conditions, one for smolt outmigration and one for juvenile summer rearing. Both classifications focus on a 0.2-ft Riffle Crest Thalweg Depth (RCTD) threshold which is intended to represent the minimum flow conditions required to provide suitable habitat for salmonids (optimal habitat conditions require higher RCTDs than these minimum thresholds). We also compiled available continuous temperature data collected by CDFW, Trout Unlimited, CA Sea Grant, and Sonoma Water from 15 locations to develop a simple water temperature classification based on Maximum Weekly Maximum Temperature (MWMT) relative to thresholds of impairment for salmonids. Finally, we compiled available physical habitat data from CDFW habitat surveys and our own field observations to describe other important factors for salmonid habitat including pool characteristics along with spawning and winter refugia conditions.

A simple scoring system was used for each flow classification. Scores range from zero for reaches where RCTDs never reach the target of 0.2-ft during the summer rearing and spring outmigration timeframes in the 10-yr average condition to four for reaches that continuously maintain 0.2-ft RCTDs even during drought conditions. We developed a final habitat suitability classification based primarily on the flow and temperature classifications but also informed by the other available physical habitat data and recent fisheries monitoring information.

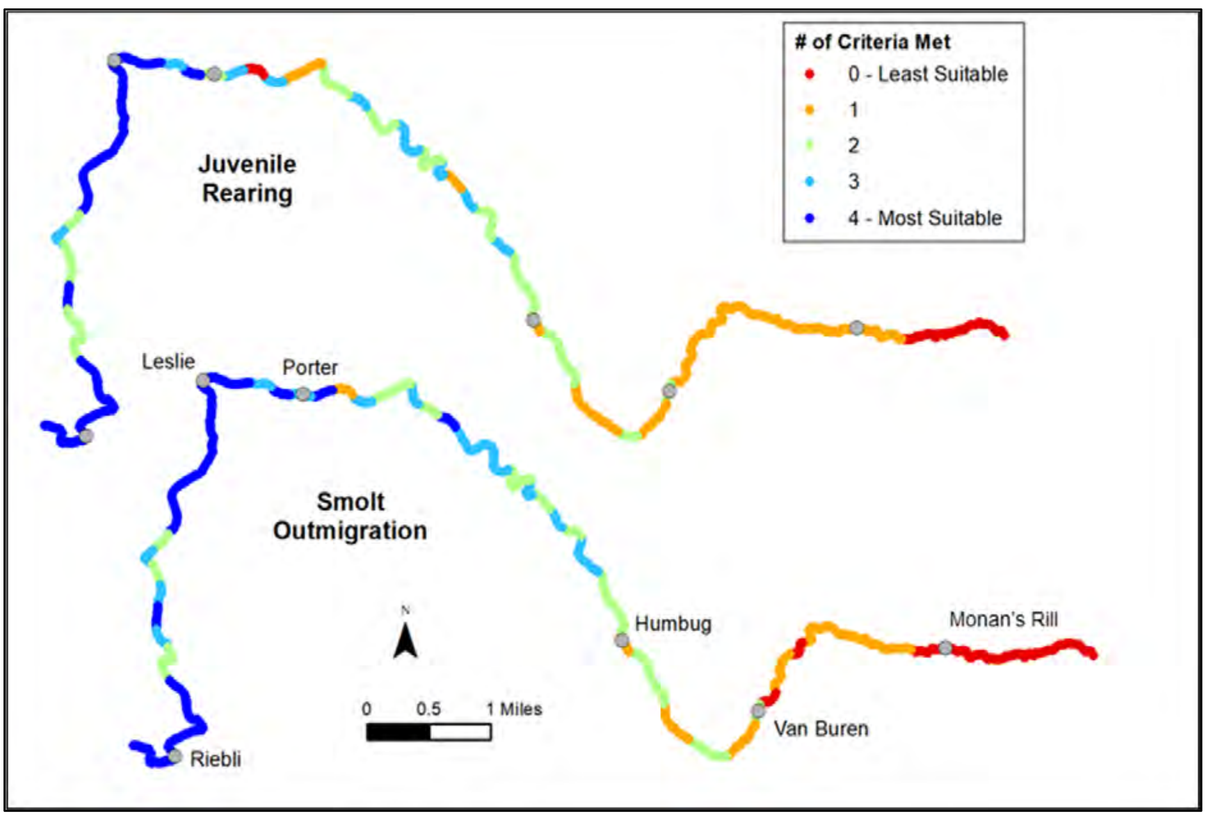


Figure E5: Flow-based habitat suitability classifications for juvenile rearing and smolt outmigration in mainstem Mark West Creek.

The flow-based habitat classification results indicate that most reaches are impaired for smolt outmigration and juvenile rearing (Figure E5). Upstream of Van Buren Creek either zero or one of four flow classification criteria are met, most reaches between Humbug Creek and Porter Creek meet two or three of the criteria, and most reaches below Porter Creek meet three or four criteria (Figure E5). Notable exceptions to this include short reaches upstream of Porter Creek and between Leslie and Riebli Creeks which are more flow-limited than adjacent upstream and downstream reaches. Most reaches are also impaired with respect to stream temperature, with two of three temperature criteria met upstream of Van Buren Creek and only one criterion met between Van Buren Creek and a point about 2-miles upstream of Porter Creek (Figure E5). Documented temperature impairment is most severe in the 2-mile reach upstream of Porter Creek with none of the criteria met (MWMT > 23.1 °C) at available monitoring stations; no data was available farther downstream (Figure E6).

We examined temporal variations in temperatures relative to streamflows observed at the stream gauges in the watershed and found no obvious correlations between streamflow and temperature at the most temperature-impaired locations. This suggests that streamflow is not the primary control on temperature and that even significant streamflow enhancement is unlikely to mitigate elevated temperatures. We also examined the relationship between pool depth and temperature in six pools monitored in 2017 by CDFW upstream and downstream of Humbug Creek. Pools with depths greater than 3.5-ft maintained temperatures below severely impaired levels whereas shallower pools less than 2.5-ft deep did not. Although based on a limited sample size and a single water year, these observations suggest that deep pools likely

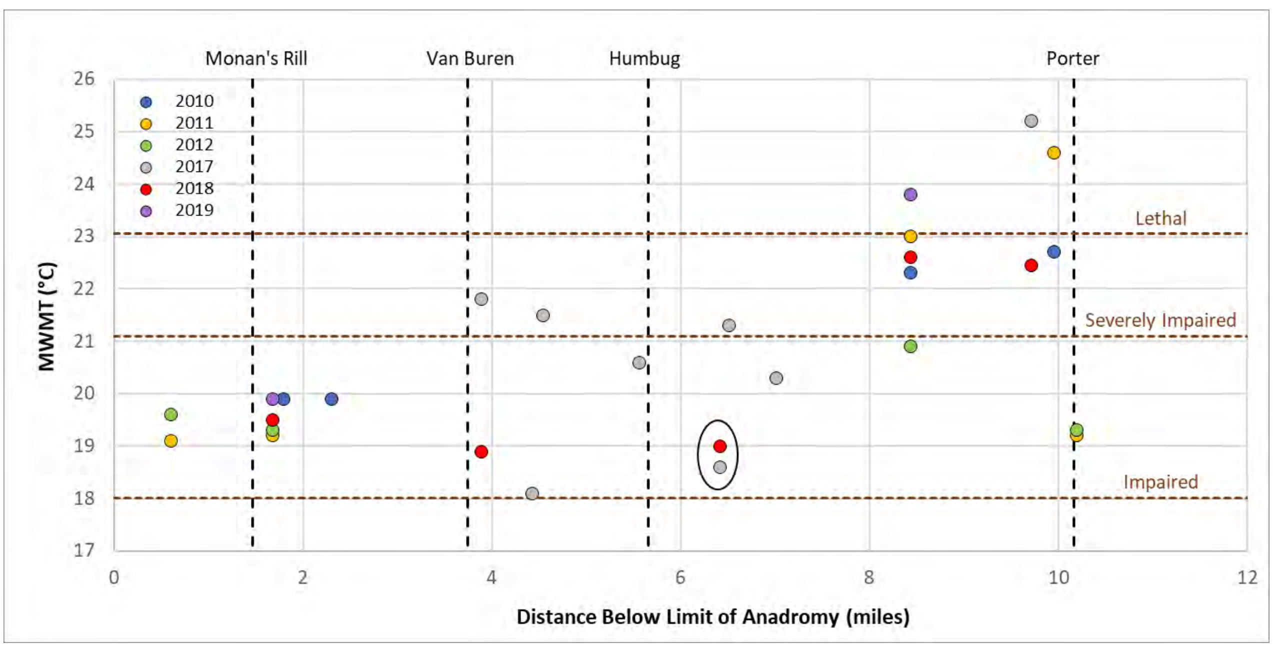


Figure E6: Longitudinal and temporal variations in Mean Weekly Maximum Water Temperature (MWMT) derived from continuous temperature data at 15 stations between 2010 and 2019, black oval indicates location of deep pool cold water refugia; temperature data from CDFW, Sonoma RCD, CA Sea Grant, and Trout Unlimited.

provide critical refugia for salmonids in Mark West Creek when extreme high temperatures occur in shallower pool habitats.

The overall salmonid habitat classification identifies an ~4 mile reach of Mark West Creek between about 0.5 river miles downstream of Van Buren Creek and about 2 river miles upstream of Porter Creek as providing the best overall habitat for salmonids in the watershed (Figure E7). This reach is considered most suitable because it represents the best combination of flow and water temperature conditions and is also consistent with available data and observations about other indicators of habitat quality such as pool and spawning conditions.

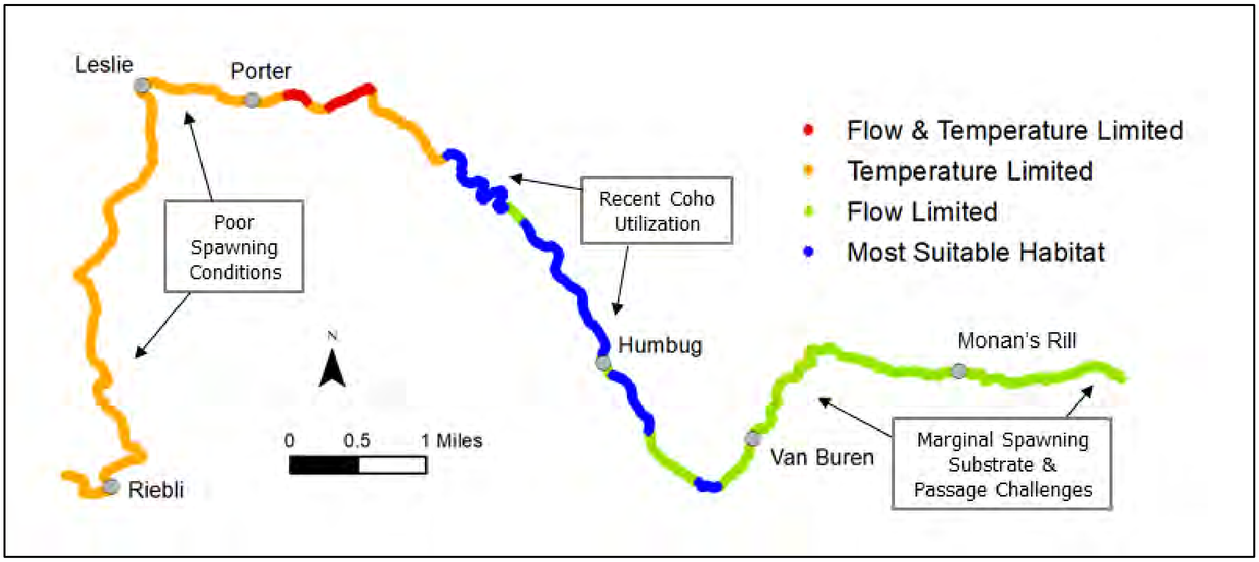


Figure E7: Final overall habitat suitability classification for Mark West Creek identifying the high priority reaches with the most suitable overall habitat conditions in blue.

Scenario Analysis

The model was used to evaluate alternative streamflow enhancement strategies along with predictions of climate change effects on streamflow. Individual enhancement strategies, combinations of these strategies, and alternative future climate conditions were evaluated in different model runs (scenarios) to identify advantages and disadvantages of different strategies under a variety of conditions. The scenario analysis is intended to provide guidance regarding streamflow management to stakeholders in the watershed, natural resource managers, and government regulatory authorities. Scenarios analyzed are summarized in Table E2.

Water Use

Analysis of changes in streamflow revealed that the sustained cumulative effects of surface water diversions and groundwater pumping are modest and that cessation of all water use would result in increases in mean summer streamflow of about 6% (0.04 cfs) in the ~4-mile high priority reach and ~8% (0.09 cfs) at the watershed outlet (Figure E13). The analysis suggests that the groundwater response timescales are long and the reported flow increases represent conditions in the 10-yr period following 40-yrs without water use. Cumulatively, surface water diversion and groundwater pumping each have an approximately equal sustained effect on streamflows, however cumulative groundwater use is more than five times that of surface water use in the watershed. Surface water diversions were also found to result in more substantial short-term (daily) streamflow depletion up to about 14% with the largest impacts occurring in the reach downstream of Humbug Creek (Figure E8).

Streamflow depletion from groundwater pumping was found to occur over long (decadal) timescales. While we did find some sensitivity in the rate of depletion as a function of distance of wells from streams and springs and depths of screened intervals, all wells generated depletion given enough time. The rate of depletion from near-stream wells (within 500-ft) screened in the upper 200-ft was about 1.7 times the rate for wells at greater horizontal distance from streams screened at depths greater than 200-ft. No direct relationship between the seasonality of pumping and the timing of streamflow depletion was apparent, with maximum depletion occurring during winter despite maximum pumping occurring during the summer months. This results from pumping effects on groundwater recharge and discharge processes being most pronounced during the active recharge season and from buffering of summer streamflow depletion by reductions in transpiration of riparian vegetation.

Pond Releases

The summer pond release scenario generated the largest increases in average summer streamflow of the stand-alone scenarios, with increases of about 13-14% (0.08 cfs in the high priority reach and 0.16 cfs at the watershed outlet) (Figure E13). The predominance of gaining streamflow conditions (groundwater discharge to streams) in most reaches of the creek causes only limited flow losses to groundwater (losing streamflow condition) downstream of the releases, which makes this strategy particularly well-suited for this watershed which is characterized by a lack of thick alluvial deposits adjacent to streams. The springtime pond release scenario was designed to increase flows over a short (3-week) period coinciding with the timing of the end of typical peak smolt outmigration in May. Examination of discharge and riffle depth hydrographs during drought conditions of 2014 shows that the spring releases substantially increase flows in the identified high priority reach during this critical period, extending the duration of passable conditions by approximately two weeks.

Forest, Grassland, & Runoff Management

Large-scale implementation of forest, grassland, and runoff management projects resulted in modest but significant changes in the water balance. All three strategies increase groundwater recharge but through different mechanisms. Forest management decreased actual evapotranspiration by about 5% on treated lands resulting in more water available for recharge, grassland management increased the water holding capacity of soils increasing soil water availability for recharge, and runoff management increased infiltration resulting in increased recharge as well as AET (Figure E9). Watershed-wide increases in infiltration recharge ranged from about 2-4% (230-420 ac-ft/yr).

Table E2: Overview of the scenarios evaluated with the hydrologic model.

Scenario Category	Scenario #	Scenario Name	Brief Description
Water Use	1	No Diversions	All surface water diversions turned off
	2	No Groundwater Pumping	All groundwater pumping turned off
	2B	No Pumping Near Streams	Wells within 500-ft of streams and screened in upper 200-ft turned off
	2C	No Pumping Near Springs	Wells within 500-ft of springs turned off
	2D	No Pumping From Tuff	Wells screened in surficial tuffaceous materials turned off
	2E	No Distal Pumping	Wells distal to streams/springs/tuff and not screened in upper 200-ft turned off
	3	No Water Use	All surface diversions and groundwater pumping turned off
Land/Water Management	4	Forest Management	Forest treatment on 7,054 acres of oak and Douglas Fir forests
	5	Grassland Management	Application of organic matter on 2,874 acres of grasslands
	6	Runoff Management	Manage runoff from 310 acres of developed lands to maximize infiltration
	7	Summer Pond Releases	Release water from three ponds with a total release of 0.19 cfs from June 15^{th} to Sept 15^{th}
	7B	Spring Pond Releases	Release water from three ponds with a total release of 0.82 cfs from May 7^{th} to May 28^{th}
	8	Combined Management	Combination of Scenarios 4 through 7
Climate Change	9	CNRM Climate Change	2070-2099 timeframe future climate as predicted by the CNRM model under the rcp8.5 emmisions pathway
	10	CCSM4 Climate Change	2070-2099 timeframe future climate as predicted by the CCSM4 model under the rcp8.5 emmisions pathway
	11	GFDL Climate Change	2070-2099 timeframe future climate as predicted by the GFDL model under the SRES B1 emmisions pathway
	12	MIROC esm Climate Change	2070-2099 timeframe future climate as predicted by the MIROC esm model under the rcp8.5 emmisions pathway
Mitigated	13	GFDL & Pond Releases	Combination of Scenarios 11 & 7 or 7B
	14	GFDL & Combined Management	Combination of Scenarios 11 & 7 or 7B

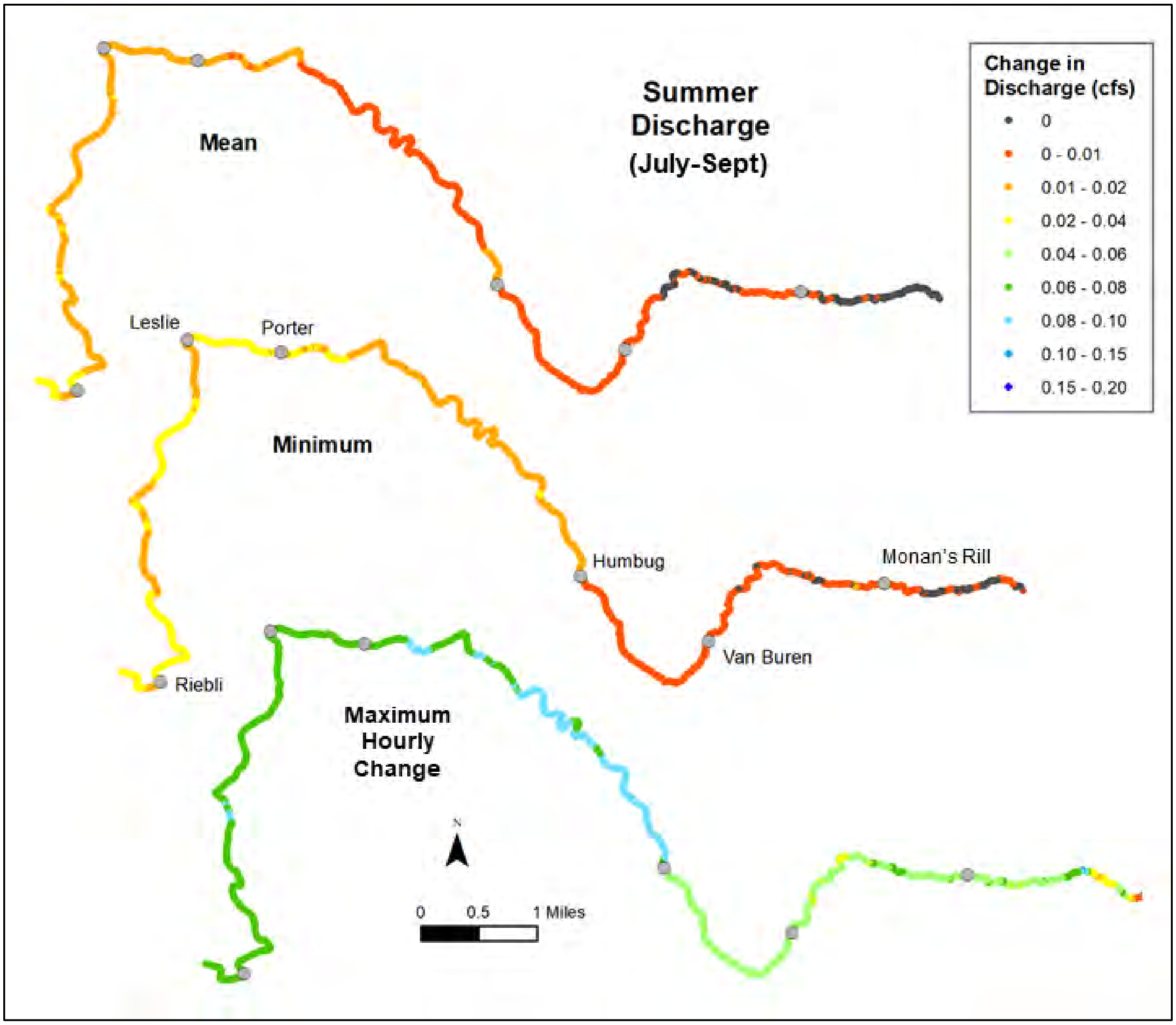


Figure E8: Changes to mean and minimum summer streamflow, and maximum hourly changes from cessation of all surface water diversions (Scenario 1).

Of the three management scenarios, forest management generated the largest increases in average summer streamflow (6%) in the high-priority reach followed by runoff management (3%), and grassland management (2%) (Figure E13). Runoff management generated a larger response at the watershed outlet (10%) reflecting the concentration of developed areas in the lower watershed. Increases in springtime discharges for the runoff and grassland management scenarios were minimal, however the forest management scenario generated increases of 0.5-0.7 in the high priority reach. These changes represent 4-6% of the total flow and primarily reflect small increases in runoff during spring storms.

Combined Management

Combining all the land/water management scenarios (pond releases with forest, grassland and runoff management), mean summer discharges in the high priority reach increased by about 21% (0.13 cfs) and by about 28% (0.31 cfs) at the watershed outlet (Figures E10 & E13). These changes represent about 86% of the sum of the changes of the four individual scenarios indicating a small negative feedback in effectiveness when the effects on the water balance dynamics from the various actions are combined.

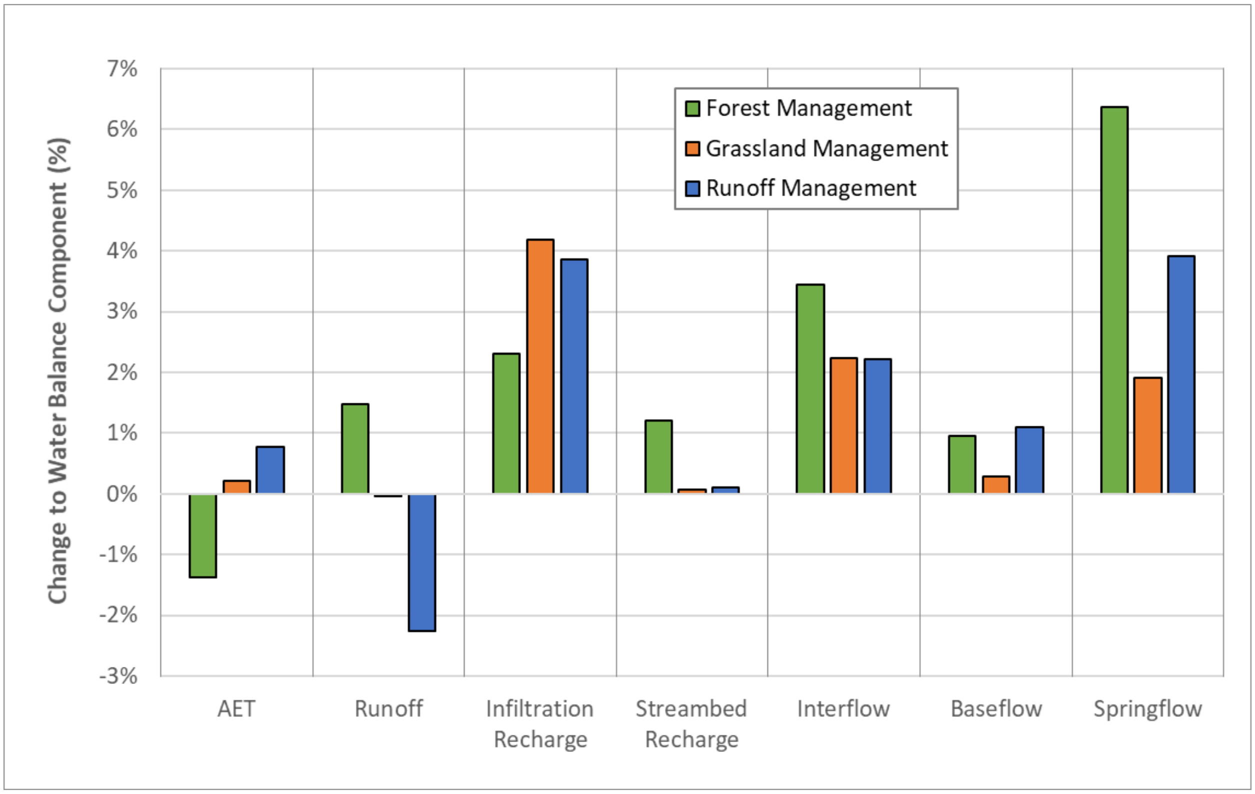


Figure E9: Watershed-wide percent change in select water balance components for the forest, grassland, and runoff management scenarios (Scenarios 4-6).

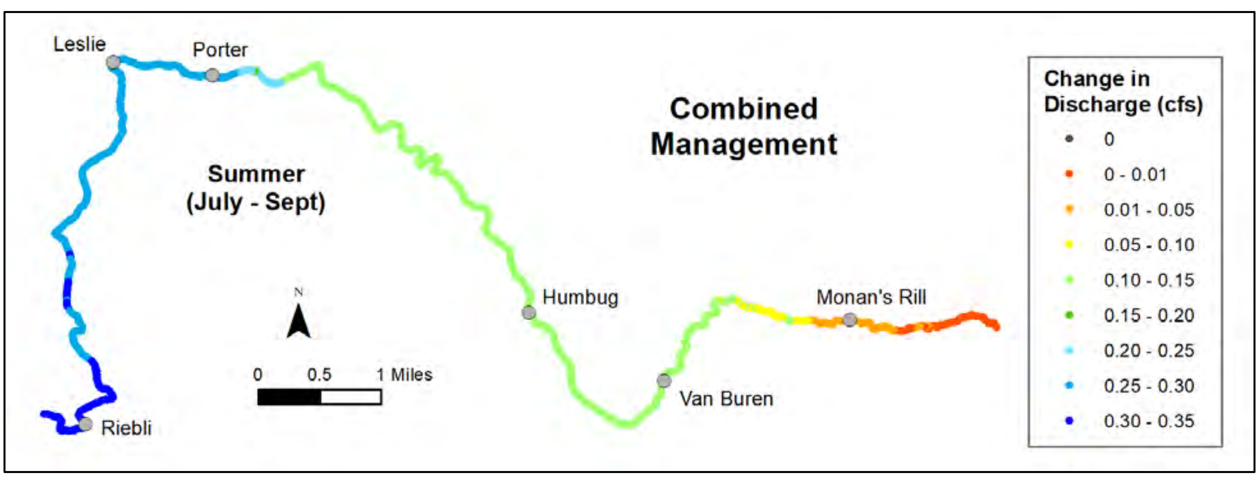


Figure E10: Simulated changes to the 10-yr average mean summer streamflow for the combined management scenario (Scenario 8, note the scale in the legend is different from previous figures for other scenarios).

Climate Change

Four climate change scenarios were selected to represent the range of plausible changes to precipitation and temperatures as predicted by available climate model data, and to include a scenario representative of the mean projections. These scenarios predict a range of maximum temperature increases of between 3.7 and 11.0°F and changes in mean annual precipitation ranging from a decrease of 21% to an increase of 37%.

The 10-yr mean annual water balance results indicate substantial variability in predictions of future hydrologic changes. The CNRM scenario predicts large increases in both infiltration recharge (44%) and streambed recharge (33%), the CCSM4 model predicts minimal changes in recharge, and the GFDL and MIROC esm scenarios predict significant decreases in infiltration recharge (29-40%) and streambed recharge (17-25%) (Figure E11). Increased recharge in the CNRM scenario results in increases in groundwater discharge expressed as interflow (32%), baseflow (11%), and springflow (36%). Similarly, groundwater discharge decreases for the scenarios that predict decreases in recharge. The largest decreases are predicted by the MIROC esm scenario where interflow, baseflow, and springflow are predicted to decrease by 30%, 21%, and 46% respectively (Figure E11). Comparison of the water balance for the driest of the 10 years in each simulation reveals that the trajectories of the changes in the water balance between the four scenarios are more similar during drought conditions than for long term average conditions, with all four scenarios predicting decreases in runoff, infiltration recharge, and streambed recharge under drought conditions (Figure E11).

All four scenarios indicate increases in Climatic Water Deficit (CWD). The mean CWD for the watershed over the 10-yr simulation period is predicted to increase from 26.0 in/yr under existing conditions to between 30.3 and 33.9 in/yr under future climate conditions. Increases in CWD of this magnitude (17-30%) may be expected to lead to significant changes in vegetation communities and increases in fire risk. It is important to note that these simulations represent the hydrologic effects of changes in climate but do not include secondary effects that may be expected under a significantly altered future climate regime such as changes in vegetation cover and irrigation water demands.

The climate change scenarios generated a wide range of predictions of future streamflows with three of the four scenarios indicating decreases in average summer streamflow of between 6% and 47% and one scenario indicating increases of about 15-19% (Figure E13). In contrast to the variable predictions in mean summer discharges, all four models predict large decreases in mean spring discharges that would be expected to hinder outmigration of juvenile salmonids. The CNRM scenario produces the smallest decreases with mean spring discharge in the high-priority reach of Mark West Creek decreasing from 7.8 cfs to 5.1 cfs (Figure E13). The MIROC esm scenario predicts the largest decreases with flows in the high priority reach decreasing from 7.8 cfs to 3.0 cfs.

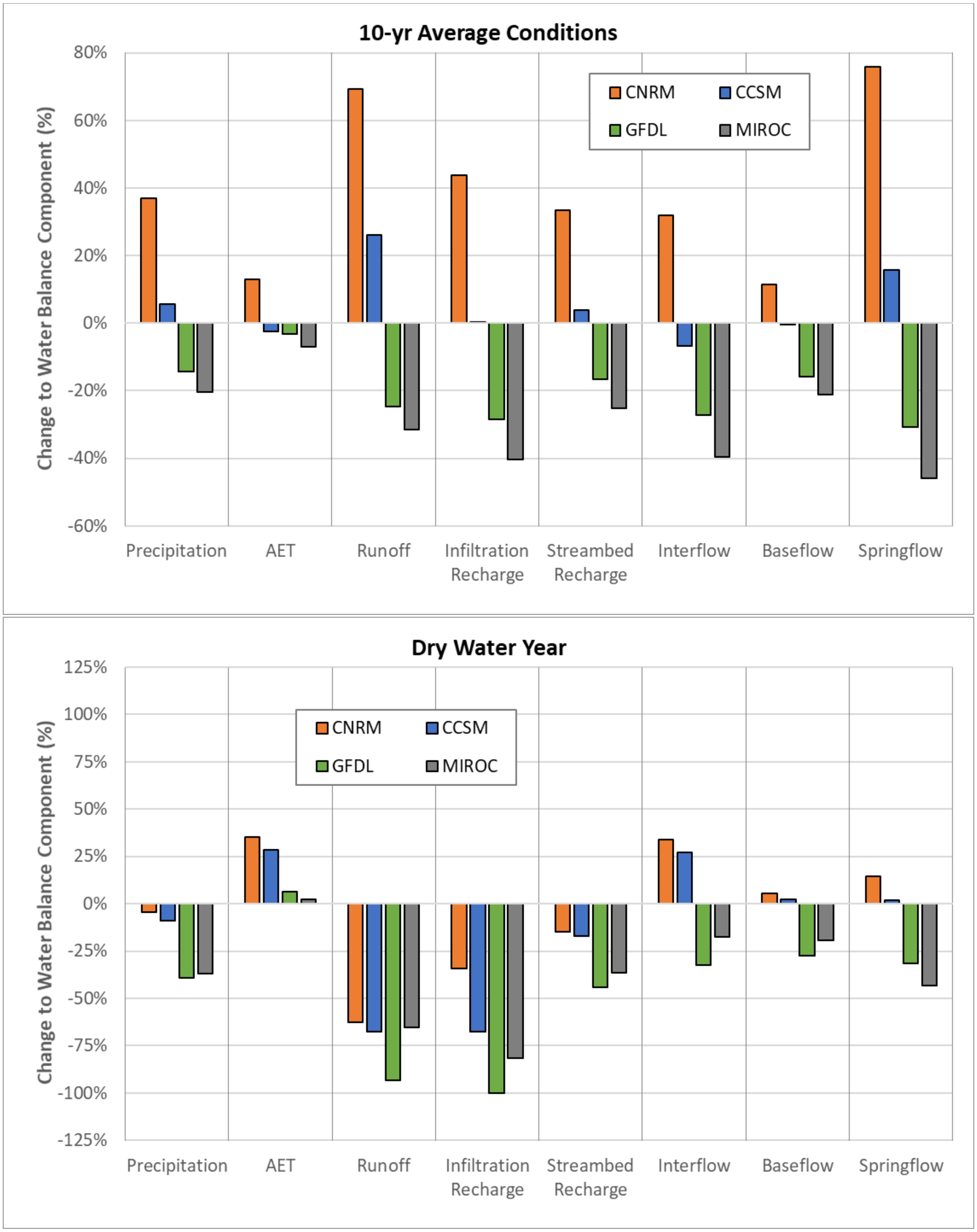


Figure E11: Percent change in various components of the water balance for the four climate change scenarios relative to existing conditions; 10-yr average conditions (top) and the driest water year in each 10-yr simulation period (bottom).

Mitigated Scenarios

The mitigated scenarios combine the pond release and combined management scenarios with the GFDL future climate scenario. These scenarios indicate that pond releases can likely offset a significant portion of the projected decreases in summer streamflow predicted by some of the climate models and if combined with forest, grassland, and runoff management, are likely large enough to completely offset these projected decreases (Figures E12 & E13). If future climate more closely resembles the predictions of the CNRM or CCSM4 models, pond releases and combined management would be expected to result in summer flow enhancement above existing conditions. None of the potential actions generate changes large enough to significantly offset the substantial decreases in springtime discharges predicted by the four climate scenarios. Shorter-duration flow releases over periods of days to weeks strategically timed during the critical smolt outmigration period in spring could increase flow depths above fish passage thresholds and likely provide a key climate change mitigation strategy to address predicted reductions in streamflow during the spring season (Figure E12).

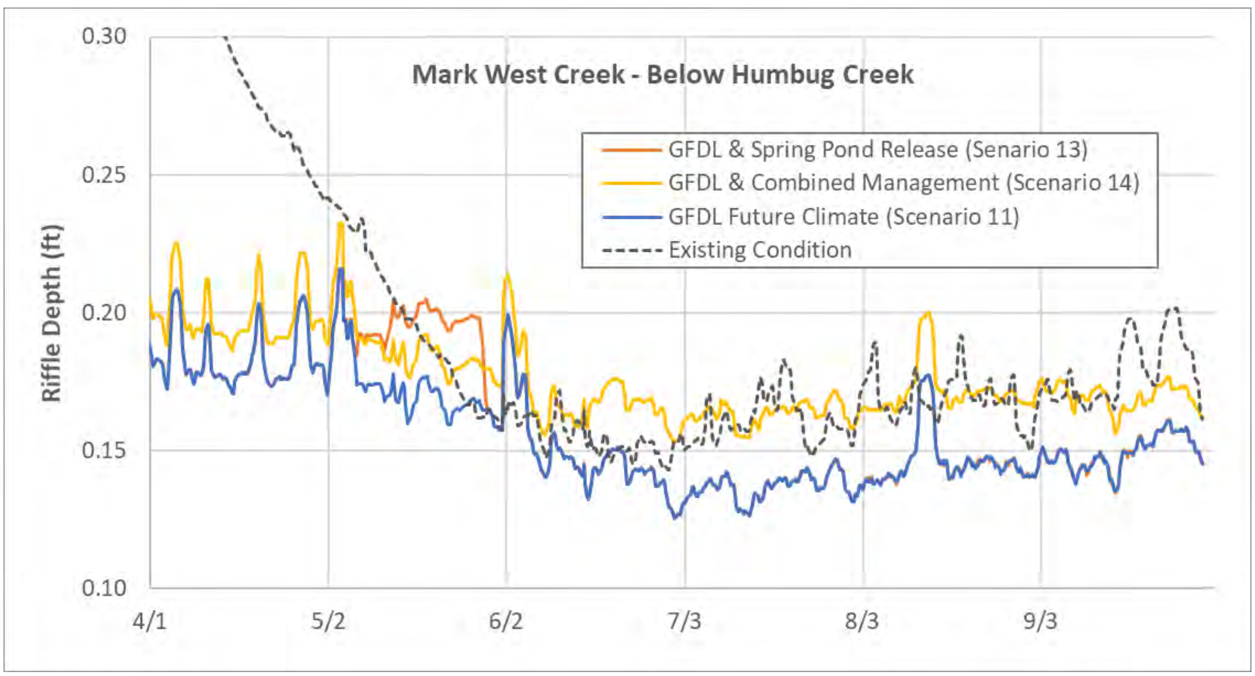


Figure E12: Spring and summer riffle depths for the driest year in the 10-yr simulation in Mark West Creek below Humbug Creek for existing conditions, the GFDL future climate scenario (Scenario 11), the GFDL & spring pond release scenario (Scenario 13), and the GFDL & combined management scenario (Scenario 14).

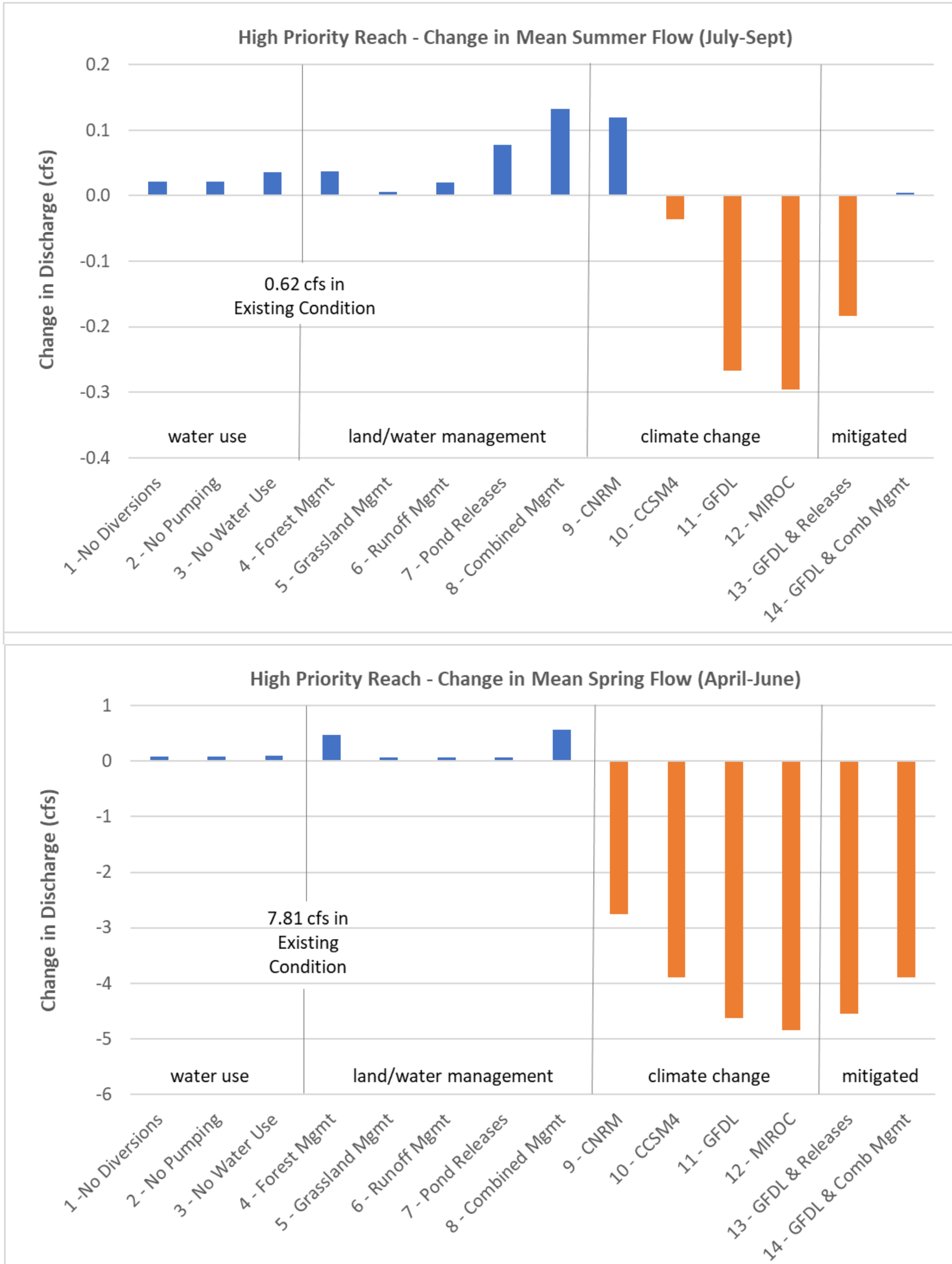


Figure E13: Summary of the simulated changes in mean summer (top) and mean spring (bottom) streamflow for Scenarios 1-14 averaged over the high-priority habitat reach.

Restoration & Management Recommendations

Habitat Enhancement

Based on simulated riffle depth and observed water temperature data informed by CDFW habitat inventory and CA Sea Grant fisheries monitoring data, the four mile reach extending from 0.2 miles upstream of Alpine Creek to 2.0 miles upstream of the Porter Creek confluence has the best overall conditions for supporting salmonids (Figure E14). We recommend that habitat enhancement projects be focused in this high priority reach where there exists the greatest likelihood of supporting overall reach conditions suitable for salmonids.

Based on a limited number of sample sites, water temperatures in the high priority reach appear to remain below severely impaired levels in pools with depths above about 3.5-ft whereas severely impaired temperatures occur in shallower pools (see Figure E6). More temperature monitoring and pool inventory analysis is recommended to identify pools providing critical temperature refugia. A temperature study is also warranted to better understand the controls on water temperatures and identify possible mitigation actions. Our preliminary findings suggest that streamflow is not the primary control on temperature and that encouraging formation of stable deep pools and maximizing shade on the stream surface are likely the most important immediate mitigation actions.

In-stream large wood (logs and trees) loads are low in Mark West Creek and projects to install large wood to encourage formation and enhancement of existing deep pools is recommended. Where needed, riparian planting projects to maximize shading of the summer water surface are recommended. Opportunities for development of off-channel habitat projects to enhance winter rearing habitat are also available in the identified reach, and these types of projects are also recommended to support improved conditions in the reach for other limiting life cycle stages.

Flow Protection/Enhancement

Summer baseflow throughout Mark West Creek is controlled primarily by spring discharge concentrated in the upper watershed. We recommend that the various flow protection and enhancement actions described below be focused in the watershed area contributing to the identified high priority reach where they are more likely to provide the most meaningful flow benefits. The portion of the watershed upstream of Van Buren Creek is of even greater importance for streamflow protection and enhancement given the disproportionate role this area plays in generating summer streamflow supplied to downstream reaches (Figure E14).

To assist in understanding the relative effectiveness of the various flow enhancement strategies we normalized simulated increases in streamflow based on a ‘typical’ parcel/project for six project types in consultation with Sonoma RCD. We also developed a rough cost estimate for each typical project and normalized the results again based on a $25,000 project cost. The six projects and estimated costs include:

- Groundwater Pumping Offset – installation of a 10,000 gallon rainwater catchment tank and associated reduction in groundwater pumping - $38,000

- <u>Surface Diversion Replacement</u> – replacement of a direct stream or spring diversion with a new groundwater well - $33,000
- <u>Runoff Management</u> – construction of an infiltration basin sized to capture the 10-yr 48-hr storm volume from a 3,000 ft^2 rooftop or other impervious area - $22,500
- <u>Grassland Management</u> – compost application on 4.6 acres of grassland (average per parcel acreage in the model scenario) - $7,000
- <u>Forest Management</u> – thinning and/or controlled burning on 5.6 acres of forested lands requiring treatment (average per parcel acreage in the model scenario) - $15,000
- <u>Pond Release</u> – summer flow release of 11.3 ac-ft from an existing on-stream pond (average release volume of the three ponds in the model scenario) - $20,000

Releasing water from existing ponds was found to be by far the most effective individual strategy for enhancing streamflows. On a cost basis, the streamflow benefits of one flow release project were found to be more than 50 times greater than an average surface water diversion replacement project and more than 500 times greater than an average grassland management project (the second and third most effective strategies, Figure E15). Examination of existing ponds revealed that there are only three ponds upstream of the high-priority reach with sufficient storage to provide meaningful releases, and we recommend that flow release projects be developed for these ponds if possible.

There are many existing ponds that could likely be enhanced, and new ponds could be created specifically for flow releases. Given the disproportionate effectiveness of pond releases for streamflow enhancement this approach should be seriously considered. Water temperature and other water quality and invasive species considerations should be an important aspect of planning flow release projects since water temperatures are already impaired and it is critical that flow releases do not further increase temperatures or introduce invasive species. There are various strategies that may be employed to mitigate elevated pond temperatures during planning and design (e.g. bottom releases, surface covering, cooling towers).

Replacing direct stream or spring diversions from surface water with groundwater pumping was the second most effective of the six project types, whereas offsetting groundwater pumping with storage was the least effective (Figure E15). While the modeling did suggest some relationship between the degree of streamflow depletion and the screen depth and distance of wells from streams/springs, these differences were modest and we did not find any direct relationship between the timing of pumping and the timing of streamflow depletion. These findings suggest that replacing direct stream and spring diversions with storage and/or groundwater pumping is a viable approach for enhancing streamflow conditions but that offsetting groundwater pumping with storage or shifting the timing of pumping from summer to winter is unlikely to lead to appreciable improvements in flow conditions. This is not to suggest that specific wells in specific locations are incapable of streamflow depletion; however, our review of well data and modeling results indicate that this would be uncommon in the study area.

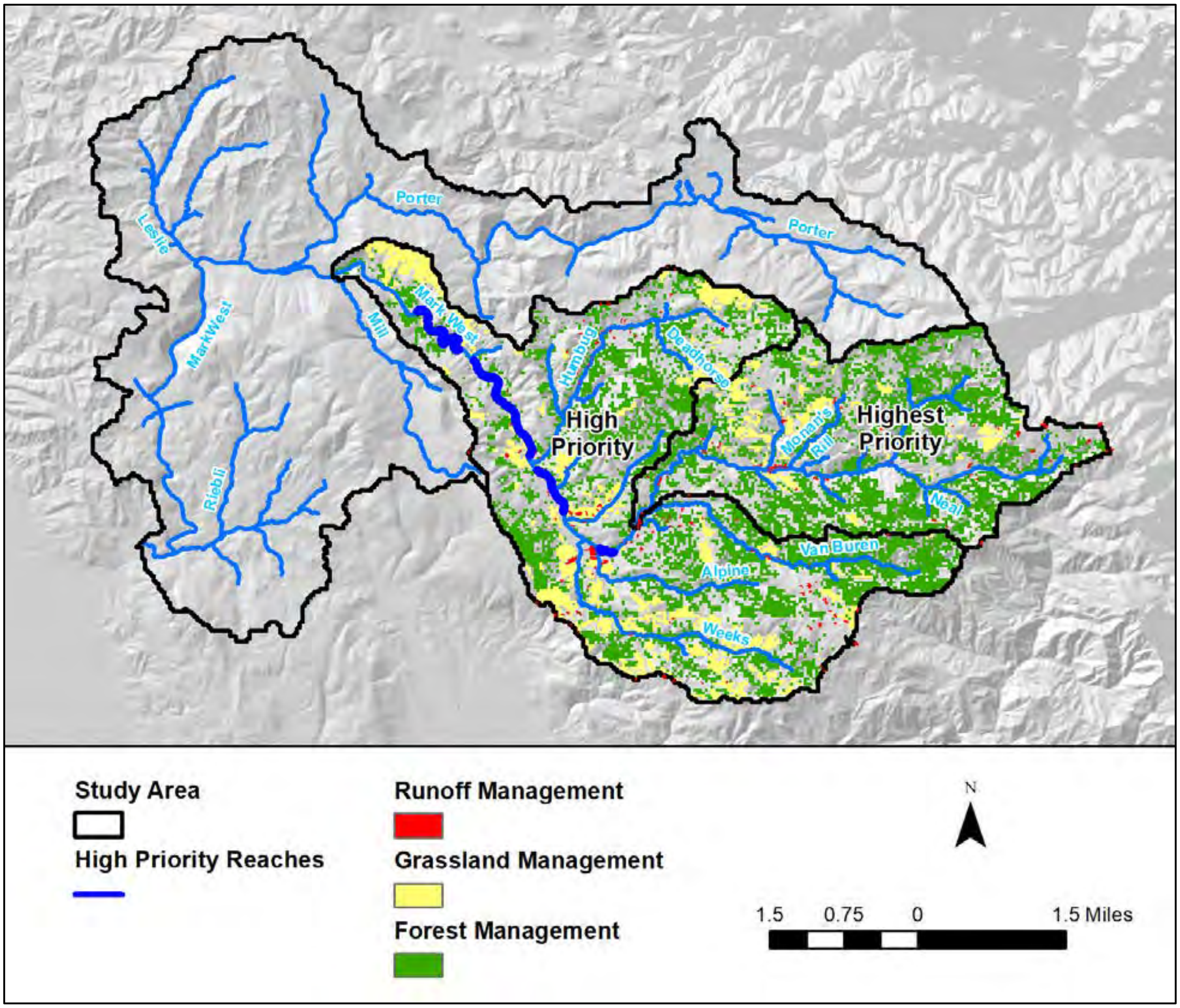


Figure E14: Locations of the identified high priority reaches for habitat enhancement projects and high priority watershed areas for flow enhancement projects.

Requiring new wells to be drilled at a specified minimum distance from a stream or spring or screened at a minimum depth may extend the length of time before streamflow depletion occurs; however, it will not prevent streamflow depletion from occurring. The long response timescale (decades) of streamflow to groundwater pumping revealed by our modeling suggests that a volumetric approach to managing groundwater is more likely to mitigate streamflow depletion compared to approaches focused on well location or time of use. It is important to note that the total pumping stress in the watershed is relatively small (~3% of mean annual infiltration recharge) and that the limited degree of streamflow depletion under existing conditions is not meant to suggest that groundwater pumping could not lead to significant streamflow depletion were the total volume of pumping to increase substantially in the future. That said, our analysis indicates that streamflow is not very sensitive to groundwater pumping at current rates.

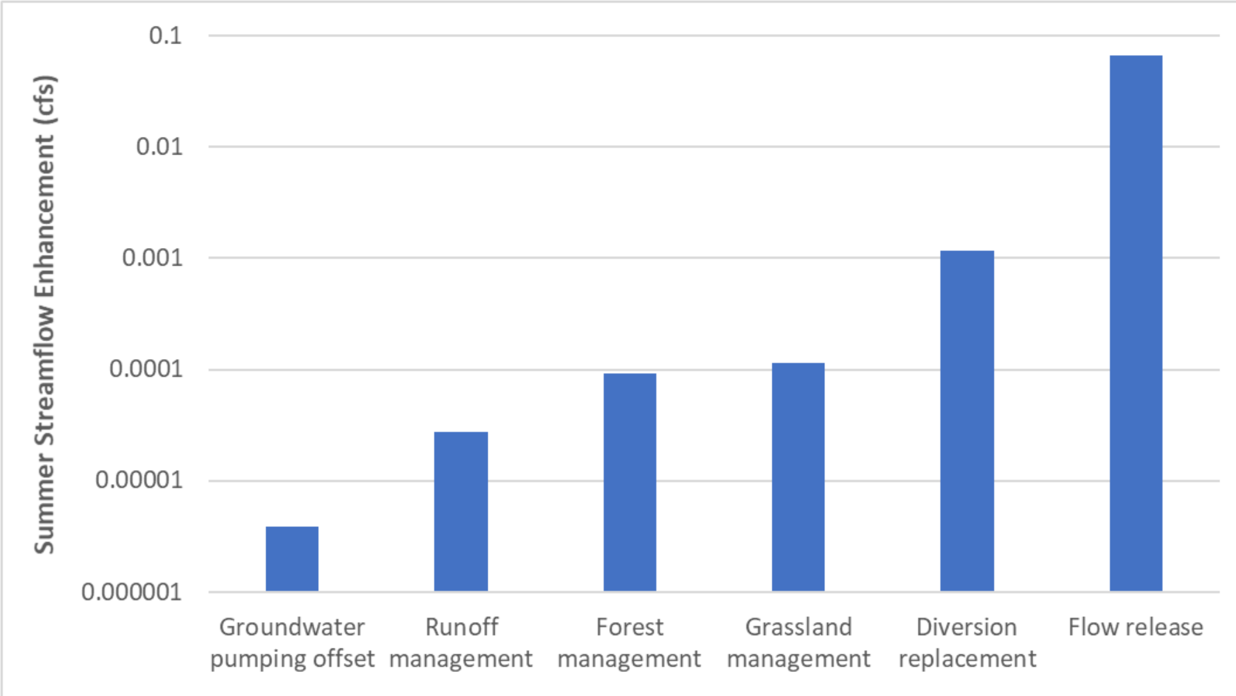


Figure E15: Summary of the simulated increase in mean summer streamflow for the six primary individual flow enhancement actions represented by the model scenarios and normalized to a $25,000 average project cost.

Grassland, forest, and runoff management were also found to result in summer streamflow improvement; however, the benefits per unit cost are one to two orders of magnitude lower than those of pond releases or diversion replacement (Figure E15). Grassland and forest management resulted in about equal benefits on a unit cost basis with about three to four times the effectiveness of runoff management. These three strategies also have important secondary hydrologic benefits in addition to enhancing streamflows in that they reduce seasonal vegetation moisture stress which may be expected to reduce fire risk. These benefits are in addition to the primary non-hydrologic benefits of these types of projects for reducing fuel loads (forest management) and sequestering carbon (grassland management). There are also potential negative consequences of extensive forest management in terms of potential habitat loss for avian and terrestrial species which must be carefully considered. In summary, while runoff, forest, and grassland management may not directly result in substantial streamflow improvement, these efforts have multiple benefits and are likely important strategies for managing fire risk and mitigating climate change impacts as discussed in more detail below.

<u>Climate Change Adaptation</u>

Climate change is expected to result in a dramatic decrease in springtime streamflow, particularly during drought conditions. These declines are expected to have significant effects on salmonid outmigration with some scenarios predicting impassable conditions developing as early as late winter and persisting through spring and summer. The only feasible strategy to mitigate these changes is to implement spring pond releases. While it may not be possible to significantly improve conditions throughout the smolt outmigration period, relatively high release rates could be achieved for a period of several days to weeks to provide a window of passable flow conditions timed to coincide with expected peak smolt outmigration. Although the summer streamflow predictions vary widely, some scenarios show significant declines in summer streamflow. We recommend that flow release projects be developed and adaptively managed to provide a combination of larger pulses of streamflow during outmigration and lower-magnitude releases to sustain streamflow during summer baseflow depending on conditions in a given year.

The runoff, forest, and grassland management strategies influence the quantity of flow from springs which in general is relatively cold, therefore these approaches may be expected to assist in mitigating elevated water temperatures whereas the more effective strategies (pond releases and diversion replacement) would not be expected to provide significant temperature benefits. These strategies also help reduce vegetation moisture stress by increasing the quantity of water available to plants in the case of runoff and grassland management and decreasing water demand from the landscape for the case of forest management. Reduced moisture stress may be considered an important benefit in terms of reducing current wildfire risk and the increase in wildfire risk expected resulting from climate change. In summary, implementation of runoff, forest, and grassland management projects are expected to help build resiliency to climate change by providing multiple benefits beyond potential streamflow improvement and spring and summer pond releases provide a means of adaptively managing flow conditions for salmonids in the face of a changing climate.

Conceptual Designs

The final phase of the project involved development of conceptual designs for two site specific streamflow enhancement projects. The projects focus on the approach of runoff management and were selected to take advantage of local site conditions and project opportunities on properties managed by our project partners the Pepperwood Foundation and Sonoma County Regional Parks. The projects illustrate two possible approaches to managing runoff for enhanced groundwater recharge and we anticipate similar approaches as well as other alternative methods could be applied on parcels throughout the watershed.

Goodman Meadow

Site 1 is located within the Pepperwood Preserve at the Goodman Meadow near the headwaters of Leslie Creek in the northwest corner of the Mark West Creek watershed. The Goodman Meadow site consists of a relatively flat, approximately 12-acre natural basin perched on a topographic bench. The design converts portions of the meadow into an infiltration basin by constructing a berm and outlet structure along the downstream edge of the meadow (see Appendix A). The design creates approximately 5.3 ac-ft of storage within 1.4-acres comprising the lower portion of the meadow. Based on hydrologic modeling of the conceptual design, the basin would be capable of generating about 1.9 ac-ft/yr of additional infiltration recharge. This enhanced recharge would increase the mean springtime flow in upper Leslie Creek by about 0.01 cfs and extend the duration of connected surface flow by about 12 to 21 days.

Mark West Regional Park

Site 2 is located on a terrace on the east bank of Porter Creek about 1,800-ft upstream of its confluence with Mark West Creek. The site is slated to be developed as the main entrance and parking area for Mark West Regional Park managed by Sonoma County Regional Parks. Park facilities have not yet been designed in detail but are expected to be contained within approximately 3.1 acres currently occupied by a barn structure and an adjacent parking area and gravel road (see Appendix B). The stormwater management design described here is intended to become a part of the overall design for the park facilities and consists of collecting runoff from the developed portions of the park entrance in a network of diversion ditches and directing these flows into a series of two linear, gravel filled infiltration basins designed to maximize groundwater recharge. The total storage capacity of the basins is 0.65 ac-ft.

The scale of the site design features is too fine to be accurately represented in the regional hydrologic model; however, based on regional runoff management scenario results, we estimate that the project will generate between 0.3 and 1.2 ac-ft/yr of additional infiltration recharge. It is unlikely that the project by itself will generate significant increases in streamflow in Porter Creek, however the regional modeling suggests that large-scale adoption of stormwater best management practices has the potential to increase the mean springtime streamflow in lower Porter Creek by about 0.05 cfs and extend the duration of surface flow connection by up to 13 days.

Chapter 1 – Introduction

The project described in this report was completed by O'Connor Environmental, Inc. (OEI) under the direction of the Coast Range Watershed Institute (CRWI) in cooperation with the Sonoma Resource Conservation District (SRCD), Friends of Mark West Creek, Sonoma County Regional Parks, and the Pepperwood Foundation. The project was funded by a Proposition 1 Streamflow Enhancement Program grant (Grant Agreement No. WC-1996AP) from the California Wildlife Conservation Board (WCB).

The Mark West Creek watershed has been identified by California Department of Fish & Wildlife (CDFW) and National Oceanic & Atmospheric Administration National Marine Fisheries Service (NMFS) as providing some of the best remaining habitat for coho salmon (*Oncorhynchus kisutch*) in the Russian River watershed. Several factors have been identified as limiting for coho survival in the watershed including lack of quality pool habitat, lack of winter refugia, and insufficient summer baseflows (CDFG, 2004; NMFS, 2012). Numerous restoration projects have been implemented in the watershed in recent years aimed primarily at improving pool and off-channel habitat conditions. Additional efforts have begun to address the problem of insufficient stream flow primarily through water storage and flow release projects. Successful efforts to improve streamflow conditions will require greater understanding regarding the distribution of flow conditions and the various natural and man-made controls on these flows.

The combination of frequent drought conditions, ongoing and future climate change, and increasing human demand for water make development of strategies for sustaining or improving summer streamflow conditions of paramount importance for coho recovery in the Mark West Creek watershed. The goal of this project was to conduct a comprehensive analysis of the spatial and temporal distribution of streamflow conditions throughout the watershed relative to coho habitat requirements to assist in prioritizing restoration efforts and developing strategies for protecting/enhancing summer baseflows.

Specifically, this project involved the development, calibration, and application of a distributed hydrologic model (MIKE SHE) with inputs comprised of climate, topographic, land cover, soils, water use, and hydrogeologic data for the watershed. Model outputs include estimates of the annual and seasonal water balance, simulated stream flow hydrographs, and predicted groundwater elevations and flow gradients among many other hydrologic parameters. The modeling results provided the basis for performing an analysis of streamflow, characterizing the distribution and quality of available habitat for juvenile coho, and making recommendations about restoration priorities for various sub-reaches within the study area.

Additionally, the model has been applied to evaluate potential improvements to streamflow and aquatic habitat conditions resulting from various streamflow restoration strategies including forest management, stormwater management and recharge enhancement, adjustments to surface diversions and groundwater pumping regimes, and flow releases from existing ponds. Conceptual designs were developed for two specific projects which were identified and evaluated as part of the project. The model was also used to investigate the effects of ongoing climate change on streamflow and habitat conditions. In addition to the findings and recommendations discussed in this report, the model also provides a working Decision Support System for ongoing restoration efforts and land and water management decision making and should be considered a “living” model that can be updated as new data and information become available and utilized to help answer new management questions as they arise.

Chapter 2 – Study Area Description

Overview

The Mark West Creek (MWC) watershed is part of the Coast Range Geomorphic Province draining approximately 57 mi^2 of the lower Russian River watershed discharging to the Laguna de Santa Rosa about five miles upstream of its confluence with the Russian River. MWC watershed is commonly divided into an upper watershed in the Mayacamas Mountains and a lower watershed located within the Santa Rosa Plain. Neighboring watersheds include Franz and Maacama Creeks to the north, Santa Rosa Creek to the south, and the Napa River to the east.

The study area is defined as the MWC watershed above Quietwater Road which encompasses all of the 40 mi^2 upper MWC watershed (Figure 1). The upper MWC watershed is characterized by relatively steep topography, confined channels, and bedrock aquifers. Elevations range from 180 feet at Quietwater Road to over 2,300 feet near the headwaters. The study area includes 18 river miles of MWC, several major tributaries such as Porter, Leslie, Humbug, Mill, Weeks, Alpine, and Van Buren Creeks as well as numerous smaller tributary streams. Quietwater Road was selected as the downstream boundary of the study area because it coincides with the extent of the reach identified as critical salmonid summer rearing habitat in the State Water Resources Control Board Emergency Order (WR 2015-0026-DWR). This boundary also approximately coincides with the boundary of the Santa Rosa Plain aquifer as defined by the State Groundwater Management Act (SGMA). Below Quietwater Road, MWC enters the alluvial system of the Santa Rosa Plain which has significantly different characteristics and water management issues.

Upper MWC was severely affected by the October 2017 Tubbs Fire which burned through approximately 48% of the study watershed (19.4 mi^2). Following the fire, forest management and fuel reduction have become a greater concern to many residents in the watershed. The watershed has a substantial number of existing and proposed cannabis cultivation operations which has also generated significant concern among residents, and county, state, and federal regulatory authorities regarding potential adverse impacts of cannabis cultivation on streamflow and salmonid habitat. In addition to being identified in state and federal recovery plans as a high priority watershed for restoration of endangered coho, MWC watershed was identified in the 2014 California Water Action Plan as one of five priority streams, and is the site of several ongoing studies including a CDFW Instream Flow Study and a hydrologic modeling effort by the U.S. Geological Survey (USGS) and Sonoma Water coupled to implementation of the SGMA in the Santa Rosa Plain Groundwater Basin.

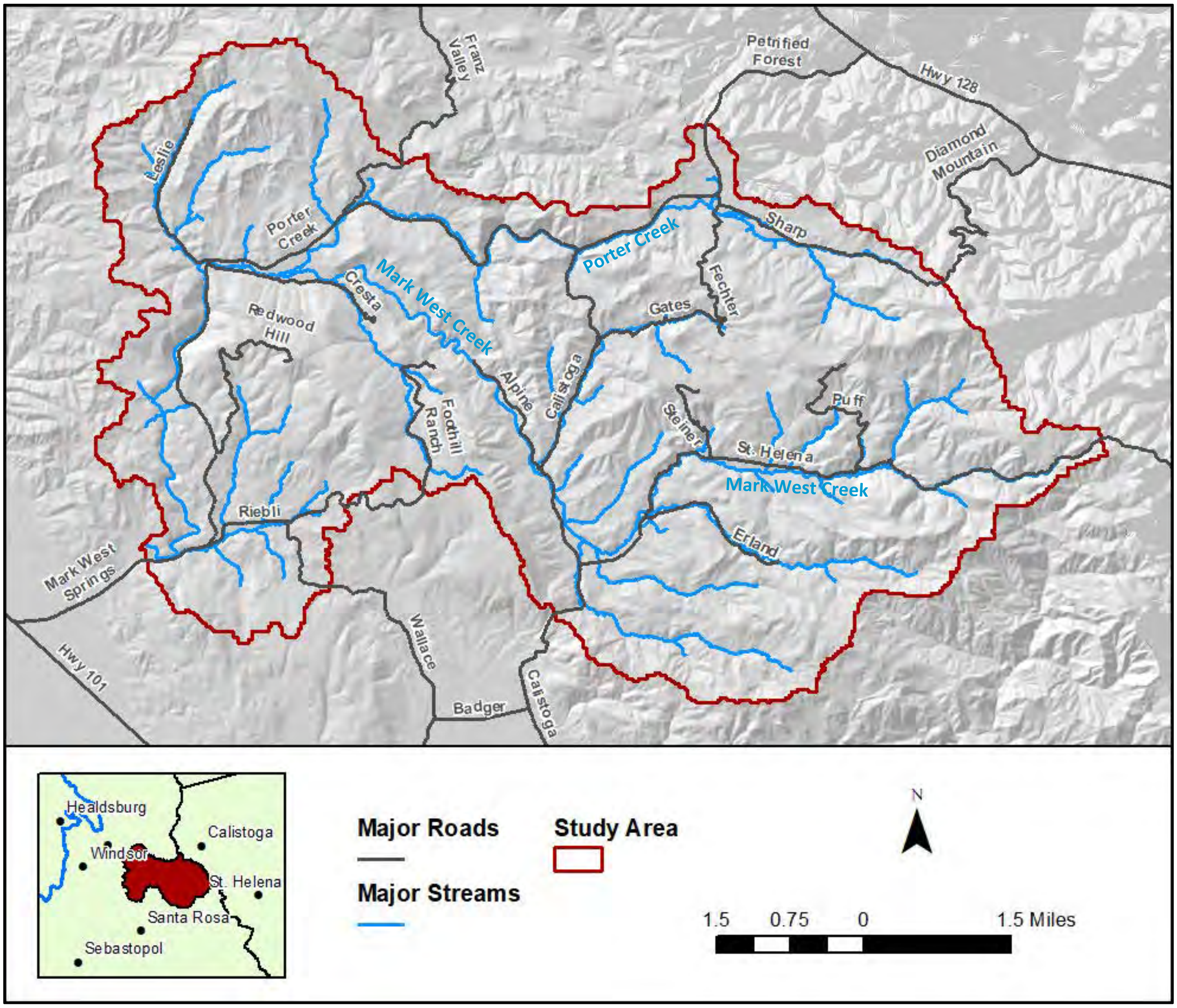


Figure 1: Map of the study area showing major roads and streams.

Climate

The upper MWC watershed has a Mediterranean climate characterized by cool wet winters and warm dry summers. Precipitation varies substantially across the study area from an average of approximately 38 inches per year near the Santa Rosa Plain to approximately 51 inches per year near the crest of the Mayacamas Mountains (Flint & Flint, 2014). For much of the year there is a strong east/west temperature gradient with warmer conditions in the higher elevations to the east relative to lower elevations to the west. This gradient is most pronounced during the daytime where mean maximum monthly temperatures are up to 6.9 °F (3.8 °C) higher at the St. Helena 4WSW climate station in the Mayacamas compared to the Santa Rosa climate station in the Santa Rosa Plain. During the winter (November – February) this gradient flattens or reverses with temperatures in the Mayacamas being the same or slightly (~1 °F) cooler than in the Santa Rosa Plain.

Land Use

Early settlement of the watershed began in earnest during the 1850s and 1860s due to reports of gold in the Russian River area and passage of the Homestead Act. During this time, land use activity in the upper portions of the watershed was focused on mining for silver and mercury, and livestock grazing. Agricultural activities were primarily focused in the lower portions of the watershed and included orchards, vineyards, and hop fields. Logging operations and associated road building also began around this time to clear fields for crops and support the demand for timber from the growing population in the Bay Area. Since World War II, agricultural development has increasingly been replaced by residential development (SRCD, 2015).

Existing land cover is primarily forest (72%), with the remainder divided between grassland (16%), shrubland (7%), developed and sparsely vegetated areas (3%), and agriculture (2%). Most of the forest areas are comprised of various species of oak (48%) and Douglas Fir (36%) with significant stands of Bay Laurel (5%), Coast Redwood (4%), and Madrone (2%) comprising most of the remainder. Ongoing forest succession has been occurring in the watershed in recent decades with expansion of Douglas Fir into Oak Woodlands. Vegetation recovery and potential changes to vegetation patterns following the October 2017 Tubbs Fire which burned about 48% of the study watershed area (20% with moderate or high burn severity) have not been well-quantified.

Land ownership in the watershed is primarily privately-owned rural residential properties with a few agricultural parcels. The Sonoma County Agricultural Preservation and Open Space District and Sonoma County Regional Parks own multiple properties including the Saddle Mountain Preserve, and the Cresta and McCullough Ranch which is slated to become the Mark West Regional Park. The Pepperwood Preserve in the northern portion of the watershed is the site of many ongoing scientific investigations and educational programs. The watershed also includes the Safari West wildlife preserve and portions of the Mayacamas Golf Club.

Geology

The geology of the Upper Mark West Creek watershed is complex and includes several distinct rock types which are offset by a series of faults and fracture zones. The northwest by southeast-trending Maacama Fault Zone bisects the study area and separates distinct geologies to the east and west. West of the Maacama Fault Zone, the study area is dominated by the early-Pleistocene and Pliocene-aged Glen Ellen Formation and bedrock units of the Pliocene and late-Miocene-aged Sonoma Volcanics (basalt and volcanic tuff). East of the fault zone, the study area is dominated by volcanic tuff and andesite of the Sonoma Volcanics and by the Cretaceous and Jurassic-aged Franciscan Complex. Other significant faults include the Larkfield, Rincon Creek, and Mark West Fault Zones to the west of the Maacama Fault Zone which form contacts between the Sonoma Volcanics and the Glen Ellen Formation. The Gates Canyon and Petrified Forest Thrust to the east of the Maacama Fault Zone place rocks of the Sonoma Volcanics in contact with older rocks of the Franciscan Formation.

Other geologic formations, including the Pliocene-aged Fluvial and Lacustrine Deposits of Humbug Creek and the Cretaceous and Jurassic-aged Great Valley Sequence occupy smaller portions of the study area. Quaternary-aged landslide and fluvial deposits are also present but are typically shallow and occupy a relatively small portion of the study area. Interpretation of subsurface geologic conditions from Well Completion Reports reveals that the landslide and fluvial deposits are generally less than 25-ft thick and that most wells are completed in underlying bedrock units. The thickest and most widespread alluvium is found along Mark West Creek near its confluence with Porter Creek where it reaches thicknesses of up to 65-ft. Examination of Well Completion Reports also revealed that the Glen Ellen Formation is generally unsaturated and relatively thin (50-100 ft). Most wells drilled in the Glen Ellen Formation extend into the underlying Sonoma Volcanics where groundwater is more frequently found.

Aquatic Habitat

Coho salmon (*Oncorhynchus kisutch*) and steelhead trout (*Oncorhynchus mykiss*) are present in upper MWC and its tributaries. CDFW habitat surveys were conducted in Porter Creek in 1974 and 1996, in Humbug Creek in 1996, and in Horse Hill, Mill, Weeks, and Van Buren creeks in 1997. These surveys documented steelhead presence in Porter, Mill, Humbug, and Van Buren creeks but not in Horse Hill or Weeks Creek. Coho were not documented in any of these tributary surveys. Notable limiting factors in the tributaries included insufficient summer flows, inadequate pool habitat and riparian canopy, and a lack of quality spawning gravels.

Wild coho were observed in upper MWC in 2001 by CDFW during a snorkel survey as well as in more recent CA Sea Grant snorkel surveys. Available data from Sonoma Water and CA Sea Grant indicates that adult coho returned to spawn in MWC in water year 2011, 2012, and 2013 but not during the drought conditions of 2014. The Russian River Coho Salmon Captive Broodstock Program first released hatchery salmon into the MWC watershed in autumn of 2011; between 13,000 and 23,000 juvenile coho were released in Mark West Creek and Porter Creek each year between 2011 and 2014, and in 2016. In 2017, 6,000 fish were released only in Porter Creek. In addition to salmonids, California red-legged frog (*Rana draytonii*) and yellow-legged frog (*Rana boylii*), which are both listed as threatened, have been documented in the watershed.

Chapter 3 – Numerical Modeling Methodology

The hydrologic model of the upper Mark West Creek watershed was constructed using the MIKE SHE model (Graham and Butts, 2005; DHI 2017). Model code development activities have been ongoing since its inception in 1977 and the model has been applied successfully to hundreds of research and consultancy projects covering a wide range of climatic and hydrologic regimes around the world (Graham and Butts, 2005).

The MIKE SHE model is a fully-distributed, physically-based model capable of simulating all the land-based phases of the hydrologic cycle including overland flow, channel flow, evapotranspiration, unsaturated flow, saturated flow, and stream/aquifer interactions. The distributed nature of the model makes it well-suited for examining the hydrologic impacts of changes in climate and water management. Complex physics-based watershed models, while powerful tools, require extensive input data and should ideally be well-calibrated to observed stream flow and groundwater data spanning a number of years. It is important to bear in mind that a model is a simplification of a complex and in some ways unknowable hydrologic system and although it can provide useful estimates of various flows and storages within the system, the estimates contain uncertainty and should not be viewed as a replacement for real data or as a static condition. Such models are best updated on a periodic basis as new data become available.

Overland Flow

The overland flow component of MIKE SHE solves the two-dimensional St. Venant equations for shallow free surface flows using the diffusive wave approximation. A finite-difference scheme is used to compute the fluxes of water between grid cells on a two-dimensional topographic surface. Net precipitation, evaporation, and infiltration are introduced as sources or sinks and the model assumes that a sheet flow approximation is valid for non-channelized surface flows and that roughness is uniform over various flow depths. The primary inputs of the overland flow module include topographic information in the form of a digital elevation model (DEM) and a corresponding spatial distribution of overland roughness coefficients (Manning's n) which is generally referenced to the model's land cover categories. Sub-grid-scale depressions in the topography and barriers to overland flow are represented conceptually through use of a detention storage parameter.

Channel Flow

The channel flow component of the model calculates unsteady water levels and discharges using an implicit finite-difference formulation to solve the one-dimensional St. Venant equations for open channel flow. The model is capable of simulating ephemeral stream conditions and backwater effects and includes formulations for a variety of hydraulic structure types including bridges, weirs, and culverts. Either a no-flow or a discharge boundary can be used as the upstream boundary condition, and the downstream boundary can be represented using a stage or stage discharge relation. Other than boundary conditions, the primary inputs for the channel flow model include channel geometry information and roughness coefficients for channelized flow (Manning's n).

Channel Flow Interactions

Interaction between the channel flow and overland flow components for the model is driven by the gradient between the overland water depths in a given grid cell and the head in a corresponding computational node in the channels and is computed using a broad crested weir equation. Depending on the direction of the gradient, the channel flow component of the model can either receive overland flow during runoff events or release water back into the floodplain as overland flow. The model is also capable of simulating backwater effects onto the overland flow plane due to restricted channel flow.

Evapotranspiration and Interception

Evapotranspiration (ET) is handled in the model using a two-layer water balance approach which divides the unsaturated zone into a root zone from which water can be transpired and a lower zone where it cannot. The model computes actual evapotranspiration (AET) as a function of potential evapotranspiration (PET) and the available water content in the vegetation canopy, overland flow plane, and the unsaturated zone. The model first extracts water from interception storage which is based on vegetation properties including leaf area index (LAI) and an interception storage coefficient. Next, water is extracted from ponded water on the land surface and, finally, from within the unsaturated zone or, if the rooting depth exceeds the depth to water for a given timestep, the saturated zone. PET can be adjusted for each land cover category in the model through use of a crop coefficient (Kc). The simulated position of the water table along with the specified rooting depth determines the thickness of the zone of transpiration.

Unsaturated Flow

The unsaturated flow component of MIKE SHE functions with the two-layer water balance method described above. The method considers average conditions in the unsaturated zone and tracks available soil moisture to regulate ET and groundwater recharge using a one-dimensional (vertical) formulation. A soil map Is used to distribute the primary soil properties used to drive the model, including saturated hydraulic conductivity (K_{sat}) and moisture contents (Θ) at saturation, field capacity, and wilting point. The unsaturated flow component of the model interacts with the overland flow component by serving as a sink term (infiltration) and with the groundwater flow component by serving as a source term (recharge).

The unsaturated zone component of the model does not explicitly represent lateral movement through and discharge from the unsaturated zone commonly referred to as interflow. In the MWC watershed, interflow occurring at or near the contact between soils and underlying bedrock is expected to be an important process. Because interflow is often associated with a temporary increase in groundwater elevations during and following precipitation events, interflow processes can be approximated in MIKE SHE with a saturated zone drainage function.

Saturated Flow

The groundwater component of the model solves the three-dimensional Darcy equation for flow through saturated porous media using an implicit finite difference numerical scheme solved using the preconditioned conjugate gradient (PCG) technique which is nearly identical to that used in MODFLOW, a widely used U.S. Geological Survey groundwater model. The primary inputs to the model are horizontal and vertical hydraulic conductivity, specific yield, storage coefficients, and the upper and lower elevation of each layer(s) considered in the model. External boundary conditions can be no-flow, head, or gradient boundaries and pumping wells can be added as internal sinks. The lower boundary of the model is zero-flux or a specified flux-boundary, and the upper boundary condition is a flux term calculated by the unsaturated flow component of the model (recharge). If the water table reaches land surface, the unsaturated flow calculations are disabled and the groundwater component of the model interacts directly with the overland flow plane.

Chapter 4 – Model Construction

Model Overview

The Upper Mark West Creek hydrologic model is defined as the Mark West Creek watershed upstream of Quietwater Road. The model is discretized into over 50,000 45-meter by 45-meter (0.5-acre) grid cells covering a 40.2 mi^2 area. The grid resolution was selected to represent the watershed in as much detail as possible consistent with the overall resolution of input data while enabling reasonable computation times (about 100 hours).

The model simulates a continuous 10-yr period from 10/1/2009 through 9/30/2019 (Water Years 2010 - 2019). This period was selected because it corresponds to the period with the most data available for model calibration, is representative of long-term average precipitation conditions, and includes a wide variety of precipitation conditions ranging from the very dry Water Year (WY) 2014 when annual precipitation at the Santa Rosa and St. Helena 4SW climate stations was 14.9 and 28.9 inches respectively to the very wet WY 2017 when annual precipitation at the two stations was 50.2 and 74.0 inches respectively (Figures 2 & 3). Based on the long-term precipitation record for Santa Rosa from 1906 – 2019, WY 2014 was the 4th driest year on record and WY 2017 was the 5th wettest (Figure 2). The 2-yr rainfall total for WY 2013-2014 was the second driest on record (14.9 inches versus 12.8 inches for 1976-1977). Mean annual precipitation at the Santa Rosa climate station for the simulation period was 31.1 inches, which is similar to both the 1906-2019 and 1981-2010 averages of 30.2 and 32.1 inches respectively (Figure 2).

A longer streamflow record is available for the upper watershed, but streamflow data from the lower watershed (developed for this project to facilitate model calibration) is only available for WY 2018 and 2019. Although simulation of post-fire hydrologic impacts and subsequent recovery from the Tubbs Fire was not part of the scope of this project, given the timing and scale of the October 2017 fire event just prior to collection of streamflow data, it was necessary to incorporate a simplistic representation of the post-fire landscape into the model to facilitate calibration. Post-fire hydrologic effects are complex and adjust rapidly in the years following disturbance. An ongoing USGS is underway to better understand the effects of the fire on soil hydrologic conditions, and preliminary findings suggest highly localized effects and that recovery to pre-fire characteristics occurs rapidly (Perkins, personal communication).

We did not attempt to represent the long-term effects of fire or recovery; rather, we developed a version of the model representing the short-term effects (first and second year after disturbance) of the fire exclusively for calibration purposes, and maintained the pre-fire landscape for the primary simulation of existing conditions and future scenarios. This decision acknowledges that the available data describing vegetation in the watershed was collected prior to the fire and that the long-term recovered landscape is likely to more closely resemble the pre-fire landscape than the short-term post-fire landscape, and thus represents a more appropriate basis for evaluating management decisions.

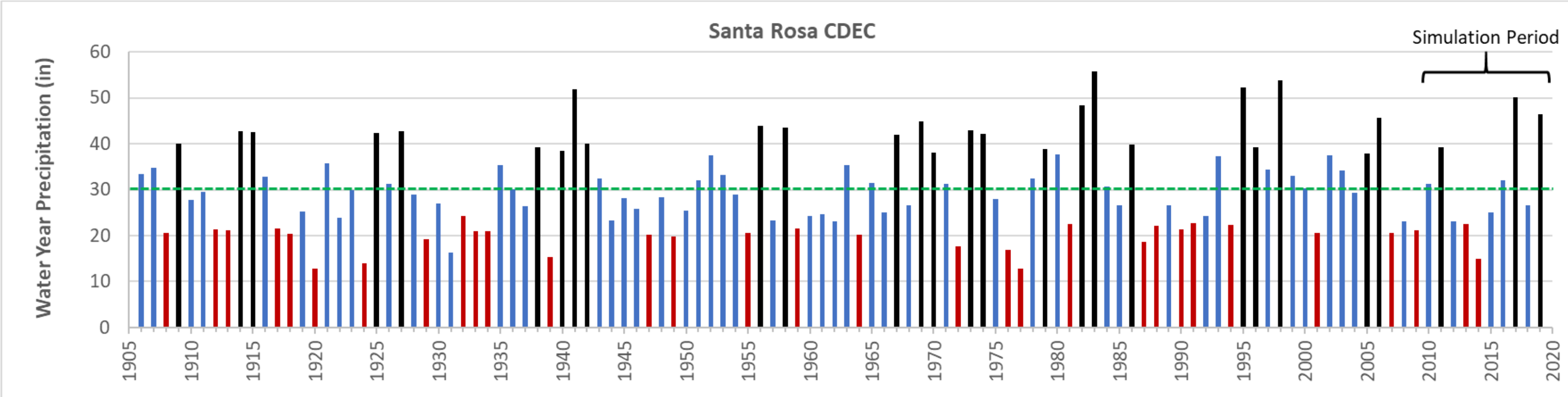


Figure 2: Long-term annual precipitation record for the Santa Rosa CDEC climate station (black and red values indicate wet and dry years defined as +/- 25% of the long-term average as shown with the dashed line).

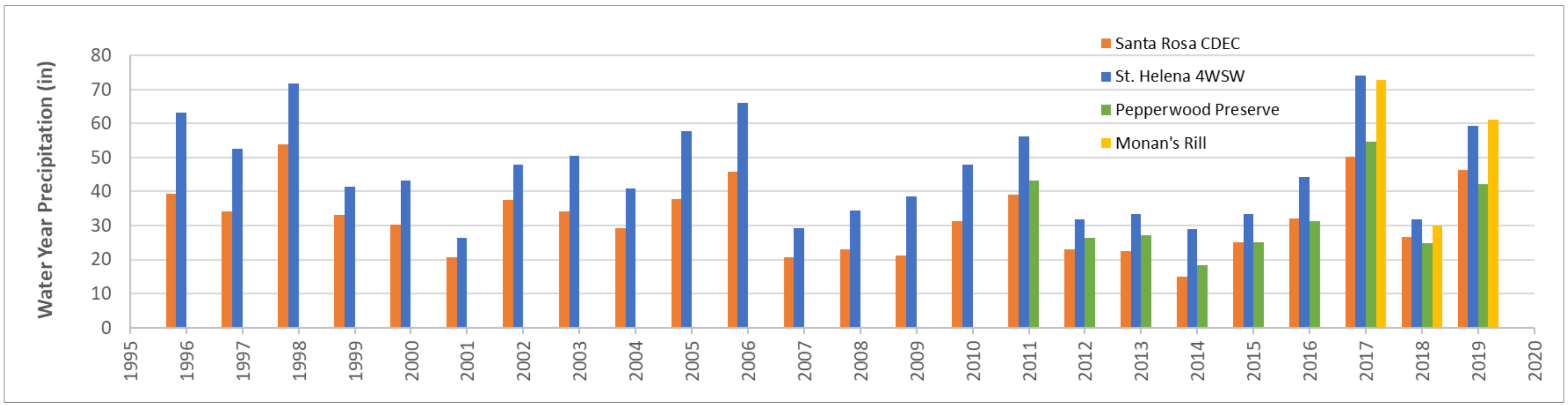


Figure 3: Annual precipitation records for various climate stations in and around the MWC watershed.

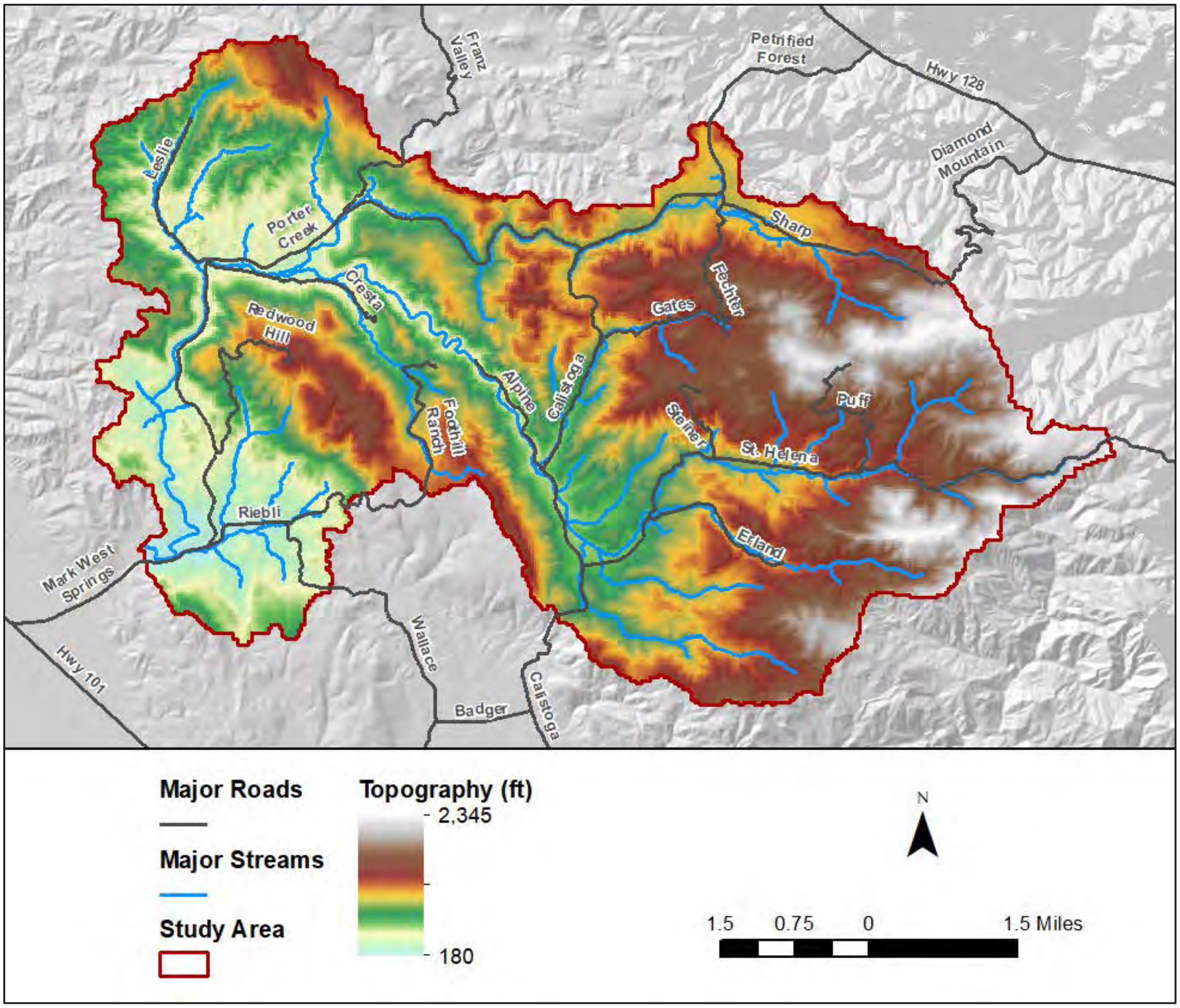


Figure 4: Topography used in the MWC hydrologic model.

Topography

Model topography is based on the 3-foot resolution Sonoma County LiDAR dataset (WSI, 2016) which was resampled to conform to the 45-meter grid cells used in the model. Elevations in the model domain range from 180 feet near Quietwater Road to 2,345 feet on Diamond Mountain near the border between Sonoma and Napa Counties (Figure 4).

Climate

Precipitation and Potential Evapotranspiration (PET) are the primary climatic inputs to the model; both are represented on a daily timestep. Based on the Basin Characterization Model (BCM) (Flint et al., 2013; Flint & Flint, 2014) which provides gridded estimates of average annual precipitation for the 1980-2010 period throughout California, a significant east-west gradient in precipitation exists across the watershed. Mean annual precipitation is estimated to increase from 38 in/yr near the Santa Rosa Plain to 51 in/yr near the crest of the Mayacamas Mountains. Based on analysis performed for this study (as described below) PET varies primarily with aspect and is estimated to range from 30 to 52 in/yr. To account for the spatial variability in climate, the model domain was divided into 1-inch interval precipitation and PET zones (Figures 5 & 6).

Precipitation

There are several weather stations within the Upper Mark West watershed and surrounding areas (Figure 5). A long-term daily precipitation record dating back to Water Year (WY) 1906 is available from the Santa Rosa station operated by Sonoma County and located southwest of the watershed in the Santa Rosa Plain (Figure 2). A shorter but significant precipitation record dating to WY 1996 is available from the St. Helena 4WSW station operated by the California Department of Water Resources (DWR) and located southeast of the watershed along the ridge separating Sonoma and Napa County. Another significant record dating to WY 1991 is available from the Windsor station operated by the California Irrigation Management Information System (CIMIS) and located near the Town of Windsor. The Pepperwood Preserve has the longest operating precipitation station in the watershed dating to WY 2011. CRWI operated two stations at the Monan's Rill community in the upper watershed beginning in WY 2017. Three additional stations were installed by Sonoma Water in the watershed in February 2018 including Mark West Creek at Michelle Way, Mark West Creek at Porter Creek Road, and Mark West Regional Park (Figures 3 & 5).

The model domain is divided into 14 precipitation zones to account for the west to east gradient in precipitation (Figure 5). These zones are based on 1-inch annual isohyets derived from the BCM 1981-2010 mean annual precipitation data which is available at a 270-meter spatial resolution (Flint and Flint, 2014). Each zone was assigned to a rainfall station and precipitation was scaled up or down based on the ratio of the mean annual precipitation in the zone to the mean annual precipitation at the corresponding weather station. The station assignments vary throughout the simulation period as more stations became available during more recent time periods. For 10/1/2009 through 10/4/2010, all zones utilized the St. Helena 4WSW station. For the period 10/5/2010 to 11/15/2016, all zones utilized the Pepperwood station, and for the period 11/16/2016 to 2/1/2018, the 38 to 44-inch zones utilized the Pepperwood station and the 45 to 51-inch zones utilized the Monan's Rill station. For the most recent time period from 2/2/2018 to 9/30/2019, the 38 and 39-inch zones utilized the Michelle Way station, the 40 to 42-inch zones utilized the Pepperwood station, the 43 to 45-inch zones utilized the Mark West Regional Park station, and the 46 to 51-inch zones utilized the Monan's Rill station (Table 1 & Figure 7).

Comparisons between the BCM long-term average precipitation and the long-term average precipitation at the Santa Rosa and St. Helena 4WSW gages suggest that the BCM may over-predict rainfall by ~15-20%. Nevertheless, the magnitude of the gradient across the MWC watershed as predicted by the BCM agrees well with the station data, and the BCM provides the

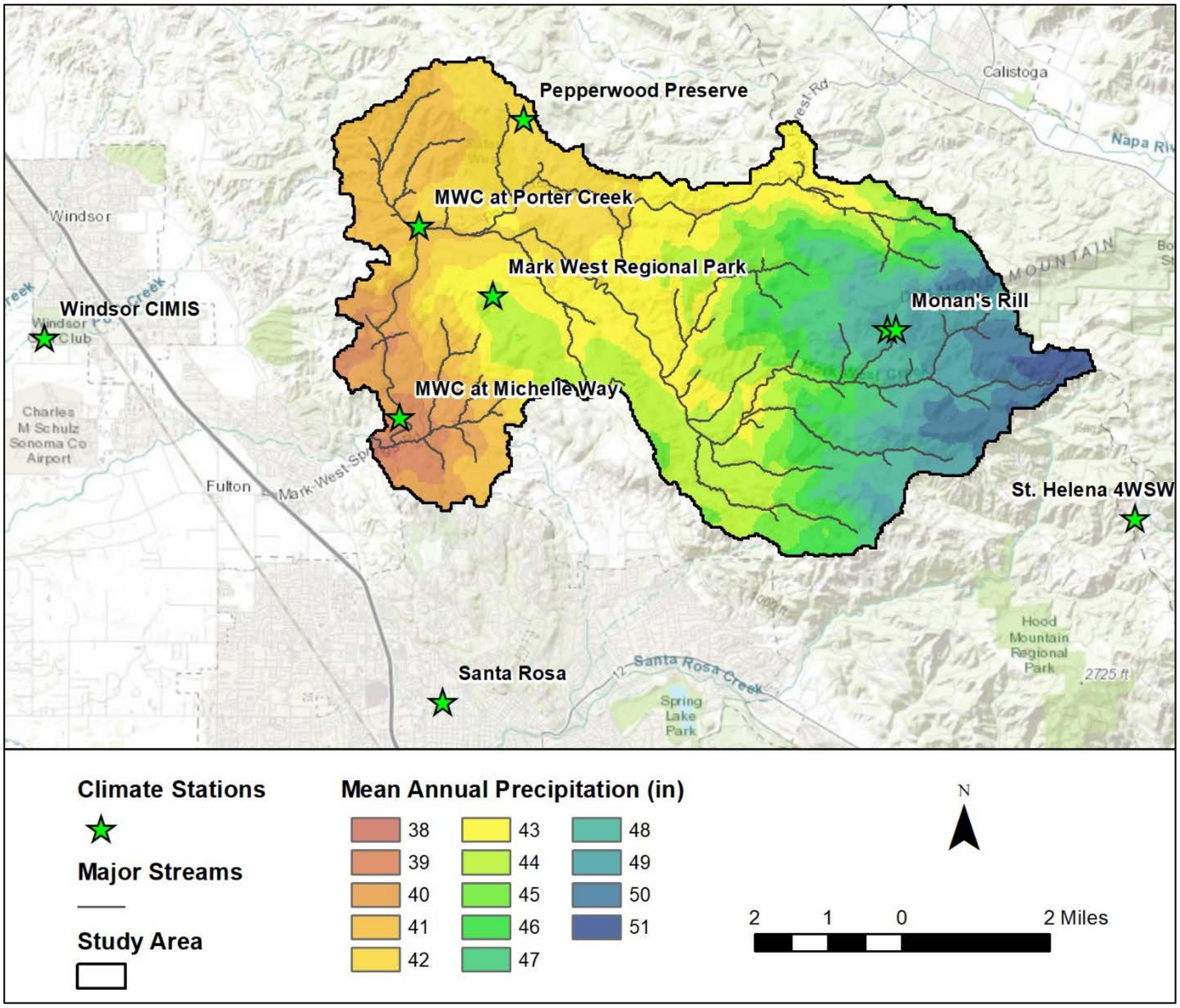


Figure 5: Precipitation zones and climate stations used in the MWC hydrologic model.

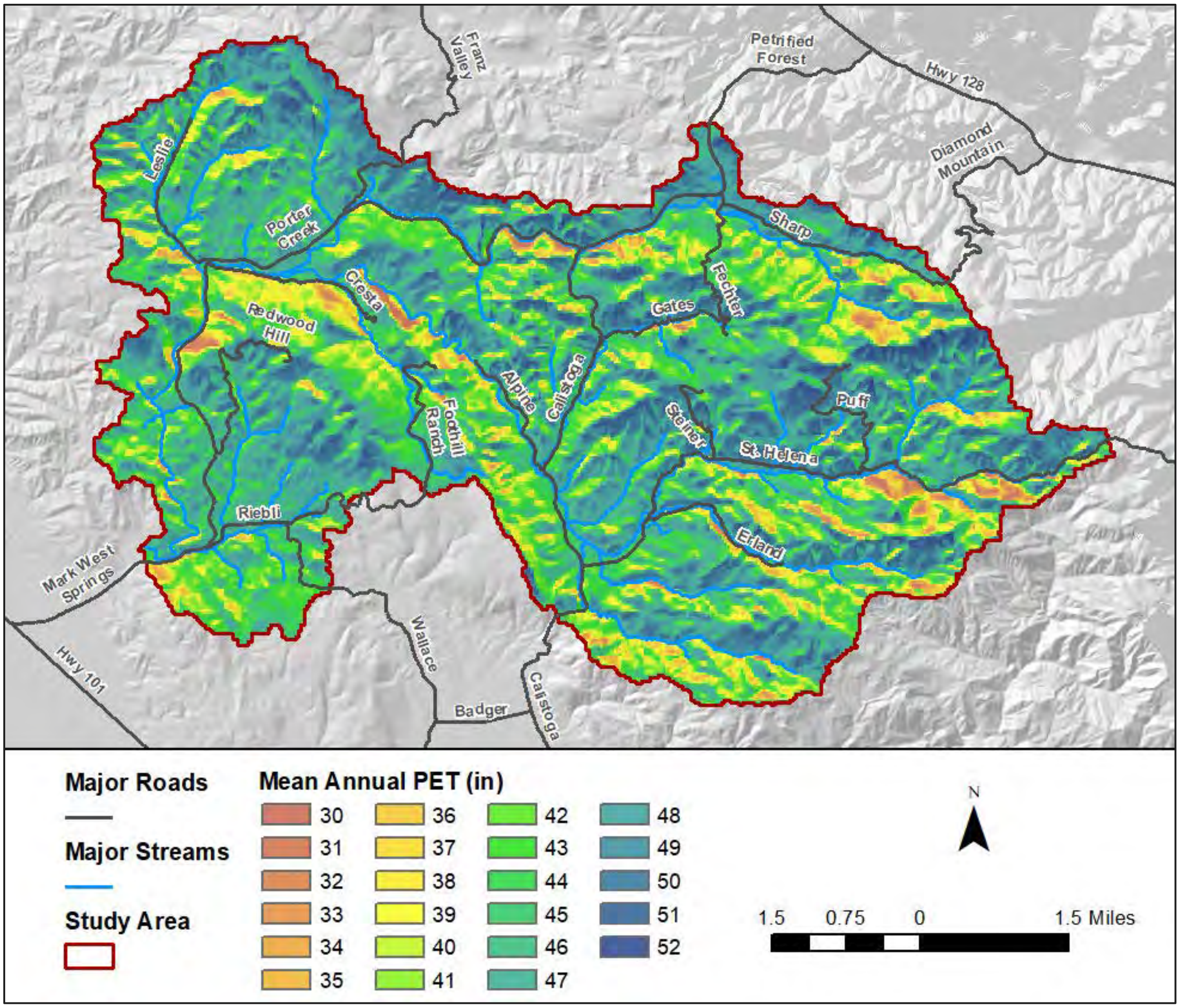


Figure 6: PET zones used in the MWC hydrologic model.

Table 1: Precipitation station assignments used for various time periods. Station codes and associated BCM mean annual precipitation values are as follows: MW – Michelle Way 38.5-in, PEP – Pepperwood 41.5-in, MWRP – Mark West Regional Park 43.8-in, MR – Monan's Rill 48.5-in, SH – St. Helena 4WSW 49.7-in.

	Precipitation Zone													
Time Period	**38**	**39**	**40**	**41**	**42**	**43**	**44**	**45**	**46**	**47**	**48**	**49**	**50**	**51**
10/1/2009 - 10/4/2010	SH	SH	SH	SH	SH	SH	SH	SH	SH	SH	SH	SH	SH	SH
10/5/2010 - 11/15/2016	PEP	PEP	PEP	PEP	PEP	PEP	PEP	PEP	PEP	PEP	PEP	PEP	PEP	PEP
11/16/2016 - 2/1/2018	PEP	PEP	PEP	PEP	PEP	PEP	PEP	MR	MR	MR	MR	MR	MR	MR
2/2/2018 - 9/30/2019	MW	MW	PEP	PEP	PEP	MWRP	MWRP	MWRP	MR	MR	MR	MR	MR	MR

best means to spatially distribute the available rainfall station data across the watershed. The actual 10-yr simulation period mean rainfall in the model varies from 30.8 inches/yr to 43.3 inches/yr consistent with the long-term mean from the available gauging data, whereas the BCM shows this variation as 38 to 51 inches.

Potential Evapotranspiration (PET)

Daily PET data from the Windsor CIMIS station was used to derive the PET timeseries used in the model (Figures 6 & 8). A gridded distribution of mean annual PET was created using the Hargreaves-Samani equation (Hargreaves and Samani, 1982). The calculations were performed using gridded solar radiation data from the National Solar Radiation Database (NSRDB, 2010) and average monthly minimum and maximum temperatures for the 1980 -2010 period from the BCM dataset (Flint & Flint, 2014). The empirically derived KT coefficient was calibrated based on reported PET from the Santa Rosa and Windsor CIMIS Stations. A KT value of 0.152 was selected, consistent with KT values of 0.15 to 0.16 previously proposed for the Bay Area.

From this annual distribution, the model domain was divided into zones, each corresponding to a one-inch range in average annual PET. Scaling factors were calculated for each zone as the ratio of PET at the Windsor CIMIS gage and the PET for a given zone. These scaling factors were then applied to the daily CIMIS data and applied to each zone in the model. From February 2013 to March 2017 PET was not reported at the Windsor CIMIS gage. This gap was filled using scaled data from the Santa Rosa CIMIS gage located west of Sebastopol. Smaller gaps and missing days of data were also filled using Santa Rosa data.

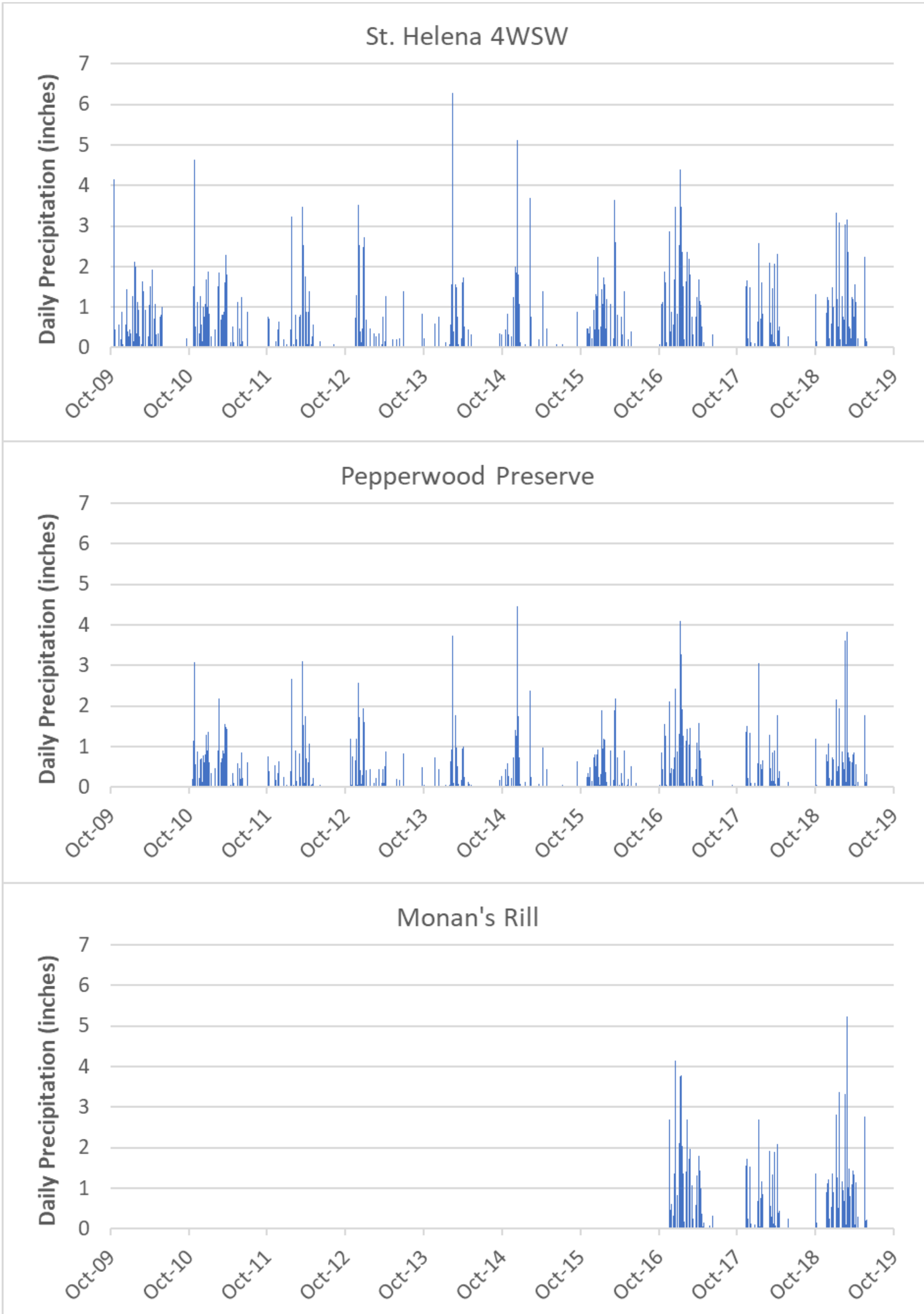


Figure 7: Daily precipitation at the five climate stations used in the MWC hydrologic model for the WY 2010 – 2019 simulation period.

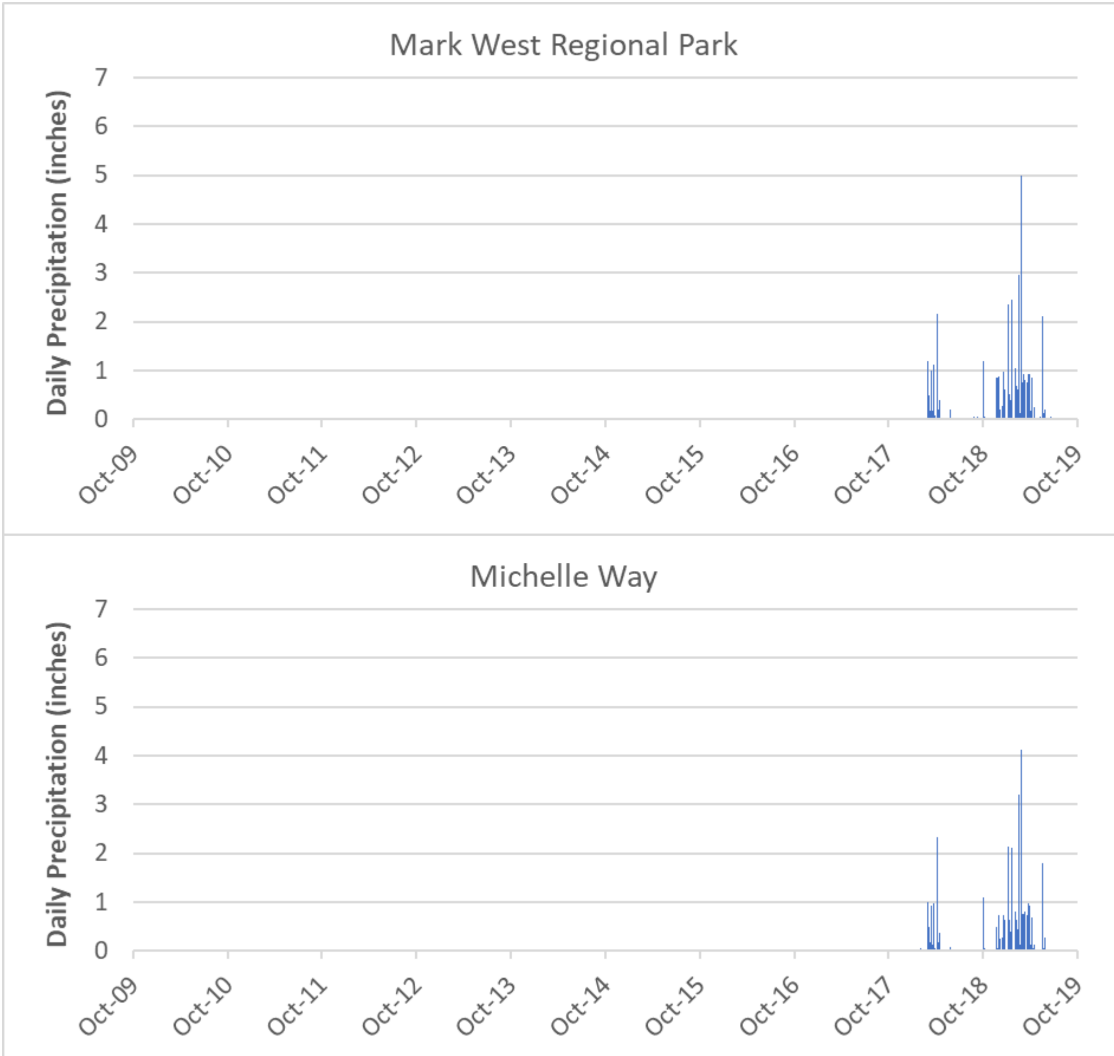


Figure 7 (continued)

Land Cover

Within the upper Mark West watershed, coniferous and deciduous forest are the dominant landcover types with grasslands making up much of the remaining area (Table 2). Land cover varies significantly with elevation in the watershed. Downstream of St. Helena Road, Mark West Creek and several other tributaries including Leslie, Porter, Riebli, and Weeks Creeks contain predominately oak woodland interspersed with other deciduous woodlands and grasslands. Upstream of St. Helena Road, Mark West Creek has several tributaries including Alpine, Humbug, and Van Buren Creeks; these tributary watersheds are dominated by coniferous forest including Coastal Redwoods and Douglas Fir. Several vineyards are located along the mainstem of Mark West Creek as well as along Porter and Riebli Creeks. Much of the Riebli Creek watershed, as

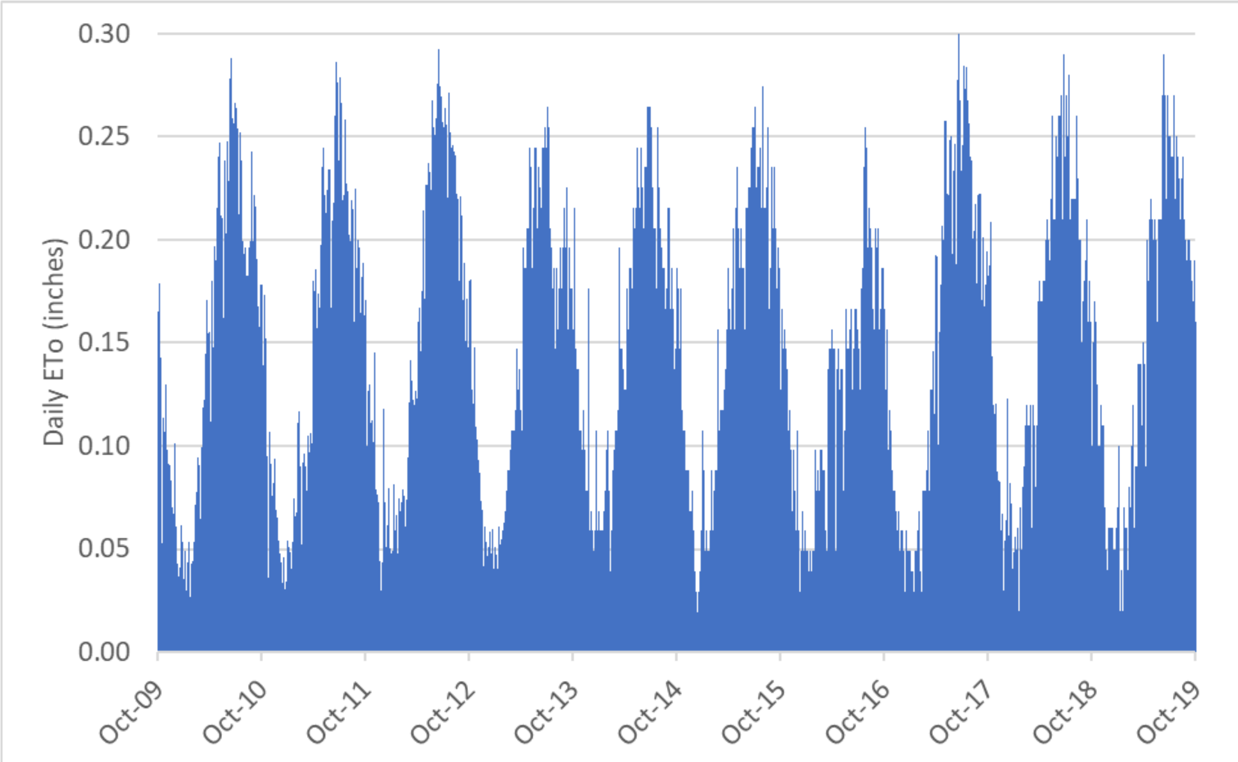


Figure 8: Daily PET at the Winsor CIMIS station used in the MWC hydrologic model for the WY 2010 – 2019 simulation period.

well as small portions of the uppermost Mark West Creek and Humbug Creek watersheds, contain relatively dense rural residential development.

The model domain was discretized into 28 land cover zones based on vegetation classes from the Sonoma County Vegetation Mapping & LiDAR Program's Fine Scale Vegetation and Habitat Map (Figure 9) (SCVMLP, 2015). This map was generated for the Vegetation Mapping & LiDAR Program using automated processing of returns from the 2013 countywide LiDAR flight and interpretation of aerial imagery by the modelers (SCVMLP, 2015). It includes a detailed accounting of dominant species including several species of oak and conifer and is intended for use at a scale of 1:5000 or smaller. Land cover zones that represent less than 0.3% of the model domain (approximately 0.1 mi^2) are grouped with similar or adjacent cover types. Because these land cover zones are based on 2013 data, they do not reflect changes caused by the 2017 Tubbs Fire which were accounted for separately as described below.

A unique combination of model parameters was assigned to each of the 28 land cover zones. These parameters include Leaf Area Index (LAI), Rooting Depth, Manning's Roughness Coefficient for overland flow, and Detention Storage. For land cover types with a deciduous vegetation component, the Leaf Area Index and Rooting Depth vary seasonally based on an assumed growing season of April 15th to October 15th with gradual parameter transitions occurring from March 15th to April 15th and from October 15th to November 15th. Dormant season values for deciduous land

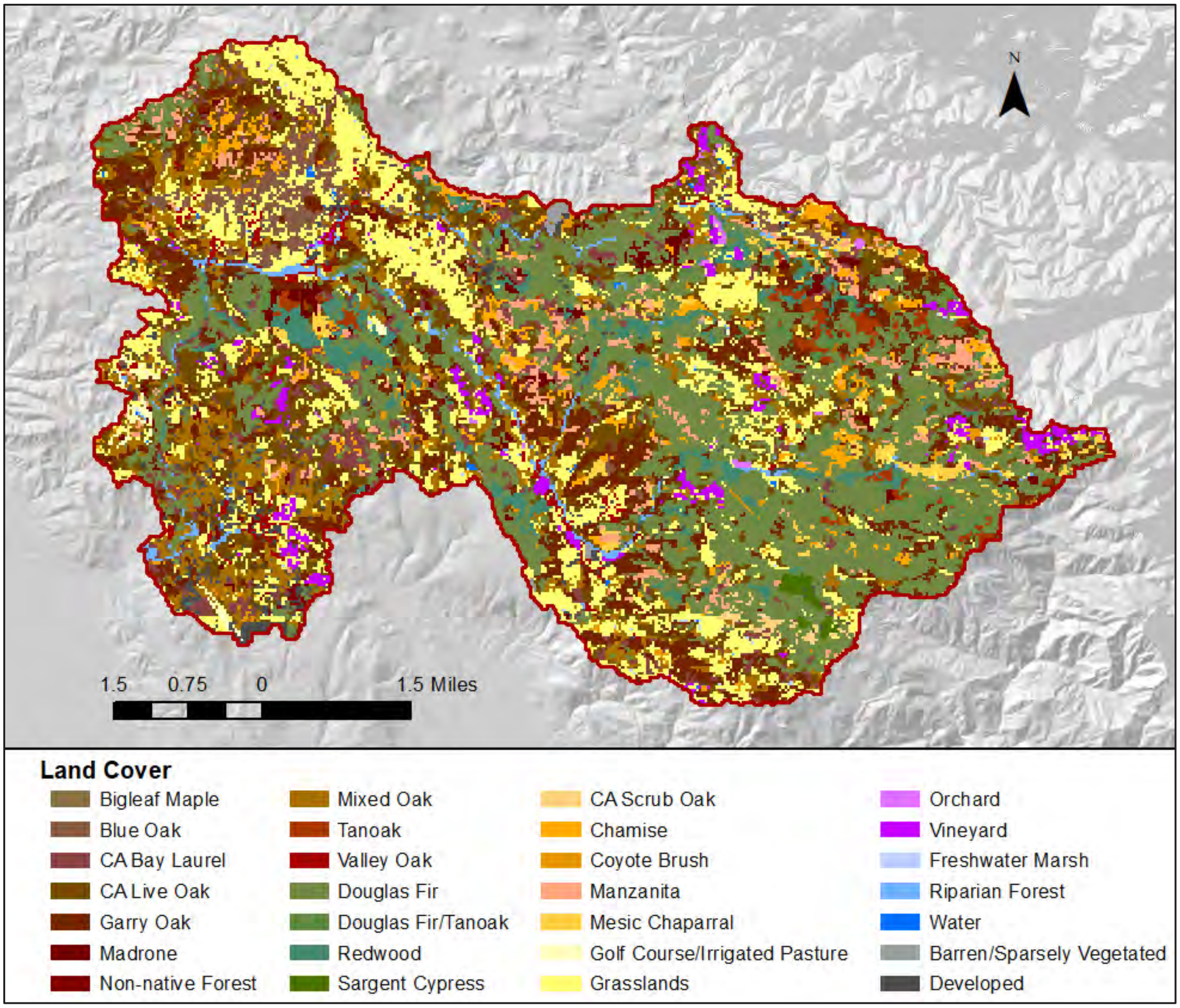


Figure 9: Land cover categories used in the MWC hydrologic model.

cover types were assumed to be equivalent to grassland values. For grasslands, the growing season was assumed to occur from December 15th to May 15th and the dormant season was assumed to occur from July 1st to October 15th with gradual parameter transitions in between. Many of these parameters are difficult to measure in the field and site-specific values are generally unavailable. With the exception of LAI, land cover parameters were initially estimated from literature values (e.g. Allen et al., 1988; TNC, 2018) and then adjusted within the range of reasonable limits as part of the calibration process (Table 2).

LAI was estimated for each vegetation zone using a spatially distributed LAI dataset created by the University of Maryland (Tang, personal communication, Tang, 2015) (Figure 10). This dataset was created using vegetation returns from the countywide LiDAR dataset and has a 3-foot spatial resolution. The remotely sensed LAI values in this dataset represent a combination of the canopy properties of individual plants and the density and spacing of those plants. This differs from LAI

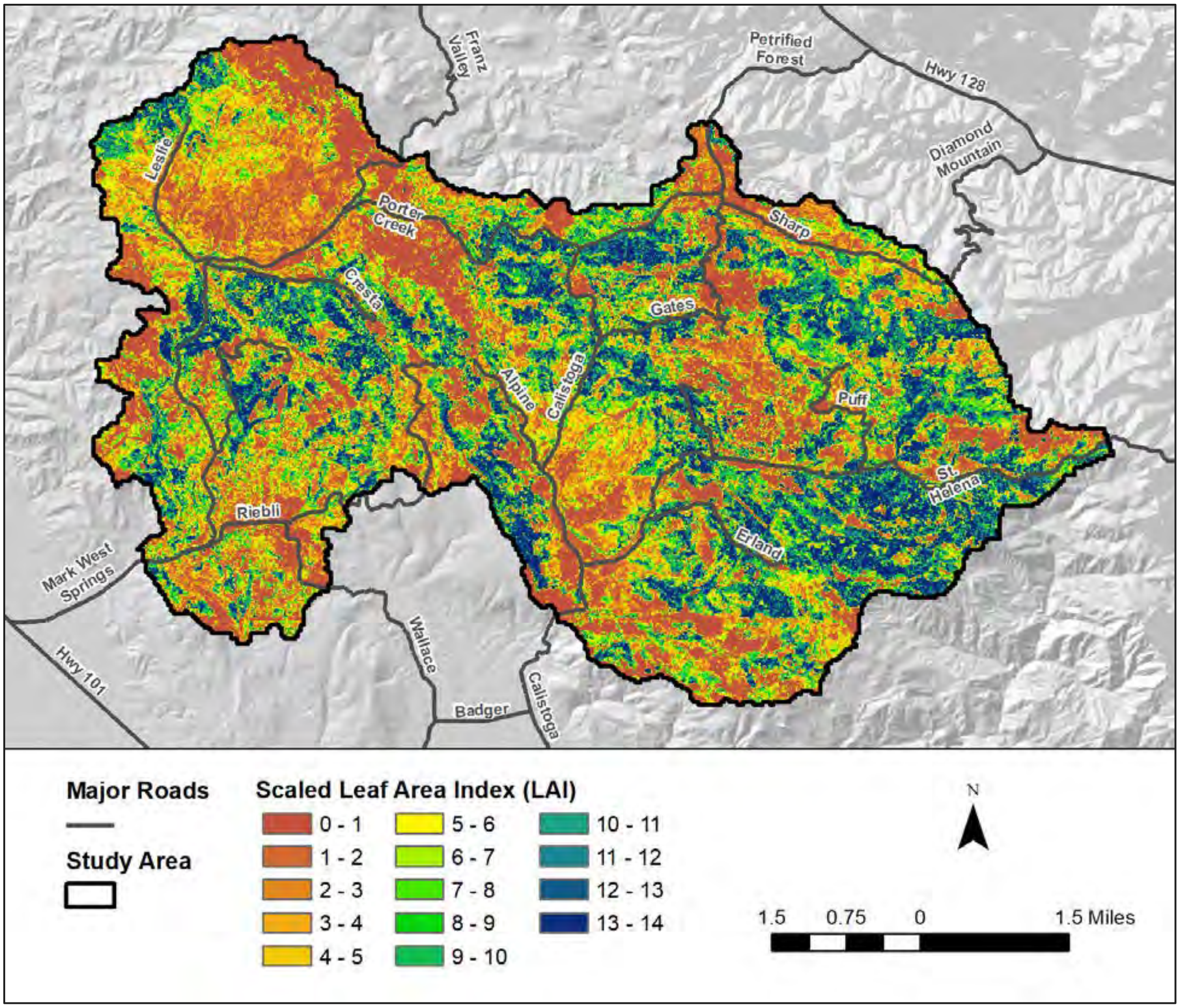


Figure 10: Distribution of LiDAR-derived Leaf Area Index (LAI).

Table 2: Land cover types and associated hydraulic and vegetation properties used in the MWC hydrologic model.

Land Cover Category	Proportion of Model Domain	Overland Flow Mannings n	LAI	Rooting Depth (ft)	Detention Storage (in)
Bigleaf Maple	0.2%	0.60	7.4	11.5	0.9
Chamise	2.2%	0.40	2.7	6.4	0.3
Madrone	1.3%	0.60	9.8	8.6	0.9
Manzanita	3.0%	0.40	4.3	6.6	0.3
Coyote Brush	0.8%	0.40	1.5	6.5	0.3
Barren/Sparsely Vegetated	0.2%	0.04	0.3	0.5	0.0
Grasslands	15.4%	0.24	0.4	2.1	0.3
Mesic Chaparral	1.5%	0.40	4.1	5.0	0.3
Sargent Cypress	0.3%	0.60	4.5	5.6	0.9
Irrigated Pasture	0.4%	0.24	0.4	3.1	0.3
Non-native Forest	0.2%	0.60	3.7	7.6	0.9
Tanoak	0.9%	0.60	1.5	15.0	0.9
Orchard	0.2%	0.24	11.3	6.7	0.9
Douglas Fir/Tanoak	0.9%	0.60	(8.0 - 14.7)	9.4	0.9
Douglas Fir	25.6%	0.60	(7.2 - 15.1)	3.7	0.9
Mixed Oak	8.4%	0.60	(4.0 - 10.1)	19.5	0.9
CA Live Oak	11.3%	0.60	(5.0 - 10.2)	24.0	0.9
Blue Oak	2.1%	0.60	(2.7 - 9.0)	15.0	0.9
CA Scrub Oak	0.3%	0.60	2.8	15.0	0.9
Garry Oak	11.3%	0.60	(4.0 - 10.8)	15.0	0.9
Valley Oak	0.9%	0.60	(3.9 - 9.8)	24.0	0.9
Redwood	3.2%	0.60	11.2	11.1	0.9
CA Bay Laurel	3.9%	0.60	8.1	3.0	0.9
Riparian Forest	1.1%	0.60	6.0	7.3	0.9
Vineyard	1.7%	0.24	1.0	4.9	0.3
Water	0.1%	0.04	1.0	0.5	0.0
Marsh	0.1%	0.04	0.5	1.3	0.0
Developed	2.3%	0.04	2.9	5.9	0.0

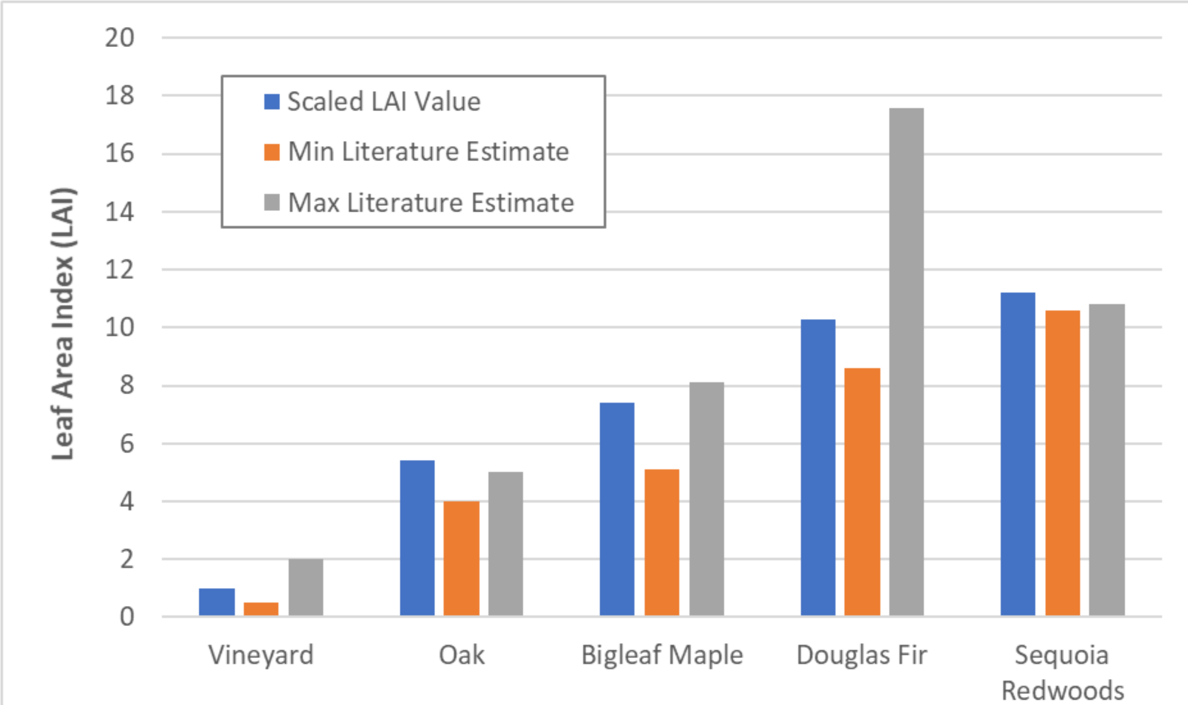


Figure 11: Comparison between scaled LAI values used in the MWC hydrologic model and estimates from the literature for various vegetation types.

values representing individual plant specimens which is the standard convention for empirical evapotranspiration equations used in our model. We compared the remotely sensed LAI values for various vegetation classes with individual specimen values from the literature (Iio & Ito, 2014; Johnson, 2003; Karlik & McKay, 2002; Scurlock et al., 2001) and translated the LiDAR-derived values to specimen values consistent with the literature by applying a uniform scaling factor to the LiDAR-derived LAI (Figure 11). LAI values were calculated for each of the vegetation zones in the model by calculating the mean LAI for each zone from the scaled LAI dataset (Table 2). For Douglas Fir, Douglas Fir/Tanoak, and the various types of Oaks, we further subdivided the LAI estimates into areas requiring no forest treatment, minor treatment, and major treatment based on LAI thresholds we defined from plot-scale forest mapping performed in the upper watershed as described in greater detail in the Chapter 8.

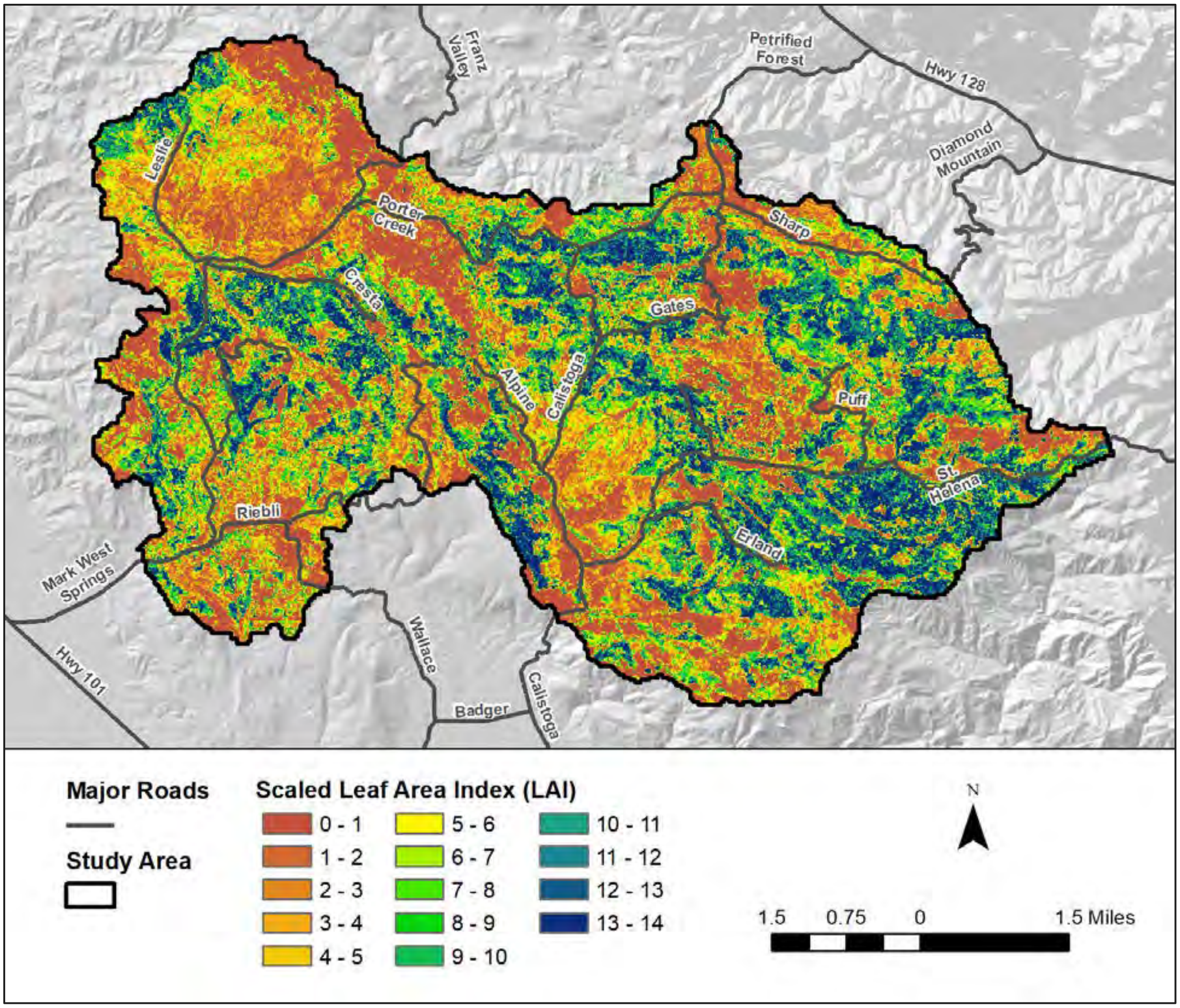


Figure 10: Distribution of scaled LiDAR-derived Leaf Area Index (LAI).

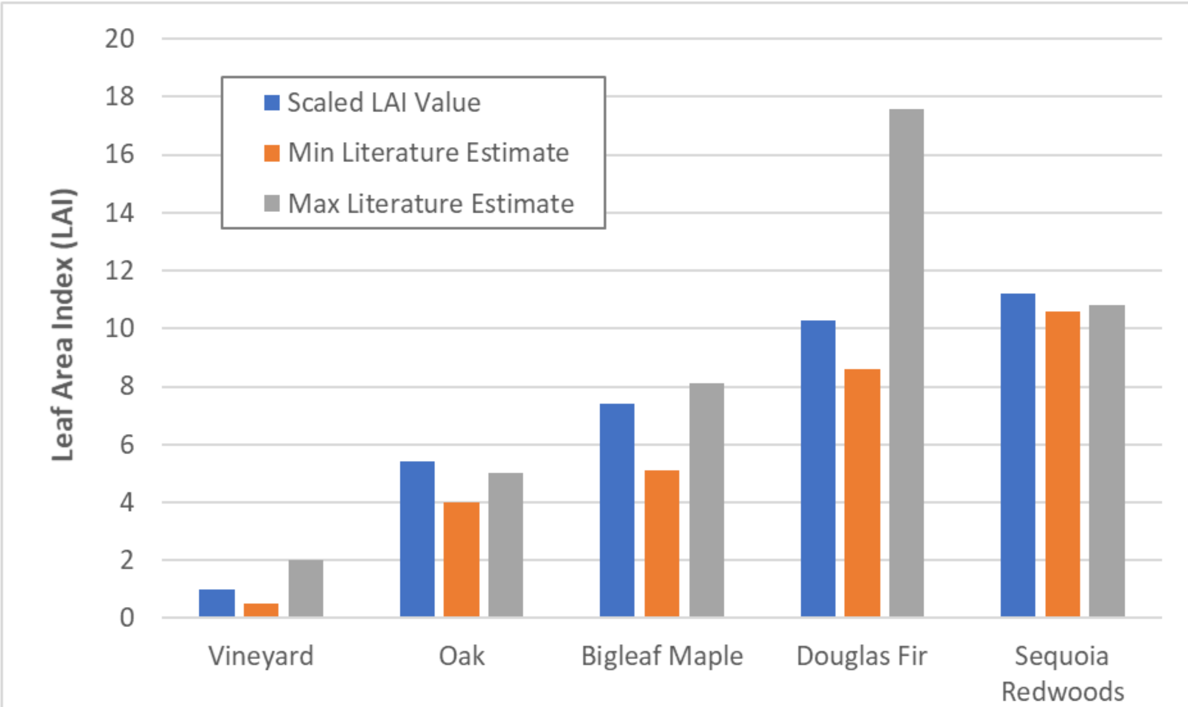


Figure 11: Comparison between scaled LAI values used in the MWC hydrologic model and estimates from the literature for various vegetation types.

Land Cover Adjustments for the Tubbs Fire

As discussed at the beginning of this chapter, we developed a second version of the model incorporating the short-term effects of the Tubbs Fire to facilitate calibrating the model to post-fire streamflow data collected within the burn area at Michelle Way. The canopy-damage raster dataset generated by SCAPOSD (Green & Tuckman, 2018) and Soil Burn Severity dataset generated by the U.S. Forest Service (USFS, 2018) were used to identify the portions of the watershed where we judged that the fire was severe enough to result in significant short-term changes in evapotranspiration. These areas included forested lands where canopy damage was >80% and non-forested lands where soil burn severity was classified as moderate or severe (Figure 12). The delineated area of hydrologically-significant vegetation damage is about 18% of the upper MWC watershed evaluated in this study and approximately 42% of the total identified burn area.

Post-fire vegetation data or Leaf Area Index (LAI) mapping is not available, therefore a simple means of adjusting vegetation parameters was employed for the subset of the burn area judged to have hydrologically significant fire damage. The vegetation in the burn area was assumed to have LAI and rooting depth properties mid-way between the original cover type (undisturbed) and grasslands (full conversion). This simple representation is intended to approximate the short-term effects (1-2 yrs) of the fire on evapotranspiration but is not intended to reflect long-term landscape recovery. A CalFire parcel-based shapefile identifying burned structures was used to identify wells and surface water diversions within the burn area to turn off in the model.

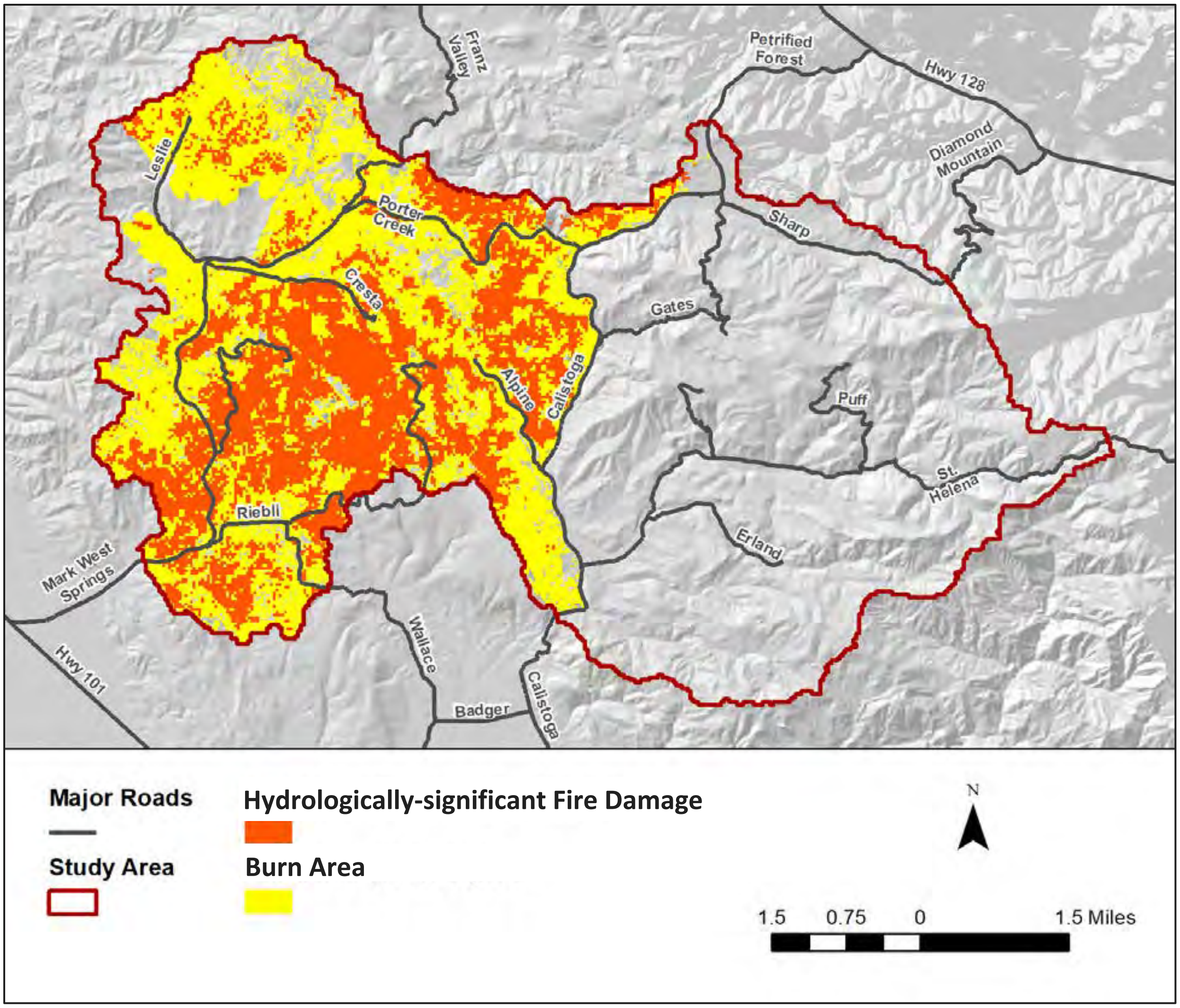


Figure 12: Footprint of the 2017 Tubbs Fire and the severely burned portion of the burn area where vegetation properties were adjusted in the MWC hydrologic model to reflect the fire for the purposes of model calibration.

Short-term fire effects on overland roughness and detention storage or soil hydraulic conductivities were not considered.

The version of the model with these adjustments to land cover values was used for model calibration only. The pre-fire representation of cover was retained for model simulations of existing conditions and scenario evaluations since the long-term effects of the fire on vegetation patterns are unknown and future vegetation is expected to resemble pre-fire conditions more so than immediate post-fire conditions.

Surface Water

Channelized flows are represented using a detailed stream network derived from the 3-foot resolution Sonoma County LiDAR dataset (WSI, 2016). This network includes all major perennial streams and many smaller tributaries as well as all major on-stream ponds. Off-channel ponds, some intermittent streams, and ephemeral tributaries are not explicitly represented in the stream network. In total, 79 river miles of stream and 18 on-stream ponds are included and represented by approximately 3,300 cross-sections in the surface water hydraulics component of the model.

Streams

The stream network includes all channels with a drainage area of more than 0.2 mi^2 and a stream length of at least 500 feet. These limits were designed to maximize the extent of the channel network within the limits of the ability of the LiDAR data to accurately represent channel geometry and to avoid excess computational burden. These thresholds allow for inclusion of all perennial streams and all reaches with slope characteristics (<7%) indicative of potential salmonid habitat suitability. In a limited number of cases, channels were extended to include on-stream ponds. Additionally, three channels with drainage areas of less than 0.2 mi^2 were included based on the presence of perennial summer baseflow as observed during stream surveys performed August 27th through August 29th, 2018 by OEI and CDFW staff.

The stream network was derived from the 3-foot Sonoma County LiDAR dataset by computing flow directions and flow accumulations using standard ArcGIS techniques. Channel-cross sections were extracted from the LiDAR DEM at 100-ft intervals for major channels and those known to contain salmonids, including Mark West, Alpine, Humbug, Leslie, Mill, Porter, Riebli, Van Buren, and Weeks Creeks. For the remaining channels, cross-sections were extracted at 200-ft intervals.

Prior to defining the stream network and extracting cross sections, a series of cross sections were surveyed in the field and compared to LiDAR-derived cross sections at various drainage areas and locations throughout the watershed. These comparisons revealed that the LiDAR dataset represents the channel geometry with acceptable accuracy at drainage areas above about 0.2 mi^2. In some cases, accuracy was reasonably high in smaller drainage areas; however, when smaller streams were incised relatively deeply the LiDAR did not capture the details of the channel geometry in sufficient detail for hydraulic modeling. Examples comparing survey- and LiDAR-derived cross sections with accuracy judged to be acceptable for purposes of hydraulic simulation in the model are shown in Figure 14.

A uniform Manning's Roughness coefficient (n) of 0.055, representative of rocky channels with brush along the banks (Chow, 1959), was applied to all cross-sections. A downstream boundary condition was defined as a rating curve established using normal depth calculations for the downstream-most cross section in the model. Because all inflows are generated by other spatially distributed components of the MIKE SHE model, upstream boundary conditions are zero-discharge inflows.

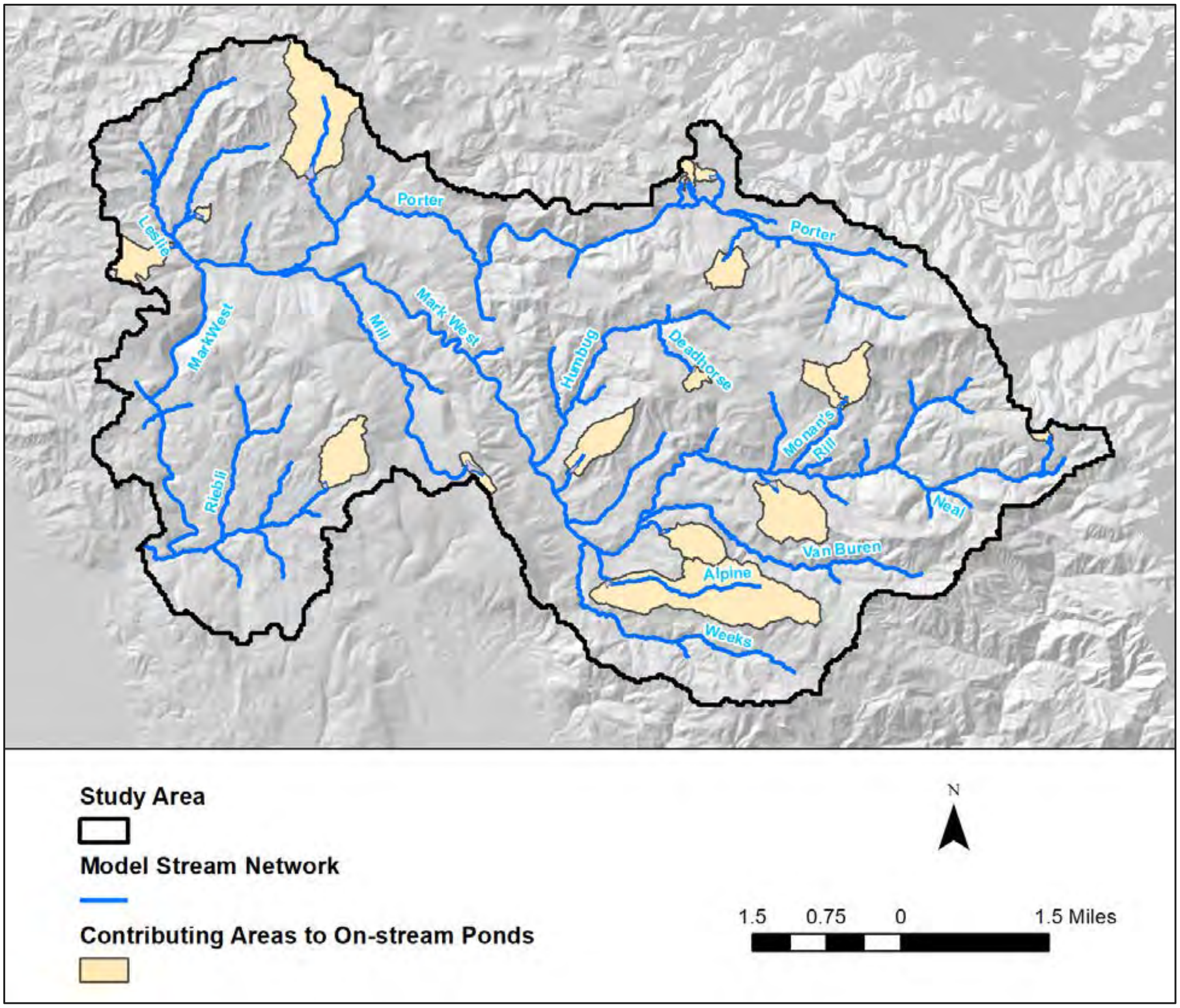


Figure 13: Stream network and on-stream ponds included in the MWC hydrologic model.

Ponds

Within the model domain, approximately 80 ponds have been identified using the 3-foot Sonoma County LiDAR DEM and aerial photography. The majority of these are small off-stream ponds which were not explicitly included in the surface water component of the model. Thirteen on-stream ponds with significant (>0.2 mi^2) contributing areas were included in the model along with five ponds with smaller contributing areas but significant reported water uses.

A stage-storage relationship for each of the 18 ponds included in the model was derived from the 3-foot Sonoma County LiDAR DEM. These data were collected in autumn 2013 and observed water surface elevations are assumed to reflect typical end-of-season storage levels in each pond. The stage-storage relationship for a given pond was associated with cross sections at the upstream and downstream edges of the pond, and cross sections were added at the pond's spillway. Water in the ponds is not explicitly represented in the model grid therefore evaporation

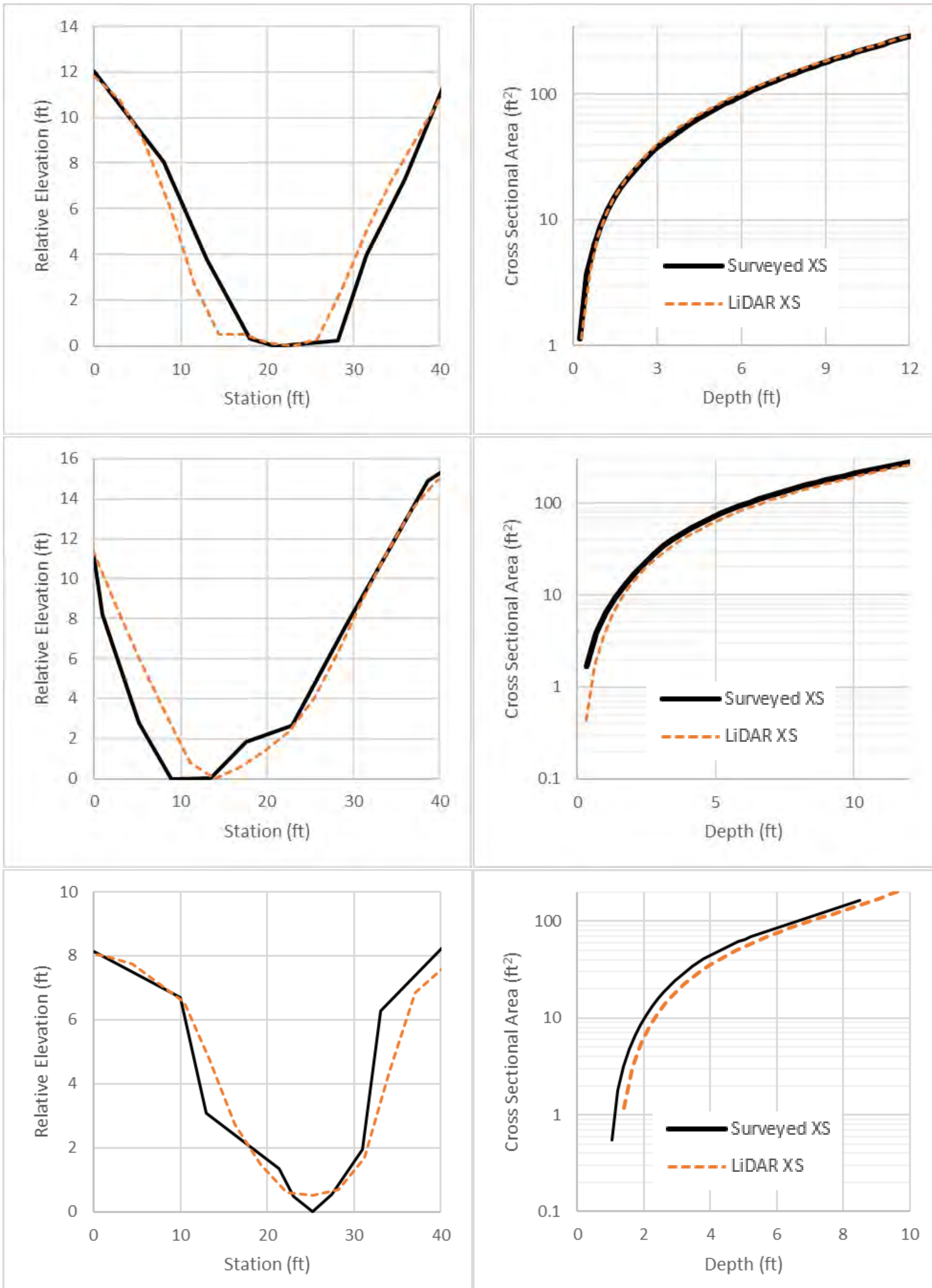


Figure 14: Comparisons between survey- and LiDAR-derived channel cross sections and corresponding depth/area relationships for an unnamed tributary to Mark West Creek with a 0.3 mi² drainage area (top), upper Mark West Creek with a 0.5 mi² drainage area (middle), and upper Porter Creek with a 2.0 mi² drainage area (bottom).

from each pond was included as a surface water boundary condition based on the surface area of the pond and the daily PET data described above.

Soils

The model domain is discretized into 23 different soil zones based on the National Resource Conservation Service's (NRCS) Soil survey Geographic Database (SSURGO) accessed through the Web Soil Survey (WSS). Where reported soil types are similar or where they represent a small portion of the model domain, they are grouped with other similar soil types.

Most soils in the model domain are loams and clay loams. The distribution of soil textures appears to be correlated with underlying geology. Loam soils generally occur in areas underlain by the Sonoma Volcanics and clay loam soils occur in areas underlain by the Franciscan Complex. A major divide in soil types is formed by the Maacama Fault Zone which runs through the central

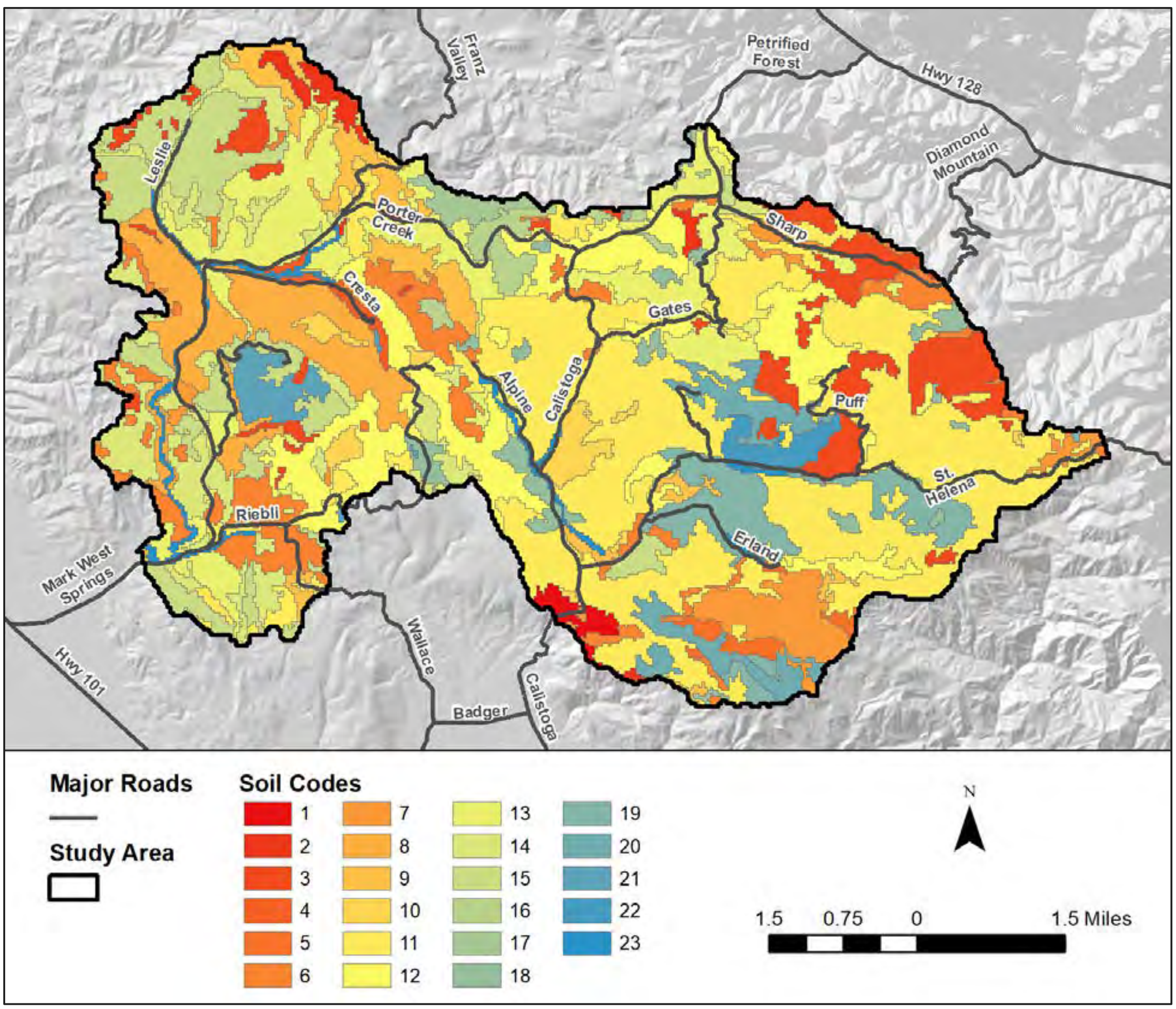


Figure 15: Soil codes used in the MWC hydrologic model (see Table 3 for associated property values).

portion of the study area intersecting Mark West Creek near the confluence with Porter Creek. Downstream of the confluence, the model domain is dominated by NRCS Hydrologic Soil Group B and C soils including the Felta Very Gravelly Loam, Laniger Loam, and Red Hill Clay Loam. Upstream of the confluence, the model domain is dominated by Group D and some Group C soils including the Boomer Loam, Goulding Clay Loam, Henneke Gravelly Loam, and Laniger Loam. Group B soils are relatively well-drained and can absorb and transmit water at relatively high rates whereas Group D soils absorb and transmit water very slowly and thus generate high runoff rates. Group C soils have hydrologic properties intermediate between B and D soils. Group A soils do not occur in the study area.

Initial estimates of the saturated hydraulic conductivity and the moisture contents at saturation, field capacity, and the wilting point for each of these soil types were derived from the physical properties report in the SSURGO database and final values have been determined through model calibration. For each zone, saturated hydraulic conductivity was initially estimated using the rate

Table 3: Final calibrated values of soil moisture contents at saturation, field capacity, and wilting point, and saturated hydraulic conductivities used in the MWC hydrologic model.

Soil Code	θsat	θfc	θwp	Ksat (ft/day)
1	0.485	0.366	0.191	0.001
2	0.483	0.220	0.175	0.001
3	0.472	0.216	0.114	0.002
4	0.464	0.271	0.150	0.002
5	0.453	0.161	0.058	0.002
6	0.458	0.301	0.157	0.003
7	0.468	0.195	0.105	0.004
8	0.457	0.304	0.135	0.006
9	0.502	0.342	0.173	0.006
10	0.453	0.270	0.125	0.007
11	0.461	0.195	0.097	0.011
12	0.460	0.224	0.109	0.011
13	0.463	0.235	0.073	0.011
14	0.468	0.103	0.056	0.011
15	0.468	0.139	0.076	0.011
16	0.483	0.232	0.071	0.013
17	0.463	0.186	0.075	0.013
18	0.423	0.246	0.145	0.014
19	0.479	0.254	0.120	0.026
20	0.457	0.280	0.132	0.026
21	0.498	0.350	0.177	0.050
22	0.463	0.168	0.049	0.079
23	0.377	0.019	0.002	0.116

reported for the most limiting layer of each soil. Initial values for water content at field capacity and wilting point were estimated using the weighted average for all horizons within each zone. Saturated water content is not reported by SSURGO and initial values were estimated using the reported average bulk density for each zone and an assumed soil particle density of 2.65 g/cm^3.

The initial values for soil moisture contents were not adjusted significantly. Excluding the alluvial soils which have significantly different properties, soil moisture content at saturation, field capacity, and the wilting point ranged from 0.42 to 0.50, 0.10 to 0.37, and 0.05 to 0.19 respectively. Successful calibration required significantly lower Ksat values relative to the SSURGO estimates. This can be attributed to the model's simplified 2-layer water balance approach which does not account for variations in Ksat as a function of soil moisture, and thus typically requires lower Ksat values to represent overall infiltration dynamics. Additionally, the unsaturated zone in much of the watershed is relatively thick and comprised of soil strata plus underlying weathered and unweathered bedrock, therefore this parameter reflects an average Ksat value for the full unsaturated zone derived from calibration rather than a true soil property. The calibrated saturated hydraulic conductivity values ranged from 0.01 ft/day for clay soils to 0.12 ft/day for alluvial soils (Table 3).

Interflow

As described in Chapter 3, interflow is represented in the model with a saturated zone drainage function. Drain levels and time constants were derived through calibration and primarily influence the springtime flow recession. A time-varying drain level tied to precipitation patterns was required to adequately reproduce the springtime flow recession. A spatially uniform drain level of 20-ft below land surface was used to activate the drainage process during and following

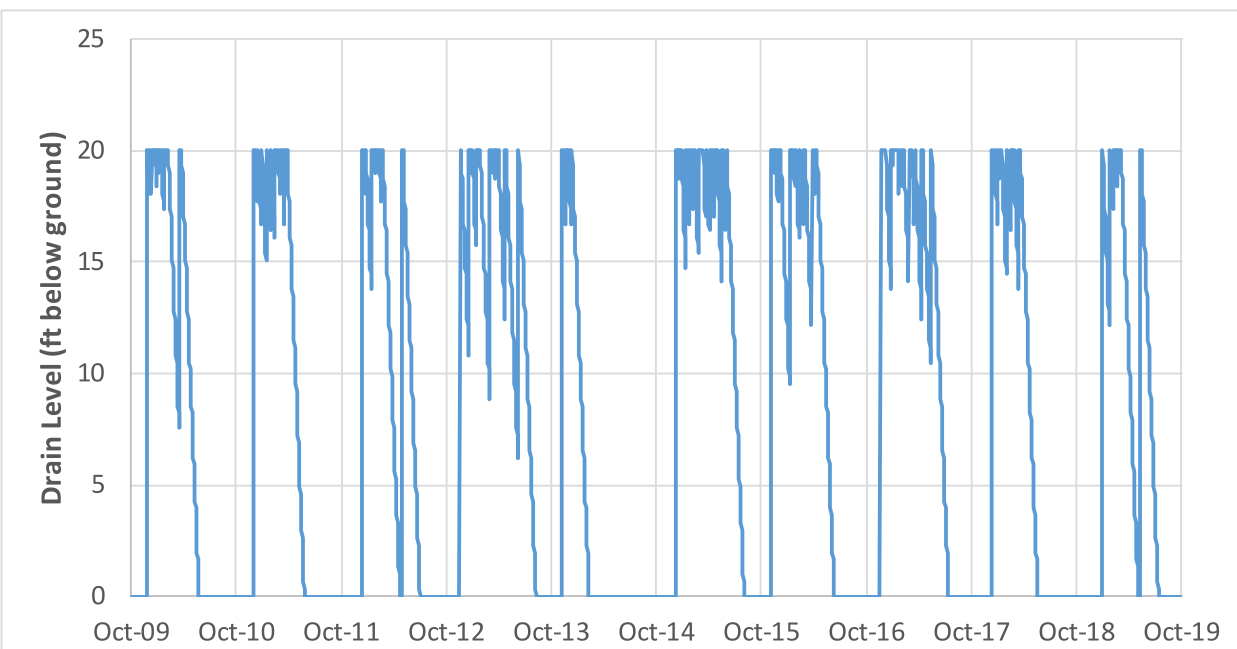


Figure 16: Timeseries of drain levels used to represent interflow in the MWC hydrologic model.

significant precipitation events (defined here as >0.2 in/day). On the third consecutive day with no significant precipitation, drain levels were decreased towards zero at a uniform rate of 0.33 ft/day until a subsequent precipitation event triggered levels to be reset to 20-ft. To account for the delay in the onset of interflow due to low antecedent soil moisture at the beginning of each wet season, drainage was only activated when 2.5 inches of precipitation had fallen over the preceding 21 days (Figure 16).

Hydrogeology

Model Discretization and Boundary Conditions

The geology in the MWC watershed is complex and much of the watershed is characterized by alternating layers of more permeable tuffaceous materials and less permeable basalt and andesite of the Sonoma Volcanics. These layers have varying extents and thicknesses and in some areas are mantled by younger rocks of the Glen Ellen Formation and/or Quaternary Alluvium. As described in detail below, substantial subsurface information could be gleaned from available geologic logs included in Well Completion Reports (WCRs) and aquifer test data obtained from pump test data collected as part of Sonoma County's regulatory requirements for development in water-scarce areas that culminate in Well Yield Certification (WYC).

Despite the available data, it was not possible to accurately delineate individual layers or lenses of geologic materials to use in developing the vertical discretization of the model layers. Given this complexity, we discretized the model into six layers, with layer elevations defined relative to the surface topography. Layers 1-5 generally having a uniform 100-ft thickness and Layer 6 has a uniform 300-ft thickness for a total thickness of 800-ft. The only variation in layer thickness is associated with the alluvium where Layer 1 ranges in thickness from 25- to 50-ft and gradually increases to 100-ft outside of the alluvial body. Where Layer 1 thickness is less than 100-ft, Layer 2 thickness is correspondingly greater than 100-ft such that the base of Layer 2 is 200-ft below land surface (Figure 17 & Table 4).

The base of Layer 6 is defined as a no flow boundary as are the lateral boundaries around the model domain. Available groundwater elevation data is very limited and insufficient for characterizing any groundwater inflows/outflows that may occur across the watershed boundaries. In most areas the no flow boundary assumption (equivalent to assuming a groundwater divide occurs coincident with surface topography) is likely reasonably accurate, however some groundwater outflow likely occurs along portions of the south and southwest watershed divides where more permeable units of the Sonoma Volcanics may contribute flow to alluvial materials in the Santa Rosa Plain down-gradient from our study area. We did not attempt to quantify this component of the groundwater budget as part of our analysis owing to a lack of available data and our focus on processes within the upper watershed.

With the exception of pumping wells which are described in the Water Use section below, all other saturated zone boundary conditions such as infiltration recharge, ET from groundwater, and stream/aquifer interactions are calculated internally by the model through the coupling to other components of the model rather than specified as model inputs.

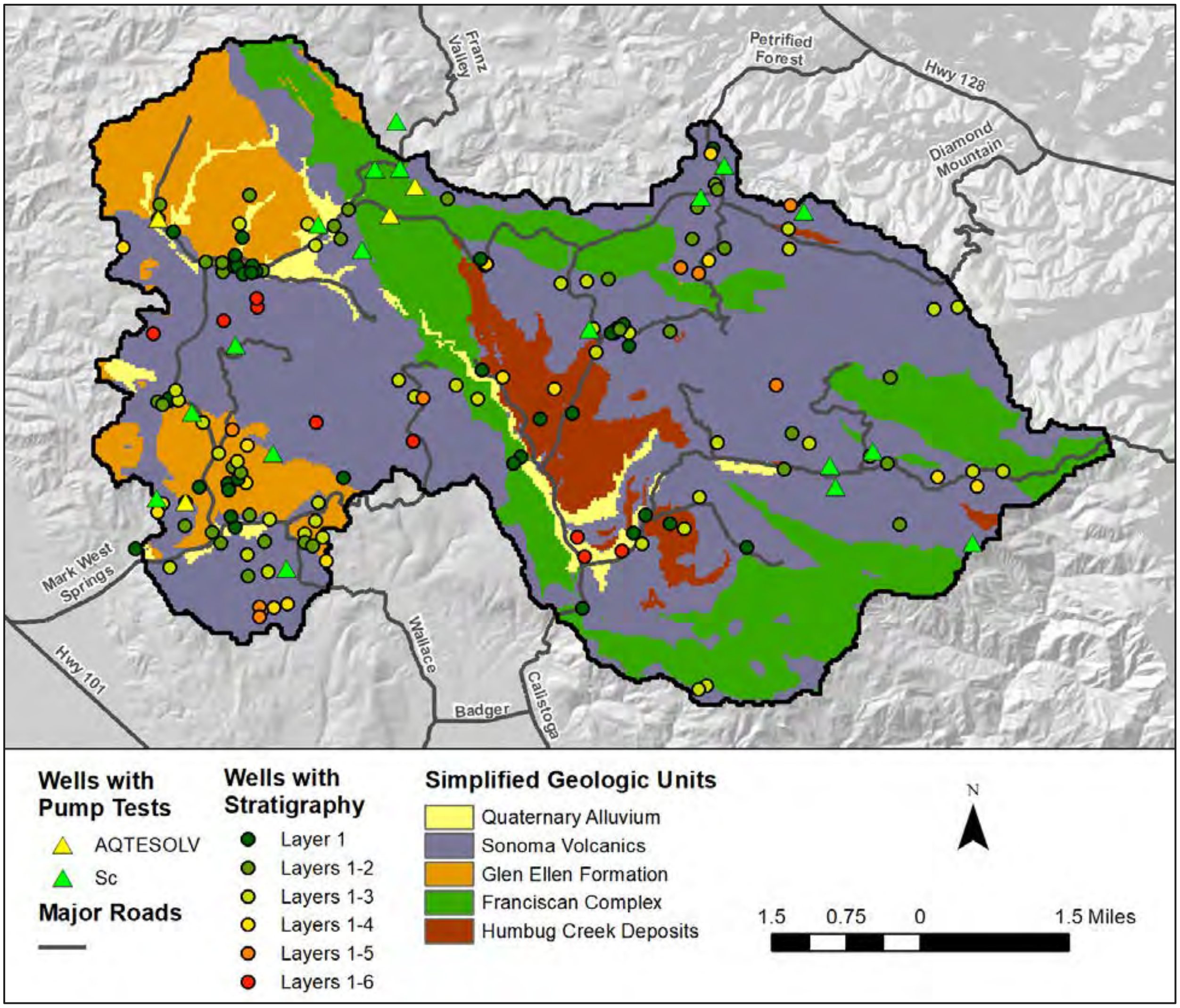


Figure 17: Simplified geologic map and locations of wells where pump test data was available and locations of wells where stratigraphic data was available.

Table 4: Layer thicknesses used in the groundwater component of the MWC hydrologic model.

Layer	Thickness (ft)
1	25 - 100
2	100 - 175
3	100
4	100
5	100
6	300

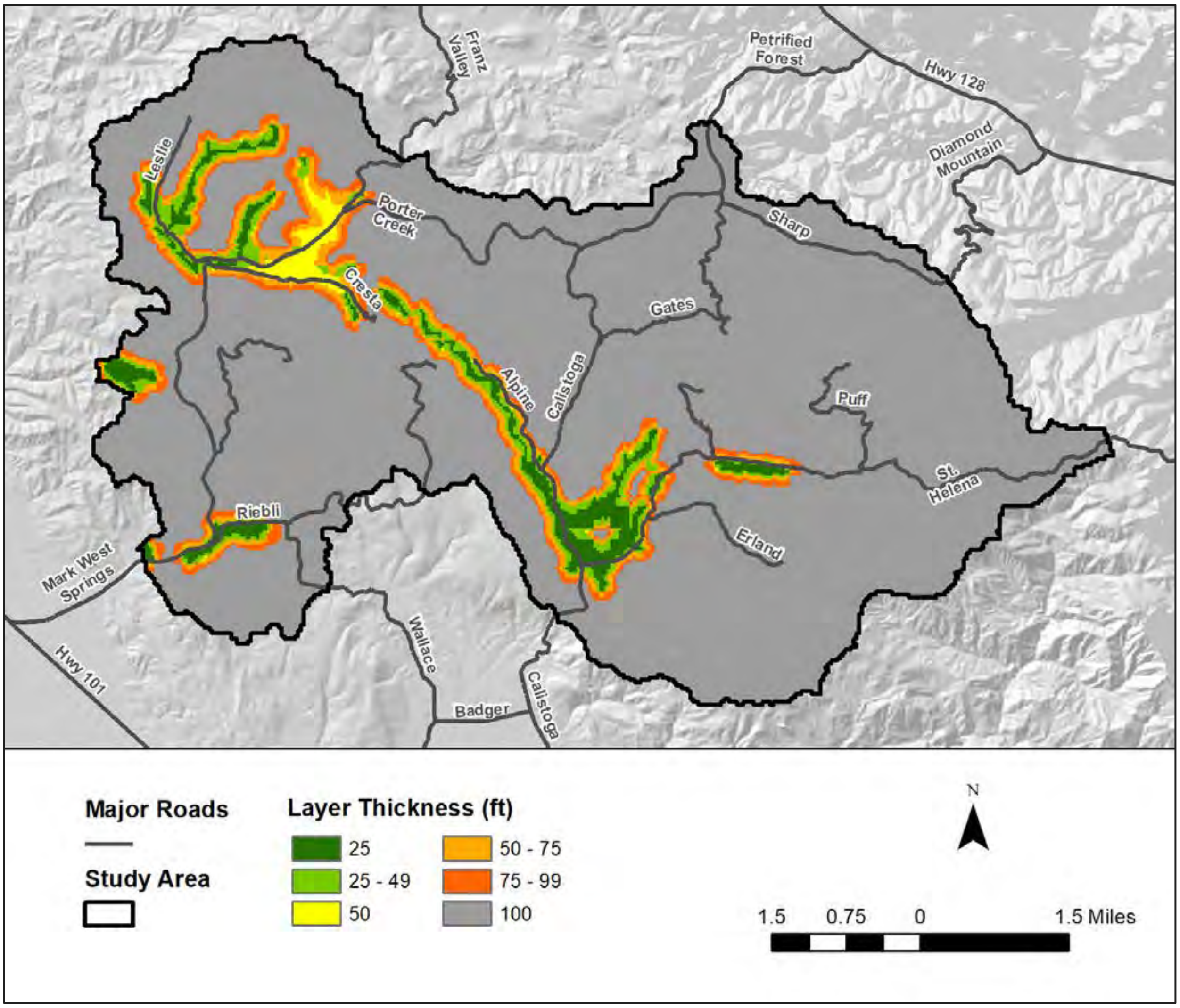


Figure 18: Thickness of groundwater model Layer 1.

Despite the available data, it was not possible to accurately delineate individual layers or lenses of geologic materials to use in developing the vertical discretization of the model layers. Given this complexity, we discretized the model into six layers, with layer elevations defined relative to the surface topography. Layers 1-5 generally having a uniform 100-ft thickness and Layer 6 has a uniform 300-ft thickness for a total thickness of 800-ft. The only variation in layer thickness is associated with the alluvium where Layer 1 ranges in thickness from 25- to 50-ft and gradually increases to 100-ft outside of the alluvial body. Where Layer 1 thickness is less than 100-ft, Layer 2 thickness is correspondingly greater than 100-ft such that the base of Layer 2 is 200-ft below land surface (Figure 18; Table 4).

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With the exception of pumping wells which are described in the Water Use section below, all other saturated zone boundary conditions such as infiltration recharge, ET from groundwater, and stream/aquifer interactions are calculated internally by the model through the coupling to other components of the model rather than specified as model inputs.

Distribution and Description of Geologic Materials

WCRs were obtained for more than 350 wells in the watershed and a subset of these had both detailed descriptions of geologic materials as a function of depth (geologic logs contained in WCRs) to provide useful stratigraphic information and reliable location information to associate the well with a parcel or a specific location. Geologic contacts (vertical boundaries between significantly different rock types) were identified in the logs depending on the geologic materials intersected.

Sonoma Volcanics

Most geologic logs from wells in the Sonoma Volcanics (SV) identify alternating layers of tuffaceous material and other volcanic rocks with andesite being the dominant material in the eastern portion of the watershed and basalt in the western portion. Contacts between tuffaceous materials and other volcanic rocks were delineated where a relatively clear interpretation could be made from the geologic log. Approximately 148 wells provided stratigraphic information within the SV (Figure 17). Within each 100-ft to 300-ft thick model layer interval penetrated by a given well, the geologic materials were classified as predominately (>80% of a given interval) tuffaceous material, predominately basalt or andesite, a combination of materials (<80% of either material), or underlying Franciscan Formation. In most portions of the watershed rocks of the SV extend through the full 800-ft sequence represented in the model. The interpretation becomes less certain with increasing depth from Layer 1 through Layer 6 as the number of wells penetrating a given interval decreases from 148 in Layer 1 to 74 in Layer 3 to just 9 wells in Layer 6 (Figure 17).

Glen Ellen Formation

In and near the Leslie and Riebli Creek subwatersheds, the contact between the Glen Ellen Formation and the underlying Sonoma Volcanics was delineated at 15 wells (Figure 17). These wells revealed that the Glen Ellen Formation ranges in thickness from approximately 130-ft in the upper Leslie Creek watershed to less than 50-ft in the lower watershed and in the Riebli Creek watershed exposure. Static water levels reported in these WCRs revealed that the formation is generally unsaturated and that all the wells are screened predominately in the underlying

Sonoma Volcanics where groundwater is available. The Leslie Creek watershed exposure is much coarser than the materials in Riebli Creek with the former typically described as sand and gravel or sandstone, and the latter typically described as clay or sandy clay. The spatial extent of the available data is insufficient for interpolating an isopach map, therefore a highly simplified representation of the Glen Ellen thickness was developed based on the available information. The Glen Ellen is only present in Layer 1 where we assumed 50-ft thickness in the Riebli Creek and lower portions of the Leslie Creek exposures and 100-ft thickness in the portions of the Leslie Creek exposure above 700-ft in elevation.

Franciscan Complex and Great Valley Sequence

A contact between the Sonoma Volcanics and the underlying rocks of the Franciscan Complex was delineated in a few wells located in the vicinity of the surficial contact between the units. The orientation of these contacts is unknown and the model generally assumes a vertical contact between these materials that extends across the full 800-ft thickness of the model consistent with the deepest available geologic logs which show both of these materials extending to considerable depth. Although hydrogeologic properties may vary substantially within the Franciscan, these variations are expected to depend upon the degree and interconnectivity of fracturing which cannot be characterized from the available data. Owing to the lack of data and the typically low permeability of the Franciscan relative to other geologic materials in the watershed, this unit was assigned uniform hydrogeologic properties. No available wells were located within the exposures of Great Valley Sequence materials in the watershed, consistent with the general experience in the region indicating that that this geologic unit provides poor aquifer material. These materials account for only a small portion of the study area and were treated as equivalent to the Franciscan Complex.

Quaternary Alluvium

A total of 35 WCRs were located within alluvial materials in the watershed (Figure 17). Water level data from the WCRs indicate that the alluvium is unsaturated at about half of these well locations and generally thin (< 25-ft at 22 of the 35 wells), only exceeding 50-ft in the vicinity of the Porter Creek/Mark West Creek confluence where the maximum reported thickness was 60-ft. The alluvium does not appear to be a significant source of water to wells and all of the wells are screened predominately within the underlying geologic materials where groundwater is available. The available geologic logs indicate the alluvium consists of primarily sand, gravel, and boulders with lesser quantities of clay and sandy clay.

The spatial extent of the data is insufficient for interpolating an isopach map, therefore a simplified representation of alluvium thickness was developed based on the available information. Using available surficial geologic mapping, topographic expressions interpreted from LiDAR data, and the subsurface thicknesses as described in WCRs, we reduced the extent of alluvium so as to exclude areas where thicknesses are too small to represent in the model. The alluvium falls entirely within Layer 1, and for most of the revised alluvium extent we assumed a 25-ft thickness, except for the area upstream of the confluence of Mark West and Porter Creeks where we assumed a 50-ft thickness (see Figure 17 for extent & Figure 18 for thickness).

Humbug Creek Lacustrine Deposits

Only a few of the available wells penetrated the Humbug Creek Lacustrine Deposits. They indicate that this material is generally around 25-ft thick and very fine-grained. It is typically described as clay and is generally unsaturated with wells screened in underlying geologic materials. We represented this material in model Layer 1 and assumed a uniform 25-ft thickness based on the extent of the mapped surface exposure.

Aquifer Properties

Hydraulic Conductivity Values

We compiled available pump test data from Well Yield Certifications obtained from the County of Sonoma. A subset of four tests was selected for aquifer analysis based on those tests where 1) the well completion details were known, 2) the test was performed for at least eight hours with a relatively constant pumping rate, 3) drawdowns and pumping rates were reported frequently enough to generate a detailed time-drawdown curve, and 4) the drawdown had stabilized by the end of the test (Figure 17). For the four tests meeting all criteria, the time drawdown data was analyzed using AQTESOLV software and a type-curve matching approach was used to derive estimates of the aquifer Transmissivity (T). The Storage Coefficient (S) cannot be estimated from single-well test data, therefore we solved for T using a range of reasonable estimates of S from the literature and from our previous experience evaluating aquifer test data in similar geologic materials in the region. Depending on the aquifer conditions and drawdown responses, a variety of solutions were used including radial solutions such as the Theis and Cooper-Jacob solutions (Theis, 1935; Cooper & Jacob, 1946), as well dual-porosity solutions such as the Moench slab blocks solution (Moench, 1984). Where more than one solution provided an equally valid description of the data, final T values used in the model were derived by averaging the estimates from the individual solutions.

An additional 19 tests also met the afore-mentioned criteria with the exception of the time-drawdown data which was not detailed enough for type-curve matching to drawdown data (Figure 17). For these tests, the Specific Capacity (Sc) was calculated and used to estimate T using an empirical relationship (Driscoll, 1986). We found good agreement between the T values estimated in AQTESOLV and the T values derived empirically using Sc suggesting that the simplified Sc-based approach is capable of providing reasonable estimates of T (Table 5). The dual-porosity solutions yield an estimate of the Hydraulic Conductivity (K) directly, and T values from the radial solutions were converted to K estimates using the aquifer thickness as derived from the test data and well completion details (Table 6).

We grouped the test data into five categories based on the dominant lithology as interpreted from available WCRs. Test data were classified as representative of Franciscan Complex or one of four categories within in the Sonoma Volcanics: predominately tuff, predominately basalt, predominately andesite, or a mixture of tuffaceous and other volcanics. There are obvious contrasts in well completion details and responses to pumping between the various lithologies with shallower wells (mean of 158-ft) and limited drawdowns (mean of 1.7-ft) within the tuff and deeper wells (mean of 387-ft) and larger drawdowns (mean of 9.9-ft for basalt and 48-ft for andesite) in the hard rock volcanics. Wells in the Franciscan Complex were also generally deeper (mean of 331-ft) and experienced much larger drawdowns (mean of 214-ft) (Table 6).

We calculated the geometric mean of the K estimates for the Sonoma Volcanics for each lithologic category and found that K values varied by nearly two orders of magnitude between the various volcanic materials. The highest value, 23 ft/day, was found for the tuff, followed by the mixed volcanics (3.7 ft/day), and the basalt (0.94 ft/day) and andesite (0.37 ft/day). In the Franciscan Complex, K values were an order of magnitude lower than the andesite (geometric mean of 0.029 ft/day) (Table 6).

No pump test data was available for wells screened entirely within the Glen Ellen Formation, the Humbug Creek Lacustrine Deposits, or the Quaternary Alluvium. This is not surprising given that our analysis showed that few if any wells are completed in these materials which are generally thin and often unsaturated. We relied on descriptions of the geologic materials as described in geologic logs on available WCRs to estimate K values for these materials from literature values (Domenico & Schwartz, 1990). Our initial estimates of K for the coarse-grained northern exposure of the Glen Ellen Formation was 30 ft/day and 0.038 ft/day for the fine-grained southern exposure and for the Humbug Creek deposits. Initial estimates for the alluvium were 30 ft/day in most of the study area and 120 ft/day for the thicker alluvial body delineated upstream of the confluence of Mark West and Porter Creek.

As described in Chapter 5, the initial K estimates were adjusted within reasonable limits to obtain a good fit between measured and simulated potentiometric surface elevations measured at monitored wells and baseflows as described from stream gauge data. Within the Sonoma Volcanics, values were adjusted using a uniform scaling factor in order to maintain the degree of contrast between materials as described from the pump test analyses. The final calibrated values are ~3.8% of the original estimates within the Sonoma Volcanics, the Glen Ellen Formation, and the Humbug Creek deposits. Final values for the Franciscan are ~3.2% of the original estimates, and final values for the alluvium were left unchanged (Table 7). The differences between the original and final values are generally within an order of magnitude of the range of estimates from individual pump tests. These differences are significant but also relatively modest considering that K varies by at least six orders of magnitude in the various materials in Sonoma County and that K estimates for individual pump tests evaluated in this project vary by more than four orders of magnitude. It is plausible that values derived from pump tests over-estimate bulk K values for the large sequences of geologic materials represented by the model layers since most drillers of production wells seek to preferentially screen wells within tuffaceous or highly fractured bedrock intervals to maximize well production and efficiency. Anisotropy in the form of the ratio between horizontal and vertical K was derived through calibration, and the final value was 94 in all units except the alluvium which was parameterized as isotropic.

<u>Specific Yield and Storage Coefficient Values</u>
Previous estimates of the Specific Yield (Sy) for the Sonoma Volcanics range from less than 0.01 to 0.05 and estimates for the Glen Ellen Formation range from 0.03 to 0.20 (Cardwell, 1958; Herbst et al. 1982). Our final calibrated value for Sy in the Sonoma Volcanics was 0.05, and we

Table 5: Comparison of estimates of Transmissivity (T) derived from pump test data analyzed in AQTESOLV and calculated based on the Specific Capacity (Sc).

Material	AQTESOLV T (ft^2/day)	Sc Derived T (ft^2/day)
Sonoma Volcanics	350	710
Sonoma Volcanics	930	1200
Franciscan Complex	1.2	4.9
Franciscan Complex	16	11

Table 6: Pump test and well completion details and estimates of aquifer Hydraulic Conductivity (ft/day).

	Well Depth (ft)	Drawdown (ft)	Test Length (min)	Average Pumping Rate (gpm)	Aquifer Thickness (ft)	Sc (gpm/ft)	K (ft/day)	Source
Sonoma Volcanics Tuff	100	1.7	480	11.4	118	6.7	15	Sc
	150	2.0	480	17.0	138	8.5	16	Sc
	260	2.0	510	25.3	177	13	19	Sc
	70	1.8	480	10.7	61	5.9	26	Sc
	210	1.1	480	14.2	70	13	49	Sc
	158	**1.7**	**486**	**15.7**	**113**	**9.3**	**23**	
Sonoma Volcanics Basalt	807	6.0	510	4.0	177	0.67	1.0	Sc
	420	13.0	480	11.6	215	0.89	1.1	Sc
	200	10.8	500	13.7	140	1.3	2.4	Sc
	476	**9.9**	**497**	**9.8**	**177**	**0.94**	**1.4**	
Sonoma Volcanics Andesite	320	86.0	510	5.0	144	0.06	0.11	Sc
	460	49.0	600	5.0	209	0.10	0.13	Sc
	420	47.0	480	45.3	386	1.0	0.67	Sc
	80	10.0	1440	3.5	91	0.35	1.0	Sc
	320	**48.0**	**758**	**14.7**	**208**	**0.37**	**0.31**	
Sonoma Volcanics Undifferentiated	260	20.0	1530	7.5	91	0.38	1.1	Sc
	220	8.0	1230	21.2	229	2.6	1.5	AQTESOLV
	320	25.0	720	30.0	143	1.2	2.2	Sc
	200	4.8	540	8.9	181	1.9	2.7	Sc
	305	2.0	540	4.4	79	2.2	7.4	Sc
	380	2.0	520	6.5	95	3.3	9.2	Sc
	76	3.3	730	14.7	65	4.4	14	AQTESOLV
	252	**9.3**	**830**	**13.3**	**126**	**2.3**	**3.7**	
Franciscan Complex	540	428.0	720	7.8	614	0.018	0.0019	AQTESOLV
	280	175.0	480	6.0	270	0.034	0.034	Sc
	245	209.9	875	8.3	296	0.040	0.054	AQTESOLV
	260	40.9	510	4.4	152	0.11	0.189	Sc
	331	**213.5**	**646**	**6.6**	**333**	**0.050**	**0.029**	

Table 7: Final hydrogeologic properties used in the calibrated MWC hydrologic model.

Material	Present in Layers	Kh (ft/day)	Kh/Kv	Sy	S (ft^{-1})
Sonoma Volcanics	1 to 6	0.0082 - 0.60	94	0.05	2.0E-04
Franciscan	1 to 6	0.00090	94	0.10	1.1E-05
Glen Ellen	1 to 2	0.0010 - 0.79	94	0.04 - 0.20	1.0E-04 - 5.4E-04
Humbug Creek	1	0.001	94	0.04	5.4E-04
Alluvium	1	30 - 120	1	0.30	1.5E-04

Table 8: Range and average Hydraulic Conductivity (K) values for the Sonoma Volcanics in model Layers 1 through 6.

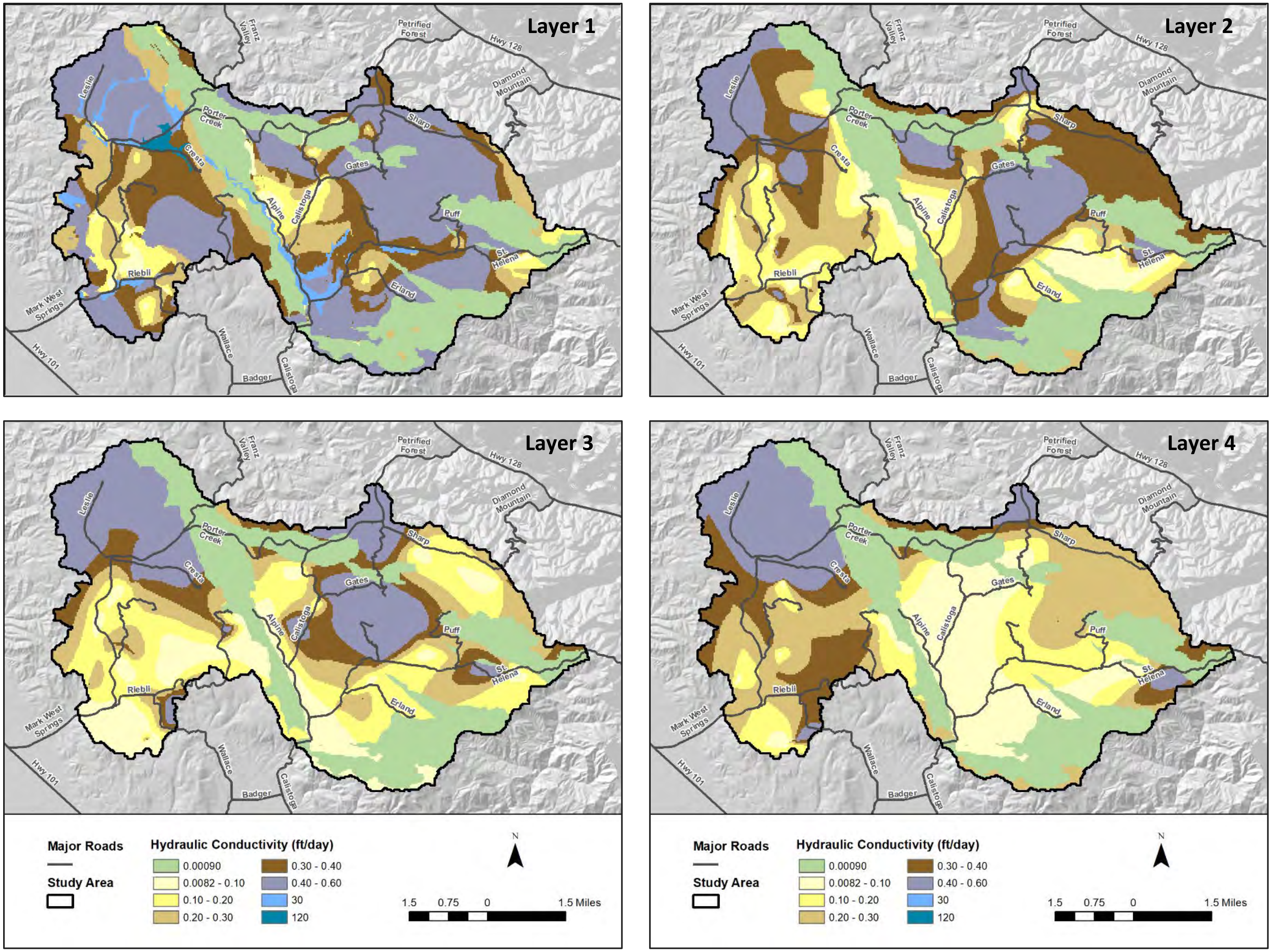
Layer	Sonoma Volcanics Kh (ft/day)	
	Range	Mean
1	0.0082 - 0.60	0.40
2	0.0082 - 0.60	0.29
3	0.0082 - 0.60	0.28
4	0.0082 - 0.60	0.24
5	0.0082 - 0.60	0.21
6	0.0082 - 0.32	0.10

used a value of 0.04 in the fine-grained Reibli Creek exposure of the Glen Ellen and 0.20 in the coarser Leslie Creek exposure (Table 7). No estimates of Sy were available for the Franciscan Complex, the Humbug Creek Deposits, or the Alluvium in the study area, thus estimates were based on literature values from similar materials (Freeze & Cherry, 1979; Domenico & Schwartz, 1990). We used values of 0.04, 0.10, and 0.30 for the Humbug Creek, Franciscan, and alluvium respectively (Table 7). Johnson (1977) estimated a value for the Storage Coefficient (S) for the Sonoma Volcanics of 1.6E-04 (ft^{-1}). No estimates of S are available for the other geologic materials in the watershed; therefore, estimates were based on literature values from similar materials (Domenico & Mifflin, 1965). Values ranged from 1.1E-05 (ft^{-1}) for the Franciscan Complex to 5.4E-04 (ft^{-1}) for the Humbug Creek Deposits (Table 7).

Hydrogeologic Property Distributions

As described above under the heading Distribution and Description of Geologic Materials, we classified geologic materials within the Sonoma Volcanics in each vertical interval corresponding to one of the six model layers using the same four categories examined with the pump test analyses. We assigned each of the well locations with available stratigraphic information the corresponding geometric mean K value from the pump test analyses and interpolated K distributions for each layer in a GIS using kriging (Figure 19). K values for the other materials were assumed to be homogeneous and these materials were assigned corresponding K values from literature estimates as described above. The model layering was constructed such that the base of Layer 1 corresponded to the base of the Quaternary Alluvium; therefore, K estimates were used directly in the model for areas of Layer 1 with alluvium. For the Humbug Creek deposits and lower portions of the Glen Ellen Formation which do not penetrate the full thickness of Layer 1, we calculated a depth-averaged K value based on the relative thicknesses of these materials and underlying formations (Figure 19).

The interpolated K maps for the Sonoma Volcanics reveal that tuffaceous material is widespread in the watershed and that the proportion of tuffaceous versus other volcanic rocks (principally andesite and basalt) generally decreases with depth as is apparent from the mean K value for the volcanics which decreases from 0.40 in Layer 1 to 0.10 in Layer 6 (Figure 19). A significant block of primarily tuffaceous material is present in the upper Mark West and Humbug Creek watersheds, and the interpreted WCRs indicate that the volcanics become dominated by andesite below about 300-ft (Figure 19). Another significant block of primarily tuffaceous material underlies the Glen Ellen Formation in the Leslie Creek watershed where it extends from the base of the Glen Ellen to about 400-ft below land surface and becomes more basaltic-dominated material at greater depths. A third relatively thin block of tuff occurs at greater depth (400 to 500-ft below land surface) in portions of the lower watershed, and less widespread and generally thin blocks of tuff are also present in other portions of the upper Mark West and Porter Creek watersheds (Figure 19).


Layer 1
Layer 2
Layer 3
Layer 4
Franz Valley
Petrified Forest
Hwy 128
Diamond Mountain
Leslie
Porter Creek
Sharp
Cresta
Gates
Alpine
Calistoga
Puff
St. Helena
Riebli
Erland
Mark West Springs
Hwy 101
Wallace
Badger
Major Roads
Study Area
Hydraulic Conductivity (ft/day)
0.00090
0.0082 - 0.10
0.10 - 0.20
0.20 - 0.30
0.30 - 0.40
0.40 - 0.60
30
120
N
1.5 0.75 0 1.5 Miles

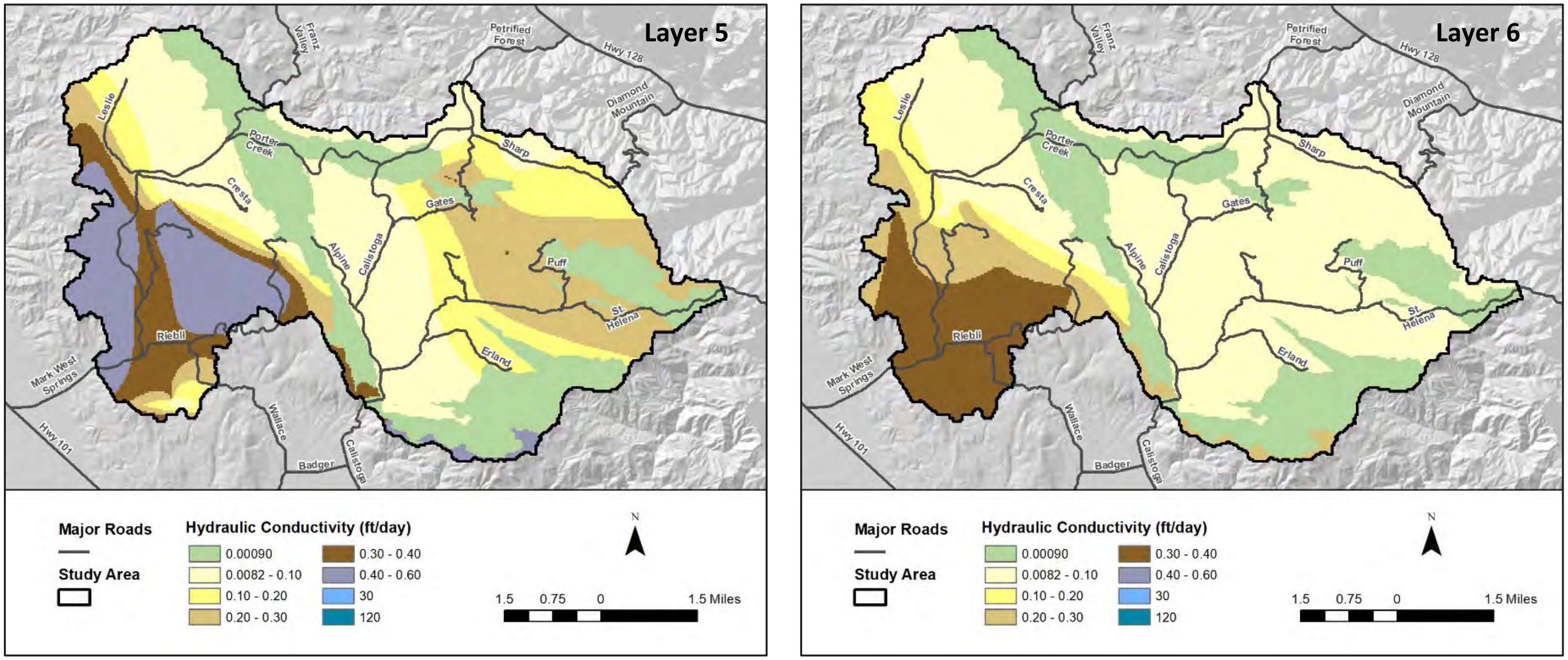


Figure 19: Horizontal Hydraulic Conductivity distributions for model Layers 1 through 6.

Water Use

Water Use Categories and Spatial Distribution

Water uses were calculated on a parcel by parcel basis. We identified the following use categories: Residential, Vineyard Irrigation, Pasture Irrigation, Cannabis Irrigation, Irrigation of Other Miscellaneous Crops, Vineyard Frost Protection, Winery Production and Visitation Use, and Miscellaneous Industrial Uses. The water uses on each parcel were identified using a variety of remotely sensed data and other datasets provided by various governmental entities. Acreages of vineyard, pasture, and other croplands were obtained from the Sonoma County Vegetation Mapping & LiDAR Program's Fine Scale Vegetation and Habitat Map (SCVMLP, 2015). Satellite imagery was reviewed to verify the accuracy of the identified agricultural lands and to identify vineyards planted after 2013 when the underlying LiDAR dataset on which this map is based was collected. In total we found 442.4 acres of vineyard and 12.8 acres of irrigated pasture and other crops (primarily olives).

All vineyards with frost protection systems that use water are required to register with the Sonoma County Agricultural Commissioner's office. Most vineyards in the model domain are located on ridgetops and hillsides where vineyards in Sonoma County are generally less likely to require frost protection than vineyards located on valley bottoms. Additionally, some vineyards may also have permanent or portable fans or heaters for frost protection. A review of the Sonoma County Frost Protection Registration database revealed that three parcels within the model domain are registered as using water for frost protection. One additional parcel with vineyard in the model domain indicated in the SWRCB's 2015 Russian River Information Order (SWRCB Information Order) that they also use water for frost protection. One of these vineyards obtains water from ponds located outside the watershed and three use groundwater from within the watershed. The three vineyards using water from within the watershed for frost protection total 16.9 acres.

Existing cannabis cultivation operations were identified from registration and permit records from the NCRWQCB and the County of Sonoma. It is common knowledge that many existing operations are not identified in the permit system. To account for water use by unregistered cannabis cultivators, we reviewed publicly-available satellite imagery and identified the size and location of all visible cultivation sites in the watershed. In total we identified 47 parcels with outdoor and mixed-light cannabis operations totaling approximately 9.8 acres of cultivation area. Indoor operations could not be identified by aerial imagery and thus this component of cannabis irrigation use may be under-estimated.

The number of residences on each parcel was obtained from the County of Sonoma's parcel GIS coverage. Seven small mutual water companies and the City of Santa Rosa each serve a small area in the southwest portion of the watershed. Information about the well locations and number of residences supplied by each well was obtained from the SWRCB's State Drinking Water Information System (SDWIS) and used to adjust the residential use estimate to account for residences supplied by water from outside the watershed and residences not in the watershed but supplied by water from within the watershed. Census block data from the 2010

U.S. Census provided an estimate of the total population served by water from the watershed. When combined with the corresponding number of residences, this yields an estimate of the average number of people per residence (2.09) which could then be used along with per capita use rates to calculate the total residential use for each parcel. In total there are approximately 2,518 people served by water obtained from within the watershed.

Winery production volumes and annual guest visitation totals were obtained from a GIS dataset provided by the County of Sonoma. Total winery production for the eight wineries in the watershed is approximately 44,300 cases per year. There are only two primary industrial users in the watershed which were handled on a case-by-case basis. Quarterly water use volumes for Mark West Quarry were obtained from reports submitted to the County of Sonoma, and monthly groundwater pumping volumes for Safari West were obtained from the SWRCB Information Order. No use for the Mayacama Golf Club was included since productions wells for the golf club and associated residences are located outside the study area.

Standard Use Rates

Standard use rates were established for the various use categories in the study area using data from the SWRCB Information Order, local municipalities, and literature sources. We examined rates and use categories from the SWRCB Information Order and identified those entries in and around the study area where rates were reported to be based on physical measurements such as totalizer readings or pump fuel usage. In most cases, the method of use estimation was unknown or not based on physical measurements. Given the uncertainty in the accuracy of these estimates, we only relied on those estimates based on physical measurements. In many cases, the reported uses contained a mix of use types (e.g. vineyard irrigation and residential) which prohibited calculation of per acre irrigation or per capita residential use. After careful examination of the data, we were only able to identify four parcels where residential use could be reliably estimated and three parcels where vineyard irrigation use could be estimated.

Total annual per capita use calculated for the four residential parcels in the Mark West Creek watershed for 2014/2015 averaged approximately 23,100 gallons (0.071 acre-ft/yr). We compared the annual use estimates to data from the nearby Town of Windsor. Based on the available data from the SWRCB's Water Conservation and Production Reports from 2014 to 2018, the average annual per capita use was approximately 26,700 gallons (0.082 acre-ft/yr) which is in reasonably good agreement with the Mark West data. Due to the small sample size of the local data, the calculated monthly averages are heavily influenced by individual users, whereas the Windsor data is based on thousands of connections and is therefore expected to provide a better estimate of typical use in the area. We relied on the average per capita monthly data from the Town of Windsor to generate use estimates for the model (Table 9 & Figure 20); it is acknowledged that this method may over- or under-estimate actual residential use in the study area.

Total annual vineyard irrigation use for the three parcels in the Mark West Creek watershed for 2014/2015 (totaling 80 acres of vineyard) ranged from 0.21 to 0.53 ac-ft/ac/yr. As part of a parallel project in the Mill Creek Watershed, we obtained recycled water delivery data for

2017/2018 from the City of Healdsburg for four parcels in the Dry Creek Valley totaling 142 acres which provided a very accurate means of estimating vineyard irrigation rates for the region and validating the estimates derived from the SWRCB Information Order data. The Dry Creek data showed very similar annual rates ranging from 0.17 to 0.55 ac-ft/ac/yr, and the average annual total calculated from the Mark West parcels (0.32 ac-ft/ac/yr) was nearly identical to the average annual total calculated in Dry Creek (0.31 ac-ft/ac/yr). To provide a more robust estimate of the temporal distribution of vineyard irrigation we calculated monthly mean rates from the three parcels in Mark West plus the four parcels in Dry Creek for use in the model, which yields mean annual use of 0.32 ac-ft/ac/yr (Table 9 & Figure 20). In the model, vineyards are irrigated from May through October with irrigation peaking at 0.09 acre-ft/acre/month in June (Figure 20).

Based on guidance provided by the University of California Davis and Sonoma RCD, the timing of water use for frost protection is based on the wet-bulb temperature (Snyder, 2000; Minton et al., 2017). Wet bulb temperature was calculated on an hourly timestep using air temperature and relative humidity data from the Windsor CIMIS station (Stull, 2011). Frost protection is assumed to occur any time the hourly wet bulb temperature is 0.5°C or lower during the typical March 15th – May 15th frost protection season. The rate at which each parcel uses water for frost protection was calculated as the product of vineyard acreage and reported sprinkler and micro-sprinkler application rates as described in the Sonoma County Frost Protection Registration database (Table 9). Based on these assumptions, the annual number of hours of frost protection ranged from one in 2013 to 25 in 2011, the average annual application rate was 0.069 ac-ft/ac/yr, and the maximum rate was 0.18 ac-ft/yr.

Table 9: Standard water use rates and summary of total water use for the various use categories represented in the MWC hydrologic model.

Use Category	Unit Definition	Use per Unit (ac-ft/yr)	# of Units	Total Use (ac-ft/yr)
Residential	Person	0.082	2,518	206.5
Vineyard Irrigation	Acre	0.32	442.4	141.6
Vineyard Frost Protection	Acre	0.069	16.9	1.2
Pasture/Other Irrigation	Acre	2.00	12.8	25.6
Outdoor Cannabis	Acre	1.34	5.9	7.9
Hoop-house Cannabis	Acre	1.53	3.9	6.0
Winery	1,000 Cases of Wine	0.073	44	3.2
Misc. Industrial	Lump Sum	-	-	38.8
Sum				**430.7**

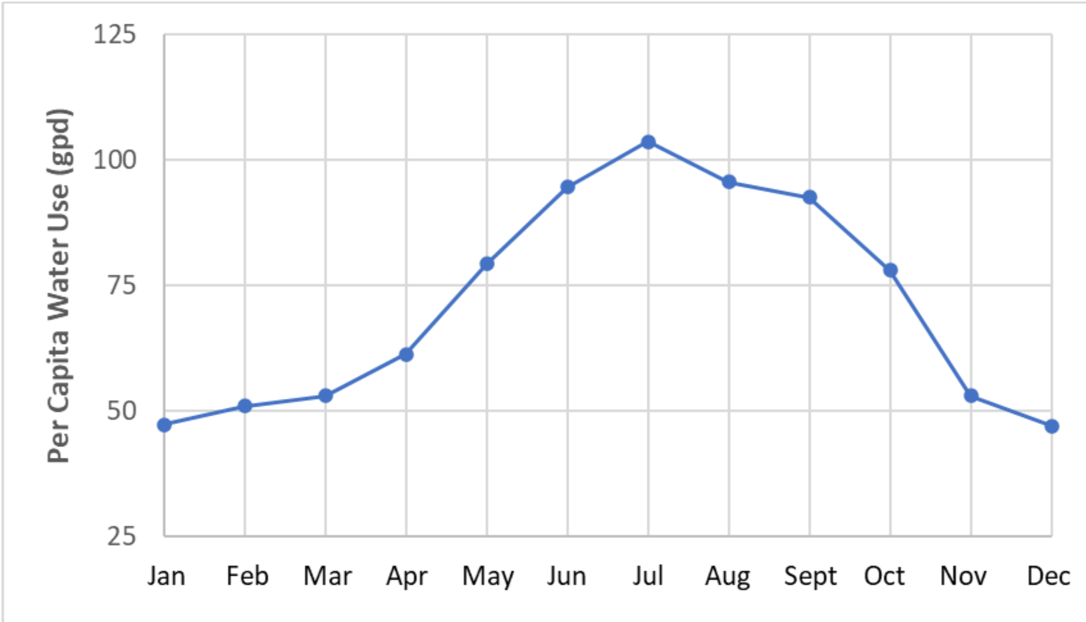


Figure 20: Mean (2014-2018) monthly per capita residential use from the Town of Windsor used to calculate residential use in the MWC hydrologic model.

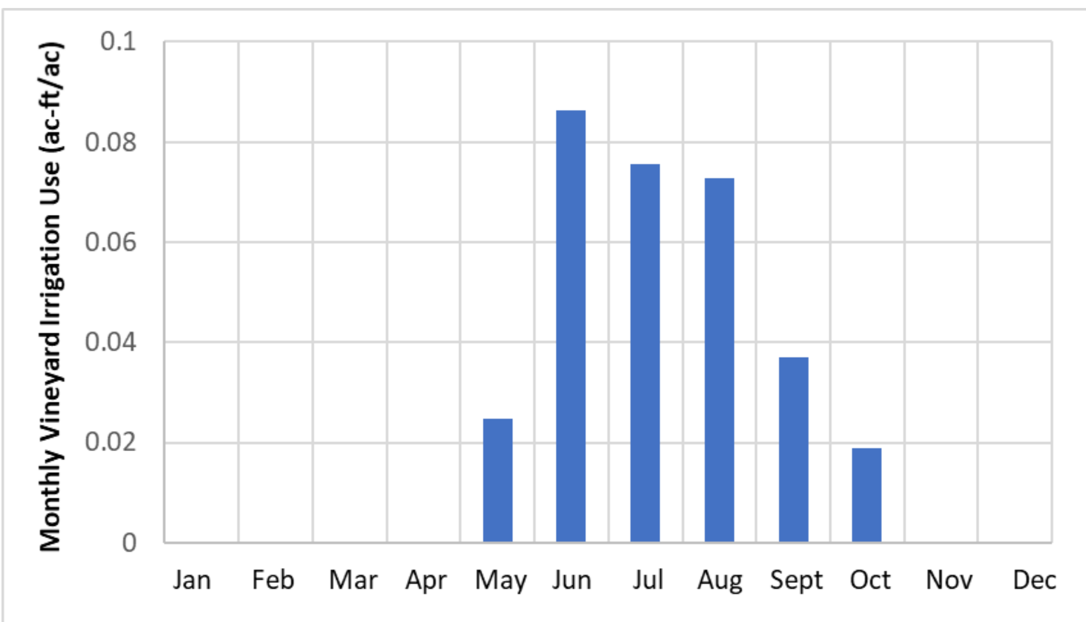


Figure 21: Mean (2014-2015 and 2017-2018) monthly per acre vineyard irrigation use compiled from Information Order data in the Mark West Creek watershed and recycled water delivery data in the Dry Creek Valley and used to calculate vineyard irrigation use in the MWC hydrologic model.

No reliable pasture irrigation rates could be determined from the available data, therefore we relied on a regionally-appropriate value of 2.0 ac-ft/ac/yr (County of Napa, 2015). Based on field reconnaissance and review of available aerial imagery and GoogleEarth Street View products, most orchards within the study area are mature walnut and apple orchards which are typically dry-farmed in Sonoma County. Less than 2 acres each of olive orchard and vegetable crops were identified and were assumed to be irrigated at rates similar to pasture. The total acreage of irrigated pasture, olive orchard, and vegetable crops in the study area is only 12.8 acres.

Cannabis use rates are based on cannabis irrigation data collected by the NCRWQCB for Humboldt, Mendocino, and Sonoma Counties. Typical irrigation rates of 1.34 ac-ft/acre/yr for outdoor cultivation and 1.53 ac-ft/acre/yr for hoop-house cultivation were selected based on a presentation summarizing this data which also provided a monthly distribution of use (Dillis, 2018) (Table 9).

Winery production, employee, and guest water use rates were based on the County of Napa's Water Availability Analysis Guidance Document (County of Napa, 2015) (Table 9). The monthly distribution of winery production was taken from the Winery Wastewater Handbook (Chapman et al., 2001). Winery guest use, which is relatively minor within the study area, was assumed to be constant throughout the year (Table 9). As discussed above Industrial use was based on parcel-specific reported rates from Sonoma County and the SWRCB Information Order rather than on standard rates.

Water Sources

Parcels with surface water diversions were identified from the SWRCB Electronic Water Rights Information Management System (eWRIMS) and the SWRCB Information Order. For unpermitted cannabis cultivation operations where the water source was unknown we assumed surface water use if there was a perennial stream, spring, or pond located on the parcel, which was the case for 9 of the 47 cannabis operations in the study area. For all other parcels we assumed groundwater use. Where multiple wells are located on a given parcel, we divided the total use for the parcel between the various individual wells. When eWRIMS or the SWRCB Information Order indicated that a parcel has both surface water and groundwater supplies, surface water diversions were subtracted from groundwater pumping.

After consolidating duplicate records from the various sources, we excluded diversions reported as inactive or with zero use, as well as those where the SWRCB Information Order states use; however, the reported uses are for evaporation losses and recreation or aesthetics rather than for consumptive uses. We only identified two off-channel ponds with small reported consumptive uses estimated to total approximately 1.3 ac-ft/yr which were accounted for as groundwater use given that the model does not explicitly represent off-stream ponds. For spring diversions, we attribute the location of the diversions to the nearest stream in our model, thus treating it as equivalent to a direct diversion. There are a total of 52 surface water diversions in the model, 24 of these are direct stream diversions, 19 are spring diversions, and 9 are diversions from on-stream ponds represented in the model (Diversion timeseries are based on average monthly diversion volumes. Where possible, reported diversion volumes from eWRIMS and the

SWRCB Information Order were used. If reported diversion volumes from the SWRCB Information Order were not based on physical measurements or if no diversion volumes were reported, volumes were calculated using the standard use rates for the uses on a given parcel.).

Where possible, wells were located at specific locations on a given parcel from location information available on WCRs, the SWRCB Information Order, and in some select cases site visits. The SWRCB Information Order was especially helpful in this regard by providing a means of tying many more wells to specific locations than would have otherwise been possible. Nevertheless, many of the locations reported in SWRCB Information Order data proved to be parcel centroids and it is not possible to locate all wells at a level of detail beyond the parcel scale. More specific location data was used for 458 of the 792 wells in the model. We initially placed all the remaining wells at parcel centroids, but review of the parcels along upper Mark West Creek and Humbug Creek revealed that residences in these areas are generally located much closer to the creek than the centroid of the parcel. There are certainly many exceptions, but wells are often placed in relatively close proximity to the areas they serve, so to avoid over-estimating the distances between wells and streams, we placed theses stream-side parcel wells along upper Mark West Creek and Humbug Creek at the centroids of the residences as indicated by the impervious areas delineated in the Sonoma County fine-scale vegetation mapping data (SCVMLP, 2017).

Well completion details could be determined from WCRs for 189 wells and we associated the wells without WCRs with the nearest well with a WCR within the same geologic terrain to estimate well depth and screened interval information for all wells in the model. About 47% of the wells are screened at least partially within the upper 100-ft of aquifer material but most of these are screened to greater depths with only 5% of the wells screened entirely in the upper 100-ft. About 34% of the wells are screened entirely within the upper 200-ft of aquifer material and about 78% are screened entirely within the upper 400-ft with the remainder screened within the upper 700-ft (Figure 22).

Water Use Timeseries

Surface Water Diversions

Diversion timeseries are based on average monthly diversion volumes. Where possible, reported diversion volumes from eWRIMS and the SWRCB Information Order were used. If reported diversion volumes from the SWRCB Information Order were not based on physical measurements or if no diversion volumes were reported, volumes were calculated using the standard use rates for the uses on a given parcel. The monthly volumes calculated for each diversion are used to calculate a diversion timeseries. These timeseries were calculated on a 6-hour timestep and account for pumps shutting on and off and the estimated capacities of these pumps. A 6-hour timestep was selected to provide a reasonable representation of sub-daily variability while maintaining reasonable computational efficiency. Separate pumping regime assumptions are made for direct diversions and for spring and pond diversions.

Direct diversions were assumed to fill storage tanks completely and then resume once these tanks had been partially emptied. Based on storage tank sizes reported in the SWRCB

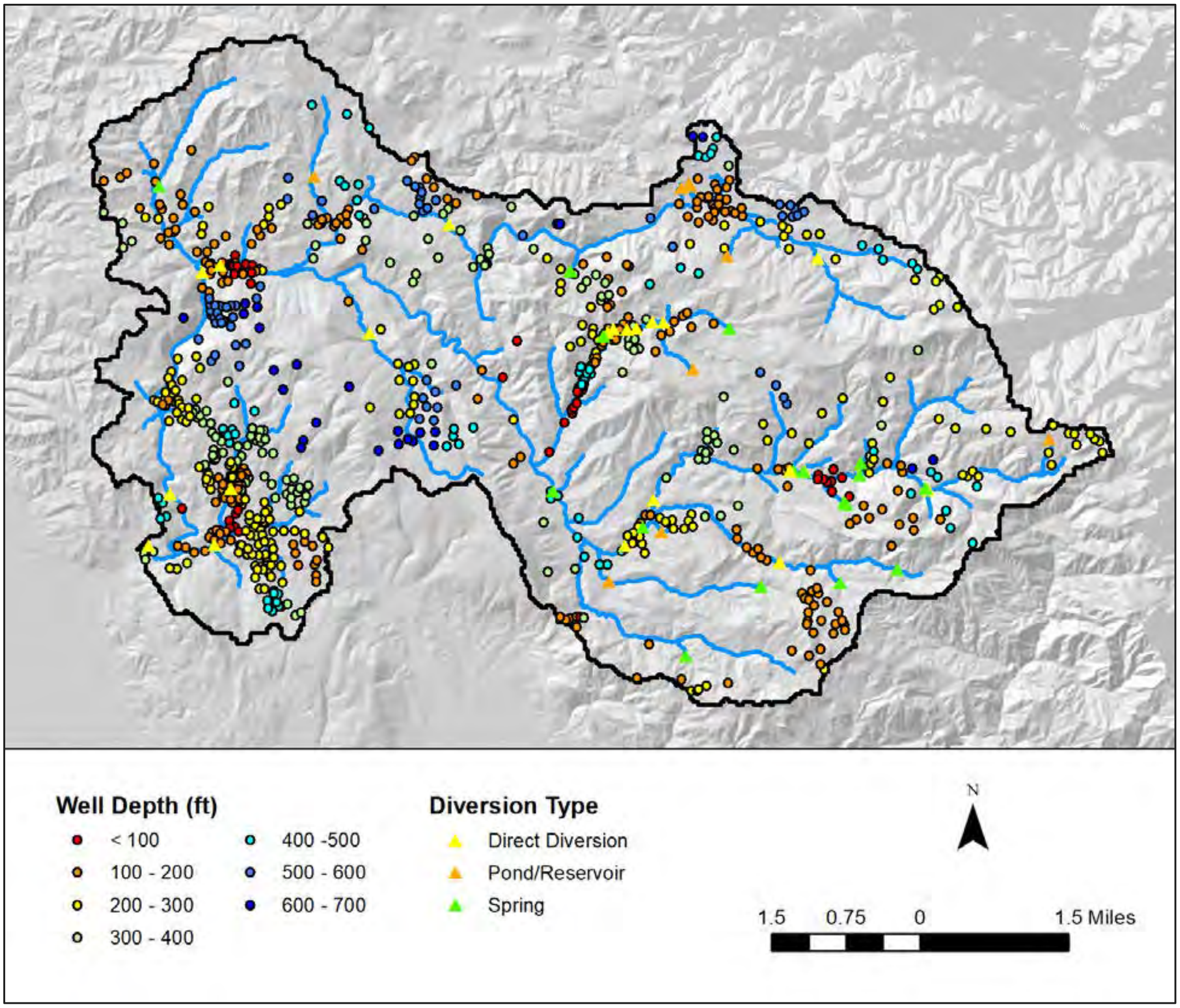


Figure 22: Locations of surface water diversions and groundwater wells in the MWC hydrologic model.

Information Order, the typical tank size for a residence with a direct diversion is approximately 3,000 gallons. Such a tank would need to be filled completely twice a month to supply a typical residence, or approximately four times per month if the tank were only partially emptied. Less data is available for agricultural tank sizes but the limited data supports use of a similar pumping frequency. Consequently, direct diversions were assumed to divert a fraction of the monthly volume on the 1st, 8th, 15th, and 22nd of each month. Some diversion volumes were met using the assumed pumping rates with less than four pumping events per month, in which case they are only active 1-3 times per month depending how quickly the demand is met for each month. For larger demands, the four per month diversion periods were assumed to continue for as long as necessary based on the diversion rate. Typical spring and pond diversions deliver water in near real-time and thus do not require large storage tanks. This results in more frequent, shorter-duration pumping intervals relative to direct diversions. Therefore, daily use was calculated from the monthly volumes and all daily use was considered to be supplied during a single 6-hour timestep.

In addition to developing estimates of the frequency and duration of diversions, it is necessary for modeling to assume a start time. There is likely little to no coordination between diverters regarding the timing of pump activation, and probably some general tendency for coincident pumping due to coincident timing of irrigation demands and work schedules. We made the conservative assumption that all diversions start simultaneously at the beginning of the day, and the diversions on weekly schedules all occur on the same days. These various assumptions result in a maximum instantaneous diversion rate on the 1st of each month, and spikes in rates at regular intervals which is considered to represent a 'worst case' diversion timing scenario (Figure 25).

Where possible the diversion rates used to calculate the diversion timeseries were obtained from eWRIMS or the SWRCB Information Order. However, most diversions rates were either not reported or the reported rates were not realistic given the reported units. Where specific rates were not available, standard rates were used as derived from reported rates in the SWRCB Information Order that were based on actual physical measurements. Standard rates were derived for two diversion types: domestic/small agricultural operations and larger agricultural operations. We combined our analysis of the SWRCB Information Order data for Mark West Creek with analysis of the data for Mill Creek where we are completing a parallel modeling study, and we also restricted the selected entries to include only those based on physical measurements. Based on twelve diversions from the Mark West and Mill Creek Watersheds, the typical residential and small agricultural diversion rate is estimated to be 2.69 gpm (0.006 cfs). Diversion rates for larger agricultural operations varied greatly but typically ranged between 0.01 and 0.03 cfs and a typical diversion rate of 9.0 gpm (0.02 cfs) was used. A monthly timeseries of the total direct and spring diversion volumes and the total pond diversion volumes in the model is shown in Figure 23 and Figure 25, and an example of the 6-hr interval total direct and spring diversion timeseries for July 2010 is shown in Figure 25.

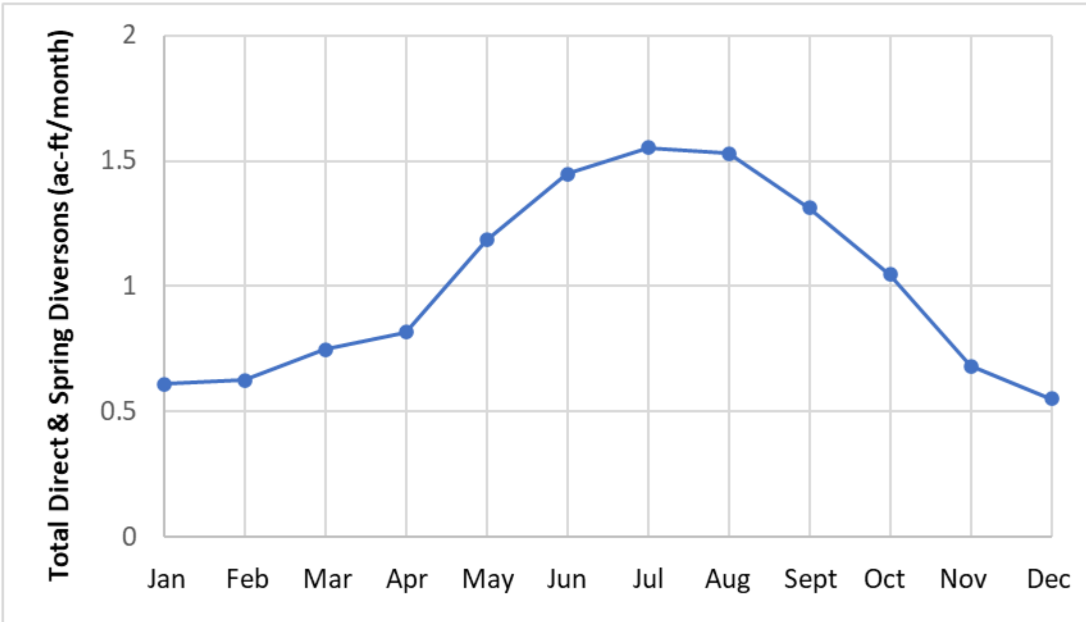


Figure 23: Total monthly direct and spring diversion volumes used in the MWC hydrologic model.

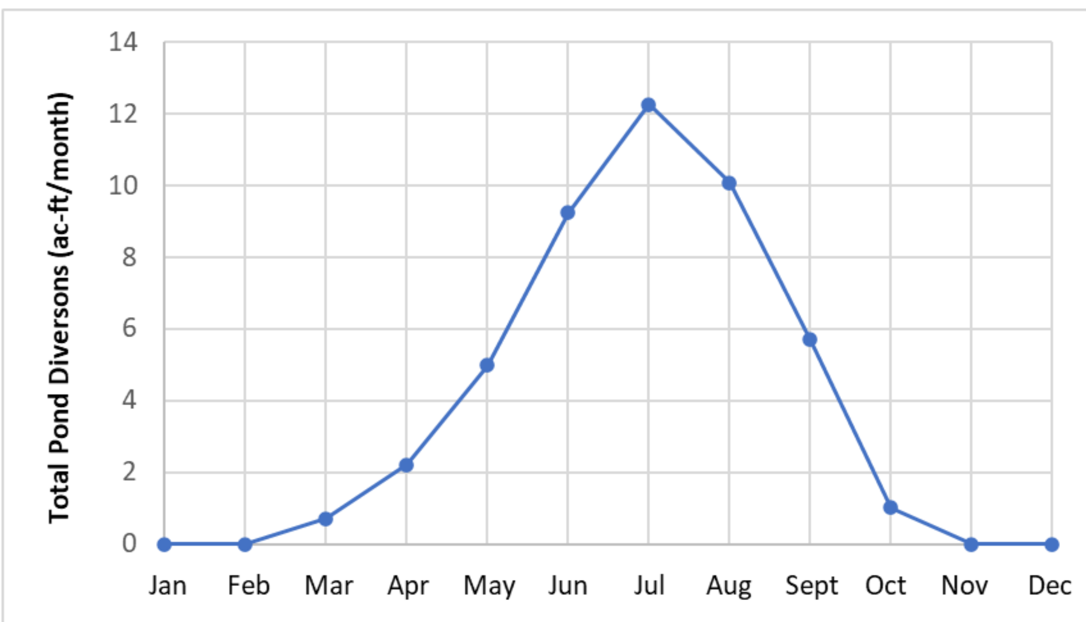


Figure 24: Total monthly pond diversion volumes used in the MWC hydrologic model.

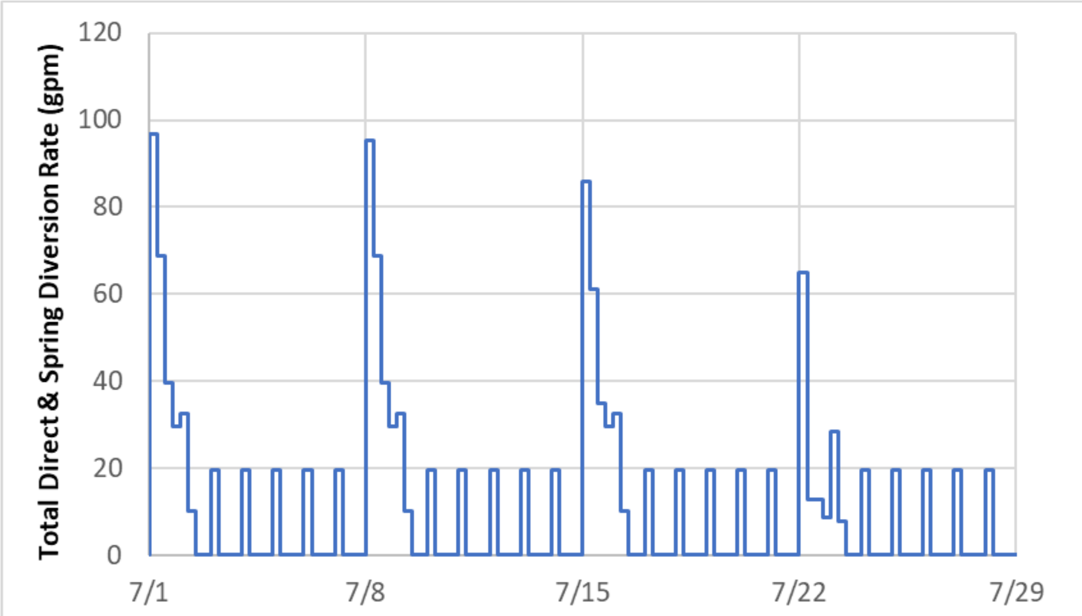


Figure 25: Example of the 6-hr interval timeseries of total direct and spring diversions used in the MWC hydrologic model for July of 2010.

Groundwater Wells

Wells are assumed to be pumped on a daily basis, either supplying water in real-time or topping off a tank. The groundwater pumping timeseries was calculated by converting estimated monthly volumes to a daily demand and pumping each well at its estimated yield until this daily demand was met. This timeseries was calculated on an hourly timestep consistent with the hourly timestep used to drive the groundwater component of the model. Estimated yields are based on pump test data associated with Well Yield Certifications obtained from the County of Sonoma as analyzed and discussed in the Aquifer Properties section above. Typical yields of 13.7 gpm and 6.6 gpm were calculated for the Sonoma Volcanics and the Franciscan Complex respectively (Table 6). Other geologic materials in the watershed including the Quaternary Alluvium, the Glen Ellen Formation, and the Humbug Creek Deposits are not a significant source of water to wells as discussed above under the heading Distribution of Geologic Materials.

Wells supplying large vineyards, used for frost protection, or supplying multiple connections as mutual water company wells are likely have higher than average yields. To account for this, the maximum daily pumping duration is capped at 6 hours per day. If a well cannot supply the required daily volume within this 6-hour window, the pumping rate was increased until it could. The pumping rates used for these wells, up to 78 gpm in the Sonoma Volcanics and up to 37 gpm in the Franciscan, are still within the range of reasonable values for these formations.

The only component of pumping that varies in the model from year to year is the frost protection pumping which accounts for a relatively small component of the total pumping. A monthly timeseries of the total groundwater pumping volumes applied in the model is shown in Figure 26 and an example of the hourly total pumping timeseries for 1 3-day period in early July is shown in Figure 27.

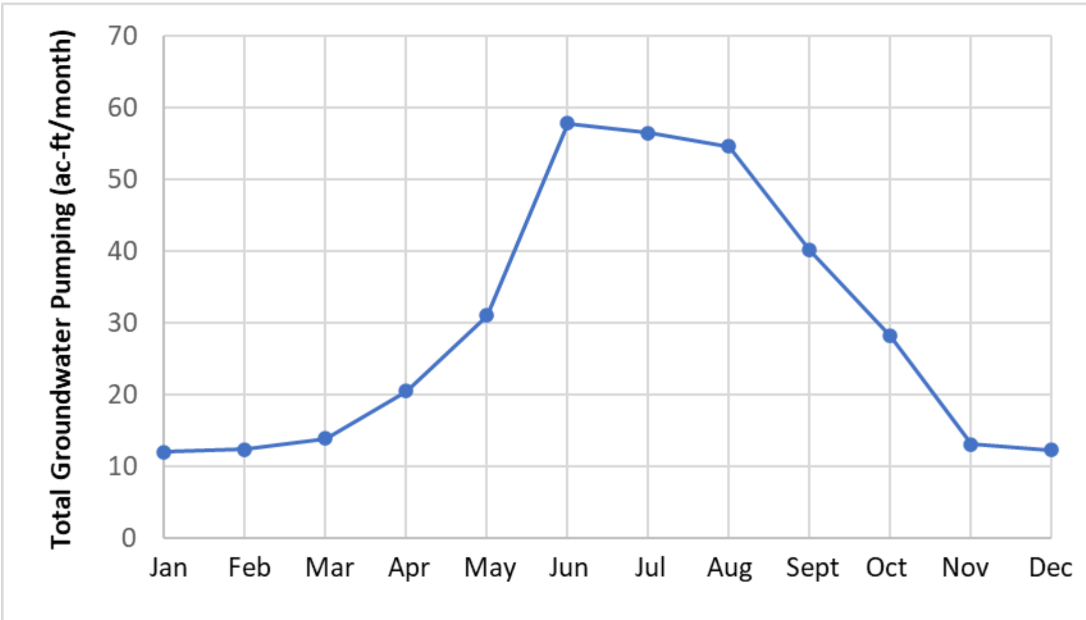


Figure 26: Total monthly groundwater pumping volumes used in the MWC hydrologic model.

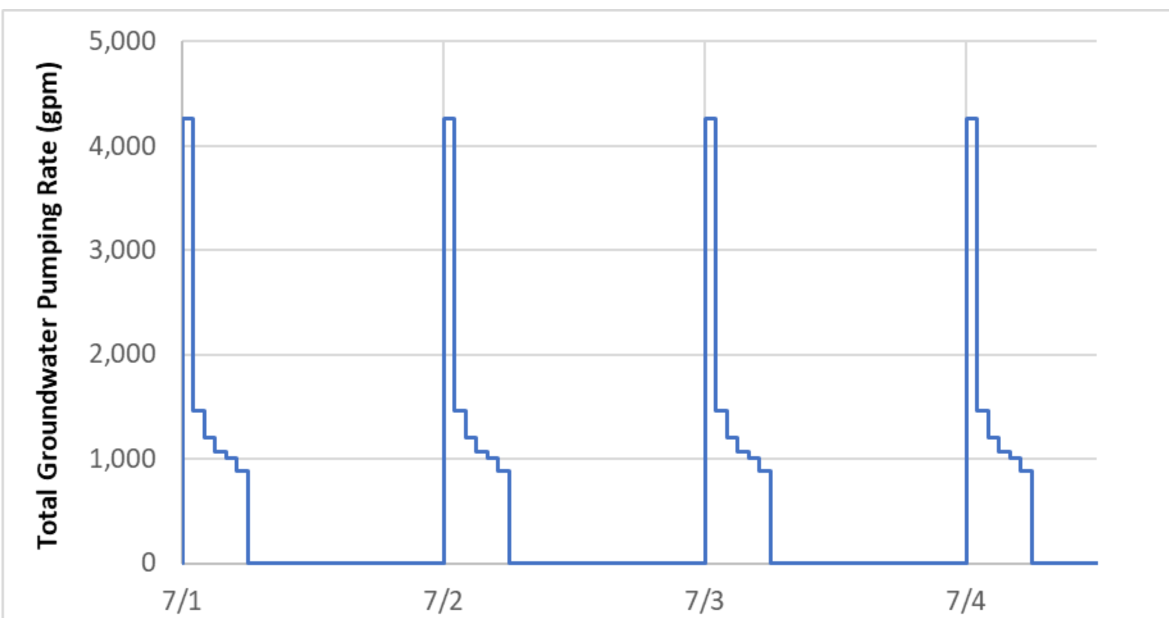


Figure 27: Example of the 1-hr interval timeseries of total groundwater pumping in the MWC hydrologic model for a 4-day period in early July.

Water Use Summary

Total water use from all sources in the watershed is estimated to be approximately 430.7 ac-ft/yr. The largest uses are residential and vineyard irrigation which account for about 48% and 33% of the total water use (Table 9; Figure 28). Industrial uses account for the next largest fraction at about 9%. The remaining 10% consists of irrigation for pasture and other crops (6%), irrigation of cannabis (3%), winery use (<1%), and vineyard frost protection (<1%) (Table 9; Figure 28). About 85% (367.1 ac-ft/yr) of the total use in the watershed is from groundwater with the remaining 15% (63.6 ac-ft/yr) coming from surface water sources. About 81% (51.5 ac-ft/yr) of the total surface water use comes from pond storage, 10% (6.7 ac-ft/yr) comes from direct stream diversions, and 9% (5.4 ac-ft/yr) comes from springs.

Direct stream and spring diversions are concentrated in Humbug Creek, and upper Mark West Creek in and upstream of Van Buren Creek (Figure 22). The highest concentration of wells occurs in the Reibli Creek subwatershed which is generally more urbanized given its proximity to the City of Santa Rosa. Higher concentrations of wells also occur in upper Mark West Creek, upper Porter Creek, and the lower Leslie Creek area (Figure 22). The pattern of development in the watershed has tended to occur along the stream corridors as can be seen in the well distribution with 50% of the wells located within 500-ft of a stream and 73% located within 1,000-ft (based on the modeled stream extent).

Irrigation

The water extracted from wells and surface water diversions for irrigation of vineyards, pasture, and other crops is applied to the land surface as irrigation in the model (see Figure 9 for locations of irrigated crops in the model). The monthly application volumes match the standard use rates as discussed above. Based on previous work with vineyard operators in Sonoma County, vineyards are typically irrigated at intervals of about one week to one month. We assumed a twice-monthly irrigation schedule and developed our irrigation timeseries by distributing the monthly volumes between the two irrigation events each month. We assumed a similar irrigation frequency for pasture and other irrigated crops in the model. Although many vineyard operators use a block rotation schedule for irrigation, the twice-monthly schedule accounts for the temporal effects of irrigation on soil moisture and is decoupled in time from the extraction of that water which is based on assumed pumping rates and tank storage volumes as discussed above. We did not apply water used for cannabis as irrigation in the model since cultivation areas are generally smaller than the 0.5-acre grid scale and many cultivators use pots or fabric bags which limit the potential for interaction with surrounding soils. Water for frost protection of vineyards was also applied back to the land surface as irrigation in the model in real-time based on the calculated demand as discussed above.

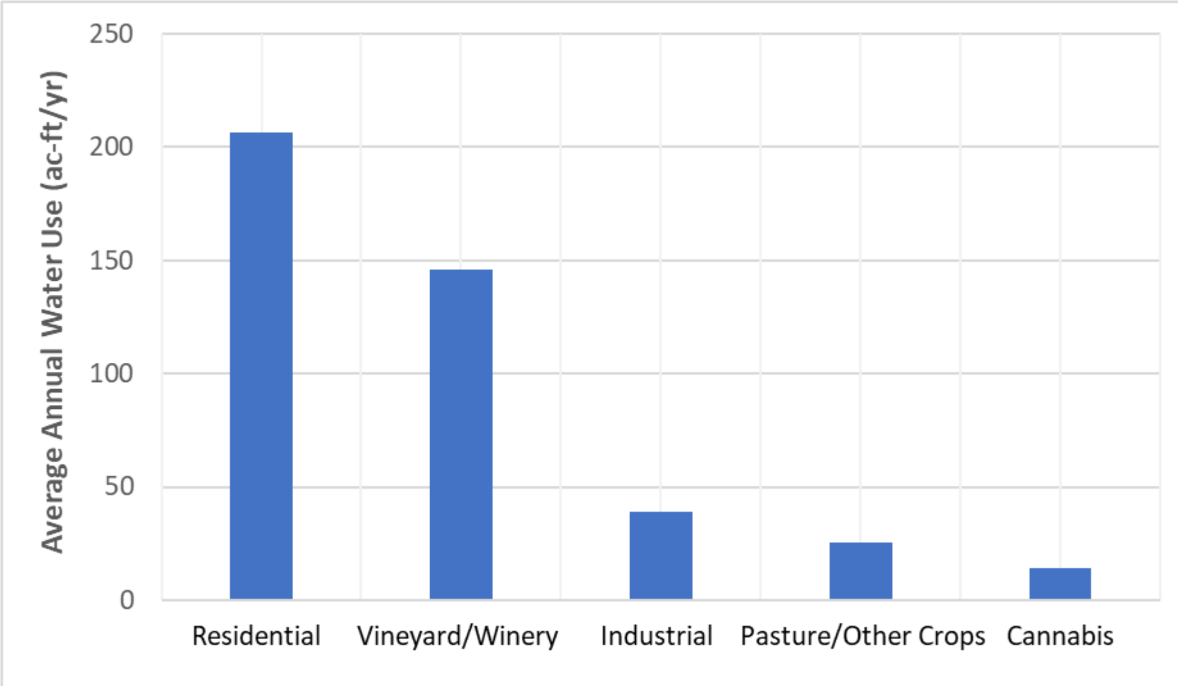


Figure 28: Breakdown of total water use in the MWC hydrologic model by use category.

Chapter 5 – Model Calibration

Calibration of a distributed hydrologic model like MIKE SHE is complicated by the large number of inter-related process and parameters involved. Previous modeling experience has indicated that results are most-sensitive to a relatively small subset of the model parameters including the overland flow Detention Storage and Roughness, unsaturated zone Saturated Hydraulic Conductivity and moisture contents, interflow Drain Levels, groundwater Hydraulic Conductivity, and the streambed Leakage Coefficient. The calibration focused on adjusting these seven parameters within a range of plausible values (to maximize the fit between observed streamflow and groundwater data and mapping information.

Available Data

Several stream gauges have been operated in the watershed at various times over the past ten years including a series of gauges installed in 2010 by the Center for Ecosystem Management and Research (no longer in existence); some of which were re-established by Trout Unlimited (TU) in 2018. In 2018, Sonoma Water established several new gauges to serve as a warning system for potentially hazardous post-fire runoff events and the CRWI installed a gauge on lower Monan's Rill in the upper watershed. Additionally, OEI installed two gauges on upper Monan's Rill tributaries in 2017 and gauging in and near Humbug Creek has also been undertaken by CDFW in recent years.

Despite the relatively large number of stage sensor records available, most of the available data is only from the past few years and only relatively limited development of rating curves and discharge records has occurred. CEMAR and TU collected streamflow measurements and developed low flow (summer baseflow) rating curves at their sites, however rating curves have not been developed for the Sonoma Water sites. Even at the CEMAR/TU sites, no discharge measurements of storm runoff were previously collected, thus prior to this study no continuous rating curves or streamflow records had been developed in the watershed.

We selected three sites for additional streamflow gauging and rating curve development, the CRWI site on Monan's Rill, one of the TU stations in the upper watershed at Rancho Mark West, and one of the Sonoma Water stations in the lower watershed at Michelle Way (Figure 29). We measured discharges at the three sites at approximately monthly intervals between March 2018 and August 2019. For lower flows we used standard wading techniques and a topset rod and flow meter, and for higher flows we used a bridge crane and a flow meter. For all gauging efforts we followed standard USGS stream gauging protocols (USGS,2010).

We obtained the discharge measurements collected by CEMAR for the previous installation at the Rancho Mark West site which operated from March 2010 to December 2014. The original pressure transducer was still installed in the channel near the new instrument that TU installed in February 2018, allowing the older and newer stage records to be combined by applying an elevation offset between the instruments as measured in the field. This made it possible to combine the older CEMAR record from 2010-2014 with data collected from 2018-2019 to develop continuous rating curves and flow records for this site from 3/11/2010 – 12/10/2014 and 2/23/2018 – 7/25/2019.

At Michelle Way, we developed rating curves from our discharge measurements which allowed for the development of continuous flow records from 2/27/2018 – 9/30/2019. We also developed rating curves at Monan's Rill; unfortunately, an instrument malfunction resulted in a large data gap and we were only able to develop continuous flow records for 5/1/2018 – 12/13/2018 and 3/25/2019 – 9/30/2019 which excludes most of the larger runoff events that occurred in 2018/2019. Given the paucity of runoff events captured at this gauge, we focused on the May through September time period for calibration at this location.

In addition to streamflow data, other supplemental sources of calibration data include locations of known springs and perennially-flowing tributaries and wet/dry mapping data collected by CA Sea Grant, CDFW, and Sonoma Water. We compiled the locations of springs and seeps mapped in the field along main-stem Mark West Creek by OEI and CDFW staff in August 2018, spring locations from the National Hydrography Dataset (NHD), springs indicated in the SWRCB's Information Order, springs identified during field reconnaissance and from landowner information, and springs mapped by Pepperwood staff on the Pepperwood Preserve. We also compiled the locations of all flowing tributaries from the August 2018 survey. These data represent all known locations of springs (a groundwater discharge output in the model), but is not a complete inventory of springs and is biased towards showing more springs in locations where detailed spring mapping has been completed such as along main-stem Mark West Creek

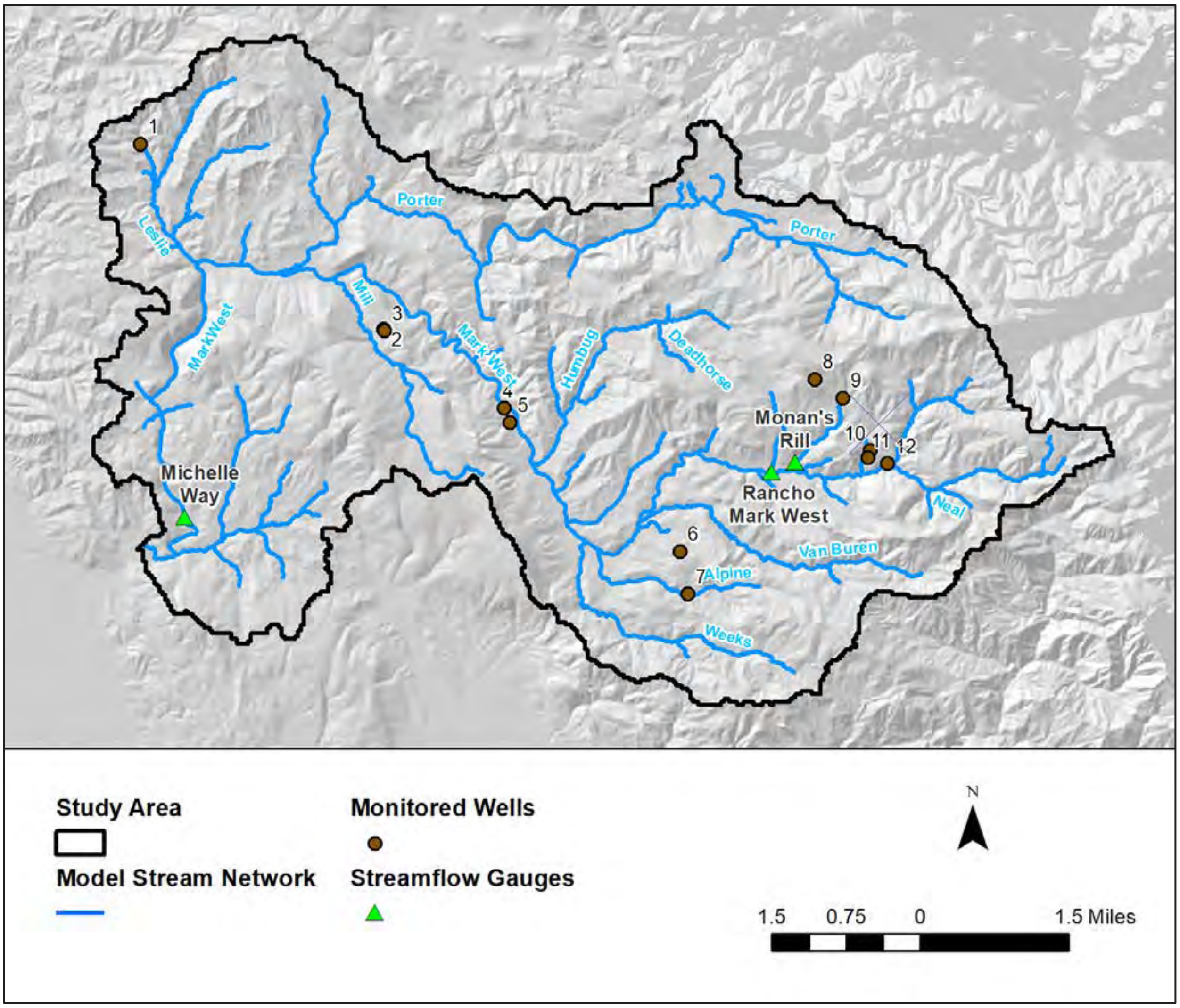


Figure 29: Locations of streamflow gauges and groundwater wells used for calibration of the MWC hydrologic model.

and at the Pepperwood Preserve. Wet/dry mapping data is available for 2012 – 2018 and we focused on the years with the most complete spatial coverage, 2015 – 2018. For purposes of this comparison we considered flows less than 0.01 cfs as equivalent to a field condition of dry and flows less than 0.10 cfs as equivalent to a field condition of intermittent.

Except for a few wells at the Pepperwood Preserve and Monan's Rill, almost no existing groundwater monitoring data was available for the watershed. To develop some field-based understanding of groundwater conditions in the watershed, we established a network of landowners willing to participate in a groundwater monitoring program and collected groundwater elevation data at 16 wells at approximately 5-week intervals between May 2018 and June 2019. Wells are completed in both of the major geologic formations in the watershed, the Franciscan Complex and the Sonoma Volcanics, and they are concentrated in the upper watershed where landowner interest in participation was high. Well casing heights were measured and data was collected relative to top of casing using an electronic sounding tape.

Many of these wells are domestic water supply wells and thus measurements could potentially be influenced by drawdown associated with recent pumping. To minimize such effects, we established a regular monitoring and notification schedule and residents voluntarily abstained from pumping for 24-hrs prior to measurements. The data for four of the wells was not useful for calibration owing to a variety of factors including obvious pumping influences, one seasonally dry hole, and one well located just outside the watershed. Of the remaining 12 wells (Figure 29), we were unable to locate a Well Completion Report for three; given the lack of screened interval information for these wells, we prepared comparisons between simulated and observed water levels but excluded them from the calibration statistics owing to the uncertainty about which model layer is represented by the observations. Seven of the nine monitoring wells used for model calibration are completed in the Sonoma Volcanics and the other two (Wells 4 & 5) are completed in the Franciscan Complex. Three of the wells are screened entirely within Layers 1 & 2 (upper 200-ft), seven are screened entirely within Layers 1-3, and two are completed entirely in Layers 1-4.

Streamflow Calibration

Four goodness-of-fit statistics were used to evaluate the agreement between model simulated stream discharges and measured stream discharges. These statistics included the Mean Error (ME), Root Mean Square Error (RMSE), the total Percent Volume Error (PVE), and the Nash-Sutcliffe model efficiency coefficient (NSME) (Nash and Sutcliffe, 1970). ME, RMSE, and PVE provide an overall measure of the model bias and have been calculated separately at all three gauges for the full period of record and for the low flow season from May through September. The NSME provides an overall measure of the predictive capability of the model. A NSME value of zero indicates that model predictions are as accurate as the mean of the measured data and a value of one indicates a perfect calibration. The PVE and NSME have only been calculated for the full period of record since it they are not well-suited for describing data with limited temporal variability such as spring/summer baseflow recessions. To avoid the May through September statistics being dominated by a handful of days with storm runoff, we defined an upper threshold below which to calculate statistics more representative of the model's ability to predict flow recession and baseflow. The thresholds were 0.4 cfs, 2 cfs, and 5 cfs at the Monan's Rill, Rancho Mark West, and Michelle Way gauges, respectively.

Due to the limited period of record it was deemed appropriate to calibrate the model to all of the available data rather than divide the simulation into calibration and validation periods as is more typically done when long-term gauging data is available. Figures 30 through 32 show the comparison between model-simulated and measured discharges at the three gauging sites for the full periods of record, and Figures 33 through 35 show the comparison between model simulated and measured discharges at the three sites for just the May through September low flow season that is most critical from the perspective of salmonid habitat.

The agreement between simulated and measured stream flows was generally good at all three of the gauging locations. The model reproduces the quick flow responses in stream flow during runoff events that is characteristic of the watershed and the overall shape of rising and receding flows. Peak flows are captured reasonably well; however, large differences in peak flows do occur for certain events particularly in the older portion of the record at the Rancho Mark West station. RMSE values for the full periods of record were 13.6 and 68 cfs and NSME were 0.79 and 0.90 at the Rancho Mark West and Michelle Way gauges respectively (Table 10). The total percent volume error was -5.2% at Rancho Mark West and 8.4% at Michelle Way (Table 10). We established targets for successful calibration as a NSME value of 0.60 or greater and a PVE of +/-10% which are met at both stations.

During low flow periods most critical for understanding coho habitat, the model performance is also generally very good. The shape of the spring flow recessions is well captured but the timing of the flow recession in the upper watershed is delayed in the model by one to two weeks relative to the observed data resulting in over-predicted flows during the May/June timeframe. The flow recession timing matches the observed timing more closely in the lower watershed. Magnitudes of summer baseflow are in reasonably good agreement, but there is a tendency to over-predict late summer flow, particularly in the lower watershed. RMSE values for the May through September low flow period ranged from 0.10 cfs at the Monan's Rill gauge to 0.83 cfs at the Michelle Way gauge (Table 10).

The map of observed springs and flowing tributaries was compared to a map of spring locations and flowing tributary streams as simulated in the model for August 2018 (Figure 36). The model correctly predicts the August 2018 flow condition in all 14 tributaries in the study area greater than 0.3 mi^2 as well as in 7 of the 11 smaller tributaries (Figure 36). The spring location comparison also indicates generally good agreement with a high concentration of springs in the upper watershed in both the observed and simulated maps. The model does not show as many springs in the central reach of Mark West Creek between Porter and Humbug creeks or on the Pepperwood Preserve property as is indicated by the field data. Concentrations of springs in upper Porter, upper Humbug, and lower Mark West Creeks not shown in the observed data likely reflect lack of mapping in those areas rather than lack of springs (Figure 36). Overall, the model appears to reproduce the general locations of groundwater discharge and perennial streamflow in Mark West Creek with reasonable accuracy.

Comparison between wet/dry mapping data collected by CA Sea Grant and Sonoma Water in August and September of 2015 through 2018 and a model simulated wet/dry classification for equivalent dates indicates that both the model and the field data show flow persisting in the majority of main-stem Mark West Creek even during dry years such as 2015 (Figure 37 - Figure 40). Both the model and the field data show dry/intermittent conditions beginning at about the same location in the upper watershed as well as dry/intermittent conditions occurring upstream of the Porter Creek confluence in some water years, however the field data indicates the reach with dry/intermittent flow conditions extends upstream of Porter considerably farther than was captured in the model (Figure 37 - Figure 40).

Table 10: Streamflow calibration statistics for the MWC hydrologic model.

Period	Gauge	Drainage Area (mi^2)	# of Daily Observations	ME (cfs)	RMSE (cfs)	PVE (%)	NSME
Full Record	Rancho Mark West	4.6	2,202	-0.4	13.6	8.4%	0.79
	Michelle Way	35.8	581	-2.6	68.0	-5.2%	0.90
May - Sept	Monan's Rill	0.5	298	0.02	0.10	-	-
	Rancho Mark West	4.6	1,017	0.15	0.28	-	-
	Michelle Way	35.8	290	0.32	0.83	-	-

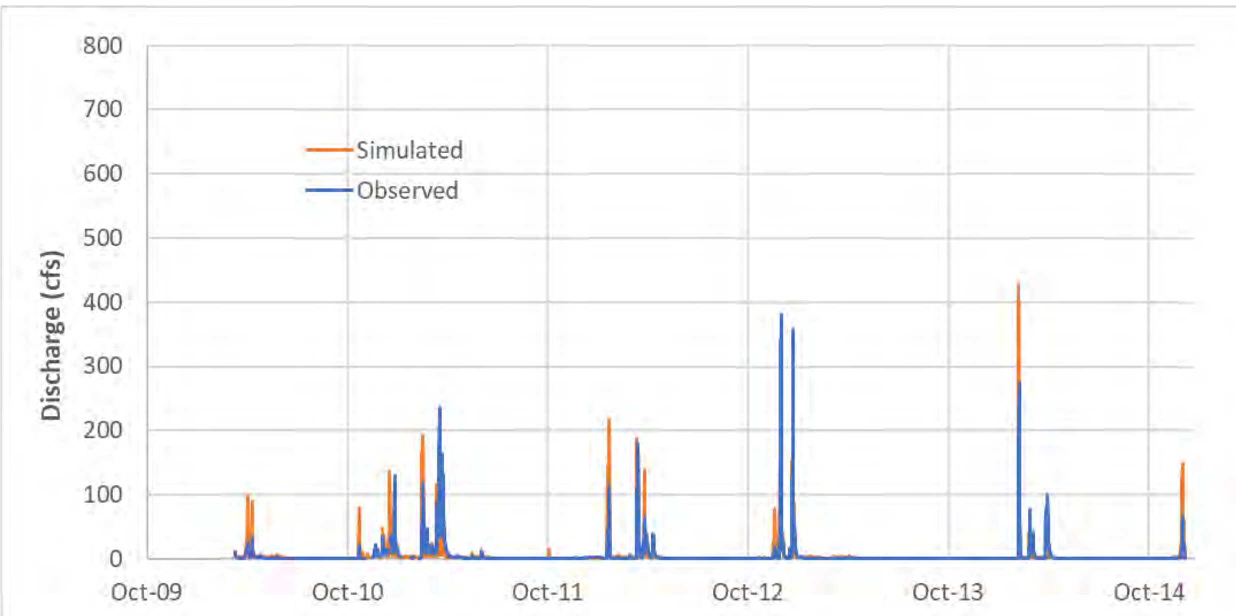


Figure 30: Comparison between model simulated and observed streamflow for the 2010 – 2014 period of record at the Mark West Creek at Rancho Mark West gauge.

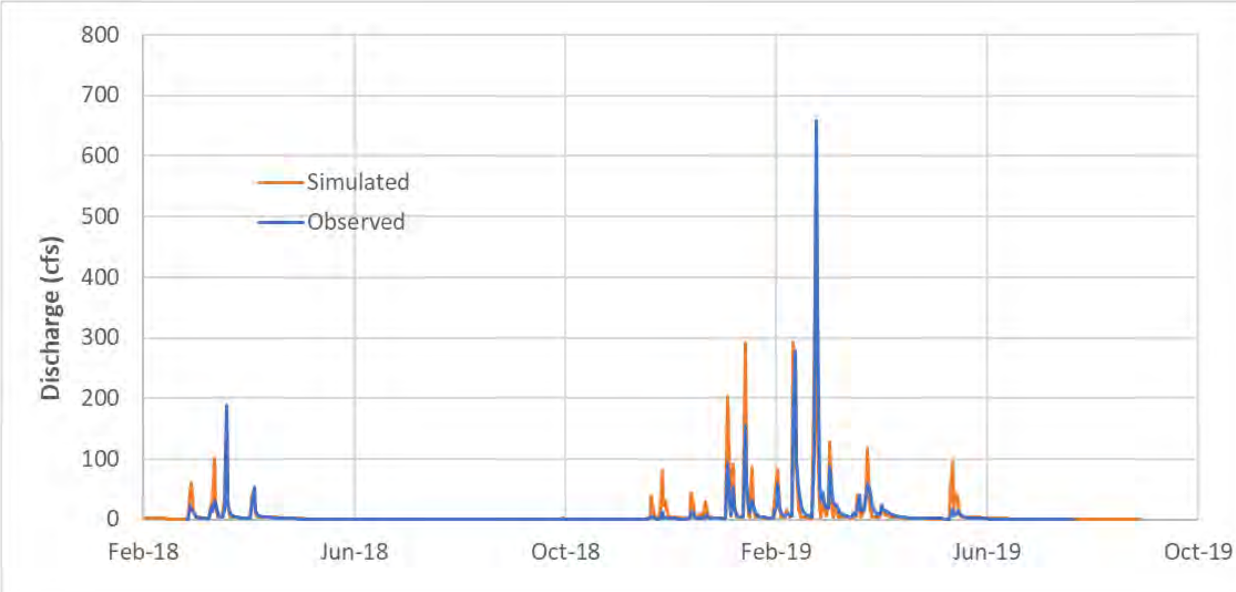


Figure 31: Comparison between model simulated and observed streamflow for the 2018 – 2019 period of record at the Mark West Creek at Rancho Mark West gauge.

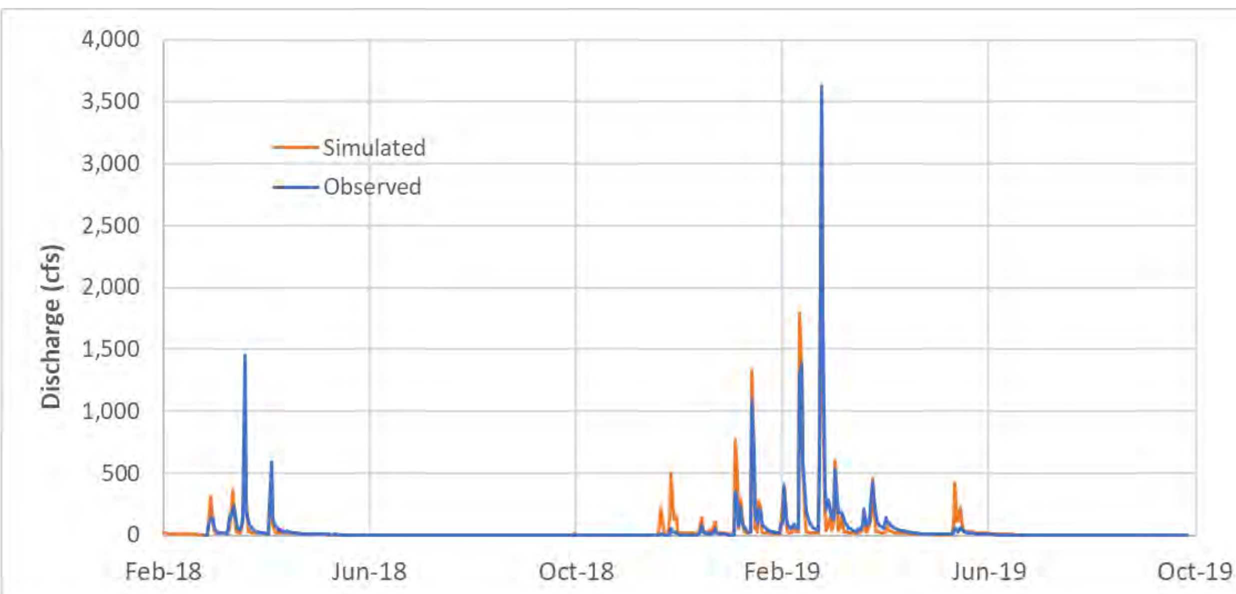


Figure 32: Comparison between model simulated and observed streamflow for the 2018 – 2019 period of record at the Mark West Creek at Michelle Way gauge.

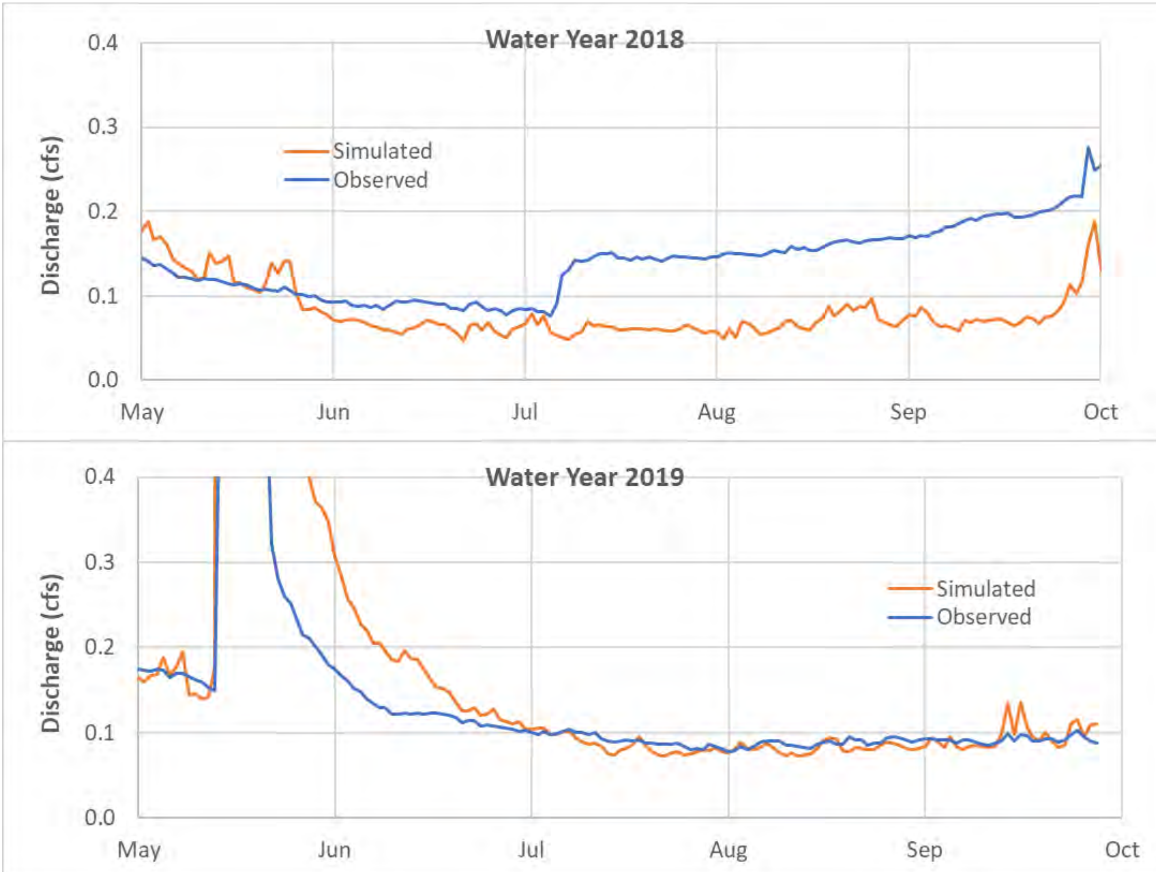
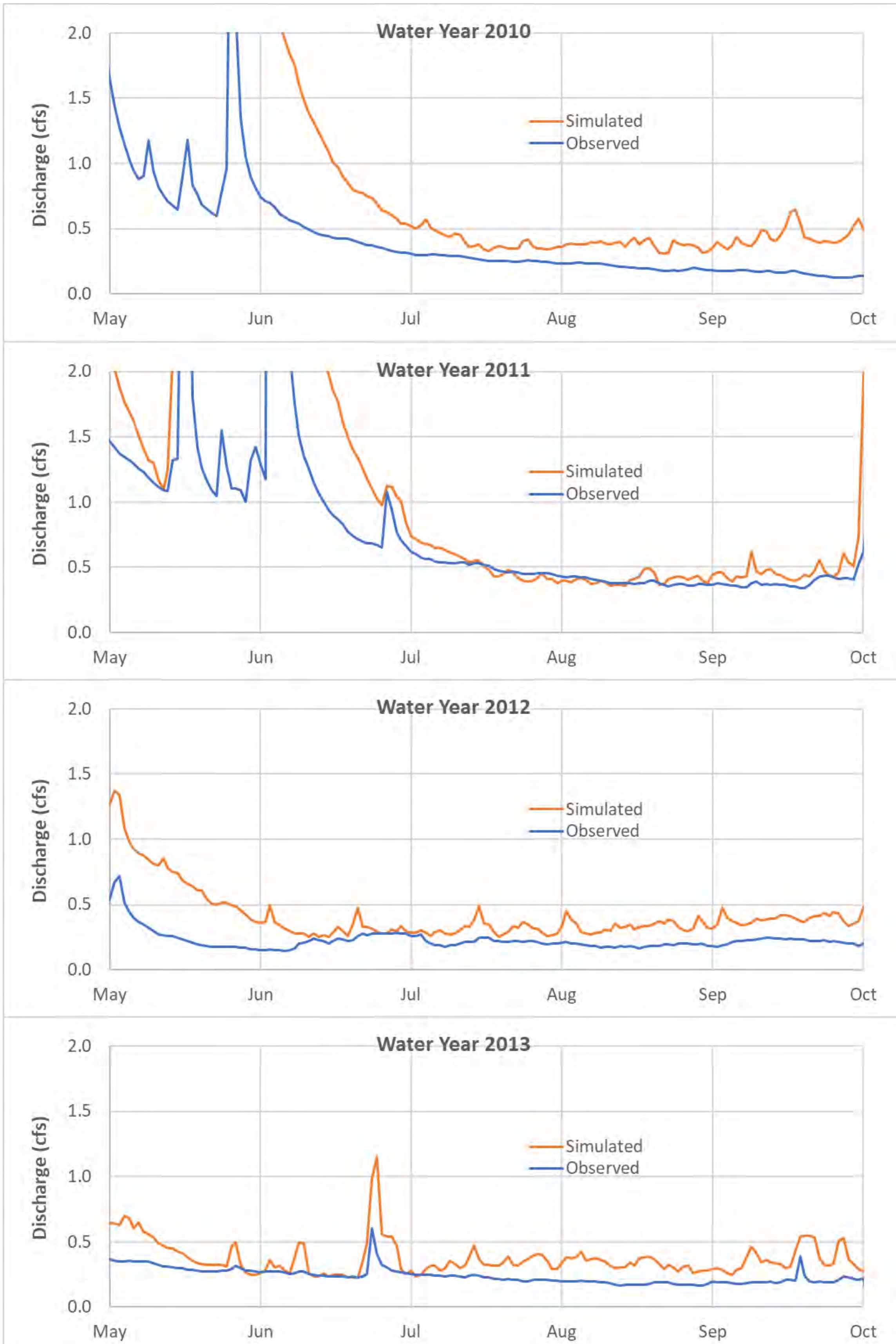


Figure 33: Comparison between model simulated and observed streamflow for the 2018 – 2019 May through September low flow period at the Monan's Rill gauge.


Water Year 2010
Discharge (cfs)
2.0
1.5
1.0
0.5
0.0
May
Jun
Jul
Aug
Sep
Oct
Simulated
Observed
Water Year 2011
Discharge (cfs)
2.0
1.5
1.0
0.5
0.0
May
Jun
Jul
Aug
Sep
Oct
Simulated
Observed
Water Year 2012
Discharge (cfs)
2.0
1.5
1.0
0.5
0.0
May
Jun
Jul
Aug
Sep
Oct
Simulated
Observed
Water Year 2013
Discharge (cfs)
2.0
1.5
1.0
0.5
0.0
May
Jun
Jul
Aug
Sep
Oct
Simulated
Observed

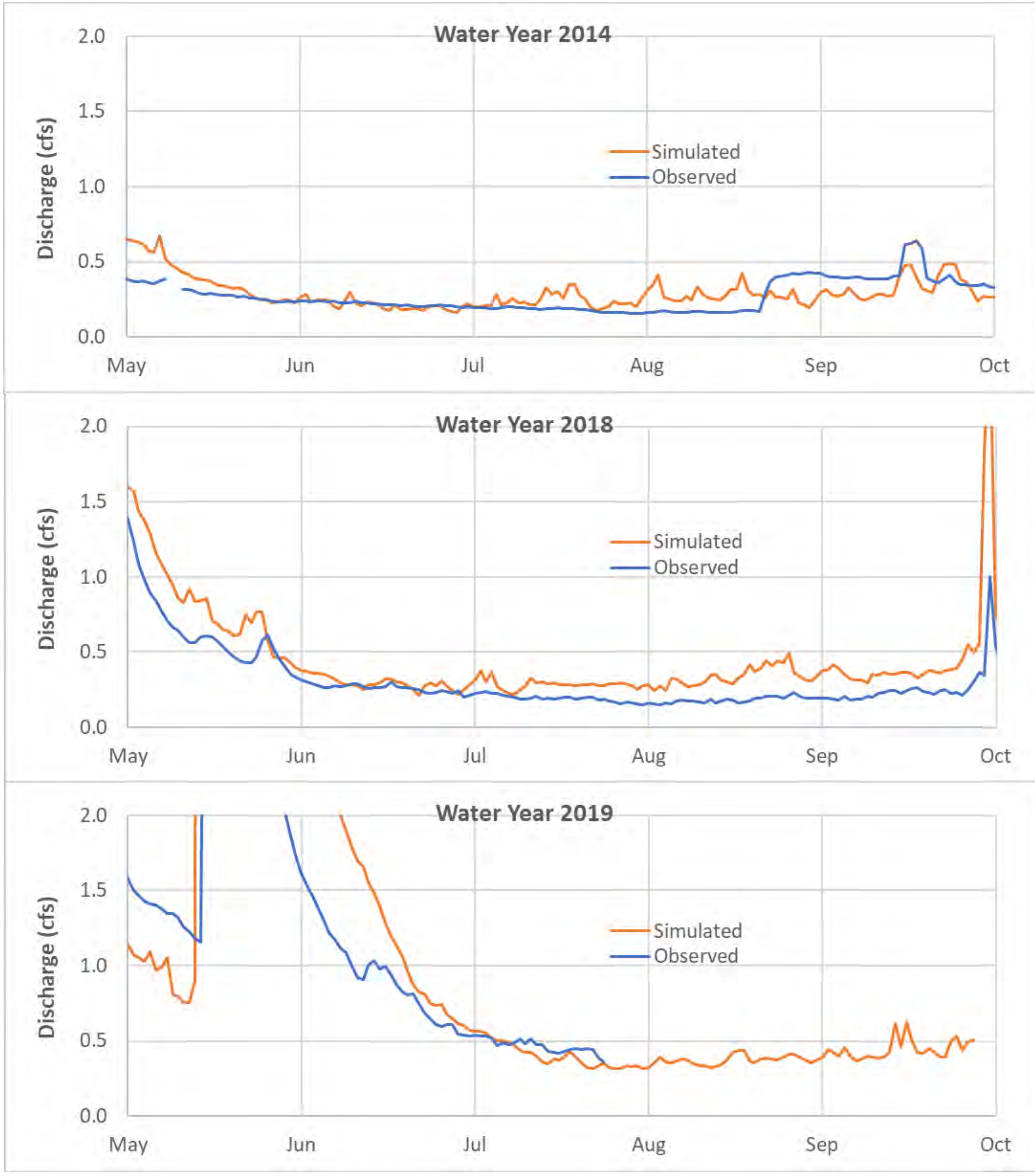


Figure 34: Comparison between model simulated and observed streamflow for the 2010 – 2014 and 2018 – 2019 May through September low flow period at the Mark West Creek at Rancho Mark West gauge.

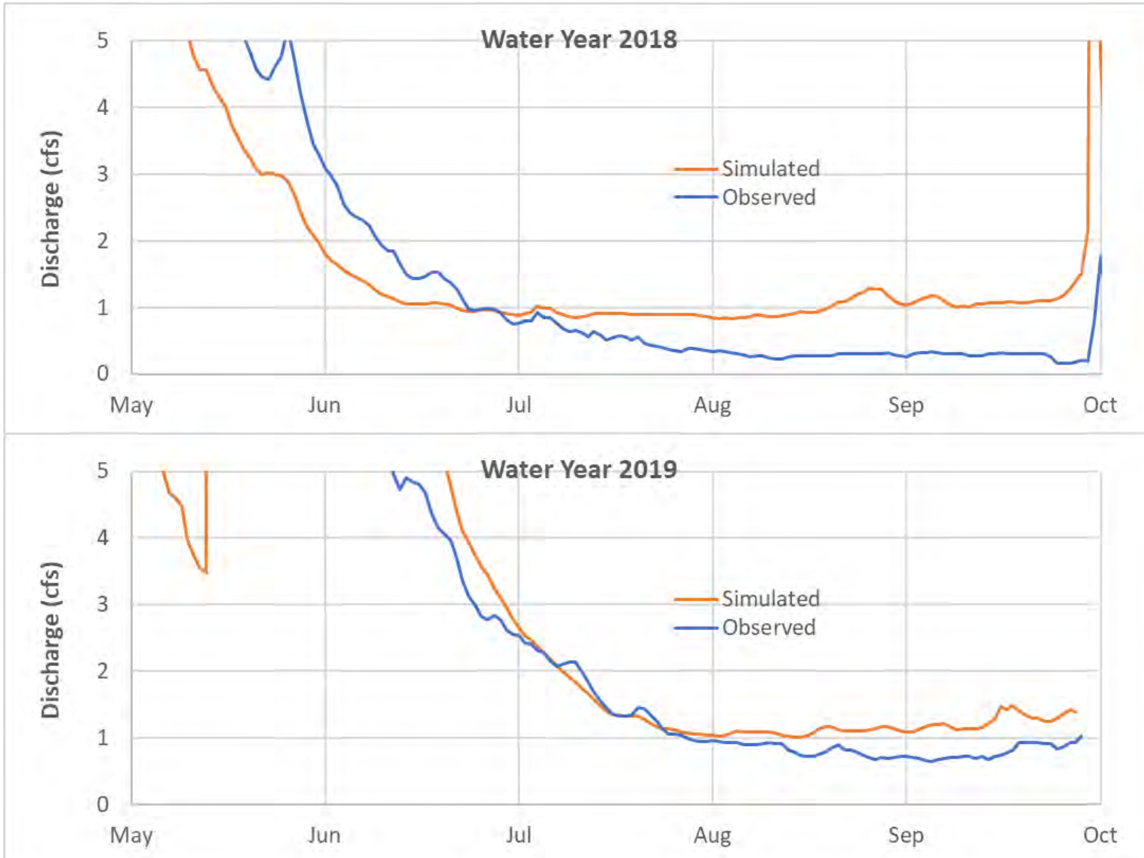


Figure 35: Comparison between model simulated and observed streamflow for the 2018 – 2019 May through September low flow period at the Mark West Creek at Michelle Way gauge.

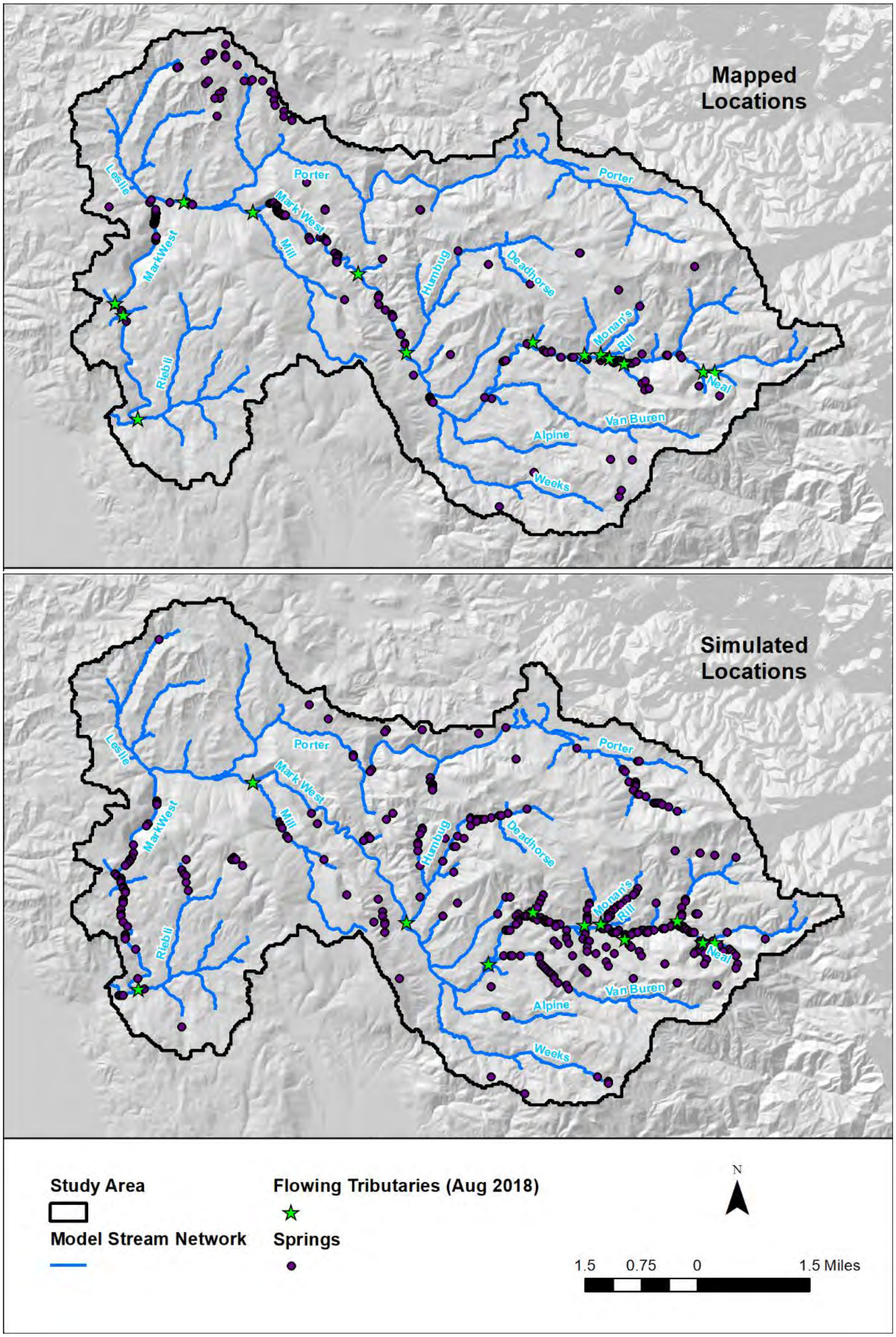


Figure 36: Comparison between known spring locations and locations of perennial springs as simulated in the MWC hydrologic model.

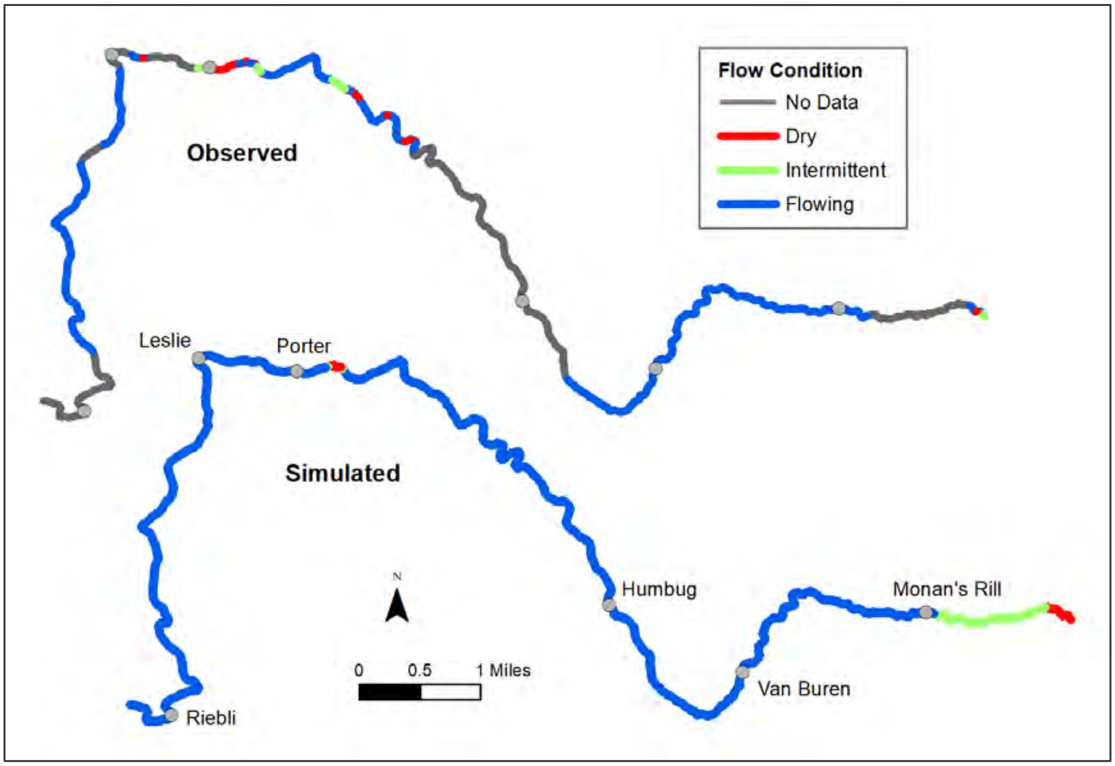


Figure 37: Comparison between observed and simulated late summer flow condition for 2015.

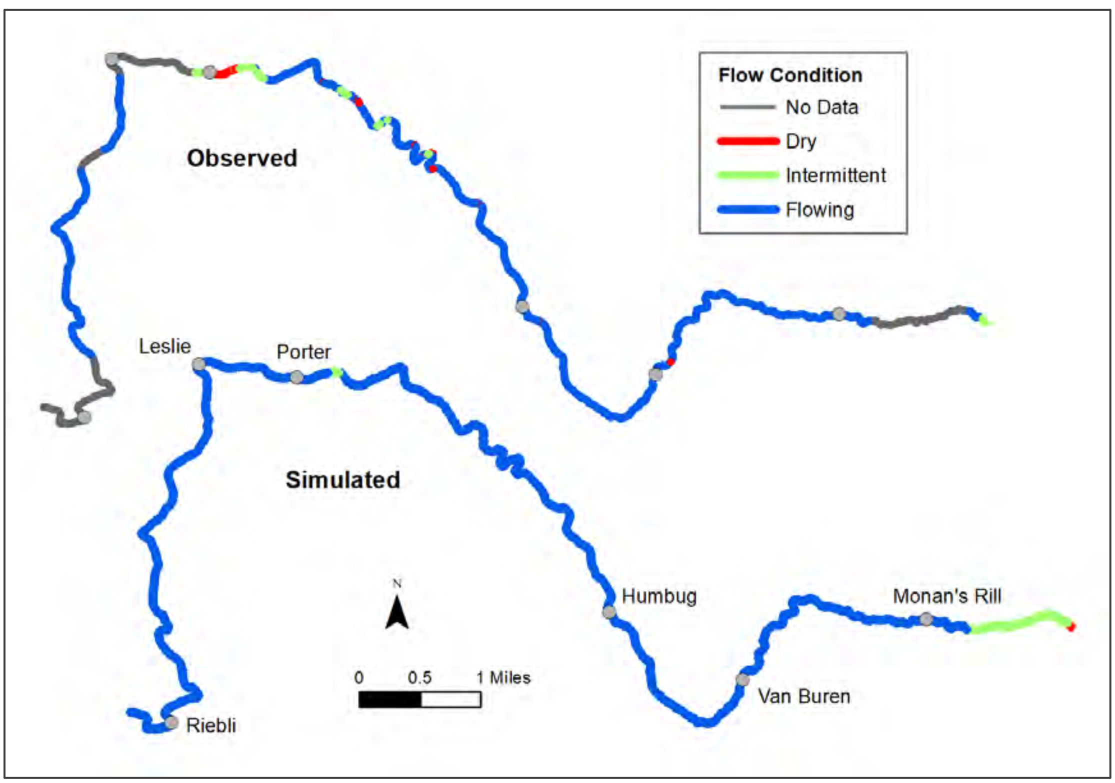


Figure 38: Comparison between observed and simulated late summer flow condition for 2016.

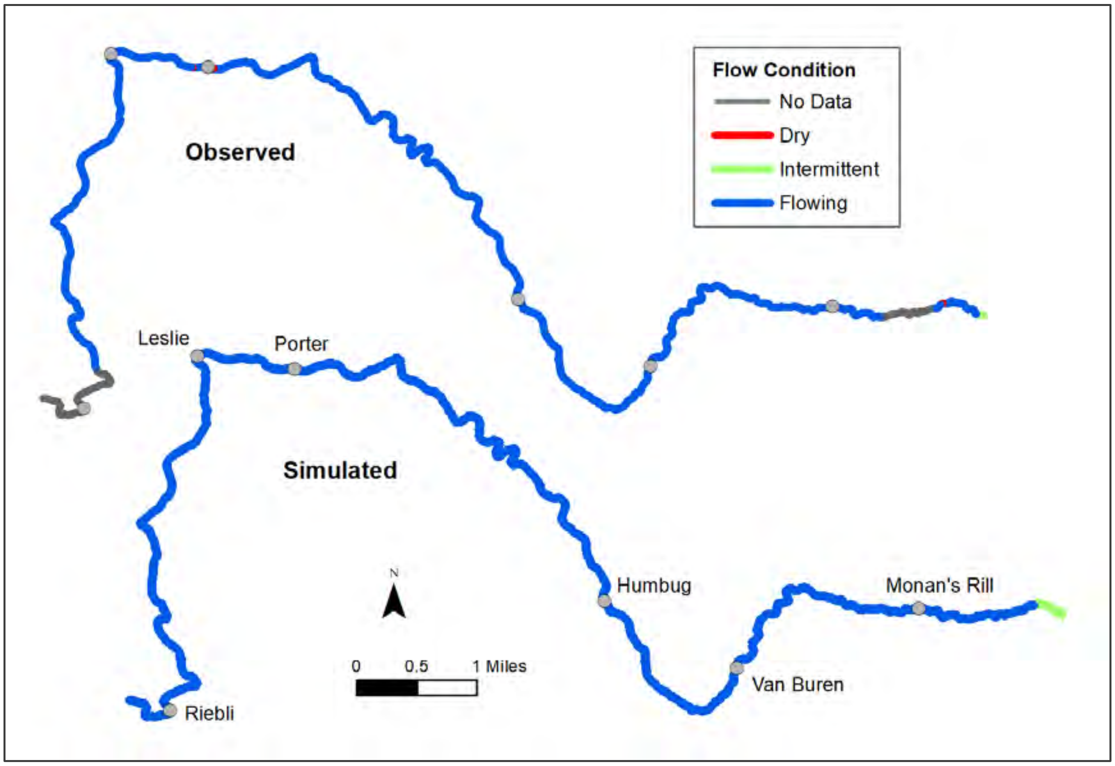


Figure 39: Comparison between observed and simulated late summer flow condition for 2017.

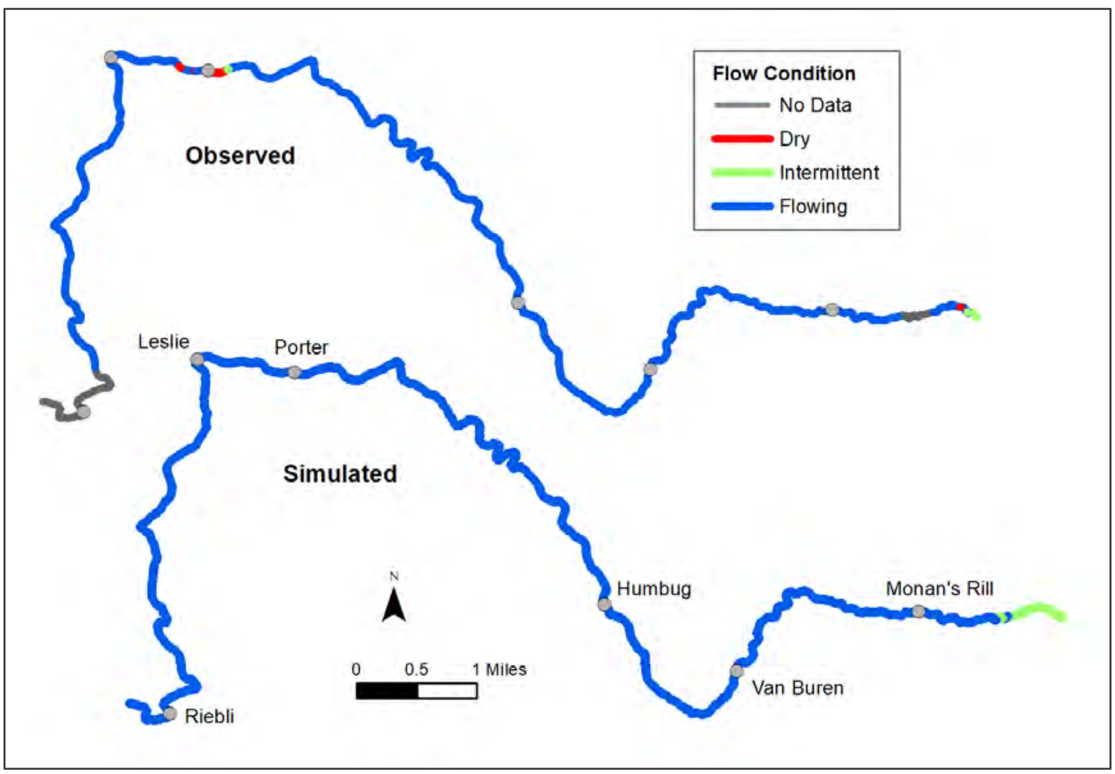


Figure 40: Comparison between observed and simulated late summer flow condition for 2018.

Groundwater Calibration

In order to evaluate the agreement between model simulated groundwater elevations and measured groundwater elevations, Mean Error (ME) and Root Mean Square Error (RMSE) were calculated for the residuals (difference between simulated and observed groundwater elevations) at each of the nine monitoring wells. Due to the limited periods of record at the available monitoring locations it was deemed appropriate to calibrate the model to all of the available data rather than divide the simulation into calibration and validation periods as is more typically done when long-term monitoring data is available. The composite comparison of simulated and measured groundwater elevations is shown in Figure 41. Figure 42 shows the comparison between model-simulated and measured groundwater elevations for each of the seven monitoring wells with available data and calibration statistics are presented in Table 11.

Overall, the observed groundwater elevations are reasonably well-predicted by the model. MEs range from –11.3 to 15.4-ft with an average error of 5.2-ft (Table 11). RMSEs range from 1.1 to 18.6-ft with an average of 9.9-ft. Small seasonal fluctuations occur in all of the wells with maximum elevations generally occurring in March or April and minimum elevations occurring in October or November presumably in response to seasonal recharge patterns. Four of the nine wells (all in the Sonoma Volcanics) show very steady elevations throughout the monitoring period (<3.5-ft annual fluctuation), four show modest fluctuations between 7 and 13-ft, and one shows significant fluctuation on the order of 35-ft (Figure 42). In most cases, the seasonal fluctuations predicted by the model are less than what was observed, with seasonal fluctuations in the model ranging from 0.2-ft to 13.2-ft. Excluding one well with anomalously high fluctuation, the mean seasonal fluctuation simulated in the model was 3.5-ft compared to 6.3-ft based on monitoring observations.

Although the model was able to reproduce observed groundwater elevations with reasonable accuracy, the available monitoring data is very limited both in spatial and temporal extent. Calibration of the groundwater component of the model was also complicated by the difficulties associated with interpreting the observed data which often represents composite head elevations from multiple screened intervals spanning as much as 250-ft. Additional groundwater monitoring from dedicated monitoring wells screened to target specific geologic layers is recommended to support further calibration/validation of the model results with respect to groundwater.

Table 11: Groundwater calibration results for the MWC hydrologic model (see Figure 29 for locations).

Well ID	# Observations	Layer #	ME	RMSE
3	8	2	0.7	3.0
4	11	1	15.0	15.5
5	12	1	-11.3	11.5
7	5	1	-5.7	5.9
8	11	1	15.4	18.6
9	10	1	11.6	12.1
10	11	1	13.9	14.0
11	10	1	7.7	7.8
12	11	1	-0.7	1.1
Mean			**5.2**	**9.9**

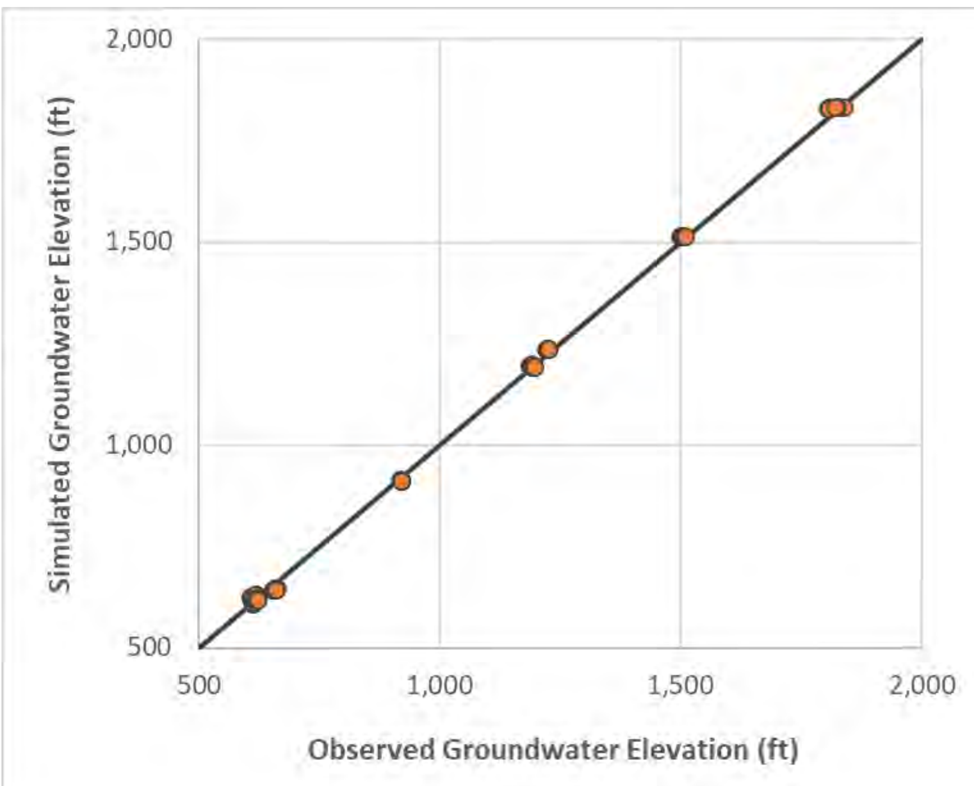
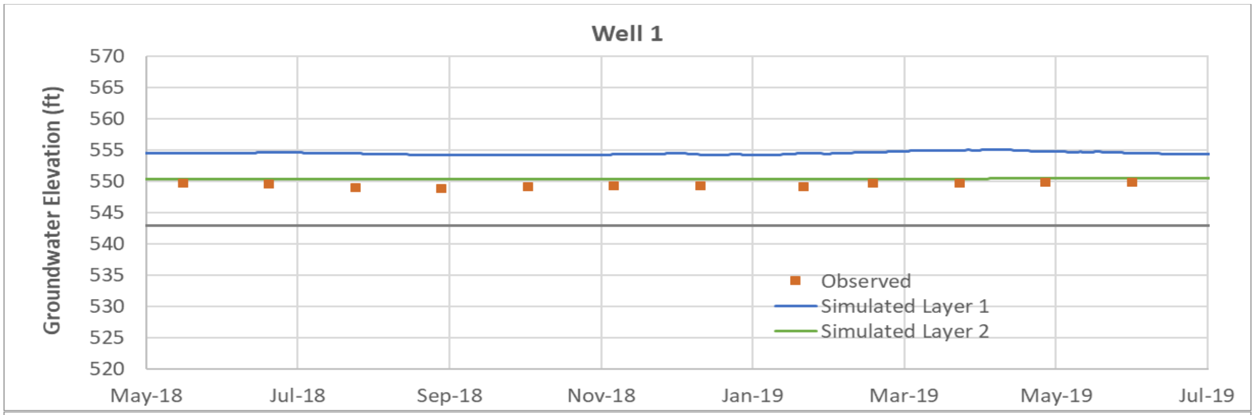
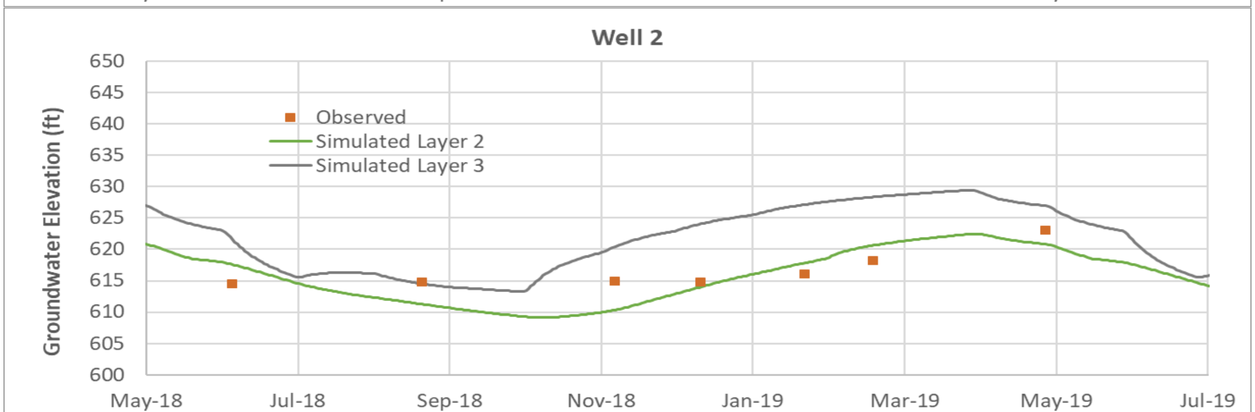
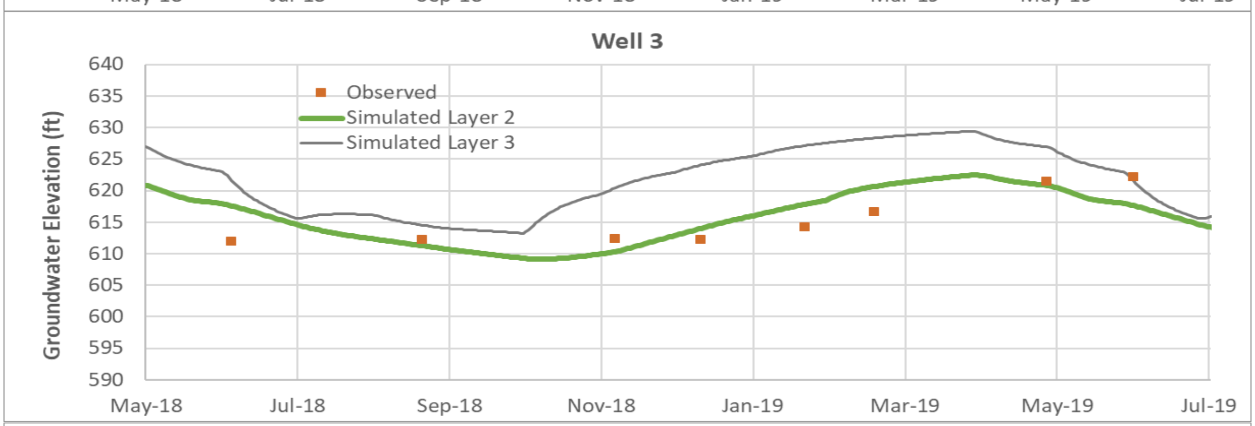
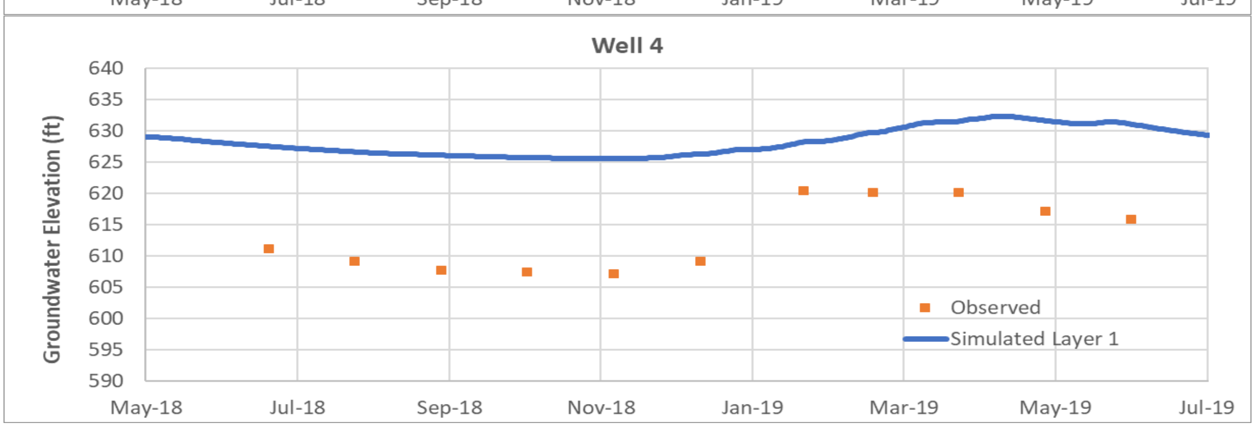


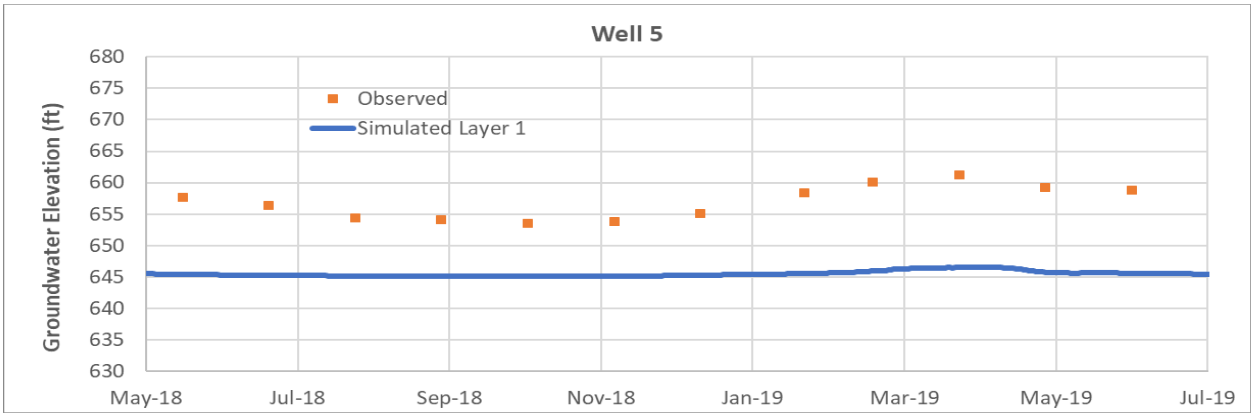
Figure 41: Composite comparison between simulated and observed groundwater elevations (black line shows a 1:1 fit).

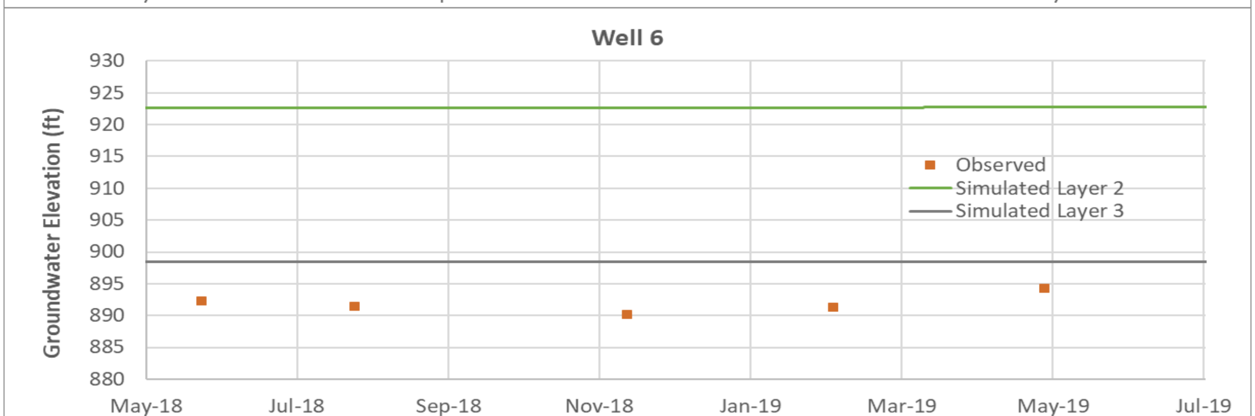

Well 1
Groundwater Elevation (ft)
570
565
560
555
550
545
540
535
530
525
520
May-18
Jul-18
Sep-18
Nov-18
Jan-19
Mar-19
May-19
Jul-19
Observed
Simulated Layer 1
Simulated Layer 2

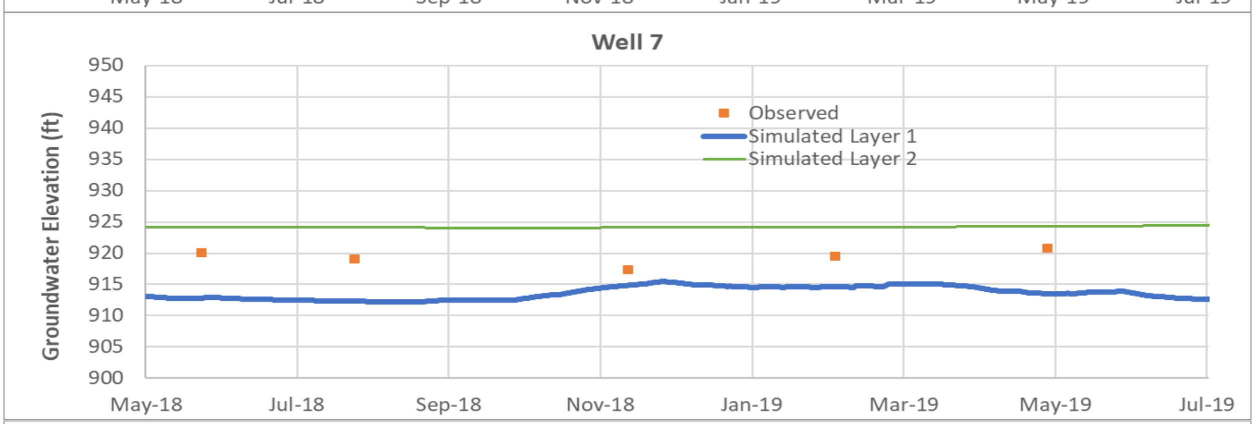

Well 2
Groundwater Elevation (ft)
650
645
640
635
630
625
620
615
610
605
600
May-18
Jul-18
Sep-18
Nov-18
Jan-19
Mar-19
May-19
Jul-19
Observed
Simulated Layer 2
Simulated Layer 3

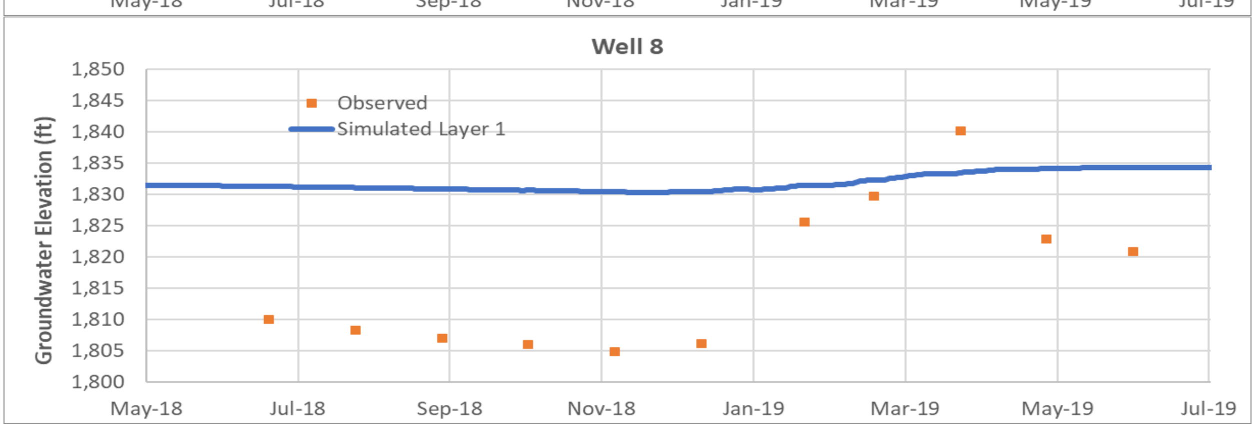

Well 3
Groundwater Elevation (ft)
640
635
630
625
620
615
610
605
600
595
590
May-18
Jul-18
Sep-18
Nov-18
Jan-19
Mar-19
May-19
Jul-19
Observed
Simulated Layer 2
Simulated Layer 3


Well 4
Groundwater Elevation (ft)
640
635
630
625
620
615
610
605
600
595
590
May-18
Jul-18
Sep-18
Nov-18
Jan-19
Mar-19
May-19
Jul-19
Observed
Simulated Layer 1


Well 5
Observed
Simulated Layer 1
Groundwater Elevation (ft)
680
675
670
665
660
655
650
645
640
635
630
May-18
Jul-18
Sep-18
Nov-18
Jan-19
Mar-19
May-19
Jul-19


Well 6
Observed
Simulated Layer 2
Simulated Layer 3
Groundwater Elevation (ft)
930
925
920
915
910
905
900
895
890
885
880
May-18
Jul-18
Sep-18
Nov-18
Jan-19
Mar-19
May-19
Jul-19


Well 7
Observed
Simulated Layer 1
Simulated Layer 2
Groundwater Elevation (ft)
950
945
940
935
930
925
920
915
910
905
900
May-18
Jul-18
Sep-18
Nov-18
Jan-19
Mar-19
May-19
Jul-19


Well 8
Observed
Simulated Layer 1
Groundwater Elevation (ft)
1,850
1,845
1,840
1,835
1,830
1,825
1,820
1,815
1,810
1,805
1,800
May-18
Jul-18
Sep-18
Nov-18
Jan-19
Mar-19
May-19
Jul-19

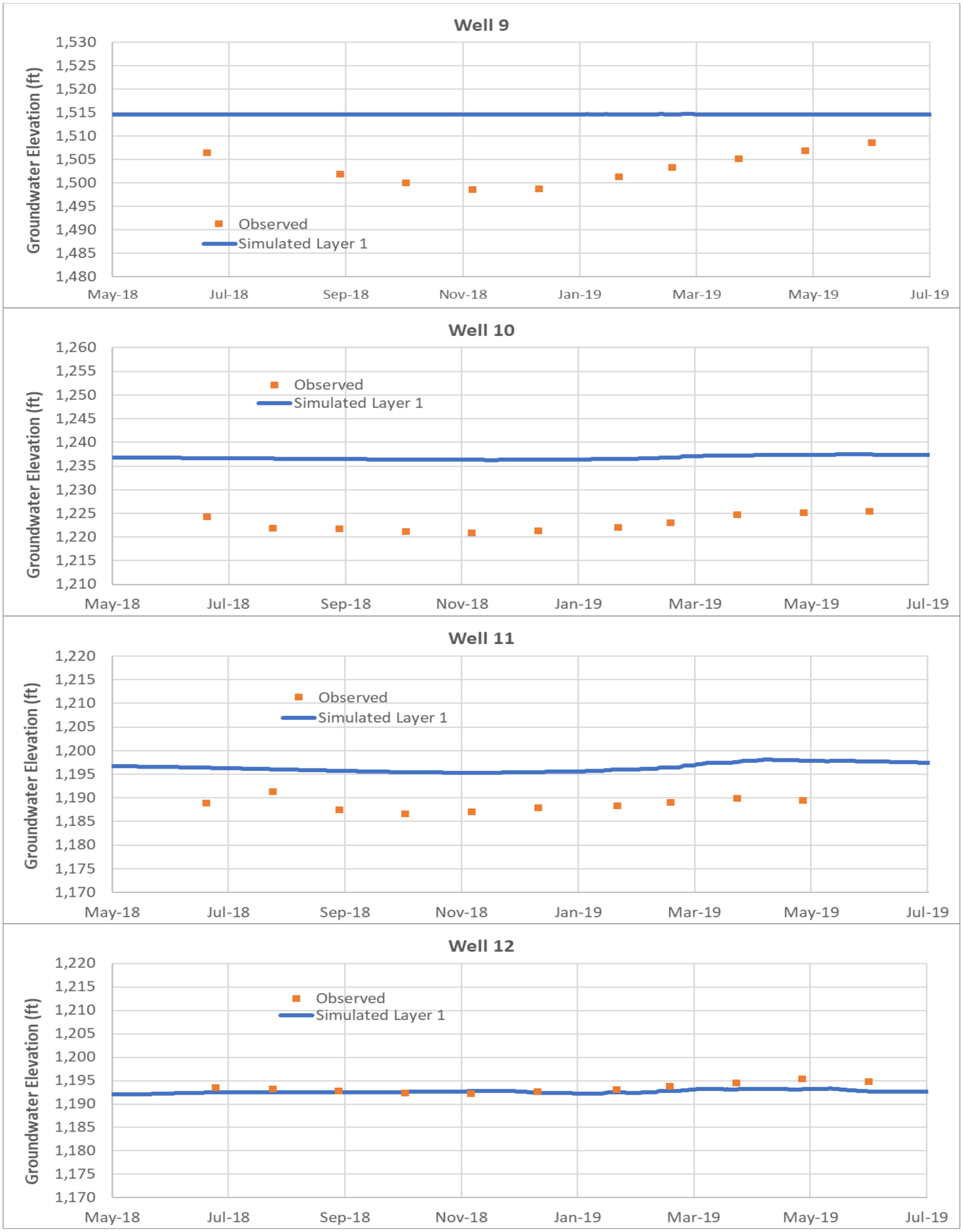


Figure 42: Comparisons between model simulated and observed groundwater elevations (thicker lines indicate simulated data used for calibration).

Chapter 6 – Model Results

Water Balance

A description of the water balance is one of the most fundamental outputs from the model. Water balance information can be extracted for the full study area or for any subarea. A water balance may be highly detailed (e.g. decompose ET into interception, evaporation, transpiration from the unsaturated zone, and transpiration from groundwater) or more general, and can be developed for the watershed as a whole or for a specific component of the hydrologic system such as the saturated zone. A general annual water balance for the whole watershed and a more detailed groundwater water balance have been developed for each of the simulated Water Years of 2010 - 2019. A monthly water budget is also presented for selected water budget terms as are maps depicting the spatial variations of key water budget components.

Watershed Water Balance

The primary inflow to the upper MWC watershed is precipitation, which ranged from 19.5 inches in the dry water year of 2014 to 61.2 inches in the wet water year of 2017 (Table 12). Irrigation is a minor additional source of inflow (0.07 in/yr) and it was uniform between water years owing to the way irrigation demands were estimated. Except for the two wettest years of the simulation (2017 & 2019) when streamflow exceeded Actual Evapotranspiration (AET), AET was the largest outflow from the watershed. Variations in AET were significantly less than variations in precipitation and ranged from 14.1 inches in 2014 to 24.1 inches in 2010 (Table 12). Stream flow was the next largest outflow from the watershed, and it varied substantially and in a similar fashion to precipitation ranging from 8.3 inches in 2014 to 32.8 inches in 2017. Groundwater pumping was approximately two orders of magnitude less than AET or stream flow (0.15 in/yr) and was relatively uniform owing to the way water demands were estimated. The watershed boundaries were represented as no-flow boundaries in all components of the model, therefore there are no external inflow or outflow terms in the water budget. Increases in storage of up to 6.9 inches occurred during the wet water year of 2017 and decreases in storage of up to 3.0 inches occurred during the dry water year of 2014 (Table 12).

Groundwater Water Balance

Infiltration recharge represented the largest source of inflow to the groundwater system in the MWC watershed and varied widely as a function of precipitation from 0.8 inches in 2014 to 10.1 inches in 2017 (Table 13). In contrast, streambed recharge was relatively constant ranging from 0.5 to 1.0 inches. In most water years, infiltration recharge is several times larger than streambed recharge. Under drought conditions such as occurred in 2014, streambed recharge becomes a more significant fraction of the total recharge accounting for about 38% of total recharge. Approximately half of the total recharge leaves the groundwater system quickly as interflow, which is the largest source of groundwater outflow varying from approximately 1.1 to 4.3 inches (Table 13). ET from groundwater was the next largest outflow term and was relatively uniform ranging from 0.8 to 1.1 inches.

Springflow and baseflow are also significant outflow terms. Both represent groundwater discharge in the model with the former representing discharge to the land surface or along unsaturated stream banks and the later representing discharge through the bed and wetted banks of the stream. Both of these discharge components were relatively uniform with springflow ranging from 0.5 to 1.0 inches and baseflow ranging from 0.5 to 0.9 inches (Table 13). Baseflow and streambed recharge are approximately equal in magnitude, thus the net gain in groundwater discharge through the bed and wetted banks of streams is near zero when averaged across the watershed; this highlights the importance of springflow as the key mechanism for sustaining summer streamflows in the watershed. Groundwater pumping was a relatively small component (~3%) of the total outflow at 0.15 inches, and there are no subsurface inflows or outflows owing to the no-flow boundary assumption used in the model. Storage decreases of up to 2.2 inches occurred in dry years such as 2014 and storage increases of up to 4.7 inches occurred in wet years such as 2017 (Table 13).

Table 12: Annual watershed water budget simulated with the MWC hydrologic model; all units are inches.

	Inflows		Outflows			
Water Year	**Precipitation**	**Irrigation**	**AET**	**Streamflow**	**Groundwater Pumping**	**Change in Storage**
2010	42.51	0.07	24.06	17.14	0.15	1.23
2011	43.97	0.07	23.13	17.92	0.15	2.84
2012	28.07	0.07	20.07	10.67	0.15	-2.76
2013	28.87	0.07	17.58	12.83	0.15	-1.62
2014	19.46	0.07	14.06	8.30	0.15	-2.97
2015	26.57	0.07	14.94	12.74	0.15	-1.19
2016	33.30	0.07	17.30	13.83	0.15	2.09
2017	61.18	0.07	21.47	32.75	0.15	6.88
2018	26.59	0.07	18.93	9.07	0.15	-1.49
2019	49.77	0.07	21.63	23.44	0.15	4.62
Average	**36.03**	**0.07**	**19.32**	**15.87**	**0.15**	**0.76**

Table 13: Annual groundwater water budget simulated with the MWC hydrologic model; all units are inches.

	Inflows		Outflows					
Water Year	**Infiltration Recharge**	**Streambed Recharge**	**Interflow**	**Baseflow**	**Springflow**	**ET from Groundwater**	**Groundwater Pumping**	**Change in Storage**
2010	6.05	0.71	4.29	0.76	0.58	0.82	0.15	0.16
2011	7.49	0.70	4.00	0.80	0.62	0.89	0.15	1.73
2012	2.22	0.57	1.72	0.63	0.84	1.08	0.15	-1.63
2013	2.39	0.58	2.19	0.60	0.68	0.98	0.15	-1.62
2014	0.84	0.52	1.09	0.50	0.76	1.06	0.15	-2.19
2015	2.10	0.66	1.53	0.59	0.67	1.02	0.15	-1.20
2016	4.44	0.60	2.55	0.67	0.48	0.75	0.15	0.44
2017	10.12	1.03	3.39	0.86	0.97	1.07	0.15	4.72
2018	2.87	0.53	1.91	0.62	0.72	1.06	0.15	-1.05
2019	8.17	1.03	3.48	0.83	0.99	0.99	0.15	2.76
Average	**4.67**	**0.69**	**2.61**	**0.69**	**0.73**	**0.97**	**0.15**	**0.21**

Spatial and Temporal Variations of Water Budget Components

The monthly water balance results illustrate the strong seasonality of precipitation and streamflow typical of Mediterranean climates (Figure 43). As a result of the seasonal fluctuations in Potential Evapotranspiration and soil moisture availability, AET was generally lowest during the late fall and early winter and highest during the spring, progressively decreasing throughout the summer months as available soil moisture diminished (Figure 43). During average and wet water years, infiltration recharge occurred in most months between November and April, whereas in the drought conditions of 2014, recharge only occurred during the month of February (Figure 43). The number of days with significant (>0.1-in) recharge varied widely between 4 days in 2014 and 34 days in 2017.

Significant variations in infiltration recharge occur across the watershed with much of the watershed generating less than 2 in/yr and portions of the upper watershed generating more than 20 in/yr (Figure 44). Numerous factors affect the recharge rates, however the spatial variations in recharge appear to be primarily controlled by soil properties, topographic position, and the west to east precipitation gradient. Recharge is concentrated in the upper Mark West Creek watershed upstream of and including the Van Buren Creek watershed, as well as in the upper Humbug Creek watershed (Figure 44). Higher recharge rates also occur locally in portions of the central Porter Creek watershed, and the upper Leslie Creek and upper Reibli Creek watersheds, although recharge rates in these watersheds are generally low. Small negative recharge rates (indicative of net groundwater discharge) occur along valley-bottom areas particularly in the lower watershed (Figure 44). As discussed earlier, recharge only occurred during four days during a single month in the drought of 2014, and much of the watershed experienced negative or near-zero recharge (Figure 45).

As discussed earlier, groundwater discharge occurs in the model both as springflow (subaerial discharge) and as baseflow (subaqueous discharge). Across the entire watershed, springflow is responsible for generating most of the summer streamflow given that net groundwater discharge in the spring and summer months is near zero (e.g. streambed recharge ≈ baseflow discharge). Locations of perennial springflow were discussed previously as part of the calibration discussion in Chapter 5 (see Figure 36). The spatial patterns of surface water/groundwater interaction indicate that gaining conditions predominate throughout the spring and summer months in much the upper watershed upstream of Van Buren Creek, as well as in upper Humbug Creek, portions of upper and central Porter Creek, and lower Mark West Creek below Leslie Creek (Figure 46 & Figure 47). During spring, losing conditions occur in Mark West Creek upstream of Porter Creek, and in the lowest portions of many of the tributary watersheds, notably Porter Creek and Weeks Creek (Figure 46). By late summer, most of the losing reaches in the tributary streams become inactive as streamflows drop to zero (Figure 47). The area overlying the deepest alluvial body in the watershed near and upstream of the confluence of Mark West and Porter Creeks is the most active area in terms of surface water/groundwater interaction. Losing conditions persist throughout the summer months in this area, however the effect on streamflow is localized given that most of the flow loss returns to the stream as baseflow where the alluvium pinches out downstream (Figure 47).

AET varies substantially throughout the watershed, and in most locations rates range from about 10 to 30 in/yr. AET as high as 50 in/yr occurs locally along certain stream channels where transpiration of riparian vegetation is not limited by soil moisture availability due to accessibility of shallow groundwater (Figure 48). Spatial variability of AET is primarily a function of variability in available soil moisture and vegetation water requirements, with the two factors being inextricably linked. Climatic water deficit (CWD) is defined as the difference between PET and AET and is a useful metric for describing the seasonal moisture stress. In the 10-yr average condition the annual CWD ranged from 15 to 40 in/yr across most of the watershed, except locally where rates were near zero due to accessibility of shallow groundwater and associated insensitivity to soil moisture availability (Figure 49). Topographic aspect appears to be a primary control on the spatial variability of CWD with north-facing slopes characterized by lower PET having significantly lower CWD values relative to south-facing slopes. During the drought of 2014, CWD values increased substantially to between 30 and 50 in/yr across most of the watershed (Figure 50). The 10-yr mean CWD across the watershed was 26.0 in/yr compared to 32.7 in/yr in 2014.

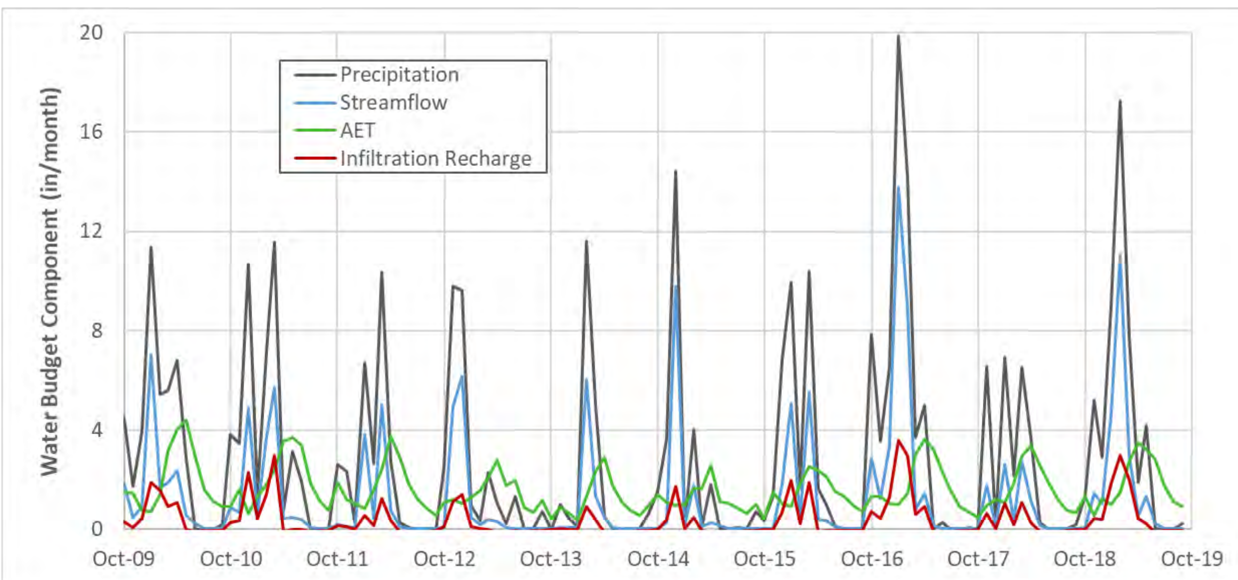


Figure 43: Monthly variation in select water budget components simulated with the MWC hydrologic model.

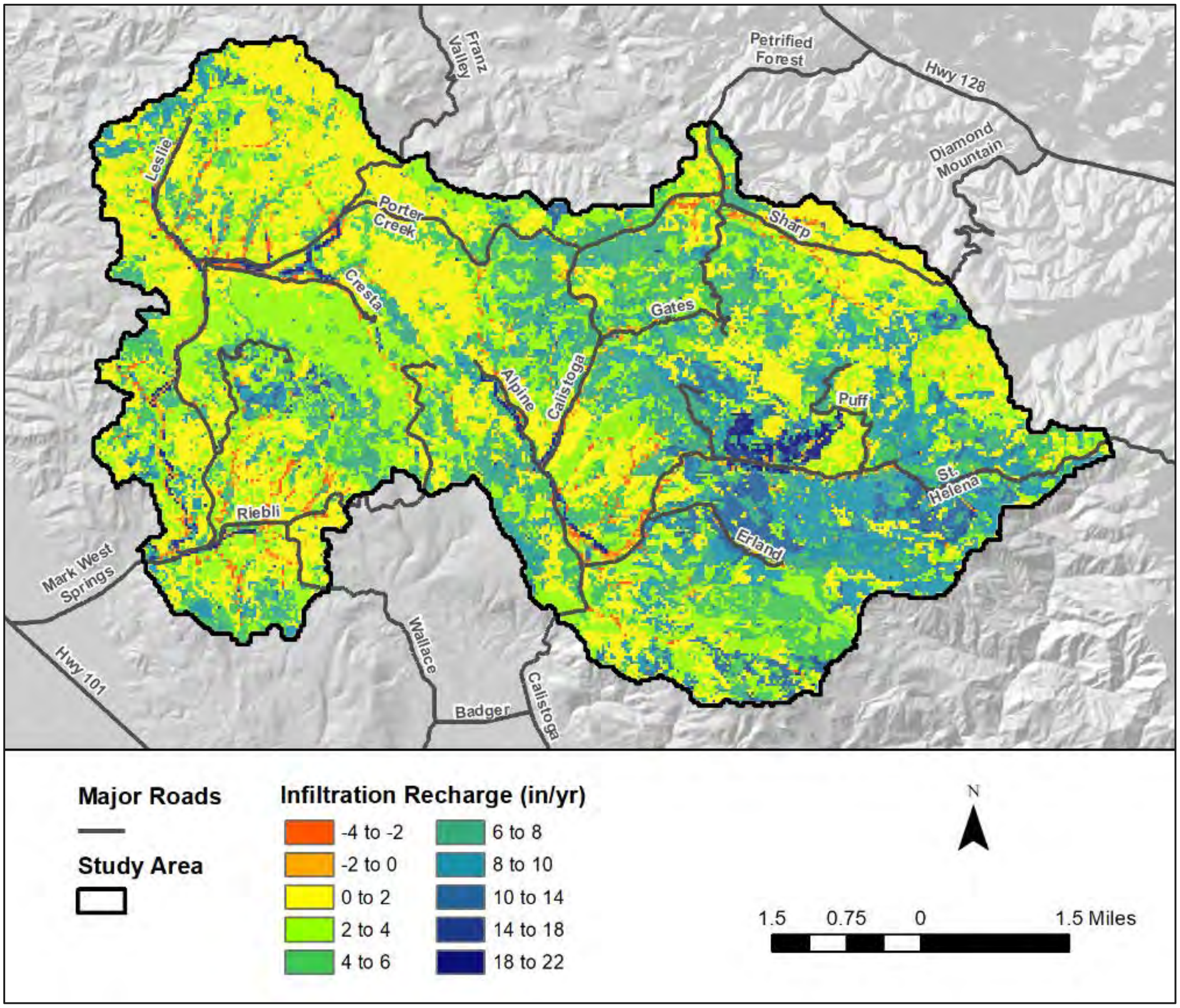


Figure 44: Mean annual infiltration recharge for water years 2010-2019 simulated with the MWC hydrologic model.

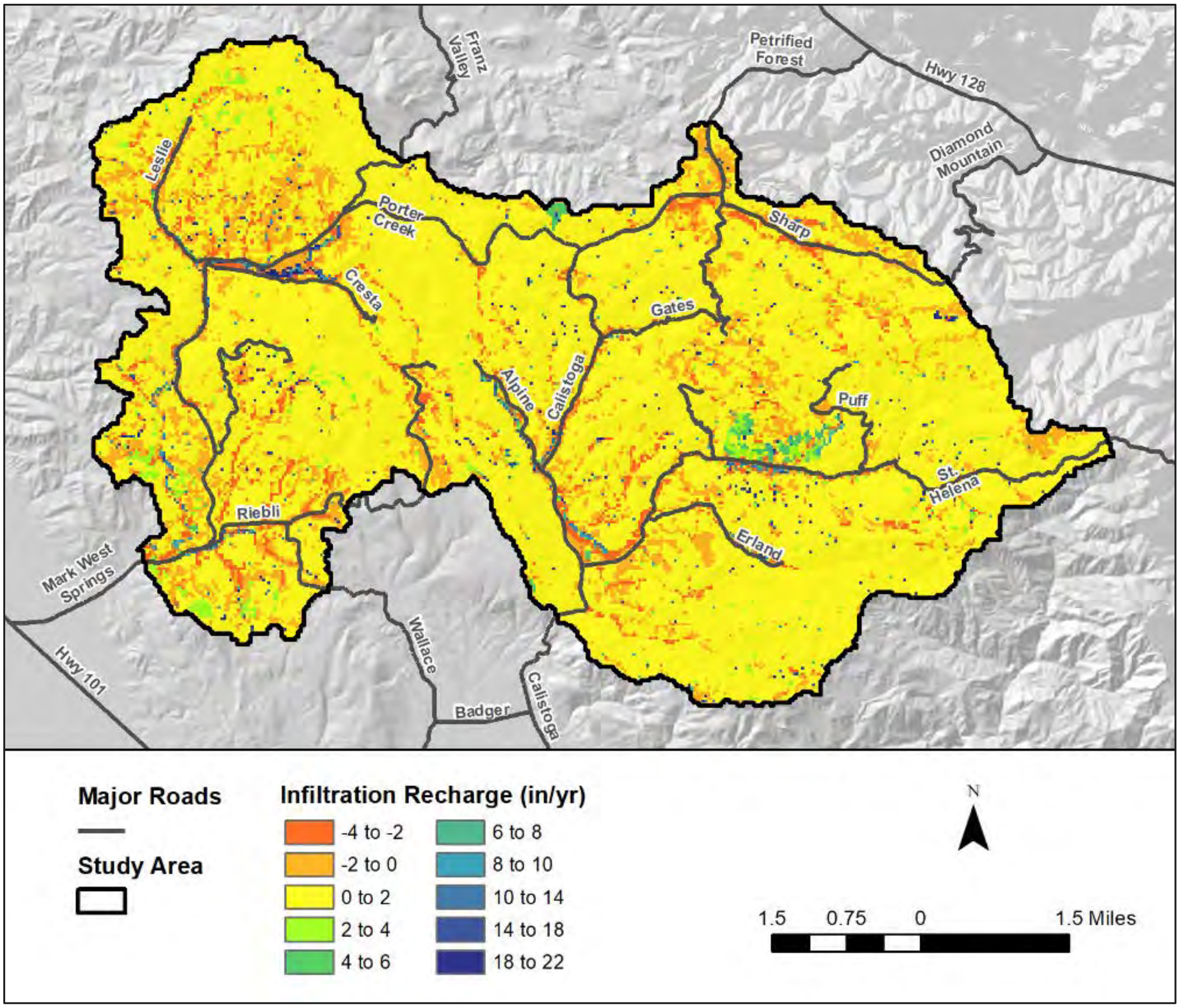


Figure 45: Infiltration recharge for water year 2014 simulated with the MWC hydrologic model.

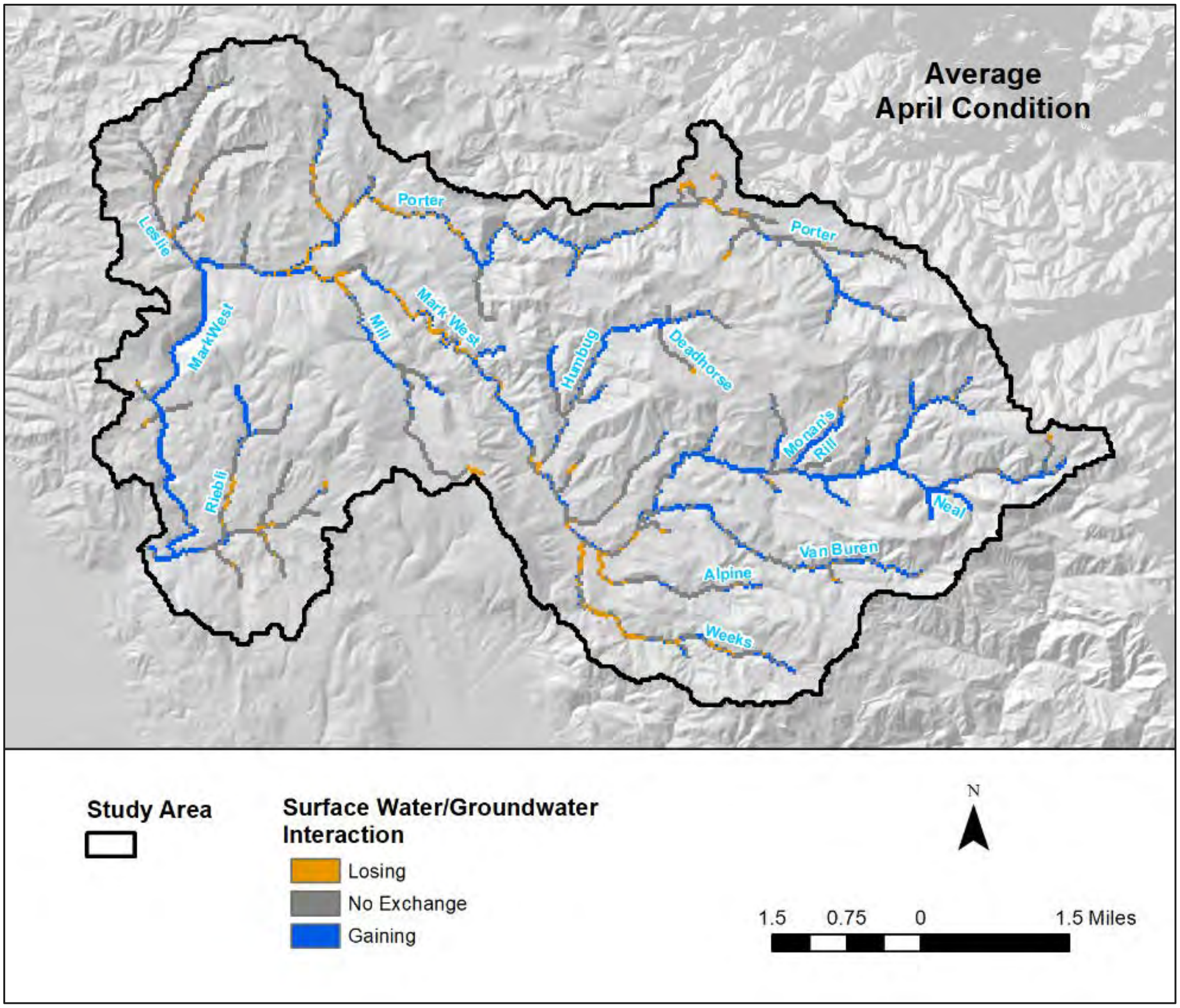


Figure 46: Extent of gaining and losing reaches for the month of April (2010-2019 mean value) as simulated with the MWC hydrologic model.

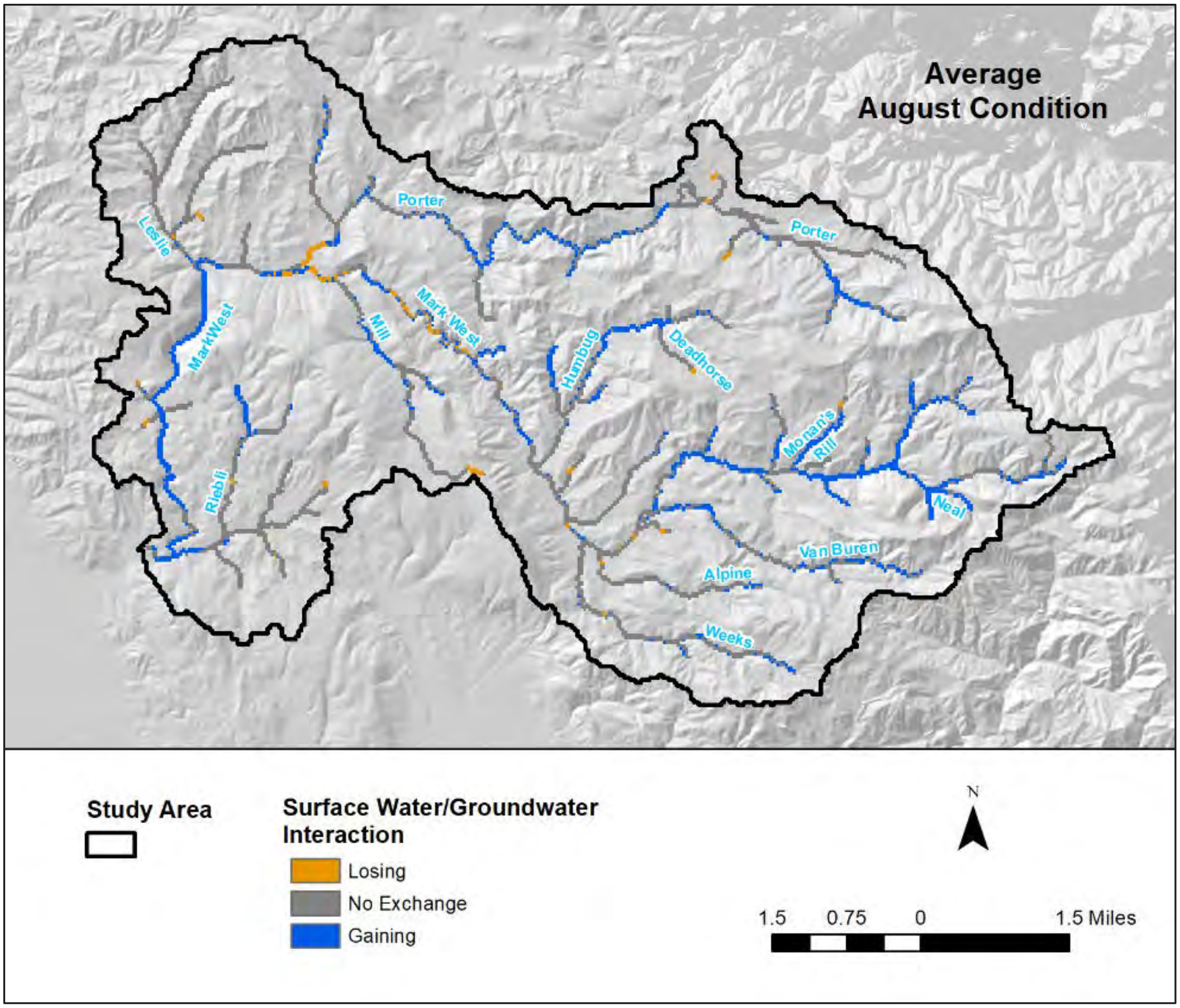


Figure 47: Extent of gaining and losing reaches for the month of August (2010-2019 mean value) as simulated with the MWC hydrologic model.

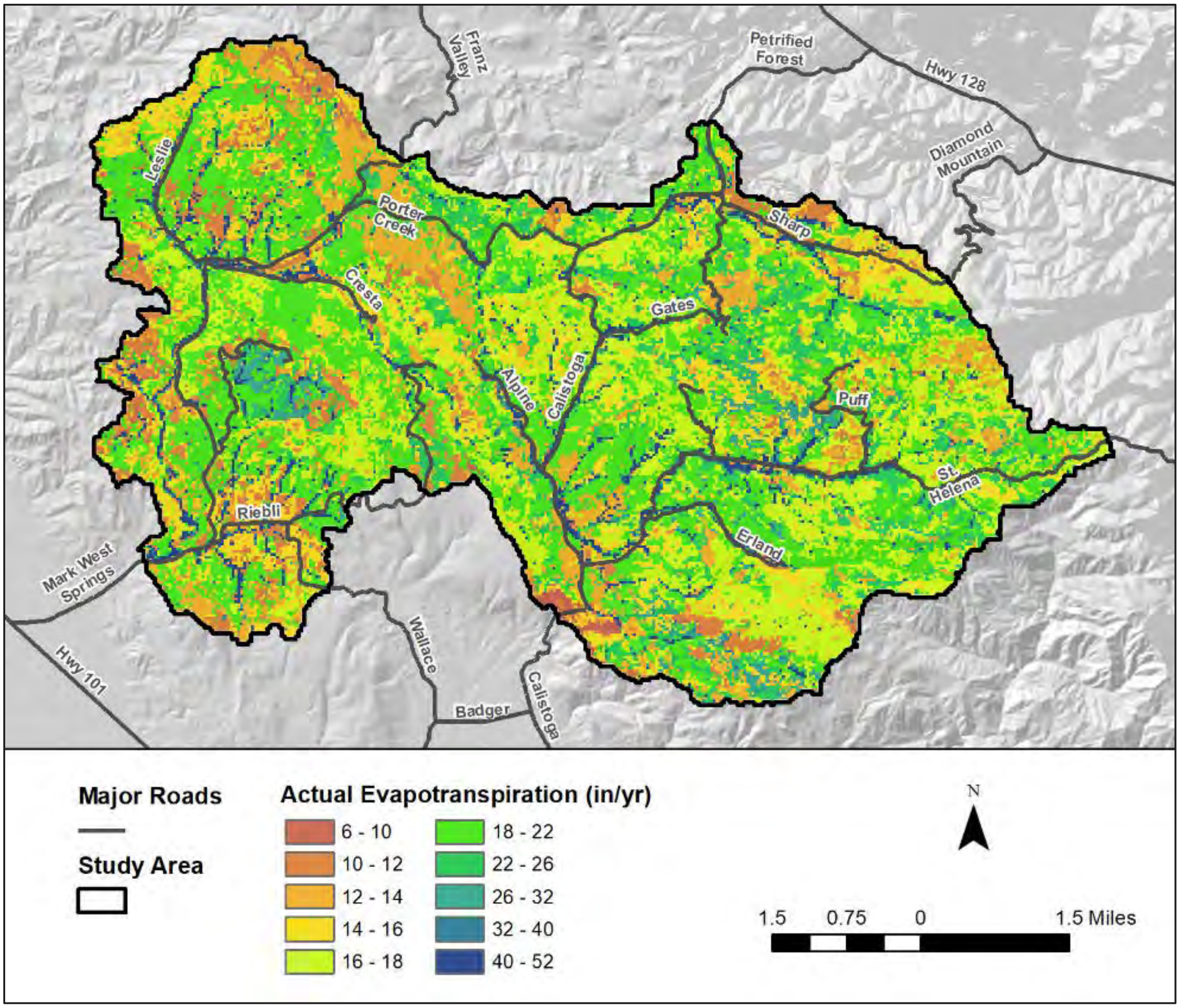


Figure 48: Mean annual Actual Evapotranspiration (AET) for water years 2010-2019 simulated with the MWC hydrologic model.

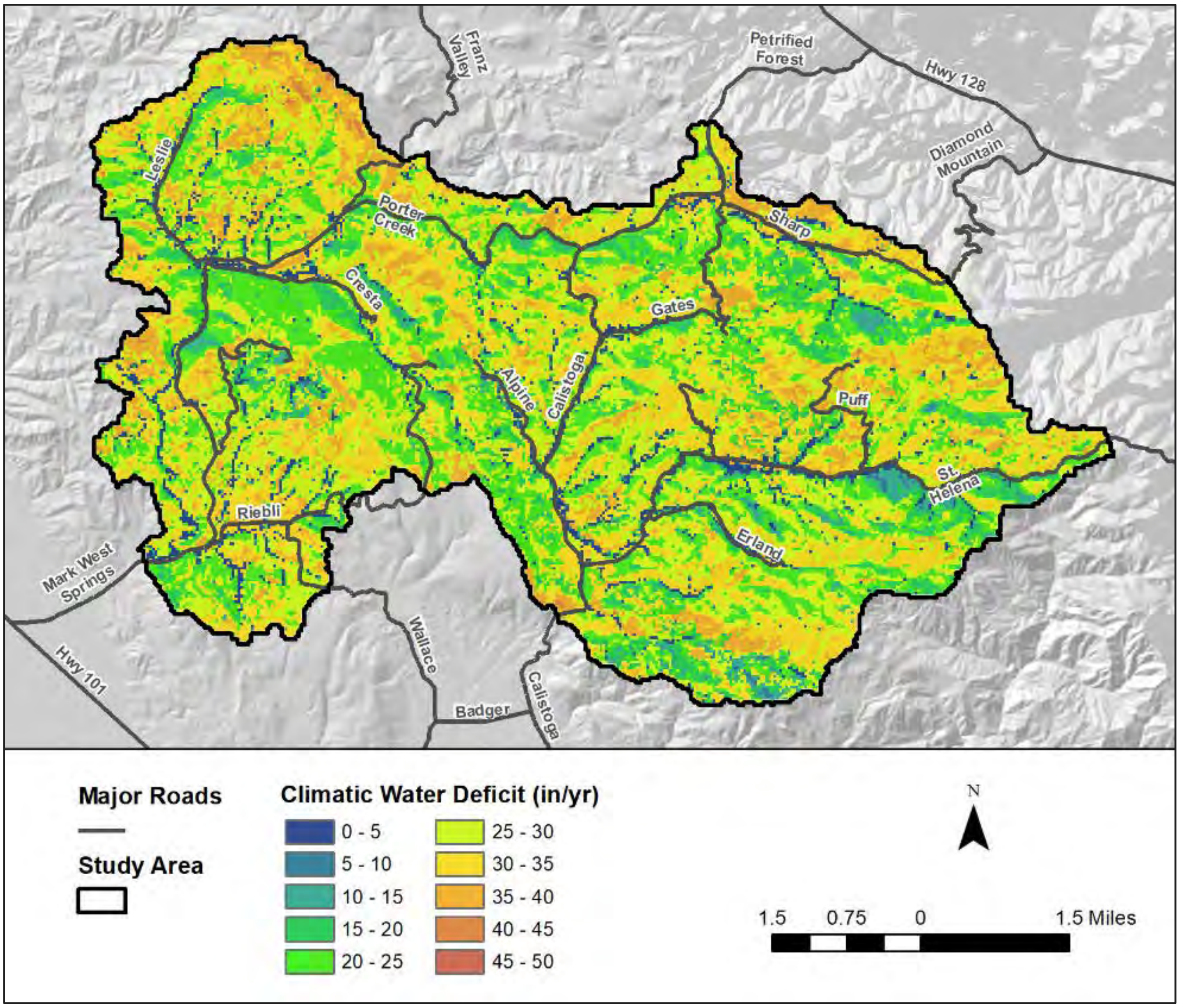


Figure 49: Mean annual Climatic Water Deficit (CWD) for water years 2010-2019 simulated with the MWC hydrologic model.

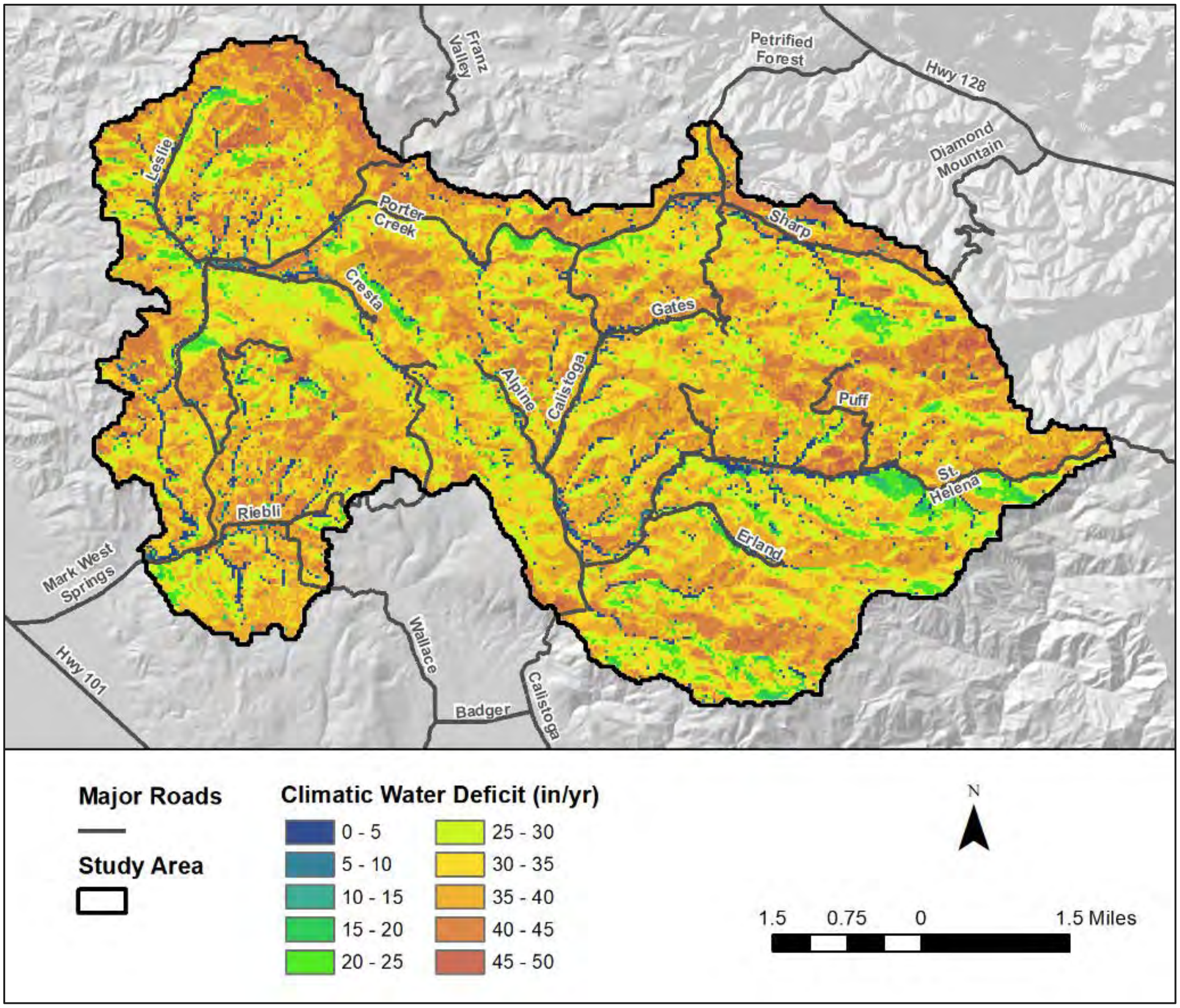


Figure 50: CWD for water year 2014 simulated with the MWC hydrologic model.

Groundwater Flow

Two hydrogeologic cross sections were prepared, one in the upper watershed downstream of Monan's Rill and one in the central watershed downstream of Humbug Creek (Figure 51). These sections show the vertical and horizontal variations in Hydraulic Conductivity, as well as the simulated equipotential lines, and approximate flow directions (perpendicular to equipotential lines) and locations of groundwater discharge predicted by the model. It is important to note that in both cross sections there is a significant downstream (out of the page) component to the flow directions not visible in this one-dimensional cross section view. Equipotentials are based on simulation results for 10/1/2010 but are representative of the regional patterns of groundwater flow throughout the simulation period which do not show significant variation at the regional scale of the cross sections.

The northern portion of the upper cross section (A-A’) passes through the area with the thickest sequence of primarily tuffaceous volcanic materials that was identified from available Well Completion Reports. A transition to more andesitic-dominated materials occurs throughout the cross section with increasing depth, which is typical of our characterization of the volcanics in the upper watershed (Figure 52). Franciscan Complex, which was represented by simple vertical contacts owing to lack of data with which to describe contact orientation, occurs in the southern portion of the cross section. A thin deposit of Quaternary Alluvium is present within a relatively narrow band along the stream channel. Flow is primarily vertical downward within the higher elevation portions of the cross section (Figure 52). Mid-way along the hillslopes above Mark West Creek, the flow directions transition toward horizontal and a vertical groundwater divide occurs beneath the creek with vertical upward flow in the upper ~300-ft (model Layers 1-3) and vertical downward flow in the lower ~500-ft (model Layers 4-6). Springs occur where upward vertical groundwater flow intersects the land surface. This primarily occurs along the lower hillslopes and stream banks in the upper watershed and appears to be associated with horizontal transitions from more tuffaceous to less tuffaceous materials as well as with steep dissected topography (Figure 52).

The cross section below Humbug Creek (B-B’) passes through the relatively thin Humbug Creek Deposits on the northeast side of Mark West Creek which are underlain by primarily andesitic rocks of the Sonoma Volcanics. (Figure 53). A contact between the volcanics and the Franciscan Complex associated with the Maacama Fault Zone occurs near the creek in this reach, and a second contact occurs ~2,000-ft southwest of the creek with a mixture of tuffaceous and andesitic materials occurring in the southwest portion of the cross section. A thin deposit of Quaternary Alluvium is present within a narrow band along the stream channel. Flow is primarily vertical downward within the higher elevation portions of the cross section (Figure 53). A shallow flow path with more horizontal flow occurs mid-way along the hillslope northeast of Mark West Creek, and a somewhat deeper horizontal flow path also occurs at a similar topographic position on the other side of the creek within the Franciscan Complex.

A vertical groundwater divide occurs beneath the creek and adjacent hillslopes with vertical upward flow in the upper ~300-ft and vertical downward flow in the lower ~500-ft. A cone of depression associated with pumping from the well located in the Franciscan Complex is readily apparent and influences the flow directions along the adjacent hillslope (Figure 53). Large persistent cones of depression like this one are relatively uncommon in the model and appear to coincide with wells exhibiting both high production rates and low aquifer Hydraulic Conductivity. Although there is some intersection of equipotentials with the land surface, rates of groundwater movement through these materials are very low and the model does not predict significant springflow in the vicinity of this cross section.

Streamflow & Riffle Depths

The model simulates streamflows and the depth of surface flow across riffles on the stream bed (i.e. riffle depths) throughout the various tributaries in the watershed; however, this discussion focuses on the main-stem of Mark West Creek where nearly all of the available suitable salmonid habitat is contained. The reach shown on subsequent maps extends upstream to the limits of anadromy associated with a natural waterfall as identified in the CDFW Fish Passage Barrier Database.

April through June (hereafter referred to as Spring) mean streamflows varied substantially between water years with the driest conditions occurring in water year 2014 when flows ranged from less than 2 cfs above Van Buren Creek to 6-10 cfs below Porter Creek. The wettest conditions occurred in water year 2010 with flows above Van Buren Creek on the order of 4-8 cfs and flows below Porter Creek in excess of 30 cfs (Figure 54). July through September (hereafter referred to as Summer) mean streamflows were significantly lower than during Spring and also varied much less between water years. The driest conditions occurred in 2015 when flows ranged from less than 0.3 cfs above Van Buren Creek to 0.6-0.8 cfs below Porter Creek. The wettest summer conditions occurred in 2011 when flows ranged from less than 0.7 cfs above Van Buren Creek to more than 1.5 cfs below Porter Creek (Figure 55).

To assist in relating flow conditions to salmonid habitat requirements, we also compiled simulated water depths (hereafter referred to as riffle depths) which were found to be loosely equivalent to riffle crest thalweg depth conditions as discussed in greater detail in Chapter 7. The results were post-processed from model output data by extracting the minimum simulated depth per 1,000-ft of channel length (10 cross sections) to better represent riffle crest conditions observed in the field. Average Spring riffle depths during the drought of 2014 ranged from less than 0.2-ft upstream of Van Buren Creek to 0.2-0.4 ft below Porter Creek. In the wet water year 2017, riffle depths in the upper reaches were above 0.2-ft all the way to upstream about one river mile beyond Monan's Rill (Figure 56). Summer mean riffle depths are significantly lower than Spring depths and are relatively consistent between water years. In typical conditions, depths remain above 0.1-ft in most locations downstream of Monan's Rill, and below Porter Creek depths reach 0.2-0.3 ft in many locations (Figure 57). The simulated spatial distributions of riffle depth reflect both reaches where riffle depths are limited by reduced streamflows, most notably the reach upstream of Porter Creek which loses flow to the alluvium, as well as where depths are limited by geomorphic controls such as the reaches about 1-mile upstream of Riebli Creek (Figures 56 & 57).

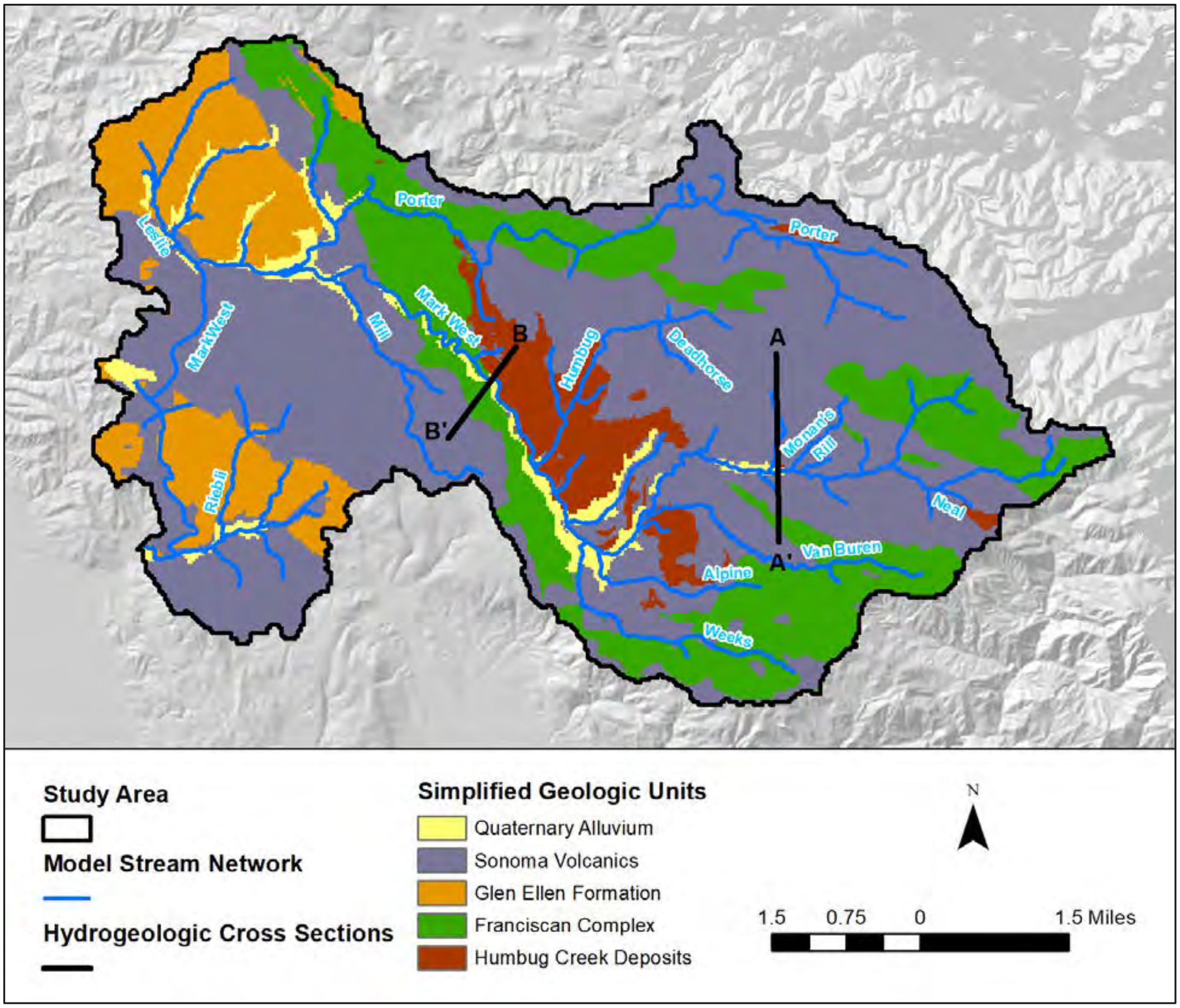


Figure 51: Simplified geologic map and locations of hydrogeologic cross sections A-A' and B-B'.

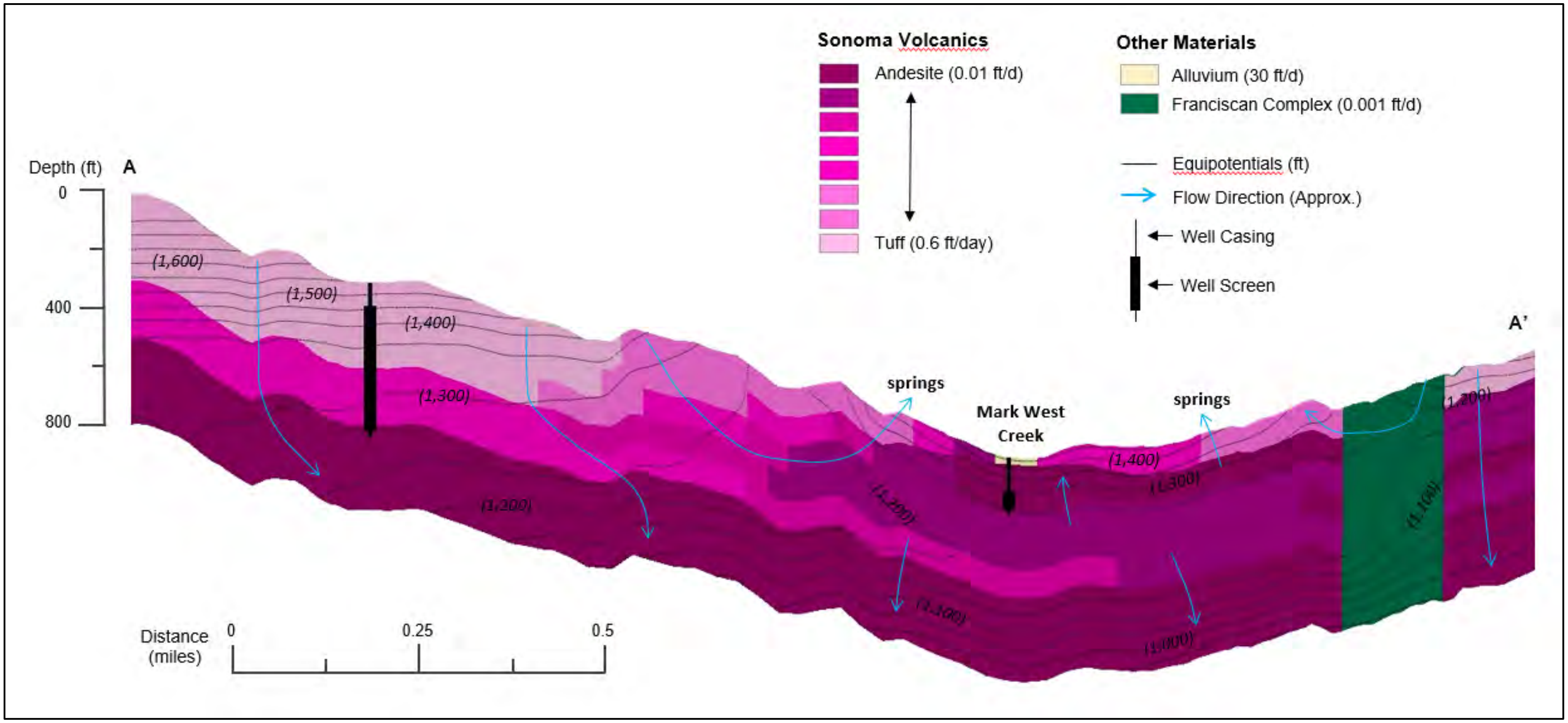


Figure 52: Hydrogeologic cross section A-A' showing hydraulic conductivities, equipotentials, and approximate flow directions as simulated with the MWC hydrologic model (see Figure 51 for location).

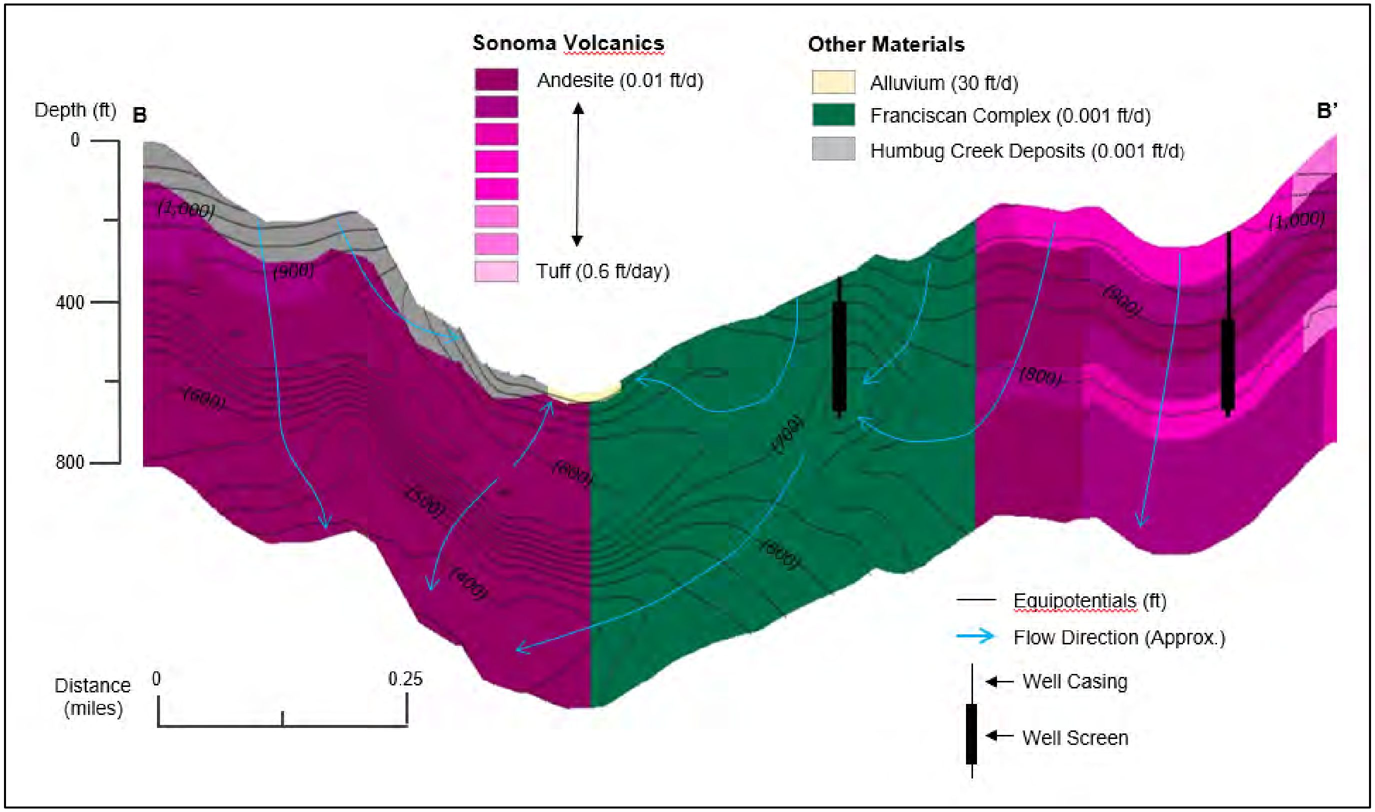


Figure 53: Hydrogeologic cross section B-B' showing hydraulic conductivities, equipotentials, and approximate flow directions as simulated with the MWC hydrologic model (see Figure 51 for location).

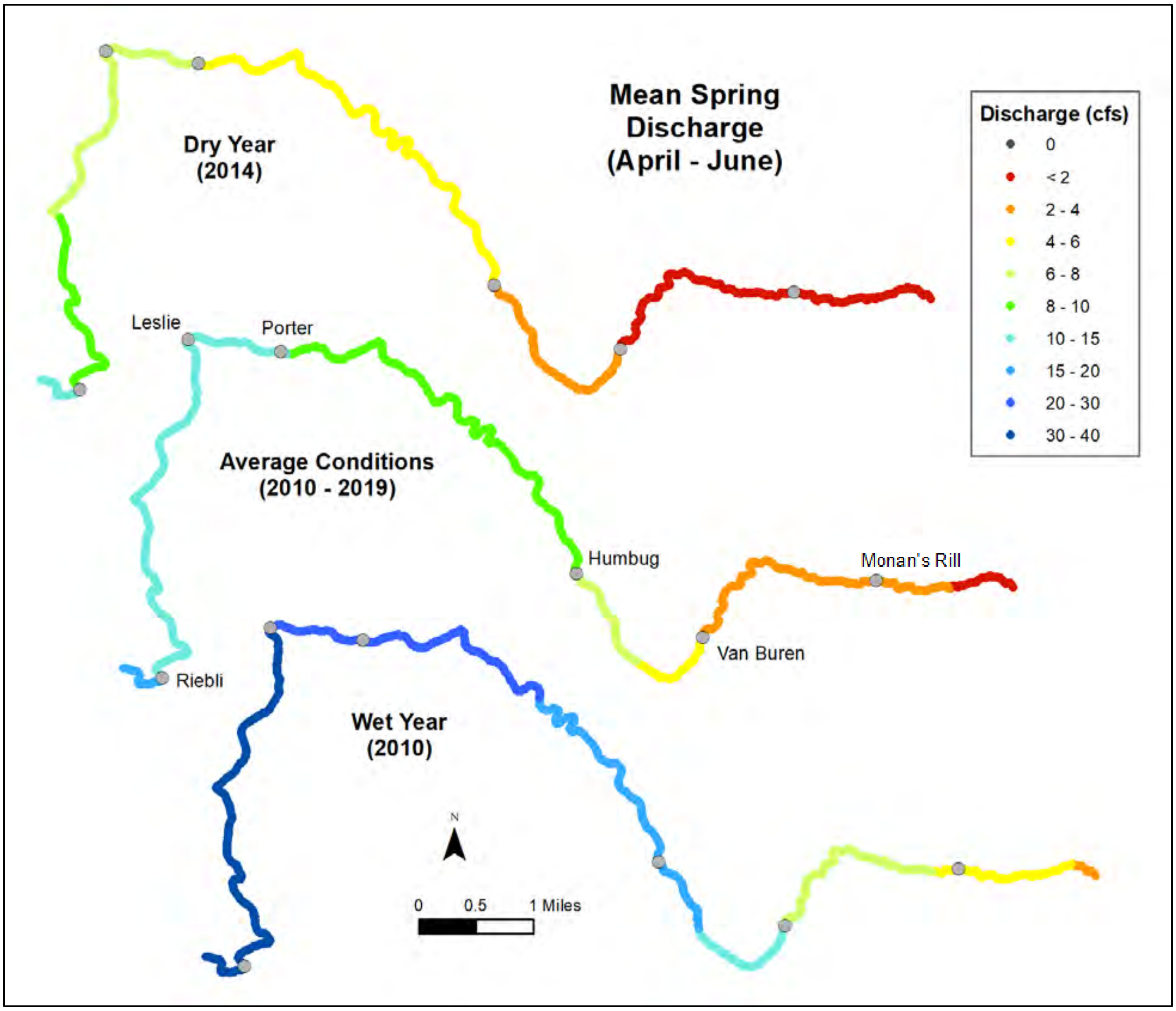


Figure 54: Mean simulated Spring (April – June) streamflows for dry, average, and wet water year conditions.

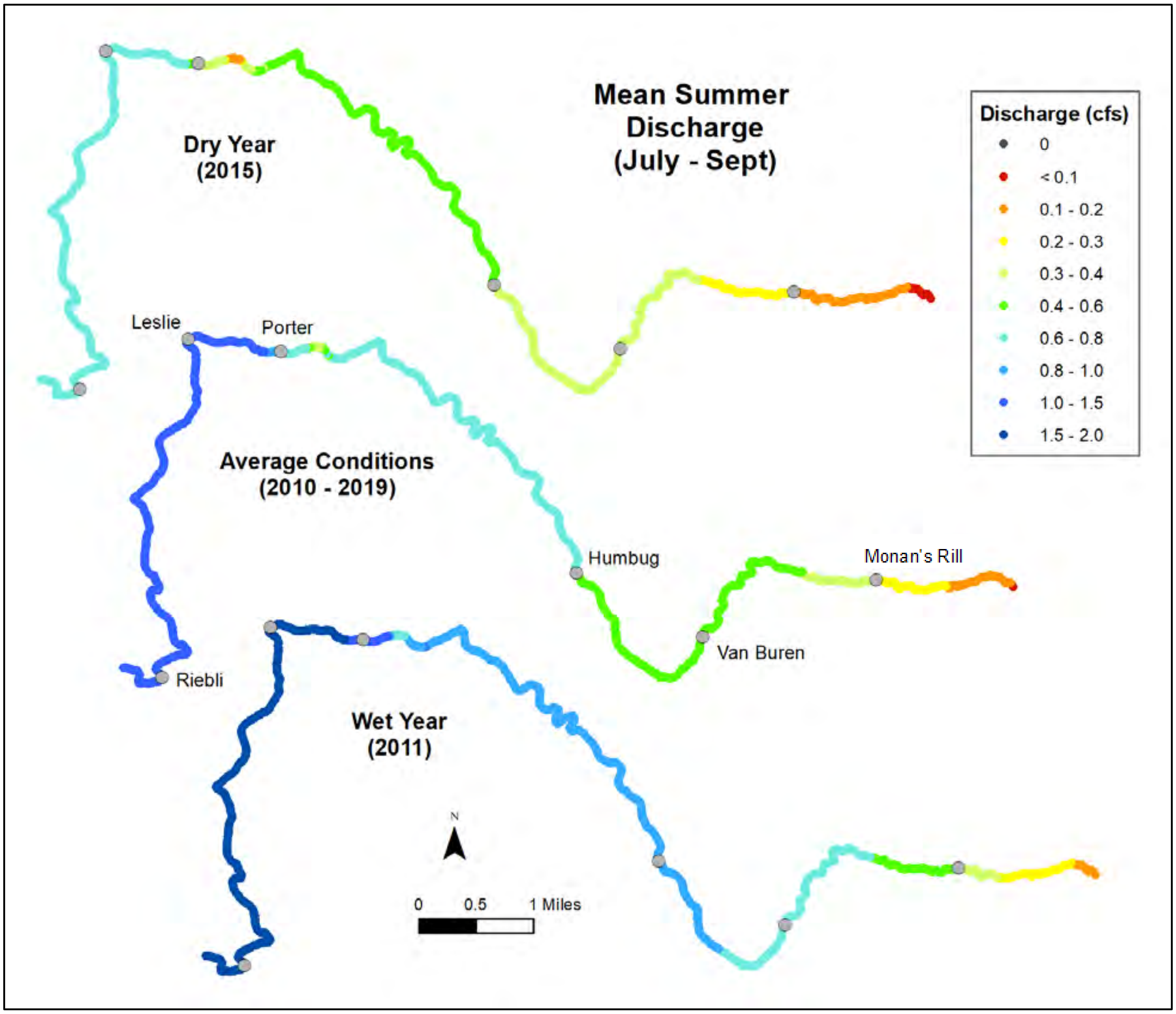


Figure 55: Mean simulated Summer (July - Sept) streamflows for dry, average, and wet water year conditions.

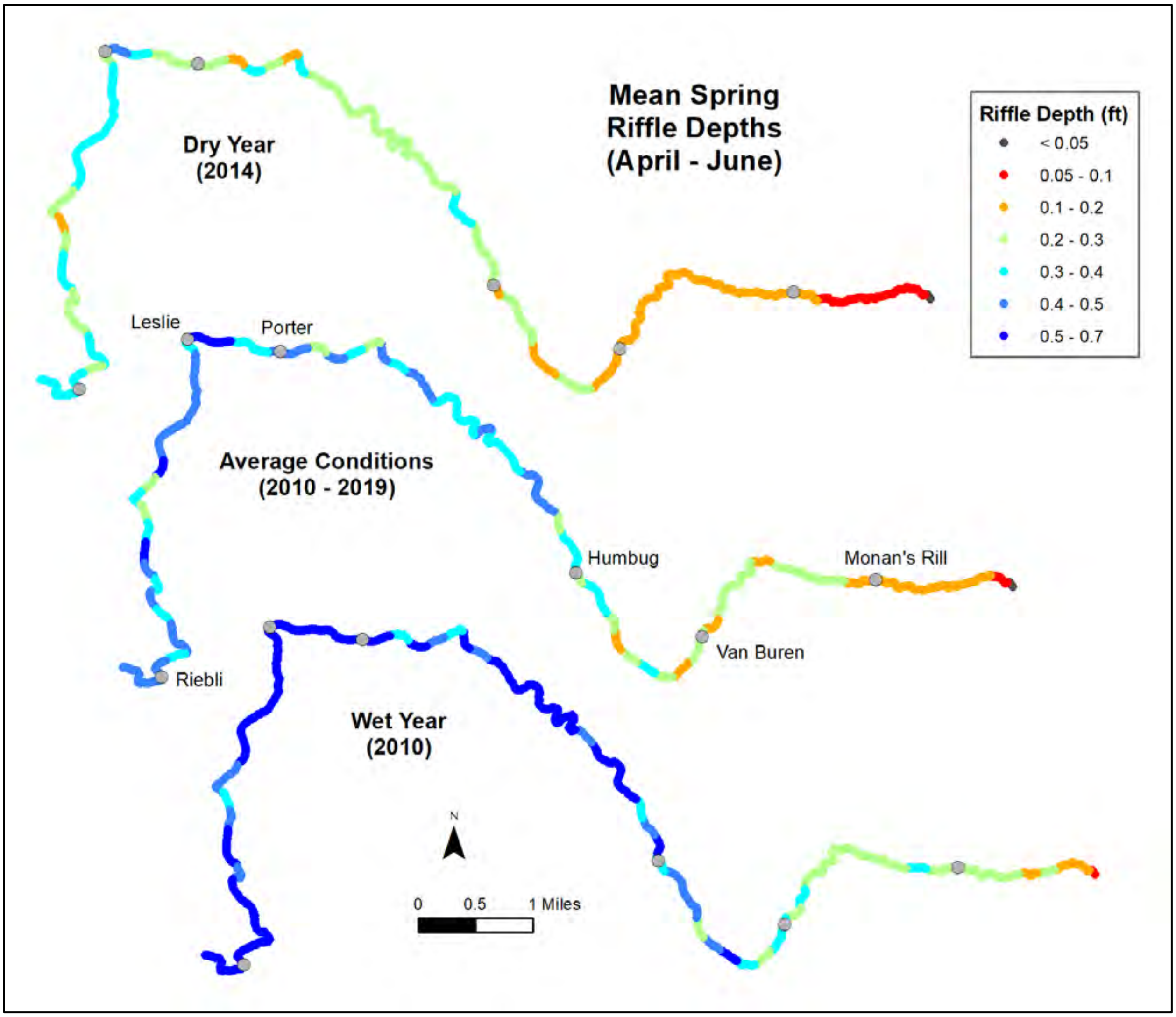


Figure 56: Mean simulated Spring (April – June) riffle depths for dry, average, and wet water year conditions.

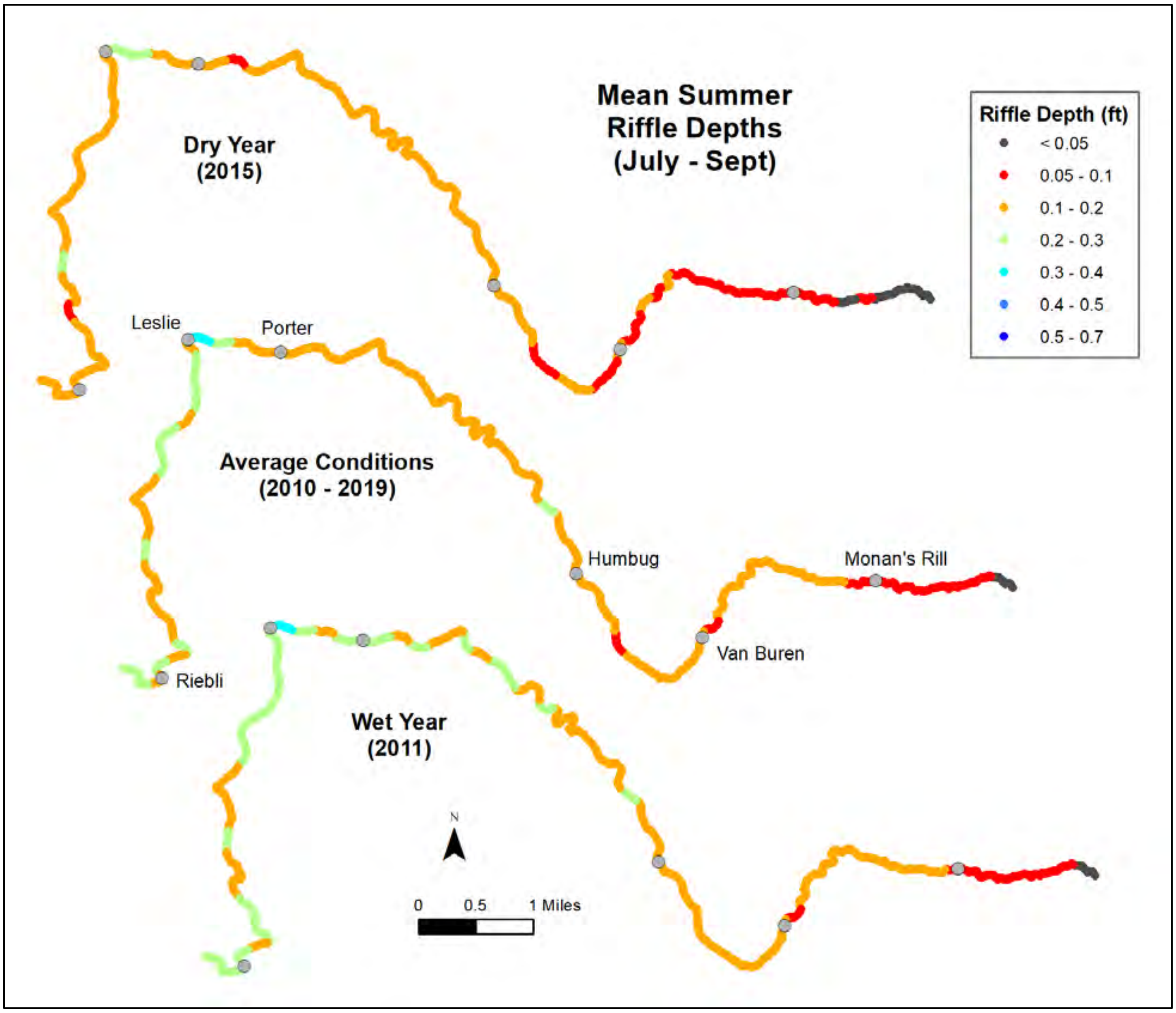


Figure 57: Mean simulated Summer (July - Sept) riffle depths for dry, average, and wet water year conditions.

Chapter 7 – Habitat Characterization and Prioritization

Background

Inadequate stream flow to support juvenile rearing habitat during the summer months has been identified as a primary limiting factor for coho survival in Russian River tributaries (CDFG, 2004; NFMS, 2012). Flows during the spring outmigration period may also be limiting in some cases. Numerous methods have been developed to relate stream flow conditions to habitat quality and define minimum flow requirements for a specific species and life stage of interest. These methods include applying regional regression equations that have been developed from multiple habitat suitability curve studies (e.g. Hatfield & Bruce, 2000), wetted perimeter and critical riffle depth methods (e.g. Swift, 1979, R2 Resource Consultants, 2008), and direct habitat mapping approaches (e.g. McBain & Trush, 2010).

Regional regression equations produce discharge estimates for Mark West Creek and other Russian River tributaries that are an order of magnitude higher than typical conditions during the summer months. Given that coho persist in these tributaries despite these very low flow conditions, application of these regional equations may be of limited value for delineating the extent and quality of existing habitat with respect to streamflow. Direct habitat mapping approaches require extensive fieldwork and site-scale characterization which is beyond the scope of this reginal planning study; a concurrent CDFW Instream Flow Study utilizing such methods is being conducted in upper Mark West Creek.

A simple approach to utilizing hydrologic model results to delineate habitat availability (and the selected approach for this study) is to relate water depths simulated in the model to riffle crest thalweg depths (RCTDs) which have been investigated as important indicators of salmonid habitat suitability. This approach assumes that the simulated water depths are representative of conditions at riffle crests. This assumption is consistent with the limitations of the LiDAR topographic data which does not penetrate water and therefore would be expected to capture riffles and pool water surfaces but not pool geometries. To validate this assumption, we measured riffle crest thalweg depths (RCTDs) at nine riffle crests identified in three reaches of Mark West Creek across a range of typical low to moderate flow conditions and compared the resulting discharge/RCTD relationships to relationships extracted from the model for equivalent locations (Figure 58).

There was generally good agreement between the measured and simulated discharge/RCTD relationships, and the agreement was improved by sampling the cross section within a given 1,000-ft reach with the lowest simulated depths (i.e. finding the cross section most representative of conditions at nearby riffle crests). At most riffle crests observed in the field, maximum depths occur across a relatively narrow width commonly associated with gaps between small clusters of individual cobbles. This level of topographic detail is not captured in the model topography, therefore a small residual depth (0.05-ft) was added to the simulated values to account for the effects of this microtopography. The simulated discharges associated with a RCTD of 0.2-ft ranged from 0.21 to 0.46 cfs based on interpolation between field measurements, and from 0.18 to 0.53 cfs as simulated in the model (Figure 58).

Previous research has demonstrated relationships between RCTDs and various indicators of salmonid habitat suitability including fish passage, water quality, and abundance of benthic macroinvertebrates. Maintaining suitable riffle depths to allow for fish passage is critically important during smolt outmigration (typically mid-February to mid-June) and is also important for facilitating pool selection prior to summer rearing. A minimum passage depth of 0.3 feet has been estimated for juvenile coho (R2 Resource Consultants, 2008; CDFW, 2017). This depth criterion and methodology is somewhat conservative by design and fish passage is thought to occur in Russian River tributaries at shallower depths, therefore it is useful to define a lower criterion below which passage is presumably not possible. For the purposes of this study, that depth was defined as 0.2 feet expressed as a RCTD. It is important to note that we are applying this depth threshold to RCTDs rather than based on CDFW critical riffle methodology. We calculated the flows required to achieve a 0.2-ft depth from our field data following CDFW protocols for performing Critical Riffle Analysis (CDFW, 2017). This resulted in estimates of required flows ranging from 2.0 to 3.2 cfs, which are about 5 to 10 times higher than the typical summer flows experienced in the watershed.

Another key factor in summer survival is the suitability of water quality conditions in the pools that provide rearing habitat for salmonids. Maintaining sufficient flow between riffles is key to maintaining oxygenation in pool habitats, and monitoring in Green Valley Creek has shown that coho survival begins to decline when pools become disconnected with mortality increasing as a function of length of disconnection (Obedzinski et al., 2018). Through extensive field monitoring in Green Valley, Dutch Bill, and Mill Creeks, CA Sea Grant found a statistically significant relationship between RCTDs and Dissolved Oxygen (DO) concentrations in intervening pools, with ~80% of the pools with RCTDs greater than 0.2-ft maintaining suitable DO concentrations above 6 mg/L (CA Sea Grant, 2019). As discussed below in greater detail, water temperature conditions are higher in Mark West Creek relative to the monitored streams nearer the Pacific Ocean in Sonoma County, therefore while we still consider RCTDs to be an important indicator of water quality in Mark West Creek, temperature considerations must be accounted for in more detail.

In addition to suitable water quality, another factor critical summer rearing habitat for salmonids is the availability of a reliable food supply in the form of benthic macroinvertebrates (BMI) which are concentrated in riffle habitats with sufficient flow velocity. Velocities at riffles between about 1.0 and 2.5 ft/s have been shown to be optimal for BMI (Giger 1973, Gore et al., 2001). As part of our riffle crest analysis in Mark West Creek we measured velocities and interpolated relationships between RCTDs and thalweg velocities (Figure 59). At lower flows, depths were too low to measure velocity at more than a few locations across the riffle, however in most cases velocities approaching those at the thalweg only occurred across a relatively small portion of the riffle profile. To ensure that the threshold velocity represents a condition that provides suitable habitat for BMI across larger swaths of the riffle we applied a minimum velocity threshold of 1.5 ft/s and do not consider the upper velocity limit important over the range of summer flows experienced in Mark West Creek. This exercise revealed that 0.2-ft was also a useful threshold for describing the approximate minimum RCTD that corresponded to adequate velocity at riffle crests for BMI (Figure 59).

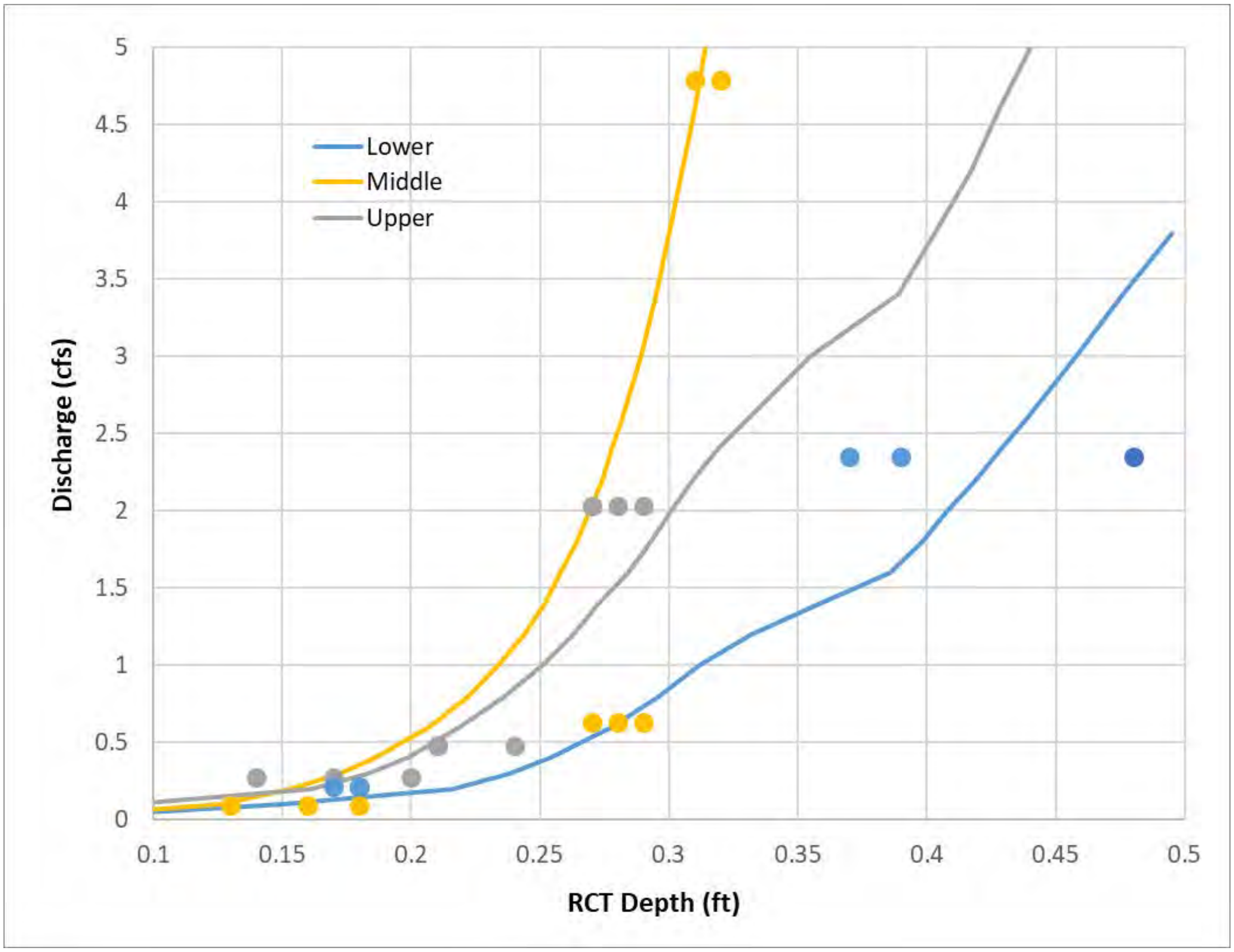


Figure 58: Comparisons between RCTD/discharge relationships measured in the field (points) and simulated with the MWC hydrologic model (lines).

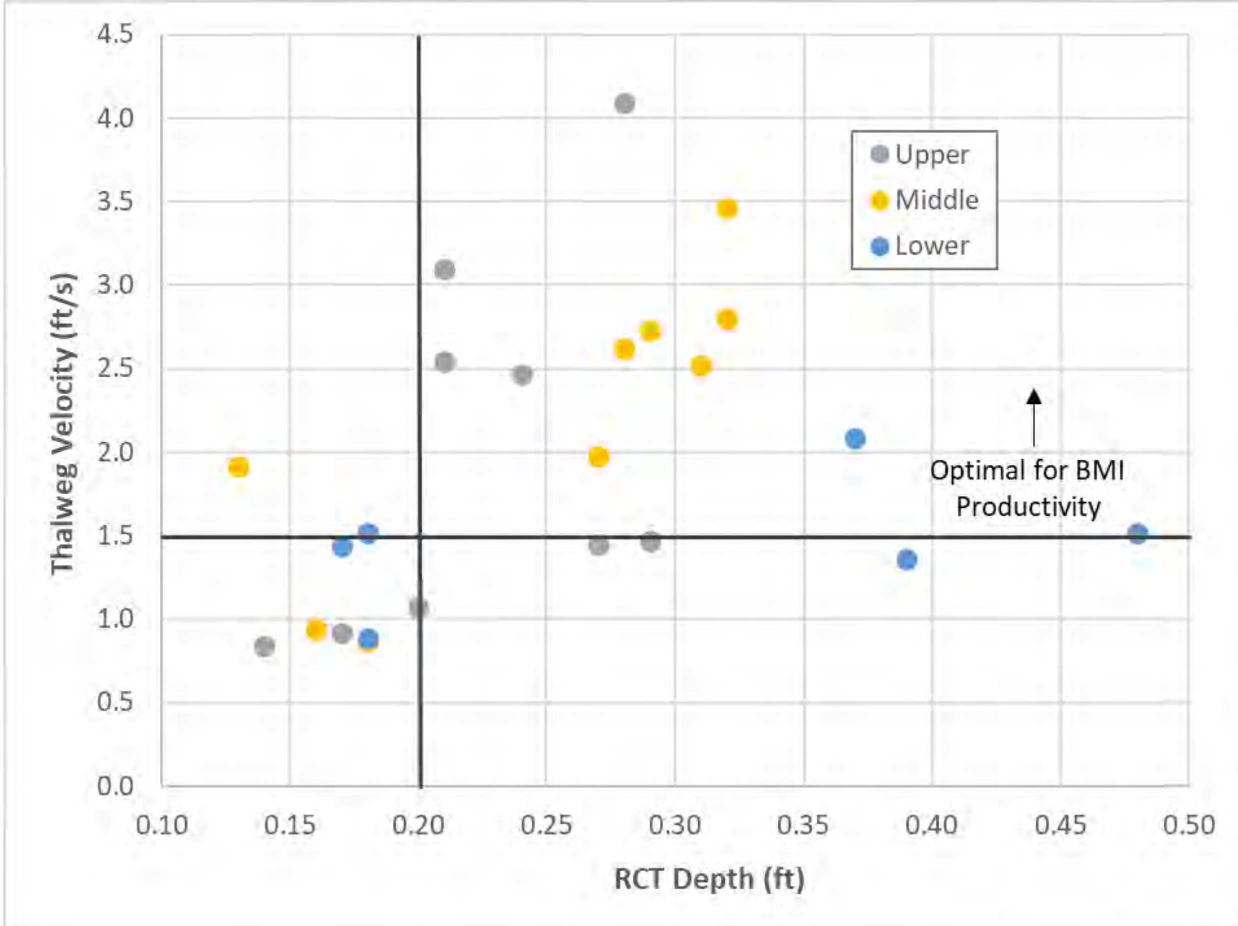


Figure 59: Relationship between RCTD and velocity based on measurements at nine riffles crests in Mark West Creek.

Approach

We developed two streamflow classifications with respect to salmonid habitat condition, one for smolt outmigration and one for juvenile rearing. Both classifications focus on the 0.2-ft RCTD threshold which is intended to represent the minimum flow conditions required to provide suitable (not optimal) habitat for salmonids. It is important to note that the primary goals in defining a minimum flow threshold for this study were to 1) assist in distinguishing between reaches with varying levels of habitat suitability under existing and plausible future flow conditions in the watershed to aid in prioritizing reaches for restoration projects, and 2) to distinguish between conditions that are likely suitable versus not suitable rather than attempting to distinguish between optimal and suboptimal conditions. Optimal summer rearing habitat conditions for salmonids, particularly coho salmon, are rarely found or non-existent in most lower Russian River tributaries.

We obtained smolt outmigrant trap data collected by Sonoma Water in Mark West Creek for 2012-2018. These traps were only deployed during April and May to capture the primary pulse of outmigration. CA Sea Grant has collected data from outmigrant traps in other Russian River tributaries over the full outmigration season from late February to late June. We compared the CA Sea Grant data in Mill Creek for 2014-2019 with the Mark West data and found very similar outmigration timing with peak outmigration occurring between the first week of April and the third week of May in both creeks. CA Sea Grant's analysis of the Mill Creek data (which we believe is representative of Mark West Creek) indicated 80% of the outmigrants had moved by the week of May 21st in a late outmigration year and 99% had moved by the week of June 18th (Nossaman Pierce, personal communication). We developed habitat suitability criteria based on these dates and a RCTD threshold of 0.2-ft as follows:

- Maintain RCTD threshold through week of May 21st in the 10-yr average condition
- Maintain RCTD threshold through week of June 18th in the 10-yr average condition
- Maintain RCTD threshold through week of May 21st in drought years
- Maintain RCTD threshold through week of June 18th in drought years

We followed a similar approach for the juvenile rearing habitat classification focused on July-September conditions. In our previous flow-based habitat classification work in Green Valley/Atascadero & Dutch Bill Creeks, we focused on differentiating between reaches where pools remain connected, become disconnected for short periods of time, and become disconnected for longer periods of time (OEI, 2016). Disconnected pools are relatively rare in Mark West Creek (with the exception of a short reach above Porter Creek), therefore this was not a useful metric for distinguishing between various levels of habitat suitability in this watershed. We developed an alternative and likely more stringent set of habitat suitability criteria for summer rearing habitat conditions as follows:

- Maintain RCTDs threshold for portions of the summer in the 10-yr average condition (always > 0.1-ft)
- Maintain RCTD threshold continuously in the 10-yr average condition
- Maintain RCTD threshold for portions of the summer in drought years (always > 0.1-ft)
- Maintain RCTD threshold continuously in drought years

We then assigned each 1,000-ft stream reach in the model with a score of zero through four based on the number of these criteria that were met to develop flow-based habitat classification maps for smolt outmigration and juvenile rearing.

Although water temperature analysis was not part of our project scope, preliminary review of available temperature data revealed that elevated water temperatures may be an even more important limiting factor for juvenile rearing habitat than flow in this watershed, therefore we compiled available temperature data from Sonoma RCD, CA Sea Grant, Trout Unlimited, and CDFW to facilitate incorporating temperature into the habitat classification. We calculated the Maximum Weekly Maximum Temperature (MWMT) from continuous temperature datasets at 15 locations in Mark West Creek. Each location had between one and five years of data between 2010-2019, however many locations had only one year of data and most years had only a few locations, complicating the interpretation of spatial and temporal patterns. Nevertheless, the data was sufficient to perform a preliminary water temperature classification based on the

MWMT and various levels of temperature impairment. Based on previous work, a threshold of 18.0 °C was used to represent impaired conditions, 21.1 °C to represent severe impairment, and 23.1 °C to represent conditions that may be lethal for salmonids given prolonged exposure (NCRWQCB, 2008). Each reach was assigned a score from zero to three based on the number of the following criteria that were met:

- Maintain MWMT < 23.1 °C
- Maintain MWMT < 21.1 °C
- Maintain MWMT < 18.0 °C

In addition to sufficient flow to enable passage, maintain water quality, and support benthic macroinvertebates, there are many other important factors for maintaining suitable salmonid habitat. These include presence of pools with sufficient depth and cover, suitable spawning gravels, and availability of refugia from high velocity winter flows, among others. To account for some of these factors in our classification, we compiled Stream Inventory Report data collected by CDFW in 1996 and ranked each of the five reaches described in the report based on the relative quality of pool habitat and spawning habitat. Although we did not collect detailed pool or substrate data, we incorporated our general observations of these conditions in our interpretations of the resulting rankings. Our observations suggest that even though the inventory data described conditions more than 20 years ago, the relative quality of habitat conditions between reaches described by the data appears to be fairly consistent with current conditions. Finally, we compiled summer snorkel survey data collected by CA Sea Grant to understand which reaches have been utilized by salmonids in recent years.

We then produced a generalized multi-factor habitat classification map by combining the flow- and temperature-based classifications and making adjustments and interpretations based on the pool and spawning habitat rankings as well as our general observations about other factors such as off-channel habitat availability and potential for redd scour, and recent patterns of salmonid utilization. The resulting maps are intended to delineate the reaches providing the best overall habitat value for salmonids in the watershed as well as the reaches where conditions are likely unsuitable due to one or more critical limiting factors.

Results

The flow-based habitat classification results indicate that most reaches are impaired with respect to flow both in terms of smolt outmigration and summer rearing (Figure 60). Both the juvenile rearing and smolt outmigration classifications show similar patterns overall. Upstream of Van Buren Creek either one or zero of the four flow criteria are met, most reaches between Humbug Creek and Porter Creek meet two or three of the criteria, and most reaches below Porter Creek meet three or four criteria (Figure 60). Notable exceptions to this include short reaches upstream of Porter Creek and between Leslie and Riebli Creeks which are more flow-limited than adjacent upstream and downstream reaches (Figure 60).

Two of the three temperature criteria are met upstream of Van Buren Creek, one of the criteria are met between Van Buren and about 2-miles upstream of Porter Creek, and none of the criteria are met (MWMT > 23.1 °C) in the reach upstream of Porter Creek (Figure 61). No continuous temperature data was available farther downstream. The available water temperature data shows an overall pattern of increasing temperature in the downstream direction with all reaches being temperature-impaired at times to varying degrees (Figure 62). In the upper watershed, maximum water temperatures generally occur in mid-July, whereas the reach above Porter Creek follows a similar trend in general but superimposed on this is a period of elevated temperatures resulting in maximum temperatures about a six weeks earlier in early June; this behavior may reflect a contrast in the timing of response to solar radiation inputs (Figure 63).

We examined the temporal variations in temperatures relative to streamflows observed at the stream gauges in the watershed and found no obvious correlations between flow and temperature at the most temperature-impaired locations. In fact, the highest temperatures in these reaches generally occur during June and begin to improve by August and September, whereas flows are generally declining throughout this period. In the reach above Porter Creek, June/July water temperatures ranged from 14.4 to 23.1 °C when flows were very low (< 0.2 cfs) and exhibited a similar range of variability (14.5 to 24.3 °C) when flows were relatively high (> 1 cfs) (Figure 64). This suggests that flow is not the primary control on temperature and that even significant streamflow enhancement is unlikely to mitigate elevated temperatures.

We also examined the relationship between pool depth and temperature in six pools monitored by CDFW upstream and downstream of Humbug Creek in 2017. Pools with depths greater than 3.5-ft maintained significantly lower temperatures than shallower pools less than 2.5-ft deep (Figure 65). Although based on a limited sample size from a single year, this suggests that deep pools likely provide critical refugia for salmonids in Mark West Creek when extreme temperatures occur in shallower pool habitats (Figure 65).

The CDFW inventory data indicates that the best pool habitat occurs in the reach above and below Humbug Creek (CDFW Reach 5) and above and below Riebli Creek (CDFW Reach 2) (Figure 66). It is important to remember that this is a relative ranking and pool conditions in these reaches are likely still impaired. The CDFW data indicates that these reaches have relatively low shelter ratings (mean of 40), shallow pools (2.5-ft mean maximum depth), and very little Large Woody Debris (1% occurrence) (Table 14). The best spawning habitat as indicated by the CDFW data occurs in the middle and lowest reaches (CDFW Reaches 2 and 4) (Figure 66). Upstream of Van Buren Creek, spawning suitability is limited by high embeddedness and the predominance of bedrock and cobble-sized substrate conditions (Table 14). Not captured in the CDFW data are considerations of potential for redd scour which is likely to increase significantly below Porter Creek due to increased stream power and sediment mobility. Therefore, the most suitable spawning habitat is likely to occur in the reach of Mark West Creek between Van Buren Creek and Porter Creek. It is important to remember that the inventory data is more than 20 years old and as such may not be reflective of current conditions other than in generally describing reach-to-reach variability.

Summer snorkel survey data is available from 2016-2019. Very few (<10) coho were observed in Mark West Creek during 2016 and 2018 and interpreting the data from 2017 is complicated by a spring release of juvenile coho in the upper watershed. Therefore, the 2019 data is the most useful for examining which reaches have been utilized by coho in recent years. Nearly all (98%) of the 734 observed coho were found in pools between Humbug Creek and Porter Creek. Within this reach, coho were highly concentrated in a relatively small number of pools, with 72% of the coho located in just 11 pools and the remaining 28% distributed between 33 additional pools (Figure 67).

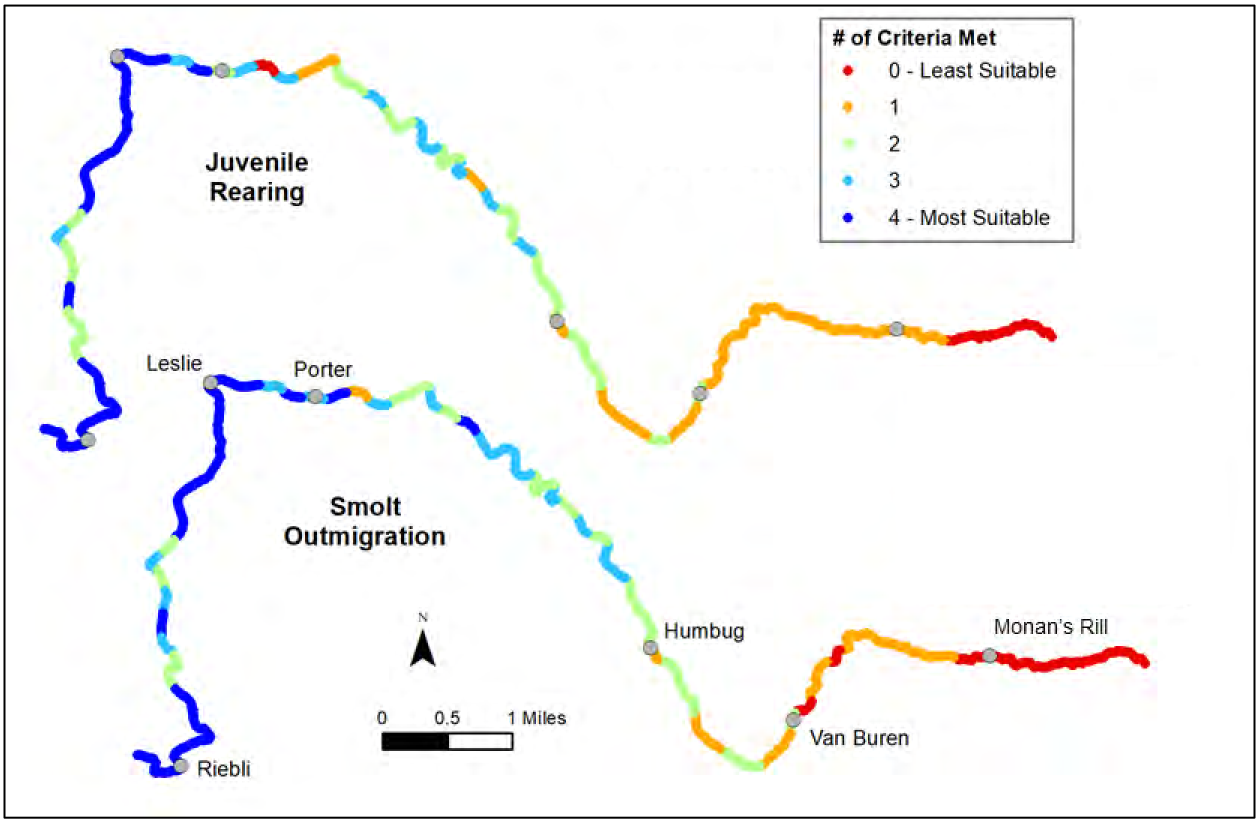


Figure 60: Flow-based habitat suitability classifications for juvenile rearing and smolt outmigration.

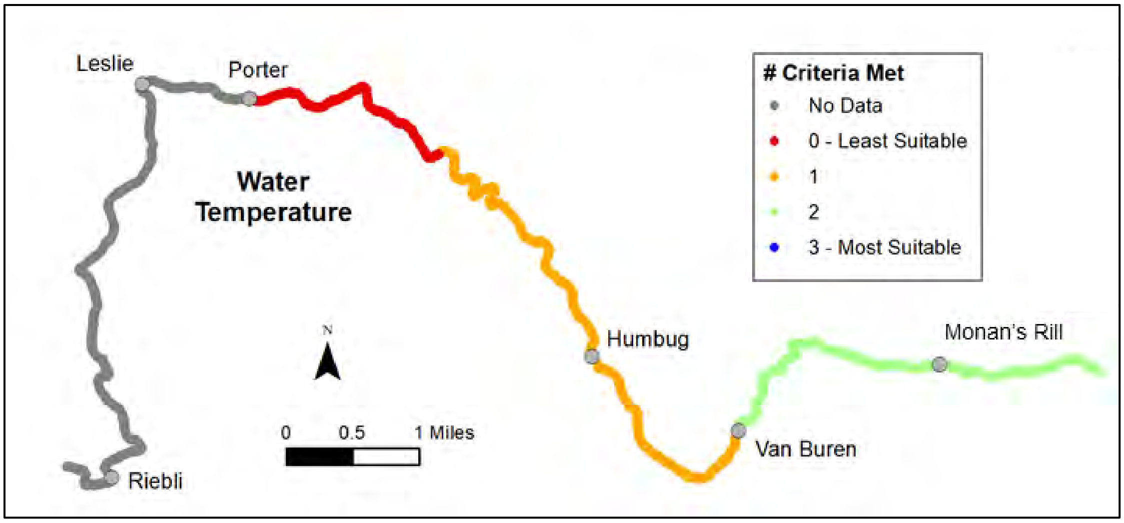


Figure 61: Water temperature-based habitat suitability classification.

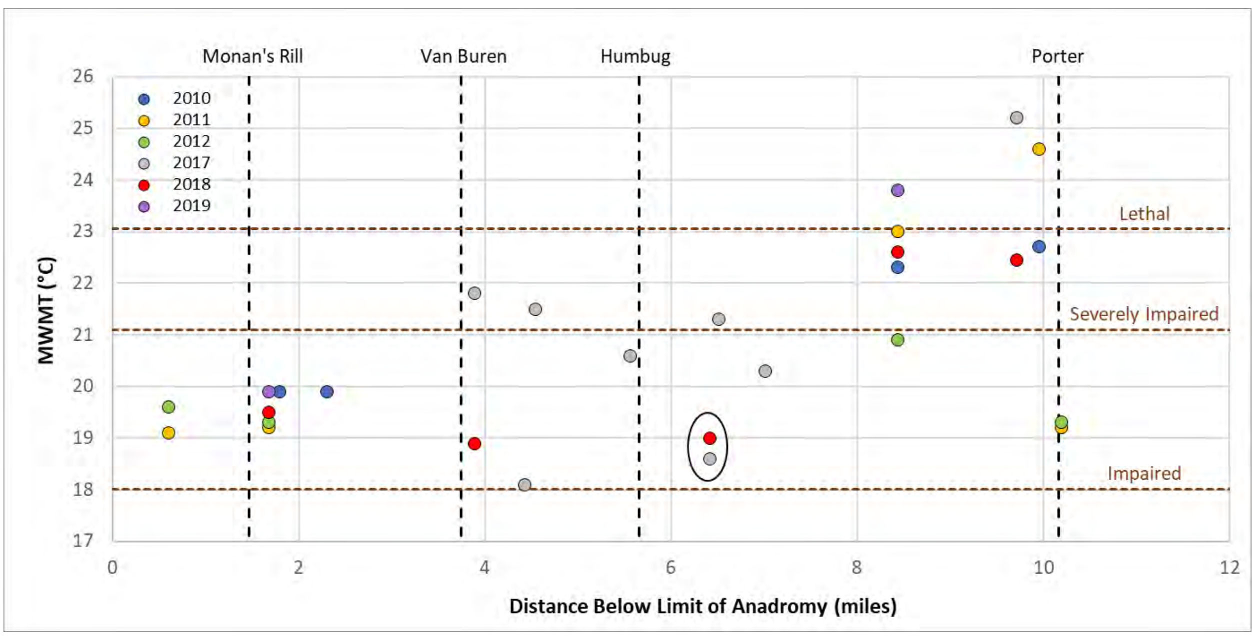


Figure 62: Longitudinal and temporal variations in Mean Weekly Maximum Water Temperature (MWMT) derived from continuous temperature data at 15 stations between 2010 and 2019, black oval indicates location of deep pool cold water refugia; temperature data from CDFW, Sonoma RCD, CA Sea Grant, and TU.

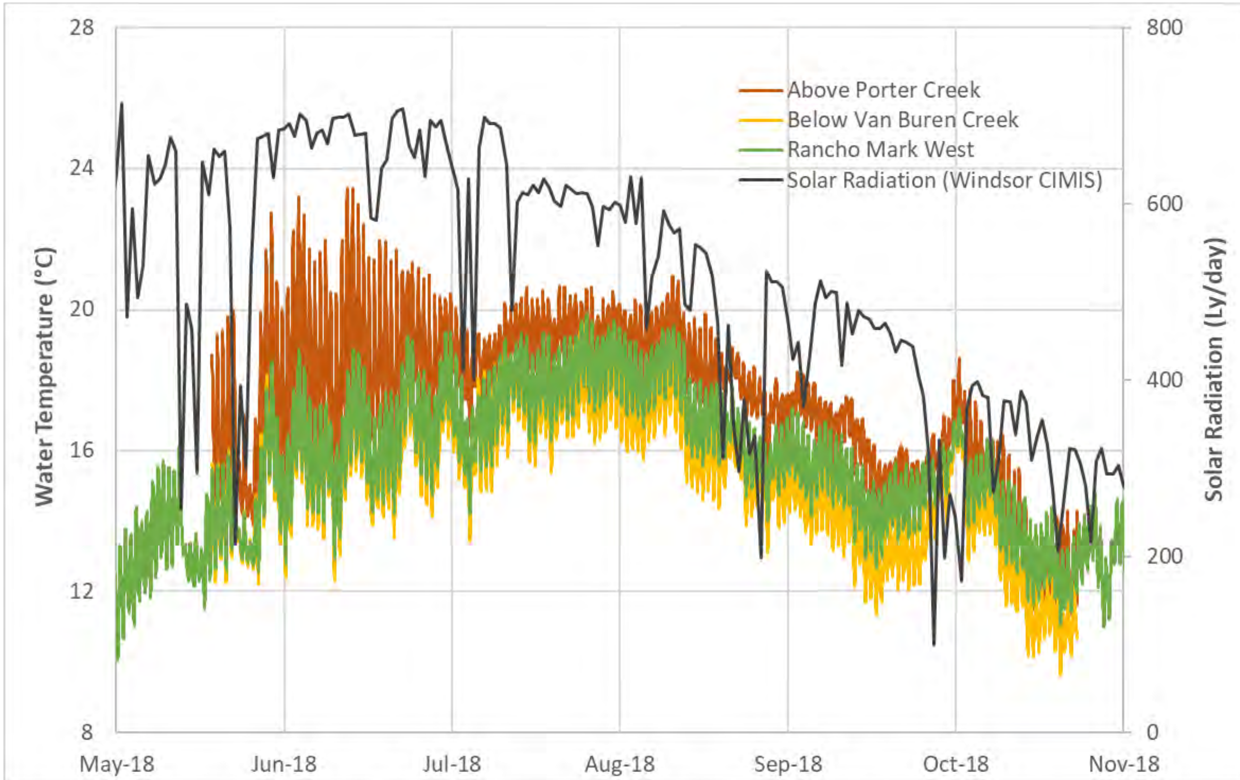


Figure 63: 15-minute interval water temperature data at three locations in Mark West Creek for 2018 and solar radiation data from the Windsor CIMIS station.

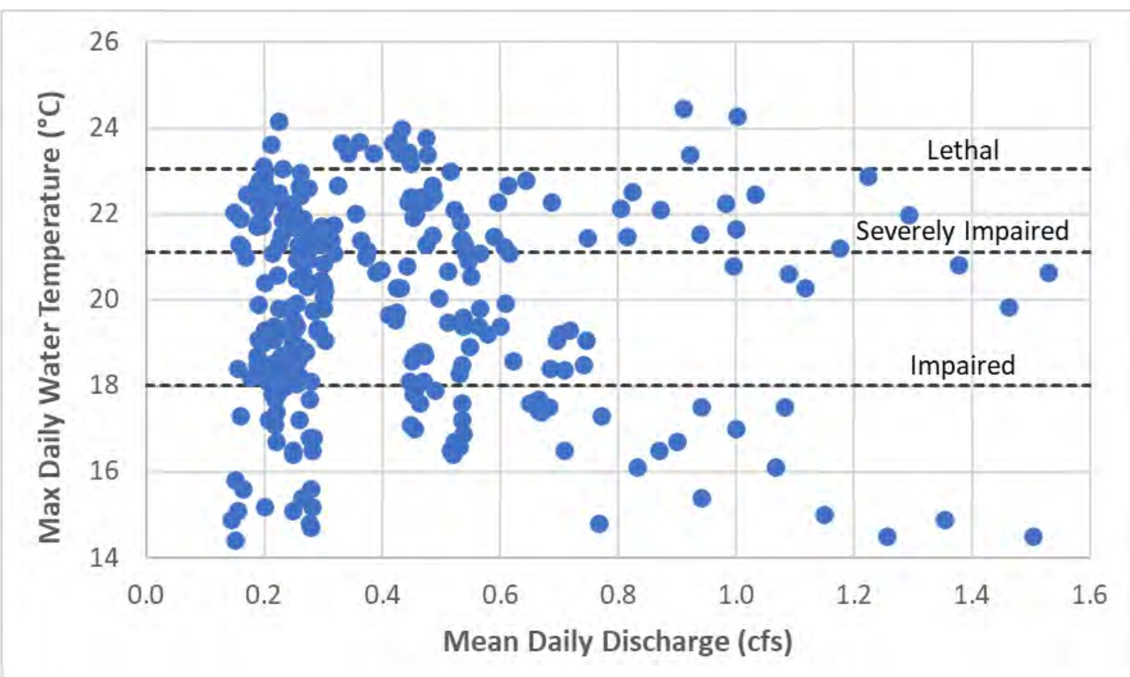


Figure 64: Comparison between Maximum Daily Water Temperature above Porter Creek during June and July of 2010-2012 & 2018-2019 and corresponding discharges as measured at the Rancho Mark West gauge.

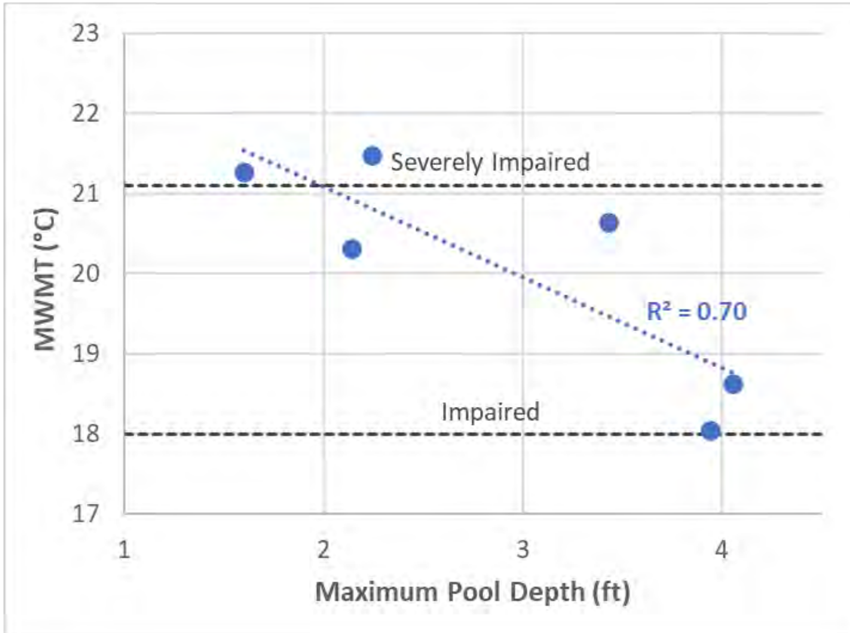


Figure 65: Relationship between maximum residual pool depth and 2017 MWMT for six pools above and below Humbug Creek, data from CDFW.

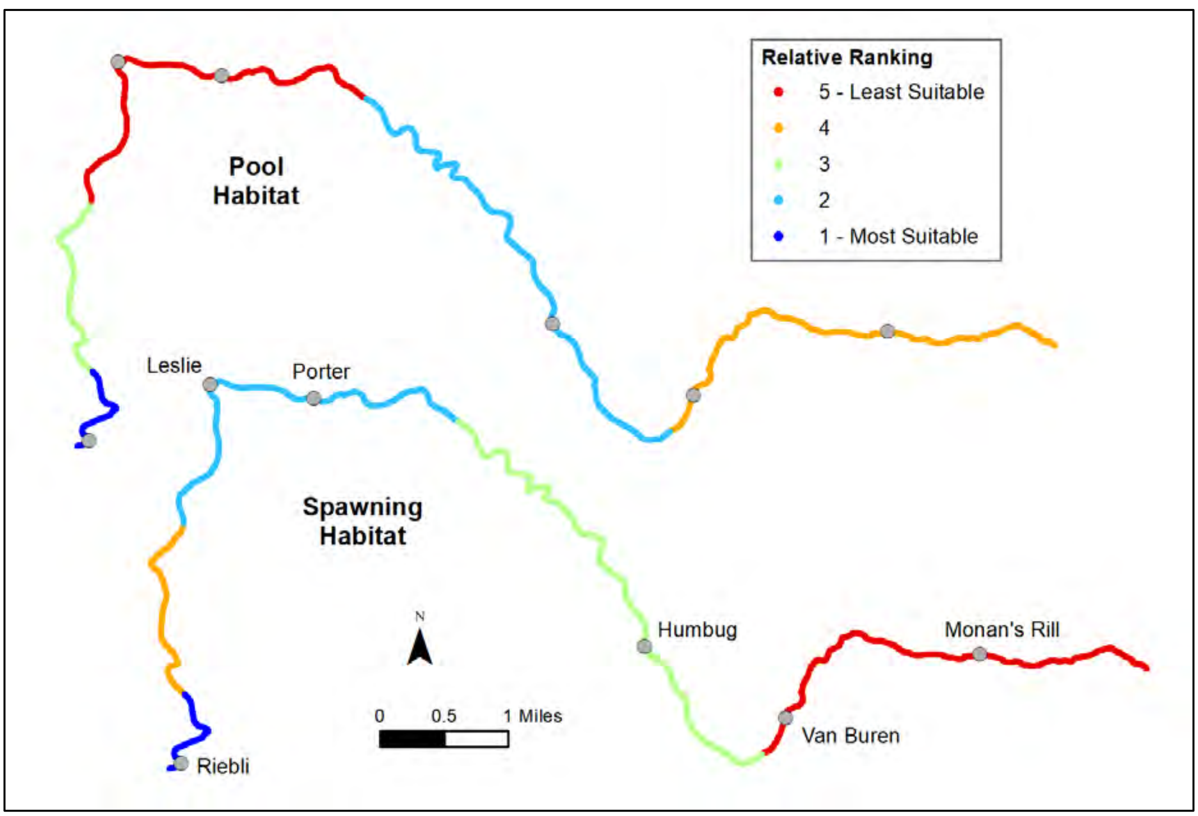


Figure 66: Pool and spawning habitat quality ranking based on the 1996 CDFW Stream Inventory Report.

Table 14: Summary of various pool and spawning habitat indicator metrics compiled from the 1996 CDFW Stream Inventory Report and used to develop the rankings presented in Figure 66.

	Pool Habitat Indicators								Spawning Suitability Indicators		
CDFW reach #	Pools as % of total length	Pools >3-ft as % of total length	Mean maximum residual depth (ft)	Residual maximum depth (ft)	Mean residual pool volume (ft^3)	Mean Shelter Rating	% occurrence of LWD	Pool Ranking	% gravel dominant	% embedded-ness 1 or 2	Spawning Ranking
6	39%	7%	2.0	5.0	379	47	3.1	**4**	14	1	**5**
5	37%	11%	2.5	8.1	751	42	1.0	**2**	12	33	**3**
4	32%	8%	2.2	3.9	784	28	2.7	**5**	32	33	**2**
3	34%	12%	2.7	5.7	1,412	33	0.2	**3**	19	19	**4**
2	49%	11%	2.6	8.9	2,562	38	1.0	**1**	33	64	**1**

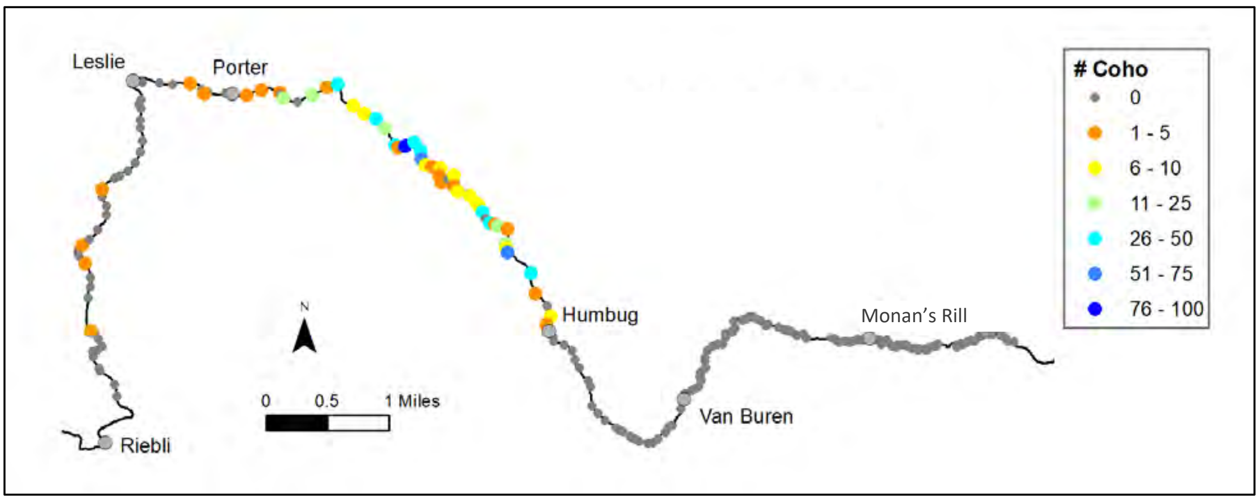


Figure 67: Snorkel survey data showing the distribution of juvenile coho observed in Mark West Creek during June/July of 2019, data from CA Sea Grant and Sonoma Water.

Restoration Prioritization & Recommendations

The overall salmonid habitat classification identifies a ~four mile reach of Mark West Creek between about 0.2 river miles upstream of Alpine Creek (~0.5 miles downstream of Van Buren Creek) and about two river miles upstream of Porter Creek as providing the best overall habitat for salmonids in the watershed (Figure 68). This reach (hereafter referred to as the high priority reach) is considered most suitable because it represents the best combination of flow and water temperature conditions and is also consistent with available data and observations about other indicators of habitat quality such as pool and spawning conditions. Upstream of this reach, no more than one of the four established flow criteria are met, spawning conditions are suboptimal, and natural bedrock controls limit deep pool development and pose migration challenges. The two-mile reach upstream of Porter Creek experiences very high temperatures (>23.1 C) which may be lethal for salmonids and portions of this reach also experience very low RCTDs and periodic pool disconnection making overall conditions problematic for juvenile salmonids. We are aware of anecdotal reports of steelhead trout using the reach upstream of Van Buren Creek, despite the evidence of poor habitat. Less is known regarding temperature conditions farther downstream below Porter Creek, however it is unlikely that conditions improve dramatically and high stream power in this reach is expected to be problematic for spawning success owing to risk of redd scour.

Although the high priority reach we identified (see Figure 68) has the highest overall habitat quality in the watershed, it is still impaired with respect to both flow and temperature, and pool habitat is also likely limited by insufficient cover and large wood. Most of the coho observed in the watershed in recent monitoring were in this reach, further supporting the importance of this reach. Although not the focus of this study, field observations suggest there are multiple opportunities for enhancing off-channel habitat (SRCD has completed a design for an off-channel habitat design project in the reach) and improving pool habitat with LWD projects within this critical reach. We recommend that restoration projects aimed at enhancing both pool and off-channel habitat be implemented in this high priority reach where they are likely to provide the greatest benefits to salmonids.

Additional data and analyses are required to better understand the controls on stream temperatures; nevertheless, our preliminary assessment of available data suggests that daily and seasonal fluctuations in temperatures are driven primarily by fluctuations in incoming solar radiation rather than by quantity of streamflow. Preliminary evidence suggests that deeper pools maintain significantly lower water temperatures than surrounding habitats. The degree of temperature-impairment in the identified high priority reach is severe enough that salmonid survival may only be possible in a relatively small number of deeper pools capable of providing cold-water refugia. Given the importance of water temperature for salmonid survival in Mark West Creek, actions to increase shading through riparian vegetation projects and actions to maintain and enhance deep pools with good cover are likely to provide the greatest benefits for salmonids in Mark West Creek. Additional water temperature investigation is also warranted to better understand the controls on water temperatures and identify the most critical pool habitats within the identified ~4-mile high priority reach.

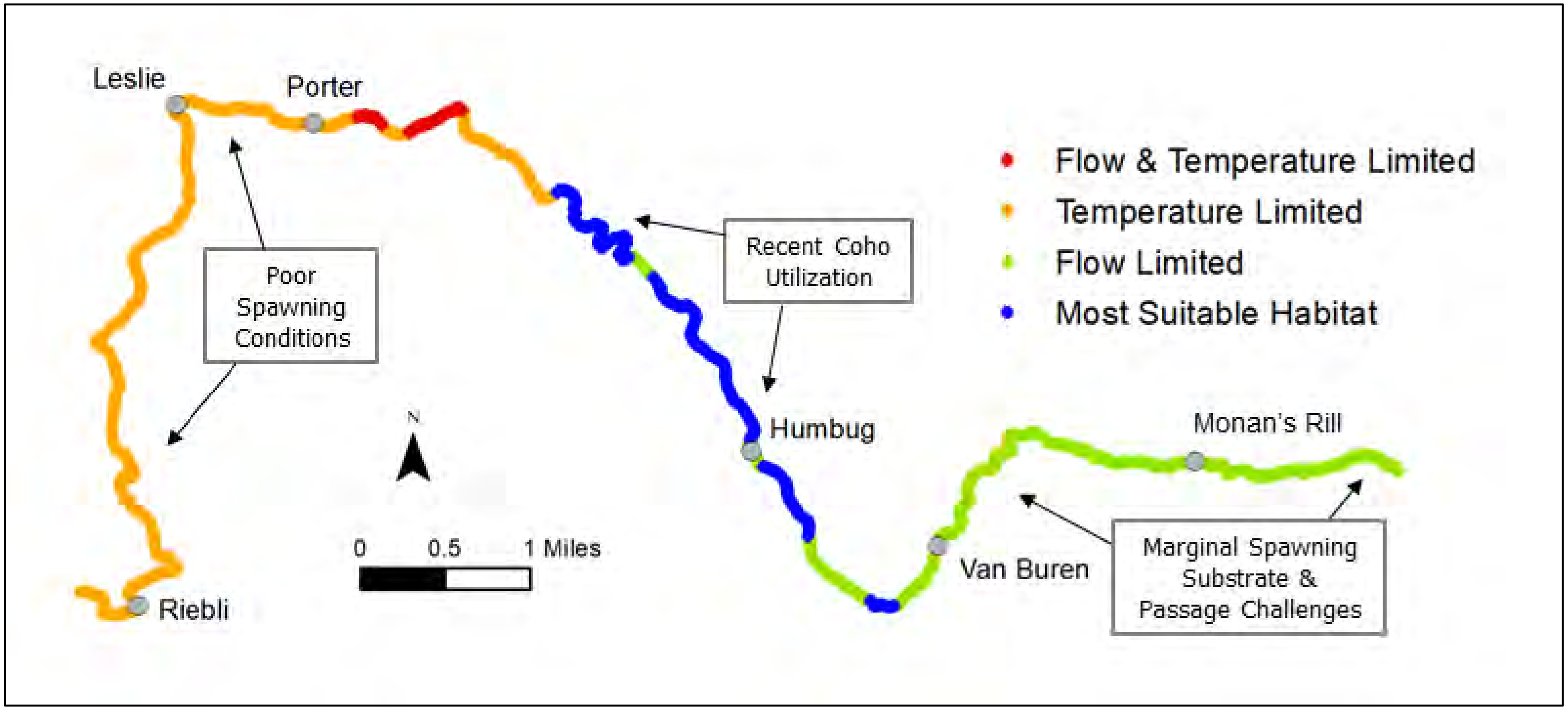


Figure 68: Final overall habitat suitability classification for Mark West Creek identifying the high priority reaches with the most suitable overall habitat conditions in blue.

Chapter 8 – Scenario Analysis

Overview

Efforts to sustain and enhance streamflow conditions have become a recent focus of restoration practitioners working in tributaries of the lower Russian River. Some actions have already been implemented such as pond and flow release projects in Green Valley, Dutch Bill, and Porter Creek (not the Porter Creek in Mark West watershed), and rainwater and diversion storage projects aimed at reducing dry season water use in Mark West Creek watershed and other tributaries. On the other hand, the watershed is subject to increasing water use pressure as new vineyard, winery, cannabis, and residential development projects are proposed, and local and state regulatory agencies are grappling with how best to regulate new groundwater use to avoid detrimental effects on streamflows and associated instream habitat. These challenges are further complicated by ongoing global climate change and the uncertainties associated with future hydrologic conditions. There is a clear need to be able to quantitatively evaluate the relative benefits of various flow enhancement strategies as well as the cumulative effects of land development and water-use on the landscape, and to do so within the context of future climate predictions so that more informed and effective management outcomes can be achieved.

To assist in meeting this need, we developed a series of model scenarios designed to provide an understanding of the hydrologic sensitivity of various hypothetical management and restoration actions as well as the effects of global climate change. There are a total of 19 scenarios grouped in four primary categories: Water Use, Land/Water Management, Climate Change, and Mitigated as described in detail below (Table 15). Each scenario was implemented by changing one or more model inputs and comparing model results to existing hydrologic conditions as simulated with the calibrated model described in previous chapters.

Approach

Water Use Scenarios

Three water use scenarios were developed to estimate the cumulative effects of diversions and groundwater pumping in the watershed: 1-No Diversions, 2-No Groundwater Pumping, and 3-No Water Use. Implementation of these scenarios was a simple matter of turning off well and diversion inputs in the model. Irrigation associated with wells and diversions was also turned off. To examine the factors that influence the degree to which a given well results in streamflow depletion, we developed four additional scenarios where we turned off between 125 and 150 wells (~17% of all wells) based on various criteria (Figure 69). These scenarios included: 2B-wells located within 500-ft of a stream and screened entirely within the upper 200-ft of aquifer material, 2C-wells located within 500-ft of a perennial spring (as simulated in the existing conditions model) regardless of screen depth, 2D-wells screened in tuffaceous materials in the upper 300-ft of aquifer material, and 2E-wells located more than 1,200-ft from a stream or spring, not completed in tuffaceous materials, and not screened in the upper 200-ft of aquifer material. Minor adjustments were made to the selected well distributions to allow for an approximately equal volume of pumping between the four scenarios (Figure 69).

Table 15: Overview of the scenarios evaluated with the MWC hydrologic model.

Scenario Category	Scenario #	Scenario Name	Brief Description
Water Use	1	No Diversions	All surface water diversions turned off
	2	No Groundwater Pumping	All groundwater pumping turned off
	2B	No Pumping Near Streams	Wells within 500-ft of streams and screened in upper 200-ft turned off
	2C	No Pumping Near Springs	Wells within 500-ft of springs turned off
	2D	No Pumping From Tuff	Wells screened in surficial tuffaceous materials turned off
	2E	No Distal Pumping	Wells distal to streams/springs/tuff and not screened in upper 200-ft turned off
	3	No Water Use	All surface diversions and groundwater pumping turned off
Land/Water Management	4	Forest Management	Forest treatment on 7,054 acres of oak and Douglas Fir forests
	5	Grassland Management	Application of organic matter on 2,874 acres of grasslands
	6	Runoff Management	Manage runoff from 310 acres of developed lands to maximize infiltration
	7	Summer Pond Releases	Release water from three ponds with a total release of 0.19 cfs from June 15th to Sept 15th
	7B	Spring Pond Releases	Release water from three ponds with a total release of 0.82 cfs from May 7th to May 28th
	8	Combined Management	Combination of Scenarios 4 through 7
Climate Change	9	CNRM Climate Change	2070-2099 timeframe future climate as predicted by the CNRM model under the rcp8.5 emmisions pathway
	10	CCSM4 Climate Change	2070-2099 timeframe future climate as predicted by the CCSM4 model under the rcp8.5 emmisions pathway
	11	GFDL Climate Change	2070-2099 timeframe future climate as predicted by the GFDL model under the SRES B1 emmisions pathway
	12	MIROC esm Climate Change	2070-2099 timeframe future climate as predicted by the MIROC esm model under the rcp8.5 emmisions pathway
Mitigated	13	GFDL & Pond Releases	Combination of Scenarios 11 & 7 or 7B
	14	GFDL & Combined Management	Combination of Scenarios 11 & 7 or 7B

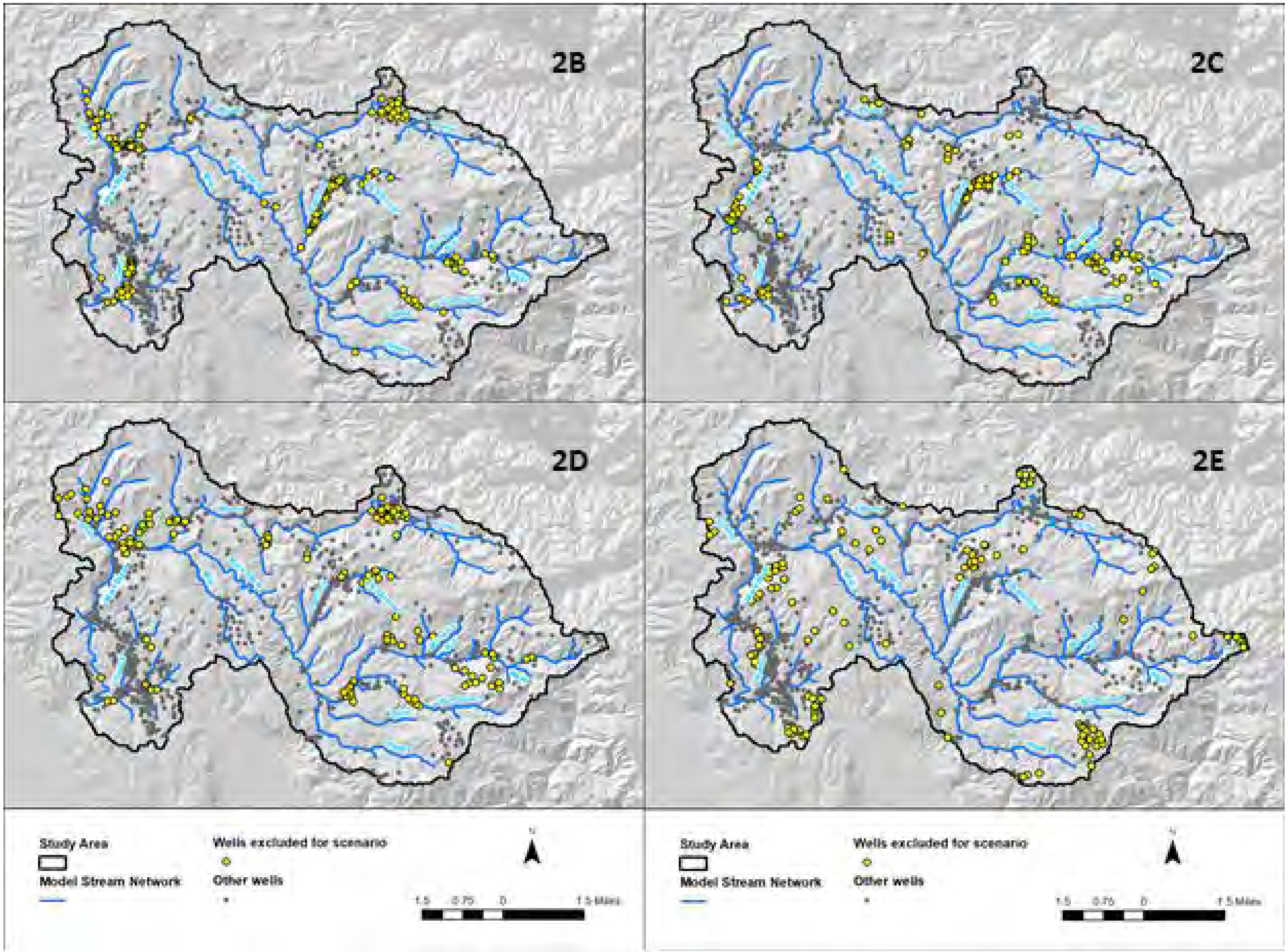


Figure 69: Distributions of wells excluded in Scenarios 2B-2E.

Land/Water Management Scenarios

Six scenarios were developed to evaluate the potential streamflow enhancement resulting from large-scale application of landscape management actions including: 4-Forest Management, 5-Grassland Management, 6-Runoff Management, 7-Summer Pond Releases, 7B-Spring Pond Releases, and 8-Combined Management (Table 15).

Forest Management

In the aftermath of the 2017 Tubbs Fire which burned through a large swath of the watershed and the 2019 Kincade Fire which burned along the north edges of the watershed, there is a very high level of awareness and interest in managing forests for reduced fuel loads. Many of the oak woodlands in the watershed are experiencing encroachment by Douglas Fir, and many Douglas Fir forests are characterized by high tree densities and abundant ladder fuels. This scenario is designed to represent wide-scale application of forest treatment strategies such as thinning and controlled burning (both of which are already occurring in portions of the watershed) and the effects of forest treatment on hydrologic conditions and streamflows.

In consultation with long-time watershed resident and forest manager Rick Kavinoky, we performed a forest condition mapping exercise on the Monan's Rill community property in the upper watershed. We mapped boundaries for nine 0.3-0.7 acre forest stands selected to represent a range of species compositions and treatment needs (determined based on qualitative assessment of tree densities and health, ladder fuel conditions, and presence of encroaching species). We sampled the Leaf Area Index data discussed in Chapter 4 to determine the mean LAI for each of the nine plots. There was a clear relationship between the stand type/treatment need categories and the mean LAI (Table 16). We used these differences to identify forested areas needing treatment throughout the watershed and to adjust the LAI values in the model to reflect implementation of treatment work.

The forest mapping indicated that stands of Black Oak and Oregon Oak not requiring treatment had a mean scaled LAI value of 3.1 and that those stands requiring minor or major treatments had mean values of 4.8 and 9.2 respectively. Douglas Fir stands not requiring treatment had a mean scaled LAI value of 7.3 and those requiring minor or major treatment had mean values of 9.5 and 14.8 respectively. The existing conditions model uses these three forest condition categories for oaks and Douglas fir forests along with these threshold LAI values (see Chapter 4), and the scenario was implemented by simply changing all minor and major treatment areas to no treatment values. Current forest conditions in areas burned by the Tubbs Fire are not captured in the LiDAR-derived LAI data and treatment needs within the burn area are unknown but may be expected to be reduced. We excluded the area of higher severity burn used to represent the Tubbs Fire in the calibration model (see Figure 12) from the identified areas needing treatment.

We used the proportional changes in LAI determined for Black/Oregon Oak and Douglas Fir to delineate treatment categories and estimate LAI for other species of oaks and for mixed Douglas Fir/Tanoak forest which were not included in the mapping at Monan's Rill. We also reduced rooting depths by 10% in the treated areas to better represent changes in transpiration not

Table 16: Forest plots mapped at Monan's Rill and associated treatment needs and Leaf Area Index (LAI) values.

Plot #	Stand Type	Treatment Needed?	Scaled LAI
1	Douglas Fir	No	7.3
7	Douglas Fir	Minor	9.5
3	Douglas Fir	Major	12.9
6	Douglas Fir w/ Tanoak	Major	16.5
5	Black Oak	No	3.0
8	Oregon Oak	No	3.2
4	Black Oak w/ Encroaching Douglas Fir	Minor	4.6
9	Oregon Oak w/ Encroaching Douglas Fir	Minor	4.9
2	Oregon Oak w/ Encroaching Douglas Fir	Major	9.2

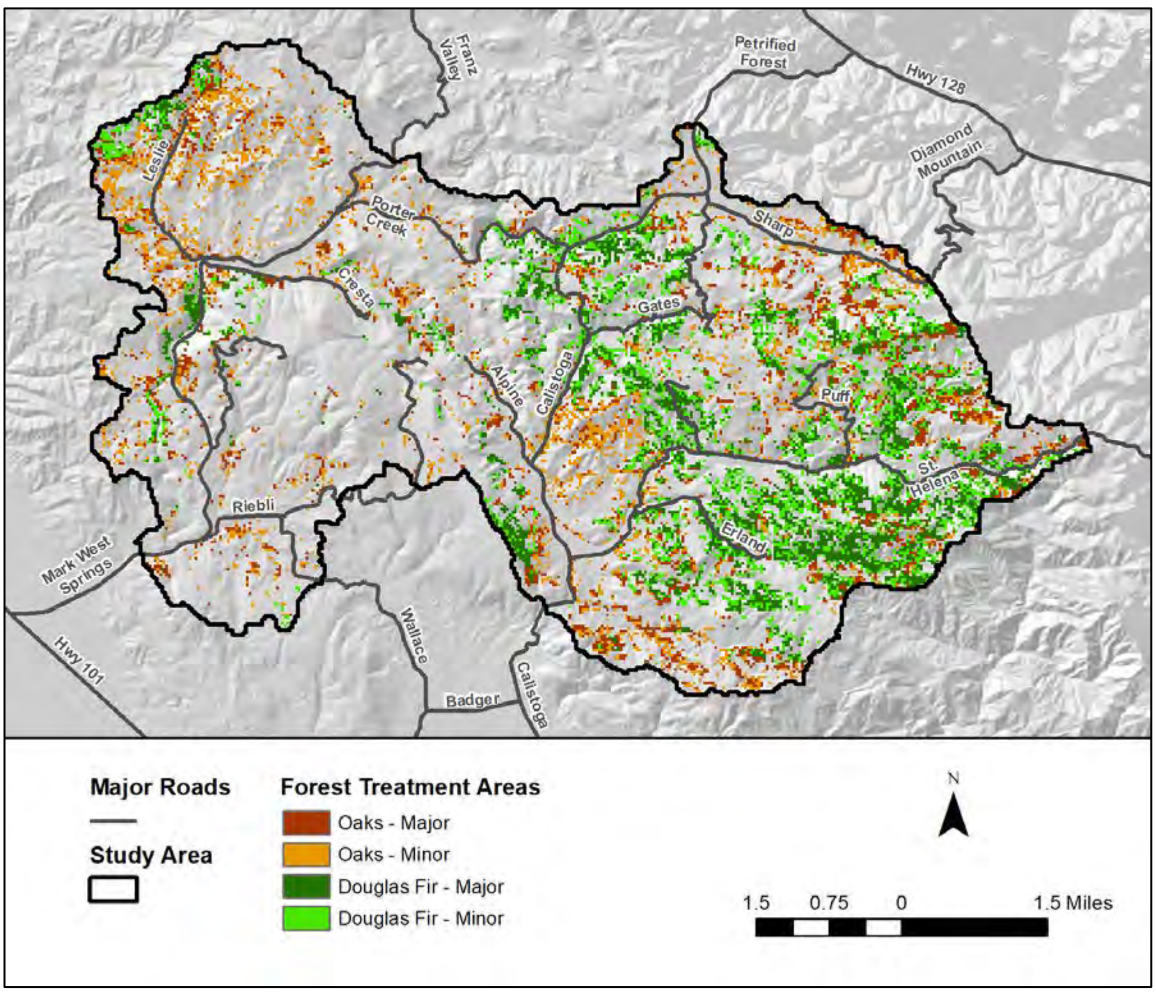


Figure 70: Areas of oak and Douglas Fir forest included as treated in the forest management scenario (Scenario 4).

captured by the LAI changes. The effects of forest treatment on other parameters such as overland roughness coefficients and detention storage are more uncertain and were assumed not to be affected by treatment for the purposes of this analysis. There are a total of 7,054 acres of treated forest represented in the model scenario which was divided approximately equally between various species of oaks (3,428 acres) and Douglas Fir (3,626 acres) (Figure 70).

Grassland Treatment

Increasing Soil Organic Carbon (SOC) on grasslands through compost application or strategic grazing practices has been identified as an important strategy for sequestering carbon (e.g. Ryals & Silver, 2013; Zomer et al., 2017). In addition to carbon sequestration benefits, increasing SOC may result in hydrologic benefits through increases in soil water availability and associated effects on seasonal soil water deficits and groundwater recharge. This scenario is designed to examine the potential hydrologic effects of large-scale adoption of grassland management practices designed to increase SOC. We assumed a 3% increase in SOC would be achievable (Flint et al., 2018) and related that change in SOC to a change in soil moisture contents at saturation, field capacity, and the wilting point based on data from 12 studies compiled by Minasny & McBratney (2018).

We implemented the grassland treatments in all grasslands in the model with more than a 2-acre contiguous area as identified in the fine-scale vegetation mapping (SCVMLP, 2017) covering a total of 2,874 acres (Figure 71). These grasslands were located in 14 different soil types as represented in the model (see Figure 15), and we classified each as fine, medium, or coarse and applied the associated mean estimates of the change in moisture contents from a 1% increase in SOC from Minasny & McBratney (2018). We scaled the estimates up to reflect a 3% increase in SOC which resulted in increases in soil moisture content at saturation, field capacity, and the wilting point of 0.10-0.14, 0.04-0.07, and 0.02-0.03 respectively, and increases in available water capacity (AWC) of 0.044-0.068. These estimates are generally consistent with the changes in AWC estimated for a 3% increase in SOC for soils of similar textures by Flint et al., (2018) which were based on the work of Saxton & Rawls (2006).

Runoff Management

Managing runoff from rooftops and impervious areas around residential and other developed areas to encourage infiltration has been recognized as an important best management practice for new development and is commonly referred to as Low Impact Development (LID). Most developed areas in Mark West Creek watershed were constructed prior to adoption of LID techniques. Traditional runoff management, on the other hand, is more likely to encourage runoff to flow quickly away from infrastructure and towards receiving water bodies via downspouts, drains, and ditches. This scenario is designed to examine the potential hydrologic benefits of large-scale adoption of LID practices on existing developed lands in the watershed.

We identified areas of contiguous impervious surface in the watershed from the developed category in our model land cover data. This spatial data is based on non-roadway impervious areas identified in the fine-scale vegetation map and resampled onto the 0.5-acre model grid.

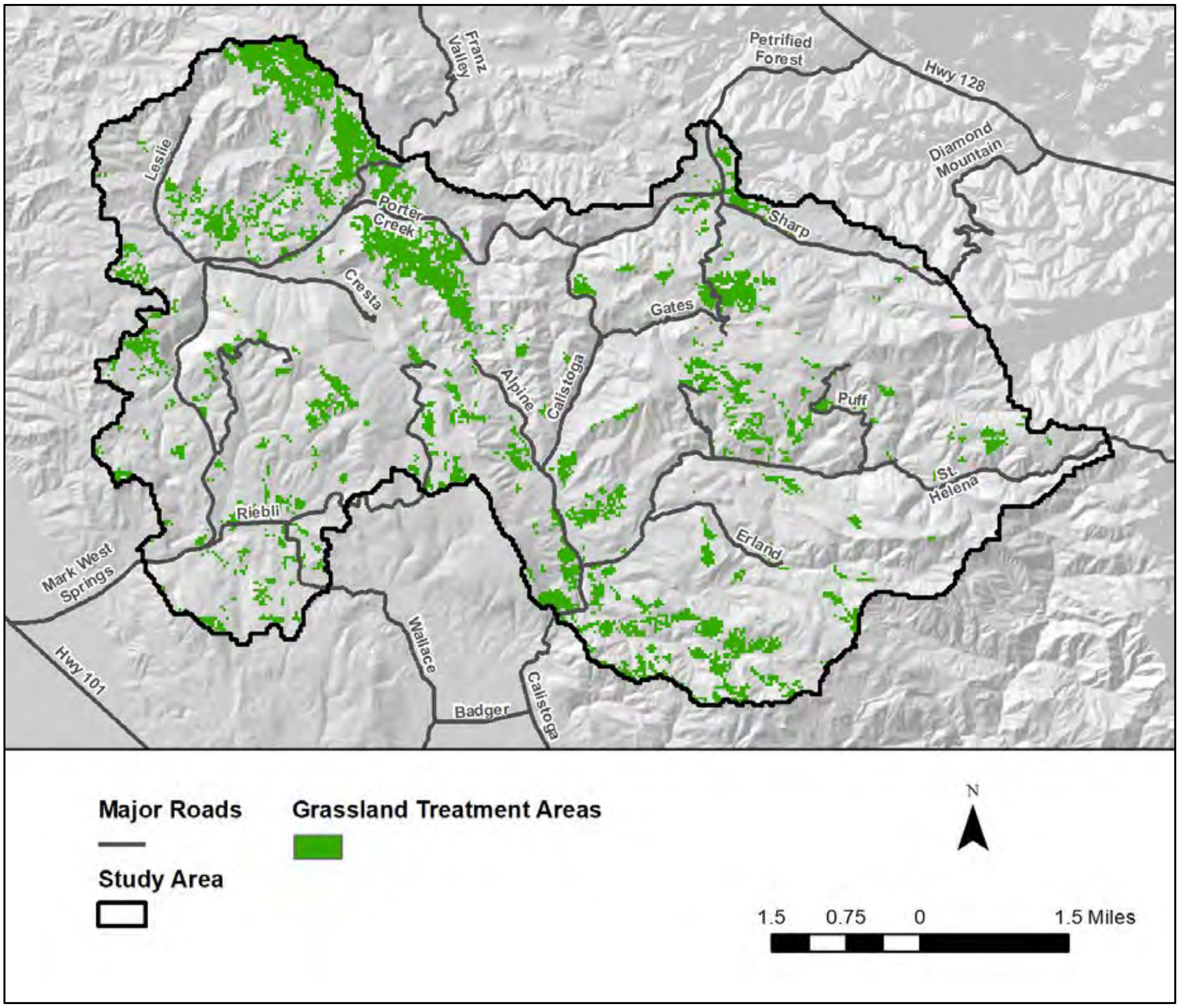


Figure 71: Treated grasslands included in the grassland management scenario (Scenario 5).

The resampling results in the exclusion of smaller impervious areas and the identification of the larger contiguous impervious areas most suitable for runoff management projects with potentially significant benefits. Roads are not represented in the scenario, although large-scale management of road runoff could have significant additional hydrologic benefits beyond what was simulated here. Development is most highly concentrated within the Riebli Creek watershed which is not considered to have high habitat value and contributes flow to Mark West Creek well downstream of the high priority reach. For these reasons, and to avoid dramatically increasing the scale of the scenario for potentially minimal benefit, we excluded Riebli Creek watershed from the analysis.

The developed areas represented in the scenario total 310 acres (Figure 72) which is about 76% of the total non-roadway impervious area in the watershed outside of the Riebli Creek drainage. There are multiple strategies possible for encouraging infiltration of runoff from these lands including use of level spreaders, bioswales, or infiltration basins. The most appropriate strategy

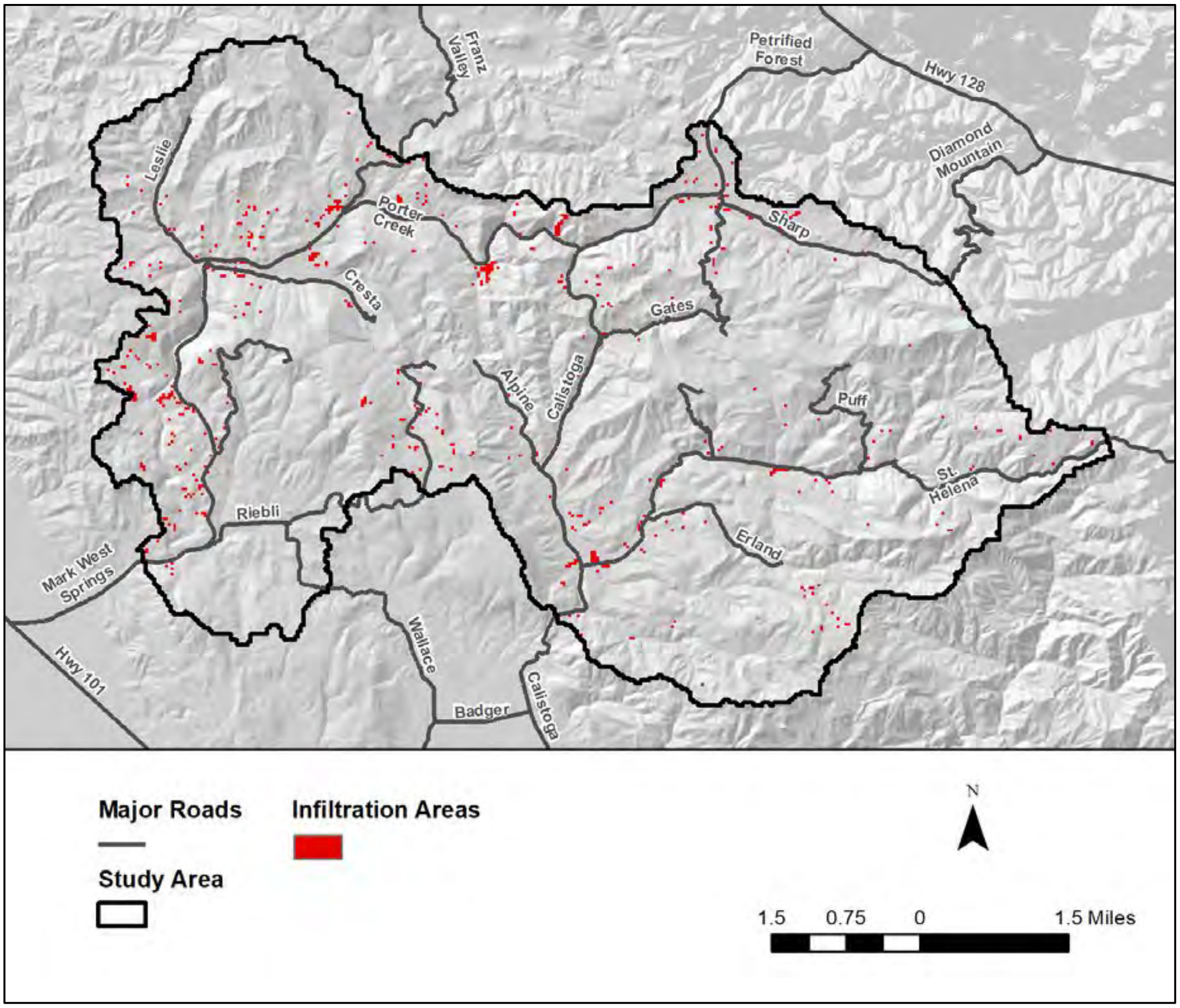


Figure 72: Developed areas included in the runoff management scenario (Scenario 6).

and design for a given location is highly site-specific and implementing the details of these stormwater management features is not practical at the 0.5-acre grid scale used in the model. Thus, for the purposes of this regional planning-level study we simply assumed that practices could be implemented to prevent all runoff generated directly from the identified developed lands from leaving the site. The scenario was implemented in the model by preventing runoff from entering or leaving each area through the use of the separated overland flow area option, and allowing water to pond, infiltrate, and evapotranspire according to the precipitation patterns and soil and evapotranspiration properties present at a given site.

The largest storm event in the 10-yr simulation was approximately a 10-yr event based on comparison to NOAA Atlas 14 precipitation frequency estimates. Thus, for projects to be equivalent to the model scenario they would need to be able to handle the peak flows and runoff volumes from a 10-yr storm. The model results indicate that in the upper watershed the 48-hr volume from this event over a 0.38 acre average per parcel developed area would be about 0.19

to 0.24 ac-ft. This would require a native soil basin on the order of 2,300 ft^2 or a gravel-filled basin of about 6,700 ft^2. These basins are large but likely feasible in many cases given the five acre average parcel size. Runoff management projects of a smaller scale are also possible; however, the goal of this scenario is consistent with the other scenarios in its focus on estimating the maximum potential benefits of runoff management projects.

Pond Releases

Releasing water from existing ponds has been recognized as a potentially important strategy for enhancing streamflows in the lower Russian River and several flow release projects have been implemented in recent years in Green Valley and Dutch Bill creeks among other locations. Most of the ponds in the MWC watershed are too small to allow for a viable release project, but we identified at least four ponds that appear large enough for such projects, and simulated releases for three of them. Out of respect for the privacy of landowners we are identifying these ponds only by their approximate locations. Available storage volumes for releases are approximate and were estimated using the LiDAR-captured water surface elevations as the late-summer residual (after water use and infiltration/evaporation losses) storage levels and a simple relationship between dam height approximated from the LiDAR and pond storage (USACE, 2018).

The three ponds include one in upper Mark West Creek with approximately 31.9 ac-ft of residual storage, one in upper Humbug Creek with approximately 5.2 ac-ft of residual storage, and one in upper Mill Creek with approximately 30.9 ac-ft of residual storage (Table 17). None of these ponds have significant consumptive water uses associated with them, therefore releasing water to augment streamflow is not expected to require new replacement water sources. Landowners we spoke with expressed concerns about fully depleting ponds because of the desire to maintain recreational and aesthetic value and maintain an emergency water source in the event of wildfire. To address these concerns, we have assumed that only half of the available residual storage could be released and the other half would be retained in storage for other uses. We also examined the simulated runoff volumes contributing to each pond and found that there is ample winter runoff to replenish the relatively small released volumes even during drought conditions and under future climate change scenarios.

We developed two flow release scenarios, one focused on enhancing summer juvenile rearing habitat (Scenario 7) and one focused on enhancing spring smolt outmigration (Scenario 7b). The summer release covers a 92-day period each year between June 15th and September 15th and release rates ranged from 0.014 – 0.088 cfs for a total release rate of ~0.19 cfs. The spring release covers a 21-day period each year between May 7th and May 28th and release rates ranged from 0.063 to 0.383 cfs for a total release rate of ~0.82 cfs (Table 17). These periods were selected based on review of historical conditions and targeted to increase minimum flow conditions during summer and the later portion of the primary outmigration period. We did not attempt to optimize the timing and release rates for this regional planning-level study, however it is likely that benefits greater than those simulated in this study could be achieved through adaptively managing releases in conjunction with real-time streamflow data which is available at several locations from Sonoma Water.

Table 17: Overview of the pond release volumes and rates included in Scenarios 7 and 7b.

Location	50% of Residual Storage (ac-ft)	Sceanrio 7 Summer Release Rate (cfs)	Scenario 7b Spring Release Rate (cfs)
Upper Mark West Creek	16.0	0.087	0.383
Upper Humbug Creek	2.6	0.014	0.063
Upper Mill Creek	15.5	0.085	0.371
Total	**34.0**	**0.187**	**0.817**

Climate Change Scenarios

Four model scenarios were developed to evaluate the effects of future climate changes on hydrologic and aquatic habitat conditions in the upper Mark West Creek Watershed. Each of these scenarios was based on projections of future climate for the 2070-2099 timeframe derived from a Global Circulation Model (GCM) scenario. The scenarios reflect changes in precipitation and temperature as predicted by each GCM, but do not address other aspects of climate change that may affect hydrologic and habitat conditions such as long-term changes in vegetation or irrigation demands that may occur in response to a modified future climate regime.

Global Circulation Model Selection

The selection of the four GCM scenarios ('futures') was based largely on the recommendations from the Climate Ready North Bay Vulnerability Assessment and the North Coast Resource Partnership's climate planning efforts (Micheli et al., 2016 & 2018). The vulnerability assessment selected a subset of six GCM futures from an ensemble of 18 futures analyzed by the USGS using the Basin Characterization Model (BCM) (Flint et al., 2013; Flint & Flint, 2014). These 18 futures were selected from the approximately 100 GCM futures included in the Intergovernmental Panel on Climate Change's (IPCC) Fourth and Fifth Assessment Reports (IPCC 2007; 2014) using statistical cluster analysis. The North Coast Resource Partnership study selected six of the eighteen futures included in the BCM, and our analysis focuses on four of these six (Figure 73 & Table 18).

The selection of these futures was designed to represent the full range of plausible changes to precipitation and temperatures, and to include a scenario representative of the mean projections (Micheli et al., 2016 & 2018). Three of the futures represent the "business as usual" emissions scenario (rcp 8.5) adopted by the IPCC's Fifth Assessment Report (IPPC, 2014). This pathway assumes high population growth and a slow adoption of clean and resource efficient technologies with atmospheric carbon dioxide concentrations rising to 936 ppm by 2100 (Hayhoe et al., 2017). One of the futures represents the "highly mitigated" emissions scenario (sres B1) reflecting a future with low population growth and the introduction of clean and resource efficient technologies; this pathway is comparable to rcp 4.5 with atmospheric carbon dioxide concentrations rising to 650 ppm by 2100 (Hayhoe et al., 2017).

Table 18: Overview of the four climate change scenarios evaluated with the MWC hydrologic model.

	GCM	Emissions Scenario	Change in Annual Precipitation (%)	Change in Maximum Temperature (°F)
Scenario 9	CNRM	rcp 8.5 (business as ususal)	37%	6.3
Scenario 10	CCSM 4	rcp 8.5 (business as ususal)	8%	5.4
Scenario 11	GFDL	sres B1 (highly mitigated)	-14%	3.7
Scenario 12	MIROC esm	rcp 8.5 (business as ususal)	-21%	11.0

Scenario 9 is a "Warm & High Rainfall" scenario based on the CNRM rcp 8.5 future, which projects a 37% increase in average annual precipitation and a 6.3°F increase in average maximum temperatures by the 2070 - 2099 timeframe relative to 1981 – 2010 (Table 18). Scenario 10 is a "Warm & Moderate Rainfall" scenario based on the CCSM4 rcp 8.5 future, which is close to the ensemble mean of the 18 futures selected for use in the BCM model and projects an 8% decrease in average annual precipitation and a 5.4°F increase in average maximum temperatures. Scenario 11 is a "Warm & Low Rainfall" scenario based on the GFDL sres B1 future which projects a 14% decrease in average annual precipitation and a 3.7°F increase in average maximum temperatures (Table 18; Figure 73). Lastly, Scenario 12 is a "Hot & Low Rainfall" scenario based on the MIROC esm rcp 8.5 future, which projects a 21% decrease in precipitation and an 11.0°F increase in temperature (Table 18).

Methodology

For all scenarios, precipitation and minimum and maximum temperature timeseries were derived from daily data from the World Climate Research Program's Coupled Model Intercomparison Project Phases 3 & 5 (CMIP3 & CMIP5) (USBR et al., 2013). The CMIP provides monthly and daily outputs from the GCMs included in the IPCC's Fourth and Fifth Risk Assessments statistically downscaled to a uniform 1/8th degree grid using a revised version of the bias corrected constructed analog method (BCCA v2).

Several studies have reported that GCMs are biased towards creating "drizzle" days with trace amounts of precipitation (Maurer et al., 2010). Mauer et al. (2010) claims that the BCCA method corrects this issue. However, when compared to observed precipitation records, downscaled precipitation timeseries still contained an un-representatively high number of days with trace precipitation. To address this documented issue, precipitation events with less than 0.02 in/day were removed from the precipitation timeseries. This removed between 50 and 105 trace events per year but changed average annual precipitation totals by only 0.6 – 1.2% over the 2070 - 2099 period. While this approach may not fully resolve the issue, it removes a

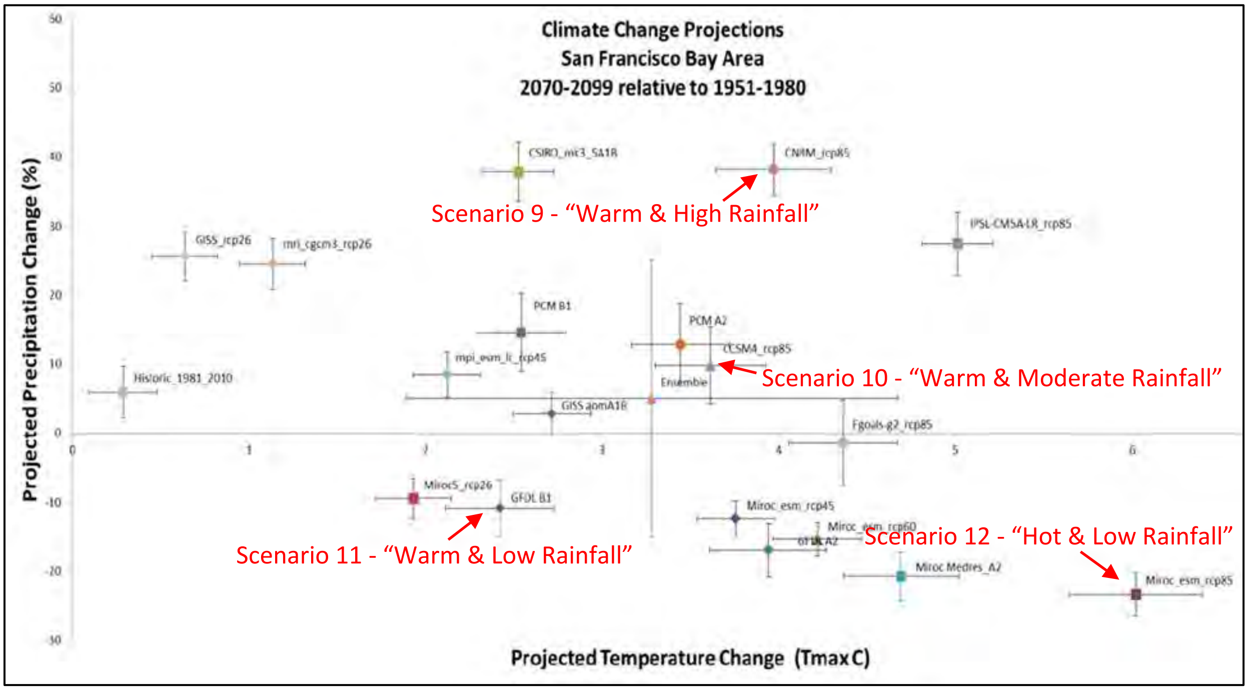


Figure 73: Projected regional changes in average annual precipitation and average maximum summer temperatures for the 18 GCMs analyzed using the Basin Characterization Model (BCM), modified from Micheli et al., 2016 to show the four scenarios included in this study.

significant number of trace precipitation events which if not filtered out could artificially increase simulated canopy interception and evapotranspiration.

Daily Potential Evapotranspiration (PET) timeseries were calculated from the CMIP minimum and maximum daily temperature timeseries using the Hargreaves-Samani Method (Hargreaves & Samani, 1982). These calculations used extraterrestrial solar radiation rates for a flat plane located at the model centroid and a KT value of 0.162 calibrated using reported temperature and evapotranspiration data from the Windsor CIMIS station. More details about the PET calculations can be found in Chapter 4.

As in the existing conditions model, precipitation and PET zone-based distributions were developed to account for the spatial variations in these parameters across the model domain. Precipitation zones are based on 1-inch average annual isohyets derived from the BCM 2070 - 2099 average annual precipitation dataset for each selected GCM future. Future PET distributions were created using the same methodology as the historic distribution discussed in the Chapter 4, in this case using average 2070 - 2099 monthly minimum and maximum temperature distributions from the BCM model. These distributions show similar spatial patterns to the historic distribution, although the range of values across each distribution varies significantly. Precipitation and PET timeseries were applied to these distributions using the same scaling factor approach as for historic conditions.

Scaling factors were calculated as the ratio of the value for each zone and the 2070 - 2099 means for the timeseries. Adjustments were made to the scaling factors applied for precipitation to correct for a high precipitation bias in the BCM dataset relative to historical conditions as observed at local climate stations (see Chapter 4 for further discussion). These adjustments were calculated such that simulated precipitation means preserve the percentage increases in mean annual precipitation between the 1981 – 2010 and 2070 – 2099 normals as estimated by the BCM.

To reduce computational requirements, each climate scenario uses timeseries from a continuous representative 10-year subset of the processed CMIP timeseries from the 2070 - 2099 period. These subsets were selected such that average annual precipitation was within 2% of the average annual precipitation estimated for the 2070 - 2099 normal for each future and such that each subset contained at least one extremely dry and one extremely wet year, as well as a multi-year drought (if present in the original 30-yr period). A summary of the annual and daily precipitation and PET inputs for the selected periods is shown in Figure 74-Figure 77. While the results of these scenarios will be compared against one another, it is not necessary for these time periods to match. GCMs simulate general climatic conditions, not specific weather events, and one would not expect conditions modeled for a given year to be comparable to conditions modeled for the same year using a different GCM.

Inputs Summary

Besides the changes in average annual precipitation and average maximum temperatures shown above in Table 18, the GCMs used as the basis for these scenarios predict several important inter- and intra-annual changes in precipitation and PET. Previous studies of large GCM ensembles have indicated that precipitation will become more volatile, that large precipitation events will become more frequent, and that the seasonal distribution of precipitation will concentrate in the core winter months (e.g. Swain et al., 2018). To assess the degree to which each of the selected GCM futures reflect these projected trends, several statistics were calculated. These include the frequency of historically wet and dry years (defined by the 80th and 20th percentile annual precipitation totals), the magnitude of large precipitation events (maximum 24-hr precipitation), and the seasonal distribution of precipitation (defined by the ratio of precipitation occurring during the core winter months of November - February and the peripheral months of October, March, and April). The baseline for these comparisons is the 2009-2019 simulation period, however as discussed in Chapter 4, conditions during this period are broadly representative of 1981-2010 conditions which is widely used as the baseline period for interpreting future climate changes.

The Scenario 9 (CNRM rcp8.5) future projects a general shift towards wetter conditions. Both the frequency and magnitude of wet years increases, as well as the frequency of higher intensity precipitation events (Table 19 & Figures 74-77). Much of this additional precipitation is projected during the core winter months, leading to a marked shift in the seasonal precipitation distribution. However, despite the large increase in average precipitation, the frequency and magnitude of dry years is projected to remain similar to historic conditions. Despite the low increase in average annual precipitation, the Scenario 10 (CCSM4 rcp8.5) future projects a large increase in annual and seasonal variability (Table 19 & Figures 74-77). It projects the single highest annual precipitation total (80.2 in), the greatest inter-annual variability, and the strongest seasonal shift in precipitation towards the winter months. It also predicts individual dry years of similar frequency and magnitude to historical conditions, but more frequent multi-year droughts.

The Scenario 11 (GFDL sresB1) future projects a general shift towards drier conditions, with increases in both the frequency and intensity of droughts (Table 19 & Figures 74-77). Although the MIROC esm rcp8.5 future projects slightly drier average conditions, the GFDL sres B1 future projects the single driest year, with an average of 11.8 inches of precipitation. This future also projects the lowest precipitation intensities, with maximum daily rainfall totals of less than 2.0 in for most years. The Scenario 12 (MIROC esm rcp8.5) future also projects a general shift towards drier conditions with both the frequency and intensity of droughts increasing (Table 19 & Figures 74-77). Historically dry years are projected to become roughly twice as common and precipitation decreases by up to 30% during the driest years. Although no years with annual totals exceeding the historic 80th percentile are projected, moderately wet years with up to 47 inches of precipitation are still present. During these wetter years, maximum daily precipitation totals are projected to be similar to historic conditions, but much lower during normal and drier years.

Despite the large differences in future projections between the scenarios, all four scenarios share some commonalities. Regardless of the scenario, droughts are predicted to become more extreme and precipitation is predicted to have increased seasonality with more precipitation focused in the core winter months. Additionally, all four scenarios predict increases in PET which vary between scenarios based on the magnitude of the predicted increases in temperatures and represent increases of about 6-14% relative to historic conditions (Table 19 & Figures 74-77).

Mitigated Scenarios

To evaluate the scale of the predicted changes in hydrologic conditions under future climate relative to potential streamflow enhancement actions, we developed two mitigated scenarios. Scenario 13 combines the GFDL future climate simulation (Scenario 11) with the pond release scenarios (Scenarios 7 and 7B), and Scenario 14 combines the GFDL future climate with the combined management scenario (Scenario 8) (Table 15). To keep the number of scenarios to a reasonable level, we only ran the mitigation scenarios using future climate as predicted by the GFDL model. We selected this model because our results showed that it represented the second most extreme predictions of future changes in streamflows which we felt would provide the best overall picture of the degree of climate change induced impacts to streamflows that could be mitigated with the investigated management actions. A higher degree of mitigation would likely be possible if future climate more closely resembles the CNRM or CCSM4 model predictions and less mitigation would be possible if future climate more closely resembles the MIROC esm model predictions.

Table 19: Summary of key climate statistics for each climate scenario evaluated with the MWC hydrologic model.

	Historic	Scenario 9 CNRM	Scenario 10 CCSM4	Scenario 11 GFDL	Scenario 12 MIROC esm
Average Annual Precipitation (in)	36.0	49.3	38.9	30.9	28.6
Maximum Annual Precipitation (in)	61.2	75.2	80.2	46.9	47.3
Minimum Annual Precipitation (in)	19.5	18.6	17.6	11.8	13.3
Interannual Variability (in)	12.9	16.5	20.2	10.6	9.4
Frequency of 80^{th} Percentile Historic Annual Precipitation	-	5	2	0	0
Frequency of 20^{th} Percentile Historic Annual Precipitation	-	2	3	5	4
Seasonal Precipitation Distribution (Core:Periphery)	2.0	4.6	5.3	3.4	3.9
Maximum 24-hr Precipitation (in)	4.7	7.3	5.0	4.5	4.8
Average Annual PET (in)	45.4	50.1	49.5	48.0	51.7

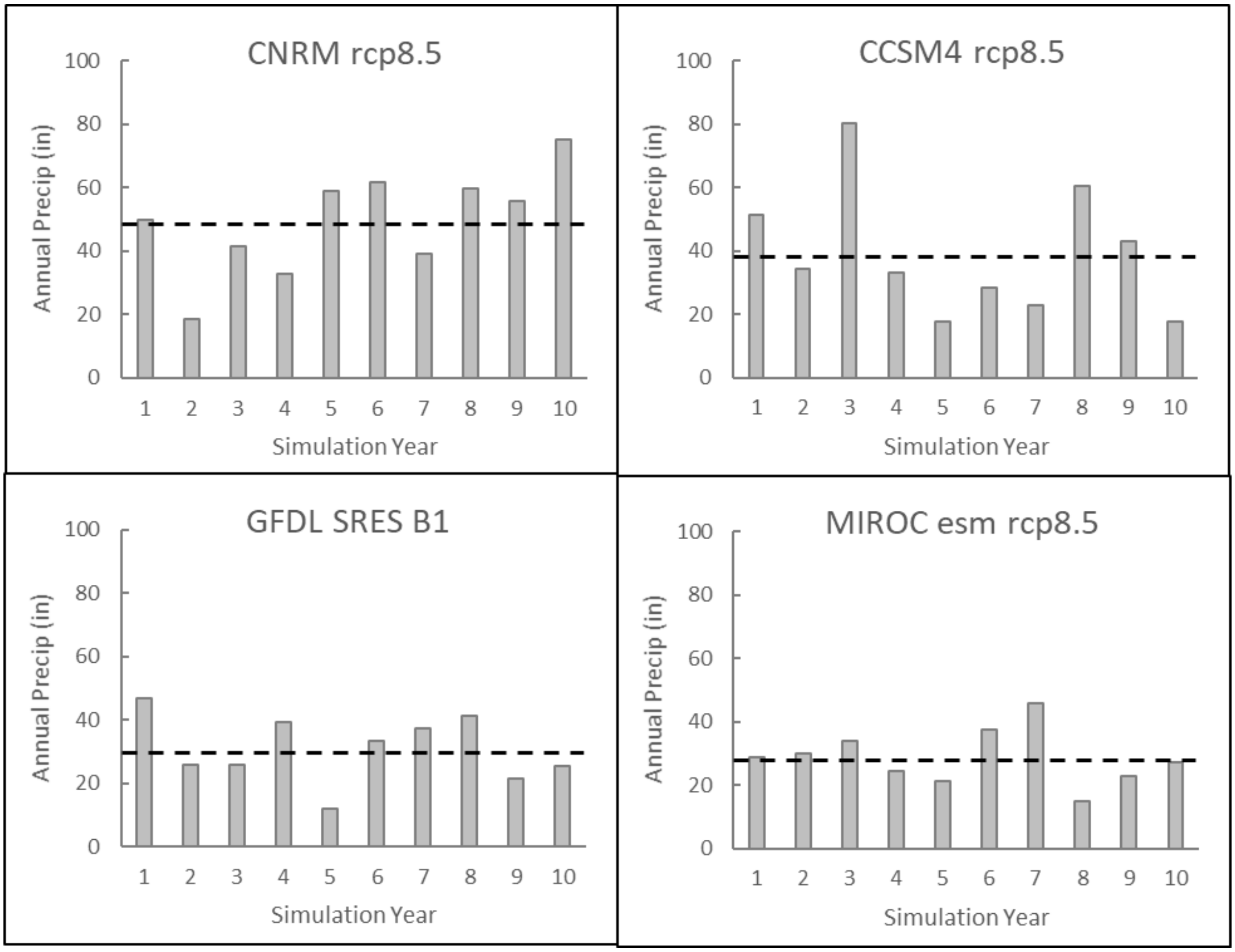


Figure 74: Spatially averaged annual precipitation within the model domain for each of the four selected climate scenarios (dashed black lines indicate the 2070-2099 mean).

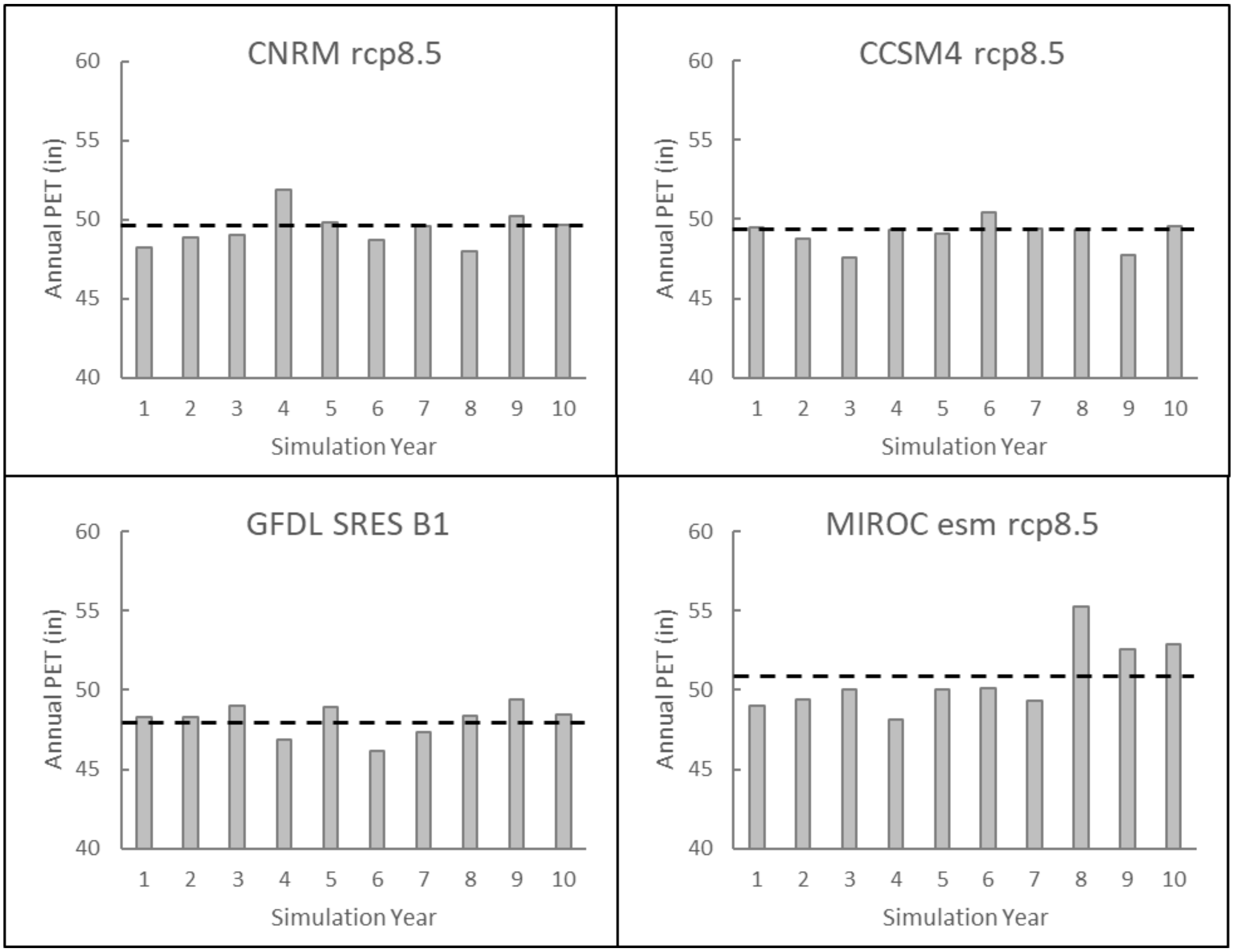


Figure 75: Spatially averaged annual Potential Evapotranspiration (PET) within the model domain for each of the four selected climate scenarios (dashed black lines indicate the 2070-2099 mean).

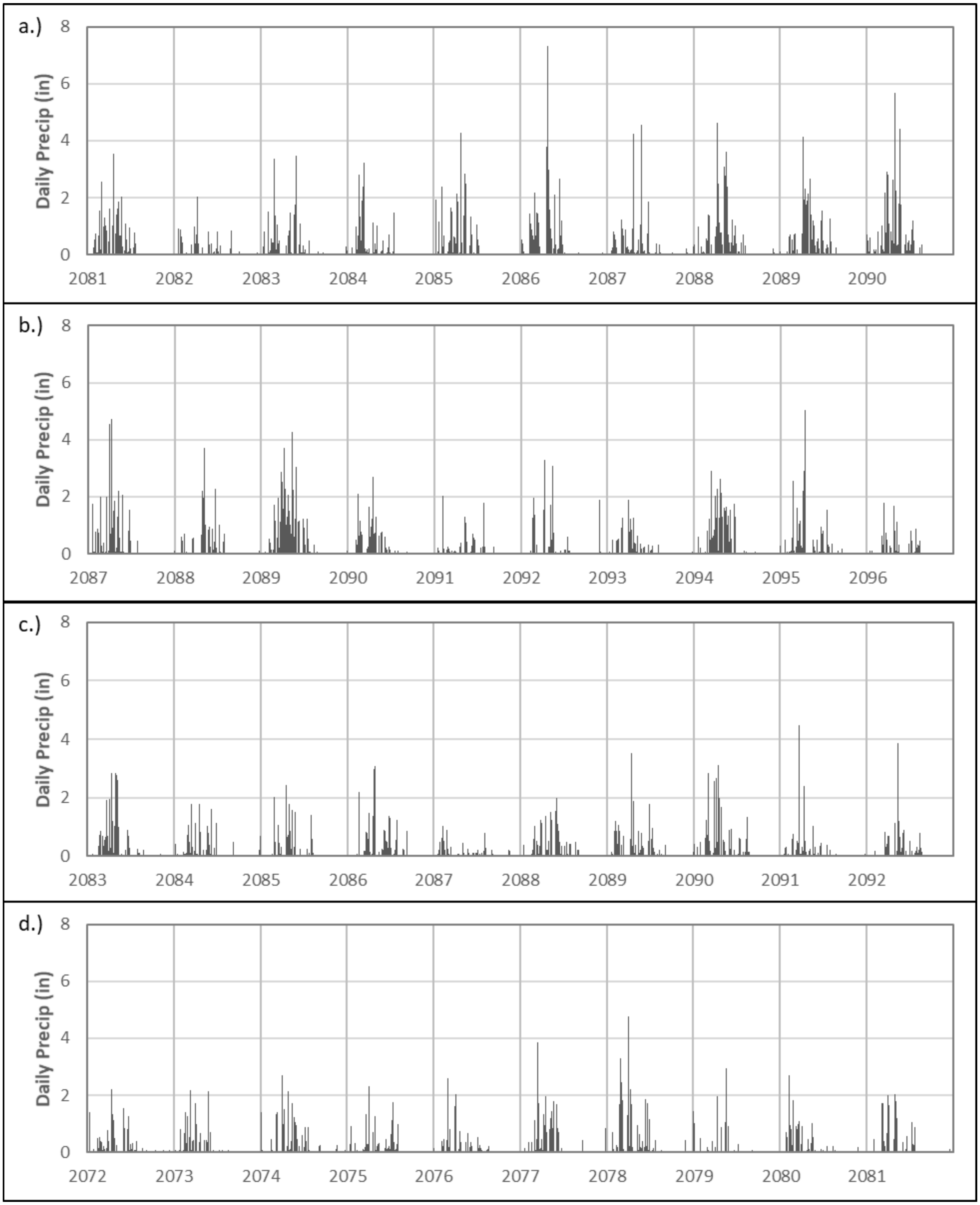


Figure 76: Spatially averaged daily precipitation used in scenarios (a) CNRM rcp8.5, (b) CCSM4 rcp8.5, (c) GFDL SRES B1, and (d) MIROC esm rcp8.5.

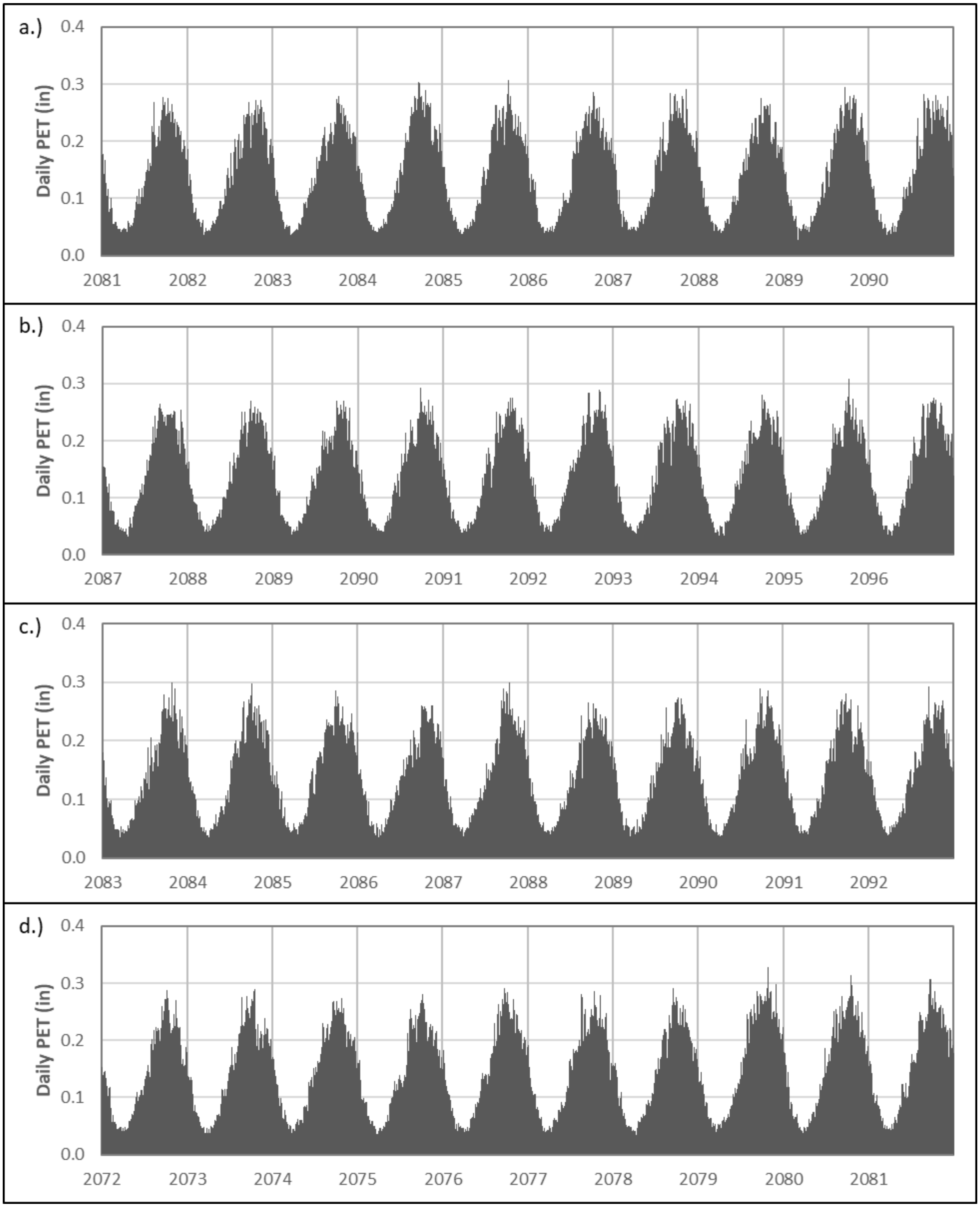


Figure 77: Spatially averaged daily Potential Evapotranspiration (PET) used in scenarios (a) CNRM rcp8.5, (b) CCSM4 rcp8.5, (c) GFDL SRES B1, and (d) MIROC esm rcp8.5.

Results

<u>Water Use Scenarios</u>

The no surface water diversion scenario (Scenario 1) revealed that the sustained cumulative effect of diversions in the watershed is relatively small. With diversions turned off, the average summer discharges increased by less than 0.01 cfs in most of the upper and middle reaches of Mark West Creek and by up to 0.03 cfs in the lowest reaches (Figure 78). The effects of diversions on mean springtime streamflow was similar but slightly greater than the summertime effects, with stream discharge increasing by 0.02-0.04 cfs at most locations downstream of Humbug Creek (Figure 81) with all diversions turned off. We compiled hourly discharge results to evaluate potential short-term diversion effects not captured with the mean summer discharge comparison. This revealed that diversions do have more significant short-term impacts on streamflow, with short-term increases in discharge under Scenario 1 of about 0.05 cfs upstream of Humbug Creek, 0.09 cfs downstream of Humbug Creek, and 0.07 cfs below Porter Creek (Figure 78).

The diversion impacts are discernable but minimal downstream of Monan's Rill and reach a maximum just downstream of Humbug Creek which has a high concentration of diversions (Figure 79). The timing of the simulated streamflow reductions is closely related to the model input assumptions regarding diversion timing and therefore the greatest changes occur on the first of each month when all diversions are active and are near zero during times when few diversions are active. Hence, it is likely that the short-term impacts are exaggerated given that the assumptions of coincident timing create a worst-case scenario. It is interesting to note that the fluctuations in flow throughout the summer due to other factors are generally larger than the fluctuations caused by diversions, therefore it would be very difficult or impossible to discern diversion impacts from examination of streamflow records alone (Figure 79).

The no groundwater pumping scenario (Scenario 2) revealed that the cumulative effect of groundwater pumping in the watershed is larger than that of surface water diversion but of modest magnitude. With groundwater pumping turned off, the average summer discharge increased by less than 0.01 cfs in the upper reaches of Mark West Creek and by up to about 0.06 cfs in the lowest reaches (Figure 80). Mean springtime discharge increases show a similar pattern to the summer increases with slightly larger changes (Figure 81). Examination of the water balance revealed that the aquifer system takes at least several decades to fully adjust to the change in pumping regime, and the reported flow increases represent the 10-yr period following 40-yrs of no pumping. Over the first 10-yr simulation cycle with no pumping, most of the volume that would have been pumped could be accounted for by increased groundwater storage, with only about 18% of the volume manifesting as increased groundwater discharge. During the fifth 10-yr cycle, the changes in storage were minimal and increased groundwater discharge accounted for about 76% of the pumped volume (Figure 82). Most of the remaining volume can be accounted for by increases in AET from the saturated zone and small decreases in recharge which serve to partially buffer the effects of pumping on streamflow (Figure 82).

We also examined the monthly changes in streamflow and other water balance components and found that volumetrically, the largest streamflow depletions occurred during December through April (~0.50 cfs at the watershed outlet) and the lowest rates occurred during July through September (0.06 cfs). This may seem counter-intuitive given that pumping rates peak in June and are at a minimum in January, however it is necessary to consider all of the effects of pumping on the water balance together to gain an understanding of the mechanisms behind the depletion seasonality. The largest month-to-month changes in the water balance occur as changes in storage. With pumping turned off and associated seasonal pumping drawdowns eliminated, not as much water enters storage during the recharge season resulting in more water available to contribute to groundwater discharge (Figure 83). Another significant but lesser effect is that higher groundwater elevations during the dry season result in more water available to riparian vegetation which serves to partially offset summer streamflow depletion through increases in AET from the saturated zone (Figure 83). This analysis suggests that strategies focused on deferring dry season pumping in favor of wet season pumping and storage (which may be effective in alluvial aquifers with short response time-scales) may not be very effective in bedrock aquifer settings like Mark West Creek. It is also important to note that the seasonal storage and AET effects from increasing levels of pumping may be expected to be asymptotic, and that since the total pumping volumes in the watershed are relatively low (~3% of annual infiltration recharge), the seasonality of streamflow depletion may be expected to become less pronounced under higher pumping stresses.

Results of the selective no pumping scenarios (Scenarios 2B-2E) indicate that the magnitude of summer streamflow depletion after 40-50 years of pumping does vary depending on distance from streams and springs, and likely also depending on well screen (perforated well casing) depth and hydrogeologic properties. To account for small differences in pumping volume reductions between the scenarios, we normalized the streamflow results by the change in pumping volume. Mean summer streamflow at the outlet of the watershed increased by 0.026 cfs per 100 ac-ft of pumping decrease for wells located within 500-ft of streams and screened within the upper 200-ft of aquifer material (Scenario 2B) (Table 20). This rate is approximately 137% of the rate determined for all wells from Scenario 2 (0.019 cfs/100 ac-ft of pumping decrease). The highest rate (0.029 cfs per 100 ac-ft of pumping decrease) was for wells located within 500-ft of springs (Scenario 2C). Wells screened within tuffaceous materials (Scenario 2D) showed streamflow effects similar to the average for all wells, and wells located more than 1,200-ft from streams and springs and not screened in the upper 200-ft of aquifer material (Scenario 2E) showed the smallest effects, with a rate of streamflow increase of 0.017 cfs per 100-ac-ft of pumping decrease which represents about 89% of the rate determined for all wells (Table 20).

This analysis suggests that proximity to springs and streams can be useful in determining the relative magnitudes of summer streamflow depletion within the 50-yr timeframe. However, it is important to note that all wells (including those distant from streams and screened at depth) may still be expected to result in streamflow depletion and the rate of depletion from near stream wells screened in the upper 200-ft was only about 1.7 times the rate for distant wells screened at depths greater than 200-ft (Table 20). It is also apparent that the 50-yr simulation timeframe is not long enough for the system to fully adjust to a change in pumping regime, and over longer timeframes it may be expected that the differences between proximal and distal well impacts would decline.

Simulation results from the no water use scenario (Scenario 3) which represents conditions in the 10-yr period following 40-yrs without water use indicate that the cumulative effect of all surface and groundwater uses in the watershed is equivalent to approximately 8% of summer streamflow. With all water uses turned off, mean summer streamflow increased by 0.01 to 0.02 cfs upstream of Van Buren Creek, by 0.02 to 0.04 cfs between Van Buren and Porter Creeks, and by 0.04 to 0.09 cfs in the reaches downstream of Porter Creek (Figure 80).

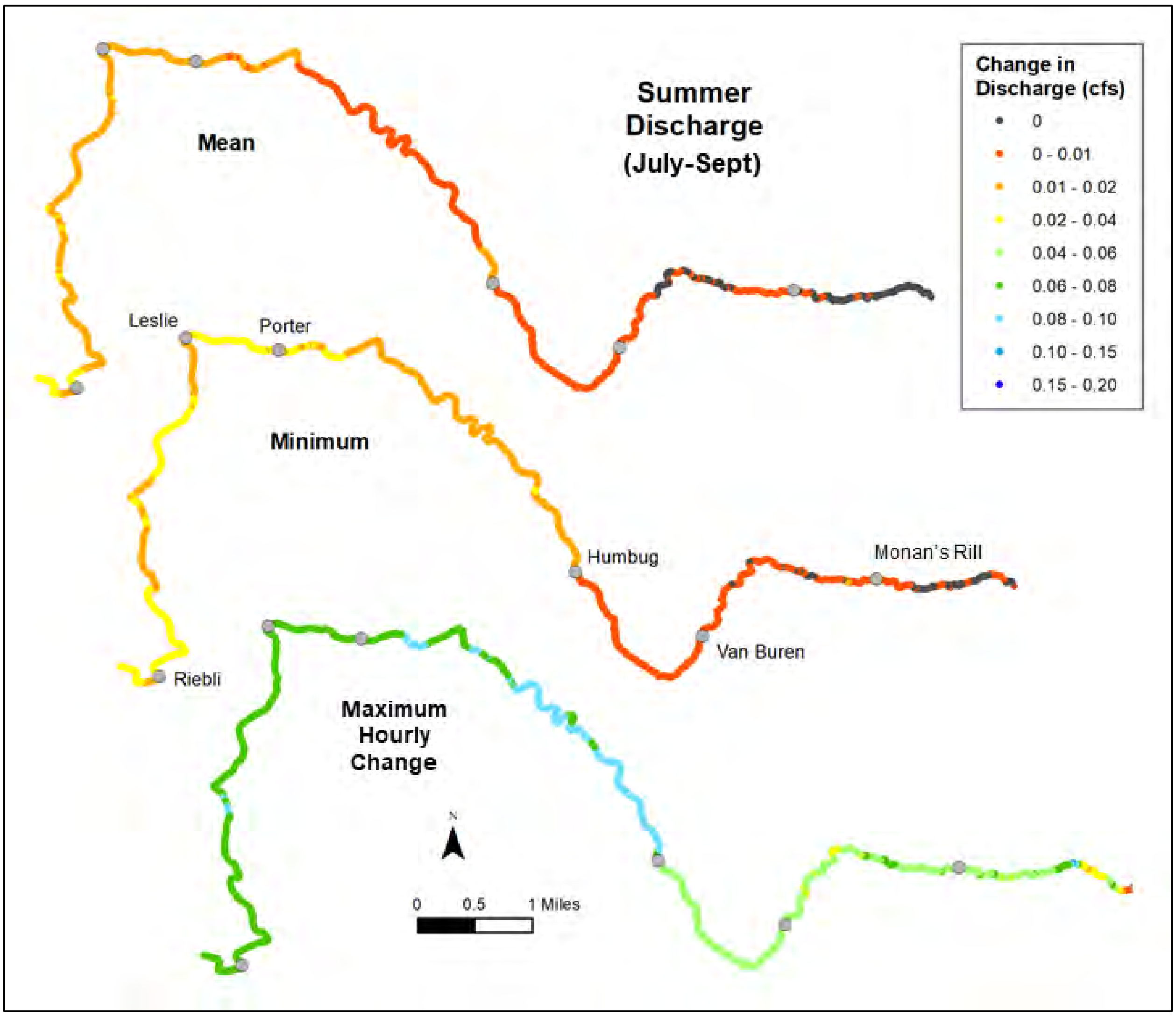


Figure 78: Changes to mean and minimum summer streamflow, and maximum hourly changes from cessation of all surface water diversions (Scenario 1).

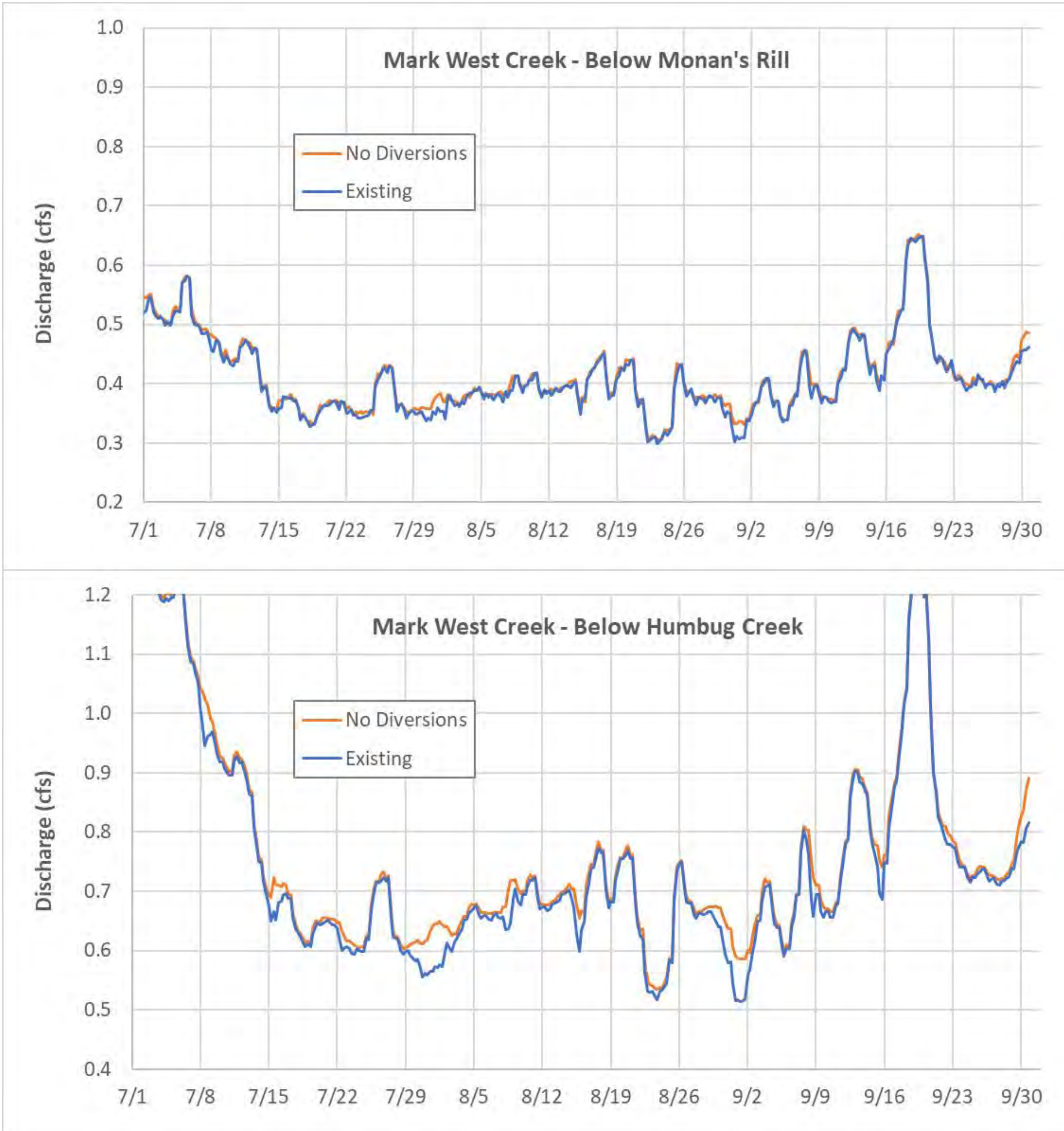


Figure 79: Simulated changes to hourly streamflow in Mark West Creek below Monan's Rill and below Humbug Creek resulting from cessation of all surface water diversions (Scenario 1).

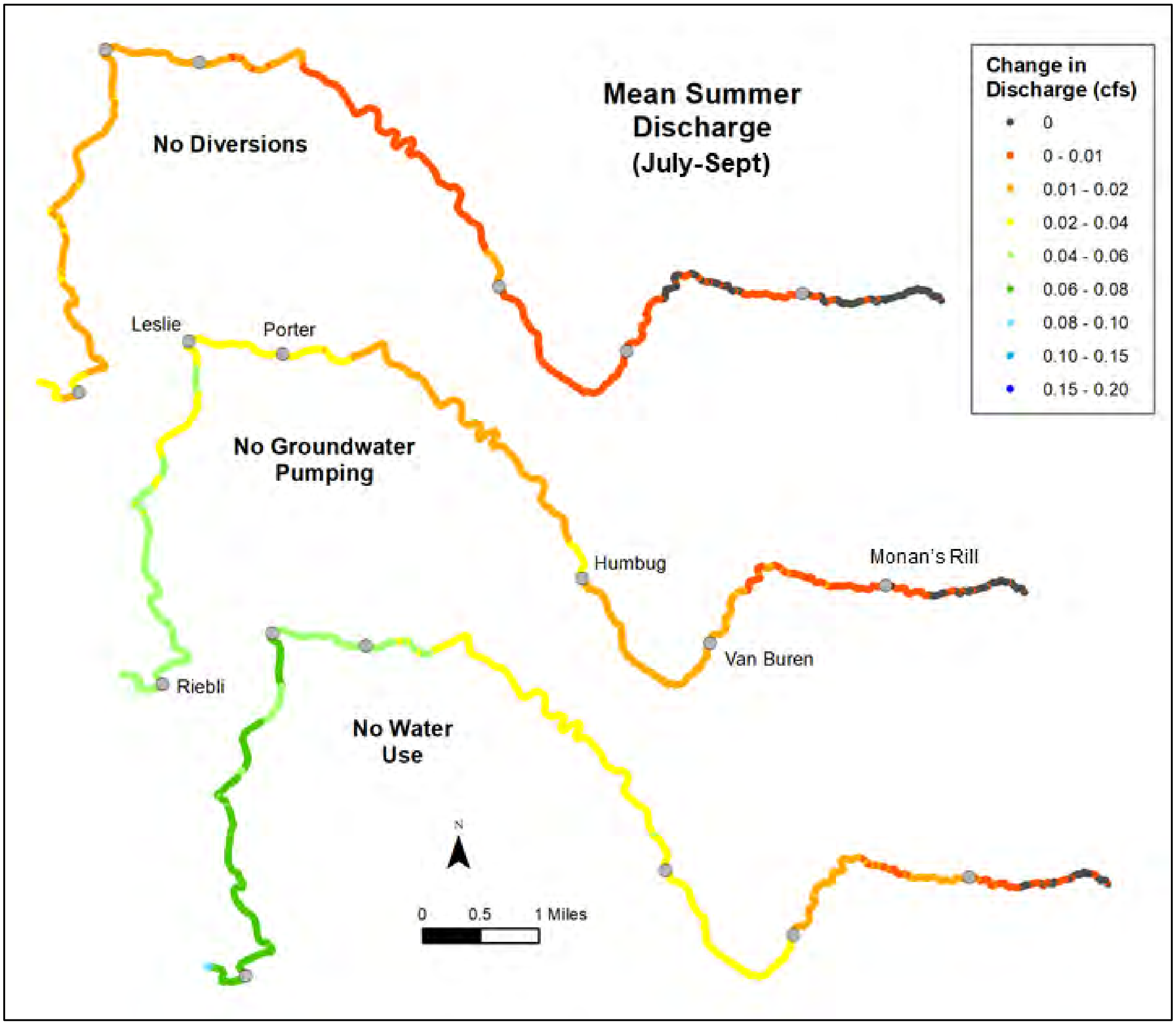


Figure 80: Simulated changes to mean summer streamflow for the three water use scenarios (Scenarios 1-3).

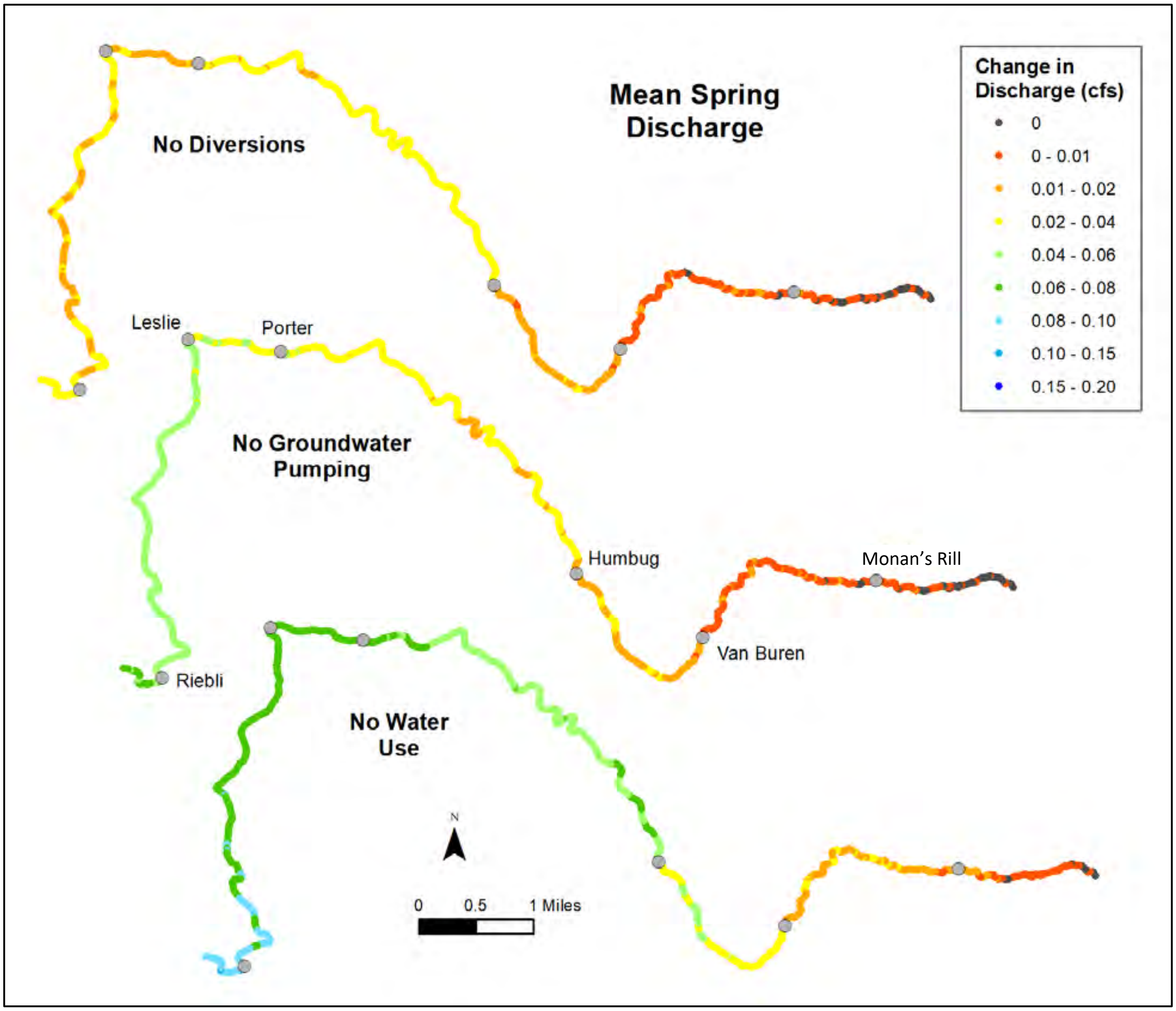


Figure 81: Simulated changes to mean spring streamflow for the three water use scenarios (Scenarios 1-3).

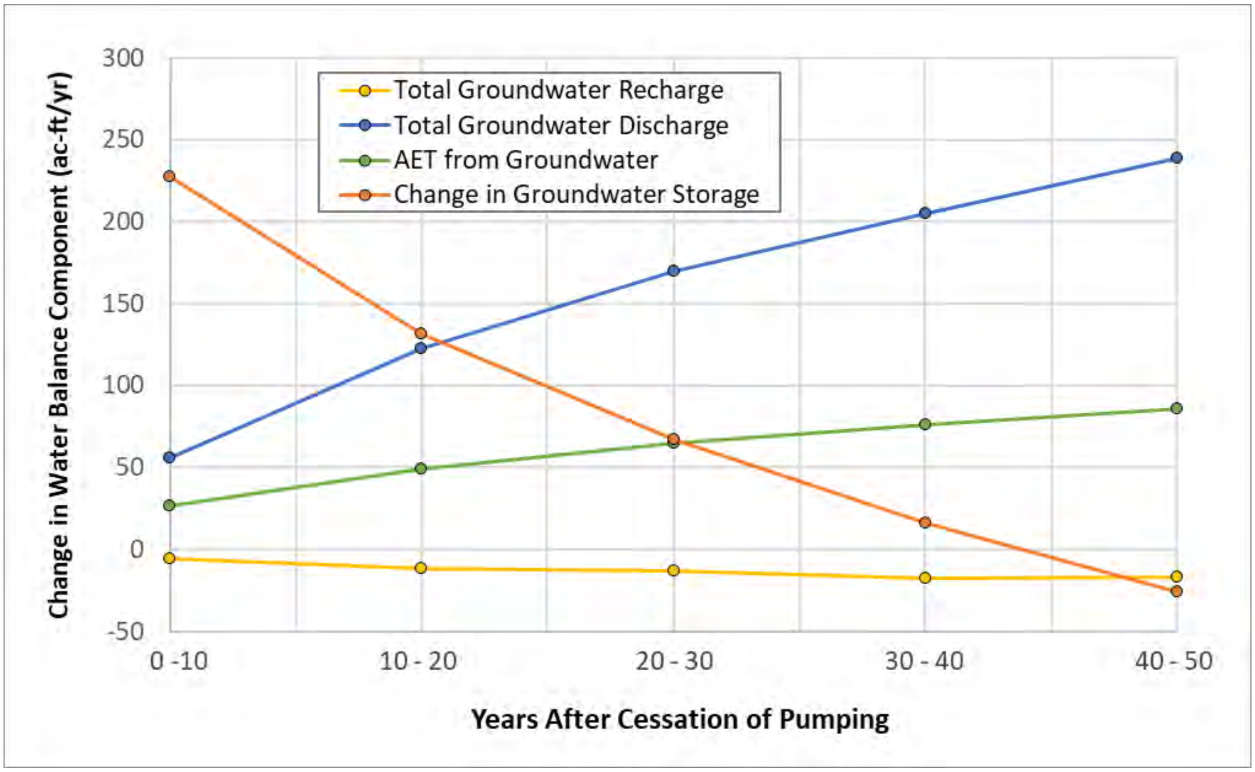


Figure 82: Changes to annual groundwater water balance components resulting from cessation of all groundwater pumping (Scenario 2) for each of the five 10-yr simulation cycles.

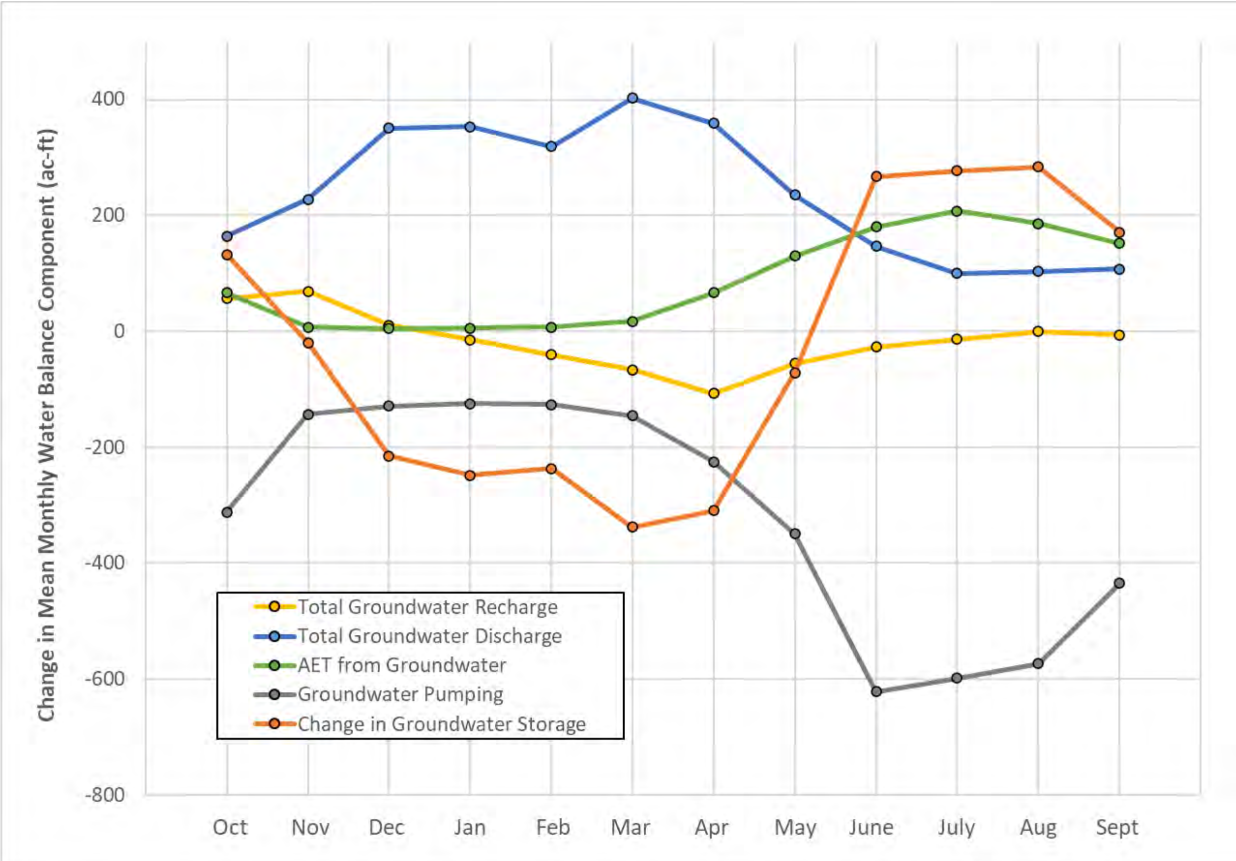


Figure 83: Mean monthly changes in the groundwater water balance resulting from cessation of all groundwater pumping (Scenario 2) for the fifth 10-yr simulation cycle.

Table 20: Summer streamflow depletion normalized by pumping volume for the various no pumping scenarios over the fifth 10-yr simulation cycle (Scenarios 2 & 2B-2E).

Scenario #	Scenario Name	Change in Mean Summer Discharge (cfs/100 ac-ft of pumping)
2	No Groundwater Pumping	0.019
2B	No Pumping Near Streams	0.026
2C	No Pumping Near Springs	0.029
2D	No Pumping From Tuff	0.019
2E	No Distal Pumping	0.017

Land/Water Management Scenarios

Forest, Grassland, and Runoff Management

The forest management scenario (Scenario 4) resulted in modest increases in mean summer discharges of 0.02 – 0.04 cfs throughout most of Mark West Creek upstream of Porter Creek and increases of 0.04 – 0.06 cfs below Porter Creek (Figure 84). These changes are equivalent to a 4-11% increase in mean summer flow depending on the location, and the average change over the full anadromous length of Mark West Creek was ~6%. The grassland management scenario (Scenario 5) resulted in smaller increases in mean summer flows of 0.02 or less throughout Mark West Creek (Figure 84). The runoff management scenario (Scenario 6) resulted in modest increases in mean summer discharges of less than 0.02 cfs upstream of Porter Creek. The majority of the area included in the scenario is located within and downstream of the Porter Creek watershed, and there is a substantial increase in the flow enhancement benefits below the confluence with Mark West Creek with mean summer discharges increasing by 0.06 - 0.12 cfs in the downstream reaches (Figure 86).

Increases in springtime streamflow for the forest management scenario were much larger than the changes for summer streamflow with increases of 0.5 - 0.6 cfs below Humbug Creek and 0.7 - 0.9 below Porter Creek (Figure 85); these changes represent 4 - 6% of the total flow. The changes in springtime streamflow for the forest management scenario are about three to five times larger than the changes for the other management scenarios. Springtime streamflow changes for the grassland management scenario were also larger than the summer changes with increases of 0.06 - 0.08 cfs below Humbug Creek and 0.10 - 0.18 cfs below Porter Creek (Figure 85). The runoff management scenario produced a similar but slightly greater increase in springtime streamflow relative to summer streamflow (Figure 87).

Comparison of the watershed-wide mean annual water balance between existing conditions and Scenarios 4 - 6 indicates that all three strategies (forest-, grassland-, and runoff-management) result in increases in infiltration recharge on the order of 2 - 4% on an annual basis (Figure 88). The mechanisms behind these increases are different for each case. Forest management results in about a 5% decrease in AET on treated lands which equates to a 1.4% decrease watershed-wide (579 ac-ft/yr) resulting in more water available for both runoff and infiltration recharge (Figure 88). In contrast, grassland management results in only minimal changes in AET and runoff and the increases in infiltration recharge are accomplished through increased soil water storage capacity which serves to extend the timeframe over which recharge can occur. Runoff management decreases runoff directly, resulting in both increases in infiltration recharge and AET (Figure 88).

The increases in infiltration recharge for all three scenarios represent a substantial volume of water (230-420 ac-ft/yr) which manifests in part through increases in groundwater discharge to streams as interflow, baseflow, and springflow (Figure 88). The springflow response is of particular interest in that springflow has been identified as the primary process generating summer streamflow in the watershed. The forest management scenario resulted in the largest increases in springflow (6.4%), followed by runoff management (3.9%), and grassland management (1.9%). The relative influence of the management actions on springflow is controlled in part by the spatial distribution of treatment areas. For example, the forest management scenario generates the largest increase in springflow despite generating the smallest increase in infiltration recharge owing to the concentrations of both springs and treatment areas in the upper watershed.

It is apparent that location on the landscape influences how changes in infiltration recharge are expressed, with the forest management scenario resulting in the smallest increases in recharge but the largest increases in springflow due to both treated forest areas and springs being concentrated in the upper watershed. It is also important to note that the acreages involved in the three scenarios are intended to represent large-scale implementation based on existing potential on the landscape, therefore the locations and acreages involved are very different between the scenarios. To compare the relative hydrologic effects of these various management actions it is useful to normalize the results by acres of managed area. This exercise reveals that runoff management is by far the most effective strategy with per area increases in summer streamflow 36 times greater than forest management and 51 times greater than grassland management (Table 21). The level of effort required to manage stormwater from one acre is, however, expected to be significantly greater than the effort involved in management of one acre of forest or grassland. Additional discussion of comparisons between strategies is included below under the heading Summary and Comparison of Scenarios.

Pond Releases

The summer pond release scenario (Scenario 7) resulted in the largest increases in summer streamflow of any of the scenarios discussed thus far. Between the pond release in upper Mark West Creek and the confluence with Mill Creek where the lower release enters, mean summer discharges increase by 0.06 – 0.07 cfs with the exception of localized increases of up to 0.09 cfs just downstream of the confluence of Humbug Creek where the middle release enters. Below the lower release on Mill Creek, discharges increase by 0.14 to 0.16 cfs (Figure 85). Averaged across the full length of anadromy in Mark West Creek, the changes in streamflow represent an increase in mean summer streamflow of approximately 13%.

The predominance of gaining conditions in most reaches of the stream result in only limited flow losses downstream of the releases, which makes this strategy particularly well-suited for this watershed which is characterized by a lack of thick alluvial deposits. The increase in summer streamflow above the middle release at Humbug Creek is equivalent to about 80% of the upper release rate and the increase in streamflow at the watershed outlet is equivalent to about 84% of the total release rate from all three releases. The losing reach below Porter Creek does reduce the increase in streamflow locally by about 0.02 cfs, but this effect does not persist downstream since much of the water that infiltrates through the streambed in this reach discharges back to the stream downstream.

The spring pond release scenario produced a similar but slightly smaller increase in springtime flows (Scenario 7B) than in summer flows (Scenario 7) (Figure 87). The spring pond release scenario was designed to increase flows over a short (3-week) period coinciding with the timing of the end of typical peak smolt outmigration in May. Examination of discharge and riffle depth hydrographs during the 2014 drought shows that the springtime releases substantially increase flows in the high priority reach during this critical time period extending the duration of passable conditions by approximately two weeks (Figure 89). The summer pond release scenario increases riffle depths significantly over the critical summer low flow period, but these changes are not large enough to maintain depths above 0.2-ft (Figure 89).

Combined Management

When all the land/water management scenarios are combined (Scenarios 4 - 7), mean summer discharge in Mark West Creek increased by 0.05 – 0.10 cfs between Monan's Rill and Van Buren Creek and by 0.10 – 0.15 between Van Buren Creek and Porter Creek. Downstream of Porter Creek streamflow increased by 0.25 – 0.35 cfs (Figure 90). These changes are similar but slightly less than the sum of the changes of the four individual scenarios. Averaged across the full length of anadromy in Mark West Creek, the changes in streamflow represent an increase in mean summer streamflow of approximately 23%.

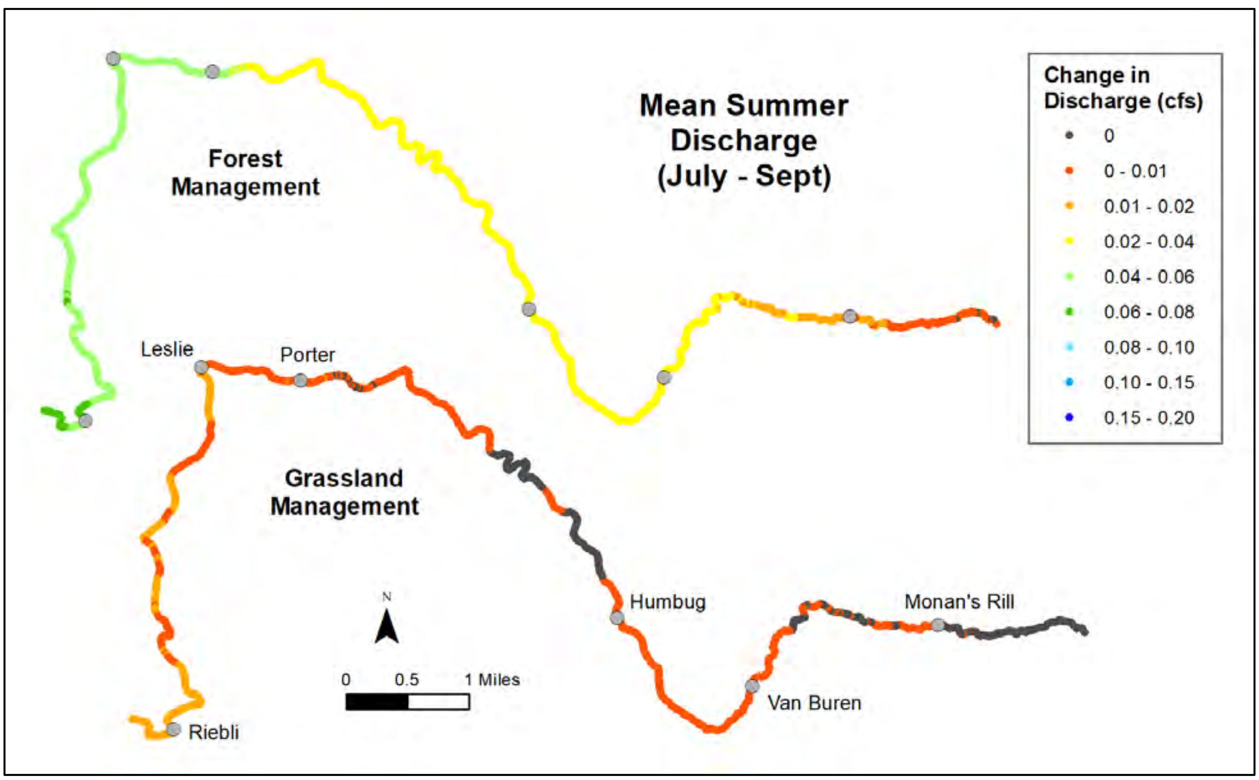


Figure 84 Simulated changes to mean summer streamflow for the forest and grassland management scenarios (Scenarios 4-5).

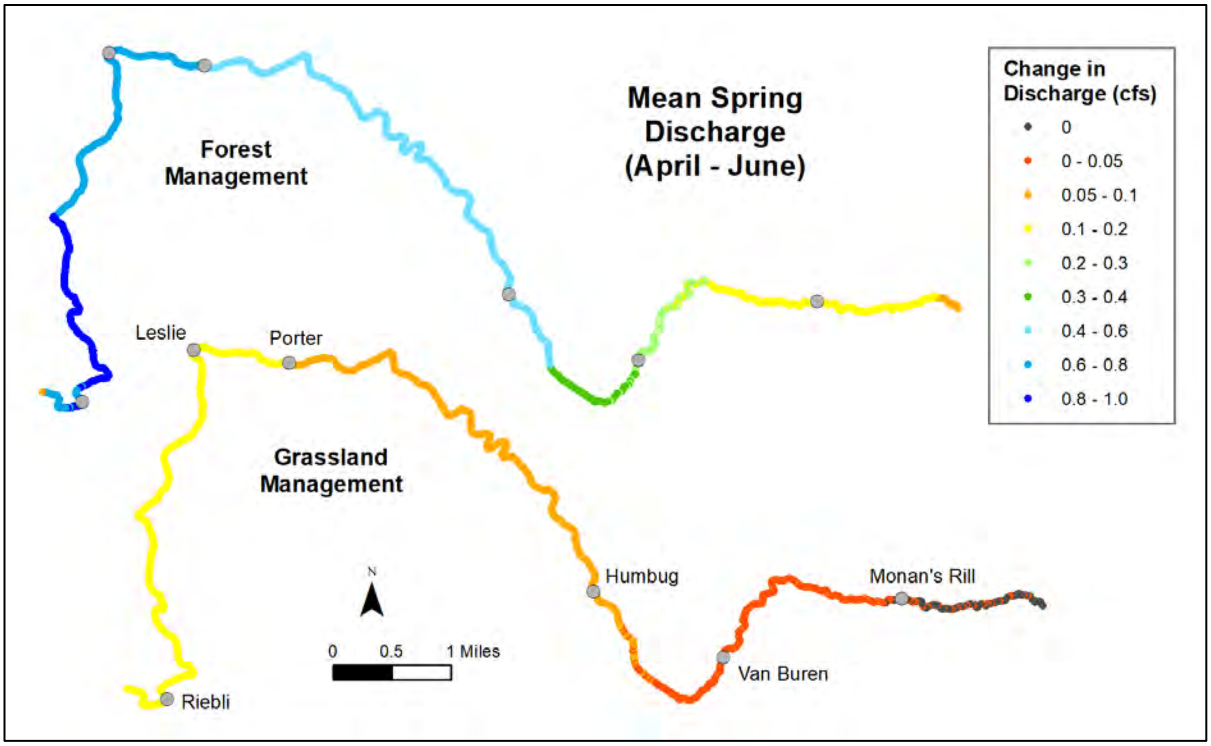


Figure 85: Simulated changes to mean springtime streamflow for the forest and grassland management scenarios (Scenarios 4-5).

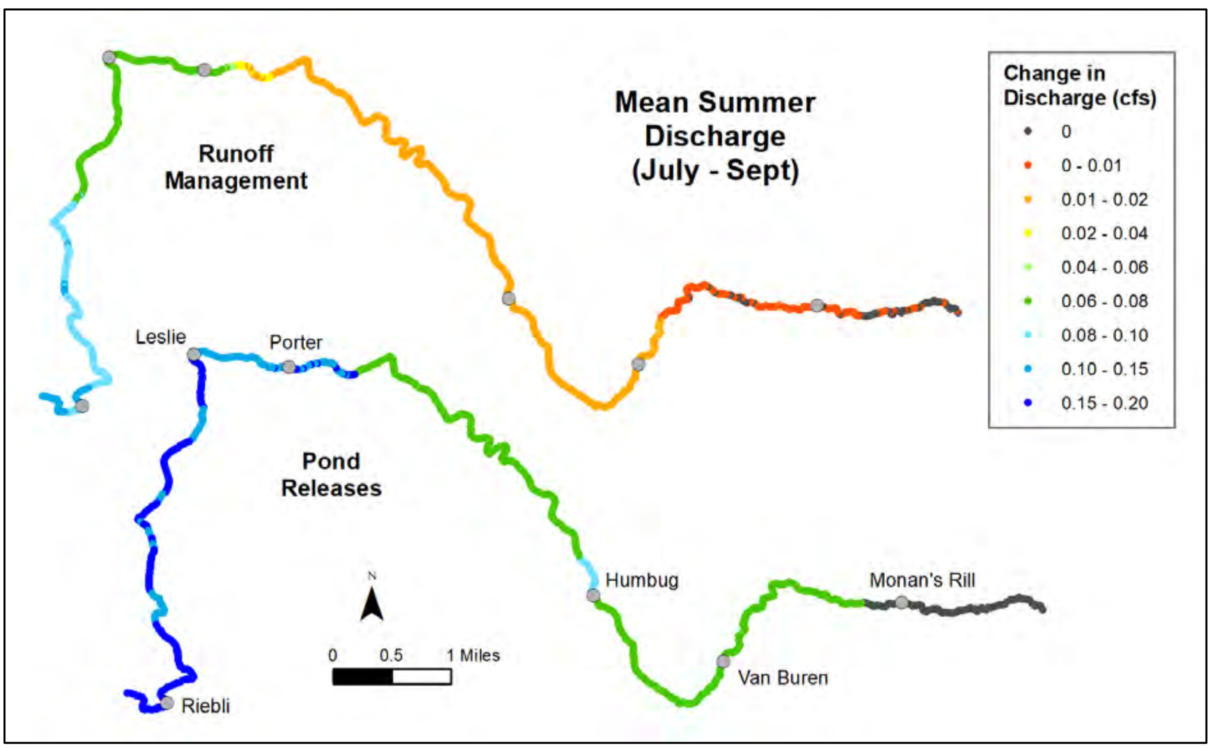


Figure 86: Simulated changes to mean springtime streamflow for the runoff management and summer pond release scenarios (Scenarios 6 & 7).

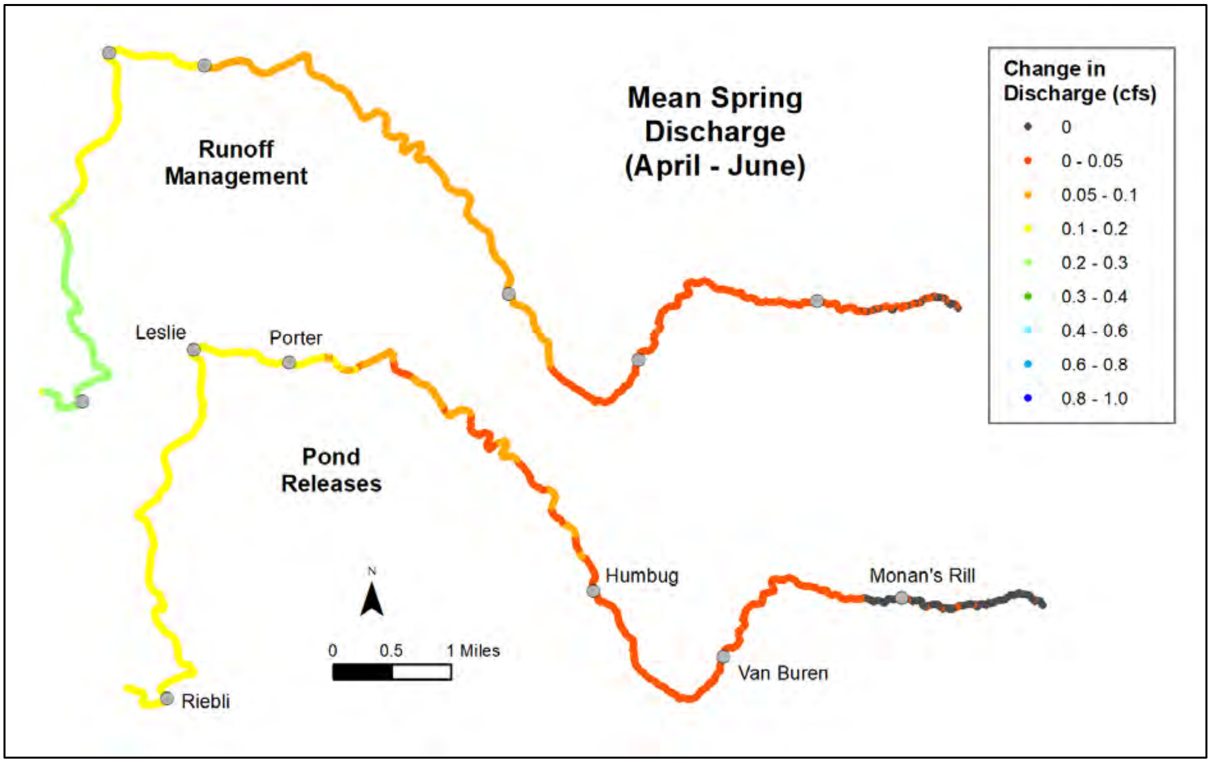


Figure 87: Simulated changes to mean springtime streamflow for the runoff management and springtime pond release scenarios (Scenarios 6 & 7B).

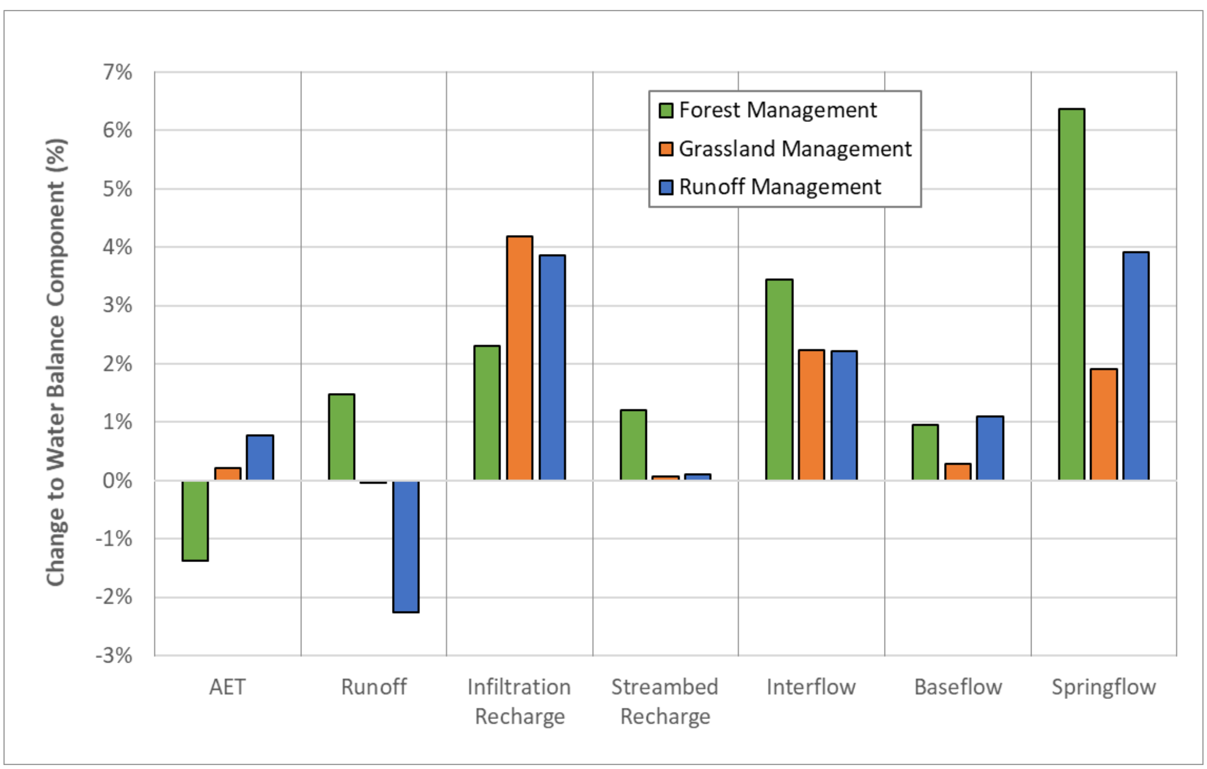


Figure 88: Percent change in select water balance components for Scenarios 4-6.

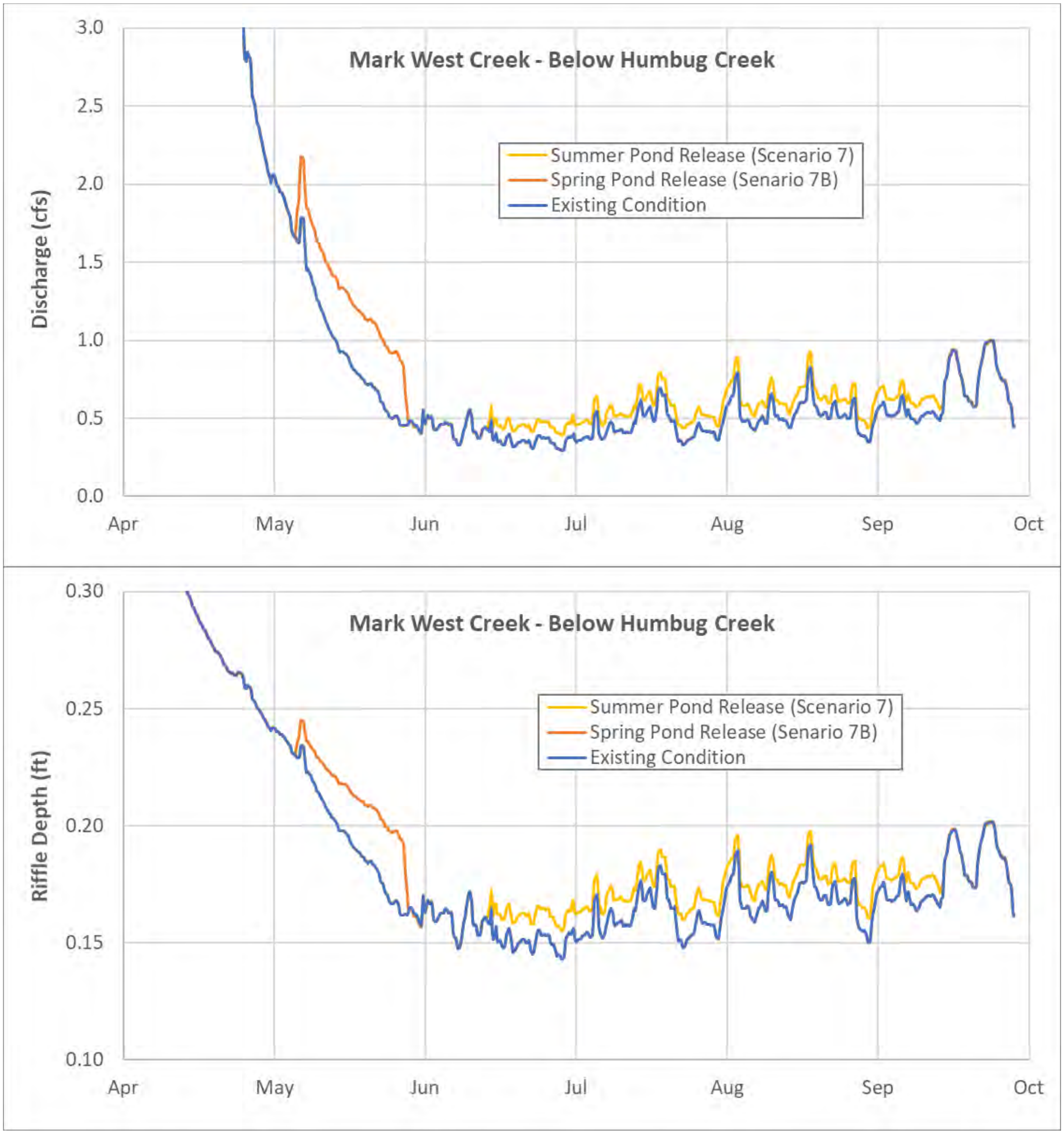


Figure 89: Spring and summer 2014 discharge (top) and riffle depth (bottom) in Mark West Creek below Humbug Creek for existing conditions and the spring and summer pond release scenarios (Scenarios 7 & 7B).

Table 21: Change in mean summer streamflow for forest, grassland, and runoff management (Scenarios 4-6) normalized to a 100-acre treatment area.

Scenario #	Scenario Name	Change in Mean Summer Discharge (cfs/100 acres of treatment area)
4	Forest Management	0.0010
5	Grassland Management	0.0007
6	Runoff Management	0.0355

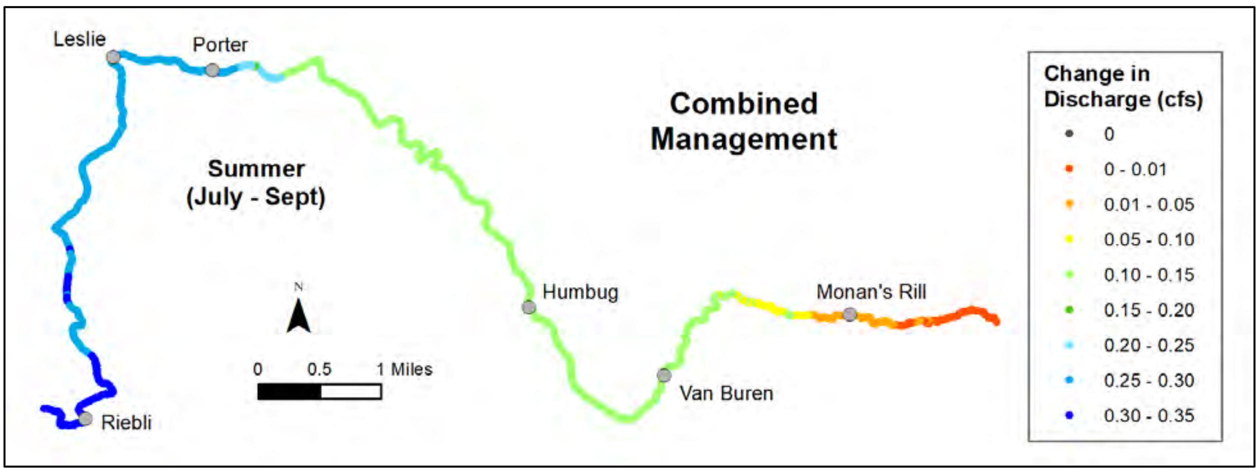


Figure 90: Simulated changes to the 10-yr average mean summer streamflow for the combined management scenario (Scenario 8; note the scale in the legend is different from previous figures for other scenarios).

<u>Climate Change Scenarios</u>

The four climate change scenarios (Scenarios 9-12) generated a wide range of predictions of future (2070-2099 timeframe) changes in discharge in Mark West Creek; nevertheless, there are some commonalities in the predictions of future streamflow trajectories. The average 10-yr mean monthly discharge is predicted to increase during late fall and winter in three of the four scenarios, with mean January flows in the CNRM scenario more than 2.5 times greater than existing conditions (Figure 91). All four scenarios show large decreases in discharge during spring with mean monthly flows during March decreasing by 48-71%. The predictions for summer flows are more variable with two scenarios predicting decreases in the mean monthly August flow on the order of 38-51% and one predicting increases of 26% (Figure 91). The future changes are even more extreme during drought conditions where winter flows are predicted to decrease dramatically in all four scenarios with high streamflow events becoming essentially non-existent in the GFDL scenario (Figure 92). The declines in springtime flows are also extreme with decreases in mean monthly discharge in March of 60-97% (Figure 92).

More careful review of the range of predicted changes in summer flows reveals that mean summer discharges increase in the CNRM scenario by about 0.1 - 0.2 cfs throughout Mark West Creek, whereas in the MIROC esm scenario, discharges between Van Buren Creek and Porter Creek drop from about 0.5 - 0.8 cfs to 0.3 - 0.4 cfs, and below Porter Creek flows drop from about 1.0 - 1.5 cfs to 0.6 - 0.8 cfs (Figure 93). In contrast to the variable predictions in mean summer discharges, all four models predict large decreases in mean spring discharges. The CNRM scenario produces the smallest decreases with flows in Mark West Creek decreasing from 4-10 cfs to 0.5 - 1 cfs between Van Buren and Porter Creeks and from 10-20 cfs to 1 - 2 cfs downstream of Porter Creek (Figure 94). The MIROC esm scenario predicts even more dramatic decreases in springtime discharges with flow of <0.5 cfs between Van Buren Creek and Porter Creek and <1 cfs below Porter Creek (Figure 94).

Examination of the 10-yr mean annual water balance (representative of the 2070-2099 timeframe) reveals that the four climate scenarios predict very different changes to the mean annual water balance. Precipitation changes range from a 37% increase in the CNRM scenario to a 20% decrease in the MIROC esm scenario (Figure 95). The significantly higher precipitation in the CNMR scenario leads to increases in AET of about 13%, whereas the other three scenarios result in modest decreases in AET of between 2 and 7%. Runoff is predicted to increase in the CNRM and CCSM4 scenarios by 26-69% and decrease in the GFDL and MIROC esm scenarios by 25 - 32% (Figure 95). The CNRM scenario predicts large increases in both infiltration recharge (44%) and streambed recharge (33%), the CCSM4 model predicts minimal changes in recharge, and the GFDL and MIROC esm scenarios predict significant decreases in infiltration recharge (29 - 40%) and streambed recharge (17 - 25%). Increased recharge in the CNRM scenario results in increases in groundwater discharge expressed as interflow (32%), baseflow (11%), and springflow (36%). Similarly, groundwater discharge decreases in the scenarios that predict decreases in recharge. The largest decreases are predicted by the MIROC esm scenario where interflow, baseflow, and springflow are predicted to decrease by 30, 21, and 46% respectively (Figure 95).

Comparison of the water balance for the driest of the 10 years in each simulation reveals that the trajectories of the changes in the water balance between the four scenarios are more similar during drought conditions than for long term average conditions. AET is predicted to increase in all four models while runoff, infiltration recharge, and streambed recharge are predicted to decrease (Figure 96). The GFDL drought predictions are extreme with close to a complete loss of both runoff and infiltration recharge. The groundwater discharge results remain variable between the scenarios with the CNRM and CCSM4 scenarios resulting in increased discharge during droughts and the GFDL and MIROC esm scenarios resulting in decreased groundwater discharge reflecting that groundwater discharge responds more to long-term fluctuations in climate rather than individual water year conditions (Figure 96).

All four scenarios indicate increases in Climatic Water Deficit (CWD). The mean CWD for the watershed over the 10-yr simulation period is predicted to increase from 26.0 in/yr under existing conditions to between 30.3 and 33.9 in/yr under future climate conditions. Increases in CWD of this magnitude (17-30%) may be expected to lead to significant changes in vegetation communities and increases in fire risk. It is important to note that these simulations represent the hydrologic effects of changes in climate but do not include secondary effects that may be expected under a significantly altered future climate regime such as changes in vegetation cover and irrigation water demands.

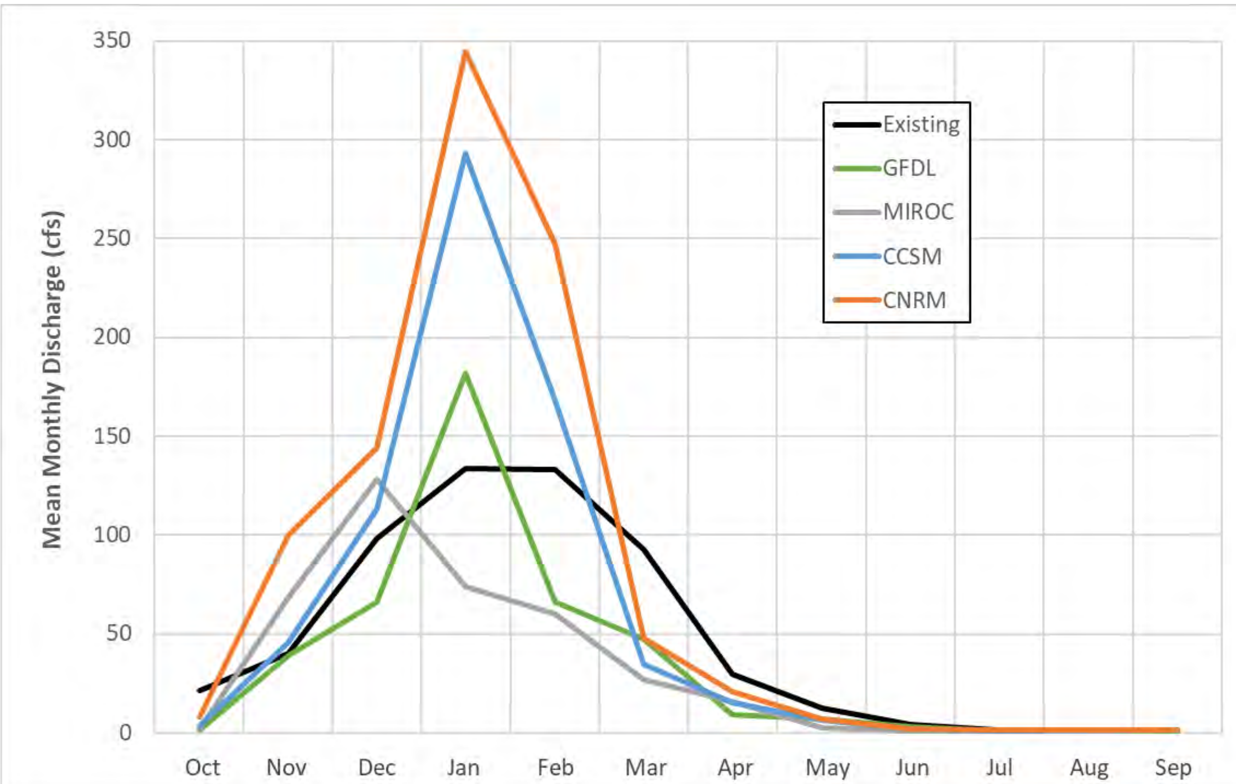


Figure 91: Comparison of mean monthly streamflow averaged over the 10-yr simulation periods for existing conditions and the four climate change scenarios (Scenarios 9-12).

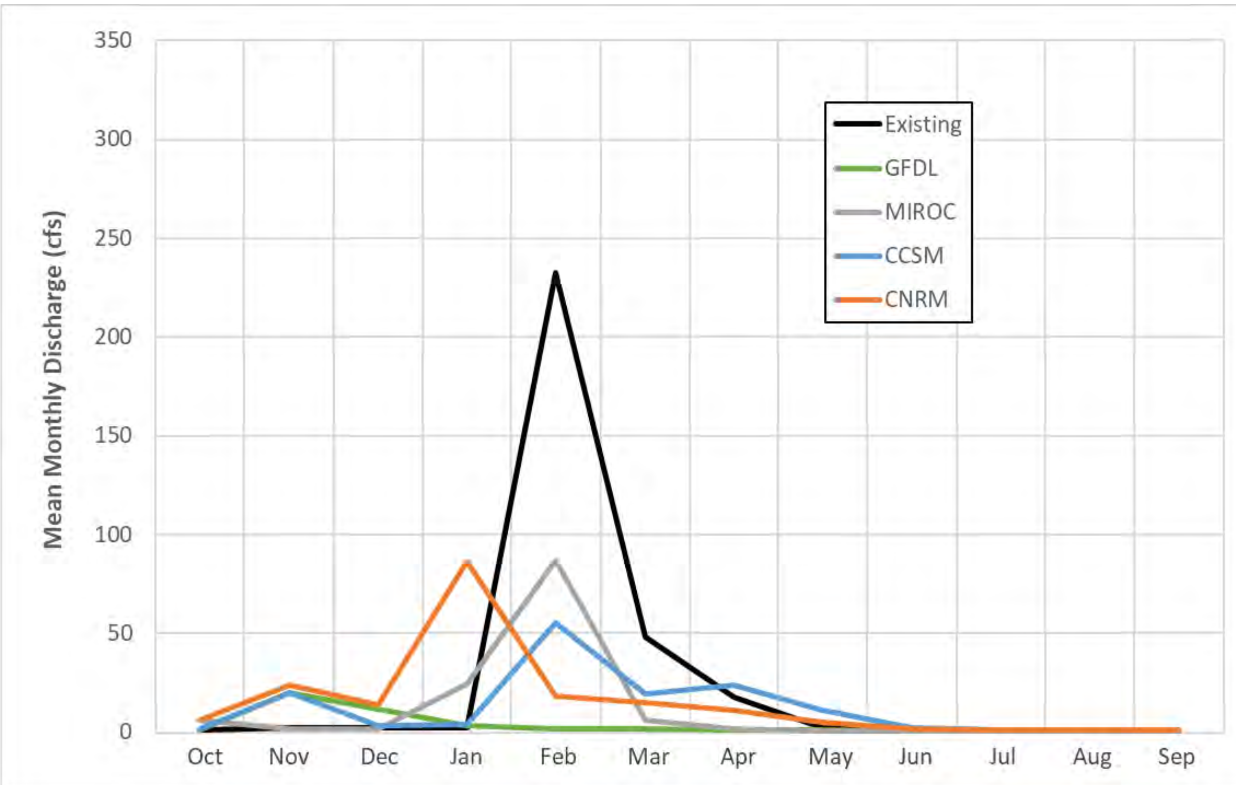


Figure 92: Comparison of mean monthly streamflow for the driest water year in each 10-yr simulation period for existing conditions and the four climate change scenarios (Scenarios 9-12).

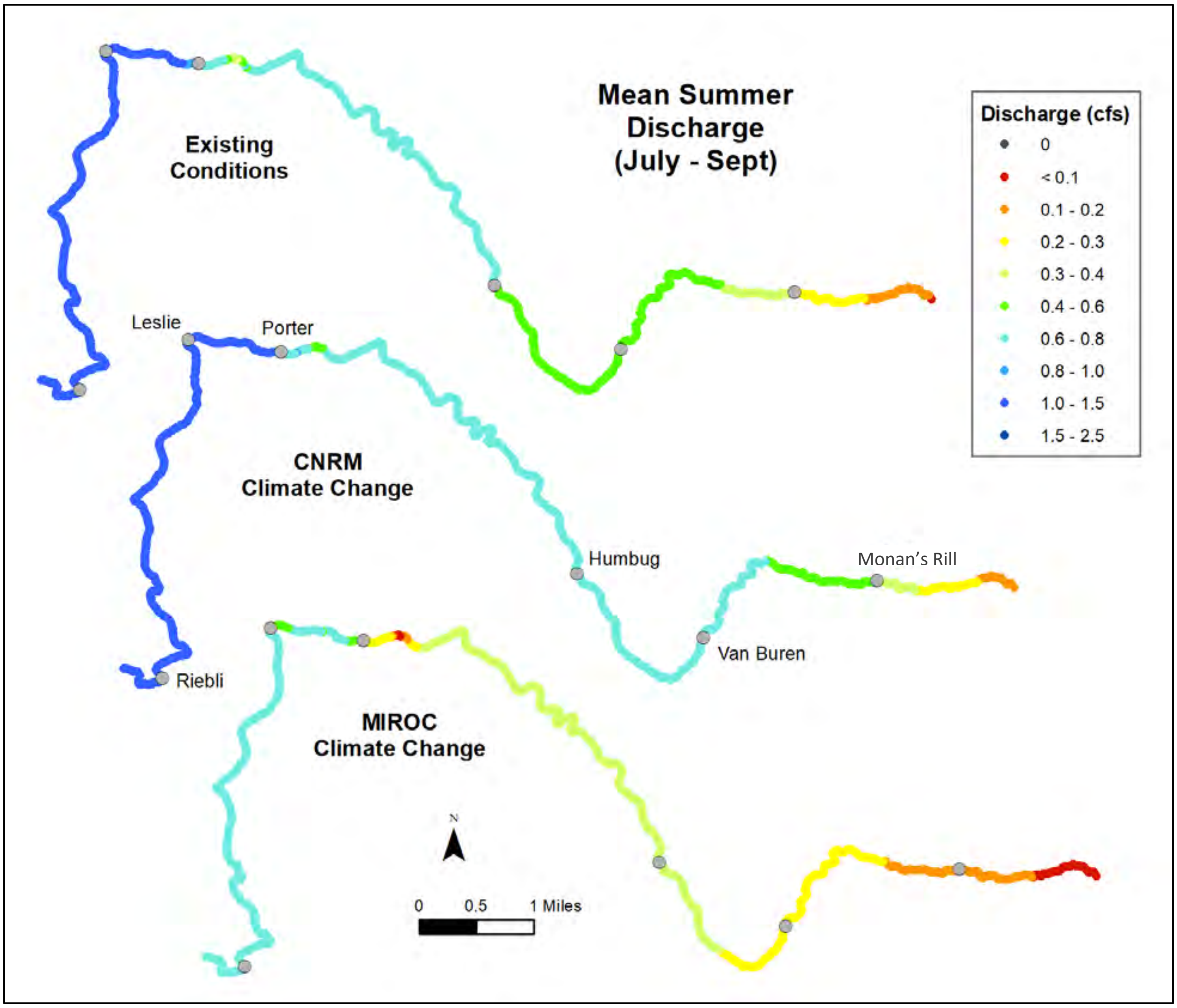


Figure 93: Simulated 10-yr average mean summer streamflow for existing conditions and the CNRM and MIROC esm scenarios (Scenarios 9 & 12) which represent the end-member predictions from the four climate change scenarios.

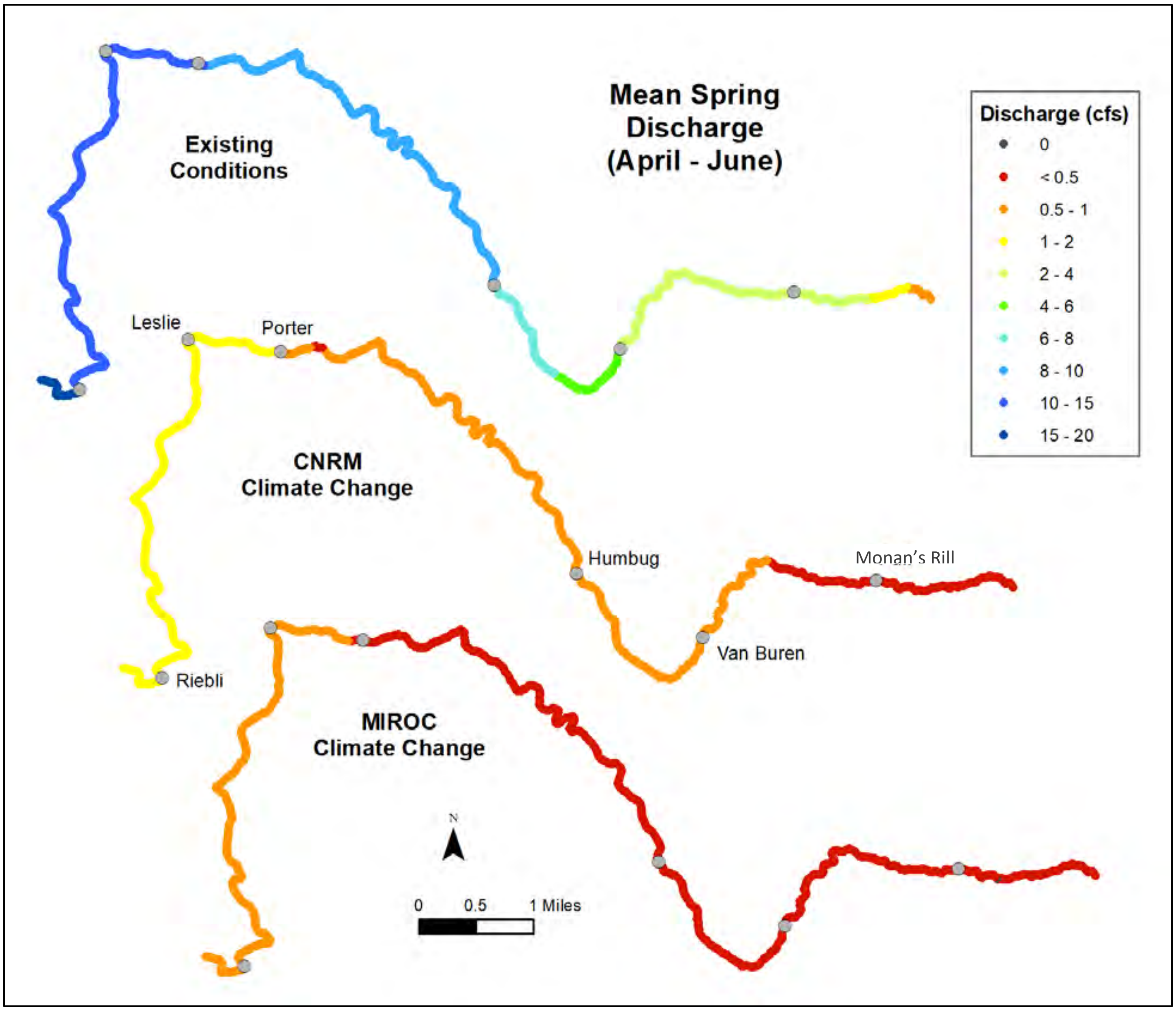


Figure 94: Simulated 10-yr average mean springtime streamflow for existing conditions and the CNRM and MIROC esm scenarios (Scenarios 9 & 12) which represent the end-member predictions from the four climate change scenarios.

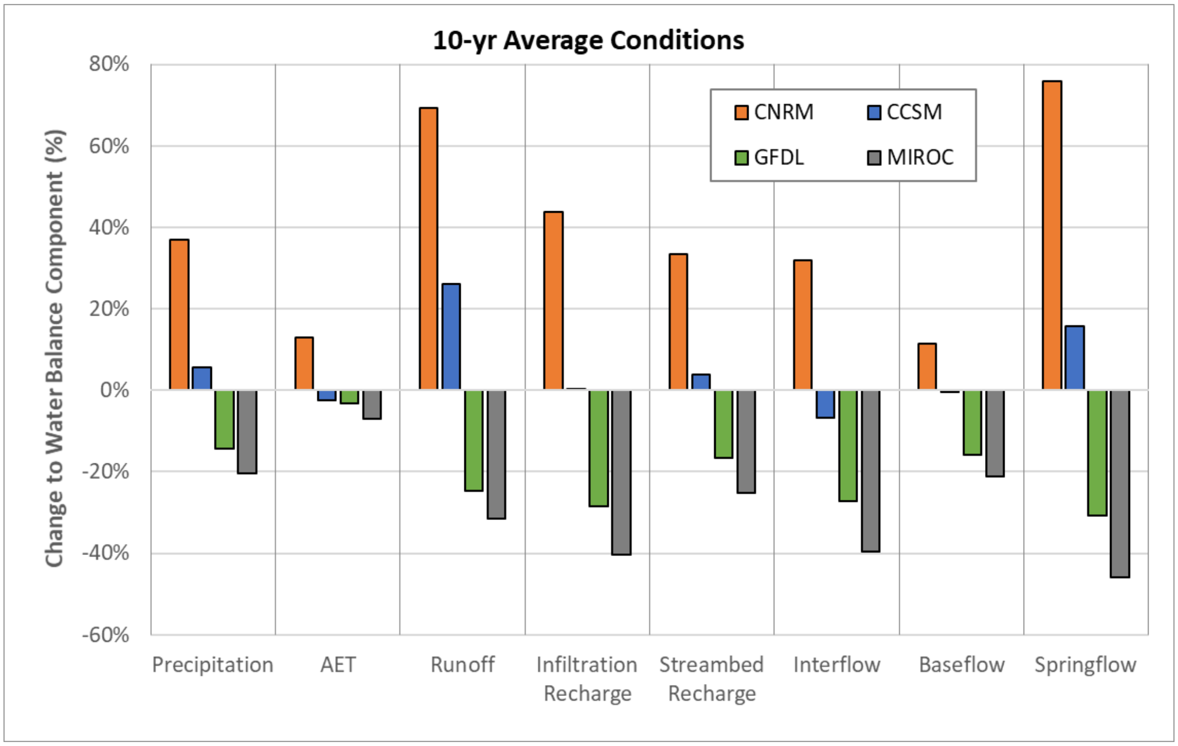


Figure 95: Percent change in various components of the water balance averaged over the 10-yr simulation periods for the four climate change scenarios relative to existing conditions.

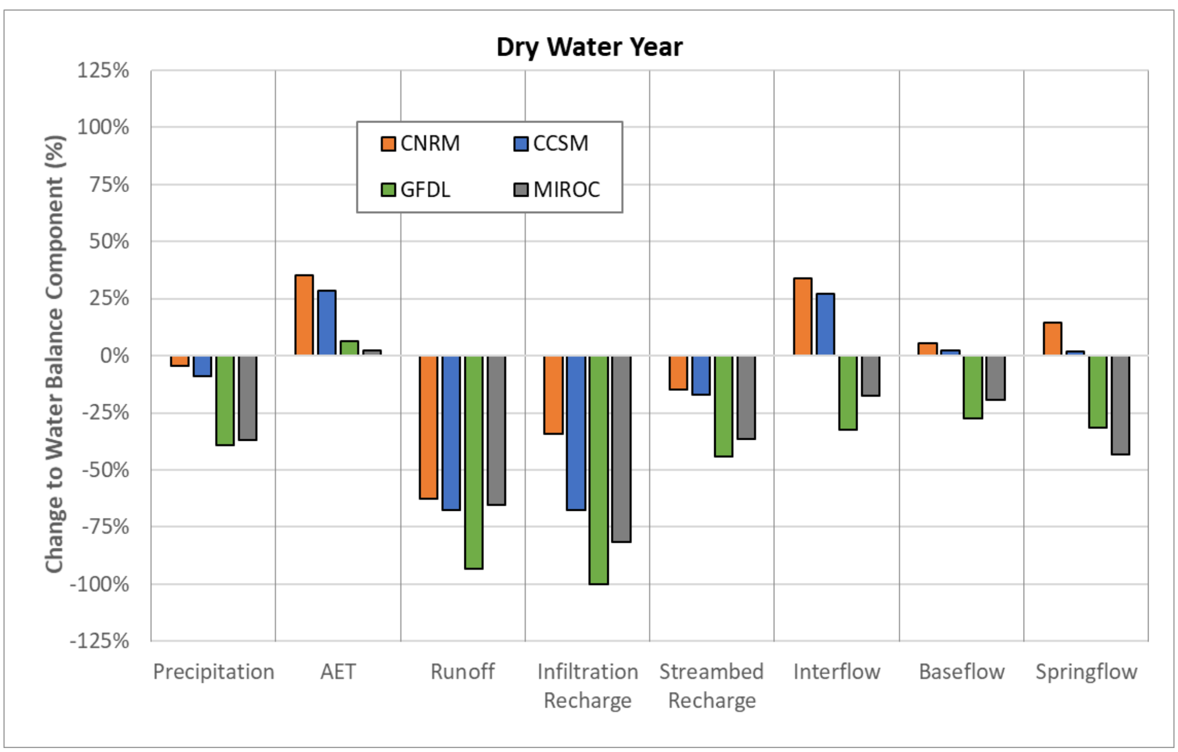


Figure 96: Percent change in various components of the water balance for the driest water year in each 10-yr simulation period for the four climate change scenarios relative to existing conditions.

Mitigated Scenarios

We combined the pond release scenarios (Scenarios 7 & 7B) and the combined management scenario (Scenario 8) with the GFDL climate scenario (Scenario 11) to evaluate the degree to which the various management actions may be capable of mitigating the changes in streamflow associated with future climate. We selected the GFDL model because it represents the second lowest predictions of future spring and summer streamflow of the four climate scenarios which provides a good benchmark for evaluating the scale of the management effects. If future climate more closely resembles the CNRM or CCSM4 scenarios the mitigating effects of the management actions would likely be larger than what is shown here, whereas if future climate more closely resembles the MIROC esm scenario, less mitigation would likely be possible.

The GFDL scenario predicts decreases in mean summer discharge of about 0.20 − 0.42 cfs at most locations in Mark West Creek, and the summer pond releases are large enough to significantly reduce these declines down to about 0.15 − 0.25 cfs (Figure 97). The combined actions of summer pond releases and forest, grassland, and recharge management generate increases in flow that are large enough to fully offset the predicted effects of the GFDL future climate on summer streamflows (Figure 97). None of the actions are capable of fully mitigating against the large decreases in springtime flows predicted by the climate scenarios; nevertheless, springtime flow releases may provide a critical management strategy to provide passable flow conditions for short critical periods of time during smolt outmigration.

Examination of riffle depth hydrographs below Humbug Creek during the driest water year in each 10-yr simulation cycle shows that under the GFDL future climate, riffle depths only reach the 0.2-ft minimum fish passage threshold for brief periods during March through May (Figure 98). This represents a dramatic change in the passage conditions experienced by outmigrants. Under existing conditions depths remain above 0.3-ft until mid-April and above 0.2-ft until early May. Springtime pond releases appear to be large enough to allow for a more sustained (several week) period with riffle depths remaining around 0.2-ft; in this scenario, releases were targeted towards the end of the primary outmigration period in May (Figure 98). Greater riffle depths could likely be achieved over shorter periods by increasing release rates and decreasing durations. The combined actions of summer pond releases, forest, grassland, and runoff management also had an appreciable effect on summer riffle depths generating depths under GFDL future climate that resemble those for existing climate (Figure 98). These findings suggest that aggressive management is capable of offsetting most or all of the summer declines in streamflow predicted for the GFDL future climate.

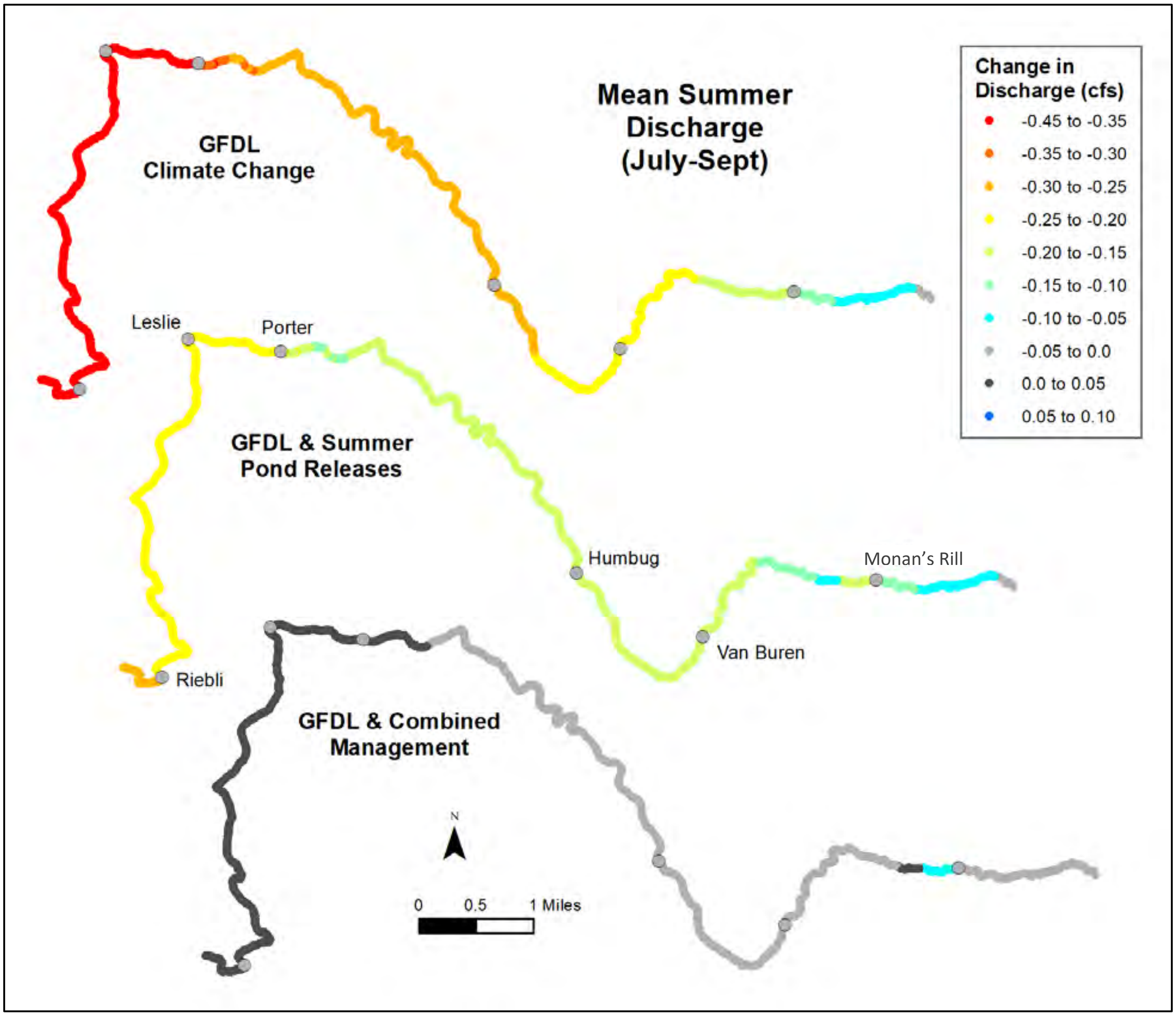


Figure 97: Simulated changes to the 10-yr mean summer streamflow for the GFDL future climate, the GFDL & spring pond release scenario (Scenario 13), and the GFDL & combined management scenario (Scenario 14).

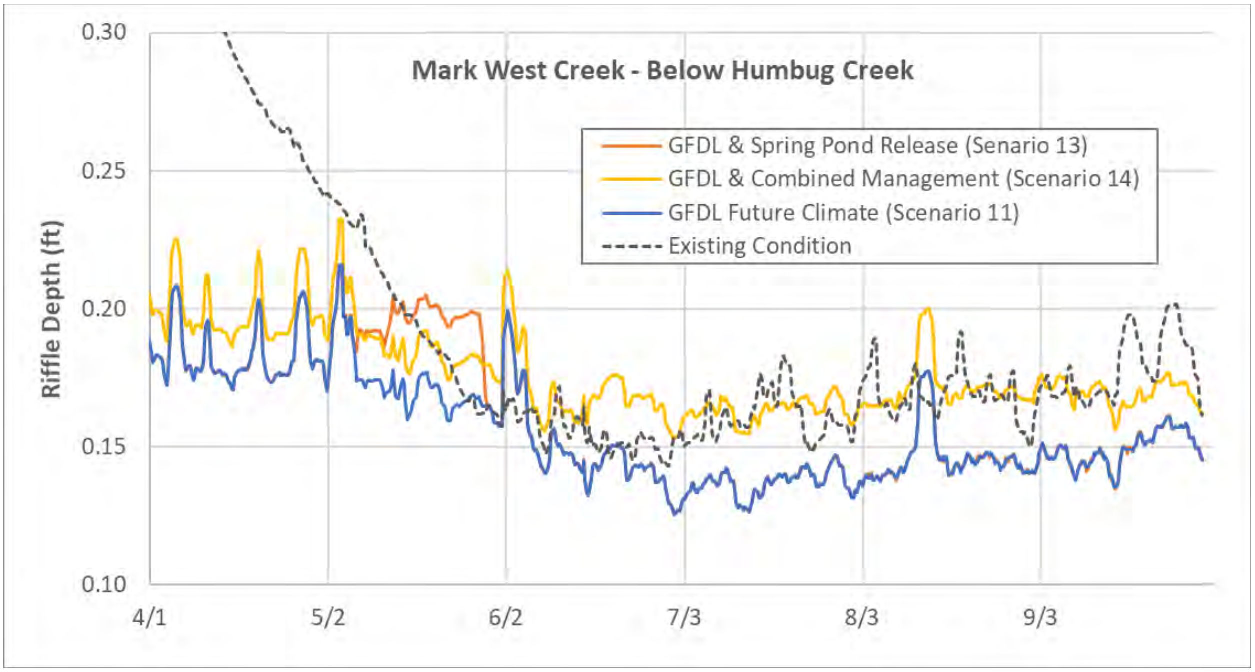


Figure 98: Spring and summer riffle depths for the driest year in the 10-yr simulation in Mark West Creek below Humbug Creek for existing conditions, GFDL future climate scenario (Scenario 11), the GFDL & springtime pond release scenario (Scenario 13), and the GFDL & combined management scenario (Scenario 14).

Summary and Comparison of Scenarios

Comparison of the changes in summer streamflow between the various scenarios indicates that the sustained cumulative effect of surface water and groundwater use are approximately equal and that cessation of all water use would eventually increase mean summer streamflow by about 6% in the ~4-mile high priority reach below Alpine Creek and ~8% at the watershed outlet (Figure 99). The pond release scenario generated the largest increases in summer streamflow of the stand-alone scenarios, with increases of about 13 - 14%. In the high priority reach, the next largest increases were from the forest management scenario, followed by the recharge management scenario (Figure 99). At the watershed outlet this order was reversed owing to the concentration of forest treatment areas in the upper watershed and the concentration of developed areas included in the runoff management scenario in the lower watershed. Runoff management generated about a 3% increase in summer streamflow in the high priority reach and a 10% increase at the outlet, whereas forest management generated about a 6% increase at both locations. The grassland management scenario generated the smallest increases in summer flows on the order of 2% (Figure 99).

The climate change scenarios generated a wide range of predictions with three of the four scenarios indicating decreases in summer streamflow of between 6 and 47% and one scenario indicating increases of about 15 - 19% (Figure 99). The mitigated scenarios indicate that pond releases can likely offset a significant portion of the projected decreases in summer streamflow predicted by some of the models and if combined with forest, grassland, and runoff management, are likely large enough to completely offset the projected decreases (Figure 99). If future climate more closely resembles the predictions of the CNRM or CCSM4 models, pond releases and combined management would be expected to result in flow enhancement above existing conditions.

The various large-scale flow enhancement actions represented by the scenarios and the foregoing comparisons are intended to represent implementation of projects of a given type based on the maximum potential on the landscape. The scenarios vary widely in their scale, feasibility, and expected cost. To better understand the relative streamflow benefits of implementing a given project, we normalized the simulated increases in streamflow based on areas for a 'typical' parcel/project in the watershed (Figure 100). To normalize the surface water diversion scenario results, we assumed a new well would be drilled to replace the entire diversion volume with groundwater pumping. We divided the cumulative diversion effects by the total number of diversions and then subtracted the cumulative groundwater pumping effects normalized by the volume of diversion offset. In most cases it is not possible or practical to completely offset groundwater pumping with rainwater or runoff capture and storage. Installation of storage tanks is a common and practical means of offsetting groundwater pumping and we assumed 10,000 gallons of tank storage offset to normalize the groundwater pumping scenario results. The average per parcel acreages of forest treatment, grassland treatment, and impervious area represented by the scenarios was used to normalize the results for these three scenarios; these acreages were 5.6, 4.6, and 0.38 acres respectively. The pond release scenario was normalized by simply dividing the cumulative enhancement benefits by the number of release projects (three).

We also developed a rough cost estimate for each typical project and normalized the results again based on a $25,000 project cost. The six projects and estimated costs include:

- Groundwater Pumping Offset – installation of a 10,000 gallon rainwater catchment tank and associated reduction in groundwater pumping - $38,000
- Surface Diversion Replacement – replacement of a direct or spring diversion with a new groundwater well - $33,000
- Runoff Management – construction of an infiltration basin sized to capture the 10-yr 48-hr storm volume from a 3,000 ft^2 rooftop or other impervious area - $22,500
- Grassland Management – compost application on 4.6 acres of grassland (average per parcel acreage in the model scenario) - $7,000
- Forest Management – thinning and/or controlled burning on 5.6 acres of forested lands requiring treatment (average per parcel acreage in the model scenario) - $15,000
- Pond Release – summer flow release of 11.3 ac-ft from an existing on-stream pond (average release volume of the three ponds in the model scenario) - $20,000

This comparison revealed that pond releases are by far the most effective strategy for enhancing streamflows (Figure 100). On a cost basis, the streamflow benefits of one flow release project were found to be more than 50 times greater than an average surface water diversion replacement project and more than 500 times greater than an average grassland management project (the second and third most effective strategies). Replacement of direct stream diversions or spring diversions of surface water with new wells is the second most effective strategy. Grassland and forest management showed a similar level of effectiveness on a cost basis and were about 3 - 4 times as effective as runoff management. Offsetting groundwater pumping with storage was the least effective of the six overall strategies considered.

It is important to recognize that runoff, forest, and grassland management may provide significant additional benefits besides streamflow enhancement compared to pond release and diversion replacement projects. These management strategies generate enhanced streamflow primarily via increasing groundwater discharge (see Figure 88), which may be expected to mitigate high water temperature, whereas flow releases from ponds may need to be carefully managed to avoid adverse temperature effects. These strategies also help reduce seasonal vegetation moisture stress which may decreases fire risk somewhat or at least help offset future increases in risk associated with climate change. In particular, the forest management scenario reduces actual evapotranspiration by about 5% on treated lands which represents a fairly large volume of water (615 ac-ft/yr), and the runoff management scenario results in a substantial decrease in the Climatic Water Deficit of about 25% on lands where they are implemented. These various benefits are in addition to the primary non-hydrologic benefits of forest and grassland management projects in reducing fuel loads and sequestering carbon respectively.

All four climate change scenarios representing the 2070-2099 timeframe indicate substantial decreases in springtime flows ranging from 35 - 62% (Figure 101). These changes greatly exceed the potential flow improvements associated with the various enhancement scenarios. Forest management generates the largest increases in mean spring discharges (~5 - 6%), and the other individual scenarios only increase spring flows by ~1 - 2% (Figure 101). As discussed above, while it may not be possible to significantly increase mean discharges during spring relative to the scale of expected decreases resulting from climate change, springtime pond releases lasting several days to weeks do provide a means of creating a period of passable flow conditions during critical outmigration periods which may be essential given the scale of the projected decreases in springtime flows (see Figure 98).

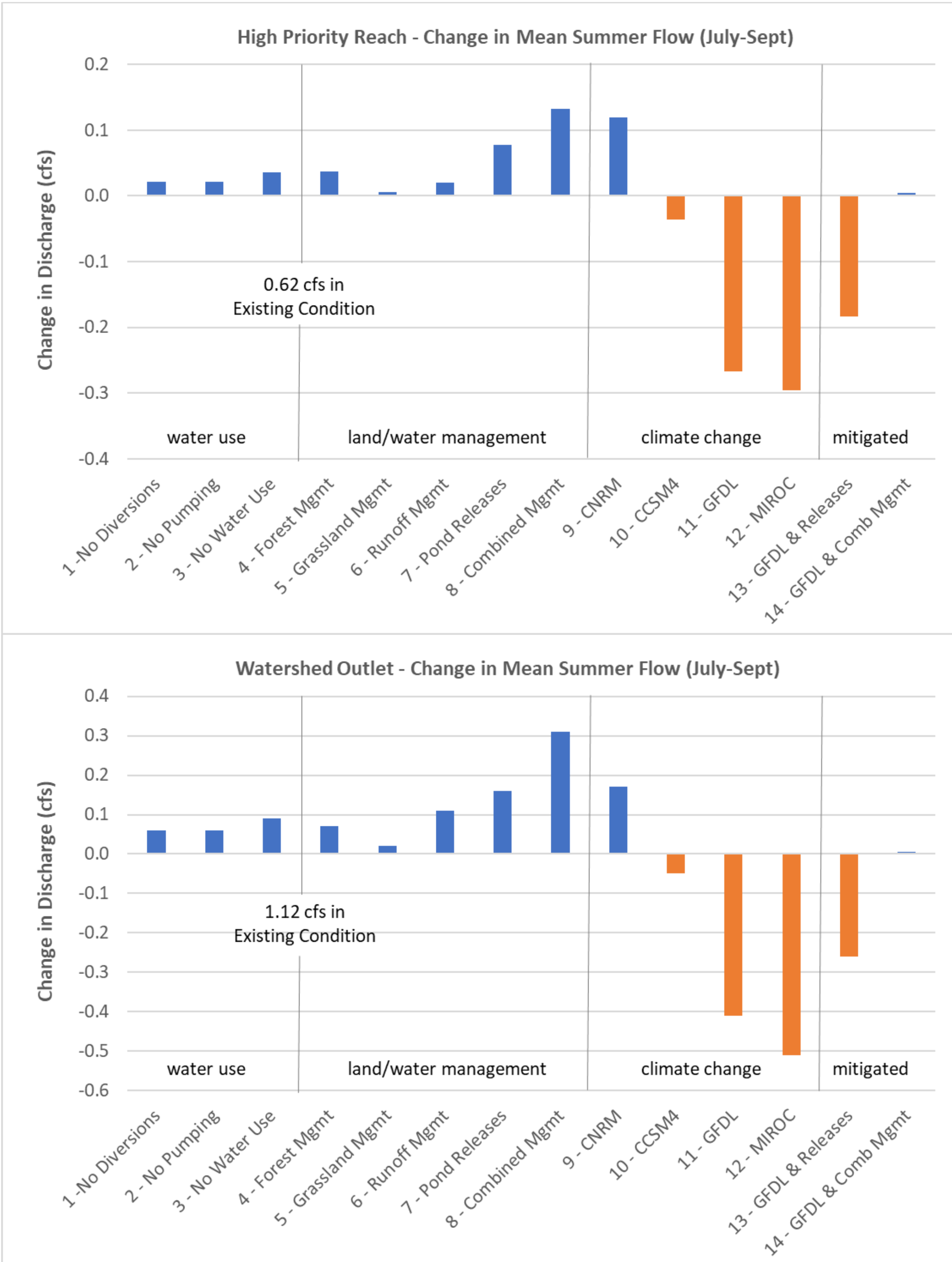


Figure 99: Summary of the simulated changes in mean summer streamflow for Scenarios 1-14 averaged over the high-priority habitat reach (top) and at the watershed outlet (bottom).

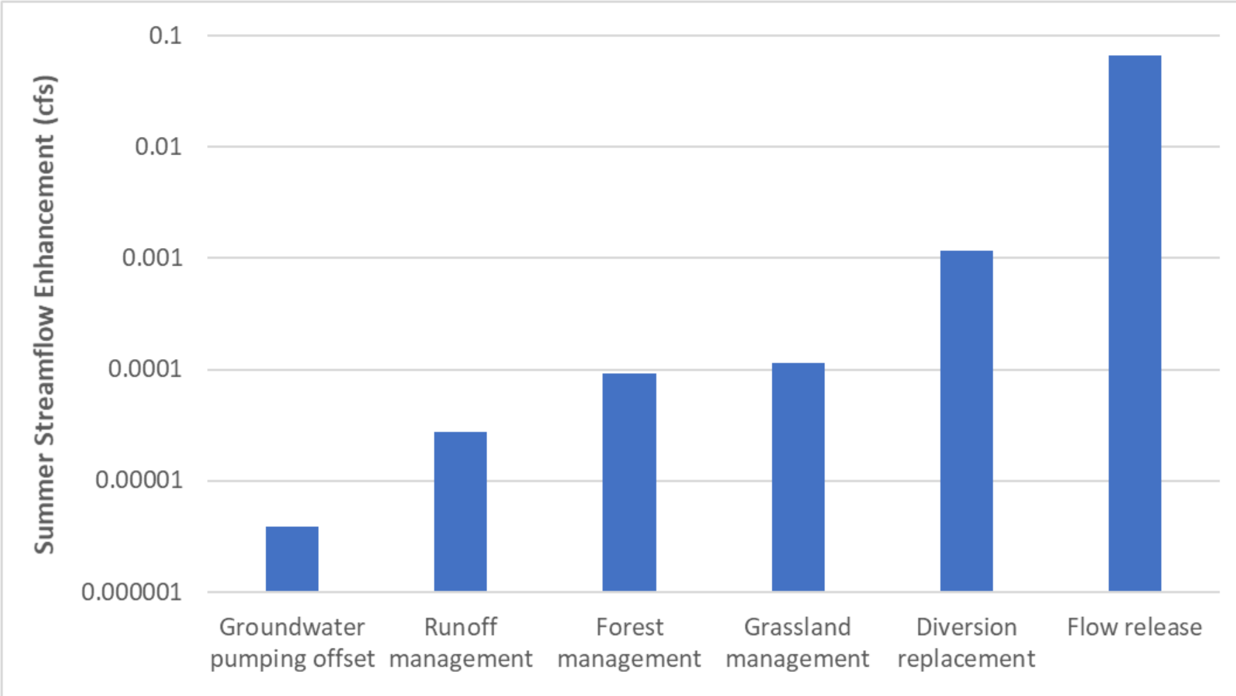


Figure 100: Summary of the simulated increase in mean summer streamflow for the six primary individual flow enhancement actions represented by the model scenarios normalized to a $25,000 project cost.

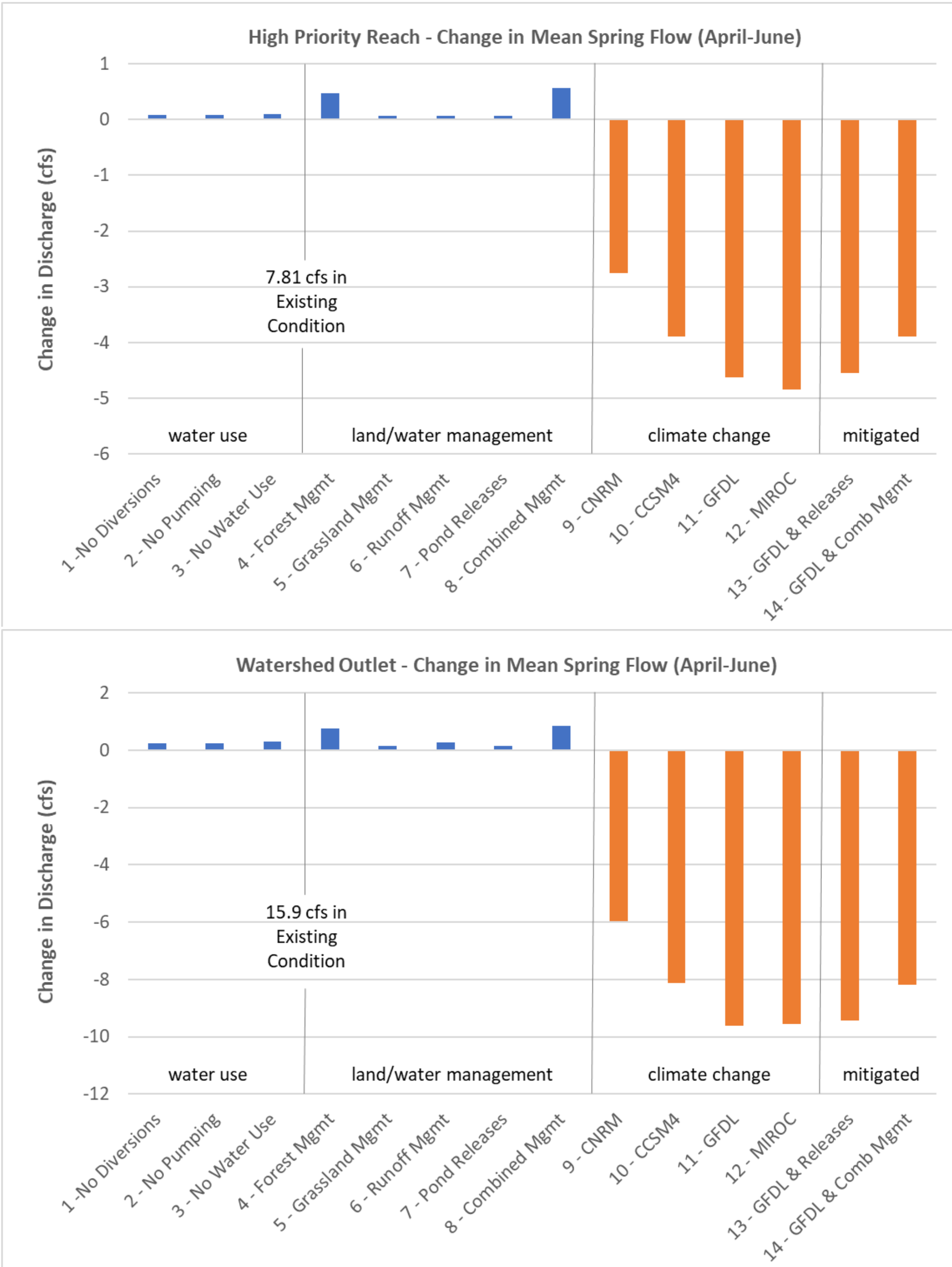


Figure 101: Summary of the simulated changes in mean springtime streamflow for Scenarios 1-14 averaged over the high-priority habitat reach (top) and at the watershed outlet (bottom).

Chapter 9 –Recommendations & Priority Restoration/Management Actions

Habitat Enhancement

Based on simulated riffle depth and observed water temperature data and informed by habitat inventory and fisheries monitoring data, the four mile reach extending from 0.2 miles upstream of Alpine Creek to 2.0 miles upstream of the Porter Creek confluence has the best overall habitat for salmonids (Figure 102). This analysis was focused on juvenile rearing and smolt outmigration; however, the identified reach is also believed to provide better spawning and winter rearing habitat conditions than upstream and downstream reaches. Conditions in the reach are far from optimal with impaired temperatures and insufficient summer streamflows. Nevertheless, the reach has the least impaired habitat conditions with significantly lower streamflows upstream and significantly higher temperatures downstream. We recommend that habitat enhancement projects be focused in this high priority reach where these efforts have the greatest likelihood of improving overall habitat conditions for salmonids.

Based on a limited number of sample sites, water temperatures in the high priority reach appear to remain below severely impaired levels in pools with depths above about 3.5-ft whereas severely impaired temperatures occur in shallower pools (see Figures Figure 62 & Figure 65). More temperature monitoring and pool inventory and analysis is recommended in the reach to identify pools providing critical temperature refugia. A temperature study is also warranted to better understand the factors affecting water temperature and to identify possible mitigation actions. Our preliminary findings suggest that streamflow is not the primary control on temperature and that encouraging formation of stable deep pools and maximizing shading are likely the most important immediate objectives. In-stream large wood (trees and logs) is very limited in Mark West Creek and installation of large wood on a broad scale at sites selected to encourage formation and protection of existing deep pools is recommended. Where needed, projects should also include riparian planting to maximize shading of the summer water surface. Opportunities for development of off-channel habitat projects to enhance winter rearing habitat are also available in the identified reach, and these types of projects are also recommended to support improved conditions in the reach for other limiting life cycle stages.

Flow Protection/Enhancement

Summer streamflow throughout Mark West Creek is generated primarily by spring discharge which most commonly occurs along streambanks with exposures of bedrock of the Sonoma Volcanics. Springflow is concentrated in the upper watershed with the watershed area upstream of Van Buren Creek supplying more than 55% of the total summer spring discharge in the watershed despite representing less than 17% of the total watershed area. We recommend that the various flow protection and enhancement actions described below be focused in the watershed area upstream of the Mill Creek confluence where they are more likely to provide flow benefits in the identified high priority reach. The watershed area upstream of Van Buren Creek could be considered even higher priority for flow protection and enhancement given the disproportionate role the area plays in generating summer streamflow supplied to downstream reaches (Figure 102).

Given that groundwater discharge from the Sonoma Volcanics is the primary driver of summer streamflow, additional monitoring and analysis of subsurface geologic conditions and connectivity of springs and recharge source areas is warranted. Collection of data from a series of dedicated monitoring wells screened in specific geologic units and paired with springflow measurements is recommended to allow for an improved understanding of groundwater processes in the volcanics. Significant prior and ongoing effort has been given to collecting stage data and summer streamflow records, however limited effort has been dedicated to comprehensive rating curve development and generation of continuous streamflow records. Such data is critical to establishing baselines and understanding the effects of flow enhancement actions and ongoing climate change in the watershed and we recommend that a comprehensive long-term streamflow monitoring program be implemented for the watershed.

Releasing water from existing ponds was found to be by far the most effective individual strategy for enhancing streamflow (see Figure 100). The streamflow benefits of a cost-normalized flow release project were found to be more than 50 times greater than surface water diversion replacement projects and more than 500 times greater than grassland management projects (the second and third most effective strategies). Except in the reach upstream of Porter Creek, thick alluvial deposits are uncommon with many reaches of exposed bedrock and predominately gaining conditions persisting throughout the summer. These conditions are ideal for allowing released flows to provide flow benefits that persist in downstream reaches. Examination of existing ponds revealed that there are only three ponds upstream of the high-priority reach with sufficient storage to provide meaningful releases and we recommend that flow release projects be developed for these ponds if possible. There are many challenges that must be overcome to implement these flow release projects including landowner willingness, uncertainty regarding longevity, water quality and invasive species considerations, and permitting and water rights requirements.

There are many existing ponds that could likely be enhanced and new ponds could be built specifically to store water for streamflow enhancement. Given the disproportionate impact that pond releases are expected to have as a mitigation strategy for effects of climate change on streamflow, this somewhat controversial idea should be seriously considered. Water temperature and other water quality considerations should be an important aspect of planning flow release projects since water temperatures are already impaired and it is critical that flow releases do not further increase temperatures. There are various strategies for coping with elevated pond temperatures (e.g. bottom releases, surface shading, cooling systems) to the extent that this poses an issue during planning and design.

Our findings suggest that direct stream and spring diversions may have a significant impact on summer streamflow conditions at least over short periods when diversions are active; however, the cumulative effects of groundwater pumping in the watershed were relatively small. While we did find some relationship between the degree of streamflow depletion and the screen depth and distance of wells from streams/springs, these differences were modest with a rate of depletion from near stream wells screened in the upper 200-ft about 1.7 times the rate from more distant wells screened at depths greater than 200-ft. We did not find any direct relationship between the timing of pumping and the timing of streamflow depletion with the primary effects of summer pumping manifesting largely as changes in water balance dynamics during the recharge season (see Figure 83). These findings suggest that replacing direct stream and spring diversions with storage and/or groundwater pumping is a viable approach for enhancing streamflow conditions but that offsetting groundwater pumping with storage or shifting the timing of pumping from summer to winter is unlikely to lead to appreciable improvements in flow conditions. Of the six general strategies considered, replacement of direct diversions is the second most-effective strategy after pond releases, whereas offsetting groundwater pumping was found to be the least effective strategy (see Figure 100).

Requiring new wells to be screened a set distance from a stream or spring or below a certain depth may extend the length of time before streamflow depletion occurs, but it will not prevent streamflow depletion from occurring. The long response timescale (decades) suggests that a volumetric approach to managing groundwater will likely lead to more successfully managing streamflow depletion compared to approaches focused on location or time of use. It is important to note that the total pumping stress in the watershed is relatively small (~3% of mean annual infiltration recharge) and that the limited degree of streamflow depletion under existing conditions should not be understood to suggest that significant streamflow depletion would not occur were the total volume of pumping to increase substantially in the future.

On a cost-normalized basis, grassland, forest, and runoff management all produced relatively small streamflow benefits with grassland and forest management being approximately 3-4 times as effective as runoff management (see Figure 100). These strategies also have important secondary hydrologic benefits in addition to enhancing streamflows in that they reduce seasonal vegetation moisture stress which may reduce fire risk. Specifically, forest management reduces actual evapotranspiration on treated lands by about 5% and runoff management decrease Climatic Water Deficits (CWD) in infiltration areas by about 25%; grassland management only resulted in a small decrease in CWD of about 1%. These benefits are in addition to the primary non-hydrologic benefits of these types of projects for reducing fuel loads (forest management) and sequestering carbon (grassland management). There are also potential negative consequences of extensive forest management in terms of potential habitat loss for avian and terrestrial species which must be considered, and the forest treatments would only be effective in the long-term if periodically repeated to maintain the intended reduction in fuel load.

We recommend that a planning study be conducted for the upper watershed to identify parcels most suitable for grassland, forest, and runoff management projects and that these projects be implemented where feasible. Given that the streamflow benefits of these strategies are more than an order of magnitude less than those of diversion replacement and more than two orders of magnitude less than those of pond releases, the various types of management projects are considered a lower priority than pond release or diversion replacement projects. That said, the long-term maintenance of streamflow under future climate conditions may require all of the flow enhancement strategies to be implemented and it is important to gain near-term experience with these management strategies and to attempt to monitor their effectiveness.

The optimal design and effectiveness of runoff management projects is highly site specific and it is recommended that projects be focused on parcels with significant impervious area that are currently well-connected to surface water features, have relatively high soil infiltration rates, and sufficient space and site conditions to allow for larger-scale infiltration features. Gravel-filled infiltration basins may be required in some cases to prevent ponding of stagnant waters for more than 72-hrs per Sonoma County vector control requirements. Native soil basins will likely work in some situations, and where space is limited basins can be combined or replaced with bioswales and/or features designed to distribute water evenly across the landscape.

In summary while runoff, forest, and grassland management may not result directly in substantial streamflow improvement, these efforts have multiple benefits and are likely important strategies for managing fire risk and mitigating climate change impacts as discussed in more detail below.

Climate Change Adaptation

Climate change is expected to result in a dramatic decrease in springtime flows particularly during drought conditions. Summer baseflows are also predicted to decrease in some simulations, however the future trajectory of summer flows is less certain with some scenarios predicting limited changes or modest increases. The decline in flows during spring is expected to have significant effects on salmonids particularly with respect to smolt outmigration with some of the climate scenarios predicting that in some years flows will fall below passage thresholds nearly continuously from mid-February through October. The only feasible means to at least partially mitigate this dire threat to salmonids appears to be the implementation of springtime pond releases. While it may not be possible to significantly improve conditions throughout the smolt outmigration period, relatively high release rates could be achieved for a period of several days to weeks to provide a period of passable flow conditions timed to coincide with expected peak smolt outmigration (see Figure 98). We recommend that flow release projects be developed and adaptively managed to provide a combination of larger pulses of streamflow during outmigration and enhanced streamflow during summer baseflow depending on conditions in a given year.

The runoff, forest, and grassland management strategies influence the quantity of streamflow from springs which in general is relatively cold, therefore these approaches may be expected to assist in mitigating elevated water temperatures whereas the more effective strategies (pond releases and diversion replacement) would not be expected to provide temperature benefits (see Figure 88). These strategies also help reduce vegetation moisture stress by increasing the quantity of water available to plants in the case of runoff and grassland management or decreasing water demand from the landscape for the case of forest management. This reduced moisture stress may be an important benefit for wildfire hazard reduction and the increase in wildfire hazard expected as a result of climate change.

In summary, implementation of runoff, forest, and grassland management projects are expected to help build resiliency to climate change by providing multiple benefits beyond potential streamflow improvement and spring and summer pond releases provide a means of adaptively managing flow conditions for salmonids in the face of a changing climate.

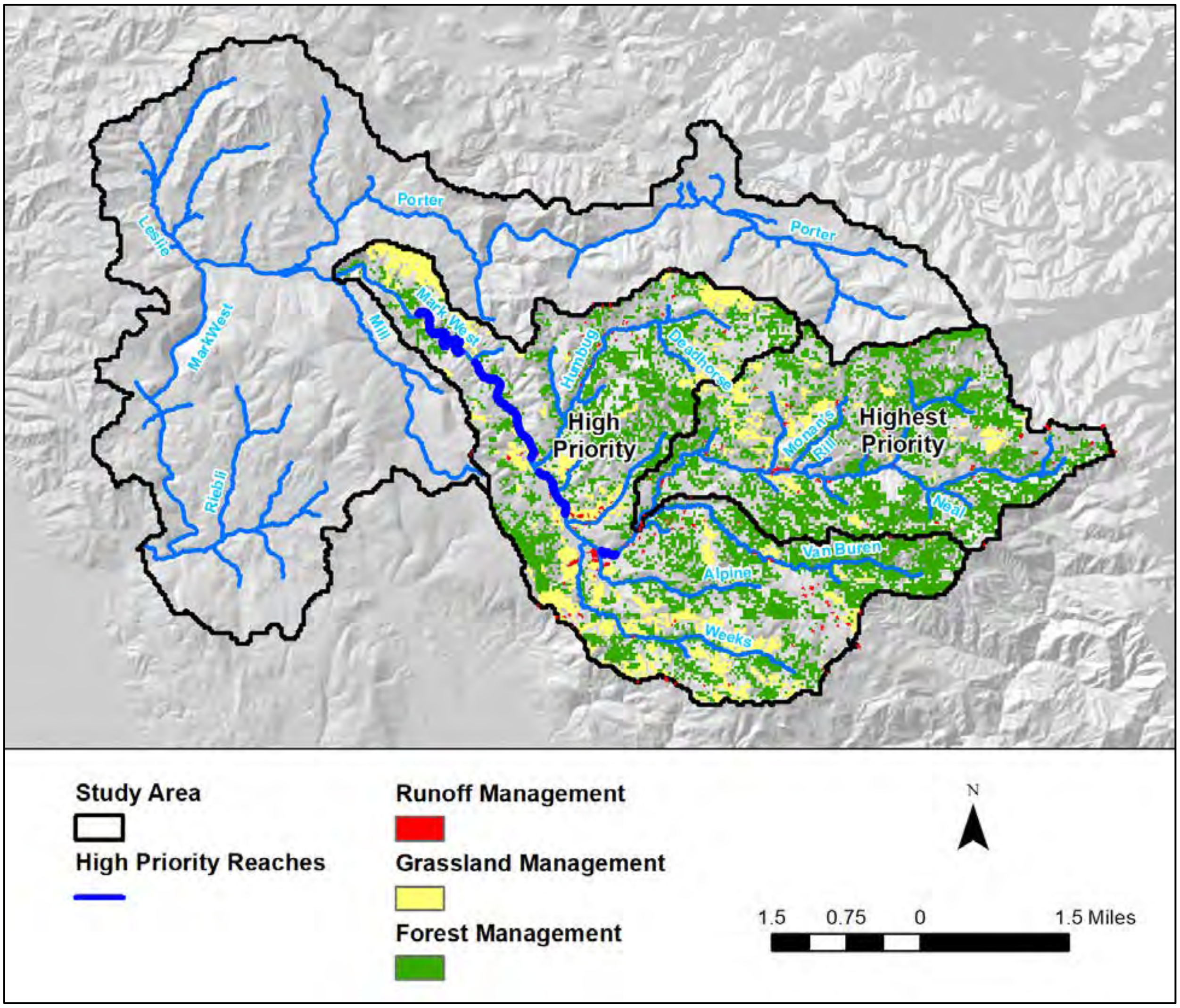


Figure 102: Locations of the identified high priority reaches for habitat enhancement projects and high priority watershed areas for flow enhancement projects.

Chapter 10 – Conceptual Design Development

The final phase of the project involved development of conceptual designs for two site specific streamflow enhancement projects. The projects focus on the approach of runoff management and were selected to take advantage of local site conditions and project opportunities on properties managed by our project partners the Pepperwood Foundation and Sonoma County Regional Parks. The projects illustrate two possible approaches to managing runoff for enhanced groundwater recharge and we anticipate similar approaches as well as other alternative methods could be applied on parcels throughout the watershed.

Goodman Meadow

Site 1 is located within the Pepperwood Preserve at the Goodman Meadow near the headwaters of Leslie Creek in the northwest corner of the watershed (Figure 103). The Goodman Meadow site consists of a relatively flat, approximately 12-acre natural basin perched on a topographic

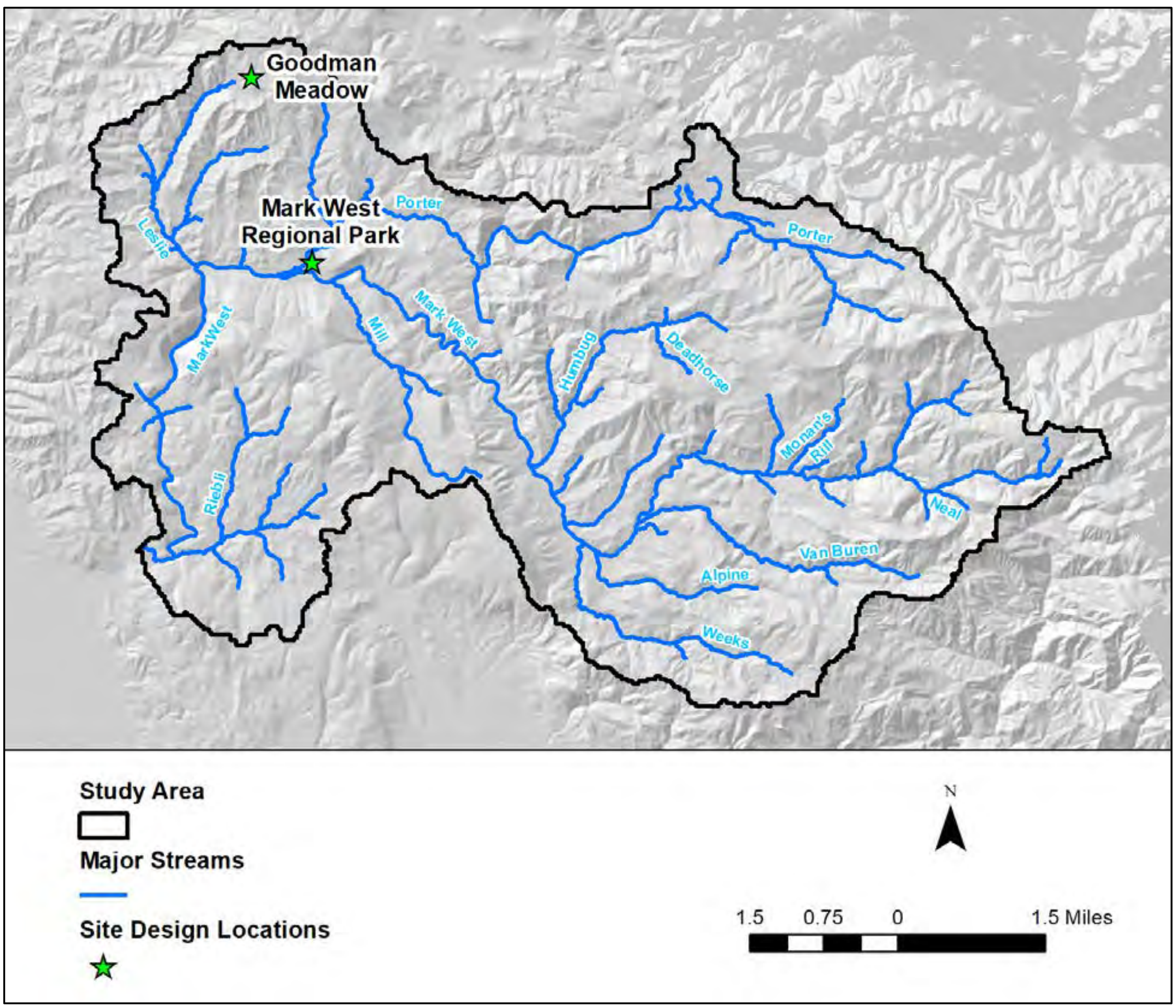


Figure 103: Locations of the two streamflow enhancement sites where conceptual designs have been developed.

bench and drained by an incised channel cutting through its western margin (see Appendix A, profile A to A'). The design consists of constructing a berm across the narrow valley at the basin outlet to retain winter runoff within the meadow and promote enhanced groundwater recharge. A channel exits the basin flowing southwest through a relatively narrow valley (approximately 60-ft wide at the base of adjacent slopes, see Appendix A section B to B') creating an optimal site for a berm or small dam. Approximately 94 acres of watershed area drain to the proposed berm site. The contributing area consists of mostly oak woodland and is not developed outside of an unpaved ranch road which traverses the hillside at the upper end of the meadow.

The basin outlet elevation will control the volume of water captured and stored within the basin. Various types of outlet structures are possible and for this conceptual design we assumed a 50-ft wide broad-crested weir with Low (1,128.0-ft) and High (1,132.5-ft) outlet elevation options (Appendix A). The Low elevation option would create an impoundment area of approximately 0.5 acres capable of storing approximately 1.1 ac-ft of water. Assuming 2-ft of freeboard above the outlet elevation, the Low elevation option would require a berm with an average height at the outlet of 4 feet above the meadow plain and a height of about 7-ft at the outlet above the incised channel bed. Based on existing LiDAR elevation data collected in 2013 (WSI, 2016), an ~98-ft long berm would be required. Assuming a 2H:1V berm side slope and a 4-ft berm top width, this would require approximately 274 yd^3 of fill (Appendix A). The High elevation option would create an impoundment area of approximately 1.4 acres and approximately 5.3 ac-ft of storage. The required berm would have an average outlet height of 8.5-ft above the meadow plain and a height of 11.5-ft at the outlet above the incised channel bed. Based on existing LiDAR elevation data, an ~132-ft long berm would be required. Assuming a 2H:1V berm side slope and a 4-ft berm top width, this would require approximately 692 yd^3 of fill (Appendix A).

A flow release structure should also be included near the base of the outlet to allow for drainage of retained water for maintenance purposes and/or for seasonal drainage if desired. An appropriate release schedule would be guided by Pepperwood Preserve's overall management strategy for the meadow and include consideration of the effects of the changed hydroperiod on grassland communities. These details would be further investigated and determined during subsequent design phases.

To evaluate the anticipated recharge and streamflow enhancement benefits associated with construction of the Goodman Meadow project, we implemented the conceptual design (using the higher of the two outlet elevations) as a scenario in the hydrologic model. The model represents the basin using a stage-storage relationship and calculates daily water levels as a function of simulated inflows from runoff and groundwater and simulated outflows across a broad-crested weir outlet structure and from evaporation and infiltration recharge.

The storage volume of the basin is relatively small compared to the available runoff and it fills to capacity during the first significant rainfall event of each year (typically in November or December). The basin remains near capacity throughout the rainy season with water levels typically beginning to decline in May or early June (Figure 104). Water levels typically reach a minimum in October by which point the upper portions of the basin are dry with 4-6-ft of water

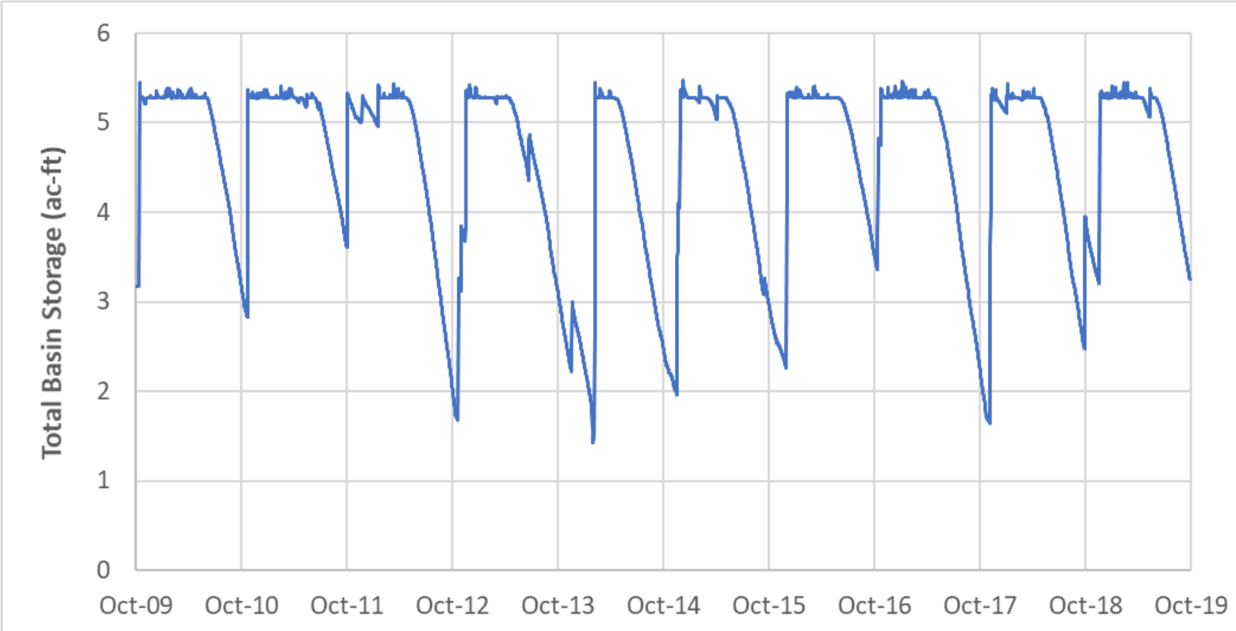


Figure 104: Daily fluctuations in storage in the Goodman Meadow recharge basin over the 10-yr hydrologic model simulation period.

remaining in the lower portions of the basin. The seasonal drawdown is dependent primarily on the duration of the dry season with minimum storage levels ranging from 1.4 to 3.6 ac-ft (26-68% of total capacity) (Figure 104).

Under existing conditions, mean annual infiltration recharge in the basin footprint was ~3.6 in/yr, and under proposed conditions this rate increases to ~18.7 in/yr. The total volume of additional recharge provided by the project is estimated to be about 1.9 ac-ft/yr. This additional recharge generates a modest increase in streamflow downstream in Leslie Creek. The upper reaches of the creek are intermittent and typically dry out sometime between late April and late June. The recharge enhancement serves to extend the length of time that the stream remains flowing each spring by between 12 and 21 days and the 10-yr mean streamflow over the April through June timeframe increases by about 0.01 cfs, representing about a 7% increase in flow.

Mark West Regional Park

Site 2 is located on a terrace on the east bank of Porter Creek just upstream of its confluence with Mark West Creek (Figure 103). The site is slated to be developed as the main entrance and parking area for the newly formed Mark West Regional Park operated by Sonoma County Regional Parks. Park facilities have not yet been designed in detail but are expected to be contained within approximately 3.1 acres currently occupied by a barn structure and an adjacent parking area and gravel road (Appendix B). The stormwater management design described here could become a part of the overall design for the park facilities and consists of collecting runoff from the developed portions of the park entrance in a network of diversion ditches and directing these flows into a series of two linear, gravel filled infiltration basins designed to maximize groundwater recharge. These basins are also expected to provide ancillary benefits by reducing peak runoff and providing filtration of pollutants from the parking area.

The basin alignment corresponds to an existing ditch that runs along the base of the slope southeast of the barn and parking lot. The upper basin is approximately 130-ft in length and runs adjacent to the existing parking area maintaining the existing slope of 0.6%. The lower basin runs approximately 490-ft behind the existing barn and maintains the existing slope of 0.2%. The two basins are separated by a road crossing where a 2.5-ft diameter, 150-ft long culvert is proposed to transport flows (Appendix B).

In addition to runoff collected from the developed footprint, the basins and associated channel will also receive flows from the adjacent hillslope which encompasses approximately 15.4 acres. The main intent of this infiltration basin design is to detain runoff from the developed areas associated with the new Mark West Regional Park entrance facilities and as such the basin has been sized to provide storage for a volume associated with a representative design storm for that area. Typically, infiltration basins are not recommended to receive runoff from drainage areas greater than 2 acres of undeveloped area due to concerns of sediment clogging which, over time could lead to a reduction in basin storage and groundwater recharge potential. Preliminary field observations suggest that runoff from the hillslope likely occurs primarily as sheetflow rather than as concentrated flow which suggests that sediment delivery to the basin may be minimal. Nevertheless, subsequent design work should include measures to minimize concentrated flow and sediment delivery to the basin from the adjacent undeveloped area such as a vegetation buffer with erosion control features along the base of the hillslope parallel to and up-gradient of the basin.

Channel dimensions were based on capacity calculations associated with the 100-yr recurrence interval storm runoff from the combined areas of the developed park and the 15.4-acre hillside. A simple Rational Runoff model for this area estimated 100-yr peak flows from the 3.1 acres of park facility and the adjacent 15.4-acre undeveloped watershed to be approximately 28 cfs. The channel and culvert sizes needed to accommodate this peak discharge were determined using standard open-channel and culvert hydraulic calculations and representative cross sections. The design channel is 2-ft deep, has a bottom width of 5-ft, and has side slopes blending into the existing topography with maximum slopes of 2:1 (Appendix B). A 2.5-ft diameter circular culvert with a slope of 2% connecting the two basins is required to convey the 100-year event (Appendix B).

This design is preliminary and further work by Sonoma County Regional Parks would be necessary to confirm feasibility of this approach. Topographic surveys, soil analysis, and infiltration testing will be necessary to generate construction ready design plans and provide infiltration performance estimates. Typical stormwater retention designs are required to eliminate ponded surface water within 72 hours to prevent mosquitos from breeding; however, this is largely mitigated by the gravel-filled basin design. We did not explicitly simulate this design in the hydrologic model because the scale of the design features is too small to accurately resolve using the 0.5-acre regional model grid. Nevertheless, results from the Runoff Management scenario described in Chapter 8 provide some context regarding the groundwater recharge enhancement and associated streamflow benefits expected from the project.

The regional scenario indicated that management of runoff from 98 acres in the Porter Creek watershed would generate approximately 73.4 ac-ft of additional infiltration recharge. The project design includes a storage volume equivalent to about 1.7% of the storage volume assumed in the regional scenario but only about 0.4% of the surface area. There are many additional factors that may increase or decrease the effectiveness of the design relative to the assumptions of the regional scenario. Nevertheless, these proportions serve as a general guide for estimating the recharge benefits of the proposed project and yield a range of expected additional recharge above background rates of between 0.3 and 1.2-ac-ft/yr.

The reach of Porter Creek adjacent to and downstream of the project site typically goes dry sometime between late May and late July depending on rainfall conditions. The regional modeling indicated that large-scale management of runoff in the Porter Creek watershed could extend the duration of streamflow adjacent to the project reach by 5 to 13 days and increase the mean April through June streamflow by about 0.05 cfs. As discussed above, the project would likely result in less than 2% of the recharge enhancement represented by the regional scenario suggesting that the streamflow benefits of the project by itself would be unlikely to significantly improve flow conditions in lower Porter Creek; though the project's proximity to the intermittent reach of Porter Creek suggests that it may provide greater streamflow benefits than projects located in upstream areas.

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EXHIBIT 6

UNITED STATES DEPARTMENT OF COMMERCE
National Oceanic and Atmospheric Administration
NATIONAL MARINE FISHERIES SERVICE
West Coast Region
777 Sonoma Avenue, Room 325
Santa Rosa, California 95404-4731

February 26, 2021

Tennis Wick, Director
County of Sonoma
Permit and Resource Management Department
2550 Ventura Avenue
Santa Rosa, California 95403

Dear Mr. Wick:

This letter communicates NOAA's National Marine Fisheries Service's (NMFS) concerns regarding the proposed Mitigated Negative Declaration (MND) addressing the Sonoma County Cannabis Land Use Ordinance Update and General Plan Amendment (Update) for cannabis cultivation in Sonoma County, California. NMFS is responsible for conserving threatened and endangered marine species under the federal Endangered Species Act (ESA), and ESA-listed Central California Coast (CCC) coho salmon (*Oncorhynchus kisutch*), CCC steelhead (*O. mykiss*), and California Coastal Chinook salmon (*O. tshawytscha*) reside within many rivers and streams throughout the County. Our concerns stem from the proposed requirements for cultivators using groundwater as their water source, and how these requirements will likely be inadequate in preventing impacts to ESA-listed salmonids and their habitat.

Surface water and underlying groundwater are likely hydraulically linked throughout much of Sonoma County, and this linkage is critically important in creating seasonal habitat for juvenile salmonids. Where the groundwater aquifer supplements streamflow, the influx of cold, clean water is critically important for maintaining temperature and flow volume during summer months. Pumping from these aquifer-stream complexes can adversely affect instream habitat by lowering groundwater levels and interrupting the hyporheic flow between the aquifer and stream.

Groundwater is the predominant source of water for cannabis cultivation operations within Sonoma County. State Water Board regulations concerning surface water diversions for cannabis cultivation contain required best management practices (BMP's) highly protective of instream flow volume and fish habitat, such as requiring summer forbearance, winter diversions, and fish friendly bypass flows. However, similar BMP's are not required by the State Water Board for cultivation sites utilizing groundwater wells as a source for cannabis cultivation. Because of this discrepancy under state law, the vast majority of cannabis cultivation applications throughout the County are opting for groundwater wells as their water source. We are concerned in particular, that wells are being drilled and pumped without appropriate analysis regarding their potential impact to surface water, especially near-stream wells that may also impact groundwater/surface water dynamics and result in streamflow depletion. With those concerns in mind, we offer the following comments.

<u>Re Page 70, Section 10(b)</u>: The MND states the following: *Future cannabis facilities in rural areas would rely on either surface (rivers, lakes, and springs) or well water sources. Accordingly, the introduction of cannabis cultivation in these areas could increase the use of groundwater.* As explained above, very few rural cultivation sites are currently using surface water

diversions as a water source, likely to work around the required BMP's mandated by the State Water Board for surface water diversions. NMFS is concerned about both surface water and groundwater diversions, as they are linked, and we believe the potential for impacts from unrestricted groundwater use is high.

<u>Re Page 71, Section 10(b)(4)(b)</u>: This section addresses near-stream wells (e.g., "well is within 500 feet of blue line stream"), and is intended to minimize streamflow depletion impacts. According to the MND, if a well is within 500 feet of a blue line stream, the applicant must document one of three things: 1) prepare a "net zero water plan", 2) document the well is near the Russian River or Dry Creek, or 3) document the well is within the Groundwater Availability Zone 1 or 2. By including the third option, the authors of the MND seem to assume that streamflow depletion impacts are unlikely in Groundwater Availability Zones 1 and 2. However, streamflow depletion can occur within any of the groundwater zones in Sonoma County, and is largely influenced by well distance from the waterway, the pumping intensity, and the transmissivity of the underlying geology, not groundwater availability zones. Thus, the current standards and requirements appear unlikely to adequately mitigate the potential impact of streamflow depletion, making a MND inappropriate. NMFS recommends the Update require either a net zero water plan, or a hydrogeologic analysis confirming streamflow depletion impacts are unlikely, before any cannabis operation utilizing a near-stream well is approved, regardless of which Groundwater Availability zone it may occur in.

Furthermore, while we understand that the current Update applies only to cannabis cultivation, NMFS recommends the County also update their well ordinance and permitting procedures to apply this requirement (i.e., require a net zero water plan, or a hydrogeologic analysis confirming streamflow depletion impacts are unlikely) to all permit applications for near-stream wells.

NMFS appreciates the opportunity to comment regarding the proposed Mitigated Negative Declaration addressing the Sonoma County Cannabis Land Use Ordinance Update and General Plan Amendment for cannabis cultivation If you have any comments or questions regarding this letter, please contact Mr. Rick Rogers at rick.rogers@noaa.gov, or 707-578-8552.

Sincerely,

Robert Coey
North Coast Branch Supervisor
North-Central Coast Office

cc: (via email)
Bryan McFadin, North Coast Regional Water Quality Control Board
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EXHIBIT 7

How climate change is fueling record-breaking California wildfires, heat and smog

By Susanne Rust, Tony Barboza

In 2001, a team of international scientists projected that during the next 100 years, the planet's inhabitants would witness higher maximum temperatures, more hot days and heat waves, an increase in the risk of forest fires and "substantially degraded air quality" in large metropolitan areas as a result of climate change.

In just the past month, nearly two decades after the third United Nations Intergovernmental Panel on Climate Change report was issued, heat records were busted across California, more than 3 million acres of land burned, and in major metropolitan areas, such as Los Angeles and San Francisco, air pollution has skyrocketed.

"This shouldn't come as a surprise to anyone," said Michael Gerrard, director of the Sabin Center for Climate Change Law at Columbia University. "Maybe we underestimated the magnitude and speed" at which these events would occur, he said, but "we've seen this long freight train barreling down on us for decades, and now the locomotive is on top of us, with no caboose in sight."

In a matter of weeks, California has experienced six of the 20 largest wildfires in modern history and toppled all-time temperature records from the desert to the coast. Millions are suffering from some of the worst air quality in years due to heat-triggered smog and fire smoke. A sooty plume has blanketed most of the West Coast, blotting out the sun and threatening people's lungs during a deadly pandemic.

California is being pushed to extremes. And the record heat, fires and pollution all have one thing in common: They were made worse by climate change. Their convergence is perhaps the strongest signal yet that the calamity climate scientists have warned of for years isn't far off in the future; it is here today and can no longer be ignored.

"What we've been seeing in California are some of the clearest events where we can say this is climate change — that climate change has clearly made this worse," said Zeke Hausfather, a climate scientist at the Breakthrough Institute, an Oakland-based think tank. "People who have lived in California for 30, 40 years are saying this is unprecedented, it has never been this hot, it has never been this smoky in all the years I've lived here."

Unprecedented, yes. But not unexpected.

Since the 1980s, government and oil industry scientists have been anticipating the events that have transpired across the state this past month.

As one 1988 internal Shell Oil Co. document noted, "by the time the global warming becomes detectable it could be too late to take effective countermeasures to reduce the effects or even to stabilize the situation."

"I'm only sorry that in 1989, I could not get an audience for what I wanted to communicate," said Jim Hansen, a retired NASA researcher and early climate change scientist, of testimony he made to Congress about the issue.

Record temperatures

Each of the extremes Californians are living through right now is fueled, at least in part, by the gradual warming of the planet, which is accelerating as greenhouse gas emissions continue to rise.

California summers are 2.5 degrees warmer than they were in the 1970s and are on track to heat up an additional 4.5 degrees by the end of the century if the world's current emissions trajectory continues, said Hausfather.

While precise attribution studies on the extreme heat waves in California in recent weeks will take time to complete, he said, they are clear examples of how climate change compounds natural weather variability to increase the likelihood of what once would have been a rare event.

"In a world without climate change, it still would have been a hot August; we still would have had some fires. But it's clear that climate change has made things notably worse," he said. "An extreme heat event that would have been 100 degrees is now 102.5 or 103 degrees, and that is actually a pretty big difference in terms of the impacts on people."

During the mid-August heat wave, Death Valley soared to 130 degrees, one of the hottest temperatures ever recorded on Earth.

Another ferocious heat wave over the Labor Day weekend brought Death Valley-like heat to other areas. Los Angeles County had its hottest temperature on record when Woodland Hills hit 121 degrees Sept. 6. At Cal Poly San Luis Obispo, it reached 120 degrees, the highest reading since record-keeping began in 1869, in an area that is less than 10 miles from the Pacific Ocean.

John Lindsey, a marine meteorologist with Pacific Gas and Electric, said the mercury rose to unprecedented levels in San Luis Obispo due to hot, downslope winds blowing from the northeast. They are known locally as Santa Lucia winds and can increase temperatures by 5.5 degrees for every 1,000 feet they descend.

"It was just rip-roaring hot," said Lindsey, who has forecast weather along the Central Coast since 1991. "You just don't expect Death Valley temperatures along coastal California."

Lindsey, who acknowledges that he was a bit of a climate skeptic in the past, said seeing the increase in seawater temperatures, in particular, over many years "was a real epiphany or wake-up call."

"By now, there's no doubt in most people's minds that the atmosphere is warming and the ocean is warming," he said. "With the way greenhouse gases are increasing, in my mind, there's no doubt that we're causing this. It's human activity that's causing this. So I'm concerned about the future. And that's somebody who's very skeptical."

Global warming has increased the odds of unprecedented heat extremes across more than 80% of the planet and "has doubled or even, in some areas, tripled the odds of record-setting hot events" in California and the Western U.S., said Stanford University climate scientist Noah Diffenbaugh.

An unprecedented firestorm

When it comes to wildfires, "what we've had in California over the last three to four weeks is unprecedented in our historical experience," Diffenbaugh said.

"This is more extreme than any other year in living memory," he said, and is consistent with the impact of global warming.

Research by Diffenbaugh and colleagues that was published last month found that the number of days with extreme wildfire weather in California has more than doubled since the early 1980s, primarily due to warming temperatures drying out vegetation.

"It means that even with no change in the frequency of strong wind events, even with no change in the frequency of lightning, the risk of wildfire and risk of large, rapidly growing wildfires goes up as a result of the effect of that warming," he said.

And it's that atmospheric warming that has set the stage for the fires raging throughout the western U.S., said Park Williams, a hydroclimatologist at Columbia University's Lamont-Doherty Earth Observatory.

"If we think of the atmosphere as a giant sponge that's always trying to extract water from the landscape, then temperature increases the sponginess," he said.

As soils become drier, heat waves become more intense. That's because the energy in the atmosphere is no longer being used in evaporation but is just building up heat. And as heat increases and soils — and, therefore, fuel for fires — dry out, the risk grows, laying the foundation for the type of wild and destructive fires we are now observing.

"That's why, I think, you keep reading quotes from these firefighters who say they are seeing fire behavior unlike anything they've seen before," he said. "As we go out in the future, in a world with this exponentially growing risk ... we're going to see fires far different than we've seen before."

He noted that fires are not unusual in California — they are an integral part of the state's history and landscape. Bad forest management, combined with human behavior — intentional and unintentional starting of fires — have contributed to the problem. But the effect of climate change is real and growing.

"We have seen the rapid warming of California summers really turbocharge the type of conditions that are suitable for rapid growth of wildfires," Hausfather said. "We see fires growing from essentially nothing to a quarter of a million acres in one day. And that's because the conditions are ripe, and temperature plays a large role."

John Abatzoglou, associate professor in the Department of Management of

Complex Systems at UC Merced, agreed.

“What we are seeing play out does indeed have human fingerprints on it, including those from climate change,” he said.

“We can see how warm and dry years catalyze these fires,” he said, adding, however, that for fires to start, “they need to have ignitions. But the heat and dryness have absolutely set the table for widespread fire activity.”

Dreadful air quality

It was no coincidence that ozone pollution levels in downtown Los Angeles spiked to their highest levels since the mid-1990s on a day in which temperatures reached an all-time high for the county, said Cesunica Ivey, an assistant professor of chemical and environmental engineering at UC Riverside who studies air quality.

The global rise in temperatures observed over decades is also occurring locally, she said, “and these frequently occurring heat waves, this upward trend in basin-wide average temperature, is contributing to ozone exacerbation.”

Southern California regulators have seen decades of progress fighting smog stymied in recent years by hotter weather and stronger, more persistent inversion layers that trap pollution near the ground. Their efforts are being hindered by rising temperatures from climate change, according to air quality experts.

That’s because hotter weather speeds up the photochemical reactions that turn pollutants from vehicle tailpipes and other sources into ozone, the invisible, lung-damaging gas in summer smog. Studies show that ozone levels are about two parts per billion higher than they would be without global warming.

What precisely is driving changes such as elevated smog levels can be hard to tease out in the middle of an extreme event because so much is happening at once, with multiple hazards piling on top of each other in a vicious feedback loop.

The recent heat spells, for instance, both fueled smog formation and led to power outages. Gov. Gavin Newsom suspended air quality rules on power plants and other polluters to ease strain on the grid, allowing more emissions to sully the air. The COVID-19 pandemic has added an additional layer of complexity at a time when Californians are trying to protect their homes, lungs and bodies from threats that seem to be coming from all sides.

“When you add COVID, extreme heat, wildfires and air pollution all together, they’re all detrimental to public health, and it just makes things worse,” said Yifang Zhu, a professor of environmental health sciences at UCLA Fielding School of Public Health who studies air pollution and its effects. “These stressors are happening at the same time. So the impact is cumulative and maybe even synergistic to each other.”

That cascading effect, in which one extreme compounds another, is a feature of global warming that experts have long warned about.

Ivey, of UC Riverside, said she and other scientists aren’t surprised to see so many extremes hitting simultaneously, “but to see it playing out is scary.”

“It’s one of those moments where ozone converged with record acres burned and a heat wave,” she said. “If the writing isn’t on the wall, then I don’t know what to tell folks.”

Global warming is also fueling increases in wildfire pollution, a mix of soot particles and gases that can fuel ozone formation and dramatically worsen smog. Those added emissions are only going to get worse as the severity and frequency of fires increases.

“People may not directly connect local air pollution to global climate change, but they are intertwined,” said Zhu. “They are two sides of the same coin.”

What this year’s extreme heat, fire and air quality degradation is showing, said Columbia’s Williams, is that we are, in a sense, blindly stepping off a cliff from a world in which we could somewhat predict what was going to happen, based on decades and centuries of data.

“We’re finding that we’ve lost complete control,” he said. “The baselines we’ve used for decades no longer apply. There really isn’t a normal anymore.”

EXHIBIT 8

E&E NEWS

CLIMATE

Fast-Moving California Wildfires Boosted by Climate Change

Nearly two dozen large blazes have burnt more than 1 million acres of the state

By Anne C. Mulkern, E&E News on August 24, 2020

Embers blow off a burned tree after the LNU Lightning Complex Fire burned through the area on August 18, 2020 in Napa, California. Credit: Justin Sullivan *Getty Images*

Firefighters battled nearly two dozen wildfires in California yesterday after a week of raging blazes blackened more than 1 million acres across the state.

The fast-moving fires, which are seen by many scientists as a sign of climate change, have killed five people, destroyed more than 1,000 structures and forced thousands to flee. More than 238,000 people either evacuated or were ready to go as more thunderstorms threatened to light new fires yesterday afternoon, according to officials.

Still-active fires are affecting at least 23 counties in Northern California, stretching from Butte to Fresno. Two of the blazes rank among the largest in state history.

The LNU Lightning Complex Fire, a group of fires centered in Napa and Sonoma counties, has grown into the second-largest blaze ever seen in California. The SCU Lightning Complex Fire, a cluster of blazes in Santa Clara, Alameda and nearby counties, is the third-largest.

Altogether, the fires have burned an area the size of Rhode Island.

"The scope [of the damage] is absolutely astonishing," said Daniel Swain, a climate scientist at UCLA. It's "hard to impress on people just how vast the acreage burned is, especially considering there were no strong offshore winds" to drive the spread.

President Trump on Saturday issued a major disaster declaration to fulfill a request by Gov. Gavin Newsom (D) to bolster the state's emergency resources. Meanwhile, the National Weather Service issued a red flag warning for more thunderstorms and lightning through today.

The racing flames show how climate change is affecting the nation's most populous state, experts said. Hotter temperatures, less dependable precipitation and snowpack that melts sooner lead to drier soil and parched vegetation. Climate change also affects how much moisture is in the air, Swain said.

"It's actually drying out the air during these extreme heat events," which zaps plants of additional moisture, Swain said. That left much of the state a tinderbox when hundreds of lightning strikes scorched the countryside last week.

"This is really a testament to how dry the vegetation is, in terms of how quickly these fires spread when they were ignited by lightning," he said.

The amount of land burned last week is more than the total burned in all of 2018, and more than double the amount burned in 2017, according to data released by the California Department of Forestry and Fire Protection (Cal Fire).

The fires on Saturday burned part of the oldest state park in California, Big Basin Redwoods State Park in Santa Cruz County. Flames damaged historic buildings, the campground and "all of the infrastructure," said Christine McMorrow, a spokeswoman with Cal Fire. It wasn't known whether redwood trees were engulfed.

The blazes threaten to outpace the state's ability to respond. Nearly all of Cal Fire's crews are in the field, with some working 72-hour shifts. Oregon, Washington, Nevada, New Mexico, Texas and other states sent firefighters, equipment or both. Officials said more than 13,000 fire personnel were on the scene.

"We have more people, but it's not enough," Newsom said at a Friday news conference. "We have more air support, but it's not enough."

REPEAT FIRE TRAUMA

Fires erupted beginning Aug. 15 when more than 1,200 lightning strikes hit the baking landscape within 72 hours.

Those came "the exact week that we were experiencing some of the hottest temperatures ever recorded in human history, 130-degree temperatures in the southern part of the state," Newsom said. It was "maybe the hottest modern recorded temperature in the history of the world," he said.

He was referring to the temperature of 130 degrees Fahrenheit on Aug. 16 in Death Valley, a high not reached on Earth in 89 years. The highest temperature ever recorded on the planet is 134 Fahrenheit. It was reached in 1913 in Death Valley. Its accuracy is disputed by some observers because there was a lack of modern technology (*Climatewire*, Aug. 18).

Altogether, more than 12,000 lightning strikes hit California last week, igniting over 600 fires. Firefighters knocked down smaller ones, but others merged into major "complex" fires.

The week was filled with horror stories and heroic efforts. Volunteers helped evacuate senior citizens from a Vacaville retirement home in the middle of the night as a fire raced toward the facility. Others helped rescue "dozens and dozens of individuals with intellectual disabilities" in Santa Clara, Newsom said.

Hundreds saw their homes destroyed.

"Tuesday night when I went to bed, I had a beautiful home on a beautiful ranch," Hank Hanson, 81, of Vacaville, told the Associated Press. "By Wednesday night, I have nothing but a bunch of ashes."

State Assemblywoman Cecilia Aguiar-Curry, who represents the Napa wine region, said at a news conference Friday that she has "half a dozen really good friends who don't have a home right now."

The American Red Cross, wary of the coronavirus pandemic, put some survivors in hotel rooms so they could be separated from other evacuees, said Jim Burns, a Red Cross spokesman. Others went to evacuation shelters where protocols were in place to keep people spaced out. The Red Cross was also talking to colleges to see whether dorm rooms were available.

The fires swept across heavily populated cities that have endured major fires in recent years. Susan Gorin, a Sonoma County supervisor, lost her home in the 2017 Tubbs Fire, a blaze that killed 22 people. She built a new house in the same location; on Friday, she found ashes on her patio from a nearby firestorm.

"It just seems so terrifyingly familiar," Gorin said as she traveled to Lake Tahoe to escape the smoke and mayhem. "This is now the third major fire in four years. We are battle-weary."

CLIMATE CONNECTION SCRUTINIZED

Swain with UCLA and other scientists earlier this year published a study that said climate change has doubled the number of extreme-risk days for California wildfires.

It said temperatures statewide rose 1.8 degrees Fahrenheit since 1980, while precipitation dropped 30%. That doubled the number of autumn days that offer extreme conditions for the ignition of wildfires (*Climatewire*, April 3).

The heat is expected to get worse with time. Climate models estimate that average state temperatures will climb 3 degrees Fahrenheit by 2050 unless the world makes sharp cuts in greenhouse gas emissions, said Michael Wehner, a senior scientist at Lawrence Berkeley National Laboratory.

Even with emissions cuts, average temperatures would rise 2 degrees by midcentury, he said.

Jon Keeley, a senior scientist at the U.S. Geological Survey Western Ecological Research Center, argued that the study from Swain and others failed to show that hotter temperatures are driving wildfires.

"Show us data that shows that level of temperature increase is actually associated with increased fire activity," Keeley said. "They don't show that."

Keeley added, "We ought to be much more concerned with ignition sources than a 1- to 2-degree change in temperature."

A big contributor to large California fires is that the state has focused on extinguishing blazes for about a century rather than allowing for controlled burns, he said. That has caused dead vegetation to accumulate.

Trump has accused California of failing to "sweep" its forests, which he has linked to fires in the state.

Keeley said that "we don't sweep forests here in the U.S., but what we do is prescription burning. ... It's potentially the same thing. It's modifying the fuels prior to a fire."

Swain, the UCLA climate scientist, said global warming is affecting how big fires get and how fast they move.

"What happens when they start burning, what is the character of those fires, and is it changing?" Swain asked. "The answer is yes."

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ABOUT THE AUTHOR(S)

Anne C. Mulkern

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EXHIBIT 9

Esri, USGS

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2020 Incident Archive

A summary of all 2020 incidents, including those managed by CAL FIRE and other partner agencies.

4,257,863 Acres
Estimated Acres Burned

9,917 Incidents
Number of Incidents

33 Fatalities
Confirmed Loss of Life

10,488 Structures
Structures Damaged or Destroyed

2020 Incidents

Name	Start Date	Counties	Acres	Containment
Sanderson Fire	12/12/2020	Riverside	1,933	100%
Cornell Fire	12/7/2020	Ventura	174	100%
Thomas Fire	12/3/2020	Lassen	24	100%
Cerritos Fire	12/2/2020	Riverside	200	100%
Bond Fire	12/2/2020	Orange	6,686	100%
Willow Fire	12/2/2020	San Diego		
Airport Fire	12/1/2020	Riverside	1,087	100%
257 Fire	11/17/2020		49	100%
San Dimas Fire	11/5/2020	Los Angeles	131	100%
Cypress Fire	11/1/2020	Riverside and San Bernardino	150	100%

2020 Fire Season

The 2020 California wildfire season was characterized by a record-setting year of wildfires that burned across the state of California as measured during the modern era of wildfire management and record keeping. As of the end of the year, nearly 10,000 fires had burned over 4.2 million acres, more than 4% of the state's roughly 100 million acres of land, making 2020 the largest wildfire season recorded in California's modern history. California's August Complex fire has been described as the first "gigafire" as the area burned exceeded 1 million acres. The fire crossed seven counties and has been described as being larger than the state of Rhode Island. On August 19, 2020, California Governor Gavin Newsom reported that the state was battling 367 known fires, many sparked by intense thunderstorms on August 16–17. In early September 2020, a combination of a record-breaking heat wave, and Diablo and Santa Ana winds sparked more fires and explosively grew the active fires, with the August Complex more than doubling the Mendocino Complex's size to become California's largest recorded wildfire.

Search our Incident Database

Search by Incident Name, Year, County or Keyword

Annual Fire Season Pages
ACTIVE | **2021** | **2020** | **2019** | **2018** | **2017** | **2016** | **2015** | **2014** | **2013**

EXHIBIT 10

2017 Sonoma Complex Fires

Share:

In October 2017, the Sonoma Complex Fires tore through our county, burning over 112,000 acres of land and destroying 5,300 homes. As our Sonoma County community continues to cope with the tragedy of losing homes, businesses, and loved ones, we remain inspired by those who continue to show immense bravery, compassion, and willingness to help others. The disastrous wildfires brought our community closer together, and that spirit of cooperation and closeness has been essential as we've begun the rebuilding and recovery process. Ag + Open Space has an integral role in the recovery of our entire community, with a specific focus on the restoration and ongoing protection of our county's natural and working lands.

Assessment of Our Protected Lands

Approximately 7,000 acres of Ag + Open Space-protected land were directly affected by the fires. In addition to reaching out to easement landowners who suffered damage to offer our support and share resources, Ag + Open Space staff conducted visits of Ag + Open Space-owned properties, including Saddle Mountain, Calabazas Creek, and Dogbane Preserves, and our Cresta and McCullough properties along Mark West Creek.

Read more here >>

Watershed Collaborative

Sonoma County Ag + Open Space took an active role in the county's post-fire watershed recovery and resiliency efforts. With direction from our Board, we convened the **Watershed Collaborative** – a countywide, multi-agency watershed recovery effort, with a focus on long-term resiliency of our natural and working lands. Together, this group developed a shared vision for short-term recovery and long-term strategies for watershed resiliency. High priority actions included health and human safety related to water quality, landslides, and flooding, as well as impacts to sensitive species and ecosystems.

Learn more here >>

Property Owner Resources

- Natural Resources Conservation Service post-fire assistance, publications, and resources – NRCS Post-Fire Assistance
- Sonoma Resource Conservation District post-fire assistance, publications, and resources – Sonoma RCD Post-Fire Assistance
- UC Cooperative Extension, Sonoma County Disaster Resources — UC Cooperative Extension
- USDA help for California Producers – California Producers Rebuild and Recover
- Farm Service Agency Disaster Assistance Programs – FSA Disaster Assistance Programs
- Official recovery page for Sonoma County and City of Santa Rosa – Sonoma County Recovers
- Access to Disaster Help and Resources – Disaster Assistance

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Post-fire cleanup of the Pelm House

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EXHIBIT 11

2019 Kincade Fire

News & Features

Recent Projects

2020 Wildfires

2019 Kincade Fire

Saddle Mountain OSP Management Plan

Healthy Lands & Healthy Economies

2017 Sonoma Complex Fires

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“Protected Forever” — Creating Ag + Open Space

Young-Armos Incubator Farm Project

Sonoma County Vegetation Mapping and LiDAR Program

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On October 23, 2019, the Kincade Fire ignited northeast of Geyserville, burning nearly 78,000 acres of land and destroying 174 homes. As with the fires of 2017, Ag + Open Space has an integral role to play in the recovery and long-term resiliency of our entire community, with a specific focus on the conservation and ongoing stewardship of our natural and working lands. In addition to providing local food, clean drinking water, increased biodiversity, and natural beauty, these protected lands also form an important buffer around our communities that can reduce the impacts of fires, floods, and other extreme events. The agency remains committed to managing its own lands to ensure ecosystem health and to reduce the risk and intensity of wildfires, and will work with easement landowners to support them in doing the same.

Assessment of Our Protected Lands

Approximately 14,000 acres of Ag + Open Space-protected land were directly affected by the fires — double the acreage of our protected land affected in the 2017 Sonoma Complex Fires. Five conservation easements located in the Mayacamas Mountains and on the outskirts of Healdsburg and Windsor burned completely, while portions of two additional conservation easements were impacted by the fire. In addition to reaching out to easement landowners to offer support and share resources, Ag + Open Space staff will soon be conducting visits to protected properties in the burned areas to assess damages.

Landowner Resources

We will be updating resources and new opportunities become available. Please feel free to reach out to us directly if you have any questions.

- Natural Resources Conservation Service post-fire assistance, publications, and resources – NRCS Post-Fire Assistance
- Sonoma Resource Conservation District post-fire assistance, publications, and resources – Sonoma RCD Post-Fire Assistance
- UC Cooperative Extension, Sonoma County Disaster Resources — UC Cooperative Extension
- Farm Service Agency Disaster Assistance Programs – FSA Disaster Assistance Programs
- Official recovery page for Sonoma County – SoCoEmergency.org

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EXHIBIT 12

2020 Wildfires

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2020 Wildfires

2019 Kincade Fire

Saddle Mountain OSP Management Plan

Healthy Lands & Healthy Economies

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Sonoma County Vegetation Mapping and LiDAR Program

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In summer and fall of 2020, several fires ignited in both west and east Sonoma County. From August through October, the Walbridge, Stewarts, Meyers, and Glass fires burned roughly 125,000 acres of land. Ag + Open Space has an integral role to play in the recovery and long-term resiliency of our entire community. The lands we protect provide local food, clean drinking water, increased biodiversity, as well as places of great natural beauty that provide solace every day. During wildfires, floods, and other extreme events, our working and natural lands provide additional support as buffers around our communities, as well as places where first responders can conduct critical firefighting operations. As always, we are committed to continuing to manage our lands to ensure ecosystem health that helps reduce the risk and intensity of wildfires, and we work with easement landowners to support them in doing the same.

Assessment of Our Protected Lands

Glass Fire

Approximately 5,300 acres of Ag + Open Space-protected land were directly affected by this fire. Saddle Mountain Open Space Preserve, our two additions to Hood Mountain Regional Parks and Open Space Preserve, Rancho Mark West, and the Auberge Ceanothus Preserve burned almost entirely. Several privately-owned properties are also almost entirely burned, if not completely.

For more about how the Glass Fire has impacted Saddle Mountain, **read more here >>**

Walbridge, Stewarts, and Meyers Fires

Approximately 1,600 acres of Ag + Open Space-protected land were directly affected by the fires. Two easement properties connected to the Austin Creek State Recreation Area burned completely, while one easement property near Armstrong Woods experienced fire over most of the property and another property further north experienced fire on about half of the property.

For a look into how the Walbridge fire affected Pryor Ranch, **read more here >>**

What we are doing

Ag + Open Space staff are reaching out to easement landowners to offer support and connect them to resources.

Building on a **multi-year collaboration with NASA**, we are assessing the effects on the landscape and Ag + Open Space protected properties, and have continued to monitor and manage the recovery of habitats and ecosystems since the 2017 Sonoma Complex Fires and the 2019 Kincade Fire.

In any emergency, Ag + Open Space employees often get reassigned to work in the County's Emergency Operations Center, evacuation centers, and local assistance centers, or perform other duties to support emergency response. During this fire, staff were dispatched to help with public information, GIS mapping, and evaluating fire-related impacts to the Russian River and coastal watersheds through the County's Watershed Task Force.

Landowner Resources

We will update resources and new opportunities as they become available. Please feel free to reach out to us directly if you have any questions.

- Natural Resources Conservation Service post-fire assistance, publications, and resources – **NRCS Post-Fire Assistance**
- Sonoma Resource Conservation District post-fire assistance, publications, and resources – **Sonoma RCD Post-Fire Assistance**
- UC Cooperative Extension, Sonoma County Disaster Resources — **UC Cooperative Extension**
- California Native Plant Society Fire Recovery Guide – **CNPS Fire Recovery Guide**
- Farm Service Agency Disaster Assistance Programs – **FSA Disaster Assistance Programs**
- Official recovery page for Sonoma County – **SoCoEmergency.org/recover**

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EXHIBIT 13

BUILT TO BURN

California's Wildlands Developments Are Playing With Fire

Center for Biological Diversity • February 2021

Satellite image of the 2018 Camp Fire near Paradise, California / NASA.

BUILT TO BURN:

California's Wildlands Developments Are Playing With Fire

Bold Land-use Reforms Needed Now to Ensure Safer, Sustainable Future

A report by the Center for Biological Diversity:
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Cover photo: Aftermath of the 2017 Tubbs Fire in the Coffey Park neighborhood of Santa Rosa, California / Bay Area Media Masters, CC-BY

Guenoc Valley area, where the 2020 LNU Complex Fire burned through / Drew Bird Photography

EXECUTIVE SUMMARY

Wildfires have occurred on California's landscapes for millennia. They're a natural and necessary process for many of California's ecosystems. But some of the recent fires have been exceptionally harmful to communities.

Since 2015 almost 200 people in the state have been killed in wildfires, more than 50,000 structures have burned down, hundreds of thousands have had to evacuate their homes and endure power outages, and millions have been exposed to unhealthy levels of smoke and air pollution. Meanwhile costs for fire suppression and damages have skyrocketed.

Policymakers must reckon with California's wildfire history and acknowledge that reckless land-use policies are increasing wildfire risk and putting more people in harm's way. Legislation that prioritizes the following proactive measures is needed immediately:

- Stop building new homes in highly fire-prone wildlands;
- Retrofit existing homes with high fire risk.

Where we place homes influences fire risk. Almost all contemporary wildfires in California, 95-97%, are caused by human sources such as power lines, car sparks and electrical equipment. Building new developments in highly fire-prone wildlands increases unintentional ignitions and places more people in danger.

Hotter, drier and windier conditions due to climate change make the landscape more conducive to wildfire ignitions and spread.

Most destruction to human communities from fire has been caused by wind-driven, human-ignited fires in highly fire-prone shrubland habitats. More than 2 million homes have high fire risk, and local governments continue to approve new construction in highly fire-prone wildlands. Such reckless sprawl development endangers all Californians.

Elected officials and planners need to consider the state's complex fire history and fire ecology to implement smarter land use that protects people and native biodiversity. Many of California's ecosystems have adaptations to survive and thrive with wildfires. But long-term fire resilience is varied depending on the habitat type and fire regime (i.e., the frequency, intensity, severity, spatial complexity and seasonality of fire over time). Changes to fire regimes threaten human communities as well as native habitats and wildlife.

Increased human ignitions due to sprawl development in highly fire-prone native shrublands are harmful to people and biodiversity. Native shrubland habitats, like chaparral and sage scrub, are adapted to high severity wildfires at relatively infrequent intervals ranging between 30 to 130 years or more. But increased fire frequency in these habitats is causing type conversion to non-native grasses and forbs that burn more easily throughout more of the year. This altered fire regime endangers human communities and the unique biodiversity those habitats support.

If California policymakers continue to expand development into highly fire-prone wildlands and dismiss the need for home hardening in high fire-risk areas, then more destructive fires will ignite and more structures will burn. More people will be killed by fires and have extended exposure to hazardous smoke. More firefighters and first responders will be put at risk. Some biodiversity and unique ecosystems will be lost. Fire suppression and recovery costs will continue to rise.

We must change these destructive land-use policies and prepare our communities to safely coexist with wildfire.

CALIFORNIANS FACING UNPRECEDENTED WILDFIRE IMPACTS

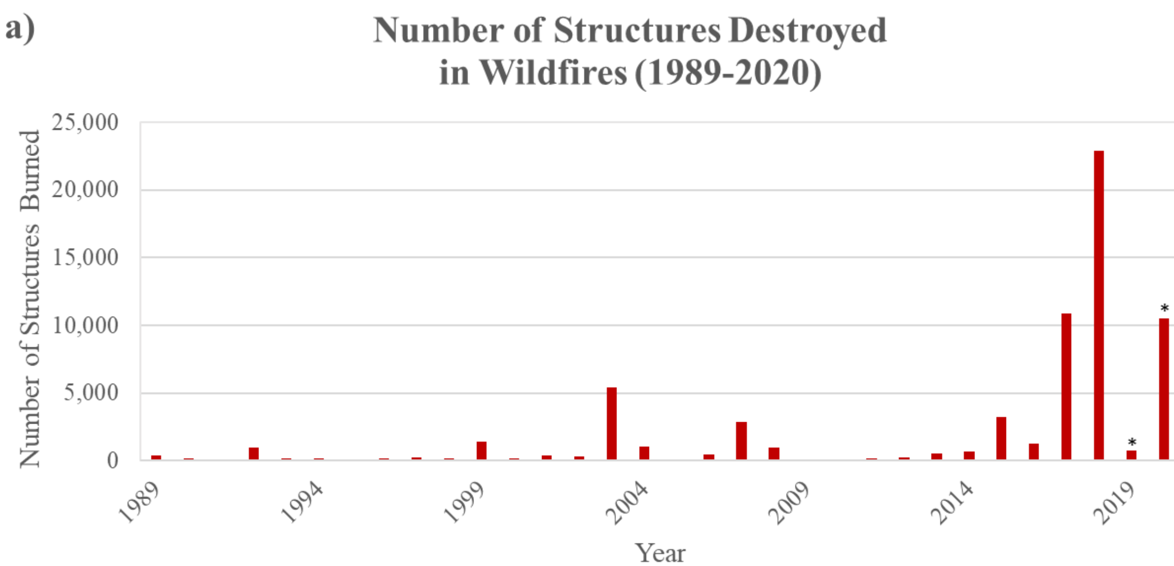
Wildfires have occurred on California's landscapes for millennia. Lightning strikes and indigenous burning drove fire regimes that varied by habitat, frequency, size, extent and seasonality (Kimmerer and Lake 2001; Stephens et al. 2007; Anderson 2018).

Approximately 4.4 to 11.9 million acres of land are estimated to have burned in California every year prior to European colonization due to lightning-caused fires and cultural burning (Stephens et al. 2007). But in the past 200 years, California's highly diverse habitats and their historical fire regimes have been disrupted (Stephens and Sugihara 2018). The impacts on human communities due to these changes have now become clear.

Pyrocumulus cloud from the 2020 Ranch 2 Fire near Azusa, California / Russ Allison Loar, Flickr CC-BY-ND

Recent fires have been exceptionally destructive to California communities (Figure 1a). Based on fire records from the past 100 years, fires have become deadlier and more destructive, and large fires are occurring at an increasing rate (Stephens and Sugihara 2018). Seventeen of the 20 largest wildfires, 18 of the 20 most destructive wildfires, and 11 of the 20 deadliest wildfires have occurred after 2003 (Cal Fire 2020a, 2020b, 2020c).

Meanwhile the cost of fire suppression and damages in areas managed by the California Department of Forestry and Fire (Cal Fire) has skyrocketed to more than $23 billion during the 2015-2018 fire seasons (Figure 1b). After adjusting for inflation, this is more than double the wildfire cost for the previous 26 years of records combined. These harmful trends will continue unless policymakers reckon with the reckless land-use policies that put our communities in harm's way.



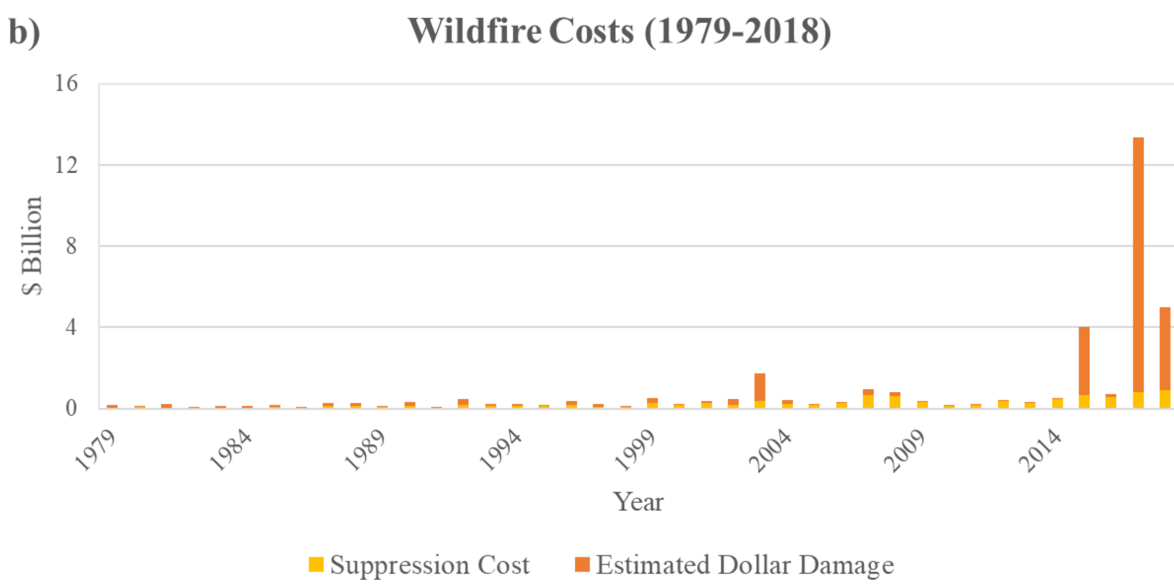


Figure 1. *Wildfire destruction and costs over time. (a) Number of structures destroyed from 1989 to 2020 (*2019 and 2020 statistics are not finalized) and (b) Cal Fire wildfire-suppression and damage costs from 1979 to 2018, adjusted for inflation. Data source: Cal Fire (https://www.fire.ca.gov/stats-events/).*

Owl soars over fire / U.S. Fish and Wildlife Service

SPRAWL DISRUPTS FIRE REGIMES AND MAKES WILDLIFE MORE VULNERABLE TO FIRE

Wildfires are a natural and necessary process in many of California's ecosystems, providing essential habitat for numerous species. For example, woodpeckers and many other animals of the Sierra Nevada rely on wildfire to create the dead trees, shrubs and post-fire vegetation within which these animals find the food they need to survive (e.g., Bond et al. 2009; Campos and Burnett 2015; Taillie et al. 2018; Blakey et al. 2019; Stillman et al. 2019). The critical role of wildfire in Sierra Nevada forests has been dramatically disrupted, however, by development, logging and fire suppression. As a result, these forests have a deficit of wildfire, meaning there's much less fire in these forests than there was historically — prior to 1800, an estimated 20 to 53 times more forest area burned each year in California than in recent decades (Stephens et al. 2007).

Researchers therefore recommend that more wildfires be allowed to burn each year in the backcountry, instead of being suppressed, in order to allow Sierra Nevada forests to rejuvenate and support the region's exceptional biodiversity. Continued sprawl development in these landscapes is an expanding impediment to efforts to restore natural fire regimes at any level.

California's shrubland habitats, on the other hand, such as chaparral and sage scrub, are experiencing a very different relationship with fire. These ecosystems are adapted to high-severity wildfires at relatively infrequent intervals ranging from 30 to 130 years or more (Keeley and Fotheringham 2001; Stephens et al. 2007; Keeley and Syphard 2018; Baker and Halsey 2020), but increased fire frequency from human ignition sources due to sprawl development is now causing these shrubland habitats to receive too much fire. This altered fire regime is the primary driver of habitat degradation and loss of biodiversity in these ecosystems (Keeley 2005) and leads to conversion of these important habitats to non-native grasses and forbs that burn more easily throughout more of the year, thereby compounding the problem of too much fire (Keeley 2005; Syphard et al. 2009; Balch et al. 2013; Sugihara et al. 2018; Syphard et al. 2019). Any additional sprawl development in these highly fire-prone habitats further undermines efforts to restore natural fire regimes and reduce human ignitions in these areas.

In addition to disrupting fire regimes, human activities have also put many of California's wild animals at risk of extinction. As a result, fire can sometimes have harmful consequences to endangered species that now only exist in very small, isolated populations due to massive habitat loss and fragmentation from sprawl development combined with other threats.

For example, two mountain lion deaths in the Santa Monica Mountains were attributed in part to the 2018 Woolsey Fire (Figure 2). Although mountain lions are highly mobile and generally able to move away from wildfires, these lions were unable to escape to safety because they were boxed in by roads and development. Such deaths can further destabilize the small mountain lion population that's already facing numerous other threats, including low genetic diversity, vehicle strikes and rodenticide poisoning, and make them more vulnerable to local extinction (Benson et al. 2016; Benson et al. 2019).

Similarly, researchers fear, post-fire landslides after the 2020 Bobcat Fire could be the end for remnant populations of sensitive species in the San Gabriel mountains that have been hard hit by sprawl development combined with disease, non-native predators and other threats, including Santa Ana suckers, unarmored threespine stickleback fish, speckled dace, arroyo chub, mountain yellow-legged frogs and western pond turtles (Figure 2) (Sahagun 2020). While historically these species would have been able to recolonize from neighboring populations after the loss of individuals or populations to fire impacts, that ability is now limited by the species' current small and fragmented population structure. Continued alteration of historical fire regimes due to sprawl development will further endanger those remnant populations.

Figure 2. *The burned paws of P-64, an adult male mountain lion whose death was attributed to the 2018 Woolsey Fire (left), and a mountain yellow-legged frog, whose remnant populations in the San Gabriel Mountains are threatened by post-fire landslides in the wake of the 2020 Bobcat Fire (right). Photo credits: National Park Service and U.S. Geological Survey (Adam Backlin).*

POOR LAND-USE PLANNING FUELS MORE DESTRUCTIVE FIRES

Reckless land-use planning is causing fires to be more destructive. Development in highly fire-prone areas increases unintentional ignitions, places more people at risk, and destroys native shrubland habitats that support high levels of biodiversity. Almost all contemporary wildfires in California (95-97%) are caused by humans in the wildland urban interface (Syphard et al. 2007; Balch et al. 2017; Radeloff et al. 2018; Syphard and Keeley 2020).

For example, the 2019 Kincade Fire, 2018 Camp and Woolsey fires, and 2017 Tubbs and Thomas fires were sparked by powerlines or electrical equipment. And although many of the 2020 fires were sparked by a lightning storm, the Apple Fire was caused by sparks from a vehicle, the El Dorado Fire was caused by pyrotechnics at a gender-reveal celebration, the Blue Ridge Fire was likely caused by a house fire, and electrical equipment is suspected to have ignited the Silverado and Zogg fires.

More than a million homes were built in the wildland-urban interface between 1990 and 2010 (Radeloff et al. 2018), and more than 2 million homes are located in high fire-risk areas (Verisk 2020). Such development in California's highly fire-prone wildlands is increasing wildfire frequency while placing more people in harm's way.

Recent fires highlight this issue: 15 of the 20 most destructive California wildfires have occurred in the past five years (Cal Fire 2020b). If current land-use practices continue, scientists estimate, 640,000 to 1.2 million new homes will be built in the state's highest wildfire-risk areas by 2050 (Mann et al. 2014), which will only worsen the devastating trend.

The contrast between the 1964 Hanly Fire and 2017 Tubbs Fire offers a poignant example of how expanding development in highly fire-prone areas increases fire risk. Both fires were caused by people: It's believed that the Hanly Fire was started by a hunter either discarding a cigarette or burning debris, while the Tubbs Fire was caused by faulty electrical equipment on private property.

These fires had similar footprints (Figure 2), yet the Tubbs Fire burned more than 5,500 structures and killed at least 22 people, while the 1964 Hanly Fire only burned about 100 structures and killed no one. From 1964 to 2017 the population of nearby Santa Rosa grew from 30,000 to 170,000 people — sprawl development had extended farther into fire-prone wildlands and put more people at fire risk (Figure 3) (Keeley and Syphard 2019).

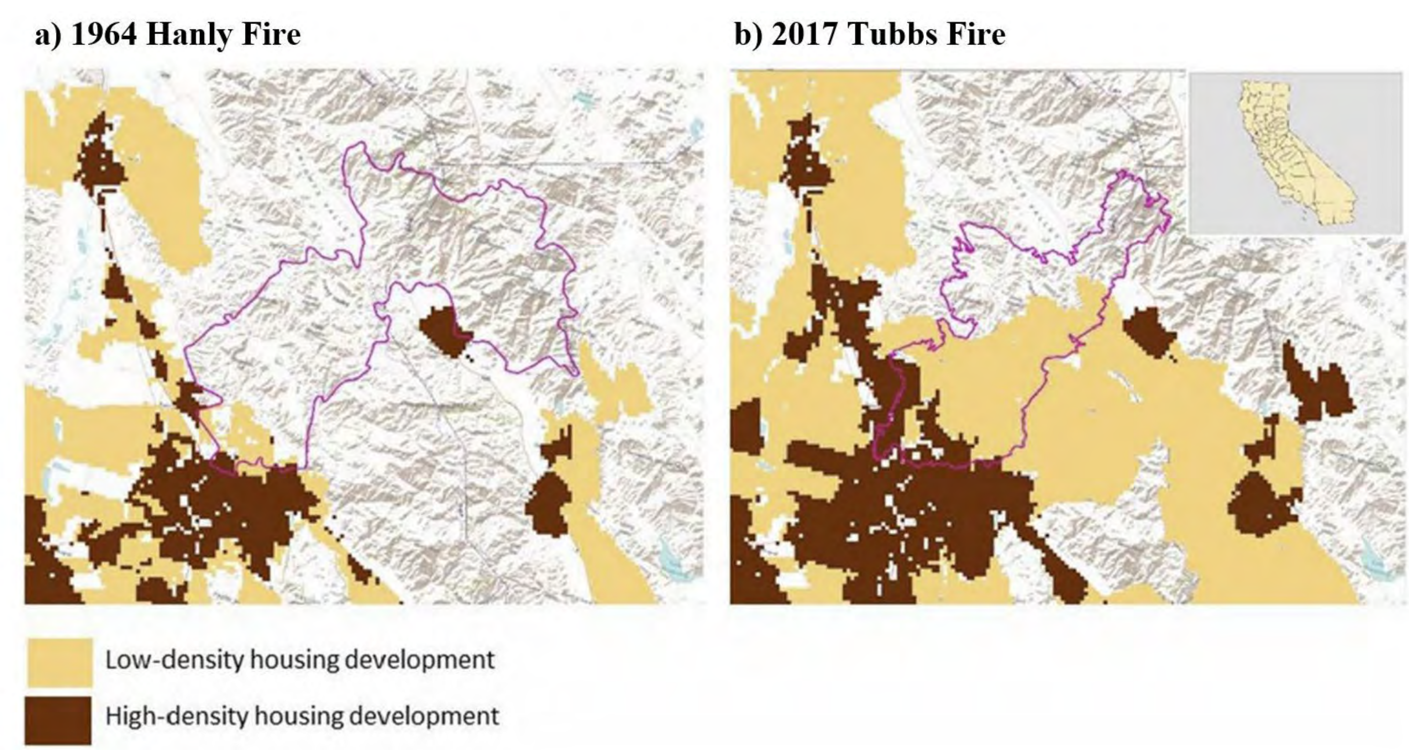


Figure 3. *A tale of two fires: the 1964 Hanly Fire (a) and the 2017 Tubbs Fire (b). Despite the simliar fire footprints (shown with the purple line), the Hanly Fire caused no deaths, and only about 100 structures were destroyed, while the Tubbs Fire killed 22 people and destroyed more than 5,500 structures. Note the extension of housing development within the fire footprint after the Hanly Fire (Keeley and Syphard 2019).*

Most destruction to human communities from fire has been caused by human-ignited fires in mixed shrubland habitats (Syphard 2020). Native shrublands like chaparral and sage scrub are highly diverse and adapted to high-intensity, relatively infrequent fires.

The 2017 Thomas Fire near the city of Ventura, California / European Space Agency

Placing developments in these highly fire-prone habitats ultimately increases fire threat over time. Continued sprawl is causing more frequent fires, which convert shrublands to non-native grasses that ignite more easily throughout more of the year. This perpetuates a dangerous cycle that increases wildfire ignitions, extends the fire season, and eliminates native shrubland habitats and biodiversity.

Wind is another important factor in wildfire risk. Foehn winds, referred to as the Santa Ana winds in the south and the Diablo or North winds in the north, commonly occur in the fall. These are dry, warm, strong winds that can spread fires dangerously fast. Winds were clocked at 40 to 95 miles per hour during the 2020 wildfire season. Wind-driven fires can cover 25,000 acres in one to two days as embers are blown ahead of the fires and toward adjacent fuels like flammable vegetation and/or structures (Syphard et al. 2011).

The 2018 Hill Fire in Ventura County spread three miles in 15 minutes (County of Los Angeles 2019). The speed at which these wind-driven fires can spread may overwhelm and outpace even the most experienced and capable agencies (County of Los Angeles 2019). And in some cases, high winds in developed areas may play a role in initiating wildfires. The 2018 Woolsey Fire, which killed three people and burned more than 1,600 structures, was sparked by powerlines that were knocked down by strong winds.

In addition, progressively hotter, drier and windier conditions due to climate change are making it easier for wildfires to ignite and spread. The number of days with extreme fire weather conditions in California has doubled since 1980, and further climate change will amplify that trend (Goss et al. 2020).

It's time for California to acknowledge that land use influences wildfire risk. Placing more homes in highly fire-prone areas increases the chances of causing larger and more destructive wildfires (Keeley and Syphard 2019; Syphard and Keeley 2020).

POLICYMAKERS CONTINUE APPROVING SPRAWL DEVELOPMENT IN HIGHLY FIRE-PRONE AREAS

Local officials continue to approve sprawl projects in high-wildfire zones. For example, in December 2018 the Los Angeles County Board of Supervisors approved the 19,000-home Centennial development in high and very high fire-hazard severity zones on the remote northern edge of the county (Agrawal 2018a). Between 1964 and 2015, Cal Fire documented 31 wildfires larger than 100 acres within five miles of the 12,000-acre development site, including four within the project's boundaries (Figure 4a) (Agrawal 2018b).

Similarly, in April 2019 the board approved the 3,150-home Northlake development, which sits in a very high fire-hazard severity zone. Multiple fires have burned the Northlake project footprint over the last few years (Figure 4b). Both projects were approved by a 4-1 vote, with Supervisor Sheila Kuehl casting the lone opposition vote.

a) Centennial Development **b) Northlake Development**

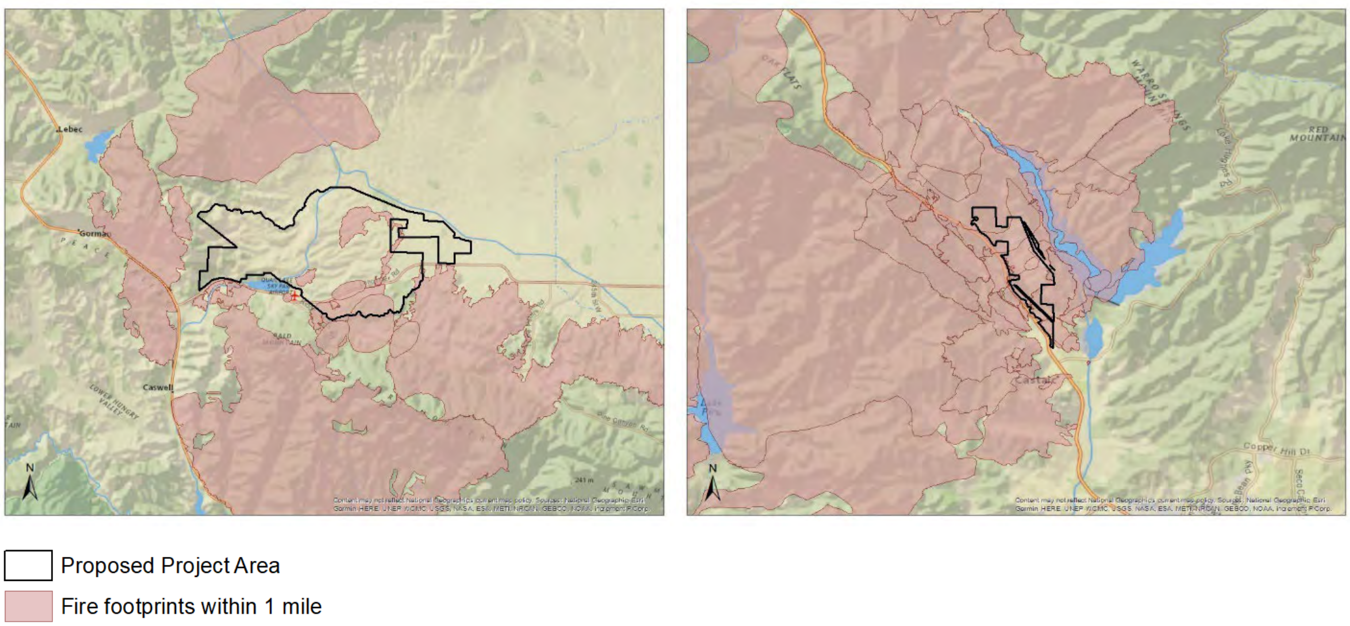


Figure 4: *Wildfire burned areas in and near the recently approved development projects of Centennial (a) and Northlake (b). Black outlines indicate development areas, and red indicates previously burned areas.*

This is a trend that's likely to continue throughout the greater Los Angeles region. The Southern California Association of Government's Regional Transportation Plan, which covers Imperial, Los Angeles, Orange, Riverside, San Bernardino and Ventura counties and was approved in September 2020, estimates that an additional 154,300 housing units will be built in very high fire-hazard zones by 2045 (SCAG 2020).

San Diego County has similarly persisted in authorizing new sprawl development in rural, highly fire-prone areas of the county. In 2018 the county approved the 2,000-unit Newland Sierra project, which would have been constructed on 2,000 acres in a very high wildfire-hazard zone. Voters repealed the county's approval by referendum in March 2020, in part due to fire concerns. Also in 2018 the county approved the fire-prone Harmony Grove South and Valiano projects, with approximately 800 combined housing units. A judge halted these projects in 2020 after finding that San Diego county hadn't adequately addressed the safety and evacuation of potential new residents.

In 2019 and 2020, San Diego County approved two more new development projects (Otay Village 14 and Otay Village 13, respectively) with over 3,000 housing units on a combined 3,000 acres in the ecologically sensitive Otay region. The project sites have been burned in several separate fires over the past two decades. In a letter to the county urging it not to approve the Otay Village 13 project, the California attorney general cited "the increased risk of wildfire that the Project will create."

Los Angeles and San Diego counties were named the top two counties in the state with the highest number of housing units located in high wildfire-risk areas (Verisk 2020). Together these counties and their local governments have recently approved the construction of more than 30,000 homes for almost 100,000 people in highly fire-prone areas (Table 1).

Table 1. *Approved development projects located in highly fire-prone areas in Los Angeles and San Diego counties. Number of people were estimated using 2019 U.S. Census data.*

County/Local Government	Approved Housing Project (Year Approved)	Number of Housing Units	Number of People	Status
Los Angeles	Centennial (2018)	19,333	57,806	Lawsuit is ongoing
Los Angeles	Northlake (2019)	3,150	9,419	Project blocked after successful litigation
San Diego	Newland Sierra (2018)	2,135	6,127	Project blocked after a successful referendum
San Diego	Harmony Grove South (2018)	453	1,300	Project blocked after successful litigation
San Diego	Valiano (2018)	326	936	Project blocked after successful litigation
San Diego	Otay Village 14 (2019)	1,119	3,212	Lawsuit is ongoing
San Diego	Otay Village 13 (2020)	1,938	5,562	Lawsuit is ongoing
City of Santee	Fanita Ranch	2,949	8,464	Lawsuit is ongoing
Total		**31,403**	**92,826**	

The problem of runaway development in risky areas is not confined to Southern California. For example, in 2020 Lake County approved a massive new luxury residential and resort project on 16,000 acres in the Guenoc Valley, northwest of Sacramento, over the objections of fire experts and the attorney general, who cited concerns about the project's risks to public safety. At the time the county was considering the project, the site had experienced at least five fires since 2006. Less than two months after the county's approval the site burned yet again in the 2020 LNU Complex Fire.

WILDFIRE IMPACTS DISPROPORTIONATELY AFFECT LOW-INCOME, MINORITY COMMUNITIES

Impacts of wildfire disproportionately affect vulnerable communities with less adaptive capacity to respond to and recover from hazards like wildfire. Low-income and minority communities, especially Native American, Black, Latinx and Southeast Asian communities, are the most marginalized groups when wildfires occur (Davies et al. 2018).

Past environmental hazards have shown that those in at-risk populations (e.g., low-income, elderly, disabled, non-English-speaking, homeless) often have limited resources for disaster planning and preparedness (Richards 2019). Vulnerable groups also have fewer resources to have cars to evacuate, buy fire insurance, implement defensible space around their homes, or rebuild, and they have less access to disaster relief during recovery (Fothergill and Peak 2004; Morris 2018; Harnett 2018; Davis 2018; Richards 2019).

The 2020 Apple Fire north of Beaumont, California / Brody Hessin, CC-BY

In addition, emergency services often miss at-risk individuals when disasters happen because of limited capacity or language constraints (Richards 2019). For example, evacuation warnings are often not conveyed to disadvantaged communities (Davies et al. 2018). In the aftermath of wildfires and other environmental disasters, news stories have repeatedly documented the lack of multilingual evacuation warnings leaving non-English speakers in danger. (Gerety 2015; Axelrod 2017; Banse 2018; Richards 2019). Survivors are left without resources to cope with the death of loved ones, physical injuries and emotional trauma from the chaos that wildfires have inflicted on their communities.

Health impacts from wildfires, particularly increased air pollution from fine particulates ($PM_{2.5}$) in smoke, also disproportionately affect vulnerable populations, including low-income communities, people of color, children, the elderly and people with pre-existing medical conditions (Künzli et al. 2006; Delfino et al. 2009; Reid et al. 2016; Hutchinson et al. 2018; Jones et al. 2020).

Increased $PM_{2.5}$ levels during wildfire events have been associated with increased respiratory and cardiovascular emergency room visits and hospitalizations, which were disproportionately higher for low socioeconomic status communities and people of color (Reid et al. 2016; Liu et al. 2017; Hutchinson et al. 2018; Jones et al. 2020). Similarly, asthma admissions were found to have increased by 34% due to smoke exposure from the 2003 wildfires in Southern California, with elderly and child age groups being the most affected (Künzli et al. 2006).

Farmworkers, who are majority people of color, often have less access to healthcare due to immigration or economic status. They are more vulnerable to the health impacts of poor air quality due to increased exposure to air pollution as they work. Yet farmworkers often have to continue working while fires burn, and smoke fills the air, or risk not getting paid (Herrera 2018; Parshley 2018; Kardas-Nelson et al. 2020).

Unprecedented California wildfires are increasing negative health impacts within and beyond its borders. A recent study found that wildfire smoke now accounts for up to 50% of ambient fine particle pollution in the western United States (Burke et al. 2021). Land-use planning must improve now.

The 2018 Camp Fire near Paradise, California / U.S. Department of Agriculture

CALIFORNIA CAN FORGE A SAFER FUTURE

Policymakers must reckon with California's wildfire history and acknowledge that reckless land-use policies are increasing wildfire risk and putting more people in harm's way. The combination of sprawl development in highly fire-prone wildlands and altered fire regimes endangers communities.

Legislation that prioritizes the following proactive measures is needed immediately:

- Stop building new homes in highly fire-prone areas;
- Retrofit existing homes with high fire risk.

Stop Building New Homes in Highly Fire-prone Wildlands

The science is clear. Placing more homes and people in highly fire-prone areas leads to more human-caused ignitions and puts more people in danger. California should prohibit new development in high fire-risk areas to keep people safe and protect its rich biodiversity.

Californians broadly support this approach — 3 out of 4 want to restrict housing developments in wildfire-prone areas, according to a 2019 poll (Dillon 2019). Yet local governments like Los Angeles and San Diego counties continue to push for sprawl development in such areas.

Developers claim that compliance with building codes written in 2008 will make their developments fire safe. This is misleading and produces a false sense of security.

While some measures can reduce fire risk, they do not make structures or communities fireproof. In an analysis that included more than 40,000 structures exposed to wildfire between 2013 and 2018 in California, many "fire-safe" structures were destroyed (Syphard and Keeley 2019). And although an analysis conducted in the aftermath of the 2017 Camp Fire showed that new building codes improved home survival, with 51% of homes built to code undamaged compared to 18% of homes built prior to 2008, about half of the homes built to fire-safety codes were still destroyed in the blaze (Kasler and Reese 2019).

The best way to limit fire risk is to avoid building homes in highly fire-prone wildlands.

The 2009 Station Fire in La Crescenta, California / Anthony Citrano, CC-BY-NC-ND

Retrofit Existing Homes With High Fire Risk

Although there are steps that can be taken to reduce risk, they do not guarantee safety from fire. Limiting new development in highly fire-prone areas is critical to reducing risk. But for homes already in high fire-risk areas, home-hardening is important to minimize the chances of human ignitions and fire spread.

It is estimated that more than 2 million homes are located in high fire-risk areas (Verisk 2020). Investing resources primarily in fire suppression without adequately addressing the human-related cause of the fires will not reduce wildfire losses (Stephens et al. 2009). State funds must be equitably distributed to retrofit existing communities in fire-prone areas to reduce the chances of unintentional ignitions and minimize spread should a fire ignite.

Retrofits should include ember-resistant vents, fire-resistant roofs and irrigated defensible space immediately adjacent to (i.e., within 100 feet of) structures. Although such features do not make homes fireproof, they have been shown to improve the chances of structure survival in fires (Syphard et al. 2014; Syphard et al. 2017). External sprinklers with an independent water source could reduce structures' flammability when fires occur (California Chaparral Institute 2018). Rooftop solar and clean energy microgrids could reduce fire risk from utilities' infrastructure during extreme weather (Roth 2019).

The state must also engage, prepare and train homeowners to harden their homes, reduce the risk of fire ignitions and spread, and be ready to safely defend their homes or evacuate early when needed (Stephens et al. 2009). As communities rebuild from recent wildfire destruction, now is the time to instill a culture of coexistence with wildfire.

California policymakers can help our state meet this crucial challenge. Strong land use policies that consider the state's diverse fire history and ecology will help improve our relationship with wildfire and ensure a safer and healthier future for both humans and wildlife.

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EXHIBIT 14

Discussion Paper
KEY ISSUES AND POLICY OPTIONS

CANNABIS CULTIVATION WITHIN
RESOURCES AND RURAL DEVELOPMENT (RRD) LANDS

BACKGROUND

The RRD zone is comprised of more sensitive natural resource lands, which are generally steep slopes, very remote, primarily accessed by unpaved narrow roads, have little to no groundwater resources, and designated as high fire hazard areas. The RRD zone makes up 39% of the County, with 56% of RRD zoned parcels measuring 10 acres or more.

According to the Sonoma County General Plan, *"the RRD land use allows residences at very low densities due to lack of infrastructures, greater distance from public services, poor access, conflicts with resource conservation and production, and significant physical constrain and hazards. Proposed amendments to the Land Use Map in this category shall consider all of these factors. The intent is that natural resource areas be managed and conserved and production activities avoid depletion and promote replenishment of renewable resources."*

Industry representatives have indicated that the majority of cannabis cultivation is occurring within the RRD zone. This is likely because the parcels are large and remote and there are not many residences. For these reasons there is a reduced concern of neighborhood compatibility issues such as odor, visibility, and loss of housing stock; however, cultivation within this zone presents other challenges. The primary concerns with permitting cultivation within the RRD zone are environmental impacts, site access, security, water availability, fire hazards, and waste water discharge.

KEY ISSUES

Fire Hazards
Cannabis operations are associated with high fire risk and have been responsible for structure fires in both urban and rural areas. Indoor and mixed light cultivation utilize large amount of electricity and operations have been known to install inadequate or improper electrical equipment, which increases the likelihood of fire hazards. The Sonoma County Hazard Mitigation Plan and GP 2020 designate the majority of RRD lands within the Wildland Fire Hazard Areas as "very high" or "high." Although cannabis cultivation operations would have to obtain proper building and electrical permits, allowing cannabis in this area would increase the number of structures and people that would potentially need emergency protection.

Emergency Services
The remote RRD zoned areas are primarily accessed by one lane gravel roads that are remnants of old logging roads. Most cultivation facilities would be required to construct paved, 2-way roads with an 18 foot minimum width, sufficient for emergency vehicle access. Water for fire suppression may also be required. Emergency response in these areas are handled by volunteer fire departments and response times vary.

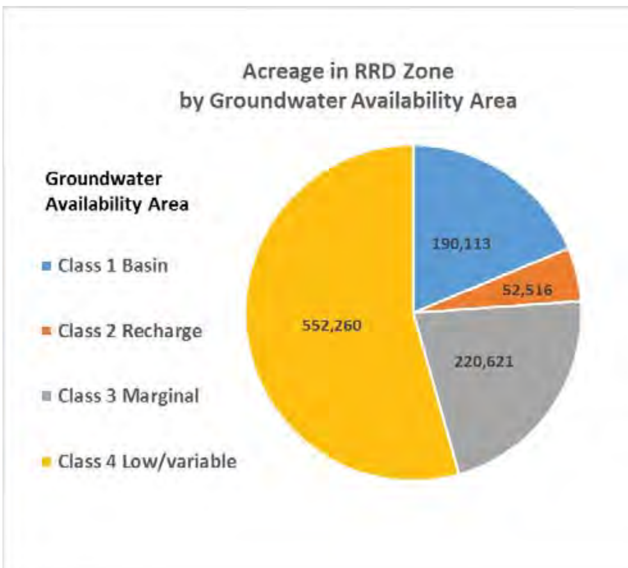
Water Availability
The majority of land within the RRD zone is water scarce, and designated Groundwater Availability Class 4 area with low or high variable water yield. This low availability of water is problematic because cannabis needs a sustained amount of moisture. Estimates of water use for cannabis cultivation operations range from one and six gallons per day per individual cannabis plant during the growing period. The table below provides a range of water demand depending on the size and type of operation, as supplied by various industry sources. For comparison purposes, a single family residence uses 1.5 to 2.0 acre-feet of water per year.

Table 1: Projected Water Use for Cannabis

Type of cultivation	Maximum Size	Number of Plants	Water Use (Gallons per year)	Water Use (Acre Feet Per Year)
Cottage	25 plants	25	9,125 to 54,750	0.03 to 0.2
Outdoor cultivation	5,000 sf	556	133, 440 to 800,640	0.4 to 2.5
Indoor cultivation	5,000 sf	556	202,940 to 1,217640	0.7 to 4.0
Outdoor cultivation	10,000 sf	1,111	266,640 to 1,599,840	0.8 to 5.0
Indoor cultivation	10,000 sf	1,111	405,515 to 2,433090	1.3 to 8.0

*Assumes a range of 1 to 6 gallons per day

Figure 1: Acreage in RRD Zone by Groundwater Availability Area



Cannabis cultivation operations may have an impact on existing groundwater resources. Within the RRD zone, Class 4 water scarce areas are typically located in the upper watershed areas with fractured rock aquifers which are difficult to characterize the extent and availability of water. The proposed Ordinance includes a strict standard that would require operations within Class 4 areas (80% of the RRD zoned parcels) to have “no net increase” in water use, achievable through implementation of water conservation measures. These could include rainwater catchment, recycled water reuse, water recharge projects, or similar measures. Of the 7,613 parcel in RRD 1,082 parcels are within Groundwater Availability Areas 1-3 and would not have to adhere to the “no net water increase” standard.

Roadways in RRD

The RRD zone is known for steep, rocky, hillsides. New road construction in steep areas may present significant hazards related to design and safety. A large addition of new roads within this zone would require ongoing maintenance and may cause erosion, sedimentation, and dust issues over the long term.

Security
The remote nature and reduced visibility of the RRD zone presents safety issues for cultivation operations. Many operations will have a 24 hour/7 days per week security guard and video surveillance. The remote locations coupled with such security measures may present safety concerns for the residents living in these areas.

Development Criteria and Operating Standards
The following abbreviated list of proposed commercial cultivation standards (Exhibit B) would reduce impacts in the RRD zone:

A. Required adherence to Building Code and Grading Ordinance
B. Property Setbacks (outdoor and mixed light) - 100 feet from property lines, 300 feet from occupied residences and business on adjacent properties
C. Biotic Assessment required for sensitive habitat areas
D. Cultivation shall not be located on slopes that exceed 15%
E. No tree removal (unless subject to a use permit)
F. Protection of Important Farmlands - no conversion unless offset
G. Cultural and historic resource protection - avoid or mitigate impacts to resources
H. Vegetation and fencing required for screening
I. Site Security Plan
J. All lighting shall be fully contained and not visible from off site
K. Stormwater Management Plan and Erosion and Sediment Control Plan
L. Fire Prevention Plan
M. Waste Management Plan
N. Waste Water Discharge Management Plan
O. Renewable Energy requirements - must be 100% renewable (via power company or on site) or carbon offsets purchased (generators are prohibited)
P. Water Supply - on site water provided by municipal, surface, or well water. Within class 4 water scarce areas there shall be no net increase in water use through implementation of conservation methods
Q. Annual permit requirement
R. Annual Inspections
S. Groundwater monitoring
T. Noise Limits- must not exceed noise limits within the General Plan

The Agricultural Commissioner will be responsible for issuing zoning permits and conducting annual inspections for outdoor cultivation areas. PRMD would be responsible for permitting and inspections for any outdoor cultivation operations requiring a use permit as well as all other types of cultivation and related support activities. Support activities such as drying, trimming, and storage would be allowed in addition to the cultivation size limitation expressed in the proposed Ordinance and Land Use Summary Table (Attachment A).

ANALYSIS AND OPTIONS

1. Cultivation Limits. The following outlines a range of policy options for the size and scale of commercial cultivation considered in the RRD zone. These terms and size limitations are consistent with the license types defined in state law.

<u>Outdoor Cultivation</u>

A. **Allow All Sizes of Outdoor Cultivation**: This option would allow all sizes of outdoor cultivation up to the one acre limit in state law.

B. **Limit the Size of Outdoor Cultivation.** This options would limit the size of outdoor cultivation in the RRD zone to either small (up to 10,000 sq. ft.) or specialty (up to 5,000 sq. ft.).

Indoor Cultivation

C. **Limit Indoor Cultivation Size.** This option restricts indoor cultivation to cottage (500 square feet) and specialty (5,000 square feet). Larger scale indoor operations would not be permitted.

D. **Limit Indoor Cultivation to Existing Structures.** Indoor cultivation could be limited to existing structures only in order to preserve the soils for other agricultural production.

Mixed Light Cultivation

E. **Limit Mixed Light Cultivation Size.** This option would limit mixed light cultivation to specialty (5,000 square feet) and small scale up to 10,000 square feet.

F. **Expand Mixed Light Cultivation Limits.** This option would expand opportunities for all sizes of mixed light cultivation up to the maximum limit allowed in state law of 22,000 square feet.

Analysis
All of the options above propose to limit indoor cultivation to some extent in order to preserve more land for potential resource uses and minimize the need for new structures. This is because indoor facilities are more industrial in nature and may not be adaptable to traditional resource uses if the cannabis use were to end, and may not be in keeping visually with the rural character of these lands. Mixed light operations, or greenhouses, may be adaptable to other types of agricultural uses, though they can also affect the scenic quality of the rural areas.

Staff Recommendation: Option A, C and D. Option A provides maximum opportunities for outdoor cultivation where standards can be met. Larger parcel sizes and topography may provide fewer compatibility concerns and allow for screening. Indoor cultivation is recommended to be limited to cottage and specialty sizes (up to 5,000 square feet) and to existing legally established structures for operations over 500 square feet. Mixed light operations are recommended up to 10,000 square feet. Staff recommends reduced scales of indoor and mixed light cultivation within this zone which will reduce the amount of grading and site development necessary for new structures, thereby reducing impacts to sensitive habitats.

2. Permit Requirements. The following policy options provide a range of permit thresholds for the recommended size of cultivation operation allowed by the previous discussion.

The following range of policy options are related to the level of permit required to allow the specified types of cultivation. The following permit thresholds are used as policy options:

- Zoning Permit – a ministerial, subject to standards, no conditioning authority
- Minor Use Permit – discretionary, can add conditions, hearing waiver if no protest
- Conditional Use Permit – discretionary, can add condition, noticed hearing

The main policy question to consider in determining appropriate permit thresholds for ministerial zoning permits is what scale of use would be consistent with the General Plan and compatible in all circumstances where the use is allowed with a ministerial permit. Special consideration should be given to cumulative impacts of ministerial land uses in determining the appropriate permit thresholds and the standards to mitigate any potential impacts. The following options are presented for each type of cultivation by size. Refer to the table: *Summary of Allowed Land Uses and Permit Requirements for Cannabis Uses (Attachment A).*

A. **Require a Minor Use Permit with potential for hearing waiver**. A minor use permit is reviewed on a case by case basis and is subject to CEQA, although due to the small scale of uses, may be found exempt. Public notification (at least 300-feet) is required and the public hearing may be waived and the permit approved administratively if no protest or request for hearing is timely filed within the 10-day notice period. Minor Use Permits are processed on an at-cost basis and range from $2,000 to $6,000 depending upon the level of CEQA review required.

B. **Require a Conditional Use Permit with hearing.** A conditional use permit is subject to CEQA and a mitigated negative declaration is most often prepared. Public notification (at least 300 feet and sign posted on site) is required and a public hearing is held by the Board of Zoning Adjustments. Conditional Use Permits are processed on an at-cost basis and can range from $6,000 to $12,000 depending on the scale, site constraints and neighborhood opposition.

C. **Require Zoning Permits, subject to standards.** Zoning permits are ministerial permits and are not subject to CEQA. The permit is approved based on adherence to the Ordinance standards and requires no public notification. The cost of a zoning permit would be established by the Board based on the cost of administering the standards and issuing the permit. Staff estimates the costs to be from $1,800 to $2,500.

D. **Require Limited Terms and Annual Renewal.** In combination with the options above, the permit would be approved for one year and would be subject to an annual renewal. This allows staff to review compliance and change conditions based on the situation or changes in the Ordinance.

Analysis
Outdoor cultivation is generally similar to other crops, except for the need for screening, fencing and other security measures (i.e. guards). Generally solid fencing is discouraged in rural areas to retain the visual and scenic quality, yet outdoor cultivation is often secured with solid 8-foot tall solid fencing and or screened to deter theft and access to youth. Indoor cultivation can require large industrial buildings that may have visual impacts on a cumulative basis and may convert land from agricultural or other resource uses or result in a loss of sensitive habitats. Mixed light cultivation likewise involves structures that can lead to visual impacts and conversion of resource lands. The siting of any new structures within the RRD zone may require significant grading, fire suppression design and infrastructure, and an increased need for emergency services.

Staff Recommendation: Options A, B and D. Staff recommends a minor use permit for all types of cottage size cultivation within the RRD zone. All larger sized operations would be required to obtain a conditional use permit, allowing close review of the site on a case by case basis. Staff recommends that the “medium” sized mixed light cultivation operations (up to 22,000 sq. ft.) be limited in Phase I due to the potential to cause significant visual impacts, and considered in Phase II once we know more about the impacts seen in less sensitive zones during Phase I. Due to the diversity of environmental issues on RRD lands, staff does not recommend the zoning permit process and instead prefers to provide the opportunity for a public hearing before the Board of Zoning Adjustments to review larger operations on a case by case basis.

3. Establish Cultivation Standards

The proposed Ordinance includes a combination of minimum parcel sizes and cultivation standards to minimize impacts. Additional policy options related to cultivation on RRD lands are provided below.

A. **Property Setbacks.** The proposed Ordinance includes a setback for outdoor and mixed light cultivation operations of 100 feet from property lines and 300 feet from occupied residences and businesses on adjacent properties. Indoor operations would be required to meet standard setbacks for structures. The Commission could modify these limits provided that the Commission finds that equivalent mitigation is included in the ordinance. The setbacks are intended to address odor and security concerns, visual impacts, and access by youth with outdoor and mixed light operations.

B. **Separation Criteria** The proposed Ordinance includes a 600 foot setback from sensitive uses for outdoor and mixed light operations. Sensitive uses include schools, parks, childcare centers, and alcohol or drug treatment facilities. These setbacks could be increased to 800 or 1,000 feet, similar to other jurisdictions and Sonoma County's existing dispensary ordinance, but could not be reduced below the 600 foot separation required in state law for schools. The Commission could consider changing the types of sensitive land uses that require separation other than schools (i.e. whether to include parks, or other businesses that primarily cater to children).

C. **Minimum Parcel Sizes.** The staff recommendation includes minimum lot sizes relative to the size of the cultivation operations. The Commission could reduce or expand the minimum lot sizes for the size of operation as long as an equivalent mitigation of impacts is provided. The minimum lot sizes apply only to outdoor and mixed light or greenhouse operations as they are more apparent with greater potential for odor and security concerns. There are no minimum lot sizes proposed for indoor cultivation, which can have odor controls and are easier to secure.

D. **Allow use of Water Trucks**. The staff recommendation includes an allowance for the trucking of recycled water with a use permit. This is due to the lack of water within the RRD zone and the related standard which requires sites within Class 4 to have "no net increase" in water use. Cultivation sites in Class 4 Areas will still need to provide a potable water supply for domestic use and employees.

E. **Prohibit use of Water Trucks.** This option would prohibit the trucking of water, except in emergencies. The delivery of water increases the number of trips to cultivation sites which may cause traffic conflicts particularly on rural roads and a cumulative increase in air quality impacts.

Analysis

Setbacks are often used to ensure neighborhood compatibility and mitigate impacts of a particular land use such as odor, noise, or light. Setbacks are effective ways to mitigate these impacts as they focus on site design elements rather than regulating ongoing behaviors. Setback requirements would ensure space between a cultivation site and the property line and/or a neighboring structure.

Minimum lot sizes are used primarily to reduce cumulative impacts and overconcentration. They also serve to mitigate impacts associated with odor, noise, and aesthetics by providing more area to separate land uses, provide screening and attenuate noise. Larger lot sizes also reduce the potential access to children and can deter crime by providing more area for screening, fencing and on-site security. The majority of the RRD zone consists of parcels that are over 10 acres and are remote in nature. For these reasons a minimum lot size requirement would not be problematic for new operators in the RRD zone.

Due to the strict standard related to water, the staff recommendation includes an allowance for recycled water to be trucked into cultivation sites with a use permit. The use of recycled water would reduce the use of onsite groundwater. This would require cultivation sites to construct sufficient water storage containers to receive the recycled water. The allowance for trucking water is also a deviation from existing policy that requires all uses to have an onsite water source adequate to support the proposed use.

Staff Recommendation: Options A-D The proposed Ordinance includes the implementation of setbacks, minimum lot sizes, and separation criteria to minimize impacts to land surrounding cannabis operations. The limitation on existing structures would protect resource lands and minimize land disturbance caused by new construction. The allowance of trucked recycled water would assist operators in meeting the water supply standard within the proposed Ordinance without relying solely on limited groundwater supplies. Potential impacts related to trucking and water storage would need to be evaluated further on a case by case basis through the use permit process.

EXHIBIT 15

Bennett Valley VOICE Newsletter (January 2021)

Status of Commercial Marijuana Projects in Bennett Valley

by Craig S. Harrison, VOICE Editor

There have been 13 ongoing operations or attempts to obtain marijuana permits in Bennett Valley since 2017. None of these grow operations existed before the cannabis ordinance in 2016. Contrary to the ordinance's stated goals, no ongoing operations were legalized in Bennett Valley; all began after the supervisors invited cultivation here. It is difficult to learn of new proposed permits, so there may be additional sites beyond those listed. The County refuses to maintain a website to provide such information, and the only way to remain current is to file periodic Public Records Act requests. This community web site attempts to provide current information as obtained from such requests: http://www.sosneighborhoods.com/

APN	Address	Permit Application Status
049-130-015	4944 Bennett Valley Road	Inactive; site ineligible because parcel under 10 acres
055-010-031	2274 Wellspring Road	Active; 5 ministerial permits issued
049-150-005	4050 Grange Road	Active; awaiting supervisors hearing
049-130-005	4065 Grange Road	Active despite lacking required easement
049-071-054	4265 Sonoma Mountain Rd	Terminated; ineligible parcel
049-030-090	5365 Sonoma Mountain Rd	Inactive; site ineligible because parcel under 10 acres
136-201-004	6480 Eagle Ridge Road	Terminated; another grower might apply
055-150-018	3141 Matanzas Creek Lane	Withdrawn; another grower might apply
055-150-011	3220 Matanzas Creek Lane	Withdrawn; another grower might apply
055-150-010	3400 Matanzas Creek Lane	Inactive; another grower might apply
055-140-015	3575 Matanzas Creek Lane	Inactive; site ineligible because parcel under 10 acres
055-140-006	3700 Matanzas Creek Lane	Inactive; awaiting BZA hearing
055-140-024	3803 Matanzas Creek Lane	Active; awaiting supervisors hearing

Four sites cultivated marijuana in 2020. Three have operated since 2017 under the Penalty Relief Program while they applied for conditional use permits: 4050 Grange Road, 4065 Grange Road, and 3803 Matanzas Creek Lane. The County Agriculture Department issued five ministerial permits for 2274 Wellspring Road, an "over the counter" checklist permit process that essentially allows no public involvement. Currently, each ministerial permit is limited to 10,000 square feet. The permit process has been piecemealed into 5 small permits to avoid the discretionary permit process that would have been required for a single project. This avoided environmental review and neighbor objections.

The supervisors may soon amend the ordinance to allow 10-acre grows and make most permits ministerial. You may awaken someday to find a large marijuana plantation next door. The supervisors will propose to amend the General Plan to deem cannabis cultivation to be an "agricultural activity." Under state law, marijuana is an "agricultural product," and the change is intended to protect growers under the County's Right-to-Farm ordinance by eliminating your rights. One supervisor said if you don't like it, you can move to another county.

Sonoma County continues to violate the SRA Fire Safe regulations by allowing grows to continue in 2020 on the very narrow Grange Road and Matanzas Creek Lane. The permit for 4065 Grange Road requires the owners to have a valid easement. But the county ignored this legal requirement in 2020 and allowed cultivation. A June county inspection found numerous violations at 4065 Grange Road, including twice the allowable number of plants. The inspector "closed the violation without penalties" at the request of the Agriculture Department. While the county demands that you to obey its laws, it apparently imposes no such obligations on marijuana growers.

EXHIBIT 16

The New York Times

‘Getting Worse, Not Better’: Illegal Pot Market Booming in California Despite Legalization

By Thomas Fuller

April 27, 2019

COSTA MESA, Calif. — In the forests of Northern California, raids by law enforcement officials continue to uncover illicit marijuana farms. In Southern California, hundreds of illegal delivery services and pot dispensaries, some of them registered as churches, serve a steady stream of customers. And in Mendocino County, north of San Francisco, the sheriff’s office recently raided an illegal cannabis production facility that was processing 500 pounds of marijuana a day.

It’s been a little more than a year since California legalized marijuana — the largest such experiment in the United States — but law enforcement officials say the unlicensed, illegal market is still thriving and in some areas has even expanded.

“There’s a lot of money to be made in the black market,” said Thomas D. Allman, the sheriff of Mendocino County, whose deputies seized cannabis oil worth more than $5 million in early April.

Legalization, Sheriff Allman said, “certainly didn’t put cops out of work.”

California’s governor, Gavin Newsom, has declared that illegal grows in Northern California “are getting worse, not better” and two months ago redeployed a contingent of National Guard troops stationed on the border with Mexico to go after illegal cannabis farms instead.

Stepped-up enforcement comes with a certain measure of irony — legalization was meant to open a new chapter for the state, free from the legacy of heavy policing and incarceration for minor infractions. Instead, there are new calls for a crackdown on illegal selling.

Conscious of the consequences that the war on drugs had on black and Latino communities, cities like Los Angeles today say they are wary of using criminal enforcement measures to police the illegal market and are unsure how to navigate this uncharted era.

The struggles of the licensed pot market in California are distinct from the experience of other states that have legalized cannabis in recent years. Sales in Colorado, Oregon and Washington grew well above 50 percent for each of the first three years of legalization, although Oregon now also has a large glut of pot.

But no other state has an illegal market on the scale of California’s, and those illicit sales are cannibalizing the revenue of licensed businesses and in some cases, experts say, forcing them out of business.

Entrepreneurs in the industry, which spent decades evading the law, are now turning to the law to demand the prosecution of unlicensed pot businesses.

“We are the taxpayers — no one else should be operating,” said Robert Taft Jr., whose licensed cannabis business in Orange County, south of Los Angeles, has seen sales drop in recent months.

It’s been a little more than a year since California legalized marijuana, but the illegal market is still thriving and in some areas has even expanded. Jenna Schoenefeld for The New York Times

“This is starting to get ridiculous,” he said of the illegal pot shops, including nearby businesses that list themselves as churches and advertise marijuana as a kind of sacrament. “It’s almost like the state is setting itself up to lose.”

California gives cities wide latitude to regulate cannabis, resulting in a confusing patchwork of regulation. Los Angeles, San Francisco, San Jose and San Diego have laws allowing cannabis businesses, but most smaller cities and towns in the state do not — 80 percent of California’s nearly 500 municipalities do not allow retail marijuana businesses. The ballot measure legalizing recreational marijuana passed in 2016 with 57 percent approval, but that relatively broad support has not translated to the local level. Cities like Compton or Laguna Beach decisively rejected allowing pot shops.

Regulators cite this tepid embrace by California municipalities as one of many reasons for the state’s persistent and pervasive illegal market. Only 620 cannabis shops have been licensed in California so far. Colorado, with a population one-sixth the size of California, has 562 licensed recreational marijuana stores.

But the more fundamental reason for the strength of the black market in California — and what sets the state apart from others — is the huge surplus of pot. Since medical marijuana was made legal in California more than two decades ago, the cannabis industry flourished with minimal oversight. Now many cannabis businesses are reluctant to go through the cumbersome and costly process to obtain the licenses that became mandatory last year.

Of the roughly 14 million pounds of marijuana grown in California annually, only a fraction — less than 20 percent according to state estimates and a private research firm — is consumed in California. The rest seeps out across the country illicitly, through the mail, express delivery services, private vehicles and small aircraft that ply trafficking routes that have existed for decades.

This illicit trade has been strengthened by the increasing popularity of vaping, cannabis-infused candies, tinctures and other derivative products. Vape cartridges are much easier to carry and conceal than bags of raw cannabis. And the monetary incentives of trafficking also remain powerful: The price of cannabis products in places like Illinois, New York or Connecticut are typically many times higher than in California.

The state’s illicit cannabis exports appear to be increasing even now, well into California’s second year of legalization. New Frontier Data, a data research company that specializes in cannabis, calculates that high demand and more advanced growing techniques will contribute to approximately half a million pounds more illicit cannabis this year compared with 2018.

The federal government still considers marijuana illegal and the Drug Enforcement Administration says it still investigates marijuana-related crimes. But a spokesman, Rusty Payne, said the agency has a bigger crisis to attend to.

“We’ve got our hands full with the opioid epidemic to be honest,” Mr. Payne said.

In wildland areas, seizures of illicit pot by the California Department of Fish and Wildlife more than doubled in 2018, the first year that recreational cannabis was legal.

The department destroyed 1.6 million marijuana plants last year, up from 700,000 in 2017 and 800,000 the year before — all of them illegally grown.

“There’s a subset of people who are just refusing to get into the process,” said Nathaniel Arnold, the department’s deputy chief of enforcement.

The Bureau of Cannabis Control, the agency charged with regulating marijuana in the state, has received around 7,500 complaints, most of them about illegal operations, and has sent out more than 3,000 letters ordering illegal businesses to shut down.

Robert Taft Jr. says his licensed cannabis business in Orange County, south of Los Angeles, has seen sales drop in recent months. Jenna Schoenefeld for The New York Times

“It’s only a matter of time before we start making a dent in the illegal market,” said Alex Traverso, a spokesman for the agency, who acknowledged there were probably more illegal shops in Los Angeles alone than licensed shops in the entire state.

Cat Packer, the executive director of the Department of Cannabis Regulation in Los Angeles, said that even when illicit businesses were shut down, they often soon reappeared.

“It’s been a game of whack-a-mole in the city of Los Angeles,” she said.

But Ms. Packer also said the city was mindful that criminal enforcement in the past had disproportionately targeted people of color.

The city is seeking to find an effective enforcement policy that does not mimic the criminal interdiction policies of the past, Ms. Packer said. One strategy is to turn off water and power services to noncompliant businesses.

“We can’t do Drug War 2.0,” she said.

Mr. Taft, the cannabis entrepreneur, has sent 450 complaints to the Bureau of Cannabis Control and is unapologetic about his calls for an aggressive approach to illegal shops, which he says is the only way that California’s giant experiment will work.

His dispensary pays a cumulative state and local tax rate of 32.25 percent. Unlicensed shops pay no tax.

One of Mr. Taft’s biggest complaints is about Weedmaps, a phone app that allows users to locate marijuana businesses nearby, both licensed and illegal.

In February last year, the Bureau of Cannabis Control sent a letter to Weedmaps saying the company was aiding and abetting illicit businesses and ordering it to “immediately cease all activity that violates state cannabis laws.”

Weedmaps replied that it was a technology company and not under the jurisdiction of the bureau. More than a year later, the company still lists hundreds of unlicensed shops.

Earlier this year, Mr. Taft resigned as a board member of the Santa Ana Cannabis Association because half the members, he said, were selling illegally and using legalization as a “shield.”

“They are playing both sides of the market,” he said.

On a recent weekday morning, Mr. Taft called the Bureau of Cannabis Control to lodge a complaint against his neighbor, a cannabis business that he said did not appear on the list of licensed businesses.

“We are being pillaged by these people,” he said. “My lawyers are ready to launch rockets!”

A version of this article appears in print on , Section A, Page 16 of the New York edition with the headline: Illicit Pot Sales Boom in California Despite Legalization

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EXHIBIT 17

News

Cannabis Black Market Thrives Despite Legalization

"It's time to end the War on Marijuana", declares an ACLU article aimed at exposing the staggering racialization of cannabis-related arrests. Remarking on the tremendous focus police departments had placed on the enforcement of possession laws prior to legalization, it laments the billions of taxpayer dollars that could be re-focused to community improvement projects if such laws were to go away.

And there's nothing wrong with this promise – a black market designed to facilitate the sale of an illegal substance should dissipate as that substance becomes legalized. This destruction of the illegal marijuana market makes logical sense – so much so that it became one of the primary arguments used by pro-legalization politicians to promote the drug. So now, years after the first legalization of recreational cannabis in 2012, the illegal markets should be fading into obscurity.

But many attentive residents of legalized states know that this promise hasn't panned out. Cannabis' illegal market is anything but dying; in some cases, it's more active than it has been in years.

Take California for example: first in the nation to legalize the medical use of the drug in 1996, the state would go on to legalize recreational use in 2016. But in just the past year, the state reported several massive illegal cannabis busts, with 20 tons of cannabis confiscated off a series of farms, $8 million worth of plants found in a thought-abandoned warehouse alongside a busy highway, and 100+ illegal operations busted in the southern town of Anza – just over the last three or four months.

What's more, police reports suggest that arrests for pot crimes have *increased* following the drug's legalization. Among such reports are a series of police records secured by the Los Angeles Times in early 2019 – compared to the rates of cannabis smuggling from before legalization was implemented, the documents suggest that arrests have risen as much as 166% since 1996.

And this smuggling is occurring too quickly and too frequently for law enforcement to handle, says Sgt. Ray Kelly of the Alameda County Sheriff's Office. Sgt. Kelly told The Los Angeles Times that his officers regularly intercept smugglers attempting to depart with large quantities of the drug. Kelly and his department "find it in about 50-pound quantities…the carry-on rate for luggage", and seemed doubtful that the enforcement is catching all the traffickers.

This troubling event touches on one of the several underlying reasons as to how cannabis's more dubious markets are managing to survive despite legalization, as recent data suggests that California produces nearly five times the amount of cannabis as is legally consumed. And the off-state smuggling business that could be created by such a surplus can only be strengthened by the drug's industrialization.

such as NETA, they naturally attempt to go where their prime competition cannot, packing up thousands of dollars worth of leaves and shipping them out of state.

But this is not to say that total legalization will bring an end to this underground market either. While it may end the current drug smuggling rush, there are distinct advantages that local, underground pot salespeople have over licensed dispensaries.

Perhaps the most significant of these advantages is the possibility for local dealers to sell bud at far lower prices. Thanks to significant $9.25 tax per ounce of flower required from dealers and an additional 15% excise tax required from the consumer, legal options in CA may end up far pricier than their underground counterparts.

And California isn't alone in this issue of taxation: Colorado employs a 15% tax from the cultivator to realtor and an additional 15% tax from realtor to consumer, Oregon levies a 17% tax on the consumer alone, and Washington requires a whopping 37% tax on all sales for recreational use.

Illegal operations have also seen an increased prominence in legal states due to the drug's overarching legalization. Some outlets choose to forgo the acquisition of a legal license while still operating out of a storefront and presenting themselves as a licensed dealer. And the process of conducting investigations against such businesses takes time – far too much time to quell the hundreds of illegal shops popping up.

Weedmaps, an online service designed to help consumers find local dispensaries, came under fire in February 2018 from the Bureau of Cannabis Control (BCC) for listing illegal outfits in addition to legal stores but was able to dodge the BCC's jurisdiction and continue operating. The app is still active today, mapping hundreds of unlicensed shops and helping the illegal cannabis market continue to thrive through legalization.

Written by Joseph Detrano, CAS Science Writer

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EXHIBIT 18

TECHNICAL ADVISORY

ON EVALUATING TRANSPORTATION IMPACTS IN CEQA

December 2018

Contents

A. Introduction

This technical advisory is one in a series of advisories provided by the Governor's Office of Planning and Research (OPR) as a service to professional planners, land use officials, and CEQA practitioners. OPR issues technical assistance on issues that broadly affect the practice of land use planning and the California Environmental Quality Act (CEQA) (Pub. Resources Code, § 21000 et seq.). (Gov. Code, § 65040, subds. (g), (l), (m).) The purpose of this document is to provide advice and recommendations, which agencies and other entities may use at their discretion. This document does not alter lead agency discretion in preparing environmental documents subject to CEQA. This document should not be construed as legal advice.

Senate Bill 743 (Steinberg, 2013), which was codified in Public Resources Code section 21099, required changes to the guidelines implementing CEQA (CEQA Guidelines) (Cal. Code Regs., Title 14, Div. 6, Ch. 3, § 15000 et seq.) regarding the analysis of transportation impacts. As one appellate court recently explained: "During the last 10 years, the Legislature has charted a course of long-term sustainability based on denser infill development, reduced reliance on individual vehicles and improved mass transit, all with the goal of reducing greenhouse gas emissions. Section 21099 is part of that strategy . . . ." (*Covina Residents for Responsible Development v. City of Covina* (2018) 21 Cal.App.5th 712, 729.) Pursuant to Section 21099, the criteria for determining the significance of transportation impacts must "promote the reduction of greenhouse gas emissions, the development of multimodal transportation networks, and a diversity of land uses." (*Id.*, subd. (b)(1); see generally, adopted CEQA Guidelines, § 15064.3, subd. (b) [Criteria for Analyzing Transportation Impacts].) To that end, in developing the criteria, OPR has proposed, and the California Natural Resources Agency (Agency) has certified and adopted, changes to the CEQA Guidelines that identify vehicle miles traveled (VMT) as the most appropriate metric to evaluate a project's transportation impacts. With the California Natural Resources Agency's certification and adoption of the changes to the CEQA Guidelines, automobile delay, as measured by "level of service" and other similar metrics, generally no longer constitutes a significant environmental effect under CEQA. (Pub. Resources Code, § 21099, subd. (b)(3).)

This advisory contains technical recommendations regarding assessment of VMT, thresholds of significance, and mitigation measures. Again, OPR provides this Technical Advisory as a resource for the public to use at their discretion. OPR is not enforcing or attempting to enforce any part of the recommendations contained herein. (Gov. Code, § 65035 ["It is not the intent of the Legislature to vest in the Office of Planning and Research any direct operating or regulatory powers over land use, public works, or other state, regional, or local projects or programs."].)

This December 2018 technical advisory is an update to the advisory it published in April 2018. OPR will continue to monitor implementation of these new provisions and may update or supplement this advisory in response to new information and advancements in modeling and methods.

B. Background

VMT and Greenhouse Gas Emissions Reduction. Senate Bill 32 (Pavley, 2016) requires California to reduce greenhouse gas (GHG) emissions 40 percent below 1990 levels by 2030, and Executive Order B-16-12 provides a target of 80 percent below 1990 emissions levels for the transportation sector by 2050. The transportation sector has three major means of reducing GHG emissions: increasing vehicle efficiency, reducing fuel carbon content, and reducing the amount of vehicle travel. The California Air Resources Board (CARB) has provided a path forward for achieving these emissions reductions from the transportation sector in its 2016 Mobile Source Strategy. CARB determined that it will not be possible to achieve the State's 2030 and post-2030 emissions goals without reducing VMT growth. Further, in its 2018 Progress Report on California's Sustainable Communities and Climate Protection Act, CARB found that despite the State meeting its 2020 climate goals, "emissions from statewide passenger vehicle travel per capita [have been] increasing and going in the wrong direction," and "California cannot meet its [long-term] climate goals without curbing growth in single-occupancy vehicle activity."[1] CARB also found that "[w]ith emissions from the transportation sector continuing to rise despite increases in fuel efficiency and decreases in the carbon content of fuel, California will not achieve the necessary greenhouse gas emissions reductions to meet mandates for 2030 and beyond without significant changes to how communities and transportation systems are planned, funded, and built."[2]

Thus, to achieve the State's long-term climate goals, California needs to reduce per capita VMT. This can occur under CEQA through VMT mitigation. Half of California's GHG emissions come from the transportation sector[3], therefore, reducing VMT is an effective climate strategy, which can also result in co-benefits.[4] Furthermore, without early VMT mitigation, the state may follow a path that meets GHG targets in the early years, but finds itself poorly positioned to meet more stringent targets later. For example, in absence of VMT analysis and mitigation in CEQA, lead agencies might rely upon verifiable offsets for GHG mitigation, ignoring the longer-term climate change impacts resulting from land use development and infrastructure investment decisions. As stated in CARB's 2017 Scoping Plan:

> "California's future climate strategy will require increased focus on integrated land use planning to support livable, transit-connected communities, and conservation of agricultural and other lands. Accommodating population and economic growth through travel- and energy-efficient land use provides GHG-efficient growth, reducing GHGs from both transportation and building energy use. GHGs can be further reduced at the project level through implementing energy-efficient construction and travel demand management approaches."[5] (*Id.* at p. 102.)

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[1] California Air Resources Board (Nov. 2018) *2018 Progress Report on California's Sustainable Communities and Climate Protection Act*, pp. 4, 5, available at https://ww2.arb.ca.gov/sites/default/files/2018-11/Final2018Report_SB150_112618_02_Report.pdf.

[2] *Id.*, p. 28.

[3] See https://ca50million.ca.gov/transportation/

[4] Fang et al. (2017) *Cutting Greenhouse Gas Emissions Is Only the Beginning: A Literature Review of the Co-Benefits of Reducing Vehicle Miles Traveled*.

[5] California Air Resources Board (Nov. 2017) *California's 2017 Climate Change Scoping Plan*, p. 102, available at https://www.arb.ca.gov/cc/scopingplan/scoping_plan_2017.pdf.

In light of this, the 2017 Scoping Plan describes and quantifies VMT reductions needed to achieve our long-term GHG emissions reduction goals, and specifically points to the need for statewide deployment of the VMT metric in CEQA:

> "Employing VMT as the metric of transportation impact statewide will help to ensure GHG reductions planned under SB 375 will be achieved through on-the-ground development, and will also play an important role in creating the additional GHG reductions needed beyond SB 375 across the State. Implementation of this change will rely, in part, on local land use decisions to reduce GHG emissions associated with the transportation sector, both at the project level, and in long-term plans (including general plans, climate action plans, specific plans, and transportation plans) and supporting sustainable community strategies developed under SB 375."[6]

VMT and Other Impacts to Health and Environment. VMT mitigation also creates substantial benefits (sometimes characterized as "co-benefits" to GHG reduction) in both in the near-term and the long-term. Beyond GHG emissions, increases in VMT also impact human health and the natural environment. Human health is impacted as increases in vehicle travel lead to more vehicle crashes, poorer air quality, increases in chronic diseases associated with reduced physical activity, and worse mental health. Increases in vehicle travel also negatively affect other road users, including pedestrians, cyclists, other motorists, and many transit users. The natural environment is impacted as higher VMT leads to more collisions with wildlife and fragments habitat. Additionally, development that leads to more vehicle travel also tends to consume more energy, water, and open space (including farmland and sensitive habitat). This increase in impermeable surfaces raises the flood risk and pollutant transport into waterways.[7]

VMT and Economic Growth. While it was previously believed that VMT growth was a necessary component of economic growth, data from the past two decades shows that economic growth is possible without a concomitant increase in VMT. (Figure 1.) Recent research shows that requiring development projects to mitigate LOS may actually reduce accessibility to destinations and impede economic growth.[8,9]

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[6] *Id.* at p. 76.

[7] Fang et al. (2017) *Cutting Greenhouse Gas Emissions Is Only the Beginning: A Literature Review of the Co-Benefits of Reducing Vehicle Miles Traveled*, available at https://ncst.ucdavis.edu/wp-content/uploads/2017/03/NCST-VMT-Co-Benefits-White-Paper_Fang_March-2017.pdf.

[8] Haynes et al. (Sept. 2015) *Congested Development: A Study of Traffic Delays, Access, and Economic Activity in Metropolitan Los Angeles*, available at http://www.its.ucla.edu/wp-content/uploads/sites/6/2015/11/Haynes_Congested-Development_1-Oct-2015_final.pdf.

[9] Osman et al. (Mar. 2016) *Not So Fast: A Study of Traffic Delays, Access, and Economic Activity in the San Francisco Bay Area*, available at http://www.its.ucla.edu/wp-content/uploads/sites/6/2016/08/Taylor-Not-so-Fast-04-01-2016_final.pdf.

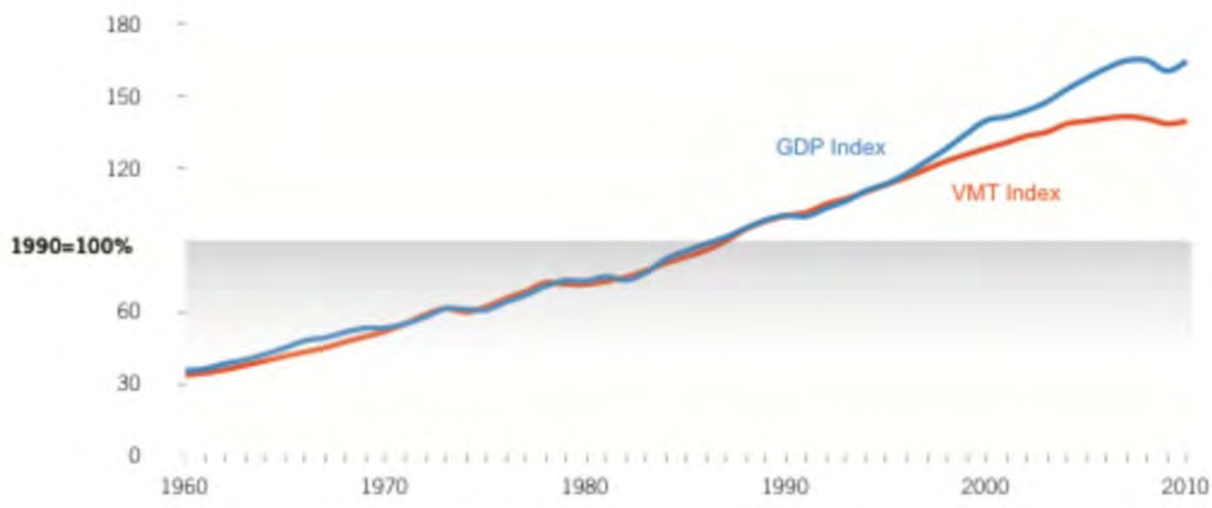

Figure 1. Kooshian and Winkelman (2011) *VMT and Gross Domestic Product (GDP), 1960-2010*.

C. Technical Considerations in Assessing Vehicle Miles Traveled

Many practitioners are familiar with accounting for VMT in connection with long-range planning, or as part of the CEQA analysis of a project's greenhouse gas emissions or energy impacts. This document provides technical information on how to assess VMT as part of a transportation impacts analysis under CEQA. Appendix 1 provides a description of which VMT to count and options on how to count it. Appendix 2 provides information on induced travel resulting from roadway capacity projects, including the mechanisms giving rise to induced travel, the research quantifying it, and information on additional approaches for assessing it.

1. Recommendations Regarding Methodology

Proposed Section 15064.3 explains that a "lead agency may use models to estimate a project's vehicle miles traveled . . . ." CEQA generally defers to lead agencies on the choice of methodology to analyze impacts. (*Santa Monica Baykeeper v. City of Malibu* (2011) 193 Cal.App.4th 1538, 1546; see *Laurel Heights Improvement Assn. v. Regents of University of California* (1988) 47 Cal.3d 376, 409 ["the issue is not whether the studies are irrefutable or whether they could have been better" … rather, the "relevant issue is only whether the studies are sufficiently credible to be considered" as part of the lead agency's overall evaluation].) This section provides suggestions to lead agencies regarding methodologies to analyze VMT associated with a project.

Vehicle Types. Proposed Section 15064.3, subdivision (a), states, "For the purposes of this section, 'vehicle miles traveled' refers to the amount and distance of automobile travel attributable to a project." Here, the term "automobile" refers to on-road passenger vehicles, specifically cars and light trucks. Heavy-duty truck VMT could be included for modeling convenience and ease of calculation (for example, where models or data provide combined auto and heavy truck VMT). For an apples-to-apples comparison, vehicle types considered should be consistent across project assessment, significance thresholds, and mitigation.

Residential and Office Projects. Tour- and trip-based approaches[10] offer the best methods for assessing VMT from residential/office projects and for comparing those assessments to VMT thresholds. These approaches also offer the most straightforward methods for assessing VMT reductions from mitigation measures for residential/office projects. When available, tour-based assessment is ideal because it captures travel behavior more comprehensively. But where tour-based tools or data are not available for all components of an analysis, a trip-based assessment of VMT serves as a reasonable proxy.

Models and methodologies used to calculate thresholds, estimate project VMT, and estimate VMT reduction due to mitigation should be comparable. For example:

- A tour-based assessment of project VMT should be compared to a tour-based threshold, or a trip-based assessment to a trip-based VMT threshold.
- Where a travel demand model is used to determine thresholds, the same model should also be used to provide trip lengths as part of assessing project VMT.
- Where only trip-based estimates of VMT reduction from mitigation are available, a trip-based threshold should be used, and project VMT should be assessed in a trip-based manner.

When a trip-based method is used to analyze a residential project, the focus can be on home-based trips. Similarly, when a trip-based method is used to analyze an office project, the focus can be on home-based work trips.

When tour-based models are used to analyze an office project, either employee work tour VMT or VMT from all employee tours may be attributed to the project. This is because workplace location influences overall travel. For consistency, the significance threshold should be based on the same metric: either employee work tour VMT or VMT from all employee tours.

For office projects that feature a customer component, such as a government office that serves the public, a lead agency can analyze the customer VMT component of the project using the methodology for retail development (see below).

Retail Projects. Generally, lead agencies should analyze the effects of a retail project by assessing the change in total VMT[11] because retail projects typically re-route travel from other retail destinations. A retail project might lead to increases or decreases in VMT, depending on previously existing retail travel patterns.

[10] See Appendix 1, *Considerations About Which VMT to Count,* for a description of these approaches.
[11] See Appendix 1, *Considerations About Which VMT to Count, "*Assessing Change in Total VMT" section, for a description of this approach.

Considerations for All Projects. Lead agencies should not truncate any VMT analysis because of jurisdictional or other boundaries, for example, by failing to count the portion of a trip that falls outside the jurisdiction or by discounting the VMT from a trip that crosses a jurisdictional boundary. CEQA requires environmental analyses to reflect a "good faith effort at full disclosure." (CEQA Guidelines, § 15151.) Thus, where methodologies exist that can estimate the full extent of vehicle travel from a project, the lead agency should apply them to do so. Where those VMT effects will grow over time, analyses should consider both a project's short-term and long-term effects on VMT.

Combining land uses for VMT analysis is not recommended. Different land uses generate different amounts of VMT, so the outcome of such an analysis could depend more on the mix of uses than on their travel efficiency. As a result, it could be difficult or impossible for a lead agency to connect a significance threshold with an environmental policy objective (such as a target set by law), inhibiting the CEQA imperative of identifying a project's significant impacts and providing mitigation where feasible. Combining land uses for a VMT analysis could streamline certain mixes of uses in a manner disconnected from policy objectives or environmental outcomes. Instead, OPR recommends analyzing each use separately, or simply focusing analysis on the dominant use, and comparing each result to the appropriate threshold. Recommendations for methods of analysis and thresholds are provided below. In the analysis of each use, a mixed-use project should take credit for internal capture.

Any project that includes in its geographic bounds a portion of an existing or planned Transit Priority Area (i.e., the project is within a ½ mile of an existing or planned major transit stop or an existing stop along a high quality transit corridor) may employ VMT as its primary metric of transportation impact for the entire project. (See Pub. Resources Code, § 21099, subds. (a)(7), (b)(1).)

Cumulative Impacts. A project's cumulative impacts are based on an assessment of whether the "incremental effects of an individual project are considerable when viewed in connection with the effects of past projects, the effects of other current projects, and the effects of probable future projects." (Pub. Resources Code, § 21083, subd. (b)(2); see CEQA Guidelines, § 15064, subd. (h)(1).) When using an absolute VMT metric, i.e., total VMT (as recommended below for retail and transportation projects), analyzing the combined impacts for a cumulative impacts analysis may be appropriate. However, metrics such as VMT per capita or VMT per employee, i.e., metrics framed in terms of efficiency (as recommended below for use on residential and office projects), cannot be summed because they employ a denominator. A project that falls below an efficiency-based threshold that is aligned with long-term environmental goals and relevant plans would have no cumulative impact distinct from the project impact. Accordingly, a finding of a less-than-significant project impact would imply a less than significant cumulative impact, and vice versa. This is similar to the analysis typically conducted for greenhouse gas emissions, air quality impacts, and impacts that utilize plan compliance as a threshold of significance. (See *Center for Biological Diversity v. Department of Fish & Wildlife* (2015) 62 Cal.4th 204, 219, 223; CEQA Guidelines, § 15064, subd. (h)(3).)

D. General Principles to Guide Consideration of VMT

SB 743 directs OPR to establish specific "criteria for determining the significance of transportation impacts of projects[.]" (Pub. Resources Code, § 21099, subd. (b)(1).) In establishing this criterion, OPR was guided by the general principles contained within CEQA, the CEQA Guidelines, and applicable case law.

To assist in the determination of significance, many lead agencies rely on "thresholds of significance." The CEQA Guidelines define a "threshold of significance" to mean "an identifiable **quantitative, qualitative**[12] **or performance level** of a particular environmental effect, non-compliance with which means the effect will ***normally*** be determined to be significant by the agency and compliance with which means the effect ***normally*** will be determined to be less than significant." (CEQA Guidelines, § 15064.7, subd. (a) (emphasis added).) Lead agencies have discretion to develop and adopt their own, or rely on thresholds recommended by other agencies, "provided the decision of the lead agency to adopt such thresholds is supported by substantial evidence." (*Id*. at subd. (c); *Save Cuyama Valley v. County of Santa Barbara* (2013) 213 Cal.App.4th 1059, 1068.) Substantial evidence means "enough relevant information and reasonable inferences from this information that a fair argument can be made to support a conclusion, even though other conclusions might also be reached." (*Id*. at § 15384 (emphasis added); *Protect the Historic Amador Waterways v. Amador Water Agency* (2004) 116 Cal.App.4th 1099, 1108-1109.)

Additionally, the analysis leading to the determination of significance need not be perfect. The CEQA Guidelines describe the standard for adequacy of environmental analyses:

> An EIR should be prepared with a sufficient degree of analysis to provide decision makers with information which enables them to **make a decision which intelligently takes account of environmental consequences**. An evaluation of the environmental effects of a proposed project need not be exhaustive, but the sufficiency of an EIR is to be reviewed in the light of what is **reasonably feasible**. Disagreement among experts does not make an EIR inadequate, but the EIR should summarize the main points of disagreement among the experts. The **courts have looked not for perfection** but for **adequacy**, **completeness**, and a **good faith effort** at full disclosure.

(CEQA Guidelines, § 15151 (emphasis added).)

These general principles guide OPR's recommendations regarding thresholds of significance for VMT set forth below.

[12] Generally, qualitative analyses should only be conducted when methods do not exist for undertaking a quantitative analysis.

E. Recommendations Regarding Significance Thresholds

As noted above, lead agencies have the discretion to set or apply their own thresholds of significance. (*Center for Biological Diversity v. California Dept. of Fish & Wildlife* (2015) 62 Cal.4th 204, 218-223 [lead agency had discretion to use compliance with AB 32's emissions goals as a significance threshold]; *Save Cuyama Valley v. County of Santa Barbara* (2013) 213 Cal.App.4th at p. 1068.) However, Section 21099 of the Public Resources Code states that the criteria for determining the significance of transportation impacts must promote: (1) reduction of greenhouse gas emissions; (2) development of multimodal transportation networks; and (3) a diversity of land uses. It further directed OPR to prepare and develop criteria for determining significance. (Pub. Resources Code, § 21099, subd. (b)(1).) This section provides OPR's suggested thresholds, as well as considerations for lead agencies that choose to adopt their own

The VMT metric can support the three statutory goals: "the reduction of greenhouse gas emissions, the development of multimodal transportation networks, ***and*** a diversity of land uses." (Pub. Resources Code, § 21099, subd. (b)(1), emphasis added.) However, in order for it to promote and support all three, lead agencies should select a significance threshold that aligns with state law on all three. State law concerning the development of multimodal transportation networks and diversity of land uses requires planning for and prioritizing increases in complete streets and infill development, but does not mandate a particular depth of implementation that could translate into a particular threshold of significance. Meanwhile, the State has clear quantitative targets for GHG emissions reduction set forth in law and based on scientific consensus, and the depth of VMT reduction needed to achieve those targets has been quantified. Tying VMT thresholds to GHG reduction also supports the two other statutory goals. Therefore, to ensure adequate analysis of transportation impacts, OPR recommends using quantitative VMT thresholds linked to GHG reduction targets when methods exist to do so.

Various legislative mandates and state policies establish quantitative greenhouse gas emissions reduction targets. For example:

- Assembly Bill 32 (2006) requires statewide GHG emissions reductions to 1990 levels by 2020 and continued reductions beyond 2020.
- Senate Bill 32 (2016) requires at least a 40 percent reduction in GHG emissions from 1990 levels by 2030.
- Pursuant to Senate Bill 375 (2008), the California Air Resources Board GHG emissions reduction targets for metropolitan planning organizations (MPOs) to achieve based on land use patterns and transportation systems specified in Regional Transportation Plans and Sustainable Community Strategies (RTP/SCS). Current targets for the State's largest MPOs call for a 19 percent reduction in GHG emissions from cars and light trucks from 2005 emissions levels by 2035.
- Executive Order B-30-15 (2015) sets a GHG emissions reduction target of 40 percent below 1990 levels by 2030.

- Executive Order S-3-05 (2005) sets a GHG emissions reduction target of 80 percent below 1990 levels by 2050.

- Executive Order B-16-12 (2012) specifies a GHG emissions reduction target of 80 percent below 1990 levels by 2050 specifically for transportation.

- Executive Order B-55-18 (2018) established an additional statewide goal of achieving carbon neutrality as soon as possible, but no later than 2045, and maintaining net negative emissions thereafter. It states, "The California Air Resources Board shall work with relevant state agencies to develop a framework for implementation and accounting that tracks progress toward this goal."

- Senate Bill 391 requires the California Transportation Plan to support 80 percent reduction in GHGs below 1990 levels by 2050.

- The *California Air Resources Board Mobile Source Strategy* (2016) describes California's strategy for containing air pollutant emissions from vehicles, and quantifies VMT growth compatible with achieving state targets.

- The California Air Resources Board's *2017 Climate Change Scoping Plan Update: The Strategy for Achieving California's 2030 Greenhouse Gas Target* describes California's strategy for containing GHG emissions from vehicles, and quantifies VMT growth compatible with achieving state targets.

Considering these various targets, the California Supreme Court observed:

> Meeting our statewide reduction goals does not preclude all new development. Rather, the Scoping Plan … assumes continued growth and depends on increased efficiency and conservation in land use and transportation from all Californians.

(*Center for Biological Diversity v. California Dept. of Fish & Wildlife*, *supra*, 62 Cal.4th at p. 220.) Indeed, the Court noted that when a lead agency uses consistency with climate goals as a way to determine significance, particularly for long-term projects, the lead agency must consider the project's effect on meeting long-term reduction goals. (*Ibid*.) And more recently, the Supreme Court stated that "CEQA requires public agencies . . . to ensure that such analysis stay in step with evolving scientific knowledge and state regulatory schemes." (*Cleveland National Forest Foundation v. San Diego Assn. of Governments* (2017) 3 Cal.5th 497, 504.)

Meeting the targets described above will require substantial reductions in existing VMT per capita to curb GHG emissions and other pollutants. But targets for overall GHG emissions reduction do not translate directly into VMT thresholds for individual projects for many reasons, including:

- Some, but not all, of the emissions reductions needed to achieve those targets could be accomplished by other measures, including increased vehicle efficiency and decreased fuel carbon content. The CARB's *First Update to the Climate Change Scoping Plan* explains:

"Achieving California's long-term criteria pollutant and GHG emissions goals will require four strategies to be employed: (1) improve vehicle efficiency and develop zero emission technologies, (2) reduce the carbon content of fuels and provide market support to get these lower-carbon fuels into the marketplace, (3) **plan and build communities to reduce vehicular GHG emissions and provide more transportation options, and (4) improve the efficiency and throughput of existing transportation systems.**"[13] CARB's *2018 Progress Report on California's Sustainable Communities and Climate Protection Act* states on page 28 that "California cannot meet its climate goals without curbing growth in single-occupancy vehicle activity." In other words, vehicle efficiency and better fuels are necessary, but insufficient, to address the GHG emissions from the transportation system. Land use patterns and transportation options also will need to change to support reductions in vehicle travel/VMT.

- New land use projects alone will not sufficiently reduce per-capita VMT to achieve those targets, nor are they expected to be the sole source of VMT reduction.

- Interactions between land use projects, and also between land use and transportation projects, existing and future, together affect VMT.

- Because location within the region is the most important determinant of VMT, in some cases, streamlining CEQA review of projects in travel efficient locations may be the most effective means of reducing VMT.

- When assessing climate impacts of some types of land use projects, use of an efficiency metric (e.g., per capita, per employee) may provide a better measure of impact than an absolute numeric threshold. (*Center for Biological Diversity*, *supra*.)

Public Resources Code section 21099 directs OPR to propose criteria for determining the significance of transportation impacts. In this Technical Advisory, OPR provides its recommendations to assist lead agencies in selecting a significance threshold that may be appropriate for their particular projects. While OPR's Technical Advisory is not binding on public agencies, CEQA allows lead agencies to "consider thresholds of significance . . . recommended by other public agencies, provided the decision to adopt those thresholds is supported by substantial evidence." (CEQA Guidelines, § 15064.7, subd. (c).) Based on OPR's extensive review of the applicable research, and in light of an assessment by the California Air Resources Board quantifying the need for VMT reduction in order to meet the State's long-term climate goals, **OPR recommends that a per capita or per employee VMT that is fifteen percent below that of existing development may be a reasonable threshold**.

Fifteen percent reductions in VMT are achievable at the project level in a variety of place types.[14]

Moreover, a fifteen percent reduction is consistent with SB 743's direction to OPR to select a threshold that will help the State achieve its climate goals. As described above, section 21099 states that the

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[13] California Air Resources Board (May 2014) *First Update to the Climate Change Scoping Plan*, p. 46 (emphasis added).
[14] CAPCOA (2010) *Quantifying Greenhouse Gas Mitigation Measures*, p. 55, available at http://www.capcoa.org/wp-content/uploads/2010/11/CAPCOA-Quantification-Report-9-14-Final.pdf.

criteria for determining significance must "promote the reduction in greenhouse gas emissions." In its document *California Air Resources Board 2017 Scoping Plan-Identified VMT Reductions and Relationship to State Climate Goals*[15], CARB assesses VMT reduction per capita consistent with its evidence-based modeling scenario that would achieve State climate goals of 40 percent GHG emissions reduction from 1990 levels by 2030 and 80 percent GHG emissions reduction levels from 1990 by 2050. Applying California Department of Finance population forecasts, CARB finds per-capita light-duty vehicle travel would need to be approximately 16.8 percent lower than existing, and overall per-capita vehicle travel would need to be approximately 14.3 percent lower than existing levels under that scenario. Below these levels, a project could be considered low VMT and would, on that metric, be consistent with 2017 Scoping Plan Update assumptions that achieve climate state climate goals.

CARB finds per capita vehicle travel would need to be kept below what today's policies and plans would achieve.

CARB's assessment is based on data in the 2017 Scoping Plan Update and 2016 Mobile Source Strategy. In those documents, CARB previously examined the relationship between VMT and the state's GHG emissions reduction targets. The Scoping Plan finds:

> "While the State can do more to accelerate and incentivize these local decisions, local actions that reduce VMT are also necessary to meet transportation sector-specific goals and achieve the 2030 target under SB 32. Through developing the Scoping Plan, CARB staff is more convinced than ever that, in addition to achieving GHG reductions from cleaner fuels and vehicles, California must also reduce VMT. Stronger SB 375 GHG reduction targets will enable the State to make significant progress toward needed reductions, but alone will not provide the VMT growth reductions needed; there is a gap between what SB 375 can provide and what is needed to meet the State's 2030 and 2050 goals."[16]

Note that, at present, consistency with RTP/SCSs does not necessarily lead to a less-than-significant VMT impact.[17] As the Final 2017 Scoping Plan Update states,

> VMT reductions are necessary to achieve the 2030 target and must be part of any strategy evaluated in this Plan. Stronger SB 375 GHG reduction targets will enable the State to make significant progress toward this goal, but alone will not provide all of the VMT growth reductions that will be needed. There is a gap between what SB 375 can provide and what is needed to meet the State's 2030 and 2050 goals."[18]

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[15] California Air Resources Board (Jan. 2019) *California Air Resources Board 2017 Scoping Plan-Identified VMT Reductions and Relationship to State Climate Goals*, available at https://ww2.arb.ca.gov/resources/documents/carb-2017-scoping-plan-identified-vmt-reductions-and-relationship-state-climate.

[16] California Air Resources Board (Nov. 2017) *California's 2017 Climate Change Scoping Plan*, p. 101.

[17] California Air Resources Board (Feb. 2018) *Updated Final Staff Report: Proposed Update to the SB 375 Greenhouse Gas Emission Reduction Targets*, Figure 3, p. 35, available at https://www.arb.ca.gov/cc/sb375/sb375_target_update_final_staff_report_feb2018.pdf.

[18] California Air Resources Board (Nov. 2017) *California's 2017 Climate Change Scoping Plan*, p. 75.

Also, in order to capture the full effects of induced travel resulting from roadway capacity projects, an RTP/SCS would need to include an assessment of land use effects of those projects, and the effects of those land uses on VMT. (See section titled "*Estimating VMT Impacts from Transportation Projects*" below.) RTP/SCSs typically model VMT using a collaboratively-developed land use "vision" for the region's land use, rather than studying the effects on land use of the proposed transportation investments.

In summary, achieving 15 percent lower per capita (residential) or per employee (office) VMT than existing development is both generally achievable and is supported by evidence that connects this level of reduction to the State's emissions goals.

1. Screening Thresholds for Land Use Projects

Many agencies use "screening thresholds" to quickly identify when a project should be expected to cause a less-than-significant impact without conducting a detailed study. (See e.g., CEQA Guidelines, §§ 15063(c)(3)(C), 15128, and Appendix G.) As explained below, this technical advisory suggests that lead agencies may screen out VMT impacts using project size, maps, transit availability, and provision of affordable housing.

Screening Threshold for Small Projects

Many local agencies have developed screening thresholds to indicate when detailed analysis is needed. Absent substantial evidence indicating that a project would generate a potentially significant level of VMT, or inconsistency with a Sustainable Communities Strategy (SCS) or general plan, projects that generate or attract fewer than 110 trips per day[19] generally may be assumed to cause a less-than-significant transportation impact.

Map-Based Screening for Residential and Office Projects

Residential and office projects that locate in areas with low VMT, and that incorporate similar features (i.e., density, mix of uses, transit accessibility), will tend to exhibit similarly low VMT. Maps created with VMT data, for example from a travel survey or a travel demand model, can illustrate areas that are

[19] CEQA provides a categorical exemption for existing facilities, including additions to existing structures of up to 10,000 square feet, so long as the project is in an area where public infrastructure is available to allow for maximum planned development and the project is not in an environmentally sensitive area. (CEQA Guidelines, § 15301, subd. (e)(2).) Typical project types for which trip generation increases relatively linearly with building footprint (i.e., general office building, single tenant office building, office park, and business park) generate or attract an additional 110-124 trips per 10,000 square feet. Therefore, absent substantial evidence otherwise, it is reasonable to conclude that the addition of 110 or fewer trips could be considered not to lead to a significant impact.

currently below threshold VMT (see recommendations below). Because new development in such locations would likely result in a similar level of VMT, such maps can be used to screen out residential and office projects from needing to prepare a detailed VMT analysis.

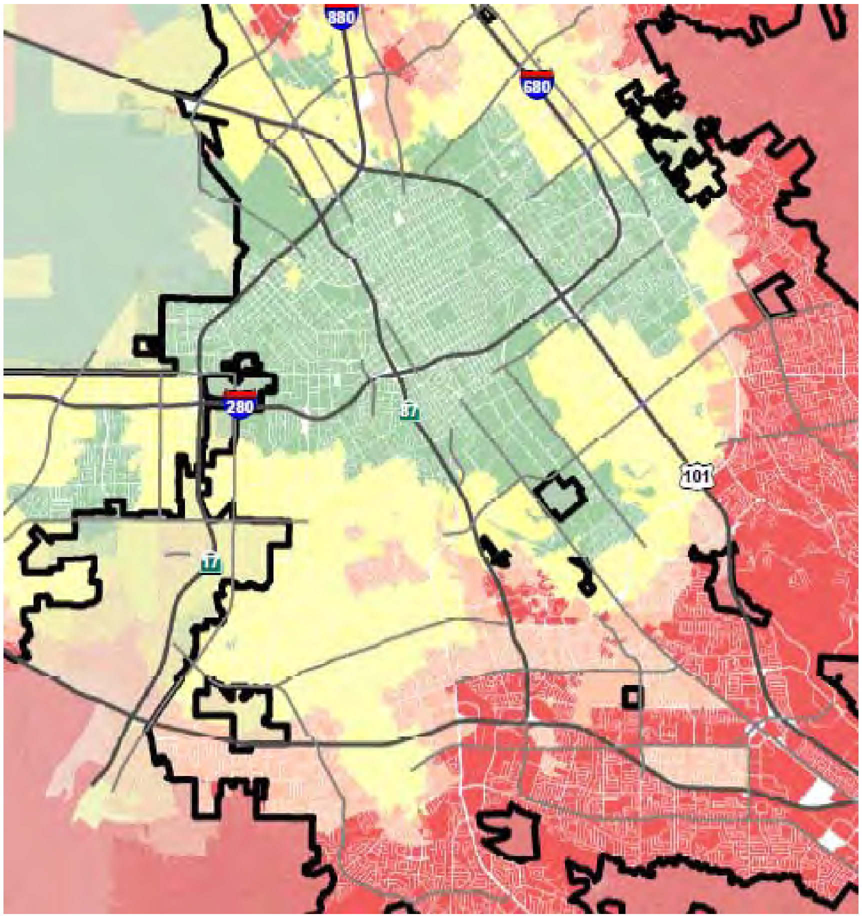

Figure 2. Example map of household VMT that could be used to delineate areas eligible to receive streamlining for VMT analysis. (Source: City of San José, Department of Transportation, draft output of City Transportation Model.)

Presumption of Less Than Significant Impact Near Transit Stations

Proposed CEQA Guideline Section 15064.3, subdivision (b)(1), states that lead agencies generally should presume that certain projects (including residential, retail, and office projects, as well as projects that are a mix of these uses) proposed within ½ mile of an existing major transit stop[20] or an existing stop

[20] Pub. Resources Code, § 21064.3 ("'Major transit stop' means a site containing an existing rail transit station, a ferry terminal served by either a bus or rail transit service, or the intersection of two or more major bus routes with a frequency of service interval of 15 minutes or less during the morning and afternoon peak commute periods.").

along a high quality transit corridor[21] will have a less-than-significant impact on VMT. This presumption would not apply, however, if project-specific or location-specific information indicates that the project will still generate significant levels of VMT. For example, the presumption might not be appropriate if the project:

- Has a Floor Area Ratio (FAR) of less than 0.75
- Includes more parking for use by residents, customers, or employees of the project than required by the jurisdiction (if the jurisdiction requires the project to supply parking)
- Is inconsistent with the applicable Sustainable Communities Strategy (as determined by the lead agency, with input from the Metropolitan Planning Organization)
- Replaces affordable residential units with a smaller number of moderate- or high-income residential units

A project or plan near transit which replaces affordable residential units[22] with a smaller number of moderate- or high-income residential units may increase overall VMT because the increase in VMT of displaced residents could overwhelm the improvements in travel efficiency enjoyed by new residents.[23]

If any of these exceptions to the presumption might apply, the lead agency should conduct a detailed VMT analysis to determine whether the project would exceed VMT thresholds (see below).

Presumption of Less Than Significant Impact for Affordable Residential Development

Adding affordable housing to infill locations generally improves jobs-housing match, in turn shortening commutes and reducing VMT.[24,25] Further, "… low-wage workers in particular would be more likely to choose a residential location close to their workplace, if one is available."[26] In areas where existing jobs-housing match is closer to optimal, low income housing nevertheless generates less VMT than market-

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[21] Pub. Resources Code, § 21155 ("For purposes of this section, a high-quality transit corridor means a corridor with fixed route bus service with service intervals no longer than 15 minutes during peak commute hours.").
[22] Including naturally-occurring affordable residential units.
[23] Chapple et al. (2017) *Developing a New Methodology for Analyzing Potential Displacement,* Chapter 4, pp. 159-160, available at https://www.arb.ca.gov/research/apr/past/13-310.pdf.
[24] Karner and Benner (2016) *The convergence of social equity and environmental sustainability: Jobs-housing fit and commute distance* ("[P]olicies that advance a more equitable distribution of jobs and housing by linking the affordability of locally available housing with local wage levels are likely to be associated with reduced commuting distances").
[25] Karner and Benner (2015) *Low-wage jobs-housing fit: identifying locations of affordable housing shortages.*
[26] Karner and Benner (2015) *Low-wage jobs-housing fit: identifying locations of affordable housing shortages.*

rate housing.[27,28] Therefore, a project consisting of a high percentage of affordable housing may be a basis for the lead agency to find a less-than-significant impact on VMT. Evidence supports a presumption of less than significant impact for a 100 percent affordable residential development (or the residential component of a mixed-use development) in infill locations. Lead agencies may develop their own presumption of less than significant impact for residential projects (or residential portions of mixed use projects) containing a particular amount of affordable housing, based on local circumstances and evidence. Furthermore, a project which includes any affordable residential units may factor the effect of the affordability on VMT into the assessment of VMT generated by those units.

2. Recommended Numeric Thresholds for Residential, Office, and Retail Projects

Recommended threshold for residential projects: A proposed project exceeding a level of 15 percent below existing VMT per capita may indicate a significant transportation impact. Existing VMT per capita may be measured as regional VMT per capita or as city VMT per capita. Proposed development referencing a threshold based on city VMT per capita (rather than regional VMT per capita) should not cumulatively exceed the number of units specified in the SCS for that city, and should be consistent with the SCS.

Residential development that would generate vehicle travel that is 15 or more percent below the existing residential VMT per capita, measured against the region or city, may indicate a less-than-significant transportation impact. In MPO areas, development measured against city VMT per capita (rather than regional VMT per capita) should not cumulatively exceed the population or number of units specified in the SCS for that city because greater-than-planned amounts of development in areas above the region-based threshold would undermine the VMT containment needed to achieve regional targets under SB 375.

For residential projects in unincorporated county areas, the local agency can compare a residential project's VMT to (1) the region's VMT per capita, or (2) the aggregate population-weighted VMT per capita of all cities in the region. In MPO areas, development in unincorporated areas measured against aggregate city VMT per capita (rather than regional VMT per capita) should not cumulatively exceed the population or number of units specified in the SCS for that city because greater-than-planned amounts of development in areas above the regional threshold would undermine achievement of regional targets under SB 375.

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[27] Chapple et al. (2017) *Developing a New Methodology for Analyzing Potential Displacement*, available at https://www.arb.ca.gov/research/apr/past/13-310.pdf.

[28] CAPCOA (2010) *Quantifying Greenhouse Gas Mitigation Measures*, pp. 176-178, available at http://www.capcoa.org/wp-content/uploads/2010/11/CAPCOA-Quantification-Report-9-14-Final.pdf.

These thresholds can be applied to either household (i.e., tour-based) VMT or home-based (i.e., trip-based) VMT assessments.[29] It is critical, however, that the agency be consistent in its VMT measurement approach throughout the analysis to maintain an "apples-to-apples" comparison. For example, if the agency uses a home-based VMT for the threshold, it should also be use home-based VMT for calculating project VMT and VMT reduction due to mitigation measures.

Recommended threshold for office projects: A proposed project exceeding a level of 15 percent below existing regional VMT per employee may indicate a significant transportation impact.

Office projects that would generate vehicle travel exceeding 15 percent below existing VMT per employee for the region may indicate a significant transportation impact. In cases where the region is substantially larger than the geography over which most workers would be expected to live, it might be appropriate to refer to a smaller geography, such as the county, that includes the area over which nearly all workers would be expected to live.

Office VMT screening maps can be developed using tour-based data, considering either total employee VMT or employee work tour VMT. Similarly, tour-based analysis of office project VMT could consider either total employee VMT or employee work tour VMT. Where tour-based information is unavailable for threshold determination, project assessment, or assessment of mitigation, home-based work trip VMT should be used throughout all steps of the analysis to maintain an "apples-to-apples" comparison.

Recommended threshold for retail projects: A net increase in total VMT may indicate a significant transportation impact.

Because new retail development typically redistributes shopping trips rather than creating new trips,[30] estimating the total change in VMT (i.e., the difference in total VMT in the area affected with and without the project) is the best way to analyze a retail project's transportation impacts.

By adding retail opportunities into the urban fabric and thereby improving retail destination proximity, local-serving retail development tends to shorten trips and reduce VMT. Thus, lead agencies generally may presume such development creates a less-than-significant transportation impact. Regional-serving retail development, on the other hand, which can lead to substitution of longer trips for shorter ones, may tend to have a significant impact. Where such development decreases VMT, lead agencies should consider the impact to be less-than-significant.

Many cities and counties define local-serving and regional-serving retail in their zoning codes. Lead agencies may refer to those local definitions when available, but should also consider any project-

[29] See Appendix 1 for a description of these approaches.
[30] Lovejoy, et al. (2013) *Measuring the impacts of local land-use policies on vehicle miles of travel: The case of the first big-box store in Davis, California, The Journal of Transport and Land Use*.

specific information, such as market studies or economic impacts analyses that might bear on customers' travel behavior. Because lead agencies will best understand their own communities and the likely travel behaviors of future project users, they are likely in the best position to decide when a project will likely be local-serving. Generally, however, retail development including stores larger than 50,000 square feet might be considered regional-serving, and so lead agencies should undertake an analysis to determine whether the project might increase or decrease VMT.

Mixed-Use Projects

Lead agencies can evaluate each component of a mixed-use project independently and apply the significance threshold for each project type included (e.g., residential and retail). Alternatively, a lead agency may consider only the project's dominant use. In the analysis of each use, a project should take credit for internal capture. Combining different land uses and applying one threshold to those land uses may result in an inaccurate impact assessment.

Other Project Types

Of land use projects, residential, office, and retail projects tend to have the greatest influence on VMT. For that reason, OPR recommends the quantified thresholds described above for purposes of analysis and mitigation. Lead agencies, using more location-specific information, may develop their own more specific thresholds, which may include other land use types. In developing thresholds for other project types, or thresholds different from those recommended here, lead agencies should consider the purposes described in section 21099 of the Public Resources Code and regulations in the CEQA Guidelines on the development of thresholds of significance (e.g., CEQA Guidelines, § 15064.7).

Strategies and projects that decrease local VMT but increase total VMT should be avoided. Agencies should consider whether their actions encourage development in a less travel-efficient location by limiting development in travel-efficient locations.

Redevelopment Projects

Where a project replaces existing VMT-generating land uses, if the replacement leads to a net overall decrease in VMT, the project would lead to a less-than-significant transportation impact. If the project leads to a net overall increase in VMT, then the thresholds described above should apply.

As described above, a project or plan near transit which replaces affordable[31] residential units with a smaller number of moderate- or high-income residential units may increase overall VMT, because

[31] Including naturally-occurring affordable residential units.

displaced residents' VMT may increase.[32] A lead agency should analyze VMT for such a project even if it otherwise would have been presumed less than significant. The assessment should incorporate an estimate of the aggregate VMT increase experienced by displaced residents. That additional VMT should be included in the numerator of the VMT per capita assessed for the project.

If a residential or office project leads to a net increase in VMT, then the project's VMT per capita (residential) or per employee (office) should be compared to thresholds recommended above. Per capita and per employee VMT are efficiency metrics, and, as such, apply only to the existing project without regard to the VMT generated by the previously existing land use.

If the project leads to a net increase in provision of locally-serving retail, transportation impacts from the retail portion of the development should be presumed to be less than significant. If the project consists of regionally-serving retail, and increases overall VMT compared to with existing uses, then the project would lead to a significant transportation impact.

RTP/SCS Consistency (All Land Use Projects)

Section 15125, subdivision (d), of the CEQA Guidelines provides that lead agencies should analyze impacts resulting from inconsistencies with regional plans, including regional transportation plans. For this reason, if a project is inconsistent with the Regional Transportation Plan and Sustainable Communities Strategy (RTP/SCS), the lead agency should evaluate whether that inconsistency indicates a significant impact on transportation. For example, a development may be inconsistent with an RTP/SCS if the development is outside the footprint of development or within an area specified as open space as shown in the SCS.

3. Recommendations Regarding Land Use Plans

As with projects, agencies should analyze VMT outcomes of land use plans across the full area over which the plan may substantively affect travel patterns, including beyond the boundary of the plan or jurisdiction's geography. And as with projects, VMT should be counted in full rather than split between origin and destination. (Emissions inventories have sometimes spit cross-boundary trips in order to sum to a regional total, but CEQA requires accounting for the full impact without truncation or discounting). Analysis of specific plans may employ the same thresholds described above for projects. A general plan, area plan, or community plan may have a significant impact on transportation if proposed new residential, office, or retail land uses would in aggregate exceed the respective thresholds recommended above. Where the lead agency tiers from a general plan EIR pursuant to CEQA Guidelines sections 15152 and 15166, the lead agency generally focuses on the environmental impacts that are specific to the later project and were not analyzed as significant impacts in the prior EIR. (Pub. Resources Code, § 21068.5; Guidelines, § 15152, subd. (a).) Thus, in analyzing the later project, the lead agency

[32] Chapple et al. (2017) *Developing a New Methodology for Analyzing Potential Displacement,* Chapter 4, pp. 159-160, available at https://www.arb.ca.gov/research/apr/past/13-310.pdf.

would focus on the VMT impacts that were not adequately addressed in the prior EIR. In the tiered document, the lead agency should continue to apply the thresholds recommended above.

Thresholds for plans in non-MPO areas may be determined on a case-by-case basis.

4. Other Considerations

Rural Projects Outside of MPOs

In rural areas of non-MPO counties (i.e., areas not near established or incorporated cities or towns), fewer options may be available for reducing VMT, and significance thresholds may be best determined on a case-by-case basis. Note, however, that clustered small towns and small town main streets may have substantial VMT benefits compared to isolated rural development, similar to the transit oriented development described above.

Impacts to Transit

Because criteria for determining the significance of transportation impacts must promote "the development of multimodal transportation networks" pursuant to Public Resources Code section 21099, subd. (b)(1), lead agencies should consider project impacts to transit systems and bicycle and pedestrian networks. For example, a project that blocks access to a transit stop or blocks a transit route itself may interfere with transit functions. Lead agencies should consult with transit agencies as early as possible in the development process, particularly for projects that are located within one half mile of transit stops.

When evaluating impacts to multimodal transportation networks, lead agencies generally should not treat the addition of new transit users as an adverse impact. An infill development may add riders to transit systems and the additional boarding and alighting may slow transit vehicles, but it also adds destinations, improving proximity and accessibility. Such development also improves regional vehicle flow by adding less vehicle travel onto the regional network.

Increased demand throughout a region may, however, cause a cumulative impact by requiring new or additional transit infrastructure. Such impacts may be adequately addressed through a fee program that fairly allocates the cost of improvements not just to projects that happen to locate near transit, but rather across a region to all projects that impose burdens on the entire transportation system, since transit can broadly improve the function of the transportation system.

F. Considering the Effects of Transportation Projects on Vehicle Travel

Many transportation projects change travel patterns. A transportation project which leads to additional vehicle travel on the roadway network, commonly referred to as "induced vehicle travel," would need to quantify the amount of additional vehicle travel in order to assess air quality impacts, greenhouse gas emissions impacts, energy impacts, and noise impacts. Transportation projects also are required to examine induced growth impacts under CEQA. (See generally, Pub. Resources Code, §§ 21065 [defining "project" under CEQA as an activity as causing either a direct or reasonably foreseeable indirect physical change], 21065.3 [defining "project-specific effect" to mean all direct or indirect environmental effects], 21100, subd. (b) [required contents of an EIR].) For any project that increases vehicle travel, explicit assessment and quantitative reporting of the amount of additional vehicle travel should not be omitted from the document; such information may be useful and necessary for a full understanding of a project's environmental impacts. (See Pub. Resources Code, §§ 21000, 21001, 21001.1, 21002, 21002.1 [discussing the policies of CEQA].) A lead agency that uses the VMT metric to assess the transportation impacts of a transportation project may simply report that change in VMT as the impact. When the lead agency uses another metric to analyze the transportation impacts of a roadway project, changes in amount of vehicle travel added to the roadway network should still be analyzed and reported.[33]

While CEQA does not require perfection, it is important to make a reasonably accurate estimate of transportation projects' effects on vehicle travel in order to make reasonably accurate estimates of GHG emissions, air quality emissions, energy impacts, and noise impacts. (See, e.g., *California Clean Energy Com. v. City of Woodland* (2014) 225 Cal.App.4th 173, 210 [EIR failed to consider project's transportation energy impacts]; *Ukiah Citizens for Safety First v. City of Ukiah* (2016) 248 Cal.App.4th 256, 266.) Appendix 2 describes in detail the causes of induced vehicle travel, the robust empirical evidence of induced vehicle travel, and how models and research can be used in conjunction to quantitatively assess induced vehicle travel with reasonable accuracy.

If a project would likely lead to a measurable and substantial increase in vehicle travel, the lead agency should conduct an analysis assessing the amount of vehicle travel the project will induce. Project types that would likely lead to a measurable and substantial increase in vehicle travel generally include:

- Addition of through lanes on existing or new highways, including general purpose lanes, HOV lanes, peak period lanes, auxiliary lanes, or lanes through grade-separated interchanges

Projects that would not likely lead to a substantial or measurable increase in vehicle travel, and therefore generally should not require an induced travel analysis, include:

- Rehabilitation, maintenance, replacement, safety, and repair projects designed to improve the condition of existing transportation assets (e.g., highways; roadways; bridges; culverts; Transportation Management System field elements such as cameras, message signs, detection, or signals; tunnels; transit systems; and assets that serve bicycle and pedestrian facilities) and that do not add additional motor vehicle capacity
- Roadside safety devices or hardware installation such as median barriers and guardrails

[33] See, e.g., California Department of Transportation (2006) *Guidance for Preparers of Growth-related, Indirect Impact Analyses*, available at http://www.dot.ca.gov/ser/Growth-related_IndirectImpactAnalysis/GRI_guidance06May_files/gri_guidance.pdf.

- Roadway shoulder enhancements to provide “breakdown space,” dedicated space for use only by transit vehicles, to provide bicycle access, or to otherwise improve safety, but which will not be used as automobile vehicle travel lanes
- Addition of an auxiliary lane of less than one mile in length designed to improve roadway safety
- Installation, removal, or reconfiguration of traffic lanes that are not for through traffic, such as left, right, and U-turn pockets, two-way left turn lanes, or emergency breakdown lanes that are not utilized as through lanes
- Addition of roadway capacity on local or collector streets provided the project also substantially improves conditions for pedestrians, cyclists, and, if applicable, transit
- Conversion of existing general purpose lanes (including ramps) to managed lanes or transit lanes, or changing lane management in a manner that would not substantially increase vehicle travel
- Addition of a new lane that is permanently restricted to use only by transit vehicles
- Reduction in number of through lanes
- Grade separation to separate vehicles from rail, transit, pedestrians or bicycles, or to replace a lane in order to separate preferential vehicles (e.g., HOV, HOT, or trucks) from general vehicles
- Installation, removal, or reconfiguration of traffic control devices, including Transit Signal Priority (TSP) features
- Installation of traffic metering systems, detection systems, cameras, changeable message signs and other electronics designed to optimize vehicle, bicycle, or pedestrian flow
- Timing of signals to optimize vehicle, bicycle, or pedestrian flow
- Installation of roundabouts or traffic circles
- Installation or reconfiguration of traffic calming devices
- Adoption of or increase in tolls
- Addition of tolled lanes, where tolls are sufficient to mitigate VMT increase
- Initiation of new transit service
- Conversion of streets from one-way to two-way operation with no net increase in number of traffic lanes
- Removal or relocation of off-street or on-street parking spaces
- Adoption or modification of on-street parking or loading restrictions (including meters, time limits, accessible spaces, and preferential/reserved parking permit programs)
- Addition of traffic wayfinding signage
- Rehabilitation and maintenance projects that do not add motor vehicle capacity
- Addition of new or enhanced bike or pedestrian facilities on existing streets/highways or within existing public rights-of-way
- Addition of Class I bike paths, trails, multi-use paths, or other off-road facilities that serve non-motorized travel
- Installation of publicly available alternative fuel/charging infrastructure
- Addition of passing lanes, truck climbing lanes, or truck brake-check lanes in rural areas that do not increase overall vehicle capacity along the corridor

1. Recommended Significance Threshold for Transportation Projects

As noted in Section 15064.3 of the CEQA Guidelines, lead agencies for roadway capacity projects have discretion, consistent with CEQA and planning requirements, to choose which metric to use to evaluate transportation impacts. This section recommends considerations for evaluating impacts using vehicle miles traveled. Lead agencies have discretion to choose a threshold of significance for transportation projects as they do for other types of projects. As explained above, Public Resources Code section 21099, subdivision (b)(1), provides that criteria for determining the significance of transportation impacts must promote the reduction of greenhouse gas emissions, the development of multimodal transportation networks, and a diversity of land uses. (*Id.;* see generally, adopted CEQA Guidelines, § 15064.3, subd. (b) [Criteria for Analyzing Transportation Impacts].) With those goals in mind, OPR prepared and the Agency adopted an appropriate transportation metric.

Whether adopting a threshold of significance, or evaluating transportation impacts on a case-by-case basis, a lead agency should ensure that the analysis addresses:

- Direct, indirect and cumulative effects of the transportation project (CEQA Guidelines, § 15064, subds. (d), (h))
- Near-term and long-term effects of the transportation project (CEQA Guidelines, §§ 15063, subd. (a)(1), 15126.2, subd. (a))
- The transportation project's consistency with state greenhouse gas reduction goals (Pub. Resources Code, § 21099)[34]
- The impact of the transportation project on the development of multimodal transportation networks (Pub. Resources Code, § 21099)
- The impact of the transportation project on the development of a diversity of land uses (Pub. Resources Code, § 21099)

The CARB Scoping Plan and the CARB Mobile Source Strategy delineate VMT levels required to achieve legally mandated GHG emissions reduction targets. A lead agency should develop a project-level threshold based on those VMT levels, and may apply the following approach:

1. Propose a fair-share allocation of those budgets to their jurisdiction (e.g., by population);

[34] The California Air Resources Board has ascertained the limits of VMT growth compatible with California containing greenhouse gas emissions to levels research shows would allow for climate stabilization. (See *The 2017 Climate Change Scoping Plan: The Strategy for Achieving California's 2030 Greenhouse Gas Target* (p. 78, p. 101); *Mobile Source Strategy* (p. 37).) CARB's *Updated Final Staff Report on Proposed Update to the SB 375 Greenhouse Gas Emission Reduction Targets* illustrates that the current Regional Transportation Plans and Sustainable Communities Strategies will fall short of achieving the necessary on-road transportation-related GHG emissions reductions called for in the 2017 Scoping Plan (Figure 3, p. 35). Accordingly, OPR recommends not basing GHG emissions or transportation impact analysis for a transportation project solely on consistency with an RTP/SCS.

2. Determine the amount of VMT growth likely to result from background population growth, and subtract that from their “budget”;
3. Allocate their jurisdiction’s share between their various VMT-increasing transportation projects, using whatever criteria the lead agency prefers.

2. Estimating VMT Impacts from Transportation Projects

CEQA requires analysis of a project’s potential growth-inducing impacts. (Pub. Resources Code, § 21100, subd. (b)(5); CEQA Guidelines, § 15126.2, subd. (d).) Many agencies are familiar with the analysis of growth inducing impacts associated with water, sewer, and other infrastructure. This technical advisory addresses growth that may be expected from roadway expansion projects.

Because a roadway expansion project can induce substantial VMT, incorporating quantitative estimates of induced VMT is critical to calculating both transportation and other impacts of these projects. Induced travel also has the potential to reduce or eliminate congestion relief benefits. An accurate estimate of induced travel is needed to accurately weigh costs and benefits of a highway capacity expansion project.

The effect of a transportation project on vehicle travel should be estimated using the “change in total VMT” method described in *Appendix 1*. This means that an assessment of total VMT without the project and an assessment with the project should be made; the difference between the two is the amount of VMT attributable to the project. The assessment should cover the full area in which driving patterns are expected to change. As with other types of projects, the VMT estimation should not be truncated at a modeling or jurisdictional boundary for convenience of analysis when travel behavior is substantially affected beyond that boundary.

Transit and Active Transportation Projects

Transit and active transportation projects generally reduce VMT and therefore are presumed to cause a less-than-significant impact on transportation. This presumption may apply to all passenger rail projects, bus and bus rapid transit projects, and bicycle and pedestrian infrastructure projects. Streamlining transit and active transportation projects aligns with each of the three statutory goals contained in SB 743 by reducing GHG emissions, increasing multimodal transportation networks, and facilitating mixed use development.

Roadway Projects

Reducing roadway capacity (for example, by removing or repurposing motor vehicle travel lanes) will generally reduce VMT and therefore is presumed to cause a less-than-significant impact on transportation. Generally, no transportation analysis is needed for such projects.

Building new roadways, adding roadway capacity in congested areas, or adding roadway capacity to areas where congestion is expected in the future, typically induces additional vehicle travel. For the types of projects previously indicated as likely to lead to additional vehicle travel, an estimate should be made of the change in vehicle travel resulting from the project.

For projects that increase roadway capacity, lead agencies can evaluate induced travel quantitatively by applying the results of existing studies that examine the magnitude of the increase of VMT resulting from a given increase in lane miles. These studies estimate the percent change in VMT for every percent change in miles to the roadway system (i.e., "elasticity").[35] Given that lead agencies have discretion in choosing their methodology, and the studies on induced travel reveal a range of elasticities, lead agencies may appropriately apply professional judgment in studying the transportation effects of a particular project. The most recent major study, estimates an elasticity of 1.0, meaning that every percent change in lane miles results in a one percent increase in VMT.[36]

To estimate VMT impacts from roadway expansion projects:

1. Determine the total lane-miles over an area that fully captures travel behavior changes resulting from the project (generally the region, but for projects affecting interregional travel look at all affected regions).
2. Determine the percent change in total lane miles that will result from the project.
3. Determine the total existing VMT over that same area.
4. Multiply the percent increase in lane miles by the existing VMT, and then multiply that by the elasticity from the induced travel literature:

[% increase in lane miles] x [existing VMT] x [elasticity] = [VMT resulting from the project]

A National Center for Sustainable Transportation tool can be used to apply this method: https://ncst.ucdavis.edu/research/tools

This method would not be suitable for rural (non-MPO) locations in the state which are neither congested nor projected to become congested. It also may not be suitable for a new road that provides new connectivity across a barrier (e.g., a bridge across a river) if it would be expected to substantially

[35] See U.C. Davis, Institute for Transportation Studies (Oct. 2015) *Increasing Highway Capacity Unlikely to Relieve Traffic Congestion*; Boarnet and Handy (Sept. 2014) *Impact of Highway Capacity and Induced Travel on Passenger Vehicle Use and Greenhouse Gas Emissions*, California Air Resources Board Policy Brief, available at https://www.arb.ca.gov/cc/sb375/policies/hwycapacity/highway_capacity_brief.pdf.
[36] See Duranton and Turner (2011) *The Fundamental Law of Road Congestion: Evidence from US cities*, available at http://www.nber.org/papers/w15376.

shorten existing trips. If it is likely to be substantial, the trips-shortening effect should be examined explicitly.

The effects of roadway capacity on vehicle travel can also be applied at a programmatic level. For example, in a regional planning process the lead agency can use that program-level analysis to streamline later project-level analysis. (See CEQA Guidelines, § 15168.) A program-level analysis of VMT should include effects of the program on land use patterns, and the VMT that results from those land use effects. In order for a program-level document to adequately analyze potential induced demand from a project or program of roadway capacity expansion, lead agencies cannot assume a fixed land use pattern (i.e., a land use pattern that does not vary in response to the provision of roadway capacity). A proper analysis should account for land use investment and development pattern changes that react in a reasonable manner to changes in accessibility created by transportation infrastructure investments (whether at the project or program level).

Mitigation and Alternatives

Induced VMT has the potential to reduce or eliminate congestion relief benefits, increase VMT, and increase other environmental impacts that result from vehicle travel.[37] If those effects are significant, the lead agency will need to consider mitigation or alternatives. In the context of increased travel that is induced by capacity increases, appropriate mitigation and alternatives that a lead agency might consider include the following:

- Tolling new lanes to encourage carpools and fund transit improvements
- Converting existing general purpose lanes to HOV or HOT lanes
- Implementing or funding off-site travel demand management
- Implementing Intelligent Transportation Systems (ITS) strategies to improve passenger throughput on existing lanes

Tolling and other management strategies can have the additional benefit of preventing congestion and maintaining free-flow conditions, conferring substantial benefits to road users as discussed above.

G. Analyzing Other Impacts Related to Transportation

While requiring a change in the methodology of assessing transportation impacts, Public Resources Code section 21099 notes that this change "does not relieve a public agency of the requirement to analyze a project's potentially significant transportation impacts related to air quality, noise, safety, or any other impact associated with transportation." OPR expects that lead agencies will continue to

[37] See National Center for Sustainable Transportation (Oct. 2015) *Increasing Highway Capacity Unlikely to Relieve Traffic Congestion*, available at http://www.dot.ca.gov/newtech/researchreports/reports/2015/10-12-2015-NCST_Brief_InducedTravel_CS6_v3.pdf; see Duranton and Turner (2011) *The Fundamental Law of Road Congestion: Evidence from US cities*, available at http://www.nber.org/papers/w15376.

address mobile source emissions in the air quality and noise sections of an environmental document and the corresponding studies that support the analysis in those sections. Lead agencies should continue to address environmental impacts of a proposed project pursuant to CEQA's requirements, using a format that is appropriate for their particular project.

Because safety concerns result from many different factors, they are best addressed at a programmatic level (i.e., in a general plan or regional transportation plan) in cooperation with local governments, metropolitan planning organizations, and, where the state highway system is involved, the California Department of Transportation. In most cases, such an analysis would not be appropriate on a project-by-project basis. Increases in traffic volumes at a particular location resulting from a project typically cannot be estimated with sufficient accuracy or precision to provide useful information for an analysis of safety concerns. Moreover, an array of factors affect travel demand (e.g., strength of the local economy, price of gasoline), causing substantial additional uncertainty. Appendix B of OPR's General Plan Guidelines summarizes research which could be used to guide a programmatic analysis under CEQA. Lead agencies should note that automobile congestion or delay does not constitute a significant environmental impact (Pub. Resources Code, §21099(b)(2)), and safety should not be used as a proxy for road capacity.

H. VMT Mitigation and Alternatives

When a lead agency identifies a significant impact, it must identify feasible mitigation measures that could avoid or substantially reduce that impact. (Pub. Resources Code, § 21002.1, subd. (a).) Additionally, CEQA requires that an environmental impact report identify feasible alternatives that could avoid or substantially reduce a project's significant environmental impacts.

Indeed, the California Court of Appeal recently held that a long-term regional transportation plan was deficient for failing to discuss an alternative which could significantly reduce total vehicle miles traveled. In *Cleveland National Forest Foundation v. San Diego Association of Governments, et al.* (2017) 17 Cal.App.5th 413, the court found that omission "inexplicable" given the lead agency's "acknowledgment in its Climate Action Strategy that the state's efforts to reduce greenhouse gas emissions from on-road transportation will not succeed if the amount of driving, or vehicle miles traveled, is not significantly reduced." (*Cleveland National Forest Foundation*, *supra*, 17 Cal.App.5th at p. 436.) Additionally, the court noted that the project alternatives focused primarily on congestion relief even though "the [regional] transportation plan is a long-term and congestion relief is not necessarily an effective long-term strategy." (*Id.* at p. 437.) The court concluded its discussion of the alternatives analysis by stating: "Given the acknowledged long-term drawbacks of congestion relief alternatives, there is not substantial evidence to support the EIR's exclusion of an alternative focused primarily on significantly reducing vehicle trips." (*Ibid*.)

Several examples of potential mitigation measures and alternatives to reduce VMT are described below. However, the selection of particular mitigation measures and alternatives are left to the discretion of the lead agency, and mitigation measures may vary, depending on the proposed project and significant impacts, if any. Further, OPR expects that agencies will continue to innovate and find new ways to reduce vehicular travel.

Potential measures to reduce vehicle miles traveled include, but are not limited to:

- Improve or increase access to transit.
- Increase access to common goods and services, such as groceries, schools, and daycare.
- Incorporate affordable housing into the project.
- Incorporate neighborhood electric vehicle network.
- Orient the project toward transit, bicycle and pedestrian facilities.
- Improve pedestrian or bicycle networks, or transit service.
- Provide traffic calming.
- Provide bicycle parking.
- Limit or eliminate parking supply.
- Unbundle parking costs.
- Provide parking cash-out programs.
- Implement roadway pricing.
- Implement or provide access to a commute reduction program.
- Provide car-sharing, bike sharing, and ride-sharing programs.
- Provide transit passes.
- Shifting single occupancy vehicle trips to carpooling or vanpooling, for example providing ride-matching services.
- Providing telework options.
- Providing incentives or subsidies that increase the use of modes other than single-occupancy vehicle.
- Providing on-site amenities at places of work, such as priority parking for carpools and vanpools, secure bike parking, and showers and locker rooms.
- Providing employee transportation coordinators at employment sites.
- Providing a guaranteed ride home service to users of non-auto modes.

Notably, because VMT is largely a regional impact, regional VMT-reduction programs may be an appropriate form of mitigation. In lieu fees have been found to be valid mitigation where there is both a commitment to pay fees and evidence that mitigation will actually occur. (*Save Our Peninsula Committee v. Monterey County Bd. of Supervisors* (2001) 87 Cal.App.4th 99, 140-141; *Gentry v. City of Murrieta* (1995) 36 Cal.App.4th 1359; *Kings County Farm Bureau v. City of Hanford* (1990) 221 Cal.App.3d 692, 727–728.) Fee programs are particularly useful to address cumulative impacts. (CEQA Guidelines, § 15130, subd. (a)(3) [a "project's incremental contribution is less than cumulatively considerable if the project is required to implement or fund its fair share of a mitigation measure or measures designed to alleviate the cumulative impact"].) The mitigation program must undergo CEQA evaluation, either on the program as a whole, or the in-lieu fees or other mitigation must be evaluated on a project-specific basis. (*California Native Plant Society v. County of El Dorado* (2009) 170 Cal.App.4th 1026.) That CEQA evaluation could be part of a larger program, such as a regional transportation plan, analyzed in a Program EIR. (CEQA Guidelines, § 15168.)

Examples of project alternatives that may reduce vehicle miles traveled include, but are not limited to:

- Locate the project in an area of the region that already exhibits low VMT.
- Locate the project near transit.
- Increase project density.
- Increase the mix of uses within the project or within the project's surroundings.
- Increase connectivity and/or intersection density on the project site.
- Deploy management strategies (e.g., pricing, vehicle occupancy requirements) on roadways or roadway lanes.

Appendix 1. Considerations About Which VMT to Count

Consistent with the obligation to make a good faith effort to disclose the environmental consequences of a project, lead agencies have discretion to choose the most appropriate methodology to evaluate project impacts.[38] A lead agency can evaluate a project's effect on VMT in numerous ways. The purpose of this document is to provide technical considerations in determining which methodology may be most useful for various project types.

Background on Estimating Vehicle Miles Traveled

Before discussing specific methodological recommendations, this section provides a brief overview of modeling and counting VMT, including some key terminology.

Here is an illustrative example of some methods of estimating vehicle miles traveled. Consider the following hypothetical travel day (all by automobile):

1. Residence to Coffee Shop
2. Coffee Shop to Work
3. Work to Sandwich Shop
4. Sandwich Shop to Work
5. Work to Residence
6. Residence to Store
7. Store to Residence

Trip-based assessment of a project's effect on travel behavior counts VMT from individual trips to and from the project. It is the most basic, and traditionally the most common, method of counting VMT. A trip-based VMT assessment of the residence in the above example would consider segments 1, 5, 6 and 7. For residential projects, the sum of home-based trips is called *home-based* VMT.

A *tour-based* assessment counts the entire home-back-to-home tour that includes the project. A tour-based VMT assessment of the residence in the above example would consider segments 1, 2, 3, 4, and 5 in one tour, and 6 and 7 in a second tour. A tour-based assessment of the workplace would include segments 1, 2, 3, 4, and 5. Together, all tours comprise *household* VMT.

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[38] The California Supreme Court has explained that when an agency has prepared an environmental impact report:

> [T]he issue is not whether the [lead agency's] studies are irrefutable or whether they could have been better. The relevant issue is only whether the studies are sufficiently credible to be considered as part of the total evidence that supports the [lead agency's] finding[.]

(*Laurel Heights Improvement Assn. v. Regents of the University of California* (1988) 47 Cal.3d 376, 409; see also *Eureka Citizens for Responsible Gov't v. City of Eureka* (2007) 147 Cal.App.4th 357, 372.)

Both trip- and tour-based assessments can be used as measures of transportation efficiency, using denominators such as per capita, per employee, or per person-trip.

Trip- and Tour-based Assessment of VMT

As illustrated above, a tour-based assessment of VMT is a more complete characterization of a project's effect on VMT. In many cases, a project affects travel behavior beyond the first destination. The location and characteristics of the home and workplace will often be the main drivers of VMT. For example, a residential or office development located near high quality transit will likely lead to some commute trips utilizing transit, affecting mode choice on the rest of the tour.

Characteristics of an office project can also affect an employee's VMT beyond the work tour. For example, a workplace located at the urban periphery, far from transit, can require an employee to own a car, which in turn affects the entirety of an employee's travel behavior and VMT. For this reason, when estimating the effect of an office development on VMT, it may be appropriate to consider total employee VMT if data and tools, such as tour-based models, are available. This is consistent with CEQA's requirement to evaluate both direct and *indirect* effects of a project. (See CEQA Guidelines, § 15064, subd. (d)(2).)

Assessing Change in Total VMT

A third method, estimating the *change in total VMT* with and without the project, can evaluate whether a project is likely to divert existing trips, and what the effect of those diversions will be on total VMT. This method answers the question, "What is the net effect of the project on area VMT?" As an illustration, assessing the total change in VMT for a grocery store built in a food desert that diverts trips from more distant stores could reveal a net VMT reduction. The analysis should address the full area over which the project affects travel behavior, even if the effect on travel behavior crosses political boundaries.

Using Models to Estimate VMT

Travel demand models, sketch models, spreadsheet models, research, and data can all be used to calculate and estimate VMT (see Appendix F of the preliminary discussion draft). To the extent possible, lead agencies should choose models that have sensitivity to features of the project that affect VMT. Those tools and resources can also assist in establishing thresholds of significance and estimating VMT reduction attributable to mitigation measures and project alternatives. When using models and tools for those various purposes, agencies should use comparable data and methods, in order to set up an "apples-to-apples" comparison between thresholds, VMT estimates, and VMT mitigation estimates.

Models can work together. For example, agencies can use travel demand models or survey data to estimate existing trip lengths and input those into sketch models such as CalEEMod to achieve more accurate results. Whenever possible, agencies should input localized trip lengths into a sketch model to tailor the analysis to the project location. However, in doing so, agencies should be careful to avoid double counting if the sketch model includes other inputs or toggles that are proxies for trip length (e.g., distance to city center). Generally, if an agency changes any sketch model defaults, it should record and report those changes for transparency of analysis. Again, trip length data should come from the same source as data used to calculate thresholds to be sure of an "apples-to-apples" comparison.

Additional background information regarding travel demand models is available in the California Transportation Commission's "2010 Regional Transportation Plan Guidelines," beginning at page 35.

Appendix 2. Induced Travel: Mechanisms, Research, and Additional Assessment Approaches

Induced travel occurs where roadway capacity is expanded in an area of present or projected future congestion. The effect typically manifests over several years. Lower travel times make the modified facility more attractive to travelers, resulting in the following trip-making changes:

- **Longer trips.** The ability to travel a long distance in a shorter time increases the attractiveness of destinations that are farther away, increasing trip length and vehicle travel.
- **Changes in mode choice.** When transportation investments are devoted to reducing automobile travel time, travelers tend to shift toward automobile use from other modes, which increases vehicle travel.
- **Route changes.** Faster travel times on a route attract more drivers to that route from other routes, which can increase or decrease vehicle travel depending on whether it shortens or lengthens trips.
- **Newly generated trips.** Increasing travel speeds can induce additional trips, which increases vehicle travel. For example, an individual who previously telecommuted or purchased goods on the internet might choose to accomplish those tasks via automobile trips as a result of increased speeds.
- **Land Use Changes.** Faster travel times along a corridor lead to land development farther along that corridor; that new development generates and attracts longer trips, which increases vehicle travel. Over several years, this induced growth component of induced vehicle travel can be substantial, making it critical to include in analyses.

Each of these effects has implications for the total amount of vehicle travel. These effects operate over different time scales. For example, changes in mode choice might occur immediately, while land use changes typically take a few years or longer. CEQA requires lead agencies to analyze both short-term and long-term effects.

Evidence of Induced Vehicle Travel. A large number of peer reviewed studies[39] have demonstrated a causal link between highway capacity increases and VMT increases. Many provide quantitative estimates of the magnitude of the induced VMT phenomenon. Collectively, they provide high quality evidence of the existence and magnitude of the induced travel effect.

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[39] See, e.g., Boarnet and Handy (Sept. 2014) Impact of Highway Capacity and Induced Travel on Passenger Vehicle Use and Greenhouse Gas Emissions, California Air Resources Board Policy Brief, available at https://www.arb.ca.gov/cc/sb375/policies/hwycapacity/highway_capacity_brief.pdf; National Center for Sustainable Transportation (Oct. 2015) *Increasing Highway Capacity Unlikely to Relieve Traffic Congestion*, available at http://www.dot.ca.gov/research/researchreports/reports/2015/10-12-2015-NCST_Brief_InducedTravel_CS6_v3.pdf.

Most of these studies express the amount of induced vehicle travel as an "elasticity," which is a multiplier that describes the additional vehicle travel resulting from an additional lane mile of roadway capacity added. For example, an elasticity of 0.6 would signify an 0.6 percent increase in vehicle travel for every 1.0 percent increase in lane miles. Many of these studies distinguish "short run elasticity" (increase in vehicle travel in the first few years) from "long run elasticity" (increase in vehicle travel beyond the first few years). Long run elasticity is larger than short run elasticity, because as time passes, more of the components of induced vehicle travel materialize. Generally, short run elasticity can be thought of as excluding the effects of land use change, while long run elasticity includes them. Most studies find a long run elasticity between 0.6 and just over 1.0,[40] meaning that every increase in lanes miles of one percent leads to an increase in vehicle travel of 0.6 to 1.0 percent. The most recent major study finds the elasticity of vehicle travel by lanes miles added to be 1.03; in other words, each percent increase in lane miles results in a 1.03 percent increase in vehicle travel.[41] (An elasticity greater than 1.0 can occur because new lanes induce vehicle travel that spills beyond the project location.) In CEQA analysis, the long-run elasticity should be used, as it captures the full effect of the project rather than just the early-stage effect.

Quantifying Induced Vehicle Travel Using Models. Lead agencies can generally achieve the most accurate assessment of induced vehicle travel resulting from roadway capacity increasing projects by applying elasticities from the academic literature, because those estimates include vehicle travel resulting from induced land use. If a lead agency chooses to use a travel demand model, additional analysis would be needed to account for induced land use. This section describes some approaches to undertaking that additional analysis.

Proper use of a travel demand model can capture the following components of induced VMT:

- Trip length (generally increases VMT)
- Mode shift (generally shifts from other modes toward automobile use, increasing VMT)
- Route changes (can act to increase or decrease VMT)
- Newly generated trips (generally increases VMT)
    - Note that not all travel demand models have sensitivity to this factor, so an off-model estimate may be necessary if this effect could be substantial.

However, estimating long-run induced VMT also requires an estimate of the project's effects on land use. This component of the analysis is important because it has the potential to be a large component of

[40] See Boarnet and Handy (Sept. 2014) *Impact of Highway Capacity and Induced Travel on Passenger Vehicle Use and Greenhouse Gas Emissions*, California Air Resources Board Policy Brief, p. 2, available at https://www.arb.ca.gov/cc/sb375/policies/hwycapacity/highway_capacity_brief.pdf.

[41] Duranton and Turner (2011) *The Fundamental Law of Road Congestion: Evidence from US cities*, available at http://www.nber.org/papers/w15376.

the overall induced travel effect. Options for estimating and incorporating the VMT effects that are caused by the subsequent land use changes include:

1. *Employ an expert panel.* An expert panel could assess changes to land use development that would likely result from the project. This assessment could then be analyzed by the travel demand model to assess effects on vehicle travel. Induced vehicle travel assessed via this approach should be verified using elasticities found in the academic literature.
2. *Adjust model results to align with the empirical research.* If the travel demand model analysis is performed without incorporating projected land use changes resulting from the project, the assessed vehicle travel should be adjusted upward to account for those land use changes. The assessed VMT after adjustment should fall within the range found in the academic literature.
3. *Employ a land use model, running it iteratively with a travel demand model.* A land use model can be used to estimate the land use effects of a roadway capacity increase, and the traffic patterns that result from the land use change can then be fed back into the travel demand model. The land use model and travel demand model can be iterated to produce an accurate result.

A project which provides new connectivity across a barrier, such as a new bridge across a river, may provide a shortened path between existing origins and destinations, thereby shortening existing trips. In rare cases, this trip-shortening effect might be substantial enough to reduce the amount of vehicle travel resulting from the project below the range found in the elasticities in the academic literature, or even lead a net reduction in vehicle travel overall. In such cases, the trip-shortening effect could be examined explicitly.

Whenever employing a travel demand model to assess induced vehicle travel, any limitation or known lack of sensitivity in the analysis that might cause substantial errors in the VMT estimate (for example, model insensitivity to one of the components of induced VMT described above) should be disclosed and characterized, and a description should be provided on how it could influence the analysis results. A discussion of the potential error or bias should be carried into analyses that rely on the VMT analysis, such as greenhouse gas emissions, air quality, energy, and noise.

EXHIBIT 19

AIR QUALITY AND LAND USE HANDBOOK: A COMMUNITY HEALTH PERSPECTIVE

April 2005

California Environmental Protection Agency
California Air Resources Board

Air Agency Contacts

Federal-

U.S. EPA, Region 9
Phone: (866)-EPA-WEST
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Email: r9.info@epa.gov

-State-

California Air Resources Board
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(800) 363-7664 (public info)
(800) 952-5588 (complaints)
(866)-397-5462 (env. justice)
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Mojave Desert AQMD
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To My Local Government Colleagues....

I am pleased to introduce this informational guide to air quality and land use issues focused on community health. As a former county supervisor, I know from experience the complexity of local land use decisions. There are multiple factors to consider and balance. This document provides important public health information that we hope will be considered along with housing needs, economic development priorities, and other quality of life issues.

An important focus of this document is prevention. We hope the air quality information provided will help inform decision-makers about the benefits of avoiding certain siting situations. The overarching goal is to avoid placing people in harm's way. Recent studies have shown that public exposure to air pollution can be substantially elevated near freeways and certain other facilities. What is encouraging is that the health risk is greatly reduced with distance. For that reason, we have provided some general recommendations aimed at keeping appropriate distances between sources of air pollution and land uses such as residences.

Land use decisions are a local government responsibility. The Air Resources Board's role is advisory and these recommendations do not establish regulatory standards of any kind. However, we hope that the information in this document will be seriously considered by local elected officials and land use agencies. We also hope that this document will promote enhanced communication between land use agencies and local air pollution control agencies. We developed this document in close coordination with the California Air Pollution Control Officers Association with that goal in mind.

I hope you find this document both informative and useful.

Barbara Riordan

Mrs. Barbara Riordian
Interim Chairman
California Air Resources Board

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Acknowledgments

The ARB staff would like to acknowledge the exceptional contributions made to this document by members of the ARB Environmental Justice Stakeholders Group. Since 2001, ARB staff has consistently relied on this group to provide critical and constructive input on implementing the specifics of ARB's environmental justice policies and actions. The Stakeholders Group is convened by the ARB, and comprised of representatives from local land use and air agencies, community interest groups, environmental justice organizations, academia, and business. Their assistance and suggestions throughout the development of this Handbook have been invaluable.

Executive Summary

The Air Resources Board's (ARB) primary goal in developing this document is to provide information that will help keep California's children and other vulnerable populations out of harm's way with respect to nearby sources of air pollution. Recent air pollution studies have shown an association between respiratory and other non-cancer health effects and proximity to high traffic roadways. Other studies have shown that diesel exhaust and other cancer-causing chemicals emitted from cars and trucks are responsible for much of the overall cancer risk from airborne toxics in California. Also, ARB community health risk assessments and regulatory programs have produced important air quality information about certain types of facilities that should be considered when siting new residences, schools, day care centers, playgrounds, and medical facilities (i.e., sensitive land uses). Sensitive land uses deserve special attention because children, pregnant women, the elderly, and those with existing health problems are especially vulnerable to the non-cancer effects of air pollution. There is also substantial evidence that children are more sensitive to cancer-causing chemicals.

Focusing attention on these siting situations is an important preventative action. ARB and local air districts have comprehensive efforts underway to address new and existing air pollution sources under their respective jurisdictions. The issue of siting is a local government function. As more data on the connection between proximity and health risk from air pollution become available, it is essential that air agencies share what we know with land use agencies. We hope this document will serve that purpose.

The first section provides ARB recommendations regarding the siting of new sensitive land uses near freeways, distribution centers, rail yards, ports, refineries, chrome plating facilities, dry cleaners, and gasoline dispensing facilities. This list consists of the air pollution sources that we have evaluated from the standpoint of the proximity issue. It is based on available information and reflects ARB's primary areas of jurisdiction – mobile sources and toxic air contaminants. A key air pollutant common to many of these sources is particulate matter from diesel engines. Diesel particulate matter (diesel PM) is a carcinogen identified by ARB as a toxic air contaminant and contributes to particulate pollution statewide.

Reducing diesel particulate emissions is one of ARB's highest public health priorities and the focus of a comprehensive statewide control program that is reducing diesel PM emissions each year. ARB's long-term goal is to reduce diesel PM emissions 85% by 2020. However, cleaning up diesel engines will take time as new engine standards phase in and programs to accelerate fleet turnover or retrofit existing engines are implemented. Also, these efforts are reducing diesel particulate emissions on a statewide basis, but do not yet capture every site where diesel vehicles and engines may congregate. Because living or going to school too close to such air pollution sources may increase both cancer and non-cancer health risks, we are recommending that proximity be considered in the siting of new sensitive land uses.

There are also other key toxic air contaminants associated with specific types of facilities. Most of these are subject to stringent state and local air district regulations. However, what we know today indicates that keeping new homes and other sensitive land uses from siting too close to such facilities would provide additional health protection. Chrome platers are a prime example of facilities that should not be located near vulnerable communities because of the cancer health risks from exposure to the toxic material used during their operations.

In addition to source specific recommendations, we also encourage land use agencies to use their planning processes to ensure the appropriate separation of industrial facilities and sensitive land uses. While we provide some suggestions, how to best achieve that goal is a local issue. In the development of these guidelines, we received valuable input from local government about the spectrum of issues that must be considered in the land use planning process. This includes addressing housing and transportation needs, the benefits of urban infill, community economic development priorities, and other quality of life issues. All of these factors are important considerations. The recommendations in the Handbook need to be balanced with other State and local policies.

Our purpose with this document is to highlight the potential health impacts associated with proximity to air pollution sources so planners explicitly consider this issue in planning processes. We believe that with careful evaluation, infill development, mixed use, higher density, transit-oriented development, and other concepts that benefit regional air quality can be compatible with protecting the health of individuals at the neighborhood level. One suggestion for achieving this goal is more communication between air agencies and land use planners. Local air districts are an important resource that should be consulted regarding sources of air pollution in their jurisdictions. ARB staff will also continue to provide updated technical information as it becomes available.

Our recommendations are as specific as possible given the nature of the available data. In some cases, like refineries, we suggest that the siting of new sensitive land uses should be avoided immediately downwind. However, we leave definition of the size of this area to local agencies based on facility specific considerations. Also, project design that would reduce air pollution exposure may be part of the picture and we encourage consultation with air agencies on this subject.

In developing the recommendations, our first consideration was the adequacy of the data available for an air pollution source category. Using that data, we assessed whether we could reasonably characterize the relative exposure and health risk from a proximity standpoint. That screening provided the list of air pollution sources that we were able to address with specific recommendations. We also considered the practical implications of making hard and fast recommendations where the potential impact area is large, emissions will be reduced with time, and air agencies are in the process of looking at options for additional emission control. In the end, we tailored our recommendations to minimize the highest exposures for each source category independently. Due to the large variability in relative risk in the source categories, we chose not to apply a uniform, quantified risk threshold as is typically done in air quality permitting programs. Instead, because these guidelines are not regulatory or binding on local agencies, we took a more qualitative approach in developing the distance-based recommendations.

Where possible, we recommend a minimum separation between a new sensitive land use and known air pollution risks. In other cases, we acknowledge that the existing health risk is too high in a relatively large area, that air agencies are working to reduce that risk, and that in the meantime, we recommend keeping new sensitive land uses out of the highest exposure areas. However, it is critical to note that our implied identification of the high exposure areas for these sources does not mean that the risk in the remaining impact area is insignificant. Rather, we hope this document will bring further attention to the potential health risk throughout the impact area and help garner support for our ongoing efforts to reduce health risk associated with air pollution sources. Areas downwind of major ports, rail yards, and other inter-modal transportation facilities are prime examples.

We developed these recommendations as a means to share important public health information. The underlying data are publicly available and referenced in this document. We also describe our rationale and the factors considered in developing each recommendation, including data limitations and uncertainties. These recommendations are advisory and should not be interpreted as defined "buffer zones." We recognize the opportunity for more detailed site-specific analyses always exists, and that there is no "one size fits all" solution to land use planning.

As California continues to grow, we collectively have the opportunity to use all the information at hand to avoid siting scenarios that may pose a health risk. As part of ARB's focus on communities and children's health, we encourage land use agencies to apply these recommendations and work more closely with air agencies. We also hope that this document will help educate a wider audience about the value of preventative action to reduce environmental exposures to air pollution.

1. ARB Recommendations on Siting New Sensitive Land Uses

Protecting California's communities and our children from the health effects of air pollution is one of the most fundamental goals of state and local air pollution control programs. Our focus on children reflects their special vulnerability to the health impacts of air pollution. Other vulnerable populations include the elderly, pregnant women, and those with serious health problems affected by air pollution. With this document, we hope to more effectively engage local land use agencies as partners in our efforts to reduce health risk from air pollution in all California communities.

Later sections emphasize the need to strengthen the connection between air quality and land use in both planning and permitting processes. Because the siting process for many, but not all air pollution sources involves permitting by local air districts, there is an opportunity for interagency coordination where the proposed location might pose a problem. To enhance the evaluation process from a land use perspective, section 4 includes recommended project related questions to help screen for potential proximity related issues.

Unlike industrial and other stationary sources of air pollution, the siting of new homes or day care centers does not require an air quality permit. Because these situations fall outside the air quality permitting process, it is especially important that land use agencies be aware of potential air pollution impacts.

The following recommendations address the issue of siting "sensitive land uses" near specific sources of air pollution; namely:

- High traffic freeways and roads
- Distribution centers
- Rail yards
- Ports
- Refineries
- Chrome plating facilities
- Dry cleaners
- Large gas dispensing facilities

The recommendations for each category include a summary of key information and guidance on what to avoid from a public health perspective.

Sensitive individuals refer to those segments of the population most susceptible to poor air quality (i.e., children, the elderly, and those with pre-existing serious health problems affected by air quality). Land uses where sensitive individuals are most likely to spend time include schools and schoolyards, parks and playgrounds, daycare centers, nursing homes, hospitals, and residential communities (sensitive sites or sensitive land uses).

We are characterizing sensitive land uses as simply as we can by using the example of residences, schools, day care centers, playgrounds, and medical facilities. However, a variety of facilities are encompassed. For example, residences can include houses, apartments, and senior living complexes. Medical facilities can include hospitals, convalescent homes, and health clinics. Playgrounds could be play areas associated with parks or community centers.

In developing these recommendations, ARB first considered the adequacy of the data available for each air pollution source category. We assessed whether we could generally characterize the relative exposure and health risk from a proximity standpoint. The documented non-cancer health risks include triggering of asthma attacks, heart attacks, and increases in daily mortality and hospitalization for heart and respiratory diseases. These health impacts are well documented in epidemiological studies, but less easy to quantify from a particular air pollution source. Therefore, the cancer health impacts are used in this document to provide a picture of relative risk. This screening process provided the list of source categories we were able to address with specific recommendations. In evaluating the available information, we also considered the practical implications of making hard and fast recommendations where the potential impact area is large, emissions will be reduced with time, and air agencies are in the process of looking at options for additional emission control. Due to the large variability in relative risk between the source categories, we chose not to apply a uniform, quantified risk threshold as is typically done in regulatory programs. Therefore, in the end, we tailored our recommendations to minimize the highest exposures for each source category independently. Additionally, because this guidance is not regulatory or binding on local agencies, we took a more qualitative approach to developing distance based recommendations.

Where possible, we recommend a minimum separation between new sensitive land uses and existing sources. However, this is not always possible, particularly where there is an elevated health risk over large geographical areas. Areas downwind of ports and rail yards are prime examples. In such cases, we recommend doing everything possible to avoid locating sensitive receptors within the highest risk zones. Concurrently, air agencies and others will be working to reduce the overall risk through controls and measures within their scope of authority.

The recommendations were developed from the standpoint of siting new sensitive land uses. Project-specific data for new and existing air pollution sources are available as part of the air quality permitting process. Where such information is available, it should be used. Our recommendations are designed to fill a gap where information about existing facilities may not be readily available. These recommendations are only guidelines and are not designed to substitute for more specific information if it exists.

A summary of our recommendations is shown in Table 1-1. The basis and references[1] supporting each of these recommendations, including health studies, air quality modeling and monitoring studies is discussed below beginning with freeways and summarized in Table 1-2. As new information becomes available, it will be included on ARB's community health web page.

[1]Detailed information on these references are available on ARB's website at: http://www.ARB.ca.gov/ch/landuse.htm.

Table 1-1

Recommendations on Siting New Sensitive Land Uses Such As Residences, Schools, Daycare Centers, Playgrounds, or Medical Facilities*

Source Category	Advisory Recommendations
Freeways and High-Traffic Roads	• Avoid siting new sensitive land uses within 500 feet of a freeway, urban roads with 100,000 vehicles/day, or rural roads with 50,000 vehicles/day.
Distribution Centers	• Avoid siting new sensitive land uses within 1,000 feet of a distribution center (that accommodates more than 100 trucks per day, more than 40 trucks with operating transport refrigeration units (TRUs) per day, or where TRU unit operations exceed 300 hours per week). • Take into account the configuration of existing distribution centers and avoid locating residences and other new sensitive land uses near entry and exit points.
Rail Yards	• Avoid siting new sensitive land uses within 1,000 feet of a major service and maintenance rail yard. • Within one mile of a rail yard, consider possible siting limitations and mitigation approaches.
Ports	• Avoid siting of new sensitive land uses immediately downwind of ports in the most heavily impacted zones. Consult local air districts or the ARB on the status of pending analyses of health risks.
Refineries	• Avoid siting new sensitive land uses immediately downwind of petroleum refineries. Consult with local air districts and other local agencies to determine an appropriate separation.
Chrome Platers	• Avoid siting new sensitive land uses within 1,000 feet of a chrome plater.
Dry Cleaners Using Perchloro-ethylene	• Avoid siting new sensitive land uses within 300 feet of any dry cleaning operation. For operations with two or more machines, provide 500 feet. For operations with 3 or more machines, consult with the local air district. • Do not site new sensitive land uses in the same building with perc dry cleaning operations.
Gasoline Dispensing Facilities	• Avoid siting new sensitive land uses within 300 feet of a large gas station (defined as a facility with a throughput of 3.6 million gallons per year or greater). A 50 foot separation is recommended for typical gas dispensing facilities.

*Notes:

- These recommendations are advisory. Land use agencies have to balance other considerations, including housing and transportation needs, economic development priorities, and other quality of life issues.

- Recommendations are based primarily on data showing that the air pollution exposures addressed here (i.e., localized) can be reduced as much as 80% with the recommended separation.
- The relative risk for these categories varies greatly (see Table 1-2). To determine the actual risk near a particular facility, a site-specific analysis would be required. Risk from diesel PM will decrease over time as cleaner technology phases in.
- These recommendations are designed to fill a gap where information about existing facilities may not be readily available and are not designed to substitute for more specific information if it exists. The recommended distances take into account other factors in addition to available health risk data (see individual category descriptions).
- Site-specific project design improvements may help reduce air pollution exposures and should also be considered when siting new sensitive land uses.
- This table does not imply that mixed residential and commercial development in general is incompatible. Rather it focuses on known problems like dry cleaners using perchloroethylene that can be addressed with reasonable preventative actions.
- A summary of the basis for the distance recommendations can be found in Table 1-2.

Table 1-2

Summary of Basis for Advisory Recommendations

Source Category	**Range of Relative Cancer Risk[1,2]**	**Summary of Basis for Advisory Recommendations**
Freeways and High-Traffic Roads	300 – 1,700	• In traffic-related studies, the additional non-cancer health risk attributable to proximity was seen within 1,000 feet and was strongest within 300 feet. California freeway studies show about a 70% drop off in particulate pollution levels at 500 feet.
Distribution Centers[3]	Up to 500	• Because ARB regulations will restrict truck idling at distribution centers, transport refrigeration unit (TRU) operations are the largest onsite diesel PM emission source followed by truck travel in and out of distribution centers. • Based on ARB and South Coast District emissions and modeling analyses, we estimate an 80 percent drop-off in pollutant concentrations at approximately 1,000 feet from a distribution center.
Rail Yards	Up to 500	• The air quality modeling conducted for the Roseville Rail Yard Study predicted the highest impact is within 1,000 feet of the Yard, and is associated with service and maintenance activities. The next highest impact is between a half to one mile of the Yard, depending on wind direction and intensity.
Ports	Studies underway	• ARB will evaluate the impacts of ports and develop a new comprehensive plan that will describe the steps needed to reduce public health impacts from port and rail activities in California. In the interim, a general advisory is appropriate based on the magnitude of diesel PM emissions associated with ports.
Refineries	Under 10	• Risk assessments conducted at California refineries show risks from air toxics to be under 10 chances of cancer per million.[4] • Distance recommendations were based on the amount and potentially hazardous nature of many of the pollutants released as part of the refinery process, particularly during non-routine emissions releases.
Chrome Platers	10-100	• ARB modeling and monitoring studies show localized risk of hexavalent chromium diminishing significantly at 300 feet. There are data limitations in both the modeling and monitoring studies. These include variability of plating activities and uncertainty of emissions such as fugitive dust. Hexavalent chromium is one of the most potent toxic air contaminants. Considering these factors, a distance of 1,000 feet was used as a precautionary measure.
Dry Cleaners Using Perchloro-ethylene (perc)	15-150	• Local air district studies indicate that individual cancer risk can be reduced by as much as 75 percent by establishing a 300 foot separation between a sensitive land use and a one-machine perc dry cleaning operation. For larger operations (2 machines or more), a separation of 500 feet can reduce risk by over 85 percent.

Source Category	Range of Relative Cancer Risk[1,2]	Summary of Basis for Advisory Recommendations
Gasoline Dispensing Facilities (GDF)[5]	Typical GDF: Less than 10 Large GDF: Between Less than 10 and 120	• Based on the CAPCOA Gasoline Service Station Industry-wide Risk Assessment Guidelines, most typical GDFs (less than 3.6 million gallons per year) have a risk of less than 10 at 50 feet under urban air dispersion conditions. Over the last few years, there has been a growing number of extremely large GDFs with sales over 3.6 and as high as 19 million gallons per year. Under rural air dispersion conditions, these large GDFs can pose a larger risk at a greater distance.

[1]For cancer health effects, risk is expressed as an estimate of the increased chances of getting cancer due to facility emissions over a 70-year lifetime. This increase in risk is expressed as chances in a million (e.g., 10 chances in a million).

[2]The estimated cancer risks are a function of the proximity to the specific category and were calculated independent of the regional health risk from air pollution. For example, the estimated regional cancer risk from air toxics in the Los Angeles region (South Coast Air Basin) is approximately 1,000 in a million.

[3]Analysis based on refrigerator trucks.

[4]Although risk assessments performed by refineries indicate they represent a low cancer risk, there is limited data on non-cancer effects of pollutants that are emitted from these facilities. Refineries are also a source of non-routine emissions and odors.

[5]A typical GDF in California dispenses under 3.6 million gallons of gasoline per year. The cancer risk for this size facility is likely to be less than 10 in a million at the fence line under urban air dispersion conditions.

A large GDF has fuel throughputs that can range from 3.6 to 19 million gallons of gasoline per year. The upper end of the risk range (i.e., 120 in a million) represents a hypothetical worst case scenario for an extremely large GDF under rural air dispersion conditions.

Freeways and High Traffic Roads

Air pollution studies indicate that living close to high traffic and the associated emissions may lead to adverse health effects beyond those associated with regional air pollution in urban areas. Many of these epidemiological studies have focused on children. A number of studies identify an association between adverse non-cancer health effects and living or attending school near heavily traveled roadways (see findings below). These studies have reported associations between residential proximity to high traffic roadways and a variety of respiratory symptoms, asthma exacerbations, and decreases in lung function in children.

One such study that found an association between traffic and respiratory symptoms in children was conducted in the San Francisco Bay Area. Measurements of traffic-related pollutants showed concentrations within 300 meters (approximately 1,000 feet) downwind of freeways were higher than regional values. Most other studies have assessed exposure based on proximity factors such as distance to freeways or traffic density.

These studies linking traffic emissions with health impacts build on a wealth of data on the adverse health effects of ambient air pollution. The data on the effects of proximity to traffic-related emissions provides additional information that can be used in land use siting and regulatory actions by air agencies. The key observation in these studies is that close proximity increases both exposure and the potential for adverse health effects. Other effects associated with traffic emissions include premature death in elderly individuals with heart disease.

Key Health Findings

- Reduced lung function in children was associated with traffic density, especially trucks, within 1,000 feet and the association was strongest within 300 feet. (Brunekreef, 1997)
- Increased asthma hospitalizations were associated with living within 650 feet of heavy traffic and heavy truck volume. (Lin, 2000)
- Asthma symptoms increased with proximity to roadways and the risk was greatest within 300 feet. (Venn, 2001)
- Asthma and bronchitis symptoms in children were associated with proximity to high traffic in a San Francisco Bay Area community with good overall regional air quality. (Kim, 2004)
- A San Diego study found increased medical visits in children living within 550 feet of heavy traffic. (English, 1999)

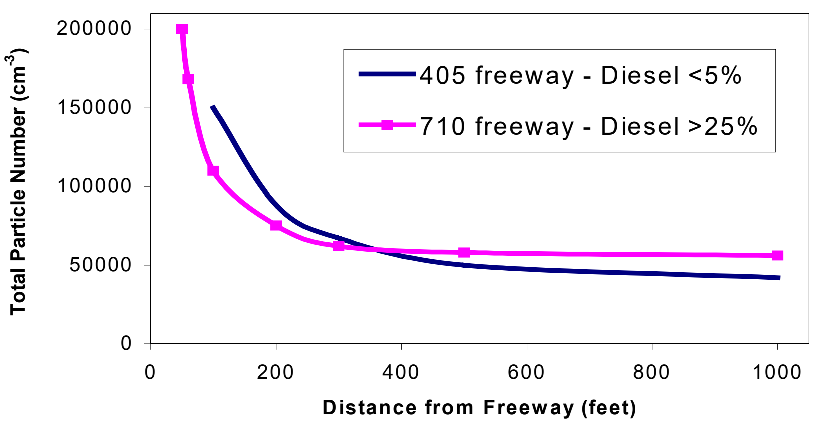
In these and other proximity studies, the distance from the roadway and truck traffic densities were key factors affecting the strength of the association with adverse health effects. In the above health studies, the association of traffic-related emissions with adverse health effects was seen within 1,000 feet and was strongest within 300 feet. This demonstrates that the adverse effects diminished with distance.

In addition to the respiratory health effects in children, proximity to freeways increases potential cancer risk and contributes to total particulate matter exposure. There are three carcinogenic toxic air contaminants that constitute the majority of the known health risk from motor vehicle traffic – diesel particulate matter (diesel PM) from trucks, and benzene and 1,3-butadiene from passenger vehicles. On a typical urban freeway (truck traffic of 10,000-20,000/day), diesel PM represents about 70 percent of the potential cancer risk from the vehicle traffic. Diesel particulate emissions are also of special concern because health studies show an association between particulate matter and premature mortality in those with existing cardiovascular disease.

<u>Distance Related Findings</u>

A southern California study (Zhu, 2002) showed measured concentrations of vehicle-related pollutants, including ultra-fine particles, decreased dramatically within approximately 300 feet of the 710 and 405 freeways. Another study looked at the validity of using distance from a roadway as a measure of exposure

Figure 1-1
Decrease In Concentration of Freeway Diesel PM Emissions With Distance



to traffic related air pollution (Knape, 1999). This study showed that concentrations of traffic related pollutants declined with distance from the road, primarily in the first 500 feet.

These findings are consistent with air quality modeling and risk analyses done by ARB staff that show an estimated range of potential cancer risk that decreases with distance from freeways. The estimated risk varies with the local meteorology, including wind pattern. As an example, at 300 feet downwind from a freeway (Interstate 80) with truck traffic of 10,000 trucks per day, the potential cancer risk was as high as 100 in one million (ARB Roseville Rail Yard Study). The cancer health risk at 300 feet on the upwind side of the freeway was much less. The risk at that distance for other freeways will vary based on local conditions – it may be higher or lower. However, in all these analyses the relative exposure and health risk dropped substantially within the first 300 feet. This phenomenon is illustrated in Figure 1-1.

State law restricts the siting of new schools within 500 feet of a freeway, urban roadways with 100,000 vehicles/day, or rural roadways with 50,000 vehicles with some exceptions.[2] However, no such requirements apply to the siting of residences, day care centers, playgrounds, or medical facilities. The available data show that exposure is greatly reduced at approximately 300 feet. In the traffic-related studies the additional health risk attributable to the proximity effect was strongest within 1,000 feet.

The combination of the children's health studies and the distance related findings suggests that it is important to avoid exposing children to elevated air pollution levels immediately downwind of freeways and high traffic roadways. These studies suggest a substantial benefit to a 500-foot separation.

The impact of traffic emissions is on a gradient that at some point becomes indistinguishable from the regional air pollution problem. As air agencies work to reduce the underlying regional health risk from diesel PM and other pollutants, the impact of proximity will also be reduced. In the meantime, as a preventative measure, we hope to avoid exposing more children and other vulnerable individuals to the highest concentrations of traffic-related emissions.

Recommendation

- Avoid siting new sensitive land uses within 500 feet of a freeway, urban roads with 100,000 vehicles/day, or rural roads with 50,000 vehicles/day.

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Distribution Centers

Distribution centers or warehouses are facilities that serve as a distribution point for the transfer of goods. Such facilities include cold storage warehouses, goods transfer facilities, and inter-modal facilities such as ports. These operations involve trucks, trailers, shipping containers, and other equipment with diesel engines. A distribution center can be comprised of multiple centers or warehouses within an area. The size can range from several to hundreds of acres, involving a number of different transfer operations and long waiting periods. A distribution center can accommodate hundreds of diesel trucks a day that deliver, load, and/or unload goods up to seven days a week. To the extent that these trucks are transporting perishable goods, they are equipped with diesel-powered transport refrigeration units (TRUs) or TRU generator sets.

The activities associated with delivering, storing, and loading freight produces diesel PM emissions. Although TRUs have relatively small diesel-powered engines, in the normal course of business, their emissions can pose a significant health risk to those nearby. In addition to onsite emissions, truck travel in and out of distribution centers contributes to the local pollution impact.

ARB is working to reduce diesel PM emissions through regulations, financial incentives, and enforcement programs. In 2004, ARB adopted two airborne toxic control measures that will reduce diesel PM emissions associated with distribution centers. The first will limit nonessential (or unnecessary) idling of diesel-fueled commercial vehicles, including those entering from other states or countries. This statewide measure, effective in 2005, prohibits idling of a vehicle more than five minutes at any one location.[3] The elimination of unnecessary idling will reduce the localized impacts caused by diesel PM and other air toxics

[3] For further information on the Anti-Idling ATCM, please click on: http://www.arb.ca.gov/toxics/idling/outreach/factsheet.pdf

in diesel vehicle exhaust. This should be a very effective new strategy for reducing diesel PM emissions at distribution centers as well as other locations.

The second measure requires that TRUs operating in California become cleaner over time. The measure establishes in-use performance standards for existing TRU engines that operate in California, including out-of-state TRUs. The requirements are phased-in beginning in 2008, and extend to 2019.[4]

ARB also operates a smoke inspection program for heavy-duty diesel trucks that focuses on reducing truck emissions in California communities. Areas with large numbers of distribution centers are a high priority.

Key Health Findings

Diesel PM has been identified by ARB as a toxic air contaminant and represents 70 percent of the known potential cancer risk from air toxics in California. Diesel PM is an important contributor to particulate matter air pollution. Particulate matter exposure is associated with premature mortality and health effects such as asthma exacerbation and hospitalization due to aggravating heart and lung disease.

Distance Related Findings

Although distribution centers are located throughout the state, they are usually clustered near transportation corridors, and are often located in or near population centers. Diesel PM emissions from associated delivery truck traffic and TRUs at these facilities may result in elevated diesel PM concentrations in neighborhoods surrounding those sites. Because ARB regulations will restrict truck idling at distribution centers, the largest continuing onsite diesel PM emission source is the operation of TRUs. Truck travel in and out of distribution centers also contributes to localized exposures, but specific travel patterns and truck volumes would be needed to identify the exact locations of the highest concentrations.

As part of the development of ARB's regulation for TRUs, ARB staff performed air quality modeling to estimate exposure and the associated potential cancer risk of onsite TRUs for a typical distribution center. For an individual person, cancer risk estimates for air pollution are commonly expressed as a probability of developing cancer from a lifetime (i.e., 70 years) of exposure. These risks were calculated independent of regional risk. For example, the estimated regional cancer risk from air toxics in the Los Angeles region (South Coast Air Basin) is approximately 1,000 additional cancer cases per one million population.

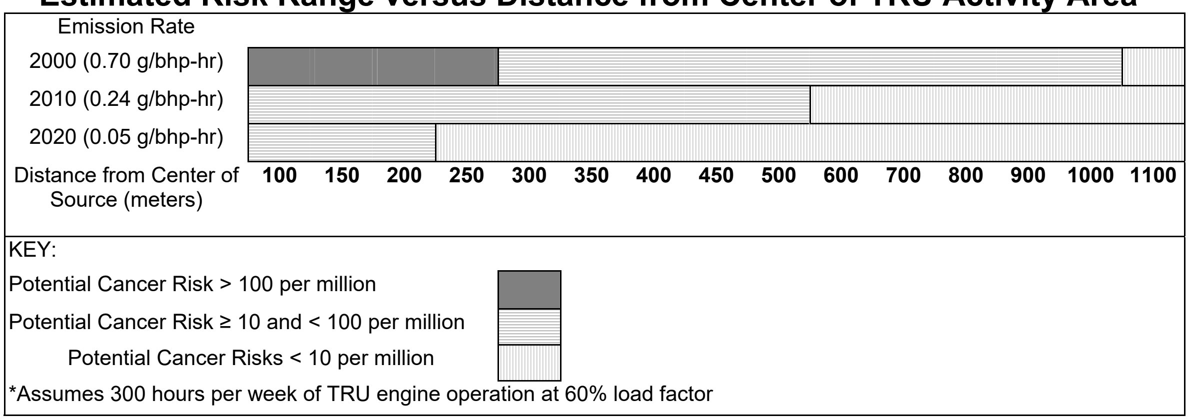
[4] For further information on the Transport Refrigeration Unit ATCM, please click on: http://www.arb.ca.gov/diesel/documents/trufaq.pdf

The diesel PM emissions from a facility are dependent on the size (horsepower), age, and number of engines, emission rates, the number of hours the truck engines and/or TRUs operate, distance, and meteorological conditions at the site. This assessment assumes a total on-site operating time for all TRUs of 300 hours per week. This would be the equivalent of 40 TRU-equipped trucks a day, each loading or unloading on-site for one hour, 12 hours a day and seven days a week.

As shown in Figure 1-2 below, at this estimated level of activity and assuming a current fleet diesel PM emission rate, the potential cancer risk would be over 100 in a million at 800 feet from the center of the TRU activity. The estimated potential cancer risk would be in the 10 to 100 per million range between 800 to 3,300 feet and fall off to less than 10 per million at approximately 3,600 feet. However with the implementation of ARB's regulation on TRUs, the risk will be significantly reduced.[5] We have not conducted a risk assessment for distribution centers based on truck traffic alone, but on an emissions basis, we would expect similar risks for a facility with truck volumes in the range of 100 per day.

Figure 1-2

Estimated Risk Range versus Distance from Center of TRU Activity Area*

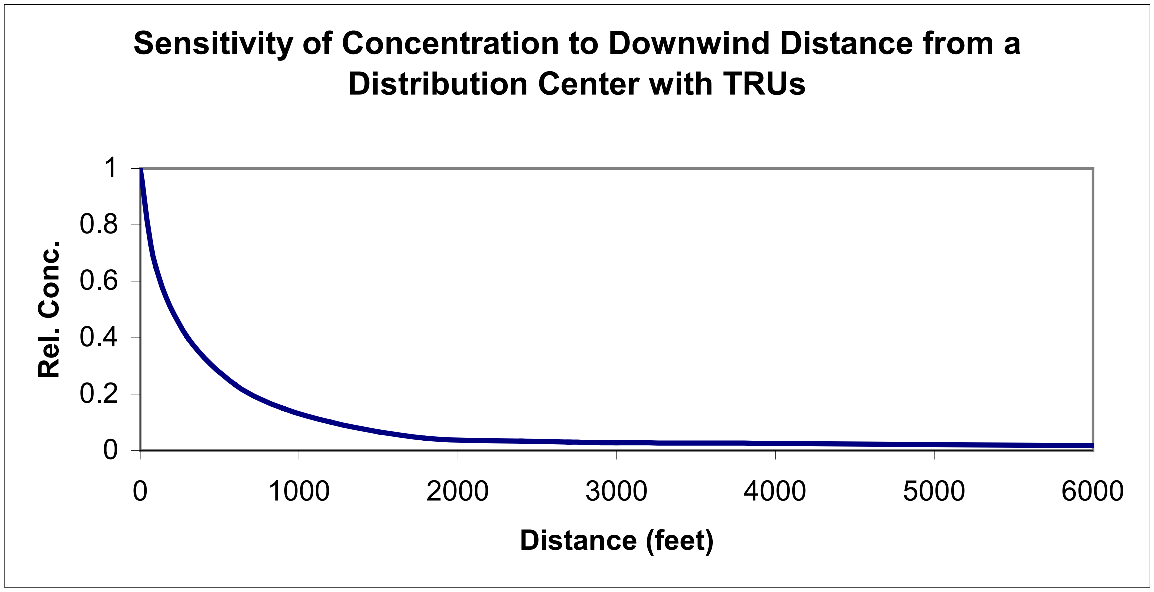


The estimated potential cancer risk level in Figure 1-2 is based on a number of assumptions that may not reflect actual conditions for a specific site. For example, increasing or decreasing the hours of diesel engine operations would change the potential risk levels. Meteorological and other facility specific parameters can also impact the results. Therefore, the results presented here are not directly applicable to any particular facility or operation. Rather, this information is intended to provide an indication as to the potential relative levels of risk that may be observed from operations at distribution centers. As shown in Figure 1-2, the estimated risk levels will decrease over time as lower-emitting diesel engines are used.

[5] These risk values assume an exposure duration of 70 years for a nearby resident and uses the methodology specified in the 2003 OEHHA health risk assessment guidelines.

Another air modeling analysis, performed by the South Coast Air Quality Management District (South Coast AQMD), evaluated the impact of diesel PM emissions from distribution center operations in the community of Mira Loma in southern California. Based on dispersion of diesel PM emissions from a large distribution center, Figure 1-3 shows the relative pollution concentrations at varying distances downwind. As Figure 1-3 shows, there is about an 80 percent drop off in concentration at approximately 1,000 feet.

Figure 1-3
Decrease In Relative Concentration of Risk
With Distance



Both the ARB and the South Coast AQMD analyses indicate that providing a separation of 1,000 feet would substantially reduce diesel PM concentrations and public exposure downwind of a distribution center. While these analyses do not provide specific risk estimates for distribution centers, they provide an indication of the range of risk and the benefits of providing a separation. ARB recommends a separation of 1,000 feet based on the combination of risk analysis done for TRUs and the decrease in exposure predicted with the South Coast AQMD modeling. However, ARB staff plans to provide further information on distribution centers as we collect more data and implement the TRU control measure.

Taking into account the configuration of distribution centers can also reduce population exposure and risk. For example, locating new sensitive land uses away from the main entry and exit points helps to reduce cancer risk and other health impacts.

Recommendations

- Avoid siting new sensitive land uses within 1,000 feet of a distribution center (that accommodates more than 100 trucks per day, more than 40 trucks with operating TRUs per day, or where TRU unit operations exceed 300 hours per week).

- Take into account the configuration of existing distribution centers and avoid locating residences and other new sensitive land uses near entry and exit points.

References

- *Airborne Toxic Control Measure To Limit Diesel-Fueled Commercial Motor Vehicle Idling.* ARB (August 20, 2004). Rule effectiveness date awaiting submittal of regulation to the Office of Administration Law. http://www.arb.ca.gov/regact/idling/idling.htm

- *Revised Staff Report: Initial Statement of Reasons for Proposed Rulemaking. Airborne Toxic Control Measure for In-Use Diesel-Fueled Transport Refrigeration Units (TRU) and TRU Generator Sets, and Facilities Where TRUs Operate.* ARB (October 28, 2003). http://www.arb.ca.gov/regact/trude03/revisor.doc

- *Health Risk Assessment Guidance for Analyzing Cancer Risks from Mobile Source Diesel Idling Emissions for CEQA Air Quality Analysis.* SCAQMD (August 2003) http://www.aqmd.gov/ceqa/handbook/diesel_analysis.doc

- *"Mira Loma Study: Analysis of the Impact of Diesel Particulate Emissions from Warehouse/Distribution Center Operations",* PowerPoint presentation. SCAQMD (July 31, 2002)

Rail Yards

Rail yards are a major source of diesel particulate air pollution. They are usually located near inter-modal facilities, which attract heavy truck traffic, and are often sited in mixed industrial and residential areas. ARB, working with the Placer County air district and Union Pacific Railroad, recently completed a study[6] of the Roseville Rail Yard (Yard) in northern California that focused on the health risk from diesel particulate. A comprehensive emissions analysis and air quality modeling were conducted to characterize the estimated potential cancer risk associated with the facility.

[6] To review the study, please click on: http://www.arb.ca.gov/diesel/documents/rrstudy.htm

The Yard encompasses about 950 acres on a one-quarter mile wide by four-mile long strip of land that parallels Interstate 80. It is surrounded by commercial, industrial, and residential properties. The Yard is one of the largest service and maintenance rail yards in the West with over 30,000 locomotives visiting annually.

Using data provided by Union Pacific Railroad, the ARB determined the number and type of locomotives visiting the Yard annually and what those locomotives were doing - moving, idling, or undergoing maintenance testing. Union Pacific provided the annual, monthly, daily, and hourly locomotive activity in the yard including locomotive movements; routes for arrival, departure, and through trains; and locomotive service and testing. This information was used to estimate the emissions of particulate matter from the locomotives, which was then used to model the potential impacts on the surrounding community.

The key findings of the study are:

- Diesel PM emissions in 2000 from locomotive operations at the Roseville Yard were estimated at about 25 tons per year.

- Of the total diesel PM in the Yard, moving locomotives accounted for about 50 percent, idling locomotives about 45 percent, and locomotive testing about five percent.

- Air quality modeling predicts potential cancer risks greater than 500 in a million (based on 70 years of exposure) in a 10-40 acre area immediately adjacent to the Yard's maintenance operations.

- The risk assessment also showed elevated cancer risk impacting a larger area covering about a 10 by 10 mile area around the Yard.

The elevated concentrations of diesel PM found in the study contribute to an increased risk of cancer and premature death due to cardiovascular disease, and non-cancer health effects such as asthma and other respiratory illnesses. The magnitude of the risk, the general location, and the size of the impacted area depended on the meteorological data used to characterize conditions at the Yard, the dispersion characteristics, and exposure assumptions. In addition to these variables, the nature of locomotive activity will influence a risk characterization at a particular rail yard. For these reasons, the quantified risk estimates in the Roseville Rail Yard Study cannot be directly applied to other rail yards. However, the study does indicate the health risk due to diesel PM from rail yards needs to be addressed. ARB, in conjunction with the U.S. Environmental Protection Agency (U.S. EPA), and local air districts, is working with the rail industry to identify and implement short term, mid-term and long-term mitigation strategies. ARB also intends to conduct a second rail study in southern California to increase its understanding of rail yard operations and the associated public health impacts.

Key Health Findings

Diesel PM has been identified by ARB as a toxic air contaminant and represents 70 percent of the known potential cancer risk from air toxics in California. Diesel PM is an important contributor to particulate matter air pollution. Particulate matter exposure is associated with premature mortality and health effects such as asthma exacerbation and hospitalization due to aggravating heart and lung disease.

Distance Related Findings

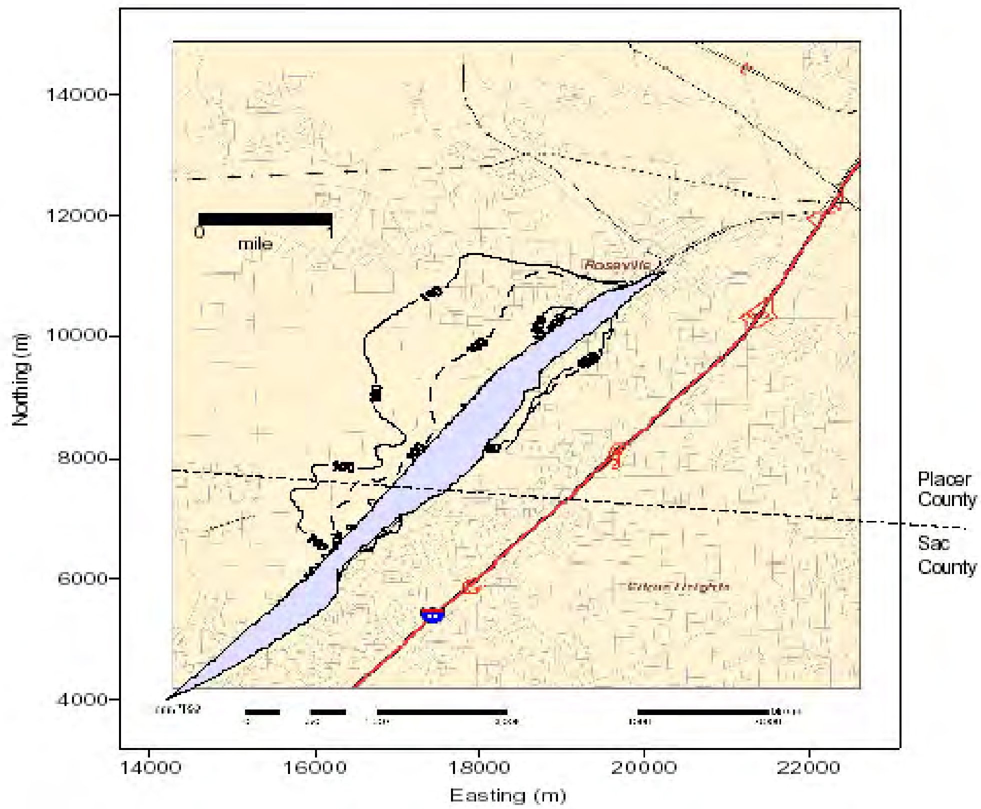
Two sets of meteorological data were used in the Roseville study because of technical limitations in the data. The size of the impact area was highly dependent on the meteorological data set used. The predicted highest impact area ranged from 10 - 40 acres with the two different meteorological data sets. This area, with risks estimated above 500 in a million, is adjacent to an area that includes a maintenance shop (see Figure 1-4). The high concentration of diesel PM emissions is due to the number of locomotives and nature of activities in this area, particularly idling locomotives.

The area of highest impact is within 1,000 feet of the Yard. The next highest impact zone as defined in the report had a predicted risk between 500 and 100 in one million and extends out between a half to one mile in some spots, depending on which meteorological conditions were assumed. The impact areas are irregular in shape making it difficult to generalize about the impact of distance at a particular location. However, the Roseville Rail Yard Study clearly indicates that the localized health risk is high, the impact area is large, and mitigation of the locomotive diesel PM emissions is needed.

For facilities like rail yards and ports, the potential impact area is so large that the real solution is to substantially reduce facility emissions. However, land use planners can avoid encroaching upon existing rail facilities and those scheduled for expansion. We also recommend that while air agencies tackle this problem, land use planners try not to add new sensitive individuals into the highest exposure areas. Finally, we recommend that land use agencies consider the potential health impacts of rail yards in their planning and permitting processes. Additional limitations and mitigation may be feasible to further reduce exposure on a site-specific basis.

Figure 1-4

Estimated Cancer Risk from the Yard
(100 and 500 in a million risk isopleths)



Notes: 100/Million Contours: Solid Line – Roseville Met Data; Dashed Line-McClellan Met Data, Urban Dispersion Coefficients, 80th Percentile Breathing Rate, All Locomotives' Activities (23 TPY), 70-Year Exposure

Recommendation

- Avoid siting new sensitive land uses within 1,000 feet of a major service and maintenance rail yard[7].

- Within one mile of a rail yard, consider possible siting limitations and mitigation approaches.

References

- *Roseville Rail Yard Study.* ARB (2004)

[7] The rail yard risk analysis was conducted for the Union Pacific rail yard in Roseville, California. This rail yard is one of the largest in the state. There are other rail yards in California with comparable levels of activity that should be considered "major" for purposes of this Handbook.

Ports

Air pollution from maritime port activities is a growing concern for regional air quality as well as air quality in nearby communities. The primary air pollutant associated with port operations is directly emitted diesel particulate. Port-related activities also result in emissions that form ozone and secondary particulate in the atmosphere. The emission sources associated with ports include diesel engine-powered ocean-going ships, harbor craft, cargo handling equipment, trucks, and locomotives. The size and concentration of these diesel engines makes ports one of the biggest sources of diesel PM in the state. For that reason, ARB has made it a top priority to reduce diesel PM emissions at the ports, in surrounding communities, and throughout California.

International, national, state, and local government collaboration is critical to reducing port emissions based on both legal and practical considerations. For example, the International Maritime Organization (IMO) and the U.S. EPA establish emission standards for ocean-going vessels and U.S.-flagged harbor craft, respectively. ARB is pursuing further federal actions to tighten these standards. In addition, ARB and local air districts are reducing emissions from ports through a variety of approaches. These include: incentive programs to fund cleaner engines, enhanced enforcement of smoke emissions from ships and trucks, use of dockside electricity instead of diesel engines, cleaner fuels for ships, harbor craft, locomotives, and reduced engine idling. The two ATCMs that limit truck idling and reduce emissions from TRUs (discussed under “Distribution Centers”) also apply to ports.

ARB is also developing several other regulations that will reduce port-related emissions. One rule would require ocean-going ships to use a cleaner marine diesel fuel to power auxiliary engines while in California coastal waters and at dock. Ships that frequently visit California ports would also be required to further reduce their emissions. ARB has adopted a rule that would require harbor craft to use the same cleaner diesel fuel used by on-road trucks in California. In 2005, ARB will consider a rule that would require additional controls for in-use harbor craft, such as the use of add-on emission controls and accelerated turnover of older engines.

Key Health Findings

Port activities are a major source of diesel PM. Diesel PM has been identified by ARB as a toxic air contaminant and represents 70 percent of the known potential cancer risk from air toxics in California. Diesel PM is an important contributor to particulate matter air pollution. Particulate matter exposure is associated with premature mortality and health effects such as asthma exacerbation and hospitalization due to aggravating heart and lung disease.

Distance Related Findings

The Ports of Los Angeles and Long Beach provide an example of the emissions impact of port operations. A comprehensive emissions inventory was completed in June 2004. These ports combined are one of the world's largest and busiest seaports. Located in San Pedro Bay, about 20 miles south of downtown Los Angeles, the port complex occupies approximately 16 square miles of land and water. Port activities include five source categories that produce diesel emissions. These are ocean-going vessels, harbor craft, cargo handling equipment, railroad locomotives, and heavy-duty trucks.

The baseline emission inventory provides emission estimates for all major air pollutants. This analysis focuses on diesel PM from in-port activity because these emissions have the most potential health impact on the areas adjacent to the port. Ocean vessels are the largest overall source of diesel PM related to the ports, but these emissions occur primarily outside of the port in coastal waters, making the impact more regional in nature.

The overall in-port emission inventory for diesel particulate for the ports of Los Angeles and Long Beach is estimated to be 550 tons per year. The emissions fall in the following major categories: ocean-going vessels (17%), harbor craft (25%), cargo handling (47%), railroad locomotive (3%), and heavy duty vehicles (8%). In addition to in-port emissions, ship, rail, and trucking activities also contribute to regional emissions and increase emissions in nearby neighborhoods. Off-port emissions associated with related ship, rail, and trucking activities contribute an additional 680 tons per year of diesel particulate at the Port of Los Angeles alone.

To put this in perspective, the diesel PM emissions estimated for the Roseville Yard in ARB's 2004 study are 25 tons per year. The potential cancer risk associated with these emissions is 100 in one million at a distance of one mile, or one half mile, depending on the data set used. This rail yard covers one and a half square miles. The Los Angeles and Long Beach ports have combined diesel PM emissions of 550 tons per year emitted from a facility that covers a much larger area - 16 miles. The ports have about twice the emission density of the rail yard - 34 tons per year per square mile compared to 16 tons per year per square mile. However, while this general comparison is illustrative of the overall size of the complex, a detailed air quality modeling analysis would be needed to assess the potential health impact on specific downwind areas near the ports.

ARB is in the process of evaluating the various port-related emission sources from the standpoint of existing emissions, growth forecasts, new control options, regional air quality impacts, and localized health risk. A number of public processes - both state and local - are underway to address various aspects of these issues. Until more of these analyses are complete, there is little basis for recommending a specific separation between new sensitive land uses and ports.

For example, the type of data we have showing the relationship between air pollutant concentrations and distance from freeways is not yet available.

Also, the complexity of the port facilities makes a site-specific analysis critical. Ports are a concentration of multiple emission sources with differing dispersion and other characteristics. In the case of the Roseville rail yard, we found a high, very localized impact associated with a particular activity, service and maintenance. By contrast, the location, size, and nature of impact areas can be expected to vary substantially for different port activities. For instance, ground level emissions from dockside activities would behave differently from ship stack level emissions.

Nonetheless, on an emissions basis alone, we expect locations downwind of ports to be substantially impacted. For that reason, we recommend that land use agencies track the current assessment efforts, and consider limitations on the siting of new sensitive land uses in areas immediately downwind of ports.

Recommendations

Avoid siting new sensitive land uses immediately downwind of ports in the most heavily impacted zones. Consult local air districts or the ARB on the status of pending analyses of health risks.

References

- *Roseville Rail Yard Study.* ARB (2004)
- Final Draft, "*Port-Wide Baseline Air Emissions Inventory."* Port of Los Angeles (June 2004)
- Final Draft, "*2002 Baseline Air Emissions Inventory."* Port of Long Beach (February 2004)

Petroleum Refineries

A petroleum refinery is a complex facility where crude oil is converted into petroleum products (primarily gasoline, diesel fuel, and jet fuel), which are then transported through a system of pipelines and storage tanks for final distribution by delivery truck to fueling facilities throughout the state. In California, most crude oil is delivered either by ship from Alaska or foreign sources, or is delivered via pipeline from oil production fields within the state. The crude oil then undergoes many complex chemical and physical reactions, which include distillation, catalytic cracking, reforming, and finishing. These refining processes have the potential to emit air contaminants, and are subject to extensive emission controls by district regulations.

As a result of these regulations covering the production, marketing, and use of gasoline and other oil by-products, California has seen significant regional air quality benefits both in terms of cleaner fuels and cleaner operating facilities. In the 1990s, California refineries underwent significant modifications and modernization to produce cleaner fuels in response to changes in state law. Nevertheless, while residual emissions are small when compared to the total emissions controlled from these major sources, refineries are so large that even small amounts of fugitive, uncontrollable emissions and associated odors from the operations, can be significant. This is particularly the case for communities that may be directly downwind of the refinery. Odors can cause health symptoms such as nausea and headache. Also, because of the size, complexity, and vast numbers of refinery processes onsite, the occasional refinery upset or malfunction can potentially result in acute or short-term health effects to exposed individuals.

<u>Key Health Findings</u>

Petroleum refineries are large single sources of emissions. For volatile organic compounds (VOCs), eight of the ten largest stationary sources in California are petroleum refineries. For oxides of nitrogen (NOx), four of the ten largest stationary sources in California are petroleum refineries. Both of these compounds react in the presence of sunlight to form ozone. Ozone impacts lung function by irritating and damaging the respiratory system. Petroleum refineries are also large stationary sources of both particulate matter under 10 microns in size (PM_{10}) and particulate matter under 2.5 microns in size ($PM_{2.5}$). Exposure to particulate matter aggravates a number of respiratory illnesses, including asthma, and is associated with premature mortality in people with existing cardiac and respiratory disease. Both long-term and short-term exposure can have adverse health impacts. Finer particles pose an increased health risk because they can deposit deep in the lung and contain substances that are particularly harmful to human health. NOx are also significant contributors to the secondary formation of $PM_{2.5}$.

Petroleum refineries also emit a variety of toxic air pollutants. These air toxics vary by facility and process operation but may include: acetaldehyde, arsenic, antimony, benzene, beryllium, 1,3-butadiene, cadmium compounds, carbonyl sulfide, carbon disulfide, chlorine, dibenzofurans, diesel particulate matter, formaldehyde, hexane, hydrogen chloride, lead compounds, mercury compounds, nickel compounds, phenol, 2,3,7,8 tetrachlorodibenzo-p-dioxin, toluene, and xylenes (mixed) among others. The potential health effects associated with these air toxics can include cancer, respiratory irritation, and damage to the central nervous system, depending on exposure levels.

<u>Distance Related Findings</u>

Health risk assessments for petroleum refineries have shown risks from toxic air pollutants that have quantifiable health risk values to be around 10 potential cancer cases per million. Routine air monitoring and several air monitoring studies conducted in the San Francisco Bay Area (Crockett) and the South Coast Air Basin (Wilmington) have not identified significant health risks specifically associated with refineries. However, these studies did not measure diesel PM as no accepted method currently exists, and there are many toxic air pollutants that do not have quantifiable health risk values.

In 2002, ARB published a report on the results of the state and local air district air monitoring done near oil refineries. The purpose of this evaluation was to try to determine how refinery-related emissions might impact nearby communities. This inventory of air monitoring activities included 10 ambient air monitoring stations located near refineries in Crockett and four stations near refineries in Wilmington. These monitoring results did not identify significant increased health risks associated with the petroleum refineries. In 2002-2003, ARB conducted additional monitoring studies in communities downwind of refineries in Crockett and Wilmington. These monitoring results also did not indicate significant increased health risks from the petroleum refineries.

Consequently, there are no air quality modeling or air monitoring data that provides a quantifiable basis for recommending a specific separation between refineries and new sensitive land uses. However, in view of the amount and potentially hazardous nature of many of the pollutants released as part of the refinery process, we believe the siting of new sensitive land uses immediately downwind should be avoided. Land use agencies should consult with the local air district when considering how to define an appropriate separation for refineries within their jurisdiction.

Recommendations

- Avoid siting new sensitive land uses immediately downwind of petroleum refineries. Consult with local air districts and other local agencies to determine an appropriate separation.

References

- *Review of Current Ambient Air Monitoring Activities Related to California Bay Area and South Coast Refineries. ARB (March 2002)* http://www.arb.ca.gov/aaqm/qmosqual/special/mldrefinery.pdf
- *Community Air Quality Monitoring: Special Studies – Crockett. ARB (September 2004)* http://www.arb.ca.gov/ch/communities/studies/crockett/crockett.htm
- *Wilmington Study - Air Monitoring Results. ARB (2003)* http://www.arb.ca.gov/ch/communities/studies/wilmington/wilmington.htm

Chrome Plating Operations

Chrome plating operations rely on the use of the toxic metal hexavalent chromium, and have been subject to ARB and local air district control programs for many years. Regulation of chrome plating operations has reduced statewide emissions substantially. However, due to the nature of chrome plating operations and the highly toxic nature of hexavalent chromium, the remaining health risk to nearby residents is a continuing concern.

Chrome plating operations convert hexavalent chromium in solution to a chromium metal layer by electroplating, and are categorized based upon the thickness of the chromium metal layer applied. In “decorative plating”, a layer of nickel is first plated over a metal substrate. Following this step, a thin layer of chromium is deposited over the nickel layer to provide a decorative and protective finish, for example, on faucets and automotive wheels. “Hard chrome plating” is a process in which a thicker layer of chromium metal is deposited directly on metal substrates such as engine parts, industrial machinery, and tools to provide greater protection against corrosion and wear.

Hexavalent chromium is emitted into the air when an electric current is applied to the plating bath. Emissions are dependent upon the amount of electroplating done per year and the control requirements. A unit of production referred to as an ampere-hour represents the amount of electroplating produced. Small facilities have an annual production rate of 100,000 – 500,000 ampere-hours, while medium-size facilities may have a production rate of 500,000 to about 3 million ampere-hours. The remaining larger facilities have a range of production rates that can be as high as 80 million ampere-hours.

The control requirements, which reduce emissions from the plating tanks, vary according to the size and type of the operation. Facilities either install add-on pollution control equipment, such as filters and scrubbers, or in-tank controls, such as fume suppressants and polyballs. With this combination of controls, the overall hexavalent chromium emissions have been reduced by over 90 percent. Larger facilities typically have better controls that can achieve efficiencies greater than 99 percent. However, even with stringent controls, the lack of maintenance and good housekeeping practices can lead to problems. And, since the material itself is inherently dangerous, any lapse in compliance poses a significant risk to nearby residents.

A 2002 ARB study in the San Diego community of Barrio Logan measured unexpectedly high concentrations of hexavalent chromium near chrome platers. The facilities were located in a mixed-use area with residences nearby. The study found that fugitive dust laden with hexavalent chromium was an important source of emissions that likely contributed to the elevated cancer risk. Largely as a result of this study, ARB is in the process of updating the current requirements to further reduce the emissions from these facilities.

In December 2004, the ARB adopted an ATCM to reduce emissions of hexavalent chromium and nickel from thermal spraying operations through the installation of best available control technology. The ATCM requires all existing facilities to comply with its requirements by January 1, 2006. New and modified thermal spraying operations must comply upon initial startup. An existing thermal spraying facility may be exempt from the minimum control efficiency requirements of the ATCM if it is located at least 1,640 feet from the nearest sensitive receptor and emits no more than 0.5 pound per year of hexavalent chromium.[8]

Key Health Findings

Hexavalent chromium is one of the most toxic air pollutants regulated by the State of California. Hexavalent chromium is a carcinogen and has been identified in worker health studies as causing lung cancer. Exposure to even very low levels of hexavalent chromium should be avoided.

The California Office of Environmental Health Hazard Assessment has found that: 1) many epidemiological studies show a strong association between hexavalent chromium exposure in the work place and respiratory cancer; and 2) all short-term assays reported show that hexavalent chromium compounds can cause damage to human DNA.

Hexavalent chromium when inhaled over a period of many years can cause a variety of non-cancer health effects. These health effects include damage to the nose, blood disorders, lung disease, and kidney damage. The non-cancer health impacts occur with exposures considerably higher than exposures causing significant cancer risks. It is less likely that the public would be exposed to hexavalent chromium at levels high enough to cause these non-cancer health effects. Non-cancer health effects, unlike cancer health effects, have a threshold or exposure level below which non-cancer health effects would not be expected.

Distance Related Findings

ARB's 2002 Barrio Logan Study measured concentrations of hexavalent chromium in the air near two chrome plating facilities. The study was conducted from December 2001 to May 2002. There were two chrome platers on the street - one decorative and one hard plater. The purpose of the study was to better understand the near source impact of hexavalent chromium emissions. Air monitors were placed at residences next to the platers and at varying distances down the street. The monitors were moved periodically to look at the spatial distribution of the impact. Source testing and facility inspections identified one of the facilities as the likely source.

The first two weeks of monitoring results showed unexpectedly high levels of hexavalent chromium at a number of the monitoring sites. The high concentrations were intermittent. The concentrations ranged from 1 to 22 ng/m3 compared to the statewide average of 0.1 ng/m3. If these levels were to continue for 70 years, the potential cancer risk would be 150 in one million. The highest value was found at an air monitor behind a house adjacent to one of the

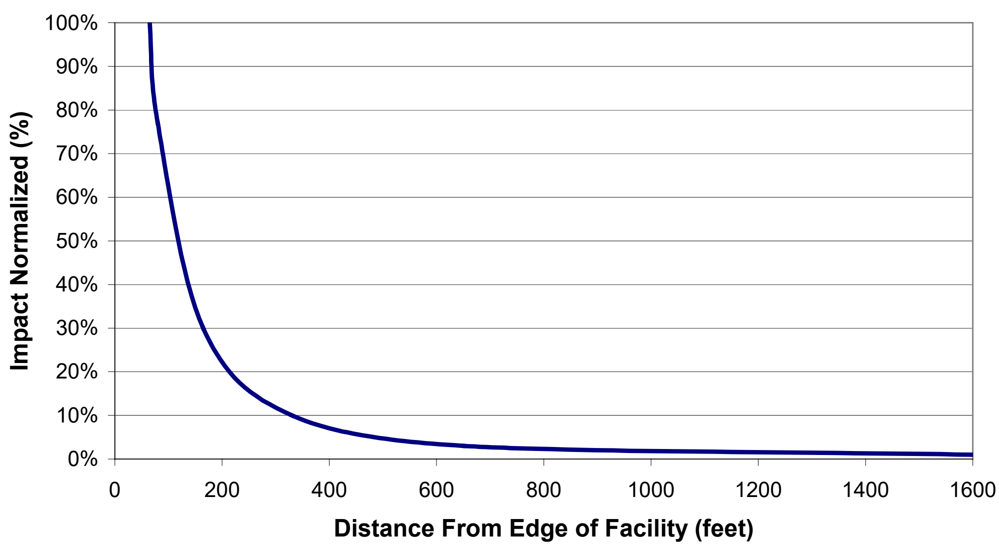
[8] For further information on the ATCM, please refer to:
http://www.arb.ca.gov/regact/thermspr/thermalspr.htm

plating facilities–approximately 30 feet from the back entrance. Lower, but significant concentrations were found at an ambient air monitor 250 feet away.

The monitoring covered a period when the facility was not operating its plating tank. During this period, one of the highest concentrations was measured at an adjacent house. It appears that chromium-laden dust was responsible for high concentrations at this location since there was no plating activity at the time. Dust samples from the facility were tested and found to contain high levels of hexavalent chromium. On the day the highest concentration was measured at the house next door, a monitor 350 feet away from the plater's entrance showed very little impact. Similar proximity effects are shown in ARB modeling studies.

Figure 1-5 shows how the relative health risk varies as a function of distance from a chrome plater. This analysis is based on a medium-sized chrome plater with an annual production rate of 3 million ampere-hours. As shown in Figure 1- 5, the potential health risk drops off rapidly, with over 90 percent reduction in risk within 300 feet. This modeling was done in 2003 as part of a review of ARB's current air toxic control measure for chrome platers and is based on data from a recent ARB survey of chrome platers in California. The emission

Figure 1-5
Risk vs. Distance From Chrome Plater
(Based on plating tank emissions)



rates are only for plating operations. Because there are insufficient data available to directly quantify the impacts, the analysis does not include fugitive emissions, which the Barrio Logan analysis indicated could be significant.

Both the ARB Barrio Logan monitoring results and ARB's 2003 modeling analysis suggests that the localized emissions impact of a chrome plater diminishes significantly at 300 feet. However, in developing our recommendation, we also considered the following factors:

- some chrome platers will have higher volumes of plating activity,
- potential dust impacts were not modeled,
- we have only one monitoring study looking at the impact of distance, and,
- hexavalent chromium is one of the most potent toxic air contaminants ARB has identified.

Given these limitations in the analysis, we recommend a separation of 1,000 feet as a precautionary measure. For large chrome platers, site specific information should be obtained from the local air district.

Recommendation

- Avoid siting new sensitive land uses within 1,000 feet of a chrome plater.

References

- *Ambient Air Monitoring for Hexavalent Chromium and Metals in Barrio Logan: May 2001 through May 2002.* ARB, Monitoring and Laboratory Division (October 14, 2003)
- *Draft Barrio Logan Report.* ARB, Planning and Technical Support Division (November 2004)
- *Proposed Amendments to the Hexavalent Chromium Control Measure for Decorative and Hard Chrome Plating and Chromic Acid Anodizing Facilities.* ARB (April 1998)
- Murchison, Linda; Suer, Carolyn; Cook, Jeff. *"Neighborhood Scale Monitoring in Barrio Logan," (*AWMA Annual Conference Proceedings, June 2003)

Dry Cleaners Using Perchloroethylene (Perc Dry Cleaners)

Perchloroethylene (perc) is the solvent most commonly used by the dry cleaning industry to clean clothes or other materials. The ARB and other public health agencies have identified perc as a potential cancer-causing compound. Perc persists in the atmosphere long enough to contribute to both regional air pollution and localized exposures. Perc dry cleaners are the major source of perc emissions in California.

Since 1990, the statewide concentrations and health risk from exposure to perc has dropped over 70 percent. This is due to a number of regulatory requirements on perc dry cleaners and other sources, including degreasing operations, brake cleaners, and adhesives. ARB adopted an Airborne Toxic Control Measure (ATCM) for Perc Emissions from Dry Cleaning Operations in 1993. ARB has also prohibited the use of perc in aerosol adhesives and automotive brake cleaners.

Perc dry cleaners statewide are required to comply with ARB and local air district regulations to reduce emissions. However, even with these controls, some emissions continue to occur. Air quality studies indicate that there is still the potential for significant risks even near well-controlled dry cleaners. The South Coast AQMD has adopted a rule requiring that all new dry cleaners use alternatives to perc and that existing dry cleaners phase out the use of perc by December 2020. Over time, transition to non-toxic alternatives should occur. However, while perc continues to be used, a preventative approach should be taken to siting of new sensitive land uses.

Key Health Findings

Inhalation of perc may result in both cancer and non-cancer health effects. An assessment by California's Office of Environmental Health Hazard Assessment (OEHHA) concluded that perc is a potential human carcinogen and can cause non-cancer health effects. In addition to the potential cancer risk, the effects of long-term exposure include dizziness, impaired judgment and perception, and damage to the liver and kidneys. Workers have shown signs of liver toxicity following chronic exposure to perc, as well as kidney dysfunction and neurological effects. Non-cancer health effects occur with higher exposure levels than those associated with significant cancer risks. The public is more likely to be exposed to perchloroethylene at levels causing significant cancer risks than to levels causing non-cancer health effects. Non-cancer health effects, unlike cancer health effects, have a threshold or exposure level below which non-cancer health effects would not be expected. The ARB formally identified perc as a toxic air contaminant in October 1991.

One study has determined that inhalation of perc is the predominant route of exposure to infants living in apartments co-located in the same building with a business operating perc dry cleaning equipment. Results of air sampling within co-residential buildings indicate that dry cleaners can cause a wide range of exposures depending on the type and maintenance of the equipment. For example, a well-maintained state-of-the-art system may have risks in the range of 10 in one million, whereas a badly maintained machine with major leaks can have potential cancer risks of thousands in one million.

The California Air Pollution Control Officers Association (CAPCOA) is developing Industry-wide Risk Assessment Guidelines for Perchloroethylene Dry Cleaners which, when published, will provide detailed information on public health risk from exposure to emissions from this source.

Distance Related Findings

Risk created by perc dry cleaning is dependent on the amount of perc emissions, the type of dry cleaning equipment, proximity to the source, and how the emissions are released and dispersed (e.g., type of ventilation system, stack parameters, and local meteorology). Dry cleaners are often located near residential areas, and near shopping centers, schools, day-care centers, and restaurants.

The vast majority of dry cleaners in California have one dry cleaning machine per facility. The South Coast AQMD estimates that an average well-controlled dry cleaner uses about 30 to 160 gallons of cleaning solvent per year, with an average of about 100 gallons. Based on these estimates, the South Coast AQMD estimates a potential cancer risk between 25 to 140 in one million at residential locations 75 feet or less from the dry cleaner, with an average of about 80 in one million. The estimate could be as high as 270 in one million for older machines.

CAPCOA's draft industry-wide risk assessment of perc dry cleaning operations indicates that the potential cancer risk for many dry cleaners may be in excess of potential cancer risk levels adopted by the local air districts. The draft document also indicates that, in general, the public's exposure can be reduced by at least 75 percent, by providing a separation distance of about 300 feet from the operation. This assessment is based on a single machine with perc use of about 100 gallons per year. At these distances, the potential cancer risk would be less than 10 potential cases per million for most scenarios.

The risk would be proportionately higher for large, industrial size, dry cleaners. These facilities typically have two or more machines and use 200 gallons or more per year of perc. Therefore, separation distances need to be greater for large dry cleaners. At a distance of 500 feet, the remaining risk for a large plant can be reduced by over 85 percent.

In California, a small number of dry cleaners that are co-located (sharing a common wall, floor, or ceiling) with a residence have the potential to expose the inhabitants of the residence to high levels of perc. However, while special requirements have been imposed on these existing facilities, the potential for exposure still exists. Avoiding these siting situations in the future is an important preventative measure.

Local air districts are a source of information regarding specific dry cleaning operations—particularly for large industrial operations with multiple machines. The 300 foot separation recommended below reflects the most common situation – a dry cleaner with only one machine. While we recommend 500 feet when there are two or more machines, site specific information should be obtained from the local air district for some very large industrial operations. Factors that can impact the risk include the number and type of machines, controls used, source configuration, building dimensions, terrain, and meteorological data.

Recommendation

- Avoid siting new sensitive land uses within 300 feet of any dry cleaning operation. For operations with two or more machines provide 500 feet. For operations with 3 or more machines, consult with the local air district.

- Do not site new sensitive land uses in the same building with perc dry cleaning operations.

References

- *Proposed Amended Rule 1421 – Control of Perchloroethylene Emissions from Dry Cleaning Systems,* Final Staff Report. South Coast AQMD. (October 2002)
- *Air Toxic Control Measure for Emissions of Perchloroethylene from Dry Cleaning Operations.* ARB (1994) (http://www.arb.ca.gov/toxics/atcm/percatcm.htm)
- *"An Assessment of Tetrachloroethylene in Human Breast Milk"*, Judith Schreiber, New York State Department of Health – Bureau of Toxic Substance Assessment, Journal of Exposure Analysis and Environmental Epidemiology, Vol.2, Suppl.2, pp. 15-26, 1992.
- Draft *Air Toxics "Hot Spots" Program Perchloroethylene Dry Cleaner Industry-wide Risk Assessment Guidelines.* (CAPCOA (November 2002)
- *Final Environmental Assessment for Proposed Amended Rule 1421 – Control of Perchloroethylene Emissions from Dry Cleaning Systems.* South Coast AQMD. (October 18, 2002)

Gasoline Dispensing Facilities

Refueling at gasoline dispensing facilities releases benzene into the air. Benzene is a potent carcinogen and is one of the highest risk air pollutants regulated by ARB. Motor vehicles and motor vehicle-related activity account for over 90 percent of benzene emissions in California. While gasoline-dispensing facilities account for a small part of total benzene emissions, near source exposures for large facilities can be significant.

Since 1990, benzene in the air has been reduced by over 75 percent statewide, primarily due to the implementation of emissions controls on motor vehicle vapor recovery equipment at gas stations, and a reduction in benzene levels in gasoline. However, benzene levels are still significant. In urban areas, average benzene exposure is equivalent to about 50 in one million.

Gasoline dispensing facilities tend to be located in areas close to residential and shopping areas. Benzene emissions from the largest gas stations may result in near source health risk beyond the regional background and district health risk thresholds. The emergence of very high gasoline throughput at large retail or wholesale outlets makes this a concern as these types of outlets are projected to account for an increasing market share in the next few years.

Key Health Findings

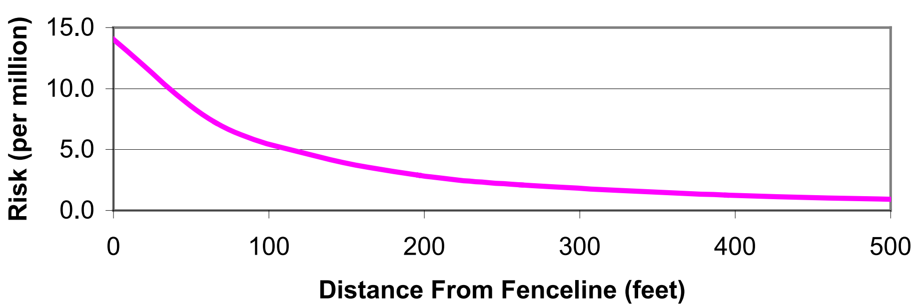
Benzene is a human carcinogen identified by ARB as a toxic air contaminant. Benzene also can cause non-cancer health effects above a certain level of exposure. Brief inhalation exposure to high concentrations can cause central nervous system depression. Acute effects include central nervous system symptoms of nausea, tremors, drowsiness, dizziness, headache, intoxication, and unconsciousness. It is unlikely that the public would be exposed to levels of benzene from gasoline dispensing facilities high enough to cause these non-cancer health effects.

Distance Related Findings

A well-maintained vapor recovery system can decrease emissions of benzene by more than 90% compared with an uncontrolled facility. Almost all facilities have emission control systems. Air quality modeling of the health risks from gasoline dispensing facilities indicate that the impact from the facilities decreases rapidly as the distance from the facility increases.

Statistics reported in the ARB's staff reports on Enhanced Vapor Recovery released in 2000 and 2002, indicated that almost 96 percent of the gasoline dispensing facilities had a throughput less than 2.4 million gallons per year. The remaining four percent, or approximately 450 facilities, had throughputs exceeding 2.4 million gallons per year. For these stations, the average gasoline throughput was 3.6 million gallons per year.

Figure 1-6
Gasoline Dispensing Facility Health Risk
for 3,600,000 gal/yr throughput



As shown in Figure 1-6, the risk levels for a gasoline dispensing facility with a throughput of 3.6 million gallons per year is about 10 in one million at a distance of 50 feet from the fenceline. However, as the throughput increases, the potential risk increases.

As mentioned above, air pollution levels in the immediate vicinity of large gasoline dispensing facilities may be higher than the surrounding area (although tailpipe emissions from motor vehicles dominates the health impacts). Very large gasoline dispensing facilities located at large wholesale and discount centers may dispense nine million gallons of gasoline per year or more. At nine million gallons, the potential risk could be around 25 in one million at 50 feet, dropping to about five in one million at 300 feet. Some facilities have throughputs as high as 19 million gallons.

Recommendation

- Avoid siting new sensitive land uses within 300 feet of a large gasoline dispensing facility (defined as a facility with a throughput of 3.6 million gallons per year or greater). A 50 foot separation is recommended for typical gas dispensing facilities.

References

- *Gasoline Service Station Industry-wide Risk Assessment Guidelines.* California Air Pollution Control Officers Association (December 1997 and revised November 1, 2001)
- *Staff Report on Enhanced Vapor Recovery.* ARB (February 4, 2000)
- *The California Almanac of Emissions and Air Quality.* ARB (2004)
- *Staff Report on Enhanced Vapor Recovery Technology Review.* ARB (October 2002)

Other Facility Types that Emit Air Pollutants of Concern

In addition to source specific recommendations, Table 1-3 includes a list of other industrial sources that could pose a significant health risk to nearby sensitive individuals depending on a number of factors. These factors include the amount of pollutant emitted and its toxicity, the distance to nearby individuals, and the type of emission controls in place. Since these types of facilities are subject to air permits from local air districts, facility specific information should be obtained where there are questions about siting a sensitive land use close to an industrial facility.

Potential Sources of Odor and Dust Complaints

Odors and dust from commercial activities are the most common sources of air pollution complaints and concerns from the public. Land use planning and permitting processes should consider the potential impacts of odor and dust on surrounding land uses, and provide for adequate separation between odor and dust sources. As with other types of air pollution, a number of factors need to be considered when determining an adequate distance or mitigation to avoid odor or

Table 1-3 – Examples of Other Facility Types That Emit[1] Air Pollutants of Concern

Categories	Facility Type	Air Pollutants of Concern
Commercial		
	Autobody Shops	Metals, Solvents
	Furniture Repair	Solvents[2], Methylene Chloride
	Film Processing Services	Solvents, Perchloroethylene
	Distribution Centers	Diesel Particulate Matter
	Printing Shops	Solvents
	Diesel Engines	Diesel Particulate Matter
Industrial		
	Construction	Particulate Matter, Asbestos
	Manufacturers	Solvents, Metals
	Metal Platers, Welders, Metal Spray (flame spray) Operations	Hexavalent Chromium, Nickel, Metals
	Chemical Producers	Solvents, Metals
	Furniture Manufacturers	Solvents
	Shipbuilding and Repair	Hexavalent chromium and other metals, Solvents
	Rock Quarries and Cement Manufacturers	Particulate Matter, Asbestos
	Hazardous Waste Incinerators	Dioxin, Solvents, Metals
	Power Plants	Benzene, Formaldehyde, Particulate Matter
	Research and Development Facilities	Solvents, Metals, etc.
Public		
	Landfills	Benzene, Vinyl Chloride, Diesel Particulate Matter
	Waste Water Treatment Plants	Hydrogen Sulfide
	Medical Waste Incinerators	Dioxin, Benzene, PAH, PCBs, 1,3-Butadiene
	Recycling, Garbage Transfer Stations	Diesel Particulate Matter
	Municipal Incinerators	Dioxin, Benzene, PAH, PCBs, 1,3-Butadiene
Transportation		
	Truck Stops	Diesel Particulate Matter
Agricultural Operations		
	Farming Operations	Diesel Particulate Matter, VOCs, NOx, PM10, CO, SOx, Pesticides
	Livestock and Dairy Operations	Ammonia, VOCs, PM10

[1]Not all facilities will emit pollutants of concern due to process changes or chemical substitution. Consult the local air district regarding specific facilities.
[2]Some solvents may emit toxic air pollutants, but not all solvents are toxic air contaminants.

dust complaints in a specific situation. Local air districts should be consulted for advice when these siting situations arise.

Table 1-4
Sources of Odor Complaints

- Sewage Treatment Plants
- Landfills
- Recycling Facilities
- Waste Transfer Stations
- Petroleum Refineries
- Biomass Operations
- Autobody Shops
- Coating Operations
- Fiberglass Manufacturing
- Foundries
- Rendering Plants
- Livestock Operations

Table 1-4 lists some of the most common sources of odor complaints received by local air districts. Complaints about odors are the responsibility of local air districts and are covered under state law. The types of facilities that can cause odor complaints are varied and can range from small commercial facilities to large industrial facilities, and may include waste disposal and recycling operations. Odors can cause health symptoms such as nausea and headache. Facilities with odors may also be sources of toxic air pollutants (See Table 1-3). Some common sources of odors emitted by facilities are sulfur compounds, organic solvents, and the decomposition/digestion of biological materials. Because of the subjective nature of an individual's sensitivity to a particular type of odor, there is no specific rule for assigning appropriate separations from odor sources. Under the right meteorological conditions, some odors may still be offensive several miles from the source.

Sources of dust are also common sources of air pollution-related complaints. Operations that can result in dust problems are rock crushing, gravel production, stone quarrying, and mining operations. A common source of complaints is the dust and noise associated with blasting that may be part of these operations. Besides the health impacts of dust as particulate matter, thick dust also impairs visibility, aesthetic values, and can soil homes and automobiles. Local air districts typically have rules for regulating dust sources in their jurisdictions, but dust sources can still be a concern. Therefore, separation of these facilities from residential and other new sensitive land uses should be considered.

In some areas of California, asbestos occurs naturally in stone deposits. Asbestos is a potent carcinogenic substance when inhaled. Asbestos-containing dust may be a public health concern in areas where asbestos-containing rock is mined, crushed, processed, or used. Situations where asbestos-containing gravel has been used in road paving materials are also a source of asbestos exposure to the general public. Planners are advised to consult with local air pollution agencies in areas where asbestos-containing gravel or stone products are produced or used.

2. Handbook Development

ARB and local air districts share responsibility for improving statewide air quality. As a result of California's air pollution control programs, air quality has improved and health risk has been reduced statewide. However, state and federal air quality standards are still exceeded in many areas of California and the statewide health risk posed by toxic air contaminants (air toxics) remains too high. Also, some communities experience higher pollution exposures than others - making localized impacts, as well regional or statewide impacts, an important consideration. It is for this reason that this Handbook has been produced - to promote better, more informed decision-making by local land use agencies that will improve air quality and public health in their communities.

Land use policies and practices, including planning, zoning, and siting activities, can play a critical role in air quality and public health at the local level. For instance, even with the best available control technology, some projects that are sited very close to homes, schools, and other public places can result in elevated air pollution exposures. The reverse is also true – siting a new school or home too close to an existing source of air pollution can pose a public health risk. The ARB recommendations in section 1 address this issue.

> *This Handbook is an informational document that we hope will strengthen the relationship between air quality and land use agencies. It highlights the need for land use agencies to address the potential for new projects to result in localized health risk or contribute to cumulative impacts where air pollution sources are concentrated.*

Avoiding these incompatible land uses is a key to reducing localized air pollution exposures that can result in adverse health impacts, especially to sensitive individuals.

Individual siting decisions that result in incompatible land uses are often the result of locating "sensitive" land uses next to polluting sources. These decisions can be of even greater concern when existing air pollution exposures in a community are considered. In general terms, this is often referred to as the issue of "cumulative impacts." ARB is working with local air districts to better define these situations and to make information about existing air pollution levels (e.g., from local businesses, motor vehicles, and other areawide sources) more readily available to land use agencies.

In December 2001, the ARB adopted "Policies and Actions for Environmental Justice" (Policies). These Policies were developed in coordination with a group of stakeholders, representing local government agencies, community interest groups, environmental justice organizations, academia, and business (Environmental Justice Stakeholders Group).

The Policies included a commitment to work with land use planners, transportation agencies, and local air districts to develop ways to identify, consider, and reduce cumulative air pollution emissions, exposure, and health risks associated with land use planning and decision-making. Developed under the auspices of the ARB's Environmental Justice Stakeholders Group, this Handbook is a first step in meeting that commitment.

ARB has produced this Handbook to help achieve several objectives:

- Provide recommendations on situations to avoid when siting new residences, schools, day care centers, playgrounds, and medical-related facilities (sensitive sites or sensitive land uses);

- Identify approaches that land use agencies can use to prevent or reduce potential air pollution impacts associated with general plan policies, new land use development, siting, and permitting decisions;

- Improve and facilitate access to air quality data and evaluation tools for use in the land use decision-making process;

- Encourage stronger collaboration between land use agencies and local air districts to reduce community exposure to source-specific and cumulative air pollution impacts; and

- Emphasize community outreach approaches that promote active public involvement in the air quality/land use decision-making process.

This Handbook builds upon California's 2003 General Plan Guidelines. These Guidelines, developed by the Governor's Office of Planning and Research (OPR), explain the land use planning process and applicable legal requirements. This Handbook also builds upon a 1997 ARB report, "The Land Use-Air Quality Linkage" ("Linkage Report").[9] The Linkage Report was an outgrowth of the California Clean Air Act which, among other things, called upon local air districts to focus particular attention on reducing emissions from sources that indirectly cause air pollution by attracting vehicle trips. Such indirect sources include, but are not limited to, shopping centers, schools and universities, employment centers, warehousing, airport hubs, medical offices, and sports arenas. The Linkage Report summarizes data as of 1997 on the relationships between land use, transportation, and air quality, and highlights strategies that can help to reduce the use of single occupancy automobile use. Such strategies

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[9] To access this report, please refer to ARB's website or click on: http://www.arb.ca.gov/ch/programs/link97.pdf

complement ARB regulatory programs that continue to reduce motor vehicle emissions.

In this Handbook, we identify types of air quality-related information that we recommend land use agencies consider in the land use decision-making processes such as the development of regional, general, and community plans; zoning ordinances; environmental reviews; project siting; and permit issuance. The Handbook provides recommendations on the siting of new sensitive land uses based on current analyses. It also contains information on approaches and methodologies for evaluating new projects from an air pollution perspective.

The Handbook looks at air quality issues associated with emissions from industrial, commercial, and mobile sources of air pollution. Mobile sources continue to be the largest overall contributors to the state's air pollution problems, representing the greatest air pollution health risk to most Californians. Based on current health risk information for air toxics, the most serious pollutants on a statewide basis are diesel PM, benzene, and 1,3-butadiene, all of which are primarily emitted by motor vehicles. From a state perspective, ARB continues to pursue new strategies to further reduce motor vehicle-related emissions in order to meet air quality standards and reduce air toxics risk.

While mobile sources are the largest overall contributors to the state's air pollution problems, industrial and commercial sources can also pose a health risk, particularly to people near the source. For this reason, the issue of incompatible land uses is an important focus of this document.

Handbook Audience

Even though the primary users of the Handbook will likely be agencies responsible for air quality and land use planning, we hope the ideas and technical issues presented in this Handbook will also be useful for:

- public and community organizations and community residents;
- federal, state and regional agencies that fund, review, regulate, oversee, or otherwise influence environmental policies and programs affected by land use policies; and
- private developers.

3. Key Community Focused Issues Land Use Agencies Should Consider

Two key air quality issues that land use agencies should consider in their planning, zoning, and permitting processes are:

1) **Incompatible Land Uses.** Localized air pollution impacts from incompatible land use can occur when polluting sources, such as a heavily trafficked roadway, warehousing facilities, or industrial or commercial facilities, are located near a land use where sensitive individuals are found such as a school, hospital, or homes.

2) **Cumulative Impacts.** Cumulative air pollution impacts can occur from a concentration of multiple sources that individually comply with air pollution control requirements or fall below risk thresholds, but in the aggregate may pose a public health risk to exposed individuals. These sources can be heavy or light-industrial operations, commercial facilities such as autobody shops, large gas dispensing facilities, dry cleaners, and chrome platers, and freeways or other nearby busy transportation corridors.

Incompatible Land Uses

Land use policies and practices can worsen air pollution exposure and adversely affect public health by mixing incompatible land uses. Examples include locating new sensitive land uses, such as housing or schools, next to small metal plating facilities that use a highly toxic form of chromium, or very near large industrial facilities or freeways. Based on recent monitoring and health-based studies, we now know that air quality impacts from incompatible land uses can contribute to increased risk of illness, missed work and school, a lower quality of life, and higher costs for public health and pollution control.[10]

Avoiding incompatible land uses can be a challenge in the context of mixed-use industrial and residential zoning. For a variety of reasons, government agencies and housing advocates have encouraged the proximity of affordable housing to employment centers, shopping areas, and transportation corridors, partially as a means to reduce vehicle trips and their associated emissions. Generally speaking, typical distances in mixed-use communities between businesses and industries and other land uses such as homes and schools, should be adequate to avoid health risks. However, generalizations do not always hold as we addressed in section 1 of this Handbook.

In terms of siting air pollution sources, the proposed location of a project is a major factor in determining whether it will result in localized air quality impacts. Often, the problem can be avoided by providing an adequate distance or setback

[10] For more information, the reader should refer to ARB's website on community health: http://www.arb.ca.gov/ch/ch.htm

between a source of emissions and nearby sensitive land uses. Sometimes, suggesting project design changes or mitigation measures in the project review phase can also reduce or avoid potential impacts. This underscores the importance of addressing potential incompatible land uses as early as possible in the project review process, ideally in the general plan itself.

Cumulative Air Pollution Impacts

The broad concept of cumulative air pollution impacts reflects the combination of regional air pollution levels and any localized impacts. Many factors contribute to air pollution levels experienced in any location. These include urban background air pollution, historic land use patterns, the prevalence of freeways and other transportation corridors, the concentration of industrial and commercial businesses, and local meteorology and terrain.

When considering the potential air quality impacts of polluting sources on individuals, project location and the concentration of emissions from air pollution sources need to be considered in the land use decision-making process. In section 4, the Handbook offers a series of questions that helps land use agencies determine if a project should undergo a more careful analysis. This holds true regardless of whether the project being sited is a polluting source or a sensitive land use project.

Large industrial areas are not the only land uses that may result in public health concerns in mixed-use communities. Cumulative air pollution impacts can also occur if land uses do not adequately provide setbacks or otherwise protect sensitive individuals from potential air pollution impacts associated with nearby light industrial sources. This can occur with activities such as truck idling and traffic congestion, or from indirect sources such as warehousing facilities that are located in a community or neighborhood.

In October 2004, Cal/EPA published its Environmental Justice Action Plan. In February 2005, the Cal/EPA Interagency Working Group approved a working definition of “cumulative impacts” for purposes of initially guiding the pilot projects that are being conducted pursuant to that plan. Cal/EPA is now in the process of developing a Cumulative Impacts Assessment Guidance document. Cal/EPA will revisit the working definition of “cumulative impacts” as the Agency develops that guidance. The following is the working definition:

> *“Cumulative impacts means exposures, public health or environmental effects from the combined emissions and discharges, in a geographic area, including environmental pollution from all sources, whether single or multi-media, routinely, accidentally, or otherwise released. Impacts will take into account sensitive populations and socio-economic factors, where applicable, and to the extent data are available.”*

4. Mechanisms for Integrating Localized Air Quality Concerns Into Land Use Processes

Land use agencies should use each of their existing planning, zoning, and permitting authorities to address the potential health risk associated with new projects. Land use-specific mechanisms can go a long way toward addressing both localized and cumulative impacts from new air pollution sources that are not otherwise addressed by environmental regulations. Likewise, close collaboration and communication between land use agencies and local air districts in both the planning and project approval stages can further reduce these impacts. Local agency partnerships can also result in early identification of potential impacts from proposed activities that might otherwise escape environmental review. When this happens, pollution problems can be prevented or reduced before projects are approved, when it is less complex and expensive to mitigate.

The land use entitlement process requires a series of planning decisions. At the highest level, the General Plan sets the policies and direction for the jurisdiction, and includes a number of mandatory elements dealing with issues such as housing, circulation, and health hazards. Zoning is the primary tool for implementing land use policies. Specific or community plans created in conjunction with a specific project also perform many of the same functions as a zoning ordinance. Zoning can be modified by means of variances and conditional use permits. The latter are frequently used to insure compatibility between otherwise conflicting land uses. Finally, new development usually requires the approval of a parcel or tract map before grading and building permits can be issued. These parcel or tract maps must be consistent with the applicable General Plan, zoning and other standards.

Land use agencies can use their planning authority to separate industrial and residential land uses, or to require mitigation where separation is not feasible. By separating incompatible land uses, land use agencies can prevent or reduce both localized and cumulative air pollution impacts without denying what might otherwise be a desirable project.[11] For instance:

- a dry cleaner could open a storefront operation in a community with actual cleaning operations performed at a remote location away from residential areas;
- gas dispensing facilities with lower fuel throughput could be sited in mixed-use areas;
- enhanced building ventilation or filtering systems in schools or senior care centers can reduce ambient air from nearby busy arterials; or
- landscaping and regular watering can be used to reduce fugitive dust at a building construction site near a school yard.

[11] It should be noted that such actions should also be considered as part of the General Plan or Plan element process.

The following general and specific land use approaches can help to reduce potential adverse air pollution impacts that projects may have on public health.

General Plans

The primary purpose of planning, and the source of government authority to engage in planning, is to protect public health, safety, and welfare. In its most basic sense, a local government General Plan expresses the community's development goals and embodies public policy relative to the distribution of future land uses, forming the basis for most land use decisions. Therefore, the most effective mechanism for dealing with the central land use concept of compatibility and its relationship to cumulative air pollution impacts is the General Plan. Well before projects are proposed within a jurisdiction, the General Plan sets the stage for where projects can be sited, and their compatibility with comprehensive community goals, objectives, and policies.

In 2003, OPR revised its General Plan Guidelines, highlighting the importance of incorporating sustainable development and environmental justice policies in the planning process. The OPR General Plan Guidelines provides an effective and long-term approach to reduce cumulative air pollution impacts at the earliest planning stages. In light of these important additions to the Guidelines, land use agencies should consider updating their General Plans or Plan elements to address these revisions.

The General Plan and related Plan elements can be used to avoid incompatible land uses by incorporating air quality considerations into these documents. For instance, a General Plan safety element with an air quality component could be used to incorporate policies or objectives that are intended to protect the public from the potential for facility breakdowns that may result in a dangerous release of air toxics. Likewise, an air quality component to the transportation circulation element of the General Plan could include policies or standards to prevent or reduce local exposure to diesel exhaust from trucks and other vehicles. For instance, the transportation circulation element could encourage the construction of alternative routes away from residential areas for heavy-duty diesel trucks. By considering the relationship between air quality and transportation, the circulation element could also include air quality policies to prevent or reduce trips and travel, and thus vehicle emissions. Policies in the land use element of the General Plan could identify areas appropriate for future industrial, commercial, and residential uses. Such policies could also introduce design and distance parameters that reduce emissions, exposure, and risk from industrial and some commercial land uses (e.g., dry cleaners) that are in close proximity to residential areas or schools.

Land use agencies should also consider updating or creating an air quality element in the jurisdiction's General Plan. In the air quality element, local decision-makers could develop long-term, effective plans and policies to address air quality issues, including cumulative impacts. The air quality element can also provide a general reference guide that informs local land use planners about regional and community level air quality, regulatory air pollution control requirements and guidelines, and references emissions and pollution source data bases and assessment and modeling tools. As is further described in Appendix C of the Handbook, new assessment tools that ARB is developing can be included into the air quality element by reference. For instance, ARB's statewide risk maps could be referenced in the air quality element as a resource that could be consulted by developers or land use agencies

Zoning

The purpose of "zoning" is to separate different land uses. Zoning ordinances establish development controls to ensure that private development takes place within a given area in a manner in which:

- All uses are compatible (e.g., an industrial plant is not permitted in a residential area);
- Common development standards are used (e.g., all homes in a given area are set back the same minimum distance from the street); and,
- Each development does not unreasonably impose a burden upon its neighbors (e.g., parking is required on site so as not to create neighborhood parking problems).

To do this, use districts called "zones" are established and standards are developed for these zones. The four basic zones are residential, commercial, industrial and institutional.

Land use agencies may wish to consider how zoning ordinances, particularly those for mixed-use areas, can be used to avoid exacerbating poor land use practices of the past or contributing to localized and cumulative air pollution impacts in the community.

Sometimes, especially in mixed-use zones, there is a potential for certain categories of existing businesses or industrial operations to result in cumulative air pollution impacts to new development projects. For example:

- An assisted living project is proposed for a mixed-use zone adjacent to an existing chrome plating facility, or several dry cleaners;
- Multiple industrial sources regulated by a local air district are located directly upwind of a new apartment complex;
- A new housing development is sited in a mixed-use zone that is downwind or adjacent to a distribution center that attracts diesel-fueled delivery trucks and TRUs; or
- A new housing development or sensitive land use is sited without adequate setbacks from an existing major transportation corridor or rail yard.

As part of the public process for making zoning changes, local land use agencies could work with community planning groups, local businesses, and community residents to determine how best to address existing incompatible land uses.

Land Use Permitting Processes

- **Questions to Consider When Reviewing New Projects**

Very often, just knowing what questions to ask can yield critical information about the potential air pollution impacts of proposed projects – both from the perspective of a specific project as well as in the nature of existing air pollution sources in the same impact area. Available land use information can reveal the proximity of air pollution sources to sensitive individuals, the potential for incompatible land uses, and the location and nature of nearby air pollution sources. Air quality data, available from the ARB and local air districts, can provide information about the types and amounts of air pollution emitted in an area, regional air quality concentrations, and health risk estimates for specific sources.

General Plans and zoning maps are an excellent starting point in reviewing project proposals for their potential air pollution impacts. These documents contain information about existing or proposed land uses for a specific location as well as the surrounding area. Often, just looking at a map of the proposed location for a facility and its surrounding area will help to identify a potential adjacent incompatible land use.

The following pages are a "pull-out" list of questions to consider along with cross-references to pertinent information in the Handbook. These questions are intended to assist land use agencies in evaluating potential air quality-related concerns associated with new project proposals.

The first group of questions contains project-related queries designed to help identify the potential for localized project impacts, particularly associated with incompatible land uses. The second group of questions focuses on the issue of potential cumulative impacts by including questions about existing emissions and air quality in the community, and community feedback. Depending on the answers to these questions, a land use agency may decide a more detailed review of the proposal is warranted.

The California Department of Education has already developed a detailed process for school siting which is outlined in Appendix E. However, school districts may also find this section helpful when evaluating the most appropriate site for new schools in their area. At a minimum, using these questions may encourage school districts to engage throughout their siting process with land use agencies and local air districts. The combined expertise of these entities can be useful in devising relevant design standards and mitigation measures that can reduce exposure to cumulative emissions, exposure, and health risk to students and school workers.

As indicated throughout the Handbook, we strongly encourage land use agencies to consult early and often with local air districts. Local air districts have the expertise, many of the analytical tools, and a working knowledge of the sources they regulate. It is also critical to fully involve the public and businesses that could be affected by the siting decision. The questions provided in the chart below do not imply any particular action should be taken by land use agencies. Rather the questions are intended to improve the assessment process and facilitate informed decision-making.

- **Project-Related Questions**

This section includes project-related questions that, in conjunction with the questions in the next section, can be used to tailor the project evaluation. These questions are designed to help identify the potential for incompatible land uses from localized project impacts.

Questions to Consider When Reviewing New Projects

Project-Related Questions	**Cross-Reference to Relevant Handbook Sections**
1. Is the proposed project: ▲ A business or commercial license renewal ▲ A new or modified commercial project ▲ A new or modified industrial project ▲ A new or modified public facility project ▲ A new or modified transportation project ▲ A housing or other development in which sensitive individuals may live or play	See Appendix A for typical land use classifications and associated project categories that could emit air pollutants.
2. Does the proposed project: ▲ Conform to the zoning designation? ▲ Require a variance to the zoning designation? ▲ Include plans to expand operations over the life of the business such that additional emissions may increase the pollution burden in the community (e.g., from additional truck operations, new industrial operations or process lines, increased hours of operation, build-out to the property line, etc.)?	See Appendix F for a general explanation of land use processes. In addition, Section 3 contains a discussion of how land use planning, zoning, and permitting practices can result in incompatible land uses or cumulative air pollution impacts.
3. Has the local air district provided comments or information to assist in the analysis?	See Section 5 and Appendix C for a description of air quality-related tools that the ARB and local air districts use to provide information on potential air pollution impacts.
4. Have public meetings been scheduled with the affected community to solicit their involvement in the decision-making process for the proposed project?	See Section 7 for a discussion of public participation, information and outreach tools.
5. If the proposed project will be subject to local air district regulations: ▲ Has the project received a permit from the local air district? ▲ Would it comply with applicable local air district requirements? ▲ Is the local air district contemplating new regulations that would reduce emissions from the source over time? ▲ Will potential emissions from the project	See Appendix C for a description of local air district programs.

Project-Related Questions	Cross-Reference to Relevant Handbook Sections
trigger the local air district's new source review for criteria pollutants or air toxics emissions? ▲ Is the local air district expected to ask the proposed project to perform a risk assessment? ▲ Is there sufficient new information or public concern to call for a more thorough environmental analysis of the proposed project? ▲ Are there plans to expand operations over time? ▲ Are there land-use based air quality significance thresholds or design standards that could be applied to this project in addition to applicable air district requirements?	
6. If the proposed project will release air pollution emissions, either directly or indirectly, but is not regulated by the local air district: ▲ Is the local air district informed of the project? ▲ Does the local air district believe that there could be potential air pollution impacts associated with this project category because of the proximity of the project to sensitive individuals? ▲ If the project is one in which individuals live or play (e.g., a home, playground, convalescent home, etc.), does the local air district believe that the project's proximity to nearby sources could pose potential air pollution impacts? ▲ Are there indirect emissions that could be associated with the project (e.g., truck traffic or idling, transport refrigeration unit operations, stationary diesel engine operations, etc.) that will be in close proximity to sensitive individuals? ▲ Will the proposed project increase or serve as a magnet for diesel traffic? ▲ Are there land-use based air quality significance thresholds or design standards that could be applied to this project in addition to applicable air district requirements? ▲ Is there sufficient new information or public concern to call for a more thorough environmental analysis of the proposed project? ▲ Should the site approval process include identification and mitigation of potential	See Section 1 for recommendations on situations to avoid when siting projects where sensitive individuals would be located (sensitive sites).

Project-Related Questions	Cross-Reference to Relevant Handbook Sections
direct or indirect emissions associated with the potential project?	
7. Does the local air district or land use agency have pertinent information on the source, such as: ▲ Available permit and enforcement data, including for the owner or operator of the proposed source that may have other sources in the State. ▲ Proximity of the proposed project to sensitive individuals. ▲ Number of potentially exposed individuals from the proposed project. ▲ Potential for the proposed project to expose sensitive individuals to odor or other air pollution nuisances. ▲ Meteorology or the prevailing wind patterns between the proposed project and the nearest receptor, or between the proposed sensitive receptor project and sources that could pose a localized or cumulative air pollution impact.	See Appendix C for a description of local air district programs. See Appendix B for a listing of useful information that land use agencies should have on hand or have accessible when reviewing proposed projects for potential air pollution impacts. Also, do not hesitate to contact your local air district regarding answers to any of these questions that might not be available at the land use agency. See Section 1 for recommendations on situations to avoid when siting projects where sensitive individuals would be located (sensitive sites).
8. Based upon the project application, its location, and the nature of the source, could the proposed project: ▲ Be a polluting source that is located in proximity to, or otherwise upwind, of a location where sensitive individuals live or play? ▲ Attract sensitive individuals and be located in proximity to or otherwise downwind, of a source or multiple sources of pollution, including polluting facilities or transportation-related sources that contribute emissions either directly or indirectly? ▲ Result in health risk to the surrounding community?	See Section 3 for a discussion of what is an incompatible land use and the potential cumulative air pollution impacts. See Section 1 for recommendations on situations to avoid when siting projects where sensitive individuals would be located (sensitive sites).
9. If a CEQA categorical exemption is proposed, were the following questions considered: ▲ Is the project site environmentally sensitive as defined by the project's location? (A project that is ordinarily insignificant in its impact on the environment may in a particularly sensitive environment be significant.) ▲ Would the project and successive future projects of the same type in the approximate location potentially result in cumulative impacts? ▲ Are there "unusual circumstances" creating the possibility of significant effects?	See CEQA Guidelines section 15300, and Public Resources Code, section 21084. See Section 1 for recommendations on situations to avoid when siting projects where sensitive individuals would be located (sensitive sites). See also Section 5 and Appendix C for a description of air quality-related tools that the ARB and local air districts use to provide information on potential air pollution impacts.

- ### Questions Related to Cumulative Impact Assessment

The following questions can be used to provide the decision-maker with a better understanding of the potential for cumulative air pollution impacts to an affected community. Answers to these questions will help to determine if new projects or activities warrant a more detailed review. It may also help to see potential environmental concerns from the perspective of the affected community. Additionally, responses can provide local decision-makers with information with which to assess the best policy options for addressing neighborhood-scale air pollution concerns.

The questions below can be used to identify whether existing tools and procedures are adequate to address land use-related air pollution issues. This process can also be used to pinpoint project characteristics that may have the greatest impact on community-level emissions, exposure, and risk. Such elements can include: the compliance record of existing sources including those owned or operated by the project proponent; the concentration of emissions from polluting sources within the approximate area of sensitive sites; transportation circulation in proximity to the proposed project; compatibility with the General Plan and General Plan elements; etc.

The local air district can provide useful assistance in the collection and evaluation of air quality-related information for some of the questions and should be consulted early in the process.

Questions Related to Cumulative Impact Assessment

Technical Questions	Cross-Reference to Relevant Handbook Sections
1. Is the community home to industrial facilities?	See Appendix A for typical land use classifications and associated project categories that could emit air pollutants.
2. Do one or more major freeways or high-traffic volume surface streets cut through the community?	See transportation circulation element of your general plan. See also Appendix B for useful information that land use agencies should have on hand or have accessible when reviewing proposed projects for potential air pollution impacts. See Section 1 for recommendations on situations to avoid when siting projects where sensitive individuals would be located (sensitive sites).
3. Is the area classified for mixed-use zoning?	See your general plan and zoning ordinances.
4. Is there an available list of air pollution sources in the community?	Contact your local air district.
5. Has a walk-through of the community been conducted to gather the following information:	See Appendix B for a listing of useful information that land use agencies

Technical Questions	Cross-Reference to Relevant Handbook Sections
▲ Corroborate available information on land use activities in the area (e.g., businesses, housing developments, sensitive individuals, etc.)? ▲ Determine the proximity of existing and anticipated future projects to residential areas or sensitive individuals? ▲ Determine the concentration of emission sources (including anticipated future projects) to residential areas or sensitive individuals?	should have on hand or have accessible when reviewing proposed projects for potential air pollution impacts. Also contact your local air district.
6. Has the local air district been contacted to obtain information on sources in the community?	See Section 7 for a discussion of public participation, information and outreach tools.
7. What categories of commercial establishments are currently located in the area and does the local air district have these sources on file as being regulated or permitted?	See Appendix A for typical land use classifications and associated project categories that could emit air pollutants. Also contact your local air district.
8. What categories of indirect sources such as distribution centers or warehouses are currently located in the area?	See Appendix A for typical land use classifications and associated project categories that emit air pollutants.
9. What air quality monitoring data are available?	Contact your local air district.
10. Have any risk assessments been performed on emission sources in the area?	Contact your local air district.
11. Does the land use agency have the capability of applying a GIS spatial mapping tool that can overlay zoning, sub-development information, and other neighborhood characteristics, with air pollution and transportation data?	See Appendix B for a listing of useful information that land use agencies should have on hand or have accessible when reviewing proposed projects for potential air pollution impacts. Also contact your local air district for tools that can be used to supplement available land use agency tools.
12. Based on available information, is it possible to determine if the affected community or neighborhood experiences elevated health risk due to a concentration of air pollution sources in close proximity, and if not, can the necessary information be obtained?	Contact your local air district. Also see Section 1 for recommendations on situations to avoid when siting projects where sensitive individuals would be located (sensitive sites).
13. Does the community have a history of chronic complaints about air quality?	See Section 7 for a discussion of public participation, information and outreach tools. Also contact your local air district.
14. Is the affected community included in the public participation process for the agency's decision?	See Section 7 for a discussion of public participation, information and outreach tools.
15. Have community leaders or groups been contacted about any pre-existing or chronic community air quality concerns?	See Section 7 for a discussion of public participation, information and outreach tools. Also contact your local air district.

- **Mitigation Approaches**

In addition to considering the suitability of the project location, opportunities for mitigation of air pollution impacts should be considered. Sometimes, a land use agency may find that selection of a different project location to avoid a health risk is not feasible. When that happens, land use agencies should consider design improvements or other strategies that would reduce the risk. Such strategies could include performance or design standards, consultation with local air districts and other agencies on appropriate actions that these agencies should, or plan to, undertake, and consultation and outreach in the affected community. Potential mitigation measures should be feasible, cost-effective solutions within the available resources and authority of implementing agencies to enforce.[12]

- **Conditional Use Permits and Performance Standards**

Some types of land uses are only allowed upon approval of a conditional use permit (also called a CUP or special use permit). A conditional use permit does not re-zone the land but specifies conditions under which a particular land use will be permitted. Such land uses could be those with potentially significant environmental impacts. Local zoning ordinances specify the uses for which a conditional use permit is required, the zones they may be allowed in, and public hearing procedures. The conditional use permit imposes special requirements to ensure that the use will not be detrimental to its surroundings.

In the context of land use planning, performance standards are requirements imposed on projects or project categories through conditional use permits to ensure compliance with general plan policies and local ordinances. These standards could apply to such project categories as distribution centers, very large gas dispensing facilities, autobody shops, dry cleaners, and metal platers. Land use agencies may wish to consider adding land use-based performance standards to zoning ordinances in existing mixed-use communities for certain air pollution project categories. Such standards would provide certainty and equitable treatment to all projects of a similar nature, and reserve the more resource intensive conditional or special use permits to projects that require a more detailed analysis. In developing project design or performance standards, land use agencies should consult with the local air district. Early and regular consultation can avoid duplication or inconsistency with local air district control requirements when considering the site-specific design and operation of a project.

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[12] A land use agency has the authority to condition or deny a project based upon information collected and evaluated through the land use decision-making process. However, any denial would need to be based upon identifiable, generally applicable, articulated standards set forth in the local government's General Plan and zoning codes. One way of averting this is to conduct early and regular outreach to the community and the local air district so that community and environmental concerns can be addressed and accommodated into the project proposal.

Examples of land use-based air quality-specific performance standards include the following:

- Placing a process vent away from the direction of the local playground that is nearby or increasing the stack height so that emissions are dispersed to reduce the emissions impact on surrounding homes or schools.
- Setbacks between the project fence line and the population center.
- Limiting the hours of operation of a facility to avoid excess emissions exposure or foul odors to nearby individuals.
- An ordinance that requires fleet operators to use cleaner vehicles before project approval (if a new business), or when expanding the fleet (if an existing business); and
- Providing alternate routes for truck operations that discourage detours into residential neighborhoods.

Outreach to Other Agencies

When questions arise regarding the air quality impacts of projects, including potential cumulative impacts, land use agencies should consult the local air district. Land use agencies should also consider the following suggestions to avoid creating new incompatible land uses:

- Consult with the local air district to help determine if emissions from a particular project will adversely impact sensitive individuals in the area, if existing or future effective regulations or permit requirements will affect the proposed project or other sources in the vicinity of the proposed project, or if additional inspections should be required.
- Check with ARB for new information and modeling tools that can help evaluate projects seeking to site within your jurisdiction.
- Become familiar with ARB's Land Use-Air Quality Linkage Report to determine whether approaches and evaluation tools contained in the Report can be used to reduce transportation-related impacts on communities.
- Contact and collaborate with other state agencies that play a role in the land use decision-making process, e.g., the State Department of Education, the California Energy Commission, and Caltrans. These agencies have information on mitigation measures and mapping tools that could be useful in addressing local problems.

- **Information Clearinghouse**

  - Land use agencies can refer to the ARB statewide electronic information clearinghouse for information on what measures other jurisdictions are using to address comparable issues or sources.[13]

[13] This information can be accessed from ARB's website by going to: http://www.arb.ca.gov/ch/clearinghouse.htm

The next section addresses available air quality assessment tools that land use agencies can use to evaluate the potential for localized or cumulative impacts in their communities.

5. Available Tools to Evaluate Cumulative Air Pollution Emissions and Risk

Until recently, California has traditionally approached air pollution control from the perspective of assessing whether the pollution was regional, category-specific, or from new or existing sources. This methodology has been generally effective in reducing statewide and regional air pollution impacts and risk levels. However, such an incremental, category-by-category, source-by-source approach may not always address community health impacts from multiple sources - including mobile, industrial, and commercial facilities.

As a result of air toxics and children's health concerns over the past several years, ARB and local air districts have begun to develop new tools to evaluate and inform the public about cumulative air pollution impacts at the community level. One aspect of ARB's programs now underway is to consolidate and make accessible air toxics emissions and monitoring data by region, using modeling tools and other analytical techniques to take a preliminary look at emissions, exposure, and health risk in communities.

ARB has developed multiple tools to assist local air districts perform assessments of cumulative emissions, exposure, and risk on a neighborhood scale. These tools include:

- Regional risk maps that show trends in potential cancer risk from toxic air pollutants in southern and central California between 1990 and 2010. These maps are based on the U.S. EPA's ASPEN model. These maps provide an estimate of background levels of toxic air pollutant risk but are not detailed enough to assess individual neighborhoods or facilities.[14]

- The Community Health Air Pollution Information System (CHAPIS) is a user-friendly, Internet-based system for displaying information on emissions from sources of air pollution in an easy to use mapping format. CHAPIS contains information on air pollution emissions from selected large facilities and small businesses that emit criteria and toxic air pollutants. It also contains information on air pollution emissions from motor vehicles. When released in 2004, CHAPIS did not contain information on every source of air pollution or every air pollutant. However, ARB continues to work with local air districts to include all of the largest air pollution sources and those with the highest documented air pollution risk. Additional facilities will be added to CHAPIS as more data become available.[15]

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[14] For further information on these maps, please visit ARB's website at: http://www.arb.ca.gov/toxics/cti/hlthrisk/hlthrisk.htm

[15] For further information on CHAPIS, please click on: http://www.arb.ca.gov/ch/chapis1/chapis1.htm

- The Hot Spots Analysis and Reporting Program (HARP) is a software database package that evaluates emissions from one or more facilities to determine the overall health risk posed by the facility(-ies) on the surrounding community. Proper use of HARP ensures that the risk assessment meets the latest risk assessment guidelines published by the State Office of Environmental Health Hazard Assessment (OEHHA). HARP is designed with air quality professionals in mind and is available from the ARB.

- The Urban Emissions Model (URBEMIS) is a computer program that can be used to estimate emissions associated with land development projects in California such as residential neighborhoods, shopping centers, office buildings, and construction projects. URBEMIS uses emission factors available from the ARB to estimate vehicle emissions associated with new land uses.

Local air districts, and others can use these tools to assess a new project, or plan revision. For example, these tools can be used to:

- Identify if there are multiple sources of air pollution in the community;
- Identify the major sources of air pollution in the area under consideration;
- Identify the background potential cancer risk from toxic air pollution in the area under consideration;
- Estimate the risk from a new facility and how it adds to the overall risk from other nearby facilities; and
- Provide information to decision-makers and key stakeholders on whether there may be significant issues related to cumulative emissions, exposure, and health risk due to a permitting or land use decision.

If an air agency wishes to perform a cumulative air pollution impact analysis using any of these tools, it should consult with the ARB and/or the local air district to obtain information or assistance on the data inputs and procedures necessary to operate the program. In addition, land use agencies could consult with local air districts to determine the availability of land use and air pollution data for entry into an electronic Geographical Information System (GIS) format. GIS is an easier mapping tool than the more sophisticated models described in Appendix C. GIS mapping makes it possible to superimpose land use with air pollution information so that the spatial relationship between air pollution sources, sensitive receptors, and air quality can be visually represented. Appendix C provides a general description of the impact assessment process and micro-scale, or community level modeling tools that are available to evaluate potential cumulative air pollution impacts. Modeling protocols will be accessible on ARB's website as they become available. The ARB will also provide land use agencies and local air districts with statewide regional modeling results and information regarding micro-scale modeling.

6. ARB Programs to Reduce Air Pollution in Communities

ARB's regulatory programs reduce air pollutant emissions through statewide strategies that improve public health in all California communities. ARB's overall program addresses motor vehicles, consumer products, air toxics, air-quality planning, research, education, enforcement, and air monitoring. Community health and environmental justice concerns are a consideration in all these programs. ARB's programs are statewide but recognize that extra efforts may be needed in some communities due to historical mixed land-use patterns, limited participation in public processes in the past, and a greater concentration of air pollution sources in some communities.

ARB's strategies are intended to result in better air quality and reduced health risk to residents throughout California. The ARB's priority is to prevent or reduce the public's exposure to air pollution, including from toxic air contaminants that pose the greatest risk, particularly to infants and children who are more vulnerable to air pollution.

In October 2003, ARB updated its statewide control strategy to reduce emissions from source categories within its regulatory authority. A primary focus of the strategy is to achieve federal and state air quality standards for ozone and particulate matter throughout California, and to reduce health risk from diesel PM. Along with local air districts, ARB will continue to address air toxics emissions from regulated sources (see Table 6-1 for a summary of ARB activities). As indicated earlier, ARB will also provide analytical tools and information to land use agencies and local air districts to help assess and mitigate cumulative air pollution impacts.

The ARB will continue to consider the adoption of or revisions to needed air toxics control measures as part of the state's ongoing air toxics assessment program.[16]

As part of its effort to reduce particulate matter and air toxics emissions from diesel PM, the ARB has developed a Diesel Risk Reduction Program[17] that lays out several strategies in a three-pronged approach to reduce emissions and their associated risk:

- Stringent emission standards for all new diesel-fueled engines;
- Aggressive reductions from in-use engines; and
- Low sulfur fuel that will reduce PM and still provide the quality of diesel fuel needed to control diesel PM.

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[16] For continuing information and updates on state measures, the reader can refer to ARB's website at http://www.arb.ca.gov/toxics/toxics.htm.

[17] For a comprehensive description of the program, please refer to ARB's website at http://www.arbB.ca.gov/diesel/dieselrrp.htm.

Table 6-1
ARB ACTIONS TO ADDRESS
CUMULATIVE AIR POLLUTION IMPACTS IN COMMUNITIES

Information Collection

- Improve emission inventories, air monitoring data, and analysis tools that can help to identify areas with high cumulative air pollution impacts
- Conduct studies in coordination with OEHHA on the potential for cancer and non-cancer health effects from air pollutants emitted by specific source categories
- Establish web-based clearinghouse for local land use strategies

Emission Reduction Approaches (2004-2006)*

- Through a public process, consider development and/or amendment of regulations and related guidance to reduce emissions, exposure, and health risk at a statewide and local level for the following sources:
  - Diesel PM sources such as stationary diesel engines, transport refrigeration units, portable diesel engines, on-road public fleets, off-road public fleets, heavy-duty diesel truck idling, harbor craft vessels, waste haulers
  - Other air toxics sources, such as formaldehyde in composite wood products, hexavalent chromium for chrome plating and chromic acid anodizing, thermal spraying, and perchloroethylene dry cleaning
- Develop technical information for the following:*
  - Distribution centers
  - Modeling tools such as HARP and CHAPIS
- Adopt rules and pollution prevention initiatives within legal authority to reduce emissions from mobile sources and fuels, and consumer products
- Develop and maintain Air Quality Handbook as a tool for use by land use agencies and local air districts to address cumulative air pollution impacts

Other Approaches

- Establish guidelines for use of statewide incentive funding for high priority mobile source emission reduction projects

*Because ARB will continue to review the need to adopt or revise statewide measures, the information contained in this chart will be updated on an ongoing basis.

A number of ARB's diesel risk reduction strategies have been adopted. These include measures to reduce emissions from refuse haulers, urban buses, transport refrigeration units, stationary and portable diesel engines, and idling trucks and school buses. These sources are all important from a community perspective.[18]

[18] The reader can refer to ARB's website for information on its mobile source-related programs at: http://www.arb.ca.gov/msprog/msprog.htm, as well as regulations adopted and under consideration as part of the Diesel Risk Reduction Program at: http://www.arb.ca.gov/diesel/dieselrrp.htm

The ARB will continue to evaluate the health effects of air pollutants while implementing programs with local air districts to reduce air pollution in all California communities.

Local air districts also have ambitious programs to reduce criteria pollutants and air toxics from regulated sources in their region. Many of these programs also benefit air quality in local communities as well as in the broader region. For more information on what is being done in your area to reduce cumulative air pollution impacts through air pollution control programs, you should contact your local air district.[19]

[19] Local air district contacts can be found on the inside cover to this Handbook.

7. Ways to Enhance Meaningful Public Participation

Community involvement is an important part of the land use process. The public is entitled to the best possible information about the air they breathe and what is being done to prevent or reduce unhealthful air pollution in their communities. In particular, information on how land use decisions can affect air pollution and public health should be made accessible to all communities, including low-income and minority communities.

Effective community participation consistently relies on a two-way flow of information – from public agencies to community members about opportunities, constraints, and impacts, and from community members back to public officials about needs, priorities, and preferences. The outreach process needed to build understanding and local neighborhood involvement requires data, methodologies, and formats tailored to the needs of the specific community. More importantly, it requires the strong collaboration of local government agencies that review and approve projects and land uses to improve the physical and environmental surroundings of the local community.

Many land use agencies, especially those in major metropolitan areas, are familiar with, and have a long-established public review process. Nevertheless, public outreach can often be improved. Active public involvement requires engaging the public in ways that do not require their previous interest in or knowledge of the land use or air pollution control requirements, and a commitment to taking action where appropriate to address the concerns that are raised.

- **Direct Community Outreach**

In conjunction with local air districts, land use agencies should consider designing an outreach program for community groups, other stakeholders, and local government agency staffs that address the problem of cumulative air pollution impacts, and the public and government role in reducing them. Such a program could consider analytical tools that assist in the preparation and presentation of information in a way that supports sensible decision-making and public involvement. Table 7-1 contains some general outreach approaches that might be considered.

Table 7-1
Public Participation Approaches

- Staff and community leadership awareness training on environmental justice programs and community-based issues
- Surveys to identify the website information needs of interested community-based organizations and other stakeholders
- Information materials on local land use and air district authorities
- Community-based councils to facilitate and invite resident participation in the planning process
- Neighborhood CEQA scoping sessions that allows for community input prior to technical analysis
- Public information materials on siting issues are under review including materials written for the affected community, and in different media that widens accessibility
- Public meetings
- Identify other opportunities to include community-based organizations in the process

To improve outreach, local land use agencies should consider the following activities:

- Hold meetings in communities affected by agency programs, policies, and projects at times and in places that encourage public participation, such as evenings and weekends at centrally located community meeting rooms, libraries, and schools.
- Assess the need for and provide translation services at public meetings.
- Hold community meetings to update residents on the results of any special air monitoring programs conducted in their neighborhood.
- Hold community meetings to discuss and evaluate the various options to address cumulative impacts in their community.
- In coordination with local air districts, make staff available to attend meetings of community organizations and neighborhood groups to listen to and, where appropriate, act upon community concerns.
- Establish a specific contact person for environmental justice issues.
- Increase student and community awareness of local government land use activities and policies through outreach opportunities.
- Make air quality and land use information available to communities in an easily understood and useful format, including fact sheets, mailings, brochures, public service announcements, and web pages, in English and other languages.
- On the local government web-site, dedicate a page or section to what the land use program is doing regarding environmental justice and cumulative environmental impacts, and, as applicable, activities conducted with local air districts such as neighborhood air monitoring studies, pollution prevention, air pollution sources in neighborhoods, and risk reduction.

- Allow, encourage, and promote community access to land use activities, including public meetings, General Plan or Community Plan updates, zoning changes, special studies, CEQA reviews, variances, etc.
- Distribute information in multiple languages, as needed, on how to contact the land use agency or local air district to obtain information and assistance regarding environmental justice programs, including how to participate in public processes.
- Create and distribute a simple, easy-to-read, and understandable public participation handbook, which may be based on the "Public Participation Guidebook" developed by ARB.

- **Other Opportunities for Meaningful Public Outreach**

  - <u>Community-Based Planning Committees</u>

  Neighborhood-based or community planning advisory councils could be established to invite and facilitate direct resident participation into the planning process. With the right training and technical assistance, such councils can provide valuable input and a forum for the review of proposed amendments to plans, zone changes, land use permits, and suggestions as to how best to prevent or reduce cumulative air pollution impacts in their community.

  - <u>Regional Partnerships</u>

  Consider creating regional coalitions of key growth-related organizations from both the private and public sectors, with corporations, communities, other jurisdictions, and government agencies. Such partnerships could facilitate agreement on common goals and win-win solutions tailored specifically for the region. With this kind of dialogue, shared vision, and collaboration, barriers can be overcome and locally acceptable sustainable solutions implemented. Over the long term, such strategies will help to bring about clean air in communities as well as regionally.

LAND USE CLASSIFICATIONS AND ASSOCIATED FACILITY CATEGORIES THAT COULD EMIT AIR POLLUTANTS

(1) Land Use Classifications – by Activity[i]	(2) Facility or Project Examples	(3) Key Pollutants[ii,iii]	(4) Air Pollution Permits[iv]
COMMERCIAL/ LIGHT INDUSTRIAL: SHOPPING, BUSINESS, AND COMMERCIAL			
▲ Primarily retail shops and stores, office, commercial activities, and light industrial or small business	Dry cleaners; drive-through restaurants; gas dispensing facilities; auto body shops; metal plating shops; photographic processing shops; textiles; apparel and furniture upholstery; leather and leather products; appliance repair shops; mechanical assembly cleaning; printing shops	VOCs, air toxics, including diesel PM, NOx, CO, SOx	Limited; Rules for applicable equipment
▲ Goods storage or handling activities, characterized by loading and unloading goods at warehouses, large storage structures, movement of goods, shipping, and trucking.	Warehousing; freight-forwarding centers; drop-off and loading areas; distribution centers	VOCs, air toxics, including diesel PM, NOx, CO, SOx	No[v]
LIGHT INDUSTRIAL: RESEARCH AND DEVELOPMENT			
▲ Medical waste at research hospitals and labs	Incineration; surgical and medical instrument manufacturers, pharmaceutical manufacturing, biotech research facilities	Air toxics, NOx, CO, SOx	Yes
▲ Electronics, electrical apparatus, components, and accessories	Computer manufacturer; integrated circuit board manufacturer; semi-conductor production	Air toxics, VOCs	Yes
▲ College or university lab or research center	Medical waste incinerators; lab chemicals handling, storage and disposal	Air toxics, NOx, CO, SOx, PM10	Yes
▲ Research and development labs	Satellite manufacturer; fiber-optics manufacturer; defense contractors; space research and technology; new vehicle and fuel testing labs	Air toxics, VOCs	Yes
▲ Commercial testing labs	Consumer products; chemical handling, storage and disposal	Air toxics, VOCs	Yes

(1) Land Use Classifications – by Activity[i]	(2) Facility or Project Examples	(3) Key Pollutants[ii,iii]	(4) Air Pollution Permits[iv]
INDUSTRIAL: NON-ENERGY-RELATED			
▲ Assembly plants, manufacturing facilities, industrial machinery	Adhesives; chemical; textiles; apparel and furniture upholstery; clay, glass, and stone products production; asphalt materials; cement manufacturers, wood products; paperboard containers and boxes; metal plating; metal and canned food product fabrication; auto manufacturing; food processing; printing and publishing; drug, vitamins, and pharmaceuticals; dyes; paints; pesticides; photographic chemicals; polish and wax; consumer products; metal and mineral smelters and foundries; fiberboard; floor tile and cover; wood and metal furniture and fixtures; leather and leather products; general industrial and metalworking machinery; musical instruments; office supplies; rubber products and plastics production; saw mills; solvent recycling; shingle and siding; surface coatings	VOCs, air toxics, including diesel PM, NOx, PM, CO, SOx	Yes
INDUSTRIAL: ENERGY AND UTILITIES			
▲ Water and sewer operations	Pumping stations; air vents; treatment	VOCs, air toxics, NOx, CO, SOx, PM10	Yes
▲ Power generation and distribution	Power plant boilers and heaters; portable diesel engines; gas turbine engines	NOx, diesel PM, NOx, CO, SOx, PM10, VOCs	Yes
▲ Refinery operations	Refinery boilers and heaters; coke cracking units; valves and flanges; flares	VOCs, air toxics, including diesel PM, NOx, CO, SOx, PM10	Yes
▲ Oil and gas extraction	Oil recovery systems; uncovered wells	NOx, diesel PM, VOCs, CO, SOx, PM10	Yes
▲ Gasoline storage, transmission, and marketing	Above and below ground storage tanks; floating roof tanks; tank farms; pipelines	VOCs, air toxics, including diesel PM, NOx, CO, SOx, PM10	Yes
▲ Solid and hazardous waste treatment, storage, and disposal activities.	Landfills; methane digester systems; process recycling facility for concrete and asphalt materials	VOCs, air toxics, NOx, CO, SOx, PM10	Yes
CONSTRUCTION (NON-TRANSPORTATION)			
	Building construction; demolition sites	PM (re-entrained road dust), asbestos, diesel PM, NOx, CO, SOx, PM10, VOCs	Limited; state and federal off-road equipment standards

(1) **Land Use Classifications – by Activity**[i]	(2) **Facility or Project Examples**	(3) **Key Pollutants**[ii,iii]	(4) **Air Pollution Permits**[iv]
DEFENSE			
	Ordnance and explosives demolition; range and testing activities; chemical production; degreasing; surface coatings; vehicle refueling; vehicle and engine operations and maintenance	VOCs, air toxics, including diesel PM, NOx, CO, SOx, PM10	Limited; prescribed burning; equipment and solvent rules
TRANSPORTATION			
▲ Vehicular movement	Residential area circulation systems; parking and idling at parking structures; drive-through establishments; car washes; special events; schools; shopping malls, etc.	VOCs, NOx, PM (re-entrained road dust) air toxics e.g., benzene, diesel PM, formaldehyde, acetaldehyde, 1,3 butadiene, CO, SOx, PM10	No
▲ Road construction and surfacing	Street paving and repair; new highway construction and expansion	VOCs, air toxics, including diesel PM, NOx, CO, SOx, PM10	No
▲ Trains	Railroads; switch yards; maintenance yards	VOCs, NOx, CO, SOx, PM10, air toxics, including diesel PM	Limited; Applicable state and federal MV standards, and possible equipment rules
▲ Marine and port activities	Recreational sailing; commercial marine operations; hotelling operations; loading and un-loading; servicing; shipping operations; port or marina expansion; truck idling		
▲ Aircraft	Takeoff, landing, and taxiing; aircraft maintenance; ground support activities		
▲ Mass transit and school buses	Bus repair and maintenance		
NATURAL RESOURCES			
▲ Farming operations	Agricultural burning; diesel operated engines and heaters; small food processors; pesticide application; agricultural off-road equipment	Diesel PM, VOCs, NOx, PM10, CO, SOx, pesticides	Limited[vi]; Agricultural burning requirements, applicable state and federal mobile source standards; pesticide rules
▲ Livestock and dairy operations	Dairies and feed lots	Ammonia, VOCs, PM10	Yes[vii]
▲ Logging	Off-road equipment e.g., diesel fueled chippers, brush hackers, etc.	Diesel PM, NOx, CO, SOx, PM10, VOCs	Limited; Applicable state/federal mobile source standards
▲ Mining operations	Quarrying or stone cutting; mining; drilling or dredging	PM10, CO, SOx, VOCs, NOx, and asbestos in some geographical areas	Applicable equipment rules and dust controls

(1) Land Use Classifications – by Activity[i]	(2) Facility or Project Examples	(3) Key Pollutants[ii,iii]	(4) Air Pollution Permits[iv]
RESIDENTIAL			
Housing	Housing developments; retirement developments; affordable housing	Fireplace emissions (PM10, NOx, VOCs, CO, air toxics); Water heater combustion (NOx, VOCs, CO)	No[vii]
ACADEMIC AND INSTITUTIONAL			
▲ Schools, including school-related recreational activities	Schools; school yards; vocational training labs/classrooms such as auto repair/painting and aviation mechanics	Air toxics	Yes/No[viii]
▲ Medical waste	Incineration	Air toxics, NOx, CO, PM10	Yes
▲ Clinics, hospitals, convalescent homes		Air toxics	Yes

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[i] These classifications were adapted from the American Planning Association's "Land Based Classification Standards." The Standards provide a consistent model for classifying land uses based on their characteristics. The model classifies land uses by refining traditional categories into multiple dimensions, such as activities, functions, building types, site development character, and ownership constraints. Each dimension has its own set of categories and subcategories. These multiple dimensions allow users to have precise control over land-use classifications. For more information, the reader should refer to the Association's website at http://www.planning.org/LBCS/GeneralInfo/.

[ii] This column includes key criteria pollutants and air toxic contaminants that are most typically associated with the identified source categories.

Additional information on specific air toxics that are attributed to facility categories can be found in ARB's Emission Inventory Criteria and Guidelines Report for the Air Toxics Hot Spots Program (May 15, 1997). This information can be viewed at ARB's web site at http://www.arb.ca.gov/ab2588/final96/guide96.pdf.

Criteria air pollutants are those air pollutants for which acceptable levels of exposure can be determined and for which an ambient air quality standard has been set. Criteria pollutants include ozone (formed by the reaction of volatile organic compounds and nitrogen oxides in the presence of sunlight), particulate matter, nitrogen dioxide, sulfur dioxide, carbon monoxide, and lead.

Volatile organic compounds (VOCs) combine with nitrogen oxides to form ozone, as well as particulate matter. VOC emissions result primarily from incomplete fuel combustion and the evaporation of chemical solvents and fuels. On-road mobile sources are the largest contributors to statewide VOC emissions. Stationary sources of VOC emissions include processes that use solvents (such as dry-cleaning, degreasing, and coating operations) and petroleum-related processes (such as petroleum refining, gasoline marketing and dispensing, and oil and gas extraction). Areawide VOC sources include consumer products, pesticides, aerosols and paints, asphalt paving and roofing, and other evaporative emissions.

Nitrogen oxides (NOx) are a group of gaseous compounds of nitrogen and oxygen, many of which contribute to the formation of ozone and particulate matter. Most NOx emissions are produced by the combustion of fuels. Mobile sources make up about 80 percent of the total statewide NOx emissions. Mobile sources include on-road vehicles and trucks, aircraft, trains, ships, recreational boats, industrial and construction equipment, farm equipment, off-road recreational vehicles, and other equipment. Stationary sources of NOx include both internal and external combustion processes in industries such as manufacturing, food processing, electric utilities, and petroleum refining. Areawide source, which include residential fuel combustion, waste burning, and fires, contribute only a small portion of the total statewide NOx emissions, but depending on the community, may contribute to a cumulative air pollution impact.

Particulate matter (PM) refers to particles small enough to be breathed into the lungs (under 10 microns in size). It is not a single substance, but a mixture of a number of highly diverse types of particles and liquid droplets. It can be formed directly, primarily as dust from vehicle travel on paved and unpaved roads, agricultural operations, construction and demolition.

Carbon monoxide (CO) is a colorless and odorless gas that is directly emitted as a by-product of combustion. The highest concentrations are generally associated with cold stagnant weather conditions that occur during winter. CO problems tend to be localized.

An Air Toxic Contaminant (air toxic) is defined as an air pollutant that may cause or contribute to an increase in mortality or in serous illness, or which may pose a present or potential hazard to human health. Similar to criteria pollutants, air toxics are emitted from stationary, areawide, and mobile sources. They contribute to elevated regional and localized risks near industrial and commercial facilities and busy roadways. The ten compounds that pose the greatest statewide risk are: acetaldehyde; benzene; 1,3-butadiene; carbon tetrachloride; diesel particulate matter (diesel PM); formaldehyde; hexavalent chromium; methylene chloride; para-dichlorobenzene; and perchloroethylene. The risk from diesel PM is by far the largest, representing about 70 percent of the known statewide cancer risk from outdoor air toxics. The exhaust from diesel-fueled engines is a complex mixture of gases, vapors, and particles, many of which are known human carcinogens. Diesel PM is emitted from both mobile and stationary sources. In California, on-road diesel-fueled vehicles contribute about 26 percent of statewide diesel PM emissions, with an additional 72 percent attributed to other mobile sources such as construction and mining equipment, agricultural equipment, and other equipment. Stationary engines in shipyards, warehouses, heavy equipment repair yards, and oil and gas production operations contribute about two percent of statewide emissions. However, when this number is disaggregated to a sub-regional scale such as neighborhoods, the risk factor can be far greater.

[iii] The level of pollution emitted is a major determinant of the significance of the impact.

[iv] Indicates whether facility activities listed in column 4 are generally subject to local air district permits to operate. This does not include regulated products such as solvents and degreasers that may be used by sources that may not require an operating permit per se, e.g., a gas station or dry cleaner.

[v] Generally speaking, warehousing or distribution centers are not subject to local air district permits. However, depending on the district, motor vehicle fleet rules may apply to trucks or off-road vehicles operated and maintained by the facility operator. Additionally, emergency generators or internal combustion engines operated on the site may require an operating permit.

[vi] Authorized by recent legislation SB700.

[vii] Local air districts do not require permits for woodburning fireplaces inside private homes. However, some local air districts and land use agencies do have rules or ordinances that require new housing developments or home re-sales to install U.S. EPA –certified stoves. Some local air districts also ban residential woodburning during weather inversions that concentrate smoke in residential areas. Likewise, home water heaters are not subject to permits; however, new heaters could be subject to emission limits that are imposed by federal or local agency regulations.

[viii] Technical training schools that conduct activities normally permitted by a local air district could be subject to an air permit.

LAND USE-BASED REFERENCE TOOLS TO EVALUATE NEW PROJECTS FOR POTENTIAL AIR POLLUTION IMPACTS

Land use agencies generally have a variety of tools and approaches at hand, or accessible from local air districts that can be useful in performing an analysis of potential air pollution impacts associated with new projects. These tools and approaches include:

- Base map of the city or county planning area and terrain elevations.
- General Plan designations of land use (existing and proposed).
- Zoning maps.
- Land use maps that identify existing land uses, including the location of facilities that are permitted or otherwise regulated by the local air district. Land use agencies should consult with their local air district for information on regulated facilities.
- Demographic data, e.g., population location and density, distribution of population by income, distribution of population by ethnicity, and distribution of population by age. The use of population data is a normal part of the planning process. However, from an air quality perspective, socioeconomic data is useful to identify potential community health and environmental justice issues.
- Emissions, monitoring, and risk-based maps created by the ARB or local air districts that show air pollution-related health risk by community across the state.
- Location of public facilities that enhance community quality of life, including parks, community centers, and open space.
- Location of industrial and commercial facilities and other land uses that use hazardous materials, or emit air pollutants. These include chemical storage facilities, hazardous waste disposal sites, dry cleaners, large gas dispensing facilities, auto body shops, and metal plating and finishing shops.
- Location of sources or facility types that result in diesel on-road and off-road emissions, e.g., stationary diesel power generators, forklifts, cranes, construction equipment, on-road vehicle idling, and operation of transportation refrigeration units. Distribution centers, marine terminals and ports, rail yards, large industrial facilities, and facilities that handle bulk goods are all examples of complex facilities where these types of emission sources are frequently concentrated.[1] Very large facilities, such as ports, marine terminals, and airports, could be analyzed regardless of proximity to a receptor if they are within the modeling area.
- Location and zoning designations for existing and proposed schools, buildings, or outdoor areas where sensitive individuals may live or play.
- Location and density of existing and proposed residential development.
- Zoning requirements, property setbacks, traffic flow requirements, and idling restrictions for trucks, trains, yard hostlers[2], construction equipment, or school buses.
- Traffic counts (including diesel truck traffic counts), within a community to validate or augment existing regional motor vehicle trip and speed data.

[1] The ARB is currently evaluating the types of facilities that may act as complex point sources and developing methods to identify them.

[2] Yard hostler means a tractor less than 300 horsepower that is used to transfer semi-truck or tractor-trailer containers in and around storage, transfer, or distribution yards or areas and is often equipped with a hydraulic lifting fifth wheel for connection to trailer containers.

ARB AND LOCAL AIR DISTRICT INFORMATION AND TOOLS CONCERNING CUMULATIVE AIR POLLUTION IMPACTS

It is the ARB's policy to support research and data collection activities toward the goal of reducing cumulative air pollution impacts. These efforts include updating and improving the air toxics emissions inventory, performing special air monitoring studies in specific communities, and conducting a more complete assessment of non-cancer health effects associated with air toxics and criteria pollutants.[1] This information is important because it helps us better understand links between air pollution and the health of sensitive individuals -- children, the elderly, and those with pre-existing serious health problems affected by air quality.

ARB is working with CAPCOA and OEHHA to improve air pollutant data and evaluation tools to determine when and where cumulative air pollution impacts may be a problem. The following provides additional information on this effort.

How are emissions assessed?

Detailed information about the sources of air pollution in an area is collected and maintained by local air districts and the ARB in what is called an emission inventory. Emission inventories contain information about the nature of the business, the location, type and amount of air pollution emitted, the air pollution-producing processes, the type of air pollution control equipment, operating hours, and seasonal variations in activity. Local districts collect emission inventory data for most stationary source categories.

Local air districts collect air pollution emission information directly from facilities and businesses that are required to obtain an air pollution operating permit. Local air districts use this information to compile an emission inventory for areas within their jurisdiction. The ARB compiles a statewide emission inventory based on the information collected by the ARB and local air districts. Local air districts provide most of the stationary source emission data, and ARB provides mobile source emissions as well as some areawide emission sources such as consumer products and paints. ARB is also developing map-based tools that will display information on air pollution sources.

Criteria pollutant data have been collected since the early 1970's, and toxic pollutant inventories began to be developed in the mid-1980's.

[1] A criteria pollutant is any air pollutant for which EPA has established a National Ambient Air Quality Standard or for which California has established a State Ambient Air Quality Standard, including: carbon monoxide, lead, nitrogen oxides, ozone, particulates and sulfur oxides. Criteria pollutants are measured in each of California's air basins to determine whether the area meets or does not meet specific federal or state air quality standards. Air toxics or air toxic contaminants are listed pollutants recognized by California or EPA as posing a potential risk to health.

How is the toxic emission inventory developed?

Emissions data for toxic air pollutants is a high priority for communities because of concerns about potential health effects. Most of ARB's air toxics data is collected through the toxic "Hot Spots" program. Local air districts collect emissions data from industrial and commercial facilities. Facilities that exceed health-based thresholds are required to report their air toxics emissions as part of the toxic "Hot Spots" program and update their emissions data every four years. Facilities are required to report their air toxics emissions data if there is an increase that would trigger the reporting threshold of the hotspots program. Air toxics emissions from motor vehicles and consumer products are estimated by the ARB. These estimates are generally regional in nature, reflecting traffic and population.

The ARB also maintains chemical speciation profiles that can be used to estimate toxics emissions when no toxic emissions data is available.

What additional toxic emissions information is needed?

In order to assess cumulative air pollution impacts, updated information from individual facilities is needed. Even for sources where emissions data are available, additional information such as the location of emissions release points is often needed to better model cumulative impacts. In terms of motor vehicles, emissions data are currently based on traffic models that only contain major roads and freeways. Local traffic data are needed so that traffic emissions can be more accurately assigned to specific streets and roads. Local information is also needed for off-road emission sources, such as ships, trains, and construction equipment. In addition, hourly maximum emissions data are needed for assessing acute air pollution impacts.

What work is underway?

ARB is working with CAPCOA to improve toxic emissions data, developing a community health air pollution information system to improve access to emission information, conducting neighborhood assessment studies to better understand toxic emission sources, and conducting surveys of sources of toxic pollutants.

How is air pollution monitored?

While emissions data identify how much air pollution is going into the air, the state's air quality monitoring network measures air pollutant levels in outdoor air. The statewide air monitoring network is primarily designed to measure regional exposure to air pollutants, and consists of more than 250 air monitoring sites.

The air toxics monitoring network consists of approximately 20 permanent sites. These sites are supplemented by special monitoring studies conducted by ARB and local air districts. These sites measure approximately sixty toxic air pollutants. Diesel PM, which is the major driver of urban air toxic risk, is not monitored directly. Ten of the

60 toxic pollutants, not including diesel, account for most of the remaining potential cancer risk in California urban areas.

What additional monitoring has been done?

Recently, additional monitoring has been done to look at air quality at the community level. ARB's community monitoring was conducted in six communities located throughout the state. Most sites were in low-income, minority communities located near major sources of air pollution, such as refineries or freeways. The monitoring took place for a year or more in each community, and included measurements of both criteria and toxic pollutants.

What is being learned from community monitoring?

In some cases, the ARB or local air districts have performed air quality monitoring or modeling studies covering a particular region of the state. When available, these studies can give information about regional air pollution exposures.

The preliminary results of ARB's community monitoring are providing insights into air pollution at the community level. Urban background levels are a major contributor to the overall risk from air toxics in urban areas, and this urban background tends to mask the differences between communities. When localized elevated air pollutant levels were measured, they were usually associated with local ground-level sources of toxic pollutants. The most common source of this type was busy streets and freeways. The impact these ground-level sources had on local air quality decreased rapidly with distance from the source. Pollutant levels usually returned to urban background levels within a few hundred meters of the source.

These results indicate that tools to assess cumulative impacts must be able to account for both localized, near-source impacts, as well as regional background air pollution. The tools that ARB is developing for this purpose are air quality models.

How can air quality modeling be used?

While air monitoring can directly measure cumulative exposure to air pollution, it is limited because all locations cannot be monitored. To address this, air quality modeling provides the capability to estimate exposure when air monitoring is not feasible. Air quality modeling can be refined to assess local exposure, identify locations of potential hot spots, and identify the relative contribution of emission sources to exposure at specific locations. The ARB has used this type of information to develop regional cumulative risk maps that estimate the cumulative cancer air pollution risk for most of California. While these maps only show one air pollution-related health risk, it does provide a useful starting point.

What is needed for community modeling?

Air quality models have been developed to assess near-source impacts, but they have very exacting data requirements. These near-source models estimate the impact of local sources, but do not routinely include the contribution from regional air pollution background. To estimate cumulative air pollution exposure at a neighborhood scale, a modeling approach needs to combine features of both micro-scale and regional models.

In addition, improved methods are needed to assess near-source impacts under light and variable wind conditions, when high local concentrations are more likely to occur. A method for modeling long-term exposure to air pollutants near freeways and other high traffic areas is also needed.

What modeling work has ARB developed?

A key component of ARB's Community Health Program is the Neighborhood Assessment Program (NAP). As described later in this section, the NAP studies are being conducted to better understand pollution impacts at the community level. Through two such studies conducted in Barrio Logan (San Diego) and Wilmington (Los Angeles), ARB is refining community-level modeling methodologies. Regional air toxics modeling is also being performed to better understand regional air pollution background levels.

In a parallel effort, ARB is developing modeling protocols for estimating cumulative emissions, exposure, and risk from air pollution. The protocols will cover modeling approaches and uncertainties, procedures for running the models, the development of statewide risk maps, and methods for estimating health risks. The protocols are subject to an extensive peer review process prior to release.

How are air pollution impacts on community health assessed?

On a statewide basis, ARB's toxic air contaminant program identifies and reduces public exposure to air toxics. The focus of the program has been on reducing potential cancer risk, because monitoring results show potential urban cancer risk levels are too high. ARB has also looked for potential non-cancer risks based on health reference levels provided by OEHHA. On a regional basis, the pollutants measured in ARB's toxic monitoring network are generally below the OEHHA non-cancer reference exposure levels.

As part of its community health program, the ARB is looking at potential cancer and non-cancer risk. This could include chronic or acute health effects. If the assessment work shows elevated exposures on a localized basis, ARB will work with OEHHA to assess the health impacts.

What tools has ARB developed to assess cumulative air pollution impacts?

ARB has developed the following tools and reports to assist land use agencies and local air districts assess and reduce cumulative emissions, exposure, and risk on a neighborhood scale.

Statewide Risk Maps

ARB has produced regional risk maps that show the statewide trends for Southern and Central California in estimated potential cancer risk from air toxics between 1990 and 2010.[2] These maps will supplement U.S. EPA's ASPEN model and are available on the ARB's Internet site. These maps are best used to obtain an estimate of the regional background air pollution health risk and are not detailed enough to estimate the exact risk at a specific location.

ARB also has maps that focus in more detail on smaller areas that fall within the Southern and Central California regions for these same modeled years. The finest visual resolution available in the maps on this web site is two by two kilometers. These maps are not detailed enough to assess individual neighborhoods or facilities.

Community Health Air Pollution Information System (CHAPIS)

CHAPIS is an Internet-based procedure for displaying information on emissions from sources of air pollution in an easy to use mapping format. CHAPIS uses Geographical Information System (GIS) software to deliver interactive maps over the Internet. CHAPIS relies on emission estimates reported to the ARB's emission inventory database - California Emissions Inventory Development and Reporting System, or CEIDARS.

Through CHAPIS, air district staff can quickly and easily identify pollutant sources and emissions within a specified area. CHAPIS contains information on air pollution emissions from selected large facilities and small businesses that emit criteria and toxic air pollutants. It also contains information on air pollution emissions from motor vehicle and areawide emissions. CHAPIS does not contain information on every source of air pollution or every air pollutant. It is a major long-term objective of CHAPIS to include all of the largest air pollution sources and those with the highest documented air pollution risk. CHAPIS will be updated on a periodic basis and additional facilities will be added to CHAPIS as more data becomes available.

CHAPIS is being developed in stages to assure data quality. The initial release of CHAPIS will include facilities emitting 10 or more tons per year of nitrogen oxides, sulfur dioxide, carbon monoxide, PM10, or reactive organic gases; air toxics from refineries and power plants of 50 megawatts or more; and facilities that conducted health risk

[2]ARB maintains state trends and local potential cancer risk maps that show statewide trends in potential inhalable cancer risk from air toxics between 1990 and 2010. This information can be viewed at ARB's web site at http://www.arb.ca.gov/toxics/cti/hlthrisk/hlthrisk.htm)

assessments under the California Air Toxics “Hot Spots” Information and Assessment Program.[3]

CHAPIS can be used to identify the emission contributions from mobile, area, and point sources on that community.

“Hot Spots” Analysis and Reporting Program (HARP)

HARP[4] is a software package available from the ARB and is designed with air quality professionals in mind. It models emissions and release data from one or more facilities to estimate the potential health risk posed by the selected facilities on the neighboring community. HARP uses the latest risk assessment guidelines published by OEHHA.

With HARP, a user can perform the following tasks:

- Create and manage facility databases;
- Perform air dispersion modeling;
- Conduct health risk analyses;
- Output data reports; and
- Output results to GIS mapping software.

HARP can model downwind concentrations of air toxics based on the calculated emissions dispersion at a single facility. HARP also has the capability of assessing the risk from multiple facilities, and for multiple locations of concern near those facilities. While HARP has the capability to assess multiple source impacts, there had been limited application of the multiple facility assessment function in the field at the time of HARP’s debut in 2003. HARP can also evaluate multi-pathway, non-inhalation health risk resulting from air pollution exposure, including skin and soil exposure, and ingestion of meat and vegetables contaminated with air toxics, and other toxics that have accumulated in a mother’s breast milk.

Neighborhood Assessment Program (NAP)

The NAP[5] has been a key component of ARB’s Community Health Program. It includes the development of tools that can be used to perform assessments of cumulative air pollution impacts on a neighborhood scale. The NAP studies have been done to better understand how air pollution affects individuals at the neighborhood level. Thus far, ARB has conducted neighborhood scale assessments in Barrio Logan and Wilmington.

As part of these studies, ARB is collecting data and developing a modeling protocol that can be used to conduct cumulative air pollution impact assessments. Initially these

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[3] California Health & Safety Code section 44300, et seq.
[4] More detailed information can be found on ARB’s website at: http://www.arb.ca.gov/toxics/harp/harp.htm
[5] For more information on the Program, please refer to: http://www.arb.ca.gov/ch/programs/nap/nap.htm

assessments will focus on cumulative inhalation cancer health risk and chronic non-cancer impacts. The major challenge is developing modeling methods that can combine both regional and localized air pollution impacts, and identifying the critical data necessary to support these models. The objective is to develop methods and tools from these studies that can ultimately be applied to other areas of the state. In addition, the ARB plans to use these methods to replace the ASPEN regional risk maps currently posted on the ARB Internet site.

Urban Emissions Model (URBEMIS)

URBEMIS[6] is a computer program that can be used to estimate emissions associated with land development projects in California such as residential neighborhoods, shopping centers, office buildings, and construction projects. URBEMIS uses emission factors available from the ARB to estimate vehicle emissions associated with new land uses. URBEMIS estimates sulfur dioxide emissions from motor vehicles in addition to reactive organic gases, nitrogen oxides, carbon monoxide, and PM10.

Land-Use Air Quality Linkage Report[7]

This report summarizes data currently available on the relationships between land use, transportation and air quality. It also highlights strategies that can help to reduce the use of the private automobile. It also briefly summarizes two ARB-funded research projects. The first project analyzes the travel patterns of residents living in five higher density, mixed use neighborhoods in California, and compares them to travel in more auto-oriented areas. The second study correlates the relationship between travel behavior and community characteristics, such as density, mixed land uses, transit service, and accessibility for pedestrians.

[6] For more information on this model, please refer to ARB’s website at http://www.arb.ca.gov/html/soft.htm.

[7] To access this report, please refer to ARB's website or click on: http://www.arb.ca.gov/ch/programs/link97.pdf

LAND USE AND AIR QUALITY AGENCY ROLES IN THE LAND USE PROCESS

A wide variety of federal, state, and local government agencies are responsible for regulatory, planning, and siting decisions that can have an impact on air pollution. They include local land use agencies, regional councils of government, school districts, local air districts, ARB, the California Department of Transportation (Caltrans), and the Governor's Office of Planning and Research (OPR) to name a few. This Section will focus on the roles and responsibilities of local and state agencies. The role of school districts will be discussed in Appendix E.

Local Land Use Agencies

Under the State Constitution, land use agencies have the primary authority to plan and control land use.[1] Each of California's incorporated cities and counties are required to adopt a comprehensive, long-term General Plan.[2]

The General Plan's long-term goals are implemented through zoning ordinances. These are local laws adopted by counties and cities that describe for specific areas the kinds of development that will be allowed within their boundaries.

Land use agencies are also the lead for doing environmental assessments under CEQA for new projects that may pose a significant environmental impact, or for new or revised General Plans.

Local Agency Formation Commissions (LAFCOs)

Operating in each of California's 58 counties, LAFCOs are composed of local elected officials and public members who are responsible for coordinating changes in local governmental boundaries, conducting special studies that review ways to reorganize, simplify, and streamline governmental structures, and preparing a sphere of influence for each city and special district within each county. Each Commission's efforts are directed toward seeing that local government services are provided efficiently and economically while agricultural and open-space lands are protected. LAFCO decisions strive to balance the competing needs in California for efficient services, affordable housing, economic opportunity, and conservation of natural resources.

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[1] The legal basis for planning and land use regulation is the "police power" of the city or county to protect the public's health, safety and welfare. The California Constitution gives cities and counties the power to make and enforce all local police, sanitary and other ordinances and regulations not in conflict with general laws. State law reference: California Constitution, Article XI §7.

[2] OPR General Plan Guidelines, 2003: http://www.opr.ca.gov/planning/PDFs/General_Plan_Guidelines_2003.pdf

Councils of Government (COG)

COGs are organizations composed of local counties and cities that serve as a focus for the development of sound regional planning, including plans for transportation, growth management, hazardous waste management, and air quality. They can also function as the metropolitan planning organization for coordinating the region's transportation programs. COGs also prepare regional housing need allocations for updates of General Plan housing elements.

Local Air Districts

Under state law, air pollution control districts or air quality management districts (local air districts) are the local government agencies responsible for improving air quality and are generally the first point of contact for resolving local air pollution issues or complaints. There are 35 local air districts in California[3] that have authority and primary responsibility for regional clean air planning. Local air districts regulate stationary sources of air pollutants within their jurisdiction including but not limited to industrial and commercial facilities, power plants, construction activities, outdoor burning, and other non-mobile sources of air pollution. Some local air districts also regulate public and private motor vehicle fleet operators such as public bus systems, private shuttle and taxi services, and commercial truck depots.

- **Regional Clean Air Plans**

Local air districts are responsible for the development and adoption of clean air plans that protect the public from the harmful effects of air pollution. These plans incorporate strategies that are necessary to attain ambient air quality standards. Also included in these regional air plans are ARB and local district measures to reduce statewide emissions from mobile sources, consumer products, and industrial sources.

- **Facility-Specific Considerations**

Permitting. In addition to the planning function, local air districts adopt and enforce regulations, issue permits, and evaluate the potential environmental impacts of projects.

Pollution is regulated through permits and technology-based rules that limit emissions from operating units within a facility or set standards that vehicle fleet operators must meet. Permits to construct and permits to operate contain very specific requirements and conditions that tell each regulated source what it must do to limit its air pollution in compliance with local air district rules, regulations, and state law. Prior to receiving a permit, new facilities must go through a New Source Review (NSR) process that establishes air pollution control requirements for the facility. Permit conditions are typically contained in the permit to operate and specify requirements that businesses must follow; these may include limits on the amount of pollution that can be emitted, the

[3] Contact information for local air districts in California is listed in the front of this Handbook.

type of pollution control equipment that must be installed and maintained, and various record-keeping requirements.

Local air districts also notify the public about new permit applications for major new facilities, or major modifications to existing facilities that seek to locate within 1,000 feet of a school.

Local air districts can also regulate other types of sources to reduce emissions. These include regulations to reduce emissions from the following sources:

- hazardous materials in products used by industry such as paints, solvents, and de-greasers;
- agricultural and residential burning;
- leaking gasoline nozzles at service stations;
- public fleet vehicles such as sanitation trucks and school buses; and
- fugitive or uncontrolled dust at construction sites.

However, while emissions from industrial and commercial sources are typically subject to the permit authority of the local air district, sensitive sites such as a day care center, convalescent home, or playground are not ordinarily subject to an air permit. Local air district permits address the air pollutant emissions of a project but not its location.

Under the state's air toxics program, local air districts regulate air toxic emissions by adopting ARB air toxic control measures, or more stringent district-specific requirements, and by requiring individual facilities to perform a health risk assessment if emissions at the source exceed district-specific health risk thresholds[4], [5] (See the section on ARB programs for a more detailed summary of this program).

One approach by which local air districts regulate air toxics emissions is through the "Hot Spots" program.[6] The risk assessments submitted by the facilities under this

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[4] Cal/EPA's Office of Environmental Health Hazard Assessment has published "A Guide to Health Risk Assessment" for lay people involved in environmental health issues, including policymakers, businesspeople, members of community groups, and others with an interest in the potential health effects of toxic chemicals. To access this information, please refer to http://www.oehha.ca.gov/pdf/HRSguide2001.pdf

[5] Section 44306 of the California Health & Safety Code defines a health risk assessment as a detailed comprehensive analysis that a polluting facility uses to evaluate and predict the dispersion of hazardous substances in the environment and the potential for exposure of human populations, and to assess and quantify both the individual and population-wide health risks associated with those levels of exposure.

[6] AB-2588 (the Air Toxics "Hot Spots" Information and Assessment Act) requires local air districts to prioritize facilities by high, intermediate, and low priority categories to determine which must perform a health risk assessment. Each district is responsible for establishing the prioritization score threshold at which facilities are required to prepare a health risk assessment. In establishing priorities for each facility, local air districts must consider the potency, toxicity, quantity, and volume of hazardous materials released from the facility, the proximity of the facility to potential receptors, and any other factors that the district determines may indicate that the facility may pose a significant risk. All facilities within the highest category must prepare a health risk assessment. In addition, each district may require facilities in the intermediate and low priority categories to also submit a health risk assessment.

Table D-1
Local Sources of Air Pollution, Responsible Agencies, and Associated Regulatory Programs

Source	Examples	Primary Agency	Applicable Regulations
Large Stationary	Refineries, power plants, chemical facilities, certain manufacturing plants	Local air districts	Operating permit rules Air Toxics "Hot Spots" Law (AB 2588) Local district rules Air Toxic Control Measures (ATCMs)* New Source Review rules Title V permit rules
Small Stationary	Dry cleaners, auto body shops, welders, chrome plating facilities, service stations, certain manufacturing plants	Local air districts	Operating permit conditions, Air Toxics "Hot Spots" Law (AB 2588) Local district rules ATCMs* New Source Review rules
Mobile (non-fleet)	Cars, trucks, buses	ARB	Emission standards Cleaner-burning fuels (e.g., unleaded gasoline, low-sulfur diesel) Inspection and repair programs (e.g., Smog Check)
Mobile Equipment	Construction equipment	ARB, U.S. EPA	ARB rules U.S. EPA rules
Mobile (fleet)	Truck depots, school buses, taxi services	Local air districts, ARB	Local air district rules ARB urban bus fleet rule
Areawide	Paints and consumer products such as hair spray and spray paint	Local air district, ARB	ARB rules Local air district rules

*ARB adopts ATCMs, but local air districts have the responsibility to implement and enforce these measures or more stringent ones.

program are reviewed by OEHHA and approved by the local air district. Risk assessments are available by contacting the local air district.

Enforcement. Local air districts also take enforcement action to ensure compliance with air quality requirements. They enforce air toxic control measures, agricultural and residential burning programs, gasoline vapor control regulations, laws that prohibit air pollution nuisances, visible emission limits, and many other requirements designed to clean the air. Local districts use a variety of enforcement tools to ensure compliance. These include notices of violation, monetary penalties, and abatement orders. Under some circumstances, a permit may be revoked.

- **Environmental Review**

As required by the California Environmental Quality Act (CEQA), local air districts also review and comment on proposed land use plans and development projects that can have a significant effect on the environment or public health.[7]

California Air Resources Board

The ARB is the air pollution control agency at the state level that is responsible for the preparation of air plans required by state and federal law. In this regard, it coordinates the activities of all local air districts to ensure all statutory requirements are met and to reduce air pollution emissions for sources under its jurisdiction.

Motor vehicles are the single largest emissions source category under ARB's jurisdiction as well as the largest overall emissions source statewide. ARB also regulates emissions from other mobile equipment and engines as well as emissions from consumer products such as hair sprays, perfumes, cleaners, and aerosol paints.

Air Toxics Program

Under state law, the ARB has a critical role to play in the identification, prioritization, and control of air toxic emissions. The ARB statewide comprehensive air toxics program was established in the early 1980's. The Toxic Air Contaminant Identification and Control Act of 1983 (AB 1807, Tanner 1983) created California's program to reduce exposure to air toxics.[8] The Air Toxics "Hot Spots" Information and Assessment Act (Hot Spots program) supplements the AB 1807 program, by requiring a statewide air toxics inventory, notification of people exposed to a significant health risk, and facility plans to reduce these risks.

Under AB 1807, the ARB is required to use certain criteria to prioritize the identification and control of air toxics. In selecting substances for review, the ARB must consider criteria relating to emissions, exposure, and health risk, as well as persistence in the atmosphere, and ambient concentrations in the community. AB 1807 also requires the ARB to use available information gathered from the Hot Spots program when prioritizing compounds.

The ARB identifies pollutants as toxic air contaminants and adopts statewide air toxic control measures (ATCMs). Once ARB adopts an ATCM, local air districts must

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[7] Section 4 of this Handbook contains more information on the CEQA process.
[8] For a general background on California's air toxics program, the reader should refer to ARB's website at http://www.arb.ca.gov/toxics/tac/appendxb.htm.

implement the measure, or adopt and implement district-specific measures that are at least as stringent as the state standard. Taken in the aggregate, these ARB programs will continue to further reduce emissions, exposure, and health risk statewide.

With regard to the land use decision-making process, ARB, in conjunction with local air districts, plays an advisory role by providing technical information on land use-related air issues.

Other Agencies

Governor's Office of Planning and Research (OPR)

In addition to serving as the Governor's advisor on land use planning, research, and liaison with local government, OPR develops and implements the state's policy on land use planning and coordinates the state's environmental justice programs. OPR updated its General Plan Guidelines in 2003 to highlight the importance of sustainable development and environmental justice policies in the planning process. OPR also advises project proponents and government agencies on CEQA provisions and operates the State Clearinghouse for environmental and federal grant documents.

California Department of Housing and Community Development

The Department of Housing and Community Development (HCD) administers a variety of state laws, programs and policies to preserve and expand housing opportunities, including the development of affordable housing. All local jurisdictions must update their housing elements according to a staggered statutory schedule, and are subject to certification by HCD. In their housing elements, cities and counties are required to include a land inventory which identifies and zones sites for future residential development to accommodate a mix of housing types, and to remove barriers to the development of housing.

An objective of state housing element law is to increase the overall supply and affordability of housing. Other fundamental goals include conserving existing affordable housing, improving the condition of the existing housing stock, removing regulatory barriers to housing production, expanding equal housing opportunities, and addressing the special housing needs of the state's most vulnerable residents (frail elderly, disabled, large families with children, farmworkers, and the homeless).

Transportation Agencies

Transportation agencies can also influence mobile source-related emissions in the land use decision-making process. Local transportation agencies work with land use agencies to develop a transportation (circulation) element for the General Plan. These local government agencies then work with other transportation-related agencies, such as the Congestion Management Agency (CMA), Metropolitan Planning Organization

(MPO), Regional Transportation Planning Agency (RTPA), and Caltrans to develop long and short range transportation plans and projects.

Caltrans is the agency responsible for setting state transportation goals and for state transportation planning, design, construction, operations and maintenance activities. Caltrans is also responsible for delivering California's multibillion-dollar state Transportation Improvement Program, a list of transportation projects that are approved for funding by the California Transportation Commission in a 4-year cycle.

When safety hazards or traffic circulation problems are identified in the existing road system, or when land use changes are proposed such as a new residential subdivision, shopping mall or manufacturing center, Caltrans and/or the local transportation agency ensure the projects meet applicable state, regional, and local goals and objectives.

Caltrans also evaluates transportation-related projects for regional air quality impacts, from the perspective of travel-related emissions as well as road congestion and increases in road capacity (new lanes).

California Energy Commission (CEC)

The CEC is the state's CEQA lead agency for permitting large thermal power plants (50 megawatts or greater). The CEC works closely with local air districts and other federal, state and local agencies to ensure compliance with applicable laws, ordinances, regulations and standards in the permitting, construction, operation and closure of such plants. The CEC uses an open and public review process that provides communities with outreach and multiple opportunities to participate and be heard. In addition to its comprehensive environmental impact and engineering design assessment process, the CEC also conducts an environmental justice evaluation. This evaluation involves an initial demographic screening to determine if a qualifying minority or low-income population exists in the vicinity of the proposed project. If such a population is present, staff considers possible environmental justice impacts including from associated project emissions in its technical assessments.[9]

Department of Pesticides Regulation (DPR)

Pesticides are industrial chemicals produced specifically for their toxicity to a target pest. They must be released into the environment to do their job. Therefore, regulation of pesticides focuses on using toxicity and other information to ensure that when pesticides are used according to their label directions, potential for harm to people and the environment is minimized. DPR imposes strict controls on use, beginning before pesticide products can be sold in California, with an extensive scientific program to ensure they can be used safely. DPR and county enforcement staff tracks the use of pesticides to ensure that pesticides are used properly. DPR collects periodic

[9] See California Energy Commission, "Environmental Performance Report," July 2001 at http://www.energy.ca.gov/reports/2001-11-20_700-01-001.PDF

measurements of any remaining amounts of pesticides in water, air, and on fresh produce. If unsafe levels are found, DPR requires changes in how pesticides are used, to reduce the possibility of harm. If this cannot be done - that is, if a pesticide cannot be used safely - use of the pesticide will be banned in California.[10]

Federal Agencies

Federal agencies have permit authority over activities on federal lands and certain resources, which have been the subject of congressional legislation, such as air, water quality, wildlife, and navigable waters. The U.S. Environmental Protection Agency generally oversees implementation of the federal Clean Air Act, and has broad authority for regulating certain activities such as mobile sources, air toxics sources, the disposal of toxic wastes, and the use of pesticides. The responsibility for implementing some federal regulatory programs such as those for air and water quality and toxics is delegated by management to specific state and local agencies. Although federal agencies are not subject to CEQA they must follow their own environmental process established under the National Environmental Policy Act (NEPA).

[10] For more information, the reader is encouraged to visit the Department of Pesticide Regulation web site at www.cdpr.ca.gov/docs/empm/pubs/tacmenu.htm.

SPECIAL PROCESSES THAT APPLY TO SCHOOL SITING

The California Education Code and the California Public Resources Code place primary authority for siting public schools with the local school district, which is the 'lead agency' for purposes of CEQA. The California Education Code requires public school districts to notify the local planning agency about siting a new public school or expanding an existing school. The planning agency then reports back to the school district regarding a project's conformity with the adopted General Plan. However, school districts can overrule local zoning and land use designations for schools if they follow specified procedures. In addition, all school districts must evaluate new school sites using site selection standards established in Section 14010 of Title 5 of the California Code of Regulations. Districts seeking state funding for school site acquisition must also obtain site approval from the California Department of Education.

Before making a final decision on a school site acquisition, a school district must comply with CEQA and evaluate the proposed site acquisition/new school project for air emissions and health risks by preparing and certifying an environmental impact report or negative declaration. Both the California Education Code section 17213 and the California Public Resources Code section 21151.8 require school districts to consult with administering agencies and local air districts when preparing the environmental assessment. Such consultation is required to identify both permitted and non-permitted "facilities" that might significantly affect health at the new site. These facilities include, but are not limited to, freeways and other busy traffic corridors, large agricultural operations, and rail yards that are within one-quarter mile of the proposed school site, and that might emit hazardous air emissions, or handle hazardous or acutely hazardous materials, substances, or waste.

As part of the CEQA process and before approving a school site, the school district must make a finding that either it found none of the facilities or significant air pollution sources, or alternatively, if the school district finds that there are such facilities or sources, it must determine either that they pose no significant health risks, or that corrective actions by another governmental entity would be taken so that there would be no actual or potential endangerment to students or school workers.

In addition, if the proposed school site boundary is within 500 feet of the edge of the closest traffic lane of a freeway or traffic corridor that has specified minimum average daily traffic counts, the school district is required to determine through specified risk assessment and air dispersion modeling that neither short-term nor long term exposure poses significant heath risks to pupils.

State law changes effective January 1, 2004 (SB352, Escutia 2003, amending Education Code section 17213 and Public Resources Code section 21151.8) also provides for cases in which the school district cannot make either of those two findings and cannot find a suitable alternative site. When this occurs, the school district must adopt a statement of over-riding considerations, as part of an environmental impact report, that the project should be approved based on the ultimate balancing of the merits.

Some school districts use a standardized assessment process to determine the environmental impacts of a proposed school site. In the assessment process, school districts can use maps and other available information to evaluate risk, including a local air district's database of permitted source emissions. School districts can also perform field surveys and record searches to identify and calculate emissions from non-permitted sources within one-quarter mile radius of a proposed site. Traffic count data and vehicular emissions data can also be obtained from Caltrans for major roadways and freeways in proximity to the proposed site to model potential emissions impacts to students and school employees. This information is available from the local COG, Caltrans, or local cities and counties for non-state maintained roads.

GENERAL PROCESSES USED BY LAND USE AGENCIES TO ADDRESS AIR POLLUTION IMPACTS

There are several separate but related processes for addressing the air pollution impacts of land use projects. One takes place as part of the planning and zoning function. This consists of preparing and implementing goals and policies contained in county or city General Plans, community or area plans, and specific plans governing land uses such as residential, educational, commercial, industrial, and recreational activities. It also includes recommending locations for thoroughfares, parks and other public improvements.

Land use agencies also have a permitting function that includes performing environmental reviews and mitigation when projects may pose a significant environmental impact. They conduct inspections for zoning permits issued, enforce the zoning regulations and issue violations as necessary, issue zoning certificates of compliance, and check compliance when approving certificates of occupancy.

Planning

- **General Plan**[1]

The General Plan is a local government "blueprint" of existing and future anticipated land uses for long-term future development. It is composed of the goals, policies, and general elements upon which land use decisions are based. Because the General Plan is the foundation for all local planning and development, it is an important tool for implementing policies and programs beneficial to air quality. Local governments may choose to adopt a separate air quality element into their General Plan or to integrate air quality-beneficial objectives, policies, and strategies in other elements of the Plan, such as the land use, circulation, conservation, and community design elements.

More information on General Plan elements is contained in Appendix D.

- **Community Plans**

Community or area plans are terms for plans that focus on a particular region or community within the overall general plan area. It refines the policies of the general plan as they apply to a smaller geographic area and is implemented by ordinances and other discretionary actions, such as zoning.

[1] In October 2003, OPR revised its General Plan Guidelines. An entire chapter is now devoted to a discussion of how sustainable development and environmental justice goals can be incorporated into the land use planning process. For further information, the reader is encouraged to obtain a copy of OPR's General Plan Guidelines, or refer to their website at: http://www.opr.ca.gov/planning/PDFs/General_Plan_Guidelines_2003.pdf

- **Specific Plan**

A specific plan is a hybrid that can combine policies with development regulations or zoning requirements. It is often used to address the development requirements for a single project such as urban infill or a planned community. As a result, its emphasis is on concrete standards and development criteria.

- **Zoning**

Zoning is the public regulation of the use of land. It involves the adoption of ordinances that divide a community into various districts or zones. For instance, zoning ordinances designate what projects and activities can be sited in particular locations. Each zone designates allowable uses of land within that zone, such as residential, commercial, or industrial. Zoning ordinances can address building development standards, e.g., minimum lot size, maximum building height, minimum building setback, parking, signage, density, and other allowable uses.

Land Use Permitting

In addition to the planning and zoning function, land use agencies issue building and business permits, and evaluate the potential environmental impacts of projects. To be approved, projects must be located in a designated zone and comply with applicable ordinances and zoning requirements.

Even if a project is sited properly in a designated zone, a land use agency may require a new source to mitigate potential localized environmental impacts to the surrounding community below what would be required by the local air district. In this case, the land use agency could condition the permit by limiting or prescribing allowable uses including operating hour restrictions, building standards and codes, property setbacks between the business property and the street or other structures, vehicle idling restrictions, or traffic diversion.

Land use agencies also evaluate the environmental impacts of proposed land use projects or activities. If a project or activity falls under CEQA, the land use agency requires an environmental review before issuing a permit to determine if there is the potential for a significant impact, and if so, to mitigate the impact or possibly deny the project.

- **Land Use Permitting Process**

In California, the authority to regulate land use is delegated to city and county governments. The local land use planning agency is the local government administrative body that typically provides information and coordinates the review of development project applications. Conditional Use Permits (CUP) typically fall within a land use agency's discretionary authority and therefore are subject to CEQA. CUPs are intended to provide an opportunity to review the location, design, and manner of development of land uses prior to project approval. A traditional purpose of the CUP is to enable a municipality to control certain uses that could have detrimental environmental effects on the community.

The process for permitting new discretionary projects is quite elaborate, but can be broken down into five fundamental components:

- Project application
- Environmental assessment
- Consultation
- Public comment
- Public hearing and decision

Project Application

The permit process begins when the land use agency receives a project application, with a detailed project description, and support documentation. During this phase, the agency reviews the submitted application for completeness. When the agency deems the application to be complete, the permit process moves into the environmental review phase.

Environmental Assessment

If the project is discretionary and the application is accepted as complete, the project proposal or activity must undergo an environmental clearance process under CEQA and the CEQA Guidelines adopted by the California Resources Agency.[2] The purpose of the CEQA process is to inform decision-makers and the public of the potential significant environmental impacts of a project or activity, to identify measures to minimize or eliminate those impacts to the point they are no longer significant, and to discuss alternatives that will accomplish the project goals and objectives in a less environmentally harmful manner.

What is a "Lead Agency"?

A lead agency is the public agency that has the principal responsibility for carrying out or approving a project that is subject to CEQA. In general, the land use agency is the preferred public agency serving as lead agency because it has jurisdiction over general land uses. The lead agency is responsible for determining the appropriate environmental document, as well as its preparation.

What is a "Responsible Agency"?

A responsible agency is a public agency with discretionary approval authority over a portion of a CEQA project (e.g., projects requiring a permit). As a responsible agency, the agency is available to the lead agency and project proponent for early consultation on a project to apprise them of applicable rules and regulations, potential adverse impacts, alternatives, and mitigation measures, and provide guidance as needed on applicable methodologies or other related issues.

What is a "Commenting Agency"?

A commenting agency is any public agency that comments on a CEQA document, but is neither a lead agency nor a responsible agency. For example, a local air district, as the agency with the responsibility for comprehensive air pollution control, could review and comment on an air quality analysis in a CEQA document for a proposed distribution center, even though the project was not subject to a permit or other pollution control requirements.

[2] Projects and activities that may have a significant adverse impact on the environment are evaluated under CEQA Guidelines set forth in title 14 of the California Code of Regulations, sections 15000 et seq.

To assist the lead agency in determining whether the project or activity may have a significant effect that would require the preparation of an EIR, the land use agency may consider criteria, or thresholds of significance, to assess the potential impacts of the project, including its air quality impacts. The land use agency must consider any credible evidence in addition to the thresholds, however, in determining whether the project or activity may have a significant effect that would trigger the preparation of an EIR.

The screening criteria to determine significance is based on a variety of factors, including local, state, and federal regulations, administrative practices of other public agencies, and commonly accepted professional standards. However, the final determination of significance for individual projects is the responsibility of the lead agency. In the case of land use projects, the lead agency would be the City Council or County Board of Supervisors.

A new land use plan or project can also trigger an environmental assessment under CEQA if, among other things, it will expose sensitive sites such as schools, day care centers, hospitals, retirement homes, convalescence facilities, and residences to substantial pollutant concentrations.[3]

CEQA only applies to "discretionary projects." Discretionary means the public agency must exercise judgment and deliberation when deciding to approve or disapprove a particular project or activity, and may append specific conditions to its approval. Examples of discretionary projects include the issuance of a CUP, re-zoning a property, or widening of a public road. Projects that are not subject to the exercise of agency discretion, and can therefore be approved administratively through the application of set standards are referred to as ministerial projects. CEQA does not apply to ministerial projects.[4] Examples of typical ministerial projects include the issuance of most building permits or a business license.

Once a potential environmental impact associated with a project is identified through an environmental assessment, mitigation must be considered. A land use agency should incorporate mitigation measures that are suggested by the local air district as part of the project review process.

Consultation

Application materials are provided to various departments and agencies that may have an interest in the project (e.g., air pollution, building, police, fire, water agency, Fish and Game, etc.) for consultation and input.

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[3] Readers interested in learning more about CEQA should contact OPR or visit their website at http://www.opr.ca.gov/.

[4] See California Public Resources Code section 21080(b)(1).

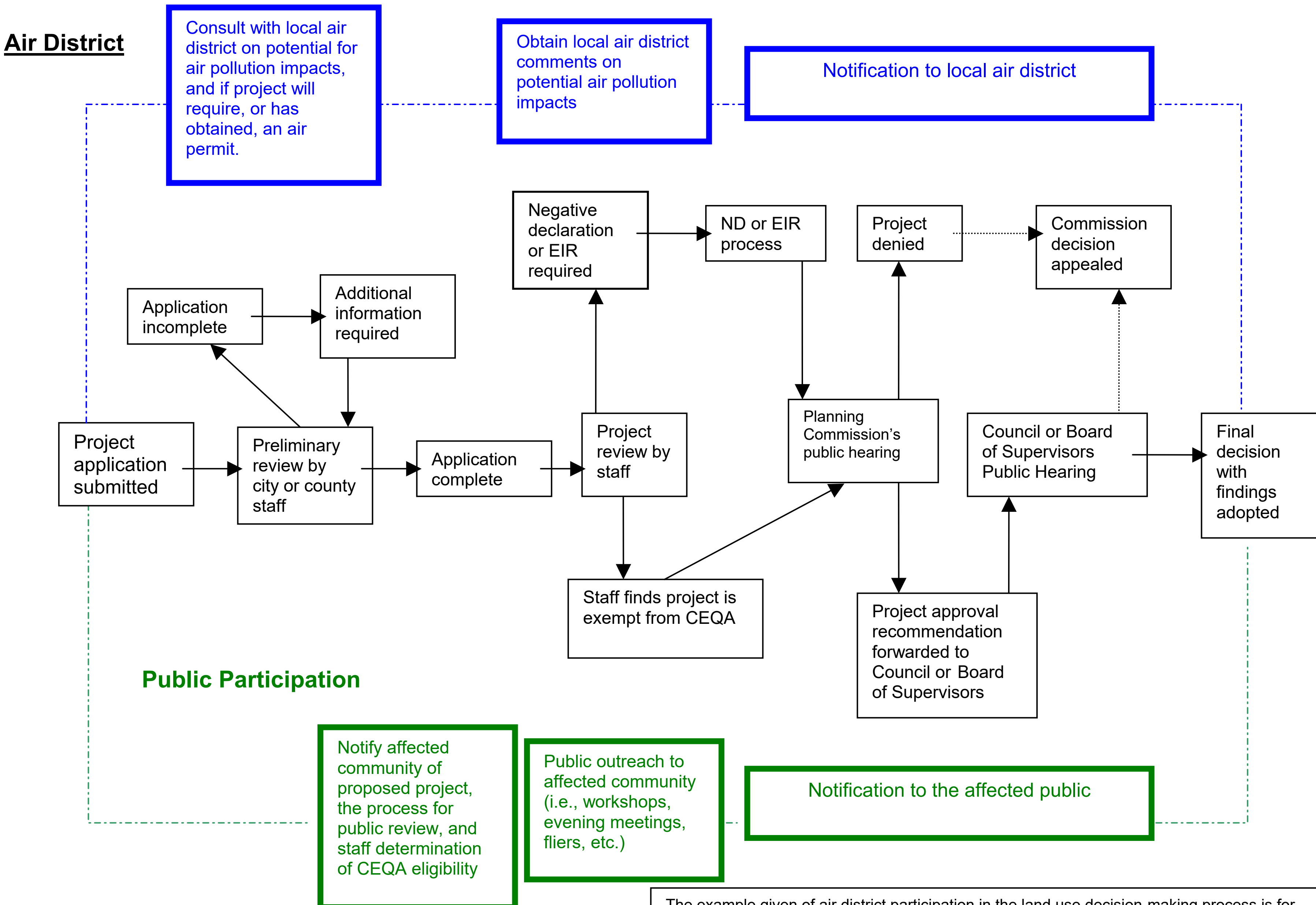
Public Comment

Following the environmental review process, the Planning Commission reviews application along with the staff's report on the project assessment and a public comment period is set and input is solicited.

Public Hearing and Decision

Permit rules vary depending on the particular permit authority in question, but the process generally involves comparing the proposed project with the land use agency standards or policies. The procedure usually leads to a public hearing, which is followed by a written decision by the agency or its designated officer. Typically, a project is approved, denied, or approved subject to specified conditions.

USE PERMIT (DISCRETIONARY ACTION) REVIEW PROCESS*



The example given of air district participation in the land use decision-making process is for illustrative purposes only. In reality, the land use siting process involves the ongoing participation of multiple affected agencies and stakeholders throughout the process.

GLOSSARY OF KEY AIR POLLUTION TERMS

Air Pollution Control Board or Air Quality Management Board: Serves as the governing board for local air districts. It consists of appointed or elected members from the public or private sector. It conducts public hearings to adopt local air pollution regulations.

Air Pollution Control Districts or Air Quality Management Districts (local air district): A county or regional agency with authority to regulate stationary and area sources of air pollution within a given county or region. Governed by a district air pollution control board.

Air Pollution Control Officer (APCO): Head of a local air pollution control or air quality management district.

Air Toxic Control Measures (ATCM): A control measure adopted by the ARB (Health and Safety Code section 39666 et seq.), which reduces emissions of toxic air contaminants.

Ambient Air Quality Standards: An air quality standard defines the maximum amount of a pollutant that can be present in the outdoor air during a specific time period without harming the public's health. Only U.S. EPA and the ARB may establish air quality standards. No other state has this authority. Air quality standards are a measure of clean air. More specifically, an air quality standard establishes the concentration at which a pollutant is known to cause adverse health effects to sensitive groups within the population, such as children and the elderly. Federal standards are referred to as National Ambient Air Quality Standards (NAAQS); state standards are referred to as California ambient air quality standards (CAAQS).

Area-wide Sources: Sources of air pollution that individually emit small amounts of pollution, but together add up to significant quantities of pollution. Examples include consumer products, fireplaces, road dust, and farming operations.

Attainment vs. Nonattainment Area: An attainment area is a geographic area that meets the National Ambient Air Quality Standards for the criteria pollutants and a non-attainment area is a geographic area that doesn't meet the NAAQS for criteria pollutants.

Attainment Plan: Attainment plans lay out measures and strategies to attain one or more air quality standards by a specified date.

California Clean Air Act (CCAA): A California law passed in 1988, which provides the basis for air quality planning and regulation independent of federal regulations. A major element of the Act is the requirement that local air districts in violation of the CAAQS must prepare attainment plans which identify air quality problems, causes, trends, and actions to be taken to attain and maintain California's air quality standards by the earliest practicable date.

California Environmental Quality Act (CEQA): A California law that sets forth a process for public agencies to make informed decisions on discretionary project approvals. The process helps decision-makers determine whether any potential, significant, adverse environmental impacts are associated with a proposed project and to identify alternatives and mitigation measures that will eliminate or reduce such adverse impacts.[1]

California Health and Safety Code: A compilation of California laws, including state air pollution laws, enacted by the Legislature to protect the health and safety of people in California. Government agencies adopt regulations to implement specific provisions of the California Health and Safety Code.

Clean Air Act (CAA): The federal Clean Air Act was adopted by the United States Congress and sets forth standards, procedures, and requirements to be implemented by the U.S. Environmental Protection Agency (U.S. EPA) to protect air quality in the United States.

Councils of Government (COGs): There are 25 COGs in California made up of city and county elected officials. COGs are regional agencies concerned primarily with transportation planning and housing; they do not directly regulate land use.

Criteria Air Pollutant: An air pollutant for which acceptable levels of exposure can be determined and for which an ambient air quality standard has been set. Examples include ozone, carbon monoxide, nitrogen dioxide, sulfur dioxide, and PM10 and PM2.5. The term "criteria air pollutants" derives from the requirement that the U.S. EPA and ARB must describe the characteristics and potential health and welfare effects of these pollutants. The U.S. EPA and ARB periodically review new scientific data and may propose revisions to the standards as a result.

District Hearing Board: Hears local air district permit appeals and issues variances and abatement orders. The local air district board appoints the members of the hearing board.

Emission Inventory: An estimate of the amount of pollutants emitted into the atmosphere from mobile, stationary, area-wide, and natural source categories over a specific period of time such as a day or a year.

Environmental Impact Report (EIR): The public document used by a governmental agency to analyze the significant environmental effects of a proposed project, to identify

[1] To track the submittal of CEQA documents to the State Clearinghouse within the Office of Planning and Research, the reader can refer to CEQAnet at http://www.ceqanet.ca.gov.

alternatives, and to disclose possible ways to reduce or avoid the possible negative environmental impacts.

Environmental Justice: California law defines environmental justice as the fair treatment of people of people of all races, cultures, and incomes with respect to the development, adoption, implementation, and enforcement of environmental laws, regulations, and policies (California Government Code sec.65040.12(c)).

General Plans: A statement of policies developed by local governments, including text and diagrams setting forth objectives, principles, standards, and plan proposals for the future physical development of the city or county.

Hazardous Air Pollutants (HAPs): An air pollutant listed under section 112 (b) of the federal Clean Air Act as particularly hazardous to health. U.S. EPA identifies emission sources of hazardous air pollutants, and emission standards are set accordingly. In California, HAPs are referred to as toxic air contaminants.

Land Use Agency: Local government agency that performs functions associated with the review, approval, and enforcement of general plans and plan elements, zoning, and land use permitting. For purposes of this Handbook, a land use agency is typically a local planning department.

Mobile Source: Sources of air pollution such as automobiles, motorcycles, trucks, off-road vehicles, boats, and airplanes.

National Ambient Air Quality Standard (NAAQS): A limit on the level of an outdoor air pollutant established by the US EPA pursuant to the Clean Air Act. There are two types of NAAQS. Primary standards set limits to protect public health and secondary standards set limits to protect public welfare.

Negative Declaration (ND): When the lead agency (the agency responsible for preparing the EIR or ND) under CEQA, finds that there is no substantial evidence that a project may have a significant environmental effect, the agency will prepare a "negative declaration" instead of an EIR.

New Source Review (NSR): A federal Clean Air Act requirement that state implementation plans must include a permit review process, which applies to the construction and operation of new or modified stationary sources in nonattainment areas. Two major elements of NSR to reduce emissions are best available control technology requirements and emission offsets.

Office of Planning and Research (OPR): OPR is part of the Governor's office. OPR has a variety of functions related to local land-use planning and environmental programs. It provides General Plan Guidelines for city and county planners, and coordinates the state clearinghouse for Environmental Impact Reports.

Ordinance: A law adopted by a City Council or County Board of Supervisors. Ordinances usually amend, repeal or supplement the municipal code; provide zoning specifications; or appropriate money for specific purposes.

Overriding Considerations: A ruling made by the lead agency in the CEQA process when the lead agency finds the importance of the project to the community outweighs potential adverse environmental impacts.

Public Comment: An opportunity for the general public to comment on regulations and other proposals made by government agencies. You can submit written or oral comments at the public meeting or send your written comments to the agency.

Public Hearing: A public hearing is an opportunity to testify on a proposed action by a governing board at a public meeting. The public and the media are welcome to attend the hearing and listen to, or participate in, the proceedings.

Public Notice: A public notice identifies the person, business, or local government seeking approval of a specific course of action (such as a regulation). It describes the activity for which approval is being sought, and describes the location where the proposed activity or public meeting will take place.

Public Nuisance: A public nuisance, for the purposes of air pollution regulations, is defined as a discharge from any source whatsoever of such quantities of air contaminants or other material which cause injury, detriment, nuisance, or annoyance to any considerable number of persons or to the public, or which endanger the comfort, repose, health, or safety of any such persons or the public, or which cause, or have a natural tendency to cause, injury or damage to business or property. (Health and Safety Code section 41700).

Property Setback: In zoning parlance, a setback is the minimum amount of space required between a lot line and a building line.

Risk: For cancer health effects, risk is expressed as an estimate of the increased chances of getting cancer due to facility emissions over a 70-year lifetime. This increase in risk is expressed as chances in a million (e.g.,10 chances in a million).

Sensitive Individuals: Refers to those segments of the population most susceptible to poor air quality (i.e., children, the elderly, and those with pre-existing serious health problems affected by air quality).

Sensitive Sites or Sensitive Land Uses: Land uses where sensitive individuals are most likely to spend time, including schools and schoolyards, parks and playgrounds, day care centers, nursing homes, hospitals, and residential communities.

Setback: An area of land separating one parcel of land from another that acts to soften or mitigate the effects of one land use on the other.

State Implementation Plan (SIP): A plan prepared by state and local agencies and submitted to U.S. EPA describing how each area will attain and maintain national ambient air quality standards. SIPs include the technical information about emission inventories, air quality monitoring, control measures and strategies, and enforcement mechanisms. A SIP is composed of local air quality management plans and state air quality regulations.

Stationary Sources: Non-mobile sources such as power plants, refineries, and manufacturing facilities.

Toxic Air Contaminant (TAC): An air pollutant, identified in regulation by the ARB, which may cause or contribute to an increase in deaths or in serious illness, or which may pose a present or potential hazard to human health. TACs are considered under a different regulatory process (California Health and Safety Code section 39650 et seq.) than pollutants subject to State Ambient Air Quality Standards. Health effects associated with TACs may occur at extremely low levels. It is often difficult to identify safe levels of exposure, which produce no adverse health effects.

Urban Background: The term is used in this Handbook to represent the ubiquitous, elevated, regional air pollution levels observed in large urban areas in California.

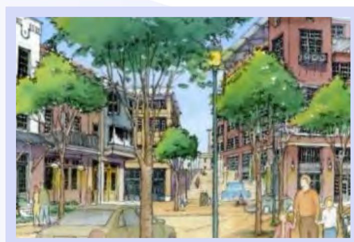
Zoning ordinances: City councils and county boards of supervisors adopts zoning ordinances that set forth land use classifications, divides the county or city into land use zones as delineated on the official zoning, maps, and set enforceable standards for future develop

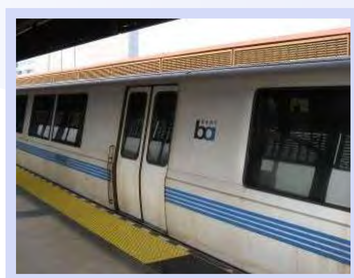
EXHIBIT 20

BAY AREA
AIR QUALITY
MANAGEMENT
DISTRICT

California Environmental Quality Act

Air Quality Guidelines





Note: This May 2017 version of the Guidelines includes revisions made to the Air District's 2010 Guidelines to address the California Supreme Court's 2015 opinion in Cal. Bldg. Indus. Ass'n vs. Bay Area Air Quality Mgmt. Dist., 62 Cal.4th 369. ***The May 2017 CEQA Guidelines update does not address outdated references, links, analytical methodologies or other technical information that may be in the Guidelines or Thresholds Justification Report. The Air District is currently working to update any outdated information in the Guidelines.*** *Please see the CEQA webpage at http://www.baaqmd.gov/plans-and-climate/california-environmental-quality-act-ceqa for status updates on the Air District's CEQA Guidelines or contact Jaclyn Winkel at jwinkel@baaqmd.gov for further information.*

May 2017

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ACRONYMS AND ABBREVIATIONS

μg/m^3	micrograms per cubic meter
AB	Assembly Bill
AB 1807	Tanner Air Toxics Act
AB 2588	Air Toxics Hot Spots Information and Assessment Act of 1987
ABAG	Association of Bay Area Governments
AMS	American Meteorological Society
APS	Alternative Planning Strategy
AQP	Air Quality Plan
ARB	California Air Resources Board
ATCM	air toxics control measures
BAAQMD	Bay Area Quality Management District
BACT	Best Available Control Technology
BMPs	Best Management Practices
CCA	Community Choice Aggregation
CAAQS	California Ambient Air Quality Standards
CALINE4	California Line Source Dispersion Model
CAP	criteria air pollutants
CARE	Community Air Risk Evaluation
CAPCOA	California Air Pollution Control Officers Association
CCAA	California Clean Air Act
CCAR	California Climate Action Registry
CCR	California Code of Regulations
CEC	California Energy Commission
CEQA	California Environmental Quality Act
CalRecycle	The California Department of Resources Recycling and Recovery (formally the California Integrated Waste Management Board)
CFC	Chlorofluorocarbon
CH_4	methane
CHAPIS	Community Health Air Pollution Information System
CO	carbon monoxide
CO Protocol	Carbon Monoxide Protocol
CO_2	Carbon dioxide
CO_2e	carbon dioxide equivalent
CRA	California Resources Agency

DOE	Department of Energy
du	dwelling units
EIR	Environmental Impact Report
EMFAC	On-Road Mobile-Source Emission Factors
EPA	U.S. Environmental Protection Agency
FAR	Floor Area Ratio
FCAA	Federal Clean Air Act
FCAAA	Federal Clean Air Act Amendments of 1990
GHG	greenhouse gas(es)
GRP	General Reporting Protocol
GVW	gross vehicle weight
GWP	global warming potential
H_2S	hydrogen sulfide
HEPA	High Efficiency Particulate Arresting (filter)
HI	Hazard Index
HRA	health risk assessment
HVAC	Heating, Ventilation, and Air Conditioning System
IPCC	Intergovernmental Panel on Climate Change
ISR	Indirect Source Review
ksf	thousand square feet
kwh	Kilowatt hour
lb/acre-day	pound per disturbed acre per day
lb/day	pounds per day
lb/kwh	pounds per kilowatt hour
LCFS	Low-Carbon Fuel Standard
LVW	loaded vehicle weight
MACT	maximum available control technology
mg	million gallons
MMT	million metric tons
mph	miles per hour
MPO	Metropolitan Planning Organizations
MT	metric tons
MTC	Metropolitan Transportation Commission
N_2O	nitrous oxide
NAAQS	National Ambient Air Quality Standards

NESHAP	national emissions standards for hazardous air pollutants
NH_3	mercaptan, ammonia
NOA	Naturally Occurring Asbestos
NOP	Notice of Preparation
NO_X	oxides of nitrogen
OEHHA	Office of Environmental Health Hazard Assessment
OPR	Governor's Office of Planning and Research
PM	particulate matter
PM_{10}	respirable particulate matter with an aerodynamic resistance diameter of 10 micrometers or less
$PM_{2.5}$	fine particulate matter with an aerodynamic resistance diameter of 2.5 micrometers or less
ppm	parts per million
PUC	Public Utilities Commission
RoadMod	Roadway Construction Emissions Model
ROG	reactive organic gases
RTP	Regional Transportation Plan
SB	Senate Bill
SCS	Sustainable Communities Strategy
SF_6	sulfur hexafluoride
SFBAAB	San Francisco Bay Area Air Basin
SIP	State Implementation Plan
SMAQMD	Sacramento Metropolitan Air Quality Management District
SO_2	sulfur dioxide
SP	Service Population
SSIM	Sustainable Systems Integration Model
TAC	toxic air contaminant
T-BACT	Toxic Best Available Control Technology
TBPs	Toxic Best Practices
tpy	tons per year
UC	University of California
URBEMIS	Urban Land Use Emissions Model
VMT	vehicle miles traveled
VT	vehicle trips
yd^3	cubic yards
yr	Year

2. The project traffic would not increase traffic volumes at affected intersections to more than 44,000 vehicles per hour.
3. The project traffic would not increase traffic volumes at affected intersections to more than 24,000 vehicles per hour where vertical and/or horizontal mixing is substantially limited (e.g., tunnel, parking garage, bridge underpass, natural or urban street canyon, below-grade roadway).

3.4. ODOR IMPACTS

Table 3-3 presents odor screening distances recommended by BAAQMD for a variety of land uses. Projects that would site a new odor source or a new receptor farther than the applicable screening distance shown in Table 3-3 from an existing receptor or odor source, respectively, would not likely result in a significant odor impact. The odor screening distances in Table 3-3 should not be used as absolute screening criteria, rather as information to consider along with the odor parameters and complaint history. Refer to *Chapter 7 Assessing and Mitigating Odor Impacts* for comprehensive guidance on significance determination.

Table 3-3
Odor Screening Distances

Land Use/Type of Operation	Project Screening Distance
Wastewater Treatment Plant	2 miles
Wastewater Pumping Facilities	1 mile
Sanitary Landfill	2 miles
Transfer Station	1 mile
Composting Facility	1 mile
Petroleum Refinery	2 miles
Asphalt Batch Plant	2 miles
Chemical Manufacturing	2 miles
Fiberglass Manufacturing	1 mile
Painting/Coating Operations	1 mile
Rendering Plant	2 miles
Coffee Roaster	1 mile
Food Processing Facility	1 mile
Confined Animal Facility/Feed Lot/Dairy	1 mile
Green Waste and Recycling Operations	1 mile
Metal Smelting Plants	2 miles
Refer to Appendix D for support documentation.	

Facilities that are regulated by CalRecycle (e.g. landfill, composting, etc.) are required to have Odor Impact Minimization Plans (OIMP) in place and have procedures that establish fence line odor detection thresholds. The Air District recognizes a Lead Agency's discretion under CEQA to use established odor detection thresholds as thresholds of significance for CEQA review for CalRecycle regulated facilities with an adopted OIMP.

7. ODOR IMPACTS[5]

Odor impacts could result from siting a new odor source near existing sensitive receptors or siting a new sensitive receptor near an existing odor source. Examples of land uses that have the potential to generate considerable odors include, but are not limited to:

1. Wastewater treatment plants;
2. Landfills;
3. Confined animal facilities;
4. Composting stations;
5. Food manufacturing plants;
6. Refineries; and
7. Chemical plants.

Odors are generally regarded as an annoyance rather than a health hazard. Manifestations of a person's reaction to odors can range from psychological (e.g., irritation, anger, or anxiety) to physiological (e.g., circulatory and respiratory effects, nausea, vomiting, and headache).

The ability to detect odors varies considerably among the population and overall is quite subjective. People may have different reactions to the same odor. An odor that is offensive to one person may be perfectly acceptable to another (e.g., coffee roaster). An unfamiliar odor is more easily detected and is more likely to cause complaints than a familiar one. Known as odor fatigue, a person can become desensitized to almost any odor and recognition only occurs with an alteration in the intensity.

Quality and intensity are two properties present in any odor. The quality of an odor indicates the nature of the smell experience. For instance, if a person describes an odor as flowery or sweet, then the person is describing the quality of the odor. Intensity refers to the strength of the odor. For example, a person may use the word strong to describe the intensity of an odor. Odor intensity depends on the concentration in the air. When an odor sample is progressively diluted, the odor concentration decreases. As this occurs, the odor intensity weakens and eventually becomes so low that the detection or recognition of the odor is quite difficult. At some point during dilution, the concentration of the odor reaches a level that is no longer detectable.

The presence of an odor impact is dependent on a number of variables including:

1. Nature of the odor source (e.g., wastewater treatment plant, food processing plant);
2. Frequency of odor generation (e.g., daily, seasonal, activity-specific);
3. Intensity of odor (e.g., concentration);
4. Distance of odor source to sensitive receptors (e.g., miles);
5. Wind direction (e.g., upwind or downwind); and
6. Sensitivity of the receptor.

The recommendations provided in this chapter only apply to assessing and mitigating odor impacts for individual projects. Please refer to Chapter 9 for recommendations for assessing and mitigating odor impacts at the plan-level.

[5] The use of the receptor thresholds is discussed in section 2.8 of these Guidelines

7.1. SIGNIFICANCE DETERMINATION

Odor impacts could occur from two different situations:

1. Siting a new odor source (e.g., the project includes a proposed odor source near existing sensitive receptors), or
2. Siting a new receptor (e.g., the project includes proposed sensitive receptors near an existing odor source).

Regardless of the situation, BAAQMD recommends completing the following steps to comprehensively analyze the potential for an odor impact.

Step 1: Disclosure of Odor Parameters
The first step in assessing potential odor impacts is to gather and disclose applicable information regarding the characteristics of the buffer zone between the sensitive receptor(s) and the odor source(s), local meteorological conditions, and the nature of the odor source. Consideration of such parameters assists in evaluating the potential for odor impacts as a result of the proposed project. Projects should clearly state the following information in odor analyses, which provide the minimum amount of information required to address potential odor impacts:

1. Type of odor source(s) the project is exposed to or the type of odor source(s) produced by the project (e.g., wastewater treatment plant, landfill, food manufacturing plant);
2. Frequency of odor events generated by odor source(s) (e.g., operating hours, seasonal);
3. Distance and landscape between the odor source(s) and the sensitive receptor(s) (e.g., topography, land features); and
4. Predominant wind direction and speed and whether the sensitive receptor(s) in question are upwind or downwind from the odor source(s).

Step 2: Odor Screening Distances
BAAQMD has developed a list of recommended odor screening distances for specific odor-generating facilities shown in Table 3-3. Projects that would locate sensitive receptor(s) to odor source(s) closer than the screening distances would be considered to result in a potential significant impact. If the proposed project would include the operation of an odor source, the screening distances should also be used to evaluate the potential impact to existing sensitive receptors. Projects that would locate sensitive receptor(s) near odor source(s) farther than the screening distances, or vice versa, would be considered to have a sufficient buffer to avoid significant impacts. The odor screening distances in Table 3-3 should not be used as absolute thresholds, rather an indicator to how much further analysis is required. The Lead Agency should also consider the other parameters listed above in Step 1 and information from Step 3 below to comprehensively evaluate potential odor impacts.

Step 3: Odor Complaint History
The impact of an existing odor source on surrounding sensitive receptors should also be evaluated by identifying the number of confirmed complaints received for that specific odor source.

Facilities that are regulated by CalRecycle (e.g. landfill, composting, etc.) are required to have Odor Impact Minimization Plans (OIMP) in place and have procedures that establish fence line odor detection thresholds. The Air District recognizes a Lead Agency's discretion under CEQA to use established odor detection thresholds as thresholds of significance for CEQA review for CalRecycle regulated facilities with an adopted OIMP.

If the proposed project would be located near an existing odor source, lead agencies should contact BAAQMD to obtain the odor complaints over the past 3 years for the source in question. Then calculate the annual average confirmed odor complaints filed for the source. BAAQMD considers a source to have a substantial number of odor complaints if the complaint history includes five or more confirmed complaints per year averaged over a 3-year period. Also, disclose the distance at which receptors were affected by the existing odor source. As discussed in Step 1, describe the topography and landscape between the receptors and the odor source. These distances and landscaping should then be compared with the distance and landscape that would separate the proposed project and the odor source.

If the proposed project would locate an odor source, first identify the location of potential sensitive receptors (i.e., distance, upwind/downwind) with respect to the project site. If the proposed odor source does not have any existing or planned sensitive receptors within the screening distances shown in Table 3-3, it may be considered less than significant for odor impacts. To evaluate how implementation of the proposed source project would affect identified sensitive receptors contact BAAQMD to obtain odor complaints in the region for facilities similar in size and type of odor produced in the past 3 years. These surrogate odor complaints should be evaluated for their distance from source to receptor, and then compared with the distance from the proposed project to receptors. Odor complaints from the surrogate odor source are considered substantial if the complaint history includes more than five confirmed complaints per year averaged over a 3-year period.

BAAQMD considers a substantial number of odor complaints, specifically, more than five confirmed complaints per year averaged over the past three years as the indication of an odor impact. As discussed above, the Lead Agency should compare the odor parameters (i.e., distance and wind direction) associated with the odor complaints that have been filed with those of the proposed project. Similar to the odor screening distances, odor complaints should not be used as an absolute threshold, but evidence to support a significance determination.

Step 4: Significance Determination

An odor source with five or more confirmed complaints per year averaged over three years is considered to have a significant impact. BAAQMD recognizes that there is not one piece of information that can solely be used to determine the significance of an odor impact. The factors (i.e., Step 1 through 3) discussed above could enhance the potential for a significant odor impact or help prevent the potential for a significant odor impact. For example, a project that would be located near an existing odor source may not discover any odor complaints for the existing odor source. It is possible that factors such as a small number of existing nearby receptors, predominate wind direction blowing away from the existing receptors, and/or seasonality of the odor source has prevented any odor complaints from being filed about the existing odor source. The results of each of the steps above should be clearly disclosed in the CEQA document. Projects should use the collective information from Steps 1 through 3 to qualitatively evaluate the potential for a significant odor impact. The Lead Agency should clearly state the reasoning for the significance determination using information from Steps 1 through 3 to support the determination.

7.2. MITIGATING ODOR IMPACTS

BAAQMD considers appropriate land use planning the primary method to mitigate odor impacts. Providing a sufficient buffer zone between sensitive receptors and odor sources should be considered prior to analyzing implementation of odor mitigation technology. Projects that would include potential sensitive receptors should consider the odor parameters, discussed in Step 1 above, during the planning process to avoid siting receptors near odor sources. Similarly, projects that would include an odor source should consider the location of nearby existing sensitive receptors that could be affected by the project.

The source types for which mitigation has been provided below have been selected based on the nature of the odors produced as a result of their operational activities. These land use types are those most likely to result in odor impacts if sensitive receptors are located in close proximity. This should not be considered an exhaustive list and due to the subjective nature of odor impacts, there is no formulaic method to assess if odor mitigation is sufficient. In determining whether the implementation of mitigation would reduce the potential odor impact to a less-than-significant level, rely on the information obtained through the steps above.

7.2.1. Wastewater Treatment Plant

Main odor sources for wastewater treatment plants typically are the headworks area where the wastewater enters the facility and large solids and grit are removed, the primary clarifiers where suspended solids are removed, and the aeration basins when poor mixing characteristics lead to inadequate dissolved oxygen levels. Lead agencies should consider applying the following odor mitigation measures to wastewater treatment plants.

1. Activated Carbon Filter/Carbon adsorption
2. Biofiltration/Bio Trickling Filters
3. Fine Bubble Aerator
4. Hooded Enclosures
5. Wet and Dry Scrubbers
6. Caustic and Hypochlorite Chemical Scrubbers
7. Ammonia Scrubber
8. Energy Efficient Blower System
9. Thermal Oxidizer
10. Capping/Covering Storage Basins and Anaerobic Ponds
11. Mixed Flow Exhaust
12. Wastewater circulation technology
13. Exhaust stack and vent location with respect to receptors

7.2.2. Landfill/Recycling/Composting Facilities

Odors generated from landfills and composting facilities are typically associated with methane production from the anaerobic decomposition of waste. Lead agencies should consider applying the mitigation measures below to reduce and treat methane in facilities. Landfill projects should also implement best management practices to avoid and minimize the creation of anaerobic conditions.

1. Passive Gas Collection
2. Active Gas Collection
3. Flaring or energy production/utilization
4. Vegetation Growth on Landfill Cover
5. Cover/Cap Landfill
6. Odor Neutralizing Spray
7. Negative aeration for compost facilities
8. Turning and mixing of compost piles

Facilities that are regulated by CalRecycle (e.g. landfill, composting, etc.) are required to have Odor Impact Minimization Plans (OIMP) in place and have procedures that establish fence line odor detection thresholds. The Air District recognizes a Lead Agency's discretion under CEQA to use established odor detection thresholds as thresholds of significance for CEQA review for CalRecycle regulated facilities with an adopted OIMP.

7.2.3. Petroleum Refinery

Odors generated from materials and processes associated with petroleum refineries include, but are not limited to, H_2S, SO_2, mercaptan, ammonia (NH_3), and petroleum coke. Installing the following current and feasible odor mitigation measures for petroleum refineries should be considered.

1. Water Injections to Hydrocracking Process
2. Vapor recovery system
3. Injection of masking odorants into process streams
4. Flare meters and controls
5. Wastewater circulation technology for Aerated Ponds
6. Exhaust stack and vent location with respect to receptors
7. Thermal oxidizers
8. Carbon absorption
9. Biofiltration/Bio Trickling Filters

7.2.4. Chemical Plant

Chemical plants can generate a variety of different odors (e.g., acrylates, phenols, and styrene) as a result of process emissions. The range of odor mitigation measures required for chemical plants may vary substantially depending on the type of odors produced. The odor mitigation measures could be applied to chemical plants.

1. Wet scrubbers (50–90 percent efficiency)
2. Catalytic oxidation (99 percent efficiency)
3. Thermal oxidation (90–99 percent efficiency)
4. Carbon adsorption (95 percent efficiency)
5. Exhaust stack and vent location with respect to receptors

7.2.5. Food Services

Restaurants, especially fast food restaurants, can generate substantial sources of odors as a result of cooking processes and waste disposal. Char broilers, deep-fryers, and ovens tend to produce food odors that can be considered offensive to some people. The food waste produced by restaurants can putrefy if not properly managed, which can also produce objectionable odors. The follow mitigation measures are management practices and odor technology that can be used to reduce the amount odors generated by food services.

1. Integral grease filtration system or grease removal system
2. Baffle filters
3. Electrostatic precipitator
4. Water cooling/cleaning unit
5. Disposable pleated or bag filters

6. Activated carbon filters
7. Oxidizing pellet beds
8. Incineration
9. Catalytic conversion
10. Proper packaging and frequency of food waste disposal
11. Exhaust stack and vent location with respect to receptors

In conclusion, odor impacts can also be minimized, contained, or prevented by implementing technologies and design measures at the source, or through planning-based measures. Where odor sources and receptors cannot be physically separated to a degree where impacts would be minimized to less-than-significant level, disclosures of odor sources to prospective tenants of sensitive land uses should be used. Mitigation for odors that is both effective and feasible shall be selected on a case-by-case basis.

EXHIBIT 21

https://www.pressdemocrat.com/article/news/neighbors-file-federal-lawsuit-to-shut-down-sonoma-county-cannabis-grower/?sba=AAS

Neighbors file federal lawsuit to shut down Sonoma County cannabis grower

JULIE JOHNSON
THE PRESS DEMOCRAT
August 31, 2018

A group of Petaluma neighbors is suing a nearby cannabis grower in what may be the first case in California using a federal racketeering and corruption law to seek to bar cultivation of marijuana since it was legalized for recreational use.

Four families living on Herrerias Way east of Petaluma filed the suit this week in U.S. District Court in San Francisco. They claim the growers, including Carlos Zambrano and his partners in Green Earth Coffee, are raising cannabis without local permits or state licenses and have prevented residents from enjoying their homes because of noxious odors and noise.

Stefan Bokaie, who with his wife, Carol Bokaie, are plaintiffs in the case, said the group took legal action because they are frustrated that Sonoma County's code enforcement process has so far failed to stop cultivation from occurring in about 40 greenhouses erected this spring on the 15-acre property on Adobe Road near his home.

"If there's an illegal cannabis grow, it should be shut down; it's very simple," said Bokaie, who has lived on Herrerias Way for about three years.

Civil RICO case

The neighbors are using a little-known civil statute of the federal Racketeer-Influenced and Corrupt Organization Act, or RICO - passed in the 1970s to prosecute criminal organizations - to sue Zambrano and Green Earth, following a tactic used in Colorado, Oregon and Massachusetts by businesses and residents trying to rid their neighborhoods of cannabis activity in states that have legalized pot.

Zambrano was out of the country and unavailable for an interview this week, according to his attorney, Joe Rogoway.

Rogoway said Zambrano and his partners have been trying to conform their operations to local and state law and believed they were following guidelines provided to them by county officials for moving an existing cannabis-growing operation from a different Petaluma area property to the Adobe Road site.

"That cultivation was occurring only because the county told them they could do it there," Rogoway said. "It's fundamentally unfair."

Public records show Sonoma County has taken steps to halt cannabis production at the Adobe Road site since late May, when a code enforcement officer inspected the property. Zambrano is appealing the county's May 29 notice ordering the company to cease all cannabis activities on the land. A hearing on the issue is scheduled for this morning.

"The county's position is it is an illegal operation," said Tim Ricard, the county's cannabis program manager.

The other plaintiffs in the lawsuit are Surinder and Marie Uppal and their son, Gurjiwan Uppal; Brenda and Patrick Ward; and Neera and Sandeep Bhandari. All are residents of Herrerias Way, a short dead-end road on Petaluma's eastern outskirts surrounded by vineyards. They are seeking unspecified punitive damages and an injunction to halt any cannabis production taking place.

In addition to Green Earth, the lawsuit also names the property owner, a company called Flying Rooster, as well as Exchange Bank, which recorded a deed of trust for the property in 2015.

Gary Hartwick, president and CEO of Exchange Bank, said the bank no longer has any ties to the property, after a severance process begun several months ago when he learned there was marijuana cultivation occurring on the site. Hartwick said the claims against his bank have no merit.

"The unfortunate thing is a group of residents - who instead of searching for the actual information - are making very false statements with respect to Exchange Bank," Hartwick said. "They have never asked us the question, 'Do you finance growing operations?' We do not."

Zambrano and Green Earth began cultivating cannabis on the Adobe Road property sometime around April in about 40 hoop houses set up in the center of a vineyard, according to the lawsuit.

The neighbors claim in their lawsuit that the strong skunky smell of cannabis cloaked the neighborhood starting around that time. The stench created or exacerbated health problems, worsening Brenda Ward's asthma and making Carol Bokaie nauseous, among other reactions, according to the suit. The neighbors claim they must keep their windows closed and homes sealed up to avoid the stench, and they and their children have stopped spending time outside.

Most significantly, the Uppals claim the stench of cannabis has caused significant breathing problems for their son, Gurjiwan, who is a paraplegic and relies on a breathing tube.

"Family members must remain near Gurjiwan at all times to guard against the risk of suffocation," according to the complaint.

Their Napa-based attorney, Kevin Block, said they are not against marijuana's legalization but they do wish to be protected from the impacts of illegal cultivation. Block said Sonoma County has failed to do that.

"They're seeking an injunction shutting down the operation, and they're seeking damages to compensate for what they've lived with over these past few months and potentially for the diminished property value," Block said.

Navigating regulations

The federal lawsuit has the potential to put a further chill on Sonoma County's cannabis industry, which has struggled to take hold under what many in the industry have described as overly burdensome regulations that favor well-financed businesses over smaller local operators.

Alexa Wall, board chairwoman of the Sonoma County Growers Alliance, said Zambrano and Green Earth are not members of the local cannabis industry advocacy group, primarily made up of local growers. County records filed by Green Earth stated the group first began cultivation in March 2017 at a property on Moro Street outside Petaluma.

Local cannabis industry attorney Omar Figureoa, who has no connection to Zambrano or his businesses, said that it appears the growers were not following county rules, but he said it was troublesome that the lawsuit was going forward even as the county was taking measures to shut their farm down.

"It's not like this is a good actor who is being targeted unfairly," Figureoa said. "My take on it is the neighbors got exasperated because they don't think the county is doing anything. But the county is just following due process."

Lawyer blames county

Rogoway said his clients have been transparent with the county in their attempt to legitimize operations, submitting permits for the Moro Street location, then moving to Adobe Road after learning it was too close to an existing drug rehabilitation facility.

Rogoway called Sonoma County's marijuana regulations "illusory" and said the county's rules are entrapping cultivators "into a sphere of illegality" by giving false promises to clients like his "who are trying to do nothing other than be a lawful cultivator." Green Earth has spent more than $400,000 on permitting fees and consultants to get its paperwork in order, he said.

Sonoma County agricultural officials have approved 18 cultivators to operate small-scale, outdoor farms since it began accepting applications for cannabis businesses in July 2017, according to Ricard. Larger projects, such as Green Earth's, must go through the planning department, which has not approved any outdoor cultivation projects.

"The county has failed to meet their end of this agreement," Rogoway said.

Peter Henning, an expert in white collar crime and civil RICO cases and a professor of law at Wayne State University in Michigan, said civil RICO cases are difficult to prove and many are dismissed early on. People or businesses can sue in federal civil court under the RICO act to seek financial compensation for impacts of a crime, but they must prove the defendant has been involved in a pattern of criminal activity, though it doesn't require a criminal conviction.

Among several hurdles, the plaintiffs must prove the illegal conduct has been continuing over time, and a general rule of thumb is that it must have been taking place for at least one year, Henning said. They will also have to prove the farm has diminished the value of their properties.

If they prevail, the plaintiffs can be awarded triple the amount they prove in damages in addition to attorney's fees.

“RICO is designed to be punitive - that’s the allure of RICO,” Henning said. “They’re looking for a big judgment, essentially to force the marijuana farmer out of business.”

Today, Rogoway will argue his client’s case at a code enforcement hearing at Sonoma County’s planning department. He said he believes they can show they followed the advice of Sonoma County staff, and that any missteps can be attributed to county failings.

Bokaie, one of the Herrerias Way plaintiffs, said he believes it is just a matter of time before Sonoma County itself is sued if it fails to more strongly enforce laws protecting residents and the environment from illegal actors in the newly legalized industry.

“I know cannabis is here to stay,” Bokaie said. “But we went through hell for three months.”

You can reach Staff Writer Julie Johnson at 707-521-5220 or julie.johnson@pressdemocrat.com. On Twitter @jjpressdem.

1348114.1

EXHIBIT 22

March 10, 2021

Dear Planning Commissioners,

I am writing in opposition to the proposed cannabis ordinance. Curiously, not much has been reported on this ordinance in the local press. I have had to do a bit of digging to find out anything at all, but now that facts are starting to surface, you need to put the brakes on this massive rule change.

Like many 'down-winders' our property has been subject to the intense and inescapable skunky smells generated by these grow operations, for many months on end. A neighbor 500 feet away had rows of (illegal) hoop houses on her land, and it was impossible to peacefully enjoy our property, where our family has owned our home for over 50 years. Sitting outside on a summer evening was impossible, and being inside was not much better.

These changes in the nature of Sonoma County's agriculture landscape are egregious for many reasons:

- the smell is intolerable, the terpenes are irritating and asthma-inducing
- the increased vehicular activity, dust and noise
- the increase incidence of crime associated with the operations, due to cash economy, etc.
- danger to wildlife and water via intensive fertilization, pesticides, rodenticides and other dangerous poisons. Organics can kill fish and birds, too…
- the razor wire, the intense lighting, the weaponization of the operations is ominous, dangerous and not good for our residents' well-being.
- These smelly operations will affect the wine industry, and interfere with tasting, an important part of the economy—several tasting rooms in Santa Barbara County have closed—we don't want this in SoCo.

The county is planted in 63,000 acres of grapes. This proposed ordinance is over-ambitious in allowing for up to 65,000+ acres of marijuana—where does the water come from? According to a *Mother Jones* article by Tom Philpott in 2014, the *Press Democrat* reported on three Mendocino operations of 30,000 plants each to gauge water usage. Philpott writes:

> "According to the ***Press Democrat***, researchers estimate each plant consumes 6 gallons of water a day. At that rate, the plants were siphoning off 180,000 gallons of water per day in each [30K plant] watershed—all together more than 160 Olympic-sized swimming pools over the average 150-day growing cycle for outdoor plants." And that was just a fraction of the grow operations.

In my rural neighborhood, a nearby new vineyard began pumping ground water from a shared aquifer—and in the next couple of years, most of the wells in our neighborhood went dry—the water table had dropped from 150' to nearly 1000' below ground. If all of these new thirsty cannabis farms are allowed to proliferate, the aquifers will be sucked dry. We are in a semi-permanent state of drought as it is.

These specifics of the proposal are especially troublesome:

- Allowing unbridled marijuana development and inevitable traffic on our narrow rural roads, especially in fire-prone areas of the county
- Issuing permits without public knowledge or participation.
- Removing the health, safety, and nuisance protections so neighbors have no recourse when subjected to noise, traffic and stench.
- Allowing greenhouses that resemble self-storage units and white hoop houses to blight our scenic vistas
- Retaining inadequate setbacks from neighboring properties

The county should analyze all of the environmental impacts of the proposal as required by the California Environmental Quality Act. It is obvious that adding 65,733 acres of outdoor cultivation and over 8,000 acres of greenhouses would have enormous effects on our beautiful landscapes, air quality (odor), rural roads and noise levels.
Reject this ordinance.

Respectfully,

Laura C. Gralapp

Santa Rosa

March 12, 2021

Dear Planning Commissioners,

I live in one of Sonoma County's 5 impaired watersheds, in Mill Creek, a heavily forested area with redwoods, madrones, firs and tan oaks as the dominant species. I have a number of serious concerns about the Cannabis ordinance proposal under consideration:

Odor: Several years ago there was an illegal cannabis cultivation site over 1 mile from my house. During the summer and fall months whenever I stepped outside, I was overwhelmed by a strong cannabis odor emanating from this site. I spend most of my day every day gardening outdoors and had, at that time, over 500 lavender plants in bloom but the only thing I could smell was the skunk-like odor of cannabis. What are the PROVEN methods for insuring that no odor will be detected off-site of the cannabis cultivation site? Are there any? What does odor mitigation mean? At what measurable level is an odor considered mitigated?

Security Risks: It has been stated by supporters of cannabis cultivation that "Cannabis is just another agricultural crop". What other agricultural crop requires armed guards? The security risks to residents should be given utmost consideration: in emergency situations the response time from the Sheriff's Dept. can be an hour or longer. Do the perceived potential benefits of cannabis cultivation in this remote area outweigh the risks to residents' security?

Fire Concerns: Mill Creek is a designated Extreme Fire Danger area and was severely impacted by the Walbridge Fire in 2020. Many of the roads in the Mill Creek community, including the primary road, Mill Creek Road, are dead-end roads with sections that are one lane only and as such, insufficiently wide to allow incoming and outgoing vehicles to drive simultaneously. Obviously this situation could have disastrous results in the event of a fire. Do the perceived potential benefits of cannabis cultivation in this remote area outweigh the increased fire risks?

Water Concerns: Mill Creek is one of the 5 impaired watersheds. We are currently experiencing a severe drought and water levels in our creeks are extremely low. Given this fact, what would be the benefits to the county in allowing a high water usage crop in an area of such extreme water stress? Do the perceived potential benefits of cannabis cultivation in this remote area outweigh the increased water stress impacts?

I participated in 2 of the zoom sessions on this subject and found it notable that the moderators and other county representatives repeatedly asked for suggestions and reports on cannabis cultivation in other locations outside of Sonoma County. What research was conducted by those who drafted this proposed ordinance? What were their sources? Were they relying heavily on the pro-cannabis lobby and stakeholders? Did they conduct their own independent research? Were the potential risks and benefits to the entire population of

Sonoma County taken into consideration? I think these questions need to be asked and thoroughly answered.

Sincerely,
Joan Conway
joanc358@gmail.com

Gmail

Grace Barresi <gmbarresi@gmail.com>

Cannabis ordinance

1 message

Pam Ress <pamress@aol.com>
To: cannabis@sonoma-county.org

Sun, Mar 14, 2021 at 1:22 PM

Dear Planning Commissioners,

Thank you for the opportunity to comment on the proposed revisions to the Cannabis Ordinance. I read through the revised Chapter 26, the new Chapter 38, and the SMND and was both alarmed by the changes that favor the cannabis industry and disappointed by the fact that our repeated complaints about inadequate setbacks and odor have fallen on deaf ears. I also found it challenging to read through all of the documents to understand what the County was actually recommending because there were inconsistencies throughout the documents.

As a long term resident of Sonoma County who has lived in my current home in Sebastopol since 1998, I care about the revisions to the Cannabis Ordinance. It has been three years since an unpermitted cannabis business with both indoor and outdoor cultivation sites popped up overnight in my neighborhood. To be more specific, the 1 acre outdoor cultivation site is 630 feet from my kitchen and the indoor cultivation sites are even closer. This cannabis business is part of the Penalty Relief Program and has not had a Permit Hearing to date. The pungent odor overwhelms my home year round and has adversely impacted my family and our ability to enjoy our property.

I have previously engaged the County to educate them on the impacts of cannabis odor. Lynda Hopkins has been out to my home and walked my yard in 2018. I also attended a special study session with the Board of Supervisors in April 2018, where the Board promised residents that they would do more to protect rural residents in Phase 2 of the Cannabis Ordinance. Each supervisor gave compelling reasons about improving neighborhood compatibility at the end of the session that gave me hope. Supervisor Gore explained his concern when a cannabis business popped up 200 feet from his home. He said, *"I turned in a grow that was 200 feet from my house".* Supervisor Gorin said ", *"Move the cultivation away from impacting residential neighborhoods." And, Supervisor Hopkins said, "We really need to focus on the impacts of cannabis cultivation."*

And, here we are, three years later, and the revisions to the ordinance do nothing to protect neighbors and improve neighborhood compatibility. If Supervisor Gore was unhappy with a cannabis business 200 feet from his home, how is a 100 foot setback to the property line adequate? How can he support such inadequate setbacks given his own personal experience?

Please address the concerns of rural residents and increase setbacks to match those for schools and other sensitive areas.

Thank you,
Pam Ress
Anita Lane

Sent from my iPad

Commercial Cannabis Ordinance Feedback

March 14, 2021

This response is from the owners, Greg & Caroline Koss, at 1096 Ferguson Rd, Sebastopol. We want to make sure the Planning Commission and BOS hears our concerns about cannabis farming in our neighborhood and the greater Sonoma County.

We have direct experience due to the fact we are the northern neighbor to the Misty Mountain cannabis operation at 885 Montgomery St, Sebastopol.

The items of concern are;

- Odor – The cannabis crop has a significantly more pungent odor than other crop grown in Sonoma County. The odor occurs during growing, harvesting, drying, and processing of the crop. Thus the local community experiences high levels of odor for multiple months every year.

  We support the standard for distance with regard to schools and other sensitive areas. We fail to understand why populations of children and adult in schools, daycare facilities, parks, or bikeways, must be protected while the same children and adults in their homes next to a cannabis grow are exempt from these protections.

- Suggestion for Setbacks & Odor Mitigation:
  - Apply the same setbacks for sensitive areas to any residential parcel or facility.
    - This will also reduce the impact of odor due to increased dispersion in the atmosphere
  - Require enclosures with negative pressure and filtration for all grows adjacent to residential structures and parcels.

- Water – Cannabis grown in soil, which comprises the vast majority of cannabis operations in Sonoma County, will require a significant increase in water usage. Or six times the water required for grape growing in the same amount of land.
  Napa County published this finding in their document here;
  https://global-uploads.webflow.com/60256d2c98afa77e5f0e7f39/60354d3303969a072d72af3a_9111_Report_082019.pdf

  This is the pertinent finding under Environmental Impacts on page 20 of the document at the above link;

  A review of a number of studies and articles regarding water usage for cannabis cultivation suggests that it takes around 250 gallons of water to produce one pound of dried cannabis flower. For our cannabis productivity projections, we commonly assume that it takes 10 square feet of canopy to produce one dried pound of cannabis outdoors. By this measure, one acre (43,560 square feet) of cannabis plants should yield around 4,356 pounds of dried flower. Applying the figure of 250 gallons of water per pound, the total water consumption for an acre of cannabis production would be around 1,100,000 gallons per year, or 3.38 acre-feet per year (AFY). By comparison, one acre of vineyard irrigation uses 0.2 to 0.5 AFY per acre (65,170 to 162,295 gallons), and primary residences use 0.5 to 0.75 AFY.

  The Biden administration via US Dept. of Commerce, NOAA, National Marine Fisheries Service is also concerned about the increased water impact on Coho Salmon, Steelhead, Chinook Salmon, and the negative impact to these fish populations in Sonoma County. The letter can be read here;
  https://global-uploads.webflow.com/60256d2c98afa77e5f0e7f39/6042ab6884622c45856fcd7b_20210226%20NMFS%20Letter%20re%20cannabis%20cultivation%20in%20Sonoma%20County.pdf

- Suggestion for Water Impact:
    - Require a water assessment prior to issuing a permit to ensure the local water supply can handle the increased usage from cannabis grows.
    - If a grow is hydroponic this requirement is unnecessary.

- Crime – This is a concern because the number of murders and assorted violent crimes in the county has increased at rate higher than expected relative to the population growth in the county. Further, cannabis operations must have a lot of cash around because they cannot use the regular banking system and payment card networks, making them a well known and popular target for criminals.

- Suggestion To Mitigate Crime From Cannabis Operations:
    - Open a county bank to allow cannabis operations to participate in the financial system and remove the cash inventories in every step of the cannabis value chain. This has been accomplished in CO with ~30 banking institutions supporting the CO cannabis industry; https://www.coloradobankers.org/page/60
    - Require every cannabis operation to post signage so everyone knows where they are located just like the wineries. This mitigates the crimes against people with no connection to cannabis but are harmed by malicious actors that can't find the cannabis operation.

      https://www.pressdemocrat.com/article/news/press-democrat-poll-finds-sharp-division-in-sonoma-county-over-cannabis-cul/
      A poll of 500 registered voters in the county said; *A substantial plurality, 46 percent, of poll respondents said they "would not feel safe with a cannabis farm within any proximity to my residence," while only 19 percent said they would feel safe with a farm adjacent to their residence.*

      Almost one-third of respondents, 31 percent, said they would feel safe with such a garden "not adjacent but within one mile of my residence."

      FBI violent crime statistics in Sonoma County for 2015-2018;
        - The Sonoma CA crime rate for 2018 was 393.81 per 100,000 population, a 41.26% increase from 2017.
        - The Sonoma CA crime rate for 2017 was 278.78 per 100,000 population, a 16.27% decline from 2016.
        - The Sonoma CA crime rate for 2016 was 332.94 per 100,000 population, a 15.56% increase from 2015.

Please make Sonoma County a better environment to operate cannabis businesses without negatively impacting the residents that also treasure being able to live, work, and raise their children in such a special place.

Respectfully,

~s~ ~s~

Gregory Koss Caroline Koss

From: Bob <bobwvi@yahoo.com>
Date: March 13, 2021 at 2:48:25 PM PST
To: Cannabis@sonoma-county.org
Subject: Cannibus application for 885 Montgomery Road, Sebastopol

As the nearest next door neighbor to the area of the outdoor grow at 885 Montgomery Road in Sebastopol that Sonoma County has allowed to continue, I have suffered with the unmitigated smell of cannabis inside my home for several years.
I understand that Mr Bell has mitigated the smell at his other sites by enclosing the grow and filtering the air, but though he seems willing to do it here, the county is not allowing him to do so at 885 Montgomery Road.
As county officials you have a responsibility to protect the citizens of the county.
Either dis-allow the grow, or mitigate the smell! Don't just run over us citizens
with bureaucratic excuses.
None of you would like the smell pumped into your homes, would you?

Bob Hirsch
1055 Montgomery Rd
Sebastopol

March 12, 2021

To: Sonoma County Planning Commission

Subject: Proposed Cannabis Ordinance

I wish you to know that we strongly object to the proposed cannabis ordinance and the supplemental mitigated negative declaration. Reasons for our objection are outlined below:

1. **Safety** - we live on Matanzas Creek Lane. Our private road is about 1.5 miles long, paid for and maintained by the residents who live Matanzas Creek Lane. The lane is about 11 feet wide at its widest. There are only a few turn-outs allowing for car to pass. This is <u>not</u> a lane that can safely allow for steady traffic, let alone commercial traffic.

   Based on a Sonoma County estimate for traffic in its 2016 (Mitigated Negative Declaration, p. 44) used these metrics: A one-acre cultivation site or a 0.25-acre indoor operation can each require 12-15 employees during peak periods. <u>Fifteen employees average 30 to 60 trips a day.</u>

   There are at least 60 acres of land on Matanzas Creek Lane that could qualify for outdoor cannabis cultivation. These acres could employ 720 (60 X 12) people, and generate between 1,440 (60 X 24) and (60 X 48) 2,880 trips per day. Indoor cultivation would result in even more traffic!

   COMMON SENSE ALONE DICTATES TOTAL IMPRACTICALLY

2. **Public Safety** - Matanzas Creek Lane intersects Bennett Valley Road at a dangerous curve - a site of many serious auto accidents. Traffic safety studies and road improvements needed must accompany increases in traffic and the County must foot the bill for road improvements to assure public safety
3. **Fire Safety** - the narrow roads in the County, like Matanzas Creek Lane must have access for fire trucks to get in and out when fires occur. It is a matter of life and death. The Planning Commission members will have to accept personal liability for preventable deaths resulting from decisions

compromising fire and public safety. An 11 foot wide, dead-end road will not accommodate fire safety - another COMMON SENSE consideration.

4. **Stench** - Cannabis creates a stench equivalent to pig manure. Even a relatively small growth has a horrible smell. There needs to be an environmental consideration and limit set to the amount of cannabis organically generated smell permitted in a given acreage
5. **Environmental Impact** - There needs to be an environmental impact study conducted throughout the County to determine cannabis water consumption relative to existing demands on the water basin and to determine waste production elimination - when will such a study be completed and publicized.
6. **Personal & Family Safety** - Cannabis and its cultivation is known to bring with it a increase in serious crime. Our family of children and grandchildren are frequently at our Matanzas Creek Lane property. We are greatly concerned for their safety. If the increased traffic, fire and public safety concerns are not enough, I bring to you the great concern for personal and family safety.

With the above points, we wish to make known to the Planning Commission reasons for our rejection of the proposed cannabis ordinance.

Sincerely,

Bill Burns
Sherilyn Burns

Bill Burns & Sherilyn Burns
3763 Matanzas Creek Lane
Santa Rosa, CA 95404

March 14, 2021

SUBMITTED VIA E-MAIL

McCall Miller
Sonoma County Planning Commission
Cannabis Program, County Administrator's Office
575 Administrative Drive, Suite 104A
Santa Rosa
California, 95403
Cannabis@sonoma-county.org

Re: Comment on proposed modification of cannabis ordinance, No. 6245, and General Plan update.

Dear McCall Miller,

Thank you for the opportunity to comment on the proposed ordinance and general plan modifications for cannabis. At the outset, we would like to make clear that this letter does not dispute the utility or value of cannabis – within reason, cannabis farmers should be allowed to grow their crops. However, the new cannabis commercialization laws cannot be to the detriment of existing homeowners in Sonoma County (Sonoma). Phase 2 of the ordinance modification was to be a "thorough" review of neighborhood compatibility issues,[1] and Sonoma has abdicated its duty to listen to, and protect, its residents. This comment letter will specifically address:

- Sonoma's failure to prepare an Environmental Impact Report (EIR) under the California Environmental Quality Act (CEQA),
- Sonoma's failure to adequately mitigate odor and air quality concerns,
- Sonoma's failure to account for the serious water use concerns related to cannabis growing in California,
- Sonoma's failure to maintain proper fire safe road regulations, and
- The classification of cannabis as an agricultural crop.

I. Sonoma should have prepared an EIR.

Proper CEQA review is of vital importance – both to address environmental impacts and also to facilitate a flow of information between government officials and the public.[2] A full EIR provides a framework through which to analyze the other issues contained in this letter,[3] and increases public trust in the democratic process.[4] Sonoma's failure to follow proper CEQA process

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[1] County of Sonoma, *Sonoma County Cannabis*, https://sonomacounty.ca.gov/Cannabis/Legislative-Updates/County-Ordinances/ (last visited March 14, 2021).

[2] Cal. Pub. Res. Code § 21000.

[3] *See id.* § 21002.1.

[4] *Laurel Heights Improvement Assn. v. Regents of Univ. of Cal.*, 47 Cal. 3d 376, 392 (1988), as modified on denial of reh'g (Jan. 26, 1989) (The EIR is also intended "to demonstrate to an apprehensive citizenry that the agency has, in fact, analyzed and considered the ecological implications of its action").

has fostered distrust in its motivations at pushing through an inadequately analyzed ordinance and placed the county's air and water quality in peril.

CEQA is "to be interpreted in such manner as to afford the fullest possible protection to the environment within the reasonable scope of the statutory language."[5] The threshold to requiring an EIR is "low," and any ambiguity should be resolved in favor of environmental review.[6] CEQA review only ends at the mitigated negative declaration step when potentially significant environmental effects can be fully mitigated by changes in the project and the project applicant agrees to incorporate those changes.[7]

Sonoma has not afforded our air and water the fullest possible protections that CEQA requires. By prematurely ending environmental review at the mitigated negative declaration stage, Sonoma has failed to analyze several potentially significant impacts and has offered inadequate mitigations.

The impacts of the proposed ordinance modification are huge. Sonoma is proposing to increase the amount of land available for cannabis farming from 50 acres to approximately 65,000 acres, *a 1300 factor increase.* For reference, that acreage exceeds the total acreage of vineyards in Sonoma.[8] Sonoma has rightly conceded that there will be impacts on various parts of the environment, notably our air and water – but its conclusion that the vast acreage of new cannabis grows can be mitigated so well that the impacts will not be significant is not supported by substantial evidence. Some of the most prominent problems are discussed below in sections II-IV.

Sonoma's decision not to prepare an EIR is at odds to other counties in California. For example, Yolo County prepared an EIR when enacting a cannabis land use ordinance.[9] Humboldt County and Trinity County have also recently prepared EIRs for commercial cannabis laws.[10]

In Yolo County, far less acreage was at stake for cannabis grows, but the county nevertheless responded fairly and capably to community concerns with a comprehensive 700-page EIR.[11] In contrast, Sonoma's reaction to public input has been sadly lacking – very few of the reasonable suggestions of the public have been incorporated in the final draft ordinance – and the Planning Commission has attempted to evade full environmental review of its actions.

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[5] *Id.* at 390.

[6] *Save the Agoura Cornell Knoll v. City of Agoura Hills*, 46 Cal. App. 5th 665, 676 (2020), *reh'g denied* (Apr. 10, 2020), *review denied* (June 24, 2020).

[7] *Id.* at 1186-87.

[8] *See* Bill Swindell, *North Coast vineyard acreage increases slightly in 2018*, The North Bay Business Journal (2018), https://www.northbaybusinessjournal.com/article/industry-news/north-coast-vineyard-acreage-increases-slightly-in-2018/ (figures from 2018).

[9] Yolo County, *Draft Environmental Impact Report on the Proposed Cannabis Land Use Ordinance for Yolo County* (2019), available at https://www.yolocounty.org/government/general-government-departments/community-services/cannabis/cannabis-land-use-ordinance (Yolo EIR).

[10] Humboldt County, *Amendments to Humboldt County Code Regulating Commercial Cannabis Activities* (2018), available at https://humboldtgov.org/DocumentCenter/View/62689/Humboldt-County-Cannabis-Program-Final-EIR-60mb-PDF; Trinity County, *Cannabis Program Final Environmental Impact Report* (2020), available at https://www.trinitycounty.org/node/2609.

[11] Yolo EIR.

Sonoma should follow the precedent set by other counties, err on the side of environmental caution and public inclusion, and prepare an EIR. We urge Sonoma to reconsider its decision to prematurely stop CEQA at the negative declaration phase.

II. Sonoma's anemic mitigation strategies will not alleviate the threat to air quality.

Toxic air quality is the number one environmental issue that needed to be addressed in Phase 2 of the cannabis ordinance modification. It is primarily a health issue, as well as an aesthetic issue, and the proposed setbacks do nothing to mitigate either concern.

Cannabis plants emit potent volatile organic compounds (VOCs) in the form of terpenes. Each plant emits roughly 2.6g per day of VOCs into our air. The VOCs emitted by commercial cannabis operations are not insignificant or innocuous – they are measurable and form a toxic cloud that travels well over a thousand feet then sits stagnant in the air causing serious health problems to those living within its grip. Humboldt County's recent EIR stated that despite efforts to mitigate odor from cannabis operations, the impact on the environment would nevertheless be **significant and unavoidable**.[12] There is no reason to believe Sonoma cannabis will be any less potent than in Humboldt – in fact the effects will likely be worse given the proposed scale of cannabis growing in the county.

A. Cannabis farm emissions lead to serious health concerns.

The residents of Herrerias Way experienced the effects of commercial cannabis grows firsthand in the summer and fall of 2018 when Sonoma allowed two illegal grow operations to spring up in an adjacent lot and harvest crops. All four households on Herrerias Way were severely affected by the VOCs that blew directly into our homes for four months.

The impact on our health was enormous. One resident, a disabled young man with severely limited physical movement could not leave his home without having his lungs pumped. To reiterate: without having his lungs pumped. A second neighbor's asthma condition was exacerbated and they had to seek additional medical treatment. A third resident, who had never previously suffered any respiratory condition had to seek urgent care for burning chest pain, and was diagnosed with lung irritation from the air. They also experienced a constant nausea from the potent cannabis fumes. These medical issues occurred after only a few months of exposure to cannabis fumes from a one-acre grow.

Since Sonoma turned a blind eye to the illegal grows, the Herrerias Way Coalition sued under private nuisance laws and shut down both operations. The medical issues detailed above have since resolved with the elimination of the cannabis grows.

B. Sonoma's setback proposals are wholly inadequate.

Sonoma now countenances expanding the size of outdoor cultivation parcels from one acre – the size that led to the severe health problems described above – to either ten acres or 10% of the size of the parcel. The anemic setback requirements intended to mitigate air quality concerns do not provide adequate protection from the toxic air quality created by cannabis grows.

Commercial growth of cannabis at 300 feet setback from a residence is not founded in any scientific basis and does not provide protection. A 1000-foot setback from the property line of residences is a well-documented and scientifically backed solution to odor control and toxic air

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[12] Humboldt EIR at 1-3.

quality concerns. Sonoma's continued adherence to setbacks measured from residences instead of property line is a slap in the face to both science and the health of Sonoma residents. Furthermore, such setbacks are outrageous given that many people now work from home and children are schooled at home. People are in their homes 24 hours a day – private residents in that situation would be exposed longer than children in schools who are afforded a 1000-foot setback from the school's property line, and children would be safer at school than in their own homes.

By ignoring public concern at the inadequacy of the proposed setbacks and failing to expand them to a scientifically-backed safe distance from the property line, Sonoma has failed to discharge its duty to protect the health, safety, and welfare of the county's residents. Sonoma must reconsider setback requirements.

C. Sonoma's other mitigation suggestions fail to address odor and air quality concerns.

To be effective, a mitigation proposal must mitigate effects "to a point where clearly no significant effect on the environment would occur" as well as ensuring "there is no substantial evidence in light of the whole record before the public agency that the project, as revised, may have a significant effect on the environment."[13]

Here, it is far from clear that the mitigation effects will alleviate the environmental impacts to a point where they are clearly not insignificant. For example, Sonoma contends in its mitigated declaration that odor and air quality concerns are partially mitigated by the fact that odors are strongest in the two months prior to harvest.[14] This is incorrect and furthermore does nothing to mitigate the odors during those two months. There clearly will be impact during the two months prior to harvest even under Sonoma's blasé assertions. As discussed above, even two months of strong odor and VOCs are enough to cause severe health problems for neighbors. Moreover, some operations have a two harvest per year schedule.

Additionally, Sonoma asserts vegetative screening will mitigate odors.[15] There is not evidence that this approach will effectively block odors from travelling beyond the cannabis operation's boundaries. Vegetation is impermanent and porous, and is easily destroyed by wind or wildfire. Furthermore, wind can blow odors beyond the vegetative screen.

Finally, Sonoma concedes that there are cases where residents will be affected but requires the odor to impact "several" people before it will investigate.[16] Even then, the mitigation measure only provides that Sonoma will require Vapor-Phase Systems (Fog Systems) to neutralize the odor. The problem with this approach is firstly Fog Systems are not designed for large-scale outdoor grows. Second, only the odor will be neutralized, not the VOCs themselves, and the odor-neutralizing chemical will remain in the air as well, which is a potential hazard to public health. Third, if Sonoma realizes there are likely going to be impacts from odors, it should require odor neutralizing technology as standard. Finally, coupled with the potential that cannabis farming will be protected under Right to Farm laws because of the General Plan update, which would shield cannabis operations from nuisance suits, residents will be left with little to no recourse to protect

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[13] Cal. Pub. Res. Code § 21064.5.

[14] Negative Declaration at 34.

[15] *Id.*

[16] Negative Declaration at 35. Of additional concern is the fact that this process involves discretionary action from Sonoma. There is no definition of "verified complaint," "objectional smell," or "several" people. This discretionary investigation is impermissible under the ministerial system Sonoma envisages.

themselves should Sonoma not find the odors are affecting several people. They would have to stand idly by as their health deteriorated and their property value plummeted.

Sonoma's mitigation policies are completely inadequate for the scale of cannabis farming that will take place following this ordinance update. The mitigation measures would only have a chance of success in conjunction with proper setback requirements – only physical distance mitigates cannabis fumes. To better understand the effects of odor and VOCs on human health and to effectively mitigate those dangers, Sonoma should have completed thorough environmental review under CEQA. Furthermore, Sonoma should explicitly state that cannabis farming will never be protected under Right to Farm laws, or any other laws, from individuals bringing private action to abate nuisance.

III. Water use on cannabis crops is a significant environmental impact.

Cannabis grows require vast quantities of water to operate.[17] One cannabis plant requires at least 6 times the water of one grape plant.[18] To compare again to Sonoma's wine industry – Sonoma could expand to 6 times as many vineyards as it currently has for the same water cost as the present ordinance affords cannabis. This is highly worrying given that California is prone to severe droughts. Humboldt County found that water demand for cannabis operations created a **significant and unavoidable impact** on public water utilities.[19]

Of further concern is the provision of emergency water when there is a local, state, or federally declared disaster.[20] This may take water away from much needed communities and Sonoma has provided no analysis of the impacts it would case to residents and the environment. Again, only a full EIR will disclose to the public the environmental impacts to water distribution and water quality, and allow county officials to make the least environmentally damaging choice.

IV. Sonoma must ensure fire road regulations are followed.

Sonoma is at high risk of wildfires, and has seen devastating blazes decimate large areas of the county in recent years. Adding 65,000 acres of a combustible crop, which is frequently surrounded by a high quantity of electrical equipment including generators, lighting, and air purifying systems, is a recipe for disaster. Adding to that, Sonoma has not ensured that existing fire road regulations will be followed.

…

V. Cannabis is not an agricultural crop and should not be given protection under Right to Farm Laws.

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[17] Negative Declaration at 94 (Cannabis cultivation "has been characterized as a high-water-demand activity").

[18] Alexander Nieves & Debra Kahn, *Wine vs. Weed in Napa Valley*, Politico (Feb 18, 2020), available at https://www.politico.com/news/2020/02/18/wine-vs-weed-in-napa-valley-115322 (citing Napa County report).

[19] Humboldt EIR at 1-4.

[20] Negative Declaration at 95.

Sonoma seeks to designate cannabis as an agricultural crop in its General Plan update. However, this fails to take into account the marked differences between cannabis and other crops. Cannabis requires constant security, including full fencing to keep people out. Its high value attracts crime, and its potent odor creates a nuisance for residents living in the area. Cannabis is also still, federally, a Controlled Substance, which can have harmful effects if abused, especially in teenagers. We strongly urge Sonoma to resist reclassifying cannabis as an agricultural crop.

If Sonoma proceeds with this redefinition, it must ensure that the many legal exemptions agricultural crops enjoy are not applied carte blanche to cannabis. First and foremost, Sonoma must make explicitly clear that the redefinition does not mean cannabis operations will ever be protected under Right to Farm laws. Sonoma residents must continue to be able to file nuisance suits to protect themselves from cannabis operations adjacent to their homes, to protect their health and property value. It is not acceptable to strip that option from private citizens and insulate the cannabis business from liability.

Second, Sonoma must make clear that it cannot in the future use the agriculture label in order to relax setback requirements or expand the cannabis industry beyond what the current definition allows. Enforceable, scientifically backed setback requirements must be in place before cannabis is reclassified, and must remain in place afterwards.

VI. Conclusion

Sonoma has not discharged its duty to protect the health, safety, and welfare of the residents of the County. To ensure that the public's voice is heard, and all environmental impacts are properly disclosed, Sonoma must restart its CEQA analysis and complete a comprehensive EIR. In the EIR Sonoma should reconsider its mitigation strategies for air quality, water quality, and fire safety, because the current plan is inadequate. This should include 1000-foot setbacks measured from the property line of residences, not from homes themselves. Failure to produce an EIR will put Sonoma residents' health in danger and jeopardize property values across the county.

Sonoma should also reconsider its rationale for classifying cannabis as an agricultural crop. If this proposal proceeds, at the very least Sonoma must ensure that residents can still bring private claims to abate the nuisance caused by cannabis odors.

To: Sonoma County Planning Commission & Board of Supervisors

Comments on Draft Cannabis Ordinance Chapter 38, Chapter 26, Subsequent Mitigated Negative Declaration

March 18, 2021, Robert Guthrie
Neighbor to a 1-acre commercial cannabis cultivation business

Cannabis cultivation

should occur in appropriate places.

Not 100 feet from neighbors.

This document outlines how Sonoma County deliberately fails to address neighborhood compatibility through a false narrative about cannabis odor and odor mitigation.

Sonoma County's False Narrative About Cannabis Odor

Sonoma County maintains a comprehensive false story about cannabis odor and odor mitigation
to avoid setting effective cannabis cultivation setbacks in neighborhoods

For over three years, neighborhoods have complained to Sonoma County about the cannabis ordinance's inadequate setbacks to cannabis cultivation, and were promised that "neighborhood compatibility" would be addressed in this new proposed ordinance. It was not. In fact, Sonoma County introduced more ways to avoid addressing it, and still **claims cannabis odor has been mitigated.** The County's success in refusing to review and change setbacks to residential uses stems from their refusal to conduct program-level environment impact reviews (PEIR) or project-specific California Environmental Quality Act (CEQA) studies.

The proper studies would reveal data and facts that Sonoma County would rather not admit or share (let alone adequately evaluate) -- **setbacks of at least 1,000 feet from commercial cannabis cultivation significantly mitigates cannabis odor nuisance and health impacts.** However, Sonoma County maintains the position that 100-foot setbacks between thousands of outdoor cannabis plants and a neighbor's swing set, patio, BBQ, for example, are adequate.

Other jurisdictions have required research and acted upon the results.

Yolo County. The Planning Commissioners recently agreed with recommendations from Trinity Consultants to include 1,000-foot buffers of 1-acre cultivation for all identified sensitive uses, including residences in any zone. Yolo County hired Trinity Consultants (an environmental, health and safety agency) to conduct a comprehensive EIR, including odor analysis and modelling, after rural residents complained about inadequate setbacks and pungent odor from cannabis cultivation sites. All volumes of the Yolo County EIR are available online at the following Link

Napa County. Napa County commissioned an independent analysis about the impacts of an initiative to support commercial cannabis cultivation and concluded: *"Unlike the County's existing rules for personal cannabis cultivation, the Initiative does not address the potential issue of odors or other nuisances from cannabis cultivation and processing. According to the Community Character Element of the County's General Plan, although odors are to be expected in agricultural areas like rural Napa County, they should be minimized and "unacceptable odors" should be avoided. The potential for adverse impacts is particularly acute for lodging facilities, resorts, wineries, restaurants, and other commercial uses which are not subject to any setbacks in the Initiative. In addition, the proposed 500-foot setback from private residences and 1000-foot setback from certain schools may not suffice to avoid adverse odors and nuisance issues". Napa 9111 Study* Link

But not Sonoma County...

The False Narrative

Sonoma County chose a path not based on science or substantive evidence from technical experts or input from neighborhoods.

Sonoma County instead creates a false narrative about cannabis odor <u>and</u> mitigation to justify keeping the setbacks unchanged which promotes commercial cannabis cultivation close to residences.

Here's how they do it:

Step 1: Admit sensitive receptors are negatively impacted by cannabis odor:

1. "Cannabis cultivation sites could potentially generate odors that adversely affect a substantial number of people" (1)
2. "Cannabis projects would generate criteria air pollutants including NOx and particulate matter" (1)

Step 2: Use "Mitigation Measures" to form a false narrative about cannabis odor <u>and</u> odor mitigation, supported by the following themes:

1. Vegetation windbreaks and chemical-based vapor systems are expected to adequately mitigate outdoor cultivation odor in neighborhoods
2. Cannabis odor lasts for only a short time
3. Wind blows cannabis odor up into the atmosphere before the odor crosses the property line
4. Cannabis parcels are large which means not many people are impacted
5. Ag parcels are expected to emit odors

Mitigation Measures (like "AIR-3") are deliberately ambiguous without an enforcement criteria, so they're designed to 'never fail'.

Step 3: Use the Mitigating Measures to form a conclusion:

"With implementation of Mitigation Measure AIR-3, the impact of cannabis odors would be **reduced to a less than significant level**." (1)

Then Sonoma County says "Mitigated!" and approves a cannabis cultivation inside a neighborhood, and obstructs residents from filing complaints about the negative impacts of living near cannabis cultivation.

The remaining pages explain in detail how Sonoma County exercises these steps.

1 ORD20-0005 DRAFT SMND

Sonoma County's misleading theories of "vegetation windbreak" odor mitigation

"Windbreaks designed according to NRCS standards are considered
to be at a fully functional height at 20 years.
...**can be functioning within as little as 5-10 years**"(1)

Sonoma County hand-selected parts of different studies suitable to fabricate misleading conclusions about cannabis odor mitigation, and inserts them in their ordinance and cannabis permit reports. Below is actual text from Sonoma County's permits and/or the proposed 2021 ordinance updates.

1. "The buffer/windbreak strategy is most effective when parcels are large (at least 10 acres) and land uses are far apart, maximizing the distance for odor dissipation" (2)

    FALSE / NOT SCIENCE BASED: That is not stated in any of the studies the County used; the County fabricated it.

2. "Vegetative buffers **deflect** the odor plume above the vegetation layer, where the odor is then diffused **into the atmosphere**." (2)

    FALSE / NOT SCIENCE BASED: the studies did not investigate or measure odor ***deflection*** into the atmosphere; they studied and measured head-on odor ***absorption*** or diffusal.

3. "...landforms and vegetation provide buffers or windbreaks that can successfully reduce odors generated by agricultural activities including poultry and swine operations" (3)

    MISLEADING: This fallaciously tries to convince you that the windbreaks used in the studies also works with cannabis terpenes.

4. "The applicant proposes to install a hedgerow buffer/windbreak that **would serve** to disperse and deflect the odor molecules released by the outdoor mature plants upwards where they will more readily dissipate and be **carried into the atmosphere**" (4)

    MISLEADING: This conclusion is 100% speculation by Sonoma County.

5. "cannabis odors will be present during the hottest months of the year, when natural air convection is highest, further enhancing the odor management potential of **planted windbreaks to deflect air and odors upwards, above residences**, to be mixed with prevailing winds and diluted further away" (2)

    FALSE / NOT SCIENCE BASED: This absurd speculation by Sonoma County infers neighborhoods are not impacted by cannabis odor during the hottest (defined as when?) time of the year.

1 Illinois NRCS - Windbreaks and Odor Management, Oct 2007
2 Sonoma County ORD20-0005 Draft Subsequent Mitigated Negative Declaration (2/16/2021), p.34
Sonoma County UPC18-0001 Misty Mountain Services Summary Report, p.12
Sonoma County UPC18-0001 PROPOSED MITIGATED NEGATIVE DECLARATION / INITIAL STUDY, p.22
Sonoma County UPC17-0020-Attachment-8-Mitigated-Negative-Declaration-March-11-2019-amended-April-11-2019, p.22
3 Sonoma County UPC18-0001 Misty Mountain Services Summary Report p.12
Sonoma County UPC18-0001 PROPOSED MITIGATED NEGATIVE DECLARATION / INITIAL STUDY, p.22
Sonoma County UPC17-0020-Attachment-8-Mitigated-Negative-Declaration-March-11-2019-amended-April-11-2019, p.22
4 Sonoma County UPC18-0001 Misty Mountain Services Summary Report, p.12

Sonoma County's ambiguous, unenforceable implementation of their "vegetation windbreaks" theory

Sonoma County requires the cannabis business to create a **self-designed vegetation windbreak** to mitigate odor from impacting neighbors. They delegate the **entire design and implementation** to the cannabis businesses to build at their leisure.

Failure to provide requirements

Sonoma County fails to define a single requirement for the vegetation windbreak, such as:

1. Success metrics
2. Vegetation density and porosity requirements
3. Timeline to create and build the vegetation windbreaks
4. Maintenance requirements during the lifecycle should a section of the windbreak die-off or needs replacement
5. A design specification
6. A list of required species of trees known to absorb cannabis terpenes (if they exist)

Deliberately hiding the facts

Sonoma County plucks certain sentences from reports that help them justify their claims, but they deliberately hide these facts from those same reports:

1. The studies are about **absorption of ammonia**, not about an ability to deflect anything into the atmosphere[(1)]
2. The **windbreak absorbed only 46%** of the animal ammonia particles; 53% passed *through* the vegetation windbreak[(1)]
3. NRCS and others **researched indoor facilities** with directional exhaust fans, not an open-air cannabis field[(1)]
4. A **windbreak takes 20 years** to become fully functional[(2)]
5. A windbreak can be functioning within **as little as 5-10 years**[(2)]
6. The **windbreaks studied are on flat plains**, not in hills, valleys, and microclimates contained within Sonoma County[(1)(2)]
7. The amount of water required to grow a tall, thick vegetation windbreak around an acre of cannabis cultivation

1 USDA NRCS 2007
2 Illinois NRCS - Windbreaks and Odor Management, Oct 2007

Failure to enforce compliance

Sonoma County **cannot enforce** their vegetation windbreak ordinance clauses **because they don't supply any requirements** about it.

Sonoma County doesn't even know which tree and bush species might absorb cannabis odors, if any species actually exist. Sonoma County will permanently obstruct an impacted neighbor's rights to enjoy their property and the ability to legally file complaints about cannabis odor nuisance **while the vegetation windbreaks grow over the 5-20 years**.

The studies occurred on flat plains with massive hedges that look like this:

Illinois NRCS - Windbreaks and Odor Management

Illinois NRCS - Windbreaks and Odor Management

Not in hills or valleys like those in West County or many other parts of Sonoma County.

Vapor-Phase Systems -- another blocker to extending setbacks to residences

Vapor-Phase Systems throw chemicals into the air with the intent they bind to odor. These systems are specifically installed near exhaust ports on indoor/greenhouse cannabis structures, so Sonoma County ***guessed*** the system works for a sprawling open-air **outdoor** cannabis field.

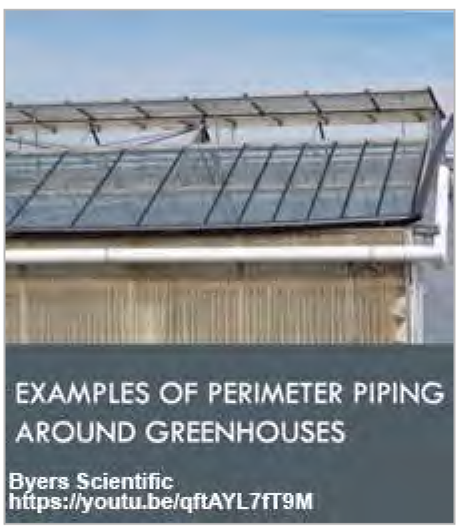
Sonoma County is now inserting guesses into their ordinance
to avoid extending the cannabis setbacks to neighbors.
Before it was ambiguity. Now it's guesses.

Sonoma County's Section AIR-3 (p35) states:

> "Permit Sonoma staff shall ...[determine] whether the outdoor cultivation operation is creating objectionable odors affecting **at least several [how many?]** people. If this is the case, Permit Sonoma staff shall require that the project go back to the Board of Zoning Adjustments **for review of additional measures to reduce outdoor odor generation**, including use of engineered solutions such as **Vapor-Phase Systems (Fog Systems)**."

Why not just extend setbacks to neighbors instead?

<u>**What does a Vapor-Phase System look like?**</u>

<table>
<tr>
<td>
</td>
<td>
</td>
<td>
</td>
</tr>
<tr>
<td>Vapor-Phase Systems are installed on structures.

Not installed throughout outdoor canopies where such vapors could risk landing on the cannabis plants.</td>
<td></td>
<td>1. Is this pump machine loud?
2. How many machines are needed?
3. What's the kWh consumption 24x7 to properly mitigate odor?</td>
</tr>
</table>

Vapor-Phase System is not an effective option for <u>outdoor</u> odor nuisance mitigation

Let's extend setbacks to neighbors' properties to at least 1,000 ft.

Sonoma County has decided *WHEN* cannabis odor occurs: only when it's strong

Sonoma County decided *<u>they</u>* define the period when cannabis odor is a nuisance for neighborhoods. By self-defining this as a "limited duration" once a year, Sonoma County attempts to claim cannabis odor doesn't classify as a public nuisance.

But in reality, because the setbacks are inadequate, **outdoor cannabis cultivation odor lasts from JUNE to NOVEMBER**, but Sonoma County refuses to accept this.

<u>Instead, Sonoma County presents a spectrum of opinions about odor, including:</u>

> "Outdoor cannabis cultivation generates the strongest odors in **September and October**, during the last [4] to [8] weeks of the growing season prior to harvest. This would restrict the timing of the **most adverse cannabis odors to no more than two months per year**." (1)
>
> "Cannabis plants start to emit odors generally starting **in early September and continuing until harvest in October**. Duration of smell would range from approximately 4-6 weeks (8-11%) of the year." (2)
>
> "Outdoor cannabis cultivation will typically start to emit odors about 3-5 weeks into the flowering period, generally starting in **August or September** and continuing until harvest in **October**." (2)

By deciding that cannabis odor incrementally reaches an arbitrary measurement of "**most adverse**" and for "**no more than two months of the year,**" Sonoma County attempts to self-justify keeping cannabis cultivation setbacks unchanged.
Sonoma County must acknowledge and treat cannabis odor nuisance per reality.

2018											
Jan 1	Feb 1	Mar 1	Apr 1	May 1	Jun 1	Jul 1	Aug 1	Sep 1	Oct 1	Nov 1	Dec 1
Jan 2	Feb 2	Mar 2	Apr 2	May 2	Jun 2	Jul 2	Aug 2	Sep 2	Oct 2	Nov 2	Dec 2
Jan 3	Feb 3	Mar 3	Apr 3	May 3	Jun 3	Jul 3	Aug 3	Sep 3	Oct 3	Nov 3	Dec 3
Jan 4	Feb 4	Mar 4	Apr 4	May 4	Jun 4	Jul 4	Aug 4	Sep 4	Oct 4	Nov 4	Dec 4
Jan 5	Feb 5	Mar 5	Apr 5	May 5	Jun 5	Jul 5	Aug 5	Sep 5	Oct 5	Nov 5	Dec 5
Jan 6	Feb 6	Mar 6	Apr 6	May 6	Jun 6	Jul 6	Aug 6	Sep 6	Oct 6	Nov 6	Dec 6
Jan 7	Feb 7	Mar 7	Apr 7	May 7	Jun 7	Jul 7	Aug 7	Sep 7	Oct 7	Nov 7	Dec 7
Jan 8	Feb 8	Mar 8	Apr 8	May 8	Jun 8	Jul 8	Aug 8	Sep 8	Oct 8	Nov 8	Dec 8
Jan 9	Feb 9	Mar 9	Apr 9	May 9	Jun 9	Jul 9	Aug 9	Sep 9	Oct 9	Nov 9	Dec 9
Jan 10	Feb 10	Mar 10	Apr 10	May 10	Jun 10	Jul 10	Aug 10	Sep 10	Oct 10	Nov 10	Dec 10
Jan 11	Feb 11	Mar 11	Apr 11	May 11	Jun 11	Jul 11	Aug 11	Sep 11	Oct 11	Nov 11	Dec 11
Jan 12	Feb 12	Mar 12	Apr 12	May 12	Jun 12	Jul 12	Aug 12	Sep 12	Oct 12	Nov 12	Dec 12
Jan 13	Feb 13	Mar 13	Apr 13	May 13	Jun 13	Jul 13	Aug 13	Sep 13	Oct 13	Nov 13	Dec 13
Jan 14	Feb 14	Mar 14	Apr 14	May 14	Jun 14	Jul 14	Aug 14	Sep 14	Oct 14	Nov 14	Dec 14
Jan 15	Feb 15	Mar 15	Apr 15	May 15	Jun 15	Jul 15	Aug 15	Sep 15	Oct 15	Nov 15	Dec 15
Jan 16	Feb 16	Mar 16	Apr 16	May 16	Jun 16	Jul 16	Aug 16	Sep 16	Oct 16	Nov 16	Dec 16
Jan 17	Feb 17	Mar 17	Apr 17	May 17	Jun 17	Jul 17	Aug 17	Sep 17	Oct 17	Nov 17	Dec 17
Jan 18	Feb 18	Mar 18	Apr 18	May 18	Jun 18	Jul 18	Aug 18	Sep 18	Oct 18	Nov 18	Dec 18
Jan 19	Feb 19	Mar 19	Apr 19	May 19	Jun 19	Jul 19	Aug 19	Sep 19	Oct 19	Nov 19	Dec 19
Jan 20	Feb 20	Mar 20	Apr 20	May 20	Jun 20	Jul 20	Aug 20	Sep 20	Oct 20	Nov 20	Dec 20
Jan 21	Feb 21	Mar 21	Apr 21	May 21	Jun 21	Jul 21	Aug 21	Sep 21	Oct 21	Nov 21	Dec 21
Jan 22	Feb 22	Mar 22	Apr 22	May 22	Jun 22	Jul 22	Aug 22	Sep 22	Oct 22	Nov 22	Dec 22
Jan 23	Feb 23	Mar 23	Apr 23	May 23	Jun 23	Jul 23	Aug 23	Sep 23	Oct 23	Nov 23	Dec 23
Jan 24	Feb 24	Mar 24	Apr 24	May 24	Jun 24	Jul 24	Aug 24	Sep 24	Oct 24	Nov 24	Dec 24
Jan 25	Feb 25	Mar 25	Apr 25	May 25	Jun 25	Jul 25	Aug 25	Sep 25	Oct 25	Nov 25	Dec 25
Jan 26	Feb 26	Mar 26	Apr 26	May 26	Jun 26	Jul 26	Aug 26	Sep 26	Oct 26	Nov 26	Dec 26
Jan 27	Feb 27	Mar 27	Apr 27	May 27	Jun 27	Jul 27	Aug 27	Sep 27	Oct 27	Nov 27	Dec 27
Jan 28	Feb 28	Mar 28	Apr 28	May 28	Jun 28	Jul 28	Aug 28	Sep 28	Oct 28	Nov 28	Dec 28
Jan 29		Mar 29	Apr 29	May 29	Jun 29	Jul 29	Aug 29	Sep 29	Oct 29	Nov 29	Dec 29
Jan 30		Mar 30	Apr 30	May 30	Jun 30	Jul 30	Aug 30	Sep 30	Oct 30	Nov 30	Dec 30
Jan 31		Mar 31		May 31		Jul 31	Aug 31		Oct 31		Dec 31

<u>Reality</u>

When cannabis odor is a nuisance

Red:
Days we experienced odor nuisance from our neighbor's commercial cannabis business.

Gray:
The Camp Fire blanketed our neighborhood with fire smoke from Nov 8-19, so we couldn't detect cannabis odor. But cannabis odor reappeared once the smoke subsided, just before Thanksgiving, 2018.

1 Sonoma County ORD20-0005 DRAFT SMND.pdf p.34
2 Sonoma County UPC18-0001 Misty Mountain Services Summary Report (10,12)

When did Sonoma County smell cannabis odor at our house?

MAY 25	Supervisor Lynda Hopkins	Smelled "pungent odor" from our kitchen door on May 25, 2018
JULY 5	Tennis Wick	Code enforcement director. Visited our house and smelled the odor on July 5, 2017.
SEP 7	Tim Ricard	Then the cannabis program director for the county. He also smelled the odor while walking on our property on September 7, 2018.

Supervisor Lynda Hopkins:

> "Some folks feel they're being deprived of the use of their property due to overwhelming odor," she said. On a visit to a site near Sebastopol whose owners have applied for an outdoor cultivation permit, Hopkins said she was surprised by "how pungent" the plants were."
>
> Press Democrat Poll finds sharp division in Sonoma County over cannabis cultivation, The Press Democrat, June 3, 2018 by Guy Kovner

---

When you live 100 feet from
4,000 to 10,000 cannabis plants,
that odor is a nuisance from
June to November.

Sonoma County's non-scientists fabricate wind and atmospheric stories

Wind:

"...deflect the cannabis odor plumes upward to diffuse into the atmosphere **above the residences."** [(1)]

Sonoma County's **outdoor cannabis setback is 100 feet to a neighbor's property**, and Sonoma County refuses to change it to match the same setback to schools and parks (minimum 1,000 ft).

Outdoor cannabis does not diffuse and bounce into the atmosphere within 100 feet. The proposed 2021 ordinance will allow 3,000, 10,000, 20,000, 40,000 cannabis plants to be 100 feet from neighbors' backyards if the cannabis parcel is big enough.

Sonoma County **intentionally keeps setbacks unchanged** because they claim "fencing and landscaping is expected to deflect odor plumes upward to diffuse into the atmosphere". [(2)]

Sonoma County's cannabis **ordinance gives the County the power to fabricate their own story about weather** patterns and atmospheric conditions for each cannabis cultivation site, without any evidence, in order to approve their cannabis permits inside neighborhoods.

Below is actual text from a cannabis permit summary to justify its approval inside a neighborhood:

1. "Western Weather has an industrial grade meteorological monitoring system located approximately **1 mile north of the proposed project** at Poplar Way and Mill Station Road. The monitoring system calculated average wind direction between the months of June 1, 2019 and November 1, 2019. Wind came from the southwest direction 16.4% of the time, south-southwest 15.6% of the time, south 8.9% of the time, southeast 10.2% of the time and east-southeast 18.9% of the time. " [(1)]

   MISLEADING: Sonoma County uses 1 weather station 1 mile away to assume how wind blows cannabis in our neighborhood and then assumes people are not impacted.

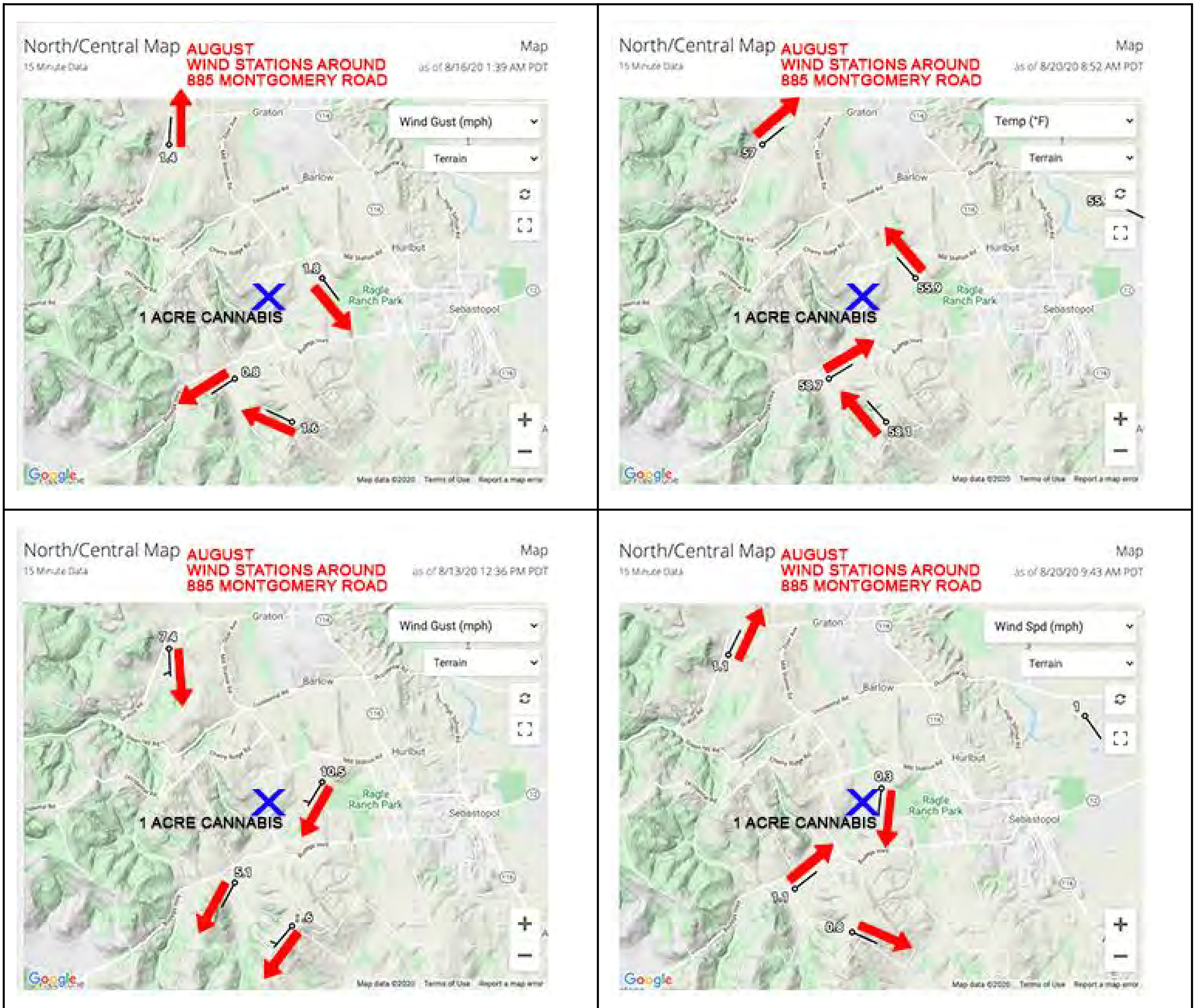
   Western Weather has 4 weather stations around this cannabis operator. Why did Sonoma County use only 1 in their report?

   Sonoma County uses deceptive conclusions by someone not qualified to make such conclusions, and who used these conclusions to recommend approving a cannabis permit.

1 UPC18-0001 Misty Mountain Services Summary Report, p.12
2 Purvine-20190930-UPC17-0020-Attachment-8-Mitigated-Negative-Declaration-March-11-2019-amended-April-11-2019, p.27

This is what Sonoma County used to recommend approving a cannabis permit

Below shows you that wind cannot be predicted from behind a desk using 1 data point because Sonoma County has hills and valleys with microcliamtes. Wind swirls in all directions throughout the day, so cannabis odor is always in someone's backyard.



The red arrows indicate a 'moment-in-time' wind direction from 4 weather stations around a cannabis business outside Sebastopol.

Sonoma County's flat refusal to conduct program-level environment impact reviews (PEIR) or project-specific California Environmental Quality Act (CEQA) studies lead them to fabricate any story they feel is suitable to approve a cannabis permit inside a neighborhood.

<u>Disclaimer:</u> This table is intended only to demonstrate that wind in the hills and valleys of West County don't always flow in one direction. I don't intend to make claims here other than to disprove Sonoma County's absurd assessment about wind and plumes, and how odor is somehow not a nuisance because wind blows cannabis odor from the residences. Or that hot air carries the odor straight up into the atmosphere.

Sonoma County claims cannabis is only in rural, less populated areas

Sonoma County's ordinance lacks any enforceable language that protects the neighborhood environment from the negative impacts of cannabis odor.

ORD20-0005 DRAFT SMND (proposed 2021 cannabis ordinance update) states:

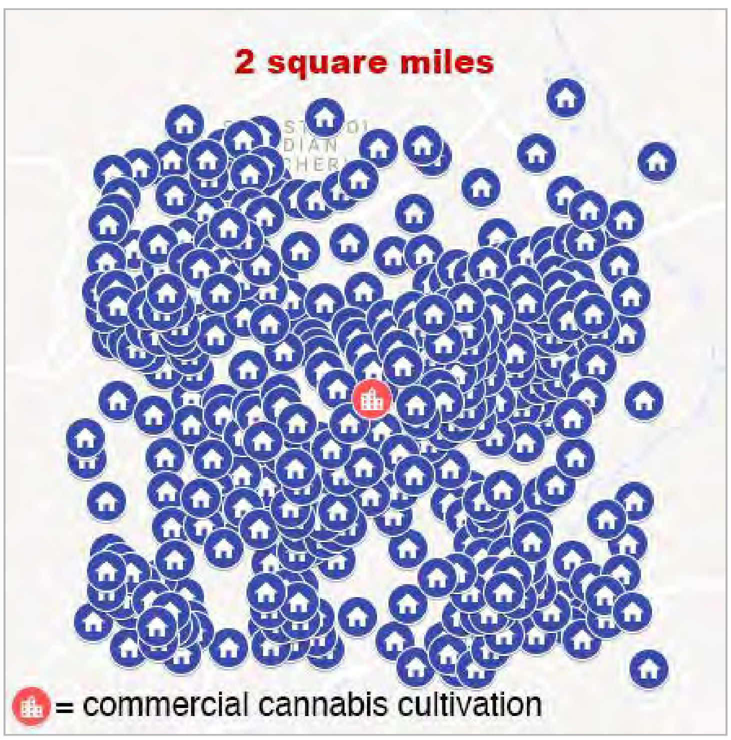
> "... most outdoor cannabis cultivation would occur in areas with a **limited number of nearby sensitive receptors such as residences**, and the odors would dilute across space before reaching sensitive receptors."

As a result, Sonoma County self-defines the number of people impacted by cannabis odor. For example, these opinions were used by Sonoma County to recommend approving a cannabis permit:

> "The [cannabis cultivation] project is located in an area **that is largely rural**" *(1)*
>
> **"the overall parcels within a 2-mile radius are rather large (10-50 acres)".** *(1)*

FALSE:
Only 38 of 399 parcels are actually 10-50 acres.(2)

The image below illustrates 399 parcels within 2 sq miles of that cannabis cultivation site.



Parcels: 399 | Under 10 acres: 361 | Over 10 acres: 38   Median parcel size = 2.0 acres

1 UPC18-0001 CEQA MND 2020-06-19
2 Sonoma County GIS

The cumulative impacts of Sonoma County's false narrative about odor

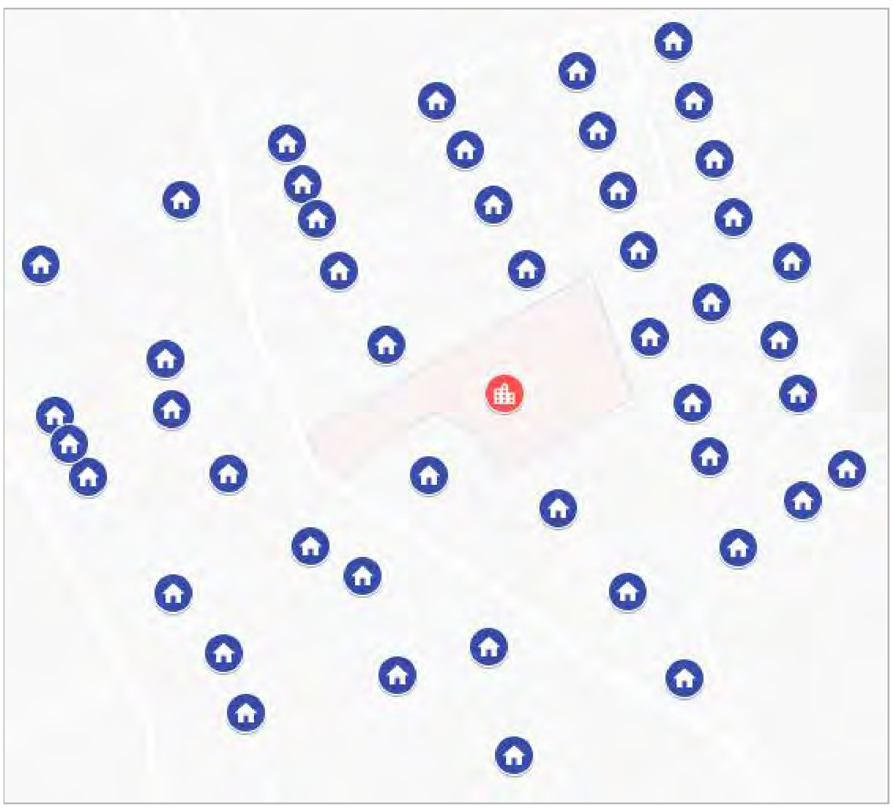
Permits get approved by leveraging the flawed cannabis ordinance.

"Staff recommends approval of the project because..."

1. "The cannabis cultivation site would meet the required **setbacks** from residential neighbors"

2. "The outdoor grow area is **separated from surrounding homes by distance, topography, and vegetation** that combine to allow **odors to dissipate**"

Meanwhile, this is the location described above as adequate for 1 acre of cannabis cultivation (red dot).



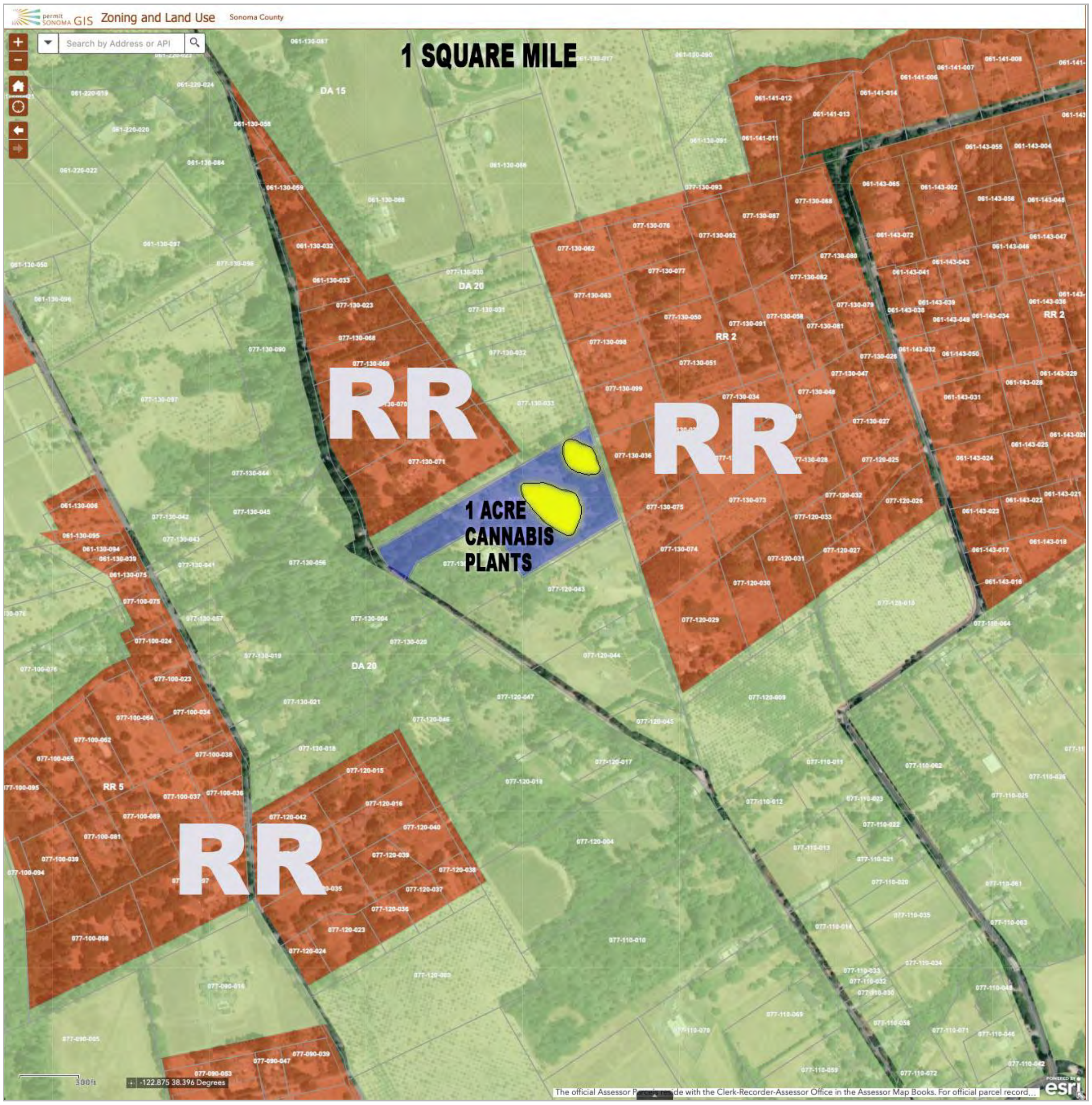
1,000 ft radius | 47 parcels | median parcel size = 2.5 acres

UPC18-0001 Misty Mountain Services Summary Report
Data source: Sonoma County GIS

Sonoma County cannabis ordinance allows commercial cannabis to border small Rural Residential (RR) zoned properties

Sonoma County's cannabis ordinance fails to acknowledge that many of the small-acre properties that surround a cannabis cultivation could be zoned **Rural Residential (RR)**, as well as small DA-zone properties.

Sonoma County must take into consideration the impact of a commercial cannabis cultivation, tourism events, hemp, and other cannabis-related activities which are adjacent to small-acre RR-zone properties. Properties with small acres do not have an escape from the noise and odor impacts from commercial cannabis businesses.



A 1 square mile view of parcels surrounding a commercial cannabis cultivation outside Sebastopol

If you think RR parcels should "expect odors" from adjacent DA parcels

It's the most famous soundbite. "You live near DA, you should expect odors." But does one Ag parcel supersede the property rights of all other parcels around it?

> "It is normal for agricultural land uses, especially animal feeding operations and farms that apply manure as a fertilizer, **to generate odors**."
> Sonoma County ORD20-0005 DRAFT SMND (proposed 2021 cannabis ordinance update)

> "...the outdoor cannabis cultivation generates odor ...**consistent with odors that would be expected within an agricultural area**."
> Sonoma County UPC18-0001 CEQA MND 2020-06-19

Let's assess that misconception:

<table>
<tr><th>A DA parcel may have livestock</th><th>A DA parcel may have cannabis</th></tr>
<tr><td>Restricted to only one of the following options:

● 5 hogs/pigs,
● Or 1 horse, mule, cow or steer,
● Or 5 goats, sheep, or similar animals,
● Or 50 chickens or similar fowl,
● Or 50 ducks or geese or 100 rabbits or similar animals
Per 20,000 of area</td><td>Unlimited number of plants

● 3,000 cannabis plants
● 5,000 cannabis plants
● 10,000 or more cannabis

Per 1 acre of of area
(or more if the 2021 ordinance passes)</td></tr>
<tr><td>Required setback to an adjacent RR parcel

500 feet

for enclosed odorous operations</td><td>Required setback to an adjacent RR parcel

100 feet

to wide-open air cannabis plants</td></tr>
<tr><td colspan="2">That 500 ft livestock setback exists for a reason. Why is cannabis only 100 feet?</td></tr>
</table>

10 pigs or 2 cows that are **500 feet away** (as mandated next to RR) can't possibly match or exceed the odor from 5,000 cannabis plants **just 100 feet** from a backyard

---

Cannabis odor must <u>*not*</u> "*be expected within an agricultural area*" when a DA parcel is surrounded by RR parcels

---

Section 26-08-010 in Chapter 26 of the Zoning Code states: "In the event that the confined animal use is proposed within five hundred feet (500') of a nonagricultural land use category, it shall require prior approval of a use permit."

What it's like to live next door to a Sonoma County commercial cannabis business?

Labor Day Weekend, 2018. Out-of-town family visited us for the holiday weekend.

FRI Sep 1

- We kept our windows closed all day
- **12:30pm**. We tried to eat lunch outside. The cannabis odor drove us back inside at 12:45pm.
- **6pm**. We BBQ'd dinner on the front yard sidewalk to escape the cannabis odors in our backyard. We still had to tolerate the smell even in the front yard.

SAT Sep 2

- We kept our windows closed all day
- **9:30am** We started to eat breakfast outside and had to go inside from the cannabis odor
- **3pm**. We spent time at our pool in the backyard. Two of us got a headache from inhaling cannabis odor for 30min
- We BBQ'd dinner again on the front yard sidewalk while the cannabis odor swirled around the house

SUN Sep 3

- We kept our windows closed all day
- **1:30am to 4am** Since someone left a bathroom window open, our hallways and our room filled with cannabis odor. The smell woke me up and I closed the window. **Didn't sleep until ~4am out of anxiety and anger from our life's situation**
- **1pm.** My family **no longer tolerated the cannabis odor** and our constant avoidance tactics, nor our constant bitching about it. They returned home, a day earlier than planned

MON Sep 4

I decided to wear a respirator in the garage while cleaning it; the cannabis odor trapped and lingered in the garage even with all doors open. The 3M P100 particulate respirator blocked the odor perfectly. So we started to wear them while outdoors.

The respirator blocked me from inhaling cannabis odor.

The New York Times

'Dead Skunk' Stench From Marijuana Farms Outrages Californians

Robert Guthrie wearing his respirator outside his home in Sebastopol, Calif. "I can't be outside more than 30 minutes," Mr. Guthrie said of peak cannabis odor times. Jim Wilson/The New York Times

It's time to make the change

Residences, schools, and parks must have the same setbacks to cannabis cultivation.

Nothing adequately mitigates outdoor cannabis odor within 100 feet.

We've been waiting for neighborhood compatibility for

3 years

when the Board of Supervisors asked Staff to work on it on April 10, 2018

Sonoma County's cannabis ordinance incorrectly assumes that odor from 1-acre of outdoor cannabis will "dilute across [100 feet] space before reaching sensitive receptors"

From: katie moore
Sent: Tuesday, March 16, 2021 12:25 PM
To: 'PlanningAgency@sonoma-county.org' <PlanningAgency@sonoma-county.org>
Subject: Comment for 3/18 Cannabis meeting

To whom it may concern,

My name is Katie Moore, and I am a 20-year resident of 2855 Fulton Road in Fulton. My property is a 5-acre parcel zoned DA-10. I am writing with great concern regarding the Supervisors' proposed cannabis ordinance and proposed sweeping changes to the amount of cannabis that may be grown in Sonoma County.

For the past two years, a cannabis farm has operated at 1737 Wood Road (UPC17-0034) under the Penalty Relief Program. This facility has neither a state nor county permit. Their county permit was denied by the BZA in December 2019 based on the presence of federally-protected habitat. The grower filed an appeal, yet an appeal hearing has yet to be heard -- more than a year later. The grower continues to operate, building multiple unpermitted structures *in the middle of the protected habitat.*

On the satellite image, below, you can see my parcel at 2855 Fulton Rd on the upper right. At the lower left is the cannabis farm at 1737 Wood Road. There is approximately 2,000 feet between the grow operations and my home. I am directly downwind of the grow.

This operation presents a constant odor during grow season. A distance of 2,000 feet does little to mitigate the smell --- especially when one is directly downwind. From Summer to Fall, I experience the smell of cannabis. When a visitor arrives at my property during the growing season, the first thing to tell them is "I am not smoking pot. There is a cannabis farm nearby."

If you drive down Wood Road on any given warm day during Summer and Fall, the smell is overwhelming and nauseating. The distance from the greenhouses to Wood Rd is approximately 400 feet, with Wood Road being upwind of the grow operations.

When I reached out to the county about the smell, I was told that growers are required to have a "filtration system" that takes care of it. When I asked for specifics on what type of filtration systems were required, no one could tell me. When I asked how a grower is supposed to filter smell from outdoor plants and hoop houses with their sides rolled up, no one could tell me. When I complained to one county official about the impact of the smell on my home and property value, I was told “this is here to stay. If you don’t like it, then move.”

So I took their advice, and considered walking away from my home of 20 years and moving. The appraiser who appraised my property told me that the presence of agricultural cannabis may reduce property value for surrounding properties by 10-30% or more --- mainly due to the smell.

If an ACRE (or less) of cannabis produces constant, noxious smells at my home 2,0000 feet away, I can only imagine what TEN ACRES would be like, both for me and for the unfortunate people who live in the general vicinity of operations like this. Opening up cannabis operations to the level proposed by the County would be a tragic disservice to the people of this community who trust and depend on our elected representatives to protect our welfare and quality of life.

Thank you for your consideration.

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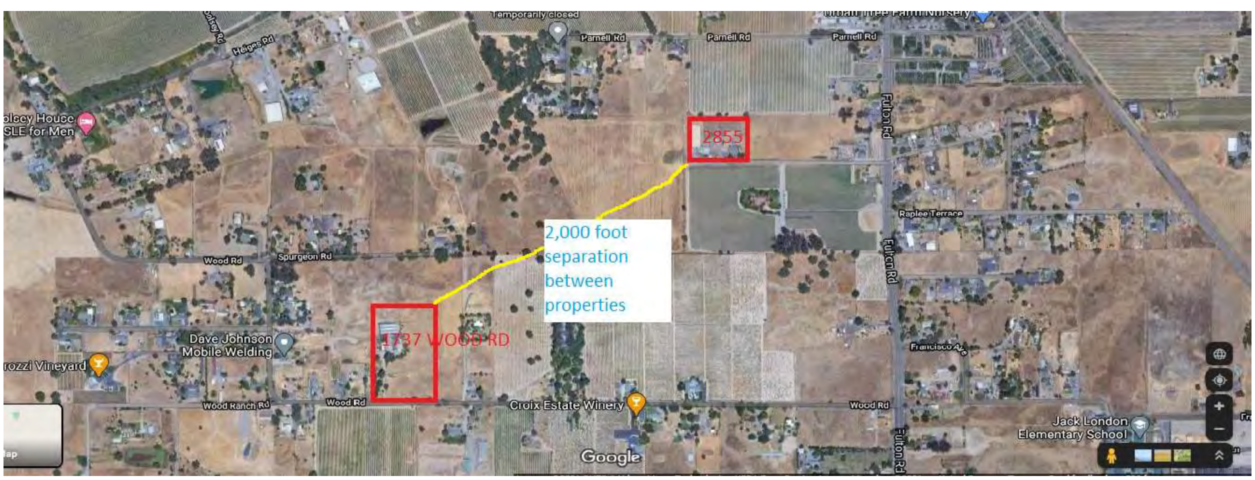

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Opposition to Proposed Cannabis Ordinance and
Supplemental Mitigated Negative Declaration

March 15, 2021

The Bennett Valley Citizens for Safe Development (BVSD) is a neighborhood group of almost 300 Bennett Valley residents who have signed a petition to make Bennett Valley a commercial cannabis-free exclusion zone. BVSD is a member of Save Our Sonoma Neighborhoods (SOSN), and endorses and fully supports the comments filed by SOSN in this proceeding. We are concerned that any mitigation measures in the Supplemental Mitigated Negative Declaration (SMND) or protections in the proposed cannabis ordinance are illusory. They will not protect residents from the reasonably foreseeable environmental consequences of the proposed revisions to the cannabis ordinance. We focus on impacts to Bennett Valley in these comments

As discussed below, there is substantial evidence to support a fair argument that the proposed revisions may have a significant detrimental effect on the environment with regard to aesthetics, odor, biological resources, water, traffic and conflicts with policies in the Bennett Valley Area Plan (BV Plan, attached). The county must undertake a full environmental impact report to fully evaluate the impacts of the proposal. Moreover, the current requirement for conditional use permits cannot be converted to ministerial under *Protecting Our Water & Environmental Resources v. County of Stanislaus*, 10 Cal.5th 479 (2020) because county officials make many discretionary decisions on every cannabis project, including analyzing reports for compliance.

The geographical area of Bennett Valley, as defined in the BV Plan, comprises about 900 parcels. Of these, 138 are over 10 acres in size and are zoned DA, LIA, and RRD (there are no LEA-zoned parcels). The total acreage of the 138 parcels eligible to cultivate commercial cannabis under the proposal is 4,702 acres: 1,586 DA, 665 LIA, and 2,451 RRD. Under the proposed cannabis ordinance, a minimum of 470 acres (10 percent of the eligible 4,702 acres) could cultivate outdoor cannabis. In addition, 138 acres of new indoor cannabis could be cultivated, and any existing buildings could grow indoor cannabis.

Checklist 1c. The proposed cannabis ordinance could substantially degrade the existing visual character and quality of public views of Bennett Valley.

Cannabis cultivation employs the construction and use of large, unattractive structures with solid fences—hoop houses for outdoor cultivation and industrial-looking greenhouses for indoor cultivation. SMND, p. 19. The fencing must be screened with vegetation that, “[u]pon maturity,” “shall largely block the view of cannabis structures from public viewpoints.” SMND, p. 23. Even when the screening vegetation reaches maturity years later, the views of the structures will only be “largely” blocked. If allowed, these commercial structures would be scattered throughout Bennett Valley and would degrade the existing visual character of our surroundings for “both public and private views.” SMND, pp. 19-20. The current screening standards are being relaxed to “remove the existing requirement to screen indoor cultivation structures from public view.” SMND, p. 22. Hoop houses, large greenhouses, indoor cultivation structures, restrooms, and solid fences will alter “the visual character of rural areas” such as Bennett Valley. SMND, pp. 21-22.

Allowing up to 470 acres of outdoor cultivation and 138 acres of greenhouses that can resemble self-storage sheds would violate the visual and scenic policies in the BV Plan. While we are raising these issues as residents, Bennett Valley is a treasure for all of Sonoma County. It is also one of many parts of Sonoma county that draws visitors for its bucolic scenery. Among the pertinent policies in the BV Plan are:

- New development throughout Bennett Valley shall be reviewed for site design and consistency with Bennett Valley development guidelines (p. 8).
- Unique scenic, visually and environmentally sensitive, and historic resources are important to the character of Bennett Valley and shall be protected (p. 9).
- Open vistas shall be protected (p. 9).
- A scenic corridor shall be established to protect views from the road . . . . (p. 10).
- The scenic quality of all transportation routes within Bennett Valley is a vital component of the rural character, and shall be protected (p. 10).

The SMND fails to analyze any of these policies. Further study and analysis are needed to address the adverse effects on scenic vistas and corrdors, especially the cumulative effects of permitting 470 acres of new outdoor cannabis cultivation and 138 acres of greenhouses. Ugly hoop houses and industrial greenhouses cannot be reconciled with the aesthetic policies in the BV Plan. A revised SMND should mitigate by forbidding such structures in Bennett Valley.

All new structures must undergo design review, and building and planting materials should be compatible with the landscape of Bennett Valley. BV Plan, p. 4. This requirement applies to agricultural appurtenances greater than 200 square feet such as hoop houses and greenhouses. BV Plan, p. 22. Development shall be sited with minimum impact on the view from the road (p. 10), and site and design structures shall be in harmony with natural surroundings (p. 14). The development standards for structures (p. 23) include roof lines that follow established lines of land and/or tree forms; utilization of color, texture, and materials that blend harmoniously with surrounding landscape; natural wood siding or shingles and natural stone for exteriors; earth-tone colors; and fire resistant and dark-toned roofs if visible. Implementing design review standards is never objective, and inherently requires public officials to exercise discretion. Even the decision whether to require design review involves discretion. A permitting process that allows the Commissioner of Agriculture unfettered discretion to decide that an unsightly hoop house covered in white plastic in his opinion meets the standards in the BV Plan is unacceptable. For this reason, all cannabis permits in Bennett Valley should be discretionary, not ministerial pursuant to *County of Stanislaus.*

Checklist 3c and 3d. The proposed ordinance will expose sensitive receptors to substantial pollutant concentrations and result in odor emissions adversely affecting a substantial number of people.

“Sensitive receptors are land uses where sensitive populations (i.e., children, the elderly, the acutely ill, and the chronically ill) are likely to be located,” and land uses include residences. SMND, p. 32. Accordingly, residences often if not typically house sensitive populations, including children and the elderly. Bennett Valley has about 900 parcels and a population of

2,500-3,000. Currently there are about 2.5 acres of commercial cannabis being cultivated in Bennett Valley. I have experienced the stench of cannabis while driving on Bennett Valley Road in October 2020 (possibly emanating from 5 coordinated ministerial permits comprising one acre on Wellspring Road), and many residents complain of marijuana smells in autumn. In 2017, the county allowed under its Penalty Relief Program an outdoor grow of about 5,000 square feet at 5245 Sonoma Mountain Road. I was then president of the Bennett Valley Community Association and received a dozen phone calls complaining about the odor. For several months during summer and autumn 2017 I would smell it within 1,000 feet when I drove by, and rolled up my windows. Marijuana can stink, and smelling the putrid odor at home could ruin your life.[1]

Allowing up to 470 acres of outdoor cultivation and 138 acres of greenhouses will expose sensitive receptors to substantial pollutant concentrations, including odor emissions adversely affecting a substantial number of people. This is about 200 times the current acreage. Terpenes are heavy molecules that sink and could be trapped in any basin such as Bennett Valley. I have lived in Bennett Valley for almost 20 years and we frequently experience thermal inversions, especially during the warmer months. Warm air rises, and the temperatures at my home (750 feet in elevation) are often 10-15 degrees higher during summer and autumn evenings than on Sonoma Mountain Road (600-650 feet in elevation). During wildland fires, especially in October 2017, heavy smoke gets trapped in the valley, making it difficult to breath. The air quality monitors for particulates on the PurpleAir website clearly show more air pollution on the valley floor than higher elevations. Allowing a vast increase in cannabis cultivation could subject hundreds of homes to a 24/7 stench for days or weeks at a time during summer and autumn when terpenes are trapped on the valley floor.

Further study and scientific analysis are needed to address exposing sensitive receptors to substantial pollutant concentrations and odor emissions that would adversely affect a substantial number of people. In particular, BVSD would object to any revised analysis that fails to include air quality modeling for Bennett Valley under a variety of weather conditions and cannabis acreage.

Checklist 4a. The proposed ordinance will have a substantial adverse effect, either directly or through habitat modifications, on candidate, sensitive, or special status species.

The SMND fails to address the existence of or cumulative impacts on sensitive species in the Matanzas Creek watershed. Allowing up to 470 acres of outdoor cultivation, 138 acres of green houses and an unknown amount of indoor cultivation in existing structures could have devasting effects on water supply. It could adversely affect directly or through habitat modifications at least five aquatic or riparian species identified as a candidate, sensitive, or special status species.

A biological assessment for 3803 Matanzas Creek Lane prepared by Darren Wiemeyer provides much information on the biological resources in this area. He found hat Matanzas Creek and its riparian corridor provides good refuge habitat for amphibians and reptiles, and identified five

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[1] Thomas Fuller, 'Dead Skunk' Stench from Marijuana Farms Outrages Californians (December 19, 2018); What it's Like to Live 100 feet from 15,000 Cannabis Plants? North Bay Biz (December 3, 2020).

rare species that are found in this watershed: California giant salamander (special concern); foothill yellow-legged frog (candidate threatened); red-legged frog (federal threatened); reed-bellied newt (special concern); and California freshwater shrimp (federal endangered).

The piecemeal diminution of aquatic habitat is why the species that live in this habitat are listed as threatened, endangered, or are being considered for listing. A factor the California Department of Fish and Wildlife considers in listing a Species of Special Concern is when they occur in small, isolated populations or in fragmented habitat, and are threatened by further isolation and population reduction. That is the situation in the Matanzas Creek watershed, and it is vital to preserve this habitat to avoid further fragmentation. The cumulative effects of this and all foreseeable marijuana projects must be evaluated with respect to year-round water flows, summer water flows, and elevated water temperatures.

As emphasized in an August 30, 2018 letter from NOAA to Sonoma County (attached), the county insufficiently protects against the lowering of ground water levels. Further study and scientific analysis are needed to address the effects on the Matanzas Creek watershed of allowing up to 470 acres of outdoor cultivation, 138 acres of green houses and an unknown amount of indoor cultivation in existing structures to be irrigated. This is substantial information to make a fair argument that the proposed cannabis ordinance will have a substantial adverse effect on five species that are identified as a candidate, sensitive, or special status species.

Checklist 11b. The project will cause significant environmental impacts due to conflicts with the BV Plan.

The proposed cannabis ordinance conflicts with the BV Plan. The SMND fails to recognize the existence of, let alone analyze, the BV Plan. The Board of Supervisors adopted the BV Plan in 1979, with an overall goal of preserving and protecting the traditional rural character and natural environment of Bennett Valley. The BV Plan was supported by an environmental impact report. Policy LU-1a of the General Plan emphasizes that where the BV Plan is more restrictive, its policies supersede those the General Plan:

> A Specific or Area Plan may establish more detailed policies affecting proposed development, but may not include policies that are in conflict with the General Plan. In any case where there appears to be a conflict between the General Plan and any Specific or Area Plan, the more restrictive policy or standard shall apply.

The BV Plan has three unique features that conflict with the proposed cannabis ordinance.

1. **Commercial marijuana development violates Land Use Policy 2.**

Land Use Policy 2 in the BV Plan, p. 8, provides "Commercial development is not considered appropriate to the rural character of Bennett Valley." The current ordinance, § 26-02-40, defines cultivation as **commercial** cannabis activity, as does § 38.02.010 (Sonoma County **Commercial** Cannabis Cultivation in Agricultural and Resource Areas Ordinance). Sonoma County Counsel has explained that the county lacks a definition of "development," but that any discretionary approval under Chapter 26, any building permit issued under chapter 7, and any grading permit issued under chapter 7 is "development." Letter from Adam L. Brand, Sonoma County Deputy County Counsel, to Kevin Block (January 19, 2019), pp. 3-4 (attached).

The BV Plan, p. 9, states "[a]griculture is a vital component of the rural character and shall be encouraged and protected." No one who developed the BV Plan over forty years ago considered marijuana to be agriculture. To the contrary, the attached Bennett Valley Study that supported the BV Plan defines "agriculture" as "orchards and vineyards."

2. **Land Use Policy 3 requires enhanced law enforcement before approving commercial marijuana development.**

Land Use Policy 3 in the BV Plan, p. 8, provides "[d]evelopment **shall** be coordinated with the public's ability to provide schools, fire, police and other needed services." Emphasis added. This policy is mandatory ("shall"). Home invasions related to marijuana grows are all too common in Sonoma County, and the risks of criminal activity is a major concern. In many cases, non-growing neighbors have been terrorized when the "wrong" home is invaded. The Board of Supervisors recognized this problem in its findings in section I, subsection O in Ordinance No. 6189. There are already insufficient sheriffs on duty, especially at night when home invasions tend to occur. It can take 30 to 45 minutes for a sheriff to respond to a call. Permitting commercial cannabis grows in Bennett Valley introduces into our community a new and dangerous activity that can attract violent criminals.

The county has done nothing to improve public safety while proposing 600 acres of commercial marijuana cultivation in Bennett Valley. Possible mitigations include establishing a sheriff's substation in Bennett Valley; banning permits on properties located on shared access roads to minimize home invasions of innocent non-growers; and banning marijuana grows adjacent to parcels that are zoned Rural Residential, Agricultural Residential, or are less than ten acres in size to limit home invasions of neighbors not involved with marijuana cultivation.

3. **Land Use Policy 3 requires improving Bennett Valley roads before approving commercial marijuana development.**

Land Use Policy 3 in the BV Plan, p. 8, provides "Development **shall** be coordinated with the public's ability to provide schools, fire, police **and other needed services**." Emphasis added. "[O]ther needed services" include roads. The road policy in the BV Plan, p. 14, provides "to avoid increasing hazard on inadequate roads, retain low density until road upgraded." As discussed below, the proposed cannabis ordinance could increase daily traffic by 24,528 to 49,056 trips. Proposing a huge increase in traffic without addressing road improvement violates the BV Plan.

Further study and analysis are needed to avoid causing significant environmental impacts due to innumerable conflicts with the BV Plan.

Checklist17a. The proposal conflicts with a plan addressing the circulation system.
Checklist 17d. The proposal results in inadequate emergency access.
Checklist 20. The proposal ignores wildfire evacuation issues.

The proposal allows the countywide acreage of outdoor cannabis cultivation projects to increase from under 50 acres to 65,733 acres. SMND, p. 19. Bennett Valley has 138 parcels eligible to cultivate commercial cannabis comprising at least 4,702 acres. Thus, 470 acres of outdoor cannabis and 138 acres of new indoor cannabis could be cultivated.

Sonoma County's 2016 Negative Declaration, p. 44, estimated that a one-acre outdoor cultivation site or a 0.25-acre indoor operation would each require 12-15 employees during peak periods (an indoor operation would require 48-60 employees for a 1-acre operation [4 x 12-15]). Conservatively using the lower estimates of employees, the proposal would allow 5,640 workers (12 employees x 470 acres) for outdoor cultivation in Bennett Valley. It would employ 6,624 workers (48 employees x 138 acres) for indoor cultivation. Together, outdoor and indoor cultivation would employ 12,264 employees (5,640 + 6,624).

Sonoma County's 2016 Negative Declaration, p. 44, estimated that each employee averages 2 to 4 trips per day (a roundtrip commute is 2 trips). Using this estimate and 12,264 employees, the proposal could increase daily traffic between 24,528 (2 x 12,264) and 49,056 (4 x 12,264) trips.

It is instructive to apply this analysis to Matanzas Creek Lane, a 11-12-foot-wide mile-long dead-end road that already has circulation problems. It has ten eligible parcels with about 200 acres. Under the proposal, 10 acres of indoor cultivation would be allowed, together with 20 acres (10 percent of 200 acres) for outdoor cultivation. Using the above analysis, the proposal could employ 240 workers (12 employees x 20 acres) for outdoor cultivation. The 10 acres of indoor cultivation could employ 480 workers (48 employees x 10 acres). Together, outdoor and indoor cultivation would employ 720 employees (240 + 480), and daily traffic could increase on Matanzas Creek Lane by between 1,440 (2 x 720) and 2,880 (4 x 720) trips.

Bennett Valley has an estimated residential population of 2,500 - 3,000. The increases in traffic, with four times as many employees as current residents, violate the following policies and guidelines in the BV Plan:

- Intensity of land use shall reflect the conditions character and capacity of roads (p. 10).
- Retain low densities for fire hazard mitigation (p. 13).
- To avoid increasing hazard on inadequate roads, retain low density until road upgraded (p. 14).
- private streets and driveways, both existing and proposed, are properly designed and located to carry the type and quantity of traffic generated by the proposed use and to minimize visual impact (p. 21).

The proposal conflicts with the BV Plan's circulation system and results in inadequate emergency access. Further study and scientific analysis are needed to address the circulation system in Bennett Valley, emergency access, and the violation of the BV Plan's policies.

EXHIBIT 23

3.3 AIR QUALITY AND ODORS

This section includes a discussion of existing air quality conditions, a summary of applicable air quality regulations, and an analysis of potential short-term and long-term air quality impacts (including odors) that could result from adoption and implementation of the proposed CLUO, including issuance of subsequent Cannabis Use Permits pursuant to the adopted CLUO.

Comments were received on the NOP pertaining to air quality and odor impacts from cannabis uses. The Yocha Dehe Wintun Nation, a tribal nation; concerned residents; and members of the public who attended the Scoping Meeting on September 13, 2019, noted concerns regarding the potential for odor emissions from cultivation. Yolo County Farm Bureau expressed concerns over dust emissions from travel on unpaved roads as well as odor impacts. These issues are considered below. The reader is referred to Appendix A for NOP comment letters.

3.3.1 Environmental Setting

The project area is located in the Sacramento Valley Air Basin (SVAB). The SVAB includes all of Butte, Colusa, Glenn, Sacramento, Shasta, Sutter, Tehama, Yolo, and Yuba Counties; the western portion of Placer County; and the eastern portion of Solano County. The ambient concentrations of air pollutant emissions are determined by the amount of emissions released by the sources of air pollutants and the atmosphere's ability to transport and dilute such emissions. Natural factors that affect transport and dilution include terrain, wind, atmospheric stability, and sunlight. Therefore, existing air quality and odor conditions in the area are determined by such natural factors as topography, meteorology, and climate, in addition to the amount of emissions released by existing air pollutant sources, as discussed separately below.

CLIMATE, METEOROLOGY, AND TOPOGRAPHY

The SVAB is a relatively flat area bordered by the north Coast Ranges to the west and the northern Sierra Nevada to the east. Air flows into the SVAB through the Carquinez Strait, the only breach in the western mountain barrier, and moves across the Sacramento–San Joaquin Delta (Delta) from the San Francisco Bay Area.

The Mediterranean climate type of the SVAB is characterized by hot, dry summers and cool, rainy winters. During the summer, daily temperatures range from 50 degrees Fahrenheit (°F) to more than 100°F. The inland location and surrounding mountains shelter the area from much of the ocean breezes that keep the coastal regions moderate in temperature. Most precipitation in the area results from air masses that move in from the Pacific Ocean, usually from the west or northwest, during the winter months. More than half the total annual precipitation falls during the winter rainy season (November through February); the average winter temperature is a moderate 49°F. Also characteristic of SVAB winters are periods of dense and persistent low-level fog, which are most prevalent between storms. The prevailing winds are moderate in speed and vary from moisture-laden breezes from the south to dry land flows from the north.

The mountains surrounding the SVAB create a barrier to airflow, which leads to the entrapment of air pollutants when meteorological conditions are unfavorable for transport and dilution. The highest frequency of poor air movement occurs in the fall and winter when high-pressure cells are often present over the SVAB. The lack of surface wind during these periods, combined with the reduced vertical flow caused by a decline in surface heating, reduces the influx of air and leads to the concentration of air pollutants under stable metrological conditions. Surface concentrations of air pollutant emissions are highest when these conditions occur in combination with agricultural burning activities or with temperature inversions, which hamper dispersion by creating a ceiling over the area and trapping air pollutants near the ground.

Elevated levels of ozone typically occur May through October in the SVAB. This period is characterized by poor air movement in the mornings with the arrival of the Delta sea breeze from the southwest in the afternoons. In addition, longer daylight hours provide a plentiful amount of sunlight to fuel photochemical reactions between reactive organic gases (ROG) and oxides of nitrogen (NO_X), which result in ozone formation. Typically, the Delta breeze transports air pollutants northward out of the SVAB; however, a phenomenon known as the Schultz Eddy prevents this from occurring during approximately half of the time from July to September. The Schultz Eddy phenomenon causes the wind to shift southward and blow air pollutants back into the SVAB. This phenomenon exacerbates the concentration of air pollutant emissions in the area and contributes to the area violating the ambient air quality standards.

The local meteorology of the project area is represented by measurements recorded at the Western Regional Climate Center Woodland 1 WNW station. The normal annual precipitation is approximately 18.5 inches. January temperatures range from a normal minimum of 37.6°F to a normal maximum of 54.1°F. July temperatures range from a normal minimum of 57.9°F to a normal maximum of 96.3°F (WRCC 2016). The prevailing wind direction is from the south southwest, as measured at the Vacaville Airport station (WRCC 2019).

CRITERIA AIR POLLUTANTS

Concentrations of criteria air pollutants are used to indicate the quality of the ambient air. A brief description of key criteria air pollutants in the SVAB and their health effects are provided below. Criteria air pollutants include ozone, carbon monoxide (CO), nitrogen dioxide (NO_2), sulfur dioxide (SO_2), respirable particulate matter (PM_{10}), fine particulate matter ($PM_{2.5}$), and lead. However, ozone, PM_{10}, and $PM_{2.5}$ are the criteria air pollutants of primary concern in this analysis due to their nonattainment status with respect to the applicable National Ambient Air Quality Standards (NAAQS) and/or California Ambient Air Quality Standards (CAAQS). The attainment status of criteria air pollutants with respect to the NAAQS and CAAQS in Yolo County are shown in Table 3.3-1. Monitoring data representative of ambient air concentrations in Yolo County are summarized in Table 3.3-2.

Table 3.3-1 Attainment Status Designations for Yolo County

Pollutant	National Ambient Air Quality Standard	California Ambient Air Quality Standard
Ozone	Nonattainment (1-hour)	Nonattainment (1-hour)
	Nonattainment (8-hour)[1]	Nonattainment (8-hour)
	Nonattainment (8-hour)[2]	
Respirable particulate matter (PM_{10})	Attainment (24-hour)	Nonattainment (24-hour)
		Nonattainment (Annual)
Fine particulate matter ($PM_{2.5}$)	Nonattainment (24-hour)	(No state standard for 24-Hour)
	Attainment (Annual)	Attainment (Annual)
Carbon monoxide (CO)	Attainment (1-hour)	Attainment (1-hour)
	Attainment (8-hour)	Attainment (8-hour)
Nitrogen dioxide (NO_2)	Attainment (1-hour)	Attainment (1-hour)
	Attainment (Annual)	Attainment (Annual)
Sulfur dioxide (SO_2)	Attainment (1-Hour)	Attainment (1-hour)
		Attainment (24-hour)
Lead (Particulate)	Attainment (3-month rolling avg.)	Attainment (30-day average)
Hydrogen Sulfide	No Federal Standard	Unclassified (1-hour)
Sulfates		Attainment (24-hour)
Visibly Reducing Particles		Unclassified (8-hour)
Vinyl Chloride		Unclassified (24-hour)

[1] 1997 Standard.
[2] 2008 Standard.
Sources: YSAQMD 2016a; CARB 2015

Table 3.3-2 Summary of Annual Data on Ambient Air Quality (2015-2017)[1]

	2015	2016	2017
Ozone			
Maximum concentration (1-hr/8-hr avg, ppm)	0.086/0.072	0.095/0.076	0.089/0.074
Number of days state standard exceeded (1-hr/8-hr)	0/4	1/4	0/2
Number of days national standard exceeded (8-hr)	3	4	2
Fine Particulate Matter ($PM_{2.5}$)			
Maximum concentration (24-hour µg/m^3)	29.4	16.4	60.1
Number of days national standard exceeded (24-hour measured[2])	0	0	12.3
Respirable Particulate Matter (PM_{10})			
Maximum concentration (µg/m^3)	69.4	68.7	130.8
Number of days state standard exceeded	12.2	12.2	18.4
Number of days national standard exceeded	0	0	0

Notes: µg/m^3 = micrograms per cubic meter; ppm = parts per million

1. Measurements from the Woodland-Gibson Road station.

Source: CARB 2019

Ozone

Ground-level ozone is not emitted directly into the air but is created by chemical reactions between ROG and NO_X. This happens when pollutants emitted by cars, power plants, industrial boilers, refineries, chemical plants, and other sources chemically react in the presence of sunlight. Ozone at ground level is a harmful air pollutant, because of its effects on people and the environment, and is the main ingredient in smog (EPA 2018).

Acute health effects of ozone exposure include increased respiratory and pulmonary resistance, cough, pain, shortness of breath, and lung inflammation. Chronic health effects include permeability of respiratory epithelia and possibility of permanent lung impairment (EPA 2018). Emissions of the ozone precursors ROG and NO_X have decreased over the past two decades because of more stringent motor vehicle standards and cleaner burning fuels (CARB 2014).

Nitrogen Dioxide

NO_2 is a brownish, highly reactive gas that is present in all urban environments. The major human-made sources of NO_2 are combustion devices, such as boilers, gas turbines, and mobile and stationary reciprocating internal combustion engines. Combustion devices emit primarily nitric oxide (NO), which reacts through oxidation in the atmosphere to form NO_2. The combined emissions of NO and NO_2 are referred to as nitrogen oxide (NO_X) and are reported as equivalent NO_2. Because NO_2 is formed and depleted by reactions associated with photochemical smog (ozone), the NO_2 concentration in a particular geographical area may not be representative of the local sources of NO_X emissions (EPA 2012).

Acute health effects of exposure to NO_X includes coughing, difficulty breathing, vomiting, headache, eye irritation, chemical pneumonitis, or pulmonary edema, breathing abnormalities, cough, cyanosis, chest pain, rapid heartbeat, and death. Chronic health effects include chronic bronchitis and decreased lung function (EPA 2018).

Particulate Matter

“Particulate matter” is the term used to describe a mixture of solid particles and liquid droplets found in the air (EPA 2018). Respirable particulate matter with an aerodynamic diameter of 10 micrometers or less is referred to as PM_{10}. PM_{10} consists of particulate matter emitted directly into the air, such as fugitive dust, soot, and smoke from mobile and stationary sources, construction operations, fires and natural windblown dust, as well as particulate matter formed in the atmosphere by reaction of gaseous precursors (CARB 2014). PM_{10} particles are often large or dark enough to see with the naked eye (EPA 2018). Fine particulate matter ($PM_{2.5}$) includes a subgroup of smaller particles that have an aerodynamic diameter of 2.5 micrometers or less. $PM_{2.5}$ particles are so small that they can only be detected using an electron microscope (EPA 2018). PM_{10} emissions in the SVAB are dominated by emissions from area sources, primarily fugitive dust from vehicle travel on unpaved and paved roads, farming operations, construction and demolition, and particles from residential fuel combustion. Direct emissions of PM_{10} are projected to remain relatively constant through 2035. Direct emissions of $PM_{2.5}$ have steadily declined in the SVAB between 2000 and 2010 and then are projected to increase very slightly through 2035. Emissions of $PM_{2.5}$ in the SVAB are primarily generated by the same sources as emissions of PM_{10} (CARB 2014).

Acute health effects of PM_{10} exposure include breathing and respiratory symptoms, aggravation of existing respiratory and cardiovascular diseases, and premature death. Chronic health effects include alternations to the immune system and carcinogenesis (EPA 2018).

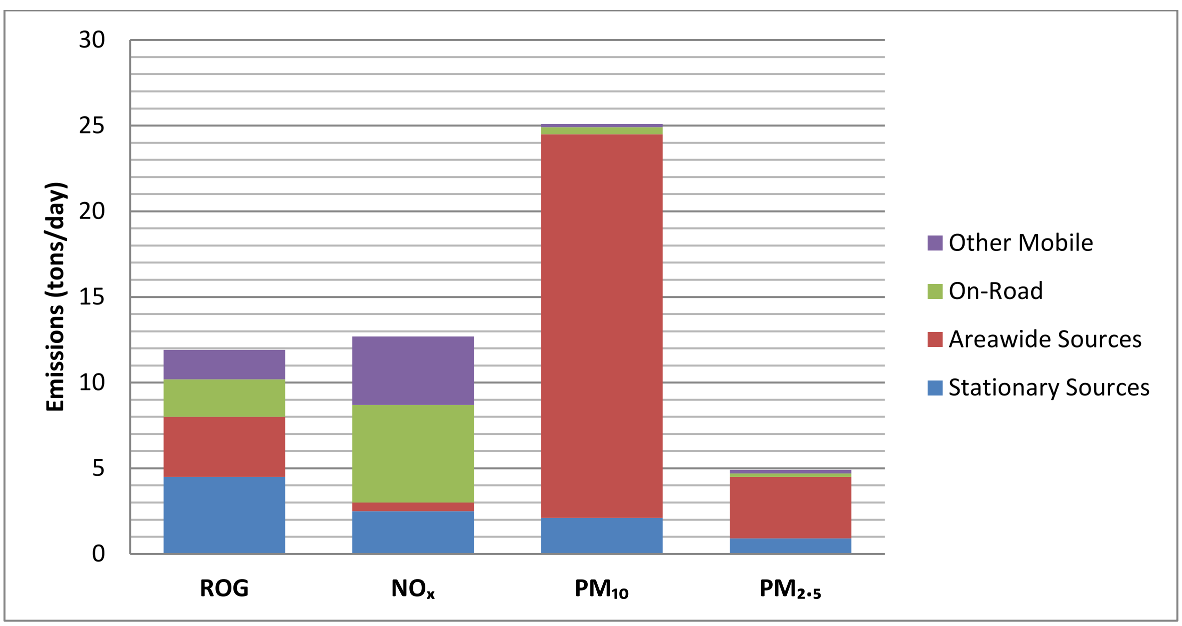
ATTAINMENT DESIGNATIONS AND MONITORING STATION DATA

Criteria air pollutant concentrations are measured at several monitoring stations in the SVAB. There are two monitoring stations in Yolo County: Woodland-Gibson Road station and the UC Davis station. The Woodland-Gibson Road station was used for consideration in this EIR of all pollutants because it is most representative of air quality in unincorporated Yolo County. Table 3.3-2 summarizes the air quality data measured at monitoring stations near the project area during the last 3 years (2015–2017).

Both the California Air Resources Board (CARB) and the U.S. Environmental Protection Agency (EPA) use monitoring data to designate areas according to their attainment status for criteria air pollutants (attainment designations are summarized below in Table 3.3-1).

EMISSIONS INVENTORY

Exhibit 3.3-1 summarizes an estimated emissions inventory of criteria air pollutants projected for Yolo County for various source categories in 2015 based on the 2016 State Implementation Plan (SIP) Emissions Projection Data from CARB. According to the emissions inventory, mobile sources are the largest contributor to the estimated daily air pollutant levels of ROG and NO_X, accounting for approximately 33 percent and 76 percent of the total daily emissions, respectively. Area-wide source (i.e., sources that occur over a large area rather than at a point source [e.g., smokestack] or a mobile source [e.g., tailpipe]) account for approximately 89 percent and 73 percent of the County's PM_{10} and $PM_{2.5}$ emissions, respectively (CARB 2016a), due in part to the agricultural and semi-rural conditions in Yolo County. This is the most current emissions inventory available for Yolo County.



Source: CARB 2016a; data compiled by Ascent Environmental in 2018.

Exhibit 3.3-1 Yolo County 2015 Criteria Air Pollutant Emissions Inventory

TOXIC AIR CONTAMINANTS

According to the *California Almanac of Emissions and Air Quality*, the majority of the estimated health risks from toxic air contaminants (TACs) can be attributed to relatively few compounds, the most important being particulate matter (PM) exhaust from diesel engines (diesel PM) (CARB 2014:5-2 to 5-4). Diesel PM differs from other TACs in that it is not a single substance, but rather a complex mixture of hundreds of substances. Although diesel PM is emitted by diesel-fueled internal combustion engines, the composition of the emissions varies depending on engine type, operating conditions, fuel composition, lubricating oil, and whether an emissions control system is being used. Unlike the other TACs, no ambient monitoring data are available for diesel PM because no routine measurement method currently exists. However, CARB has made preliminary concentration estimates based on a PM exposure method. This method uses the CARB emissions inventory's PM_{10} database, ambient PM_{10} monitoring data, and the results from several studies to estimate concentrations of diesel PM. In addition to diesel PM, the TACs for which data are available that pose the greatest existing ambient risk in California are benzene, 1,3-butadiene, acetaldehyde, carbon tetrachloride, hexavalent chromium, para-dichlorobenzene, formaldehyde, methylene chloride, and perchloroethylene.

Diesel PM poses the greatest health risk among these 10 TACs mentioned. Based on receptor modeling techniques, CARB estimated the average cancer risk associated with diesel PM concentrations in the SVAB to be 360 excess cancer cases per million people in the year 2000 (CARB 2010:5-83). Overall, statewide emissions of diesel PM are forecasted to decline by 71 percent between 2000 and 2035 (CARB 2014:3-8) due to more stringent emissions standards and the introduction of cleaner burning diesel fuel.

NATURALLY OCCURRING ASBESTOS

Asbestos is the common name for a group of naturally occurring fibrous silicate minerals that can separate into thin but strong and durable fibers. Naturally occurring asbestos, which was identified as a TAC by CARB in 1986, is located in many parts of California and is commonly associated with serpentine soils and rocks. According to the U.S. Geological Survey, Yolo County is not likely to contain naturally occurring asbestos (USGS 2011).

ODORS

Odors are generally regarded as an annoyance rather than a health hazard. However, a person's reaction to foul odors can range from psychological (e.g., irritation, anger, or anxiety) to physiological (e.g., increase in blood pressure, nausea, vomiting, and headache).

Environmental odor quantification is inherently challenging for several reasons including:

1. Odor usually results from a mixture of substances (as opposed to a single chemical or compound).
2. Odor is prone to subjectivity and opinion (not everyone agrees on what smells good or bad).
3. Odor is highly influenced by meteorological conditions such as seasonality, wind, humidity, temperature, cloud cover, precipitation, and time of day.

These challenges are important to recognize and overcome when establishing an odor verification protocol that is both practical and objective.

The strength of an odor can be objectively measured with an acceptable degree of precision using an instrument called an olfactometer. The Nasal Ranger device recently purchased by Yolo County is an example of a conventional field olfactometer. The field olfactometer provides odor data that is consistent from location to location by quantifying odor strength in the ambient air. Numerically, the strength of an odor is identified by how many clean air dilutions are required to no longer detect any given odor. The more clean air dilutions required, then the stronger the odor – and strong odors are a good indicator of potential nuisance.

An olfactometer works by controlling the proportion of "clean air" (odor-free or carbon filtered air) to "odorous" air to which an odor investigator is exposed. As an example, for a given odor, a numeric value of 60 dilutions of clean air using an olfactometer would objectively be much stronger and likely much more offensive than a value of 15 dilutions of clean area. In this example, an olfactometer value of 60 represents a stronger odor than a value of 15 because the tested air simply requires much more clean air to dilute the sample of odorous air to a level that is undetectable. These values are known as dilution-to-threshold Or "D/T" values.

While an olfactometer determines the strength of a given odor, it does not identify the character of the odor (i.e. what does the odor smell like?). Other observable characteristics such as the frequency, intensity, duration, and offensiveness of the odor are equally as important as measuring the strength. These parameters are noted alongside the numeric odor strength measurements from the olfactometer.

It is good practice to apply what is known as the "FIDOL" parameters to odor measurements. FIDOL is an acronym for the following characteristics or parameters:

Frequency – how often the odor impacts occur

Intensity – the relative odor strength (faint to overwhelming)

Duration – the length of time for a given odor event

Offensiveness – the character or description of the odor

Location – mapping impact and identifying other off-property contributing sources

As part of the odor verification process, the trained odor investigator addresses the FIDOL parameters on a standardized odor documentation field sheet. For consistency in qualifying the character of a specific odor, an odor wheel (see Exhibit 3.3-2) is commonly used to define the descriptors of possible scents and provide investigators a standard set list from which to choose. The numerical values depicted in the exhibit allow for shorthand recordkeeping of odor descriptors only and are not indicative of odor strength or offensiveness.

Reliable ambient odor measurement limits require trained odor investigators with tested sensitivity within an acceptable range for detecting odors, as defined by European Standard EN13725. Competent investigators are trained to understand the various characteristics and parameters of odor and how to document them, and also how to assess and document various externalities (such as topography and meteorology) that might have relevance to the particular odor condition.

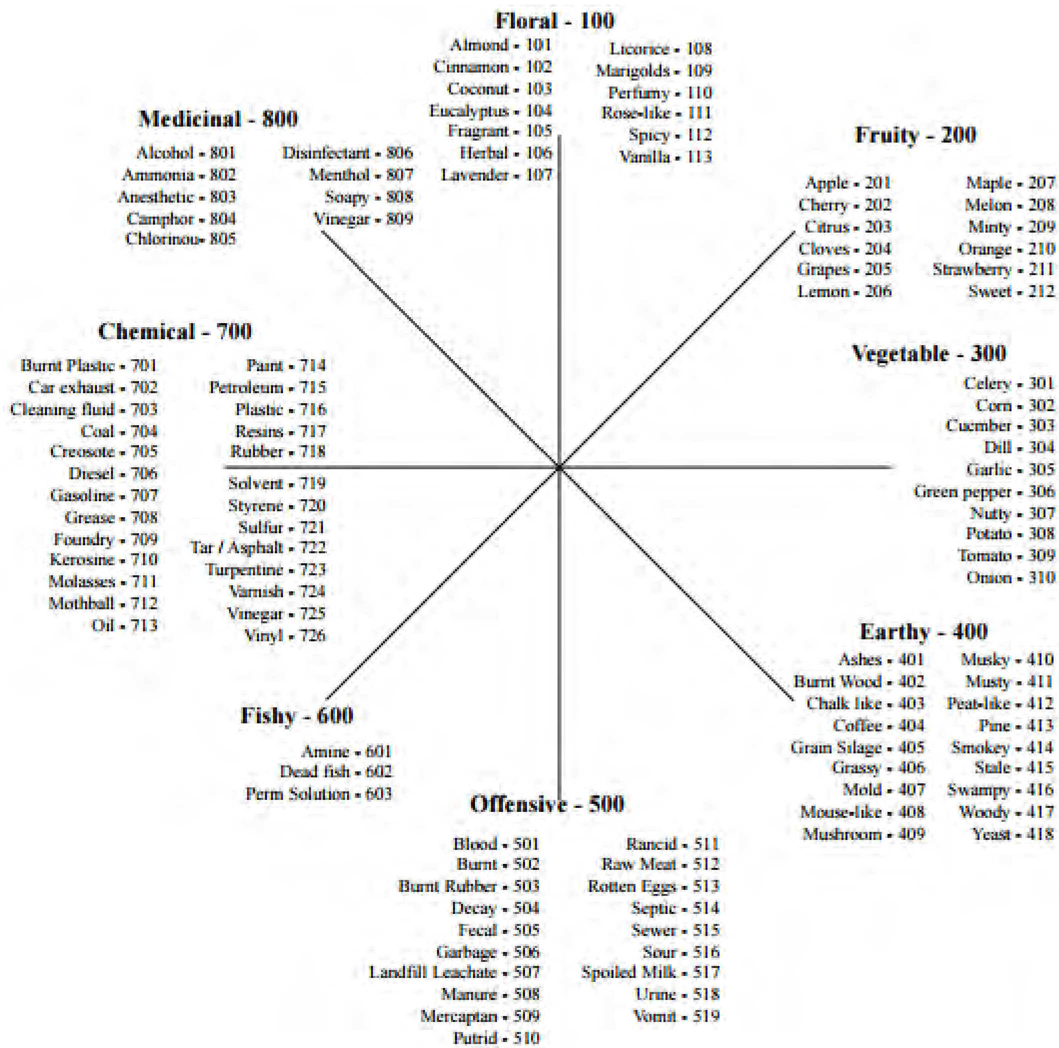


Exhibit 3.3-2 **Odor Descriptor Wheel**[1]

Cannabis Odor Research

The typical smell of cannabis originates from roughly 140 different terpenes. A terpene is a volatile, unsaturated hydrocarbon that is found in essential oils of plants, especially conifers and citrus trees. Some terpenes are identified explicitly in research (myrcene, pinene, limonene). The "skunk" odor is primarily volatile thiols[2] (i.e., commonly offensive odor that vaporizes easily). Cannabis contains alpha-linolenic acid which may break down under ultraviolet rays of sunlight into methyl and butyl thiols.

Some researchers define an "odor activity value" (OAV) which is the chemical compound concentration divided by the chemical compound odor detection threshold (which is a literature-based value). A higher OAV could mean a more significant odor. One shortcoming of the OAV is the quality of the odor detection thresholds may be low. Highly odorous compounds in low concentrations which may have more potent OAV are nonanal, decanol, o-cymene, and benzaldehyde. In other research findings, it is believed the majority of the odor in the flowers is linked to pinene, limonene, and terpinolene.

[1] Odor descriptor wheel obtained from St. Croix Sensory.
[2] Thiol is an organosulfur compound that can generate offensive odors.

Terpenes which are either commonly identified and/or thought to warrant further evaluation for odor impacts include: myrcene, pinene, limonene, b-caryophyllene, terpinolene, nonanal, decanol, o-cymene, and benzaldehyde. Utilizing published literature-based odor detection thresholds (where available) for these chemical compounds yields a range of 1 part per billion (ppb) to 3,500 ppb. Literature-based odor detection thresholds can vary widely (by orders of magnitude) for the same chemical compound.

Dispersion modeling has been conducted by other counties to determine distance that cannabis odor may be detected. This modeling indicated that specific cannabis compounds may be detectable at a distance of 2 miles or more depending on weather conditions (Kern County 2017:4.3-66 and 4.3-67).

Cannabis grown in enclosed, indoor environments (buildings and greenhouses) results in a concentration of odor-causing chemicals which can result in to the generation of significant odors within the internal air space. It has been reported that greenhouses can generate odor with strengths ranging from 30,000 to 50,000 odor units (COC, 2018). This implies that the untreated indoor air would need to be diluted up to 50,000 times with clean air to be reduced to levels which are no longer detectable to humans with normal odor sensitivity. While containment of cannabis in buildings is an effective means of addressing odors, unfiltered release of odors from vents or doors do generate concentrated odors into the surrounding areas that can create nuisances to off-site land uses and sensitive receptors.

Public Health/Nuisance Issues

In a review of recent scientific publications, there were no studies which evaluated the health effects associated with exposure to cannabis odors. An evidence brief prepared by Public Health Ontario (Public Health Ontario, Canada 2018) states that “most substances responsible for odors in the outdoor air are not present at levels that can cause long-term health effects. However, exposure to unpleasant odors may affect an individual’s quality of life and sense of well-being.” This statement was in context to odors in general and not specific to cannabis odors. The City of Denver prepared a Cannabis Environmental Best Management Practices document (City of Denver, Colorado 2018), which states that while “the rate of VOC [volatile organic compound] emissions from cannabis cultivation facilities is relatively unknown…. [T]hese VOCs from the cannabis industry typically do not pose a direct threat to human health.” Although research is limited, it is generally agreed that concentrated cannabis odors do not create a public health concern for receptors. Odor issues are discussed in further detail in Section 3.3.3, Environmental Impacts and Mitigation Measures, below.

Examples of Odor Regulations in Other Jurisdictions

There are no numerical odor thresholds (such as a D/T or an intensity rating) established at the local level by an air district or at the state level in California. As shown in Table 3.3-3, there are other states that have established numerical thresholds for all odor types along with an established frequency and receptor location (e.g., property line, off property, sensitive receptor). Compliance with these numerical odor thresholds is determined off property with tools such as a field olfactometer, dynamic olfactometer (in an odor laboratory) or through odor dispersion modeling. The sense of smell, like vision and hearing, is logarithmic. The Nasal Ranger measures 2 D/T, 4 D/T, 7 D/T, 15 D/T, 30 D/T, and 60 D/T odor strength ratios, essentially doubling the amount of clean air added to the odorous air each test measurement, to reflect an increment of change that would be perceptible to the human nose.

Table 3.3-3 Ambient Air Odor Threshold Examples

Jurisdiction	Ambient Air Odor Threshold	Observed Frequency of Potential Violation	Observed Location	Regulatory Citation (cites to a relevant law, rule or ordinance)
Colorado[1]	7 D/T (residential/commercial) 15 D/T (all other areas) 127 D/T (violation level)	2 measurements in 1 hour separated by 15 minutes	Outside the property line	Regulation Number 2
Connecticut	7 D/T	3 samples or observations in 1 hour separated by 15 minutes	Ambient air (off-property)	Section 22a-174-23
Illinois	8 D/T (residential) 16 D/T (other land uses) 24 D/T (industrial property line)	2 out of 3 positive determinations where 2 observations are 15 minutes apart within 1 hour with 3 person team	On or adjacent to specified land use	Title 35, Part 245
Kentucky	7 D/T	At any time	Ambient air	401 KAR 53:010
Nevada	8 D/T	2 measurements in 1 hour separated by 15 minutes[2]	Places of occupancy	NAC 445B.22087
North Dakota	7 D/T	May not discharge at 7 D/T or higher	Property boundary for sources in City; residential/near public receptor for sources outside of City[3]	Chapter 33-15-16
Wyoming	7 D/T	2 measurements in 1 hour separated by at least 15 minutes	Odor producer property line	WDEQ Chapter 2 Section 11

1 Colorado also has industry specific thresholds for swine, which are not summarized in the table above.

2 Nevada requires investigation when 30% or more of sample of people are exposed to odor and believe it to be objectionable; sample must be at least 20 people or 75% of those exposed if sample is less than 20 people exposed.

3 North Dakota has an additional provision for agricultural operations that have been in operation for more than 1 year and the business or residence making the complaint was built/established after the agricultural operation. There are different thresholds depending on whether the complainant is in the City or outside of the City. In this situation, for a complainant in the City, measurement must be taken within 100 ft of established residence rather than the property boundary of the agricultural operation, and the measurement may not be taken within 500 ft of the property boundary of the agricultural operation. See rule for additional provision for complainants located outside of the City.

Prepared by Trinity Consultants 2019

As shown above, many states are using 7 D/T as an odor nuisance threshold. Many states require multiple observations within an hour to establish a nuisance. However, some jurisdictions establish alternative thresholds or do not allow any odor in excess of 7 D/T (Kentucky and North Dakota). There is also some variability in where the odor must be observed or measured to constitute a nuisance (property line vs. receptor location). The 7 D/T standard is based on scientific publications on odor pollution control that have identified that odors above 7 D/T will often result in complaints (i.e., objectionable), with 15 D/T often described as a nuisance, and odors above 30 D/T described as a serious nuisance (i.e., nauseating) (McGinley 2000 and Huey et al. 1960).

The use of an olfactometer and D/T provides the strength of an odor. Examples of odor types that have been documented at the 7 D/T standard includes the following:

- Wastewater treatment plant site (on the site): smelled like a musty/musky odor
- Compost facility that accepts biosolids and food waste (across the street): smelled like manure septic odor
- Compost facility (adjacent to the site): smelled like an earthy/urine odor

- Agricultural area (adjacent to the field): smelled like a grassy odor (Wanger 2019)

Recently, the City of Denver updated its odor ordinance. The update focused on specific industry types, including cannabis (grows and cannabis-infused products). Businesses must develop and submit an Odor Control Plan (OCP) if they:

- fall within a regulated industry (together, cannabis grows and cannabis-infused products are one of the regulatory industry categories);
- have received five or more complaints from individuals in separate households/businesses within a 30-day period; or
- emit odorous contaminants that exceed state regulatory standards for odor intensity (7 D/T).

An OCP must include compliance monitoring obligations. If noncompliance is identified, it could lead to a citation. It is common to see the requirement for an OCP in municipality ordinances. Use of an OCP and/or establishment of other applicable best practices in addition to numerical limits, are common methods for regulating odor.

Cannabis Odor Complaints in Yolo County

As described in Chapter 2, “Description of Preferred Alternative and Equal Weight Alternatives,” there are 78 existing and eligible cannabis cultivation sites operating in the County. The Yolo County Cannabis Task Force investigates complaints regarding cannabis operations that include the verification of odor complaints. The process consists of the following:

- Complaint is logged through a geographic information system (automatically for e-complaints; by County staff for phone complaints).
- County staff contact the reporting party to discuss complaint with them and gather additional details.
- County staff attempt to verify odor complaint in the field.
- County staff investigate to determine if the odor could be coming from a personal or illegal grow.
- If an odor complaint is verified in the field, County staff sends email communication to the party it believes may have caused odor complaint. This communication requests correction of the odor nuisance.
- County staff may issue a Notice of Violation pursuant to Yolo County Code Section 5-20.11, requiring abatement of the odor nuisance within 72 hours.

The County has received 17 odor complaints that consist of multiple contacts between October 2017 and January 2019. The majority of these complaints were received during the summer and fall months when cannabis is ready for harvest. These complaints were associated with cultivation sites along the State Route (SR) 16 corridor west of Woodland and sites along SR 128 and Interstate 505 (I-505) south of SR 16. Weather conditions associated with these complaints generally consisted of calm weather conditions (light wind and temperatures ranging from 75 to 95°F).

SENSITIVE RECEPTORS

Sensitive receptors relative to air quality conditions are locations where human populations, especially children, seniors, and persons with poor health are found, and there is reasonable expectation of continuous human exposure according to the averaging period for ambient air quality standards. Sensitive receptors defined by the 2030 Countywide General Plan (General Plan) include residentially designated land uses, hospitals, schools, hotels and lodgings, and neighborhood parks (Yolo County 2009:CO-83). In general, these sensitive receptors are concentrated in the incorporated cities and unincorporated communities in the County; however, scattered rural residences are also located throughout the undeveloped or rural lands. Rural residences located in agricultural designated land areas of the County are not considered sensitive receptors under the General Plan.

3.3.2 Regulatory Setting

FEDERAL

U.S. Environmental Protection Agency

EPA has been charged with implementing national air quality programs. EPA's air quality mandates are drawn primarily from the federal Clean Air Act (CAA), which was enacted in 1970. The most recent major amendments made by Congress were in 1990.

<u>Criteria Air Pollutants</u>

The CAA required EPA to establish NAAQS. As shown in Table 3.3-4, EPA has established primary and secondary NAAQS for the following criteria air pollutants: ozone, CO, NO_2, SO_2, PM_{10} and $PM_{2.5}$, and lead. The primary standards protect public health and the secondary standards protect public welfare. The CAA also required each state to prepare a SIP for attaining and maintaining the NAAQS. The federal Clean Air Act Amendments of 1990 (CAAA) added requirements for states with nonattainment areas to revise their SIPs to incorporate additional control measures to reduce air pollution. The SIP is modified periodically to reflect the latest emissions inventories, planning documents, and rules and regulations of the air basins as reported by their jurisdictional agencies. EPA is responsible for reviewing all SIPs to determine whether they conform to the mandates of the CAA and its amendments, and whether implementation will achieve air quality goals. If EPA determines a SIP to be inadequate, a federal implementation plan that imposes additional control measures may be prepared for the nonattainment area. If an approvable SIP is not submitted or implemented within the mandated time frame, sanctions may be applied to transportation funding and stationary air pollution sources in the air basin.

EPA and the National Highway Traffic Safety Administration (NHTSA) regulate emissions from on-road vehicles. In 2012, EPA and NHTSA, issued final rules to further reduce emissions and improve corporate average fuel economy (CAFE) standards for light-duty vehicles for model years 2017 and beyond (77 Federal Register [FR] 62624). These rules would increase fuel economy to the equivalent of 54.5 miles per gallon (77 FR 62630). Transportation plans, such as this, rely on steadily cleaner tailpipe emissions from motor vehicles to achieve federal clean air standards (e.g., Conformity). However, on April 2, 2018, EPA administrator announced a final determination that the current standards should be revised. On August 2, 2018, the U.S. Department of Transportation (DOT) and EPA proposed the Safer Affordable Fuel-Efficient Vehicles Rule (SAFE Rule), which would amend existing CAFE standards for passenger cars and light trucks, and retaining the current model year 2020 standards through model year 2026, establish new standards covering model years 2021 through 2026. Vehicles operating in the County would be subject to the CAFE standards. However, at the time of writing this Draft EIR, the SAFE Rule has not been formally adopted by EPA, and 17 states—including California—have filed a lawsuit against EPA. The timing for ultimate approval of the SAFE Rule and the outcome of any pending or potential lawsuits (and how such could delay or affect its implementation) are unknown at this time. The SAFE Rule's impact on future motor vehicle emissions is also unknown.

Further, though the U.S. Congress preempted states from issuing any standard relating to the control of emissions from new motor vehicles, an exception was made for California in recognition of California's policy leadership and its particular problems with smog caused by vehicles. Congress included a carve-out for California that is still enshrined in the CAA today. This special exemption allows California to issue its own vehicle emission standards if it seeks a federal preemption "waiver" from EPA. As long as California's vehicle emission standards protect public health and welfare at least as strictly as federal law and are necessary to meet compelling and extraordinary conditions, the law requires EPA to grant California's request for a preemption waiver. Each time California adopts new vehicle emission standards, the state applies to EPA for a preemption waiver for those standards (e.g., over 100 have been approved). However, EPA is also proposing, in addition to the SAFE Rule but as a separate action, to revoke California's waiver that would allow the state to keep the 2021-2025 standards in place. The ultimate revocation of California's waiver and the outcome of any related lawsuits (and how such could delay or affects its implementation) is unknown at this time alongside on how future motor vehicle emissions could be affected. However, if less strict standards for model years 2021 through 2026 were actually implemented, emissions could increase.

Table 3.3-4 Ambient Air Quality Standards

Pollutant	Averaging Time	California (CAAQS)[a,b]	National (NAAQS)[c]	
			Primary[b,d]	Secondary[b,e]
Ozone	1-hour	0.09 ppm (180 μg/m^3)	–[e]	Same as primary standard
	8-hour	0.070 ppm (137 μg/m^3)	0.070 ppm (147 μg/m^3)	
Carbon monoxide (CO)	1-hour	20 ppm (23 mg/m^3)	35 ppm (40 mg/m^3)	Same as primary standard
	8-hour	9 ppm[f] (10 mg/m^3)	9 ppm (10 mg/m^3)	
Nitrogen dioxide (NO_2)	Annual arithmetic mean	0.030 ppm (57 μg/m^3)	53 ppb (100 μg/m^3)	Same as primary standard
	1-hour	0.18 ppm (339 μg/m^3)	100 ppb (188 μg/m^3)	–
Sulfur dioxide (SO_2)	24-hour	0.04 ppm (105 μg/m^3)	–	–
	3-hour	–	–	0.5 ppm (1300 μg/m^3)
	1-hour	0.25 ppm (655 μg/m^3)	75 ppb (196 μg/m^3)	–
Respirable particulate matter (PM_{10})	Annual arithmetic mean	20 μg/m^3	–	Same as primary standard
	24-hour	50 μg/m^3	150 μg/m^3	
Fine particulate matter ($PM_{2.5}$)	Annual arithmetic mean	12 μg/m^3	12.0 μg/m^3	15.0 μg/m^3
	24-hour	–	35 μg/m^3	Same as primary standard
Lead[f]	Calendar quarter	–	1.5 μg/m^3	Same as primary standard
	30-Day average	1.5 μg/m^3	–	–
	Rolling 3-Month Average	-	0.15 μg/m^3	Same as primary standard
Hydrogen sulfide	1-hour	0.03 ppm (42 μg/m^3)	No national standards	
Sulfates	24-hour	25 μg/m^3		
Vinyl chloride[f]	24-hour	0.01 ppm (26 μg/m^3)		
Visibility-reducing particulate matter	8-hour	Extinction of 0.23 per km		

Notes: μg/m^3 = micrograms per cubic meter; km = kilometers; ppb = parts per billion; ppm = parts per million (by volume).

[a] California standards for ozone, carbon monoxide, SO_2 (1- and 24-hour), NO_2, particulate matter, and visibility-reducing particles are values that are not to be exceeded. All others are not to be equaled or exceeded. California ambient air quality standards are listed in the Table of Standards in Section 70200 of Title 17 of the California Code of Regulations.

[b] Concentration expressed first in units in which it was promulgated. Equivalent units given in parentheses are based on a reference temperature of 25 degrees Celsius (°C) and a reference pressure of 760 torr. Most measurements of air quality are to be corrected to a reference temperature of 25°C and a reference pressure of 760 torr; ppm in this table refers to ppm by volume, or micromoles of pollutant per mole of gas.

[c] National standards (other than ozone, particulate matter, and those based on annual averages or annual arithmetic means) are not to be exceeded more than once a year. The ozone standard is attained when the fourth highest 8-hour concentration in a year, averaged over 3 years, is equal to or less than the standard. The PM_{10} 24-hour standard is attained when the expected number of days per calendar year with a 24-hour average concentration above 150 μg/m^3 is equal to or less than 1. The $PM_{2.5}$ 24-hour standard is attained when 98 percent of the daily concentrations, averaged over 3 years, are equal to or less than the standard.

[d] National primary standards: The levels of air quality necessary, with an adequate margin of safety to protect the public health.

[e] National secondary standards: The levels of air quality necessary to protect the public welfare from any known or anticipated adverse effects of a pollutant.

[f] The California Air Resources Board has identified lead and vinyl chloride as toxic air contaminants with no threshold of exposure for adverse health effects determined. This allows for the implementation of control measures at levels below the ambient concentrations specified for these pollutants.

Source: CARB 2016b

<u>Toxic Air Contaminants/Hazardous Air Pollutants</u>

TACs (also known as hazardous air pollutants (HAPs) for federal purposes), are a defined set of airborne pollutants that may pose a present or potential hazard to human health. A TAC is defined as an air pollutant that may cause or contribute to an increase in mortality or in serious illness, or that may pose a hazard to human health. TACs are usually present in minute quantities in the ambient air; however, their high toxicity or health risk may pose a threat to public health even at low concentrations.

A wide range of sources, from industrial plants to motor vehicles, emit TACs. The health effects associated with TACs are quite diverse and generally are assessed locally, rather than regionally. TACs can cause long-term health effects such as cancer, birth defects, neurological damage, asthma, bronchitis or genetic damage; or short-term acute affects such as eye watering, respiratory irritation (a cough), running nose, throat pain, and headaches.

For evaluation purposes, TACs are separated into carcinogens and noncarcinogens based on the nature of the physiological effects associated with exposure to the pollutant. Carcinogens are assumed to have no safe threshold below which health impacts would not occur. This contrasts with criteria air pollutants, for which acceptable levels of exposure can be determined and for which ambient standards have been established (Table 3.3-4). Cancer risk from TACs is expressed as excess cancer cases per one million exposed individuals, typically over a lifetime of exposure.

EPA and, in California, CARB regulates HAPs and TACs, respectively, through statutes and regulations that generally require the use of the maximum available control technology or best available control technology for toxics to limit emissions.

STATE

CARB is the agency responsible for coordination and oversight of state and local air pollution control programs in California and for implementing the California Clean Air Act (CCAA). The CCAA, which was adopted in 1988, required CARB to establish CAAQS (Table 3.3-4).

Criteria Air Pollutants

CARB has established CAAQS for sulfates, hydrogen sulfide, vinyl chloride, visibility-reducing particulate matter, and the above-mentioned criteria air pollutants. In most cases the CAAQS are more stringent than the NAAQS. Differences in the standards are generally explained by the health effects studies considered during the standard-setting process and the interpretation of the studies. In addition, the CAAQS incorporate a margin of safety to protect sensitive individuals.

The CCAA requires that all local air districts in the state endeavor to attain and maintain the CAAQS by the earliest date practical. The CCAA specifies that local air districts should focus particular attention on reducing the emissions from transportation and area-wide emission sources, and provides air districts with the authority to regulate indirect emission sources.

Toxic Air Contaminants

TACs in California are regulated primarily through the Tanner Air Toxics Act (AB 1807, Chapter 1047, Statutes of 1983) and the Air Toxics Hot Spots Information and Assessment Act of 1987 (Hot Spots Act) (AB 2588, Chapter 1252, Statutes of 1987). The Tanner Air Toxics Act sets forth a formal procedure for CARB to designate substances as TACs. Research, public participation, and scientific peer review are required before CARB can designate a substance as a TAC. To date, CARB has identified more than 21 TACs and adopted EPA's list of HAPs as TACs. Most recently, diesel PM was added to CARB's list of TACs.

After a TAC is identified, CARB adopts an airborne toxics control measure for sources that emit that particular TAC. If a safe threshold exists for a substance at which there is no toxic effect, the control measure must reduce exposure below that threshold. If no safe threshold exists, the measure must incorporate best available control technology for toxics to minimize emissions.

The Hot Spots Act requires that existing facilities that emit toxic substances above a specified level prepare an inventory of toxic emissions, prepare a risk assessment if emissions are significant, notify the public of significant risk levels, and prepare and implement risk reduction measures.

AB 617 (Chapter 136, Statutes of 2017) aims to help protect air quality and public health in communities around industries subject to the state's cap-and-trade program for GHG emissions, AB 617 imposes a new state-mandated local program to address nonvehicular sources (e.g., refineries, manufacturing facilities) of criteria air pollutants and TACs. The law requires CARB to identify high-pollution areas and directs air districts to focus air quality improvement efforts through adoption of community emission reduction programs within these identified areas. Currently, air districts review individual sources and impose emissions limits on emitters based on best available control technology, pollutant type, and proximity to nearby existing land uses. This law addresses the cumulative and additive nature of air pollutant health effects by requiring community-wide air quality assessment and emission reduction planning.

CARB has adopted diesel exhaust control measures and more stringent emissions standards for various transportation-related mobile sources of emissions, including transit buses, and off-road diesel equipment (e.g., tractors, generators). Over time, the replacement of older vehicles will result in a vehicle fleet that produces substantially lower levels of TACs than under current conditions. Mobile-source emissions of TACs (e.g., benzene, 1-3-butadiene, diesel PM) have been reduced significantly over the last decade and will be reduced further in California through a progression of regulatory measures (e.g., Low Emission Vehicle/Clean Fuels and Phase II reformulated gasoline regulations) and control technologies. With implementation of CARB's Risk Reduction Plan, it is expected that diesel PM concentrations will be 85 percent less in 2020 in comparison to year 2000 (CARB 2000). Adopted regulations are also expected to continue to reduce formaldehyde emissions emitted by cars and light-duty trucks. As emissions are reduced, it is expected that risks associated with exposure to the emissions will also be reduced.

California Code of Regulations

The following requirements are included in the CalCannabis regulations, CCR, Title 3, Division 8, Chapter 1 and pertain to cultivation sites.

<u>Section 8306. Generator Requirements</u>

(a) For the purposes of this section, "generator" is defined as a stationary or portable compression ignition engine pursuant to title 17, division 3, chapter 1, subchapter 7.5, section 93115.4 of the California Code of Regulations.

(b) Licensees using generators rated at 50 horsepower and greater shall demonstrate compliance with either, as applicable, the Airborne Toxic Control Measure for stationary engines pursuant to title 17, division 3, chapter 1, subchapter 7.5, sections 93115 through 93115.15 of the California Code of Regulations, or the Airborne Toxic Control Measure for portable engines pursuant to title 17, division 3, chapter 1, subchapter 7.5, sections 93116 through 93116.5 of the California Code of Regulations. Compliance shall be demonstrated by providing a copy of one of the following to the department upon request:

  (1) For portable engines, a Portable Equipment Registration Certificate provided by the California Air Resources Board; or

  (2) For portable or stationary engines, a Permit to Operate, or other proof of engine registration, obtained from the Local Air District with jurisdiction over the licensed premises.

(c) Licensees using generators rated below 50 horsepower shall comply with the following by 2023:

  (1) Either (A) or (B):

(A) Meet the “emergency definition for portable engines in title 17, division 3, chapter 1, subchapter 7.5, sections 93116.2(a)(12) of the California Code of Regulations, or the “emergency use” definition for stationary engines in title 17, division 3, chapter 1, subchapter 7.5, section 93115.4(a)(30); or

(B) Operate 80 hours or less in a calendar year; and

(2) Either (A) or (B):

(A) Meet Tier 3 with Level 3 diesel particulate filter requirements pursuant to title 13, division 3, chapter 14, sections 2700 through 2711 of the California Code of Regulations;

(B) Meet Tier 4, or current engines requirements if more stringent, pursuant to title 40, chapter 1, subchapter U, part 1039, subpart B, section 1039.101 of the Code of Federal Regulations.

(d) All generators shall be equipped with non-resettable hour-meters. If a generator does not come equipped with a non-resettable hour-meter an after-market non-resettable hour-meter shall be installed.

LOCAL

Yolo-Solano Air Quality Management District

The Yolo-Solano Air Quality Management District (YSAQMD) attains and maintains air quality conditions in Yolo and Solano Counties through a comprehensive program of planning, regulation, enforcement, technical innovation, and promotion of the understanding of air quality issues. The clean air strategy of YSAQMD includes the preparation of plans and programs for the attainment of ambient air quality standards, adoption and enforcement of rules and regulations, and issuance of permits for stationary sources. YSAQMD also inspects stationary sources, responds to citizen complaints, monitors ambient air quality and meteorological conditions, and implements other programs and regulations required by the CAA, CAAA, and CCAA.

All projects are subject to adopted YSAQMD rules and regulations in effect at the time of construction. Specific rules applicable to the construction of the project may include but are not limited to the following (YSAQMD 2016a):

- **Rule R2-3: Ringelmann Chart.** This rule prohibits stationary diesel-powered equipment from generating visible emissions that would exceed the rule’s visibility threshold. This would apply to diesel-powered off-road equipment or generators used at commercial cannabis sites.

- **Rule R2-5: Nuisance.** This rule prohibits any source from generating air contaminants or other materials that would cause injury, detriment, nuisance, or annoyance to the public; endanger the comfort, repose, health, or safety of the public; or damage businesses or property. This would apply to commercial noncultivation cannabis sites such as manufacturing uses.

- **Rule R2-6: Additional Exemption**. The provisions of Rule 2.5. do not apply to odors emanating from agricultural operations in the growing of crops or raising of fowl, animals, or bees.

- **Rule R2-11: Particulate Matter Concentration.** This rule prohibits any source that would emit dust, fumes, or total suspended particulate matter from generated emissions that would exceed the rule’s established emission concentration limit. This would apply to diesel-powered off-road equipment or generators used at commercial cannabis cultivation sites.

- **Rule R2-14: Architectural Coatings.** This rule establishes volatile organic compound (VOC) content limits for all architectural coatings supplied, sold, offered for sale, applied, solicited for application, or manufactured within YSAQMD’s jurisdiction. This would apply to all buildings at commercial cannabis sites.

- **Rule R2-16: Fuel Burning Heat or Power Generators.** This rule prohibits operation of non-mobile fuel burning equipment, such as boilers, generators, and furnaces, that exceed 200 pounds (lb) per hour of sulfur compounds, 140 lb per hour of nitrous oxides (NO_X), or 40 lb per hour of PM emissions from exhaust. This rule exempts emergency generators. This would apply to generators used at commercial cultivation cannabis sites.

- **Rule R3-1: General Permit Requirements.** This rule establishes permitting processes (i.e., Authority to Construct and Permit to Operate) to review new and modified sources of air pollution. This would apply to off-road equipment used at commercial cannabis sites.

- **Rule R9-9: Asbestos.** This rule limits the emission of asbestos to the atmosphere and requires appropriate work practice standards and waste disposal procedure, applicable to all non-exempt renovations or demolitions. This would apply to relocated commercial cannabis sites or sites renovating existing buildings.

YSAQMD's CEQA Handbook also provides a list of feasible mitigation measures to reduce fugitive dust PM_{10} emissions from construction activities that is required by all projects (YSAQMD 2007:27). This list includes the following:

- Water all active construction sites at least twice daily. Frequency should be based on the type of operation, soil, and wind exposure.

- Haul trucks shall maintain at least 2 feet of freeboard.

- Cover all trucks hauling dirt, sand, or loose materials.

- Apply nontoxic binders (e.g., latex acrylic copolymer) to exposed areas after cut and fill operations and hydroseed area.

- Apply chemical soil stabilizers on inactive construction areas (disturbed lands within construction projects that are unused for at least 4 consecutive days).

- Plant tree windbreaks on the windward perimeter of construction projects if adjacent to open land.

- Plant vegetative ground cover in disturbed areas as soon as possible.

- Cover inactive storage piles.

- Sweep streets if visible soil material is carried out from the construction site.

- Treat accesses to a distance of 100 feet from the paved road with a 6- to 12-inch layer of woodchips or mulch, or

- Treat accesses to a distance of 100 feet from the paved road with a 6-inch layer of gravel.

Criteria Air Pollutants

The CCAA requires districts to submit air quality plans for areas that do not meet state standards for ozone, CO, SO_2, NO_2, PM_{10}, and $PM_{2.5}$. YSAQMD has attained all standards with the exception of ozone and PM (YSAQMD 2016b). The CCAA does not currently require attainment plans for PM. For the attainment and maintenance of ozone, in July 2016, YSAQMD adopted its 2015 Triennial Plan Update which examined air quality conditions for 2012–2014 and documents efforts made by YSAQMD to improve air quality (YSAQMD 2016c).

In addition, as a part of the Sacramento federal ozone nonattainment area, YSAQMD works with the Sacramento Metropolitan Air Quality Management District to develop a regional air quality management plan under CAA requirements. The 2017 Sacramento Regional 2008 8-Hour Ozone Attainment and Further Reasonable Progress Plan was approved by CARB on November 16, 2017. The previous 2013 Update to the 8-Hour Ozone Attainment and Reasonable Further Progress Plan was approved and promulgated by EPA for the 1997 8-Hour Ozone Standard. EPA has not released notice of approval and promulgation of the 2017 SIP (CARB 2017).

Toxic Air Contaminants

At the local level, air pollution control or management districts may adopt and enforce CARB's control measures. Under YSAQMD Rule R3-1 ("General Permit Requirements"), Rule R3-4 ("New Source Review"), and Rule R3-8 ("Federal Operating Permits"), all sources that may possess the potential to emit TACs are required to obtain permits from the district. Permits may be granted to these operations if they are constructed and operated in accordance with applicable regulations, including new source review standards (see Rule R3-4 above) and air-toxics control measures. YSAQMD limits emissions and public exposure to TACs through many programs. YSAQMD prioritizes the permitting of TAC-emitting stationary sources based on the quantity and toxicity of the TAC emissions and the proximity of the facilities to sensitive receptors and land uses.

Sources that require a permit are analyzed by YSAQMD (e.g., health risk assessment) based on their potential to emit toxics. If it is determined that the project will emit toxics in excess of YSAQMD's threshold of significance for TACs (see Section 3.3.3, below), sources will have to implement BACT for TACs to reduce emissions. If a source cannot reduce the risk below the threshold of significance even after BACT has been implemented, YSAQMD will deny the permit required by the source. This helps to apply new technology when retrofitting with respect to TACs. Although YSAQMD regulates sources that generate TACs, it does not regulate land uses that may be sited in locations exposed to TACs. The decision on whether to approve projects in TAC-exposed locations is typically the responsibility of the lead agency charged with determining whether to approve a project.

Yolo County

Yolo County 2030 Countywide General Plan

The General Plan includes the following air quality policies that are applicable to the project:

- Policy CC-4.9: Encourage construction and other heavy equipment vehicles (e.g., mining, agriculture, etc.) to use retrofit control devices.

- Policy CC-4.11: Site specific information shall be required for each application, subject to site conditions and available technical information, as determined by the County lead department, in order to enable informed decision-making and ensure consistency with the General Plan and with the assumptions of the General Plan EIR. Technical information and surveys requested may include, but not be limited to, the following: air quality and/or greenhouse gas emissions calculations, agricultural resource assessment/agricultural and evaluation and site assessment (LESA), biological resources assessment, cultural resources assessment, fiscal impact analysis, flood risk analysis, hydrology and water quality analysis, geotechnical/soils study, land use compatibility analysis, noise analysis, Phase One environmental site assessment, sewer capacity and service analysis, storm drainage capacity and service analysis, title report, traffic and circulation study, visual simulation and lighting study, and water supply assessment.

  When a technical study is required, it must cover the entire acreage upon which development is being proposed including any off-site improvements (e.g. wells; pumps; force mains; new roads; dirt borrow sites; etc.) that may be necessary. Technical studies must meet CEQA standards and the standards in the applicable industry. As necessary, the technical studies shall include recommendations that are to be implemented as part of the project.

- **Policy CO-6.1:** Improve air quality through land use planning decisions.
- **Action CO-A105:** For discretionary permits, require agricultural Best Management Practices regarding odor control, stormwater drainage, and fugitive dust control where appropriate.
- **Policy CO-6.6:** Encourage implementation of YSAQMD Best Management Practices, such as those that reduce emissions and control dust during construction activities.

3.3.3 Environmental Impacts and Mitigation Measures

METHODS AND ASSUMPTIONS

The impact analysis below evaluates to what extent adoption and implementation of the CLUO, including issuance of subsequent Cannabis Use Permits pursuant to the CLUO, may result in significant impacts to air quality. This program-level analysis is based upon current air quality data provided by CARB as described in Section 3.3-1, "Environmental Setting," and emissions modeling tools available from the California Air Pollution Control Officers Association. The design of site-specific cannabis projects is not known at this time, but this analysis uses the extent and general locations of future cannabis uses assumed under each of the five alternatives based on Table 2-4, Table 2-5, and Exhibits 2-4 through 2-8, which are provided in Chapter 2, "Description of Preferred Alternative and Equal Weight Alternatives," Section 3.0, "Approach to the Environmental Analysis," and Appendix D to provide an assessment and comparison of reasonably foreseeable outcomes from different regulatory scenarios.

Construction Emissions

Permitted commercial cannabis cultivation and noncultivation operations could result in an increase in emissions from short-term construction-related activities. Construction activities that may result in air quality-related impacts are assumed for each alternative to take place within the activity footprint of cannabis cultivation sites and noncultivation sites as described in Chapter 2, "Description of Preferred Alternative and Equal Weight Alternatives" (see Table 2-4) and Appendix D. Details about the extent of site relocation under each alternative due to compliance with zoning and buffer standards under the CLUO is included in Appendix D. The California Emissions Estimator Model (CalEEMod) Version 2016.3.2 was used to estimate emissions of criteria air pollutants and precursors associated with the construction and operation of the types and sizes of indoor, outdoor, mixed-light, and noncultivation operations that could be allowed under the CLUO. This modeling is based on the assumed size of each license type, as well as climatic conditions in the County. It was assumed that all permitted license types would be under construction for 6 months. Construction activities would likely require forklifts, graders, rubber-tired dozers, backhoes, welders, paving equipment, and off-road haul trucks. For details about construction assumptions used in the modeling, refer to Appendix E.

Construction of commercial cannabis uses under each alternative were analyzed individually by license type using YSAQMD's construction-related thresholds for development projects. Construction of all commercial cannabis uses that could be permitted under each alternative were analyzed collectively and evaluated for consistency with applicable air quality plans, as recommended by YSAQMD for plan-level documents.

Operational Emissions

Operation of cannabis uses were assumed to be contained within the identified activity footprint for cultivation and noncultivation sites, which can be found in Appendix D. CalEEMod was also used to estimate on-site operational emissions for cultivation and noncultivation sites, including emissions generated by maintenance activity, fertilizer application, and paint for paved parking lots. The application of paint for parking lots would result in off-gassing of ROG emissions from the painting of stripes, handicap symbols, directional arrows, and car space descriptions. Paved parking lots that would include painting were assumed for only noncultivation sites. CalEEMod default energy consumption rates were adjusted to account for energy efficiency improvements from the 2019 California Energy Code, which will result in a 30 percent reduction in energy consumption compared with the 2016 California Energy Code that is included in CalEEMod. Off-road equipment includes the use of a forklift for noncultivation sites, and the use of a utility vehicle for cultivation sites. Back-up diesel generators were also assumed to be used at mixed-light and indoor cultivation sites. These auxiliary uses were all modeled using CalEEMod. Refer to Appendix E for modeling assumptions and calculations. Operational emissions were estimated for each license type that would be permitted under the CLUO and it was assumed that these sites could be fully operational by 2022.

Operation of commercial cannabis uses under each alternative were analyzed individually by license type using YSAQMD's operational thresholds for development projects. Operation of all commercial cannabis uses that could be permitted under each alternative were analyzed collectively and evaluated for consistency with applicable air quality plans, as recommended by YSAQMD for plan-level documents.

As discussed in Section 3.14, "Transportation and Circulation," the project is not anticipated to generate notable changes in vehicle miles traveled as compared to existing conditions. Thus, mobile source emissions are not included in this analysis.

As described in Section 3.3.1, "Environmental Setting," odors are generally regarded as an annoyance rather than a health hazard. However, manifestations of a person's reaction to foul odors can range from psychological (e.g., irritation, anger, or anxiety) to physiological (e.g., circulatory and respiratory effects, nausea, vomiting, and headache). Odor is inherently complex because it is often caused by a mixture of chemical substances and has subjective components associated with human perception by the olfactory senses. Thus, the impact analysis qualitatively evaluates the potential of cannabis uses to create odors that create a public nuisance or adversely affect nearby residents or businesses using existing odor complaint data and research on odor control. The analysis also evaluates the effectiveness of Sections 8-21.1408(CC) and 8-2.1408(DD) of the CLUO to address odor issues.

Specific requirements of existing laws and regulations described in the regulatory setting as well as the proposed CLUO (see Appendix C) were assessed for their ability to avoid or reduce emissions of criteria air pollutants and precursors and odors.

Chapter 4, "Cumulative Impact and Overconcentration," contains a separate detailed analysis of the potential for cumulative effects not otherwise identified in this section, and effects from concentrations or clusters of multiple cannabis uses located in distinct subregions of the County.

THRESHOLDS OF SIGNIFICANCE

YSAQMD has developed guidance for use by lead agencies when preparing CEQA documents (YSAQMD 2007). YSAQMD has adopted CEQA thresholds of significance for evaluating impacts to air quality. YSAQMD has both project-level and plan-level thresholds of significance. Project-level thresholds are intended to be used for individual developments while plan-level thresholds are intended to be used for general plan amendments, redevelopment plans, specific area plans, annexations, and similar planning activities (YSAQMD 2007:7). This project consists of individual commercial cannabis uses that could be permitted under an adopted ordinance. Because of this, individual licenses and the total licenses allowed under the ordinance are evaluated using YSAQMD's thresholds for project and plan level analyses, respectively.

CEQA-related air quality thresholds of significance are tied to achieving or maintaining attainment designations with the NAAQS and CAAQS, which are scientifically substantiated, numerical concentrations of criteria air pollutants considered to be protective of human health.

In consideration of new and more stringent NAAQS and CAAQS adopted since 2000, YSAQMD identified numerical thresholds for project-generated emissions of criteria air pollutants and precursors that would determine whether a project's discrete emissions would result in a cumulative, regional contribution (i.e., significant) to the baseline nonattainment status of the YSAQMD. YSAQMD's quantitative thresholds of significance for project-level CEQA evaluation that may be used to determine the extent to which a project's emissions of criteria air pollutants and precursors would contribute to regional degradation of ambient air quality within the SVAB.

Using federal and state guidance pertaining to TACs/HAPs, YSAQMD developed cancer risk and noncancer health hazard thresholds for TAC exposure. Unlike criteria air pollutants, there is no known safe concentration levels of TACs. Moreover, TAC emissions contribute to the deterioration of localized air quality due to the dispersion characteristics of TACs, emissions do not cause regional-scale air quality impacts. The YSAQMD thresholds are designed to ensure that a source of TACs does not contribute to a localized, significant impact to existing or new receptors.

As such, for the purpose of this analysis, the following thresholds of significance are used to determine if project-generated emissions would produce a significant localized and/or regional air quality impact such that human health would be adversely affected. Additionally, the cumulative effect of all cannabis uses under each alternative that were assumed for analysis purposes are evaluated using the plan-level thresholds recommended by YSAQMD.

Per Appendix G of the CEQA Guidelines and YSAQMD recommendations, a project would have a significant impact on air quality if it would (YSAQMD 2007):

- conflict with or obstruct implementation of the applicable air quality plan from the cumulative development of all cannabis uses;

- cause construction-generated criteria air pollutant or precursor emissions to exceed the YSAQMD-recommended thresholds of 10 tons per year for ROG and NO_X, and 80 pounds per day for PM_{10} for an individual license;

- result in a net increase in long-term operational criteria air pollutant or precursor emissions that exceed the YSAQMD-recommended thresholds of 10 tons per year for ROG and NO_X, 80 lb per day for PM_{10}, and violation of a state ambient air quality standard for CO for an individual license; or

- result in other emissions (such as those leading to odors) adversely affecting a substantial number of people.

These thresholds also address the Mandatory Findings of Significance under State CEQA Guidelines Section 15065(a)(4) on whether the environmental effects of the project will cause adverse effect on human beings, either directly or indirectly. As described in Section 3.0, “Approach to the Environmental Analysis,” implementation of the CLUO would not result in the significant impacts related to the creation of local carbon monoxide concentrations from mobile sources or expose sensitive receptors to toxic air contaminant emissions. Therefore, these impact issue areas are not further evaluated.

IMPACT ANALYSIS

Impact AQ-1: Conflict with or Obstruct Implementation of Policies and Regulations Related to the Air Quality

The CLUO incorporates dust control, odor, and generator emission standards that are consistent with YSAQMD and state regulations, General Plan policies, and YSAQMD’s 2016 Triennial Assessment and Plan Update. This impact would be **less than significant** for all alternatives.

The following CLUO sections are consistent with nuisance provisions of YSAQMD Rule 2.5. These CLUO provisions are also consistent with General Plan Policies CC-4.9, CO-6.1, and CO-6.6 that identify measures for reducing air pollutant emissions.

- Section 8-2.1408(L) Dust Control: Permittees shall comply with the requirements of the Yolo-Solano Air Quality Management District related to control of dust. Cultivation sites shall ensure dust control in a manner consistent with standard agricultural practices.

- Section 8-2.1408(T) Generators: Use of generators (of any fuel type) is allowed for CDFA licensees. Use of generators for other use types is prohibited, except for temporary use in the event of a power outage or emergency. CDFA licensees must demonstrate compliance with the requirements of the Yolo-Solano Air Quality Management District, and Section 8306, Generator Requirements, of the CDFA Regulations.

- Section 8-2.1408(CC) Nuisance: Cannabis uses shall not create a public nuisance or adversely affect the health or safety of nearby residents or businesses by, among other things, creating dust, light, glare, heat, noise, noxious gases, odor, smoke, traffic, vibration, unsafe conditions, or other impacts, in excess of allowable thresholds, or be hazardous due to the use or storage of materials, processes, products, runoff, unauthorized releases or illegal disposal of wastes.

    1. Subject to subsection 7 below, it is unlawful and it shall be a public nuisance to cause or permit persistent cannabis odors. A persistent cannabis odor is one which is verified by persons of normal odor sensitivity (as defined by European Standard EN 13725) to exist for three consecutive days within any two-week period at a maximum dilution-to-threshold (D/T ratio of seven parts clean or filtered air to one-part filtered odorous air, 7:1), measured at the property line of the site, as a result of investigations resulting from subsection 2, below.

    2. Subject to subsection 7 below, for the purposes of this subsection, cannabis odors shall be deemed to be persistent if the County enforcement officer (i) independently determines that the cannabis odor violates the standards of subsection 1 above, and/or (ii) the County enforcement officer receives three or more complaints of cannabis odor representing separate residences or places of occupied business, of a cannabis odor emanating from the subject property for three consecutive days within any two-week period, that the enforcement officer determines violates the standards of subsection 1 above.

    3. Subject to subsection 7 below, nothing in this subsection shall be deemed to require three verified complaints before the County may initiate enforcement action. The County may determine that a public nuisance exists under this subsection if less than three verified complaints are received or if no complaints are received but County officials or employees observe cannabis odor conditions that violate this subsection.

    4. Failure to effectively resolve a public nuisance shall result in enforcement action, up to and including additional conditions, suspension and revocation of the County Cannabis Use Permit and/or County Cannabis License pursuant to the process below.

    5. The County applies a three-level citation system to cannabis nuisance violations. Depending on the severity, frequency, or the failure to resolve the cause of the violation, the County enforcement officer may issue an alert, a warning citation, or a Notice of Violation. The alert shall identify the problem, identify relevant code sections, discuss the abatement process, and identify corrective action. The warning citation shall identify the problem, document the history, and mandate specific abatement actions including submittal of a plan and schedule to remedy the problem. A Notice of Violation shall follow the procedures set forth in Section 5-20.10 (*this citation will be revised one the licensing ordinance is moved to Chapter 4 of Title 20*).

    6. Subject to subsection 7 below, if at any time during the citation system identified above in subsection 5, the County enforcement officer determines that the conditions at the site are deleterious to the health, safety, or general welfare of any one or more surrounding properties, or that the permittee and/or landowner is not acting in good faith or in a manner sufficient to timely

address the complaint, the County enforcement officer may bypass the citation process and take immediate steps to address the violation, including by abatement or any other lawful means.

7. Permittees operating in compliance with this article, in particular Section 8-2.1408(DD)(1), Odor Control, the terms of their Cannabis Use Permit, and other applicable laws shall be presumptively assumed to not cause or contribute to a public nuisance.

8. The County may elect not to investigate any complaint due to resource limitations or other matters. In addition, the County may elect not to investigate complaints submitted by complainants that submit more than three unsubstantiated complaints within a one-year period.

- Section 8-2.1408(DD) Odor Control:

1. The allowable threshold for cannabis odor shall be defined as a maximum dilution-to-threshold (D/T) ratio of seven parts clean or filtered air to one-part odorous air (7:1) measured at the property line of the site. Cannabis odor at or below this threshold shall be considered acceptable and shall not be considered a nuisance. Indoor and mixed light uses must install and maintain the following minimum equipment: an exhaust air filtration system with odor control that effectively minimizes internal odors from being emitted externally; an air system that creates negative air pressure between the facilities interior and exterior so that odors outside of the facility will not exceed the maximum dilution-to-threshold (allowable threshold), as defined herein; or other odor control system which effectively minimizes odor to a level compliant with the allowable threshold.

2. Applicants shall submit the following information: a. Identification and description of cannabis odor emitting activities and nature and characteristics of emissions. b. Description of procedures and engineering controls for reducing/controlling odors. c. Certification by a Professional Engineer or Qualified Odor Professional that the procedures and engineering controls proposed to control cannabis odors are consistent with accepted/available industry-specific best control technologies and methods designed to abate odor and will be effective in abating cannabis odors to the maximum dilution-to-threshold (allowable threshold), as defined herein, measured at the property line of the site. This shall be submitted in the form of an Odor Control Plan, subject to regular monitoring and reporting.

3. Odor control for outdoor activities may include different plant strains, smaller grow areas, relocation of outdoor activities indoors or in a mixed light facility, use of site design or other technology, odor easements over neighboring property, and/or other methods proven to be effective and accepted by the County.

YSAQMD's 2016 Triennial Assessment and Plan Update includes three measures to reduce ozone emissions through the regulation of architectural coatings, printing processes for graphic arts, and process boilers. Architectural coatings are the only source of ozone precursors associated with construction. All architectural coatings applied to cannabis sites would be required to comply with YSAQMD regulations for VOC content. There is no anticipated graphic art printing associated with cannabis sites, nor are process boilers anticipated to be used at cultivation nor noncultivation sites. Thus, the project would not conflict with the 2016 Triennial Assessment and Plan Update that aims to reduce ozone precursor emissions. Because the CLUO would not conflict with or obstruct implementation of policies and regulations related to air quality and odor, this impact, would be **less than significant** for all alternatives.

Mitigation Measures

No mitigation is required for any of the alternatives.

Impact AQ-2: Generate Construction-Related Emissions of Criteria Pollutants and Precursors That Exceed YSAQMD-Recommended Thresholds

Construction-generated emissions associated with adoption and implementation of the proposed CLUO, including subsequent Cannabis Use Permits pursuant to the adopted CLUO, would not exceed YSAQMD-recommended annual emissions of ROG and NO_X and maximum daily emissions of PM_{10} for individual permitted cannabis uses. Construction of each new site permitted under the CLUO would not contribute to an existing air quality violation and would not expose sensitive receptors to substantial pollutant concentrations. Construction of all sites permitted under the CLUO would be consistent with applicable air quality plans. This impact would be **less than significant** for all alternatives.

Section 8-2.1408(V) of the CLUO requires a County Grading Permit prior to construction activities for cannabis sites that require soil erosion control, and Section 8.2-1408(L) of the CLUO requires compliance with YSAQMD's dust mitigation measures. Additionally, these measures would reduce construction emissions from individual cannabis sites permitted under the CLUO. YSAQMD's 2016 Triennial Assessment and Plan Update includes three measures to reduce ozone emissions through the regulation of architectural coatings, printing processes for graphic arts, and process boilers. Architectural coatings are the only source of ozone precursors associated with construction. All architectural coatings applied to cannabis sites would be required to comply with YSAQMD regulations for VOC content. Thus, the project would not conflict with the 2016 Triennial Assessment and Plan Update that aims to reduce ozone precursor emissions.

Construction of individual commercial cultivation and noncultivation sites would require minimal earthwork, such as grading and clearing, and use of heavy-duty off-road equipment that would generate exhaust emissions and fugitive dust. Generally, the intensity of construction activity for cultivation sites would require clearing and grading of the site. It is assumed that approximately half of new cultivation sites would require the construction of greenhouses and other related buildings, while the other half would use pre-existing structures on the sites (see Section 3.0, "Approach to the Environmental Analysis," and Appendix D). Construction of individual noncultivation sites could involve the clearing of vegetation, grading, or other earth disturbance activities to establish an activity footprint; building construction; and paving of the parking lot. Building sizes could vary based on license type and are assumed to range from 1,000 square feet (sq. ft.) to 140,000 sq. ft. for both cultivation and noncultivation sites.

The construction of new individual cultivation and noncultivation sites would last approximately 6 months at each site. Emissions of fugitive PM_{10} and $PM_{2.5}$ dust would primarily be generated by ground-disturbance during site preparation and grading and would vary as a function of such parameters as travel on unpaved roads, soil silt content, soil moisture, wind speed, and the size of the disturbance area. PM_{10} and $PM_{2.5}$ would also be emitted in vehicle and equipment exhaust.

Construction of new cannabis uses would generate exhaust emissions and fugitive dust. Construction emission impacts of each alternative is evaluated below. Emissions of criteria air pollutants and ozone precursors are shown by individual cannabis use type in Table 3.3-5. Note that the columns in Table 3.3-5 are not additive; rather, each row in the table represents construction associated with a specific cannabis use site on a particular site. Refer to Appendix E for detailed modeling input parameters and results.

Table 3.3-5 Construction-Generated Emissions of Criteria Air Pollutants and Precursors for Each Cannabis Use Type

Cannabis Use	ROG (tons/year)	NO_X (tons/year)	PM_{10} (lb/day)	$PM_{2.5}$ (lb/day)
Cultivation				
Outdoor	0.4	0.7	7	4
Mixed-Light	0.9	0.9	9	4
Indoor	0.4	0.7	7	5
Noncultivation				

Table 3.3-5 Construction-Generated Emissions of Criteria Air Pollutants and Precursors for Each Cannabis Use Type

Cannabis Use	ROG (tons/year)	NO_X (tons/year)	PM_{10} (lb/day)	$PM_{2.5}$ (lb/day)
Nursery	1.1	1.1	21	12
Processing	0.1	0.4	1	1
Manufacturing	0.1	0.3	1	1
Testing	0.1	0.5	1	1
Distribution	<0.1	0.3	1	1
Retail	0.1	0.3	1	1
Microbusiness	<0.1	0.3	1	1
YSAQMD Thresholds of Significance	**10**	**10**	**80**	**N/A**
Exceeds Threshold?	**No**	**No**	**No**	**N/A**

Notes: ROG = reactive organic gases; NO_X = oxides of nitrogen; PM_{10} = respirable particulate matter; $PM_{2.5}$ = fine particulate matter; lb/day = pounds per day; YSAQMD = Yolo-Solano Air Quality Management District; N/A = not applicable.

Source: Modeling conducted by Ascent Environmental in 2019

As shown in Table 3.3-5, construction of relocated individual cultivation sites and new cannabis sites (cultivation and noncultivation uses) would not generate annual levels of ROG and NO_X and daily levels of PM_{10} that exceed applicable YSAQMD emission thresholds for a development project. Construction activities resulting from the project would not contribute substantially to Yolo County's nonattainment status for ozone and PM_{10} and would not result in an increase in the potential for adverse health impacts to occur from exposure to ozone and PM_{10}.

The addition of NO_X, which is a precursor to ozone, could result in an increase in ambient concentrations of ozone in Yolo County and, moreover, increase the likelihood that ambient concentrations exceed the CAAQS and NAAQS. As summarized in "Environmental Setting," above, human exposure to ozone may cause acute and chronic health impacts including coughing, pulmonary distress, lung inflammation, shortness of breath, and permanent lung impairment. YSAQMD's project-level thresholds were developed to meet the CAAQS and NAAQS, which are scientifically substantiated, numerical concentrations of criteria air pollutants considered to be protective of human health.

Alternatives 1, 2, 3, and 5 assume that personal use outdoor cultivation may occur in any zoning district on a parcel with a legal residence. Personal use outdoor cultivation of up to six plants is assumed to occur within pots or garden areas of such parcels. Alternative 4 would limit personal use cultivation to indoor only. These activities would likely involve no more than 100 square feet of land area and would be required to be outside of front yard and side yard setback areas. Given the minor extent of this potential ground disturbance contained within existing developed parcels, minimal criteria air pollutant and precursor emissions would be generated that would not exceed YSAQMD thresholds.

Alternative 1: Cultivation (Ancillary Nurseries and Processing Only) with Existing Limits (Existing Operations with CLUO) (CEQA Preferred Alternative)

While most of the existing licensed commercial cannabis cultivation operations would remain in their current locations, nine of the existing sites are assumed to be required to relocate under the CLUO zoning standards. No other construction activities are assumed to occur under this alternative. The relocated sites are assumed to either construct new buildings and infrastructure or occupy existing agricultural buildings and facilities (see Section 3.0, "Environmental Analysis Approach," and Appendix D). Construction emissions associated with relocated sites were quantified and are shown in Table 3.3-5 by cultivation type for an individual site and would not exceed applicable YSAQMD emission thresholds. Individual site construction would be required to comply with Sections 8-2.1408(L) and (V) of the CLUO, as well as YSAQMD Best Management Practices, which would further reduce construction emissions. Construction assumed under Alternative 1 could generate total of 12.6 tons per year of ROG, 15.0 tons per year of NO_x, 141 lbs per day of

PM_{10}, and 74 lbs per day of $PM_{2.5}$ if all constructed at the same time period. These amounts would not conflict with the General Plan or 2016 Triennial Assessment and Plan Update. Consistency with these applicable plans would meet YSAQMD's threshold for plan-level documents.

This impact would be **less than significant** under Alternative 1.

Alternative 2: All License Types with Moderate Limits

Under Alternative 2, it was assumed for analysis purposes that there would be two new cultivation sites constructed as well as a total of 52 new noncultivation uses of which up to 47 would be vertically integrated and constructed on single parcels (see Table 2-4 and Appendix D). Additionally, it was assumed for analysis purposes that 30 of the 78 existing cultivation sites would be relocated due to zoning and buffering standards under the CLUO. As described in Section 3.0, "Approach to the Environmental Analysis," and Appendix D, relocated sites would either construct new buildings and infrastructure or occupy existing agricultural buildings and facilities.

As shown in Table 3.3-5, construction of new individual sites and relocated cultivation sites assumed for analysis purposes would not generate annual levels of ROG and NO_X and daily levels of PM_{10} that exceed applicable YSAQMD emission thresholds. Individual site construction would be required to comply with Sections 8-2.1408(L) and (V) of the CLUO, as well as YSAQMD Best Management Practices, which would further reduce construction emissions. Construction of all cannabis uses that are assumed to be constructed in a single year under Alternative 2 could generate total of 30.9 tons per year of ROG, 54.6 tons per year of NO_x, 462 lbs per day of PM_{10}, and 263 lbs per day of $PM_{2.5}$. These would not conflict with the General Plan or 2016 Triennial Assessment and Plan Update. Consistency with these applicable plans would meet YSAQMD's threshold for plan-level documents.

For these reasons, this impact would be **less than significant** under Alternative 2.

Alternative 3: All License Types with High Limits

Under Alternative 3, it was assumed for analysis purposes that construction of all new individual cannabis uses would occur over 2 years (2021 and 2022) because of the extent of new cannabis uses assumed (see Section 3.0, "Environmental Analysis Approach," and Appendix D). This alternative is assumed to result in the construction of 82 new cultivation sites and a total of 104 new noncultivation uses of which up to 94 would be vertically integrated and constructed on single parcels (see Table 2-4 and Appendix D). Additionally, it was assumed for analysis purposes that nine of the 78 existing cultivation sites would be relocated under the CLUO zoning standards. The relocated sites would either construct new buildings and infrastructure or occupy existing agricultural buildings and facilities (Appendix D). As shown in Table 3.3-5, construction of new individual sites and relocated cultivation sites assumed for analysis purposes would not generate annual levels of ROG and NO_X and daily levels of PM_{10} that exceed applicable YSAQMD emission thresholds. Individual site construction would be required to comply with Sections 8-2.1408(L) and (V) of the CLUO, as well as YSAQMD Best Management Practices, which would further reduce construction emissions. Highest construction emissions assumed under Alternative 3 could generate total of 47.9 tons per year of ROG, 83.5 tons per year of NO_x, 714 lbs per day of PM_{10}, and 406 lbs per day of $PM_{2.5}$. These would not conflict with the General Plan or 2016 Triennial Assessment and Plan Update. Consistency with these applicable plans would meet YSAQMD's threshold for plan-level documents.

For these reasons, this impact would be **less than significant** under Alternative 3.

Alternative 4: Mixed-Light/Indoor License Types Only with Moderate Limits, No Hoop Houses or Outdoor Types

Under Alternative 4, it was assumed for analysis purposes that nine of the 78 existing cultivation sites would be relocated under the CLUO zoning standards. The relocated sites would either construct new buildings and infrastructure or occupy existing agricultural facilities. It was also assumed that 75 of the existing and eligible cannabis sites with outdoor cultivation would convert entirely to indoor or mixed-light (greenhouse) cultivation. This alternative is also assumed to result in the construction of 2 new mixed-light or indoor cultivation sites and a total of 52 new noncultivation uses of which up to 47 would be vertically integrated and constructed on single parcels. Refer to Section 3.0, "Approach to the Environmental Analysis," and

Appendix D for detailed descriptions of the construction assumptions for cannabis uses. As shown in Table 3.3-5, construction of new individual sites and relocated cultivation sites assumed for analysis purposes would not generate annual levels of ROG and NO_X and daily levels of PM_{10} that exceed applicable YSAQMD emission thresholds. Individual site construction would be required to comply with Sections 8-2.1408(L) and (V) of the CLUO, as well as YSAQMD Best Management Practices, which would further reduce construction emissions. Construction of all cannabis uses that are assumed to be constructed in a single year under Alternative 4 could generate total of 73.1 tons per year of ROG, 90.9 tons per year of NO_x, 812 lbs per day of PM_{10}, and 443 lbs per day of $PM_{2.5}$ (see Section 3.0, "Environmental Analysis Approach," and Appendix D). These would not conflict with the General Plan or 2016 Triennial Assessment and Plan Update. Consistency with these applicable plans would meet YSAQMD's threshold for plan-level documents.

For these reasons, this impact would be **less than significant** under Alternative 4.

Alternative 5: All License Types with Moderate Limits, within Agricultural Zones Only, No Retail

Under Alternative 5, it was assumed for analysis purposes that there would be two new cultivation sites constructed as well as a total of 50 new noncultivation uses of which up to 45 would be vertically integrated and constructed on single parcels (see Section 3.0, "Environmental Analysis Approach," and Appendix D). Additionally, it was assumed for analysis purposes that 30 of the 78 existing cultivation sites would be relocated due to zoning and buffering standards under the CLUO. The relocated sites would either construct new buildings and infrastructure or occupy existing agricultural facilities. As shown in Table 3.3-5, construction of new individual sites and relocated cultivation sites assumed for analysis purposes would not generate annual levels of ROG and NO_X and daily levels of PM_{10} that exceed applicable YSAQMD emission thresholds. Individual site construction would be required to comply with Sections 8-2.1408(L) and (V) of the CLUO, as well as YSAQMD Best Management Practices, which would further reduce construction emissions. Construction of all cannabis uses that are assumed to be constructed in a single year under Alternative 5 could generate total of 30.8 tons per year of ROG, 53.9 tons per year of NO_x, 459lbs per day of PM_{10}, and 261 lbs per day of $PM_{2.5}$. These would not conflict with the General Plan or 2016 Triennial Assessment and Plan Update. Consistency with these applicable plans would meet YSAQMD's threshold for plan-level documents.

For these reasons, this impact would be **less than significant** under Alternative 5.

Mitigation Measures

No mitigation is required for any of the alternatives.

Impact AQ-3: Create Long-Term Operational Emissions of Criteria Pollutants and Precursors That Exceed YSAQMD-Recommended Thresholds

Operation of commercial cannabis cultivation and noncultivation sites associated with adoption and implementation of the proposed CLUO, including subsequent Cannabis Use Permits pursuant to the adopted CLUO would result in ROG, NO_X, and PM_{10} emissions. Implementation of individual permitted cannabis uses under all alternatives would not exceed the YSAQMD thresholds of significance for development projects. Operation of all sites permitted under the CLUO would be consistent with applicable air quality plans. This impact would be **less than significant** for all alternatives.

The following CLUO requirements would address operational air quality.

- Section 8-2.1408(K) Driveway Access: Driveway approaches to County and State maintained roads shall be per current County Improvement Standards or Caltrans requirements, as applicable. An encroachment permit may be required. Controlled access entries must provide a rapid entry system (e.g. Knox Box approved by the local Fire District or fire service provider) for use by emergency personnel and provide adequate space for vehicles to access the lock without impeding the right-of-way. A County assigned street address is a requirement. The address must be posted and adhere to display requirements of the Fire Code. Permittees must demonstrate safe and adequate driveway access to the satisfaction of the County or Caltrans, as applicable, in compliance with applicable standards. Access considerations identified in Section 8-1.802 of the County Code shall apply. *(For the convenience of the reader these include: will the proposed use have access characteristics different from other permitted land uses; does the proposed access have inadequate design; will emergency vehicle access be impaired; would the proposed access adversely affect safe operations on the adjoining roadway system; are site distance, visibility, proximity to parking, drainage, turning radius, angle of intersection, vertical alignment, and pavement condition adequate for the proposed use and consistent/equitable in relation to access requirements for other permitted uses; proximity to other driveways and intersections; other relevant circumstances identified by the County).* Driveways shall have an all-weather surface, such as compacted gravel.

- Section 8-2.1408(O) Energy Use: Permittees shall demonstrate availability of adequate energy, and compliance with applicable local and regional energy saving goals. Permittees shall demonstrate use of energy efficient best practices for each proposed use type. Onsite generation of energy from clean and/or renewable sources is encouraged. Permittees shall purchase or generate a minimum of 50 percent renewable power through the Valley Clean Energy Alliance or other available energy purveyor. CDFA licensees must satisfy the requirements of Section 8305, Renewable Energy Requirements, of the CDFA Regulations (effective January 1, 2023).

Section 8-2.1408(T) of the CLUO requires compliance of generators with YSAQMD rules and CCR Section 8306. These measures would reduce operational emissions from individual cannabis sites permitted under the CLUO.

YSAQMD's 2016 Triennial Assessment and Plan Update includes three measures to reduce ozone emissions through the regulation of architectural coatings, printing processes for graphic arts, and process boilers. There is no anticipated graphic art printing associated with cannabis sites, nor are process boilers anticipated to be used at cultivation and noncultivation sites. Thus, the project would not conflict with the 2016 Triennial Assessment and Plan Update that aims to reduce ozone precursor emissions.

The cultivation and noncultivation sites permitted under the CLUO would result in long-term operational emissions of ROG, NO_X, PM_{10}, and $PM_{2.5}$. ROG and NO_X emissions would be generated by area sources, building energy, stationary sources, and off-road equipment. PM_{10} emissions would be generated from the use of off-road equipment. Because VMT from on-road sources would not be expected to be notably different than existing VMT, mobile-source emissions would not increase, as previously explained.

Emissions associated with the operation of cannabis-related sites across the County would be highest when the most cultivation operations are in harvest at the same time because additional workers are needed at each commercial cannabis cultivation site to work the harvest. The harvest of a single cultivation site of any type (i.e., outdoor, mixed-light, indoor) would occur over a 6-week period between three and four times per year.

As described in Chapter 2, "Description of Preferred Alternative and Equal Weight Alternatives," cannabis uses are required to generate 50 percent of their energy demand from renewable sources under the CLUO. It was also assumed for analysis purposes that all existing cultivation sites would comply with the renewable energy requirement of the CLUO and is included in the emissions modeling. All new and relocated cultivation and noncultivation sites were assumed to meet the 2019 California Energy Code.

Regional area-source and off-road equipment emissions of criteria pollutants and precursors associated with adoption and implementation of the proposed CLUO were modeled using CalEEMod. This includes the use of fertilizers, landscaping equipment, backup diesel generators at mixed-light and indoor cultivation sites, and the use of a utility vehicle at outdoor and mixed-light cultivation sites. CCR Section 8306 would require backup diesel generators to meet Tier 3 with Level 3 diesel particulate filter requirements or Tier 4 engines standards beginning in 2023.

Air quality impacts for each alternative is evaluated below. Emissions of criteria air pollutants and ozone precursors associated with operation are shown by license type in Table 3.3-6. Note that the columns in Table 3.3-6 are not additive; rather, each row in the table represents construction associated with a specific cannabis use site on a particular site. Refer to Appendix E for detailed modeling input parameters and results.

Table 3.3-6 Operational Emissions of Criteria Air Pollutants and Precursors for Each Cannabis Use Type

Cannabis Use	ROG (tons/year)	NO_X (tons/year)	PM_{10} (lb/day)	$PM_{2.5}$ (lb/day)
Cultivation				
Outdoor	0.2	0.1	<0.1	<0.1
Mixed-Light	0.5	<0.1	<0.1	<0.1
Indoor	0.2	0.1	<0.1	<0.1
Noncultivation				
Nursery	0.7	0.1	<0.1	<0.1
Processing	<0.1	0.1	<0.1	<0.1
Manufacturing	<0.1	0.1	<0.1	<0.1
Testing	<0.1	0.1	<0.1	<0.1
Distribution	<0.1	0.1	<0.1	<0.1
Retail	<0.1	0.1	<0.1	<0.1
Microbusiness	<0.1	0.1	<0.1	<0.1
YSAQMD Thresholds of Significance	**10**	**10**	**80**	**N/A**
Exceeds Threshold?	**No**	**No**	**No**	**N/A**

Notes: ROG = reactive organic gases; NO_X = oxides of nitrogen; PM_{10} = respirable particulate matter; $PM_{2.5}$ = fine particulate matter; lb/day = pounds per day; YSAQMD = Yolo-Solano Air Quality Management District; N/A = not applicable.

Source: Modeling conducted by Ascent Environmental in 2019

Alternatives 1, 2, 3, and 5 assume that personal use outdoor cultivation may occur in any zoning district on a parcel developed with a legal residence. Personal use outdoor cultivation of up to six plants is assumed to occur within pots or garden areas of such parcels. Alternative 4 would limit personal use cultivation to indoor only. These activities would likely involve no more than 100 square feet of land area and would be required to be outside of front yard and side yard setback areas. Once operational, these activities would not differ from typical personal gardening, which would generate minimal criteria air pollutant and precursor emissions from landscaping equipment that would not exceed YSAQMD thresholds.

Alternative 1 consists of existing and eligible cultivation sites and would not create any new operational air pollutant emissions. Alternatives 2 through 5 are assumed to result in the development of new individual cannabis uses as described in Impact AQ-2. As shown in Table 3.3-6, operation of new individual cannabis sites would not result in annual emissions of ROG and NO_X or daily emissions of PM_{10} that would exceed YSAQMD's thresholds of significance. The estimate of emissions from individual sites is considered conservative because it was assumed sites would be operational by 2021 that thus the requirements of CCR Section 8306 were not included because they do not take effect until 2023.

Operation emissions of all assumed cannabis uses under each alternative could generate the following total emissions:

- Alternative 1: 20.9 tons per year of ROG, 6.3 tons per year of NO_x, 3 lbs per day of PM_{10}, and 3 lbs per day of $PM_{2.5}$.

- Alternative 2: 25.9 tons per year of ROG, 10.6 tons per year of NO_x, 6 lbs per day of PM_{10}, and 5 lbs per day of $PM_{2.5}$.

- Alternative 3: 51.5 tons per year of ROG, 21.2 tons per year of NO_x, 11 lbs per day of PM_{10}, and 10 lbs per day of $PM_{2.5}$.
- Alternative 4: 43.6 tons per year of ROG, 11.5 tons per year of NO_x, 5 lbs per day of PM_{10}, and 5 lbs per day of $PM_{2.5}$.
- Alternative 5: 25.9 tons per year of ROG, 10.5 tons per year of NO_x, 5 lbs per day of PM_{10}, and 5 lbs per day of $PM_{2.5}$.

As discussed in the “Thresholds of Significance” section, YSAQMD developed these thresholds in consideration of achieving and maintaining the NAAQS and CAAQS, which represent concentration limits of criteria air pollutants needed to adequately protect human health. Therefore, the project’s contribution to operational criteria pollutants and precursors would not result in greater acute or chronic health impacts compared to existing conditions. Operation of all cannabis sites that could be permitted under any of the alternatives would not conflict with the General Plan or 2016 Triennial Assessment and Plan Update. Consistency with these applicable plans would meet YSAQMD’s threshold for plan-level documents.

This impact would be **less than significant** under all alternatives.

Mitigation Measures

No mitigation is required for any of the alternatives.

Impact AQ-4: Expose a Substantial Number of People to Adverse Odors

Operation of cannabis uses associated with adoption and implementation of the proposed CLUO, including subsequent Cannabis Use Permits pursuant to the adopted CLUO could expose residents, businesses and recreation users to objectionable odors created by the growing, processing, and manufacturing of cannabis. The CLUO includes standards that establish a numeric threshold for the concentration of cannabis odors, requirements for the development of an Odor Control Plan, and an enforcement process to correct identified cannabis odor impacts. While these measures would minimize the likelihood of nuisance odors, the potential for odors to occur remains. This impact would be **significant** for all alternatives.

As described in Section 3.3.1, “Environmental Setting,” the typical smell of cannabis originates from roughly 140 different terpenes. A terpene is a volatile, unsaturated hydrocarbon that is found in essential oils of plants, especially conifers and citrus trees. Some terpenes are identified explicitly in research (myrcene, pinene, limonene). The “skunk” odor attributable to cannabis is primarily volatile thiols. Cannabis uses that have potential to generate nuisance odors include cultivation, processing, manufacturing, and microbusiness.

As noted above, the County received 17 odor complaints between October 2017 and January 2019 associated with existing cannabis cultivation sites. The majority of these complaints were received during the summer and fall months when cannabis is ready for harvest. These complaints were associated with cultivation sites along the State Route (SR) 16 corridor west of Woodland and sites along SR 128 and Interstate 505 (I-505) south of SR 16.

The CLUO addresses odor impacts through limiting the location of cannabis uses, buffers for outdoor cannabis uses, odor control requirements, and enforcement. The specific provisions are included below.

Section 8-2.1407 of the CLUO requires that cannabis uses to be located in agricultural, commercial, and industrial zones that generally do not contain concentrations of receptors sensitive to odors (e.g., residential uses) (see Table 2-6). In addition to the zoning standards, Section 8-2.1408(E) of the CLUO requires buffers (75 - 1,000 feet) established under alternatives 1, 2, 3, and 5 between outdoor cannabis uses and defined sensitive receptors in order to minimize to potential for nuisances:

A buffer of X feet[3] is required from the following receptors (inside or outside of the County unincorporated area): off-site individual legal residences under separate ownership, residentially designated land, licensed day cares, public parks, recognized places of worship, public or licensed private schools, licensed treatment facilities for drugs or alcohol, federal lands held in trust by the federal government or that is the subject of a trust application for a federally recognized tribal government, licensed youth centers that are in existence at the time a use permit is issued for any CDFA permittee. These buffers apply to cannabis uses as specified in Section 8-2,1407, Table of Cannabis Development Regulations, of this article. The buffer shall be measured from the closest point of the cultivation site to:

1. The closest surface of the building for residences, day cares, places of worship, schools, treatment facilities, and youth centers.

2. The closest point of the zone boundary for residentially designated land.

3. The closest point of the parcel boundary for public parks and tribal trust land.

Approved cannabis uses, operating within the terms of their approvals and conditions, shall be exempted from the buffer requirement as applicable to later new uses within the categories identified above, that locate within the described buffer distance.

Section 8-2.1408(CC) of the CLUO establishes the following limits on odor concentration at the property line of a cannabis site, defines what is considered a persistent odor nuisance, and enforcement measures to address verified odor nuisances:

Cannabis uses shall not create a public nuisance or adversely affect the health or safety of nearby residents or businesses by, among other things, creating dust, light, glare, heat, noise, noxious gases, odor, smoke, traffic, vibration, unsafe conditions, or other impacts, in excess of allowable thresholds, or be hazardous due to the use or storage of materials, processes, products, runoff, unauthorized releases or illegal disposal of wastes.

1. Subject to subsection 7 below, it is unlawful and it shall be a public nuisance to cause or permit persistent cannabis odors. A persistent cannabis odor is one which is verified by persons of normal odor sensitivity (as defined by European Standard EN 13725) to exist for three consecutive days within any two-week period at a maximum dilution-to-threshold (D/T ratio of seven parts clean or filtered air to one-part filtered odorous air, 7:1), measured at the property line of the site, as a result of investigations resulting from subsection 2, below.

2. Subject to subsection 7 below, for the purposes of this subsection, cannabis odors shall be deemed to be persistent if the County enforcement officer (i) independently determines that the cannabis odor violates the standards of subsection 1 above, and/or (ii) the County enforcement officer receives three or more complaints of cannabis odor representing separate residences or places of occupied business, of a cannabis odor emanating from the subject property for three consecutive days within any two-week period, that the enforcement officer determines violates the standards of subsection 1 above.

3. Subject to subsection 7 below, nothing in this subsection shall be deemed to require three verified complaints before the County may initiate enforcement action. The County may determine that a public nuisance exists under this subsection if less than three verified complaints are received or if no complaints are received but County officials or employees observe cannabis odor conditions that violate this subsection.

[3] The buffer distance in the CLUO will determined by the Board of Supervisors at the time of approval of the ordinance.

4. Failure to effectively resolve a public nuisance shall result in enforcement action, up to and including additional conditions, suspension and revocation of the County Cannabis Use Permit and/or County Cannabis License pursuant to the process below.

5. The County applies a three-level citation system to cannabis nuisance violations. Depending on the severity, frequency, or the failure to resolve the cause of the violation, the County enforcement officer may issue an alert, a warning citation, or a Notice of Violation. The alert shall identify the problem, identify relevant code sections, discuss the abatement process, and identify corrective action. The warning citation shall identify the problem, document the history, and mandate specific abatement actions including submittal of a plan and schedule to remedy the problem. A Notice of Violation shall follow the procedures set forth in Section 5-20.10 (*this citation will be revised one the licensing ordinance is moved to Chapter 4 of Title 20*).

6. Subject to subsection 7 below, if at any time during the citation system identified above in subsection 5, the County enforcement officer determines that the conditions at the site are deleterious to the health, safety, or general welfare of any one or more surrounding properties, or that the permittee and/or landowner is not acting in good faith or in a manner sufficient to timely address the complaint, the County enforcement officer may bypass the citation process and take immediate steps to address the violation, including by abatement or any other lawful means.

7. Permittees operating in compliance with this article, in particular Section 8-2.1408(DD)(1), Odor Control, the terms of their Cannabis Use Permit, and other applicable laws shall be presumptively assumed to not cause or contribute to a public nuisance.

8. The County may elect not to investigate any complaint due to resource limitations or other matters. In addition, the County may elect not to investigate complaints submitted by complainants that submit more than three unsubstantiated complaints within a one-year period.

Section 8-2.1408(DD) of the CLUO also provides the following requirements for odor control:

1. The allowable threshold for cannabis odor shall be defined as a maximum dilution-to-threshold (D/T) ratio of seven parts clean or filtered air to one-part odorous air (7:1) measured at the property line of the site. Cannabis odor at or below this threshold shall be considered acceptable and shall not be considered a nuisance. Indoor and mixed light uses must install and maintain the following minimum equipment: an exhaust air filtration system with odor control that effectively minimizes internal odors from being emitted externally; an air system that creates negative air pressure between the facilities interior and exterior so that odors outside of the facility will not exceed the maximum dilution-to-threshold (allowable threshold), as defined herein; or other odor control system which effectively minimizes odor to a level compliant with the allowable threshold.

2. Applicants shall submit the following information: a. Identification and description of cannabis odor emitting activities and nature and characteristics of emissions. b. Description of procedures and engineering controls for reducing/controlling odors. c. Certification by a Professional Engineer or Qualified Odor Professional that the procedures and engineering controls proposed to control cannabis odors are consistent with accepted/available industry-specific best control technologies and methods designed to abate odor and will be effective in abating cannabis odors to the maximum dilution-to-threshold (allowable threshold), as defined herein, at the property line of the site. This shall be submitted in the form of an Odor Control Plan, subject to regular monitoring and reporting.

3. Odor control for outdoor activities may include different plant strains, smaller grow areas, relocation of outdoor activities indoors or in a mixed light facility, use of site design or other technology, odor easements over neighboring property, and/or other methods proven to be effective and accepted by the County.

In addition to these standards the CLUO also includes the following requirements that address nuisance odors as well as the ability for the County to re-evaluate the effectiveness of nuisance and odor control standards:

- Section 8-2.1408(PP) Site Maintenance (General): Permittee shall at all times maintain, manage, and operate the site, all improvements and alterations, and all structures, in good repair, acceptable in appearance, and in reasonably safe condition, including securing all necessary licenses and permits for this work. The site shall be kept free of litter, clutter, and graffiti. The permittee shall prevent and eliminate conditions that constitute a public nuisance.

- Section 8-2.1410(D)(2) Operational Information Required: Odor Control Plan.

- Section 8-2.1413 Effectiveness: Assessment of Effectiveness -- Following two years of implementation of this article, staff shall present the Board of Supervisors with an assessment of its effectiveness and any recommendations for change. This evaluation shall include in particular an assessment of the effectiveness of Section 8-2.1408, Specific Use Requirements and Performance Standards, of this article, including Section 8-2.1408(E) Buffers, Section 8-2.1408(U) Good Neighbor Communication, Section 8-2.1408(CC) Nuisance, Section 8-2.1408(DD) Odor Control, and Section 8-2.1412 Enforcement.

The furthest distance cannabis odors may be recognizable or detectable is approximately two miles or more, depending on topography and meteorology (Kern County 2017). This is consistent with the experience of the Cannabis Task Force. However, recognition of an odor does not imply that the odor is a nuisance, only that it can be identified or detected as cannabis. Typically, the odor is detectable much closer to the source, such as adjacent to or on a cultivation site. The distance for odor detection is very site-specific and can be affected by many variables including meteorology, topography, plant strain, and how ready plants are for harvesting. Based on review of County odor complaint data, calm and/or light wind conditions tend to create the greatest potential for odor complaints. In addition, human perception of cannabis plant odors may be influenced by personal views regarding cannabis. Whether the odor is acceptable and the level at which it should be defined as objectionable at various strengths and distances from various land uses is a matter of policy.

The County is considering five alternative variations to the proposed CLUO, all of which rely on the same underlying regulatory requirements that would regulate cannabis activities through land use, zoning, and development standards. The alternatives vary by the assumed type of cannabis license/activity, limits on the number of operations, performance standards and buffer distances. Each EIR alternative and the buffers assumed for that alternative are summarized below:

Table 3.3-7 Alternative Buffer Distances

Alternative	Buffer
Alternative 1: Cultivation (Ancillary Nurseries and Processing Only) with Existing Limits (Existing Operations with CLUO)	75 Feet from Individual Residence 1,000 Feet from Other Sensitive Uses
Alternative 2: All License Types with Moderate Limits	1,000 Feet
Alternative 3: All License Types with High Limits	75 Feet
Alternative 4: Mixed-Light/Indoor License Types only with Moderate Limits, No Hoop Houses or Outdoor Types	None
Alternative 5: All License Types with Moderate Limits, within Agricultural Zones Only, No Retail	1,000 Feet

Pursuant to CLUO Section 8.2-1408(E), buffers would apply to the following receptors (inside or outside of the County unincorporated area): individual legal residences under separate ownership, residentially designated land, licensed day cares, public parks, recognized places of worship, public or licensed private schools, licensed treatment facilities for drugs or alcohol, federal lands held in trust by the federal government or that is the subject of a trust application for a federally recognized tribal government.

CLUO Section 1408(DD)(1) defines an acceptable level of cannabis odor as a maximum dilution-to-threshold (D/T) of seven parts clean or filtered air to one-part odorous air (7:1) or less at the property line of the site. Cannabis odor at or below 7:1 D/T may still be detected off-site; however, pursuant to the CLUO, odor at this threshold would be considered acceptable, and not a nuisance. The public may occasionally detect cannabis odors. However, as noted herein, the 7:1 D/T standard is based on scientific publications on odor pollution control that have identified that odors above 7 D/T will often result in complaints (i.e. objectionable), with 15 D/T often described as a nuisance, and odors above 30 D/T described as a serious nuisance (i.e. nauseating) (McGinley 2000 and Huey et al. 1960).

The CLUO also includes several provisions intended to minimize odor. CLUO Section 1408(DD)(1) requires that indoor and mixed light cannabis uses install odor control equipment to minimize odor. Outdoor cannabis activities are also required to implement odor control measures such as less odorous plant strains, smaller grow areas, relocation of outdoor activities indoors or in a mixed light facility, use of site design or other technology, odor easements over neighboring property, and/or other methods proven to be effective and accepted by the County.

Pursuant to CLUO Section 1408(DD)(2), Cannabis use permit applicants are also required to submit an Odor Control Plan which would include:

a. Identification and description of cannabis odor emitting activities and nature and characteristics of emissions.

b. Description of procedures and engineering controls for reducing/controlling odors.

c. Certification by a Professional Engineer or Qualified Odor Professional that the procedures and engineering controls proposed to control cannabis odors are consistent with accepted/available industry-specific best control technologies and methods designed to abate odor and will be effective in abating cannabis odors to the maximum dilution-to-threshold, as defined in the CLUO, measured at the property line of the site.

Buffers provide a means of reducing the strength or concentration of an odor and the frequency at which it may be detected since buffers provide atmospheric dispersion of odor. The larger the buffer, the more distance is available for dispersion of the odor to occur before it may reach a sensitive receptor. Given this, smaller buffers are generally not as effective in reducing the strength and frequency of the odor compared to a larger buffer distance. In addition, since a larger buffer would provide greater dispersion, it would also likely reduce the number of odor complaints and complaint verification enforcement activities.

Odors with distinct odor characteristics, emanating from proximate sources, are generally not additive or amplified. However, odor with the same or similar odor characteristics, emanating from proximate sources may be additive. Therefore, multiple odor sources in a given geographic area would not necessarily increase the strength of an odor, although a higher frequency of odor detection would be expected. It is not possible to predict what specific cannabis plant strains would occur at proximate sources. However, the overall strength of odor generally would not necessarily be worse under Alternative 3 (All License Types with High Limits) versus Alternative 1 (Existing Operations with CLUO). It should be noted that both the strength and frequency at which the odors from any specific alternative may be detected would be reduced with a large buffer as compared to a small buffer because greater dispersion would occur under the larger separation distance.

Notwithstanding implementation of the cannabis odor minimization measures specified above, including buffers, odors cannot be completely eliminated such that they would not be detectable off-site. This is true for each of the five alternatives and various buffer distances evaluated as part of this EIR. While the measures would reduce the likelihood of nuisance odors, the potential for odor emissions to occur remains. Therefore, this impact is conservatively considered significant for all alternatives, as explained further below.

To ensure the overall quality and consistency of odor investigations, odor verification is conducted by County cannabis enforcement officers who have been screened and determined to be of normal odor sensitivity pursuant to European Standard EN 13725. The officers have also been trained in odor detection using a Nasal Ranger field olfactometer.

When a complaint is received via the County's on-line cannabis complaint form, the weather conditions at the time of the complaint are automatically provided. Since meteorology plays a role in cannabis odors, the County tries to verify the complaint on a day and time when the weather conditions at the time of the complaint can best be replicated. (Strachan 2019)

Compliance with odor control requirements under CLUO Section 8-2.1408(DD)(1) for cannabis uses located within a greenhouse or building can be accomplished through the use of equipment such as the following (Trinity Consultants 2019):

- Activated carbon air filters (carbon scrubber) – forced air circulation through activated carbon filter to filter out odors prior release from the facility.
- Biofilters – a control that utilizes biological adsorptive media.
- Plasma ion technology – odorous gases and aerosols interact with ions and are neutralized.
- Air filters – air passes through densely woven fiber screens which trap odorous particulates (this is viewed as a less effective option relative to carbon scrubbers, biofilters, and is often paired with other technologies).

Using an appropriate odor control technology (such as the examples listed above) coupled with a well-engineered ventilation design, it would be expected that a facility could achieve the allowable threshold for cannabis odor in CLUO Section 8-2.1408 (DD)(1). (Scullion, 2019).

CLUO Section 8-2.1408(DD)(3) includes suggested odor control for outdoor cannabis uses that consist of using different plant strains, relocation of outdoor cultivation to mixed-light or indoor cultivation in a greenhouse or indoor building, odor easements, and/or other methods proven to be effective and accepted by the County. There are cannabis plant strains under development that have reduced odor potential. However, no technical studies are available at this time to confirm the effectiveness of these strains. As discussed above, conversion to indoor or mixed-light cultivation in a greenhouse building can provide effective odor control through operation of filtration systems and comply with the CLUO 7 D/T standard. Odor easements and buffer areas are often used for facilities such as landfills and wastewater treatment plants (e.g., Sacramento Regional Wastewater Treatment Plant) to effectively address nuisance odors. Implementation of the enforcement provisions of CLUO Section 8-2.1408(CC) when a persistent odor nuisance from a cannabis site is verified would require the County enforcement officer to either issue an alert, warning citation, or a Notice of Violation that identifies the need for corrective action. If complaints are not addressed by the cannabis site operators, the County enforcement officer may take immediate steps to address the nuisance which could include revocation of cannabis licensing and/or the Cannabis Use Permit.

Alternatives 1, 2, 3, and 5 assume that personal use outdoor cultivation may occur in any zoning district on a parcel developed with a legal residence. Personal use outdoor cultivation of up to six plants is assumed to occur within pots or garden areas of such parcels. Alternative 4 would limit personal use cultivation to indoor only. These activities would likely involve no more than 100 square feet of land area and would be required to be outside of front yard and side yard setback areas. No odor impacts are expected to occur because the limited odor potential of six plants is not expected to generate nuisance odors in excess of 7 D/T off the parcel. Personal use outdoor cultivation would be subject to enforcement actions by the County if it creates a verified persistent nuisance odor issue as provided under CLUO Sections 8-2.1408(CC) and 8-2.1412.

Alternative 1: Cultivation (Ancillary Nurseries and Processing Only) with Existing Limits (Existing Operations with CLUO) (CEQA Preferred Alternative)

While most of the existing licensed commercial cannabis cultivation operations would remain in their current locations, nine of the existing sites are assumed to be required to relocate under the CLUO zoning standards because of proposed zoning restrictions (e.g., locations in residential zones). As shown in Exhibit 2-4, most of this existing cultivation occurs along the SR 16 corridor west of the City of Woodland with 22 sites located between the communities of Rumsey and Guinda. This alternative assumes 75-foot buffers between cultivation sites and occupied residences and 1,000-foot buffers between cultivation sites and identified sensitive receptors under the CLUO. No new commercial cannabis uses are assumed under this alternative.

As identified above, the CLUO would restrict cannabis uses to agricultural, commercial, and industrial zoned land that generally does not contain sensitive receptors (CLUO Section 8-2.1407), buffers between outdoor cannabis uses and sensitive receptors (CLUO Section 8-2.1408[E] establish odor control requirements that would prohibit nuisance odors from leaving the cannabis site in excess of 7 D/T, identifies a process of corrective actions for nuisance odor conditions, and requires the development of an Odor Control Plan (CLUO Sections 8-2.1408[CC] and 8-2.1408[DD]). It is acknowledged that this could involve the conversion from outdoor cultivation operations to mixed-light or indoor cultivation within greenhouse buildings designed with odor control in order to achieve compliance with the CLUO odor standards, similar to what is assumed under Alternative 4. As noted above, this alternative is assumed to result in the relocation of nine existing cultivation sites from residential zoned areas, which would substantially reduce potential nuisance odor issues in these residential zoned areas.

While these measures would minimize the likelihood of nuisance odors, the potential for odor emissions to occur remains. This impact is conservatively considered **significant** for Alternative 1.

Alternative 2: All License Types with Moderate Limits

Under Alternative 2, it was assumed for analysis purposes that there would be two new cultivation sites constructed as well as a total of 52 new noncultivation uses. Additionally, it was assumed for analysis purposes that 30 of the 78 existing cultivation sites would be relocated due to zoning restrictions (e.g., locations in residential zones) and buffering standards under the CLUO.

New cannabis uses assumed under this alternative that could generate odors include cultivation (two new sites), nurseries (five sites), processing (five sites), microbusiness (five sites) and manufacturing (20 sites). As shown in Exhibit 2-5, this Alternative assumes the following new cannabis uses and potential odor sources in proximity to various communities:

- Guinda: three manufacturing sites and two microbusiness sites
- Esparto: one manufacturing site and one microbusiness site
- Yolo: one manufacturing site
- Dunnigan: two manufacturing site, one nursery site, one processing site, and one cultivation site

The CLUO would restrict cannabis uses to agricultural, commercial, and industrial zoned land that generally does not contain sensitive receptors (CLUO Section 8-2.1407). Buffers between outdoor cannabis uses and sensitive receptors (CLUO Section 8-2.1408[E] establish odor control requirements that would prohibit nuisance odors from leaving the cannabis site in excess of 7 D/T, identifies a process of corrective actions for nuisance odor conditions, and requires the development of an Odor Control Plan (CLUO Sections 8-

2.1408[CC] and 8-2.1408[DD]). As noted above, this alternative is assumed to result in the relocation of 30 existing cultivation sites from residential zoned areas and compliance with the buffer requirements that would substantially reduce potential nuisance odor issues associated with these existing and eligible cultivation sites by increasing the distance between the odor source and defined sensitive receptors.

While these measures would minimize the likelihood of nuisance odors, the potential for odor emissions to occur remains. This impact is conservatively considered **significant** for Alternative 2.

Alternative 3: All License Types with High Limits

This alternative is assumed to result in the construction of 82 new cultivation sites and total of 104 new noncultivation uses. Additionally, it was assumed for analysis purposes that nine of the 78 existing cultivation sites would be relocated under the CLUO zoning restrictions (e.g., locations in residential zones).

New cannabis uses assumed under this alternative that could generate odors include cultivation (82 new sites), nurseries (10 sites), processing (10 sites), microbusinesses (10 sites), and manufacturing (40 sites). As shown in Exhibit 2-6, this Alternative assumes the following new cannabis uses and potential odor sources in proximity to various communities:

- Guinda: three manufacturing sites, three cultivation sites, three microbusinesses, one nursery site, and two processing sites
- Esparto: two manufacturing sites, three cultivation sites, one microbusiness, and one processing site
- City of Woodland: four manufacturing sites and three cultivation sites
- Yolo: one manufacturing site and one cultivation site
- Dunnigan: four manufacturing sites, two cultivation sites, two nursery sites, two microbusinesses, and one processing site

As identified in Alternative 2, the CLUO would restrict cannabis uses to agricultural, commercial, and industrial zoned land that generally does not contain sensitive receptors (CLUO Section 8-2.1407). Buffers between outdoor cannabis uses and sensitive receptors (CLUO Section 8-2.1408[E] establish odor control requirements that would prohibit nuisance odors from leaving the cannabis site in excess of 7 D/T, identifies a process of corrective actions for nuisance odor conditions, and requires the development of an Odor Control Plan (CLUO Sections 8-2.1408[CC] and 8-2.1408[DD]). As noted above, this alternative is assumed to result in the relocation of nine existing cultivation sites from residential zoned areas that would substantially reduce potential nuisance odor issues in these residential zoned areas.

While these measures would minimize the likelihood of nuisance odors, the potential for odor emissions to occur remains. This impact is conservatively considered **significant** for Alternative 3.

Alternative 4: Mixed-Light/Indoor License Types Only with Moderate Limits, No Hoop Houses or Outdoor Types

Under Alternative 4, it was assumed for analysis purposes that nine of the 78 existing cultivation sites would be relocated under the CLUO zoning restrictions (e.g., locations in residential zones). It was also assumed that 75 of the existing and eligible cannabis sites with outdoor cultivation would convert entirely to indoor or mixed-light (greenhouse) cultivation. This alternative is also assumed to result in the construction of two new mixed-light or indoor cultivation sites and a total of 52 new noncultivation uses.

New cannabis uses assumed under this alternative that could generate odors include cultivation (two new sites), nurseries (five sites), processing (five sites), microbusinesses (five sites), and manufacturing (20 sites). As shown in Exhibit 2-7, this alternative assumes the following new cannabis uses and potential odor sources in proximity to various communities:

- Guinda: three manufacturing sites and two microbusiness sites
- Esparto: one manufacturing site and one microbusiness site
- Yolo: one manufacturing site
- Dunnigan: one manufacturing site, one nursery site, and one processing site

As identified in Alternative 2, the CLUO would restrict cannabis uses to agricultural, commercial, and industrial zoned land that generally does not contain sensitive receptors (CLUO Section 8-2.1407), buffers between outdoor cannabis uses and sensitive receptors (CLUO Section 8-2.1408[E] establish odor control requirements that would prohibit nuisance odors from leaving the cannabis site in excess of 7 D/T, identifies a process of corrective actions for nuisance odor conditions, and requires the development of an Odor Control Plan (CLUO Sections 8-2.1408[CC] and 8-2.1408[DD]). Odor control for building ventilation systems associated with mixed-light cultivation, indoor cultivation, nurseries, manufacturing, microbusinesses, and processing facilities would be required by CLUO Section 8-2.1408(DD).

Because Alternative 4 assumes all cannabis activities are conducted within structures, this Alternative is likely to have lower odor impacts overall than Alternatives 1, 2, 3, and 5. Specifically, CLUO Section 8-2.1408 (DD) (1) requires that: "Indoor and mixed light uses must install and maintain the following minimum equipment: an exhaust air filtration system with odor control that effectively minimizes internal odors from being emitted externally; an air system that creates negative air pressure between the facilities interior and exterior so that odors outside of the facility will not exceed the maximum dilution-to-threshold, as defined herein; or other odor control system which effectively minimizes odor. Nevertheless, while the assumptions of this alternative and the identified odor control measures would minimize the likelihood of nuisance odors, the potential for odor emissions to occur remains. This impact is conservatively considered **significant** for Alternative 4.

Alternative 5: All License Types with Moderate Limits, within Agricultural Zones Only, No Retail

Under Alternative 5, it was assumed for analysis purposes that there would be two new cultivation sites constructed as well as a total of 50 new noncultivation uses Additionally, it was assumed for analysis purposes that 30 of the 78 existing cultivation sites would be relocated due to zoning restrictions (e.g., locations in residential zones) and buffering standards under the CLUO.

New cannabis uses assumed under this alternative that could generate odors include cultivation (two new sites), nurseries (five sites), processing (five sites), microbusinesses (five sites), and manufacturing (10 sites). As shown in Exhibit 2-8, this Alternative assumes the following new cannabis uses and potential odor sources in proximity to various communities:

- Guinda: three manufacturing sites and two microbusiness sites
- Esparto: one manufacturing site and one microbusiness site
- Yolo: one manufacturing site
- Dunnigan: two manufacturing site, one nursery site, one processing site, and one cultivation site

As identified in Alternative 2, the CLUO would restrict cannabis uses to agricultural zoned land that generally does not contain sensitive receptors (CLUO Section 8-2.1407), buffers between outdoor cannabis uses and sensitive receptors (CLUO Section 8-2.1408[E] establish odor control requirements that would prohibit nuisance odors from leaving the cannabis site in excess of 7 D/T, identifies a process of corrective actions for nuisance odor conditions, and requires the development of an Odor Control Plan (CLUO Sections 8-2.1408[CC] and 8-2.1408[DD]). It is acknowledged that this may require the conversion from outdoor cultivation operations to mixed-light or indoor cultivation within greenhouse buildings designed with odor control to comply with the CLUO odor standards similar to what is assumed under Alternative 4. As noted above, this alternative is assumed to result in the relocation of 30 existing cultivation sites from residential zoned areas and compliance with the buffer requirements that would substantially reduce potential nuisance odor issues associated with these existing and eligible cultivation sites by increasing the distance between the odor source and defined sensitive receptors.

While these measures would minimize the likelihood of nuisance odors, the potential for odor emissions to occur remains. This impact is conservatively considered **significant** for Alternative 5.

Mitigation Measures

Mitigation Measure AQ-1: Conduct Wind Pattern Evaluations to Evaluate Odor Control (Alternatives 1, 2, 3, 4, and 5)

The following shall be included as a new performance standard in Section 8-2.1408 (DD) of the CLUO:

- As part of the cannabis use permit process, County staff shall conduct a wind pattern evaluation of each cannabis use application. This evaluation will utilize wind roses (a circular display of the frequency of wind coming from specific directions over a specified period of time). The wind pattern evaluation will identify receptors (as defined in Section 8.2-1408 [E]) located downwind of a proposed cannabis use and potentially affected by nuisance odor for a predominant period of time based on the wind frequency. This will provide staff with additional information for consideration when evaluating a cannabis use permit application.

Notwithstanding the implementation of this measure and other identified existing and proposed regulations, the potential for impacts to occur is conservatively identified as significant and unavoidable because:

- Cannabis remains a controversial activity.
- Some neighbors have expressed that they are very sensitive to the odor and find it to be highly objectionable.
- The proposed regulatory threshold is not zero-detect which means that some odor will be detectable and will be considered acceptable under the regulations.
- Odor exceedances in excess of the allowable level may be higher in early years as the industry and technology evolve despite the fact that enforcement will occur under the ordinance.

Therefore, this impact is conservatively considered **significant and unavoidable** for all alternatives.

EXHIBIT 24

Appendix E

Trinity Consultants Technical Memorandum Entitled “Modeling to Estimate Odor Impacts at Various Buffer Distances

MEMORANDUM

To: Susan Strachan, Yolo County; Heidi Tschudin, Tschudin Consulting Group

cc: Pat Angell, Ascent Environmental

From: Angie Wanger, Trinity Consultants; Tony Colombari, Trinity Consultants

Date: August 17, 2020

RE: Modeling to estimate odor impacts at various buffer distances

A brief air dispersion modeling simulation was completed to assist in response to comments on the Yolo County Cannabis Land Use Ordinance (CLUO).

Model Assumptions

Air dispersion models can be utilized to simulate atmospheric conditions, including meteorology and topographical influences, to quantify the ground-level impact of air pollution from a source or activity to nearby locations. Air dispersion models can also be used to evaluate odor impacts.

The United States Environmental Protection Agency (US EPA) model AERSCREEN was used to evaluate ground-level odor impacts from two hypothetical outdoor cannabis growing operations:

- 0.5 acre facility, emitting 10,000 odor units (ou)
- 1 acre facility, emitting 20,000 ou

The odor emitted, in terms of odor units, is the assumed strength of the odor from the outdoor cannabis growing operations. Recent conference presentations[1] suggested between 10,000 and 50,000 ou or more can be emitted from a cannabis greenhouse operation. There wasn't readily available information on the strength of odor from an outdoor cannabis growing operation, so strengths of 10,000 ou and 20,000 ou were assumed for this hypothetical assessment.

The model AERSCREEN was selected because it allows the user to incorporate base-level assumptions to minimize the amount of site-specific information needed for a hypothetical modeling assessment. These assumptions include:

- Default meteorological conditions
  - Temperature range of -9.67 °F to 98.33 °F
  - Minimum wind speed of 1.11 mph
  - "Average" climate profile (rather than wet or dry climate)
- Land use is cultivated land
- Flat terrain

[1] Cannabis greenhouse odor concentrations are expected to range from 10,000 ou to 50,000 ou based on "Cannabis Cultivation as Good Neighbors: A Comprehensive Approach to Odour Control" and "Cultivating Odour Management Strategies for Cannabis Facilities", presented at the First Canadian Odour Conference, December 2018.

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Model Results

The results of the hypothetical modeling assessment are depicted in the two figures below. Figure 1 represents the ground-level odor concentrations relative to distance from the fenceline for the 0.5 acre facility. Figure 2 represents the ground-level odor concentrations relative to distance from the fenceline for the 1 acre facility. The y-axis is the odor concentration and the x-axis is the distance from the fenceline. Near the top of each graph are blue boxes which show the reduction of odor concentration for 500 ft, 1000 ft, and 1500 ft from the fenceline. These distances from the fenceline represent buffer distances. In both scenarios, there is a significant decrease from 0 to 500 ft and a more gradual but still meaningful decrease from 500 to 1000 ft. Beyond 1000 ft, the slope of the curve in both graphs flatten, suggesting less of a decrease. This demonstrates that there can be a noticeable difference in odor between a 500 ft and 1000 ft buffer.

Figure 1. Ground-Level Odor Concentration vs. Distance from 0.5 Acre Facility

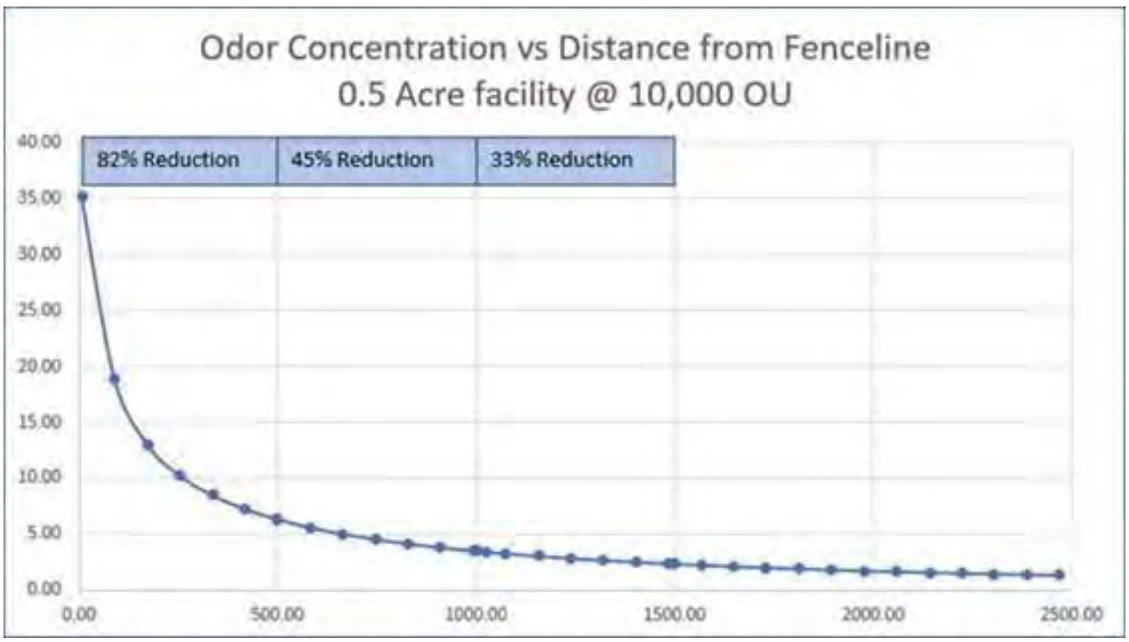
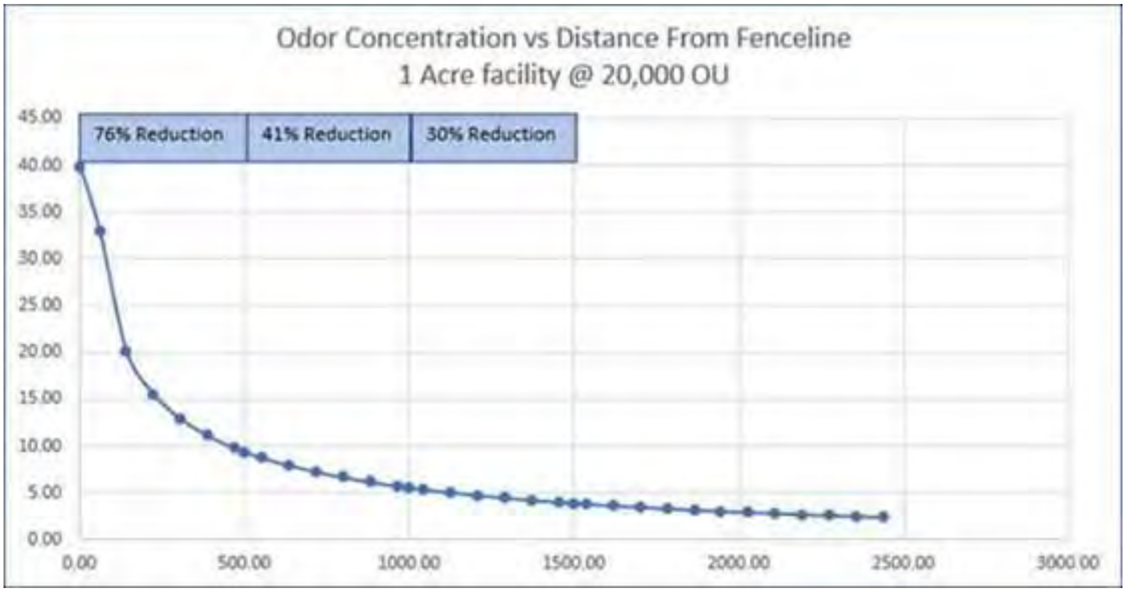


Figure 2. Ground-Level Odor Concentration vs. Distance from 1 Acre Facility



It is important to note these graphical depictions represent odor concentration/strength. They do not factor in the intensity (e.g., weak vs. strong) or offensiveness (pleasant vs. unpleasant) of the odor. At the time of preparing this hypothetical modeling assessment, we did not identify literature supporting an acceptable buffer distance for cannabis odors, which is expected to vary on a number of conditions (indoor vs. outdoor cultivation, growing cycle, strain of plant, etc.). These conditions can impact the perceived strength of the odors.

It is possible if the odor were very weak, there wouldn't be much of a noticeable difference between a 500 ft and 1000 ft buffer. The opposite might also be true, if the odor were very powerful/overwhelming, perhaps there wouldn't be much difference between a 500 ft and 1000 ft buffer. Ultimately, the odor concentration/strength reduces with distance, but it is not possible to identify where on the graph the odor would stop being a nuisance, because a "nuisance" is dependent on more than odor concentration/strength (i.e., intensity and offensiveness).

In conclusion, as demonstrated in this hypothetical modeling assessment, a noticeable reduction in odors is expected at both the 500 ft and 1000 ft buffer distances from the fenceline.

EXHIBIT 25

Fact Sheet
Using Windbreaks to Manage Odor from Livestock Facilities

Purpose

The purpose of this fact sheet is to help raise awareness of the opportunity to include windbreaks in the management of animal production facility odors. Also discussed are factors important to deciding if a windbreak is appropriate, as well as considerations for design.

Introduction

Over the past few decades, odor management has become an increasingly important issue in the livestock and poultry industries nationwide. The face of rural America has changed as production trends have shifted from small, diverse operations throughout the country to greater concentrations of large scale confined animal operations resulting in larger animal production facilities producing greater quantities of manure. The increased quantity of manure has the potential to produce more intense odor, more frequently and for longer duration.

At the same time, more people from urban areas have moved further out into rural areas. Numerous conflicts and legal actions have arisen throughout the country as a result of concerns about the impact these facilities have on quality of life, health, the environment, real estate values, communities and neighbor relations. The increased potential for litigation and conflict has resulted in a greater effort to manage odor emissions from livestock production facilities.

About Windbreaks

A windbreak is a planting of trees or shrubs designed to modify wind flow. NRCS has promoted windbreaks for the better part of the last century for a number of purposes that range from reducing soil erosion from wind, to managing snow, to protecting farmsteads, to storing carbon. Today people are beginning to explore the potential benefits windbreaks have for managing odor.

USDA NRCS Photo Gallery

Windbreaks serve many purposes. They have commonly been used to protect farmsteads and operations from harsh winter winds.

What is a windbreak?

A windbreak is a planting of trees or shrubs made up of either single or multiple rows of vegetation grown to form a wind barrier.

Windbreaks can…

- *reduce wind erosion*
- *manage snow*
- *protect farmsteads*
- *store carbon*
- *reduce odors*
- *increase habitat*

Stand downwind from a windbreak on a windy day and their benefits are immediately apparent. A windbreak creates a protected zone on the downwind side that extends from 2 to 5 times the height of the vegetation. Reduction in wind speed, to some degree, can extend up to 10 times the height of the vegetation.

About Livestock Odor

In livestock production, odors come primarily from land application areas, livestock operations with buildings or open lots, manure treatment/storage facilities or manure transport systems (Auvermann, 2002). Of these sources, surface application of hog manure is often cited as the biggest offender, followed by poultry and cattle feeding operations.

As the manure breaks down, hundreds of chemicals and chemical compounds are produced that combine to create that familiar manure smell. There is a general consensus that once these gases are emitted, if they travel any distance, they are primarily transported as attachments to dust particles.

'Large quantities of airborne dust are often found in and around animal confinement buildings' (Tyndall, 2000). The dust originates from a number of sources including feed, bedding materials and the animals themselves. Windbreaks have the potential to filter dust and reduce the movement of odor. While the limitations and benefits of using windbreaks to manage odor have yet to be fully evaluated, limited research and anecdotal evidence suggest that windbreaks can be effective tools in managing odors from livestock and poultry operations.

Odor Management Techniques

The animal production industry employs a variety of techniques to manage odor emissions from livestock and poultry facilities. The three main strategies for controlling livestock and poultry odor are:

1. *Prevention of odor through feed and manure additives, solid liquid separation, manure aeration and general good housekeeping*
2. *Capture and destruction of odorous chemicals using chemical scrubbers and biofilters*
3. *Collection, dispersion & dilution of odorous chemicals using windbreaks and shelterbelts (Tyndall, 2000)*

Windbreaks and Odor Management

As wind blows across a windbreak, a number of interactions occur that are beneficial not only for the management of wind and snow, but also for the management of odors. (Figure 1) These **interactions** include:

1. **Creation of zones of protection**
2. **Creation of an area of turbulence**
3. **Filtration**
4. **Redirection of the wind**

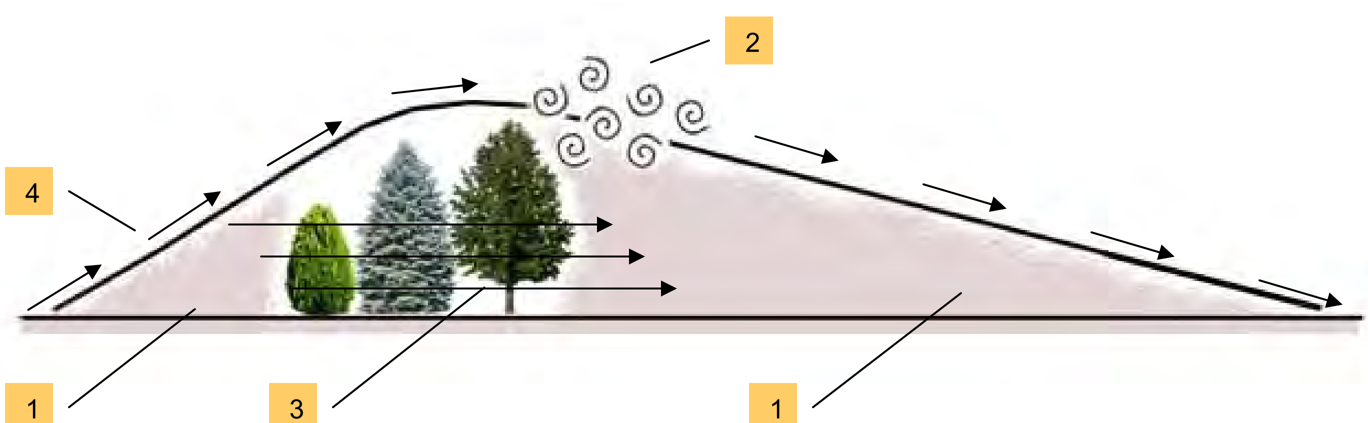


Figure 1 - Wind interacts with a windbreak in a number of ways.

These interactions can be used to manage dust and odors by designing and constructing windbreaks to:

1. Prevent odors and dust particles from being picked up by wind
2. Encourage deposition of dust particles that transport odors
3. Intercept and filter odors and dust particles already airborne
4. Disperse and dilute odors

Zone of Protection

The areas of still air or **zones of protection** created on the leeward side of a windbreak and a small zone of protection on the windward side are the most commonly recognized attributes of a windbreak. On the leeward side, the side downwind of a windbreak, an effective zone of protection extends for a distance of 2 to 5 times the height of the windbreak. A less effective but still significant reduction of wind speeds will exist up to 10 times the height of the windbreak. The zone of protection is most often used to protect farmsteads from strong winter winds. For managing odors, the zone of protection can be used to both **prevent odors from being picked up by the wind** and to encourage **deposition of dust particles** already carrying odors. (Figure 1)

Wind borne dust moving past odor sources such as open manure storage tanks, lagoons, open lots or fields where manure has recently been applied can pick up and transport odorous gases from these surfaces. Windbreaks located upwind of these odor sources would create a zone of protection to help prevent the dust and odors from being picked up and transported. (Figures 2 & 3)

Figure 2 – Open lots can be a source of particulates and odor.

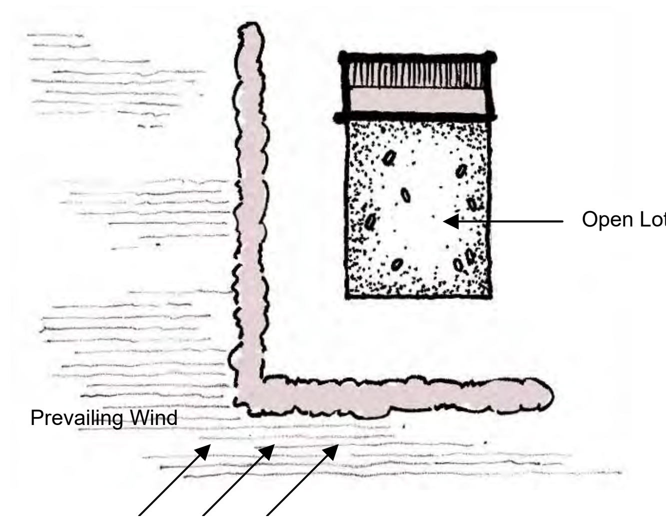


Figure 3 – A windbreak planted upwind of an open lot can reduce the movement of particulates and odor.

The decreased wind speed in the **zone of protection** can also be used to encourage **deposition** of dust particles carrying odors in the same way that windbreaks encourage the deposition of snow. The zone of protection created by a windbreak located downwind of an odor source promotes deposition of dust particles carrying odors. Deposition occurs when heavy dust particles drop out in the slower moving air.

Windbreak as Filter

When wind moves through a windbreak, the windbreak acts as a filter, trapping particulates. The leaves, branches and trunks of the vegetation **intercept and filter** dust and odor. Research suggests that vegetation such as conifers with complex leaf shapes and greater surface area collect particles more efficiently than deciduous vegetation.

Air that passes over dust and odor sources such as solid manure storage or fields where manure has recently been applied, or air that has been exhausted from mechanically vented livestock confinement buildings, will likely pick up dust and odors. Windbreaks can be located downwind of these odor sources and exhaust systems to **intercept** odor particles, **filtering** the air. (Figures 4 & 5)

Figure 4 – A windbreak in central Illinois is planted to filter particulates and odor exhausting from fans.

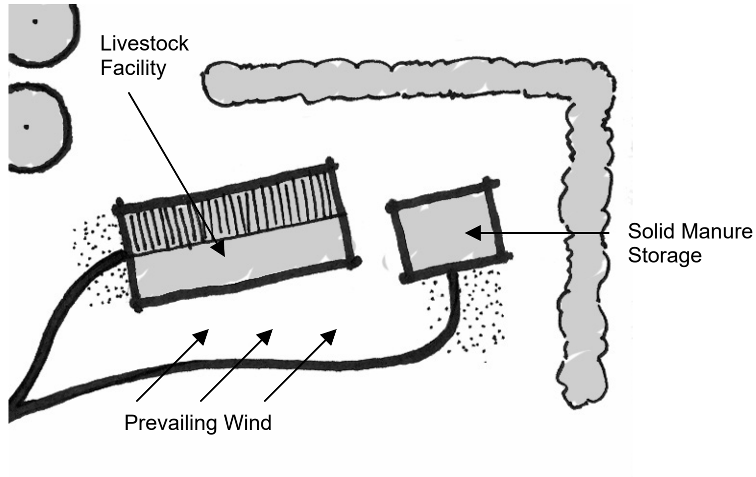


Figure 5 – Windbreak planned to filter and promote deposition of particulates coming from solid manure storage.

In addition, **filtration** can be used to **intercept** dust particles before they pass over a field where manure has been applied. Dust particles that adhere to the surface of leaves and branches are then not available to pick up or transport odors from fields where manure has been applied. At the same time the windbreak filters out dust particles about to blow across a field, a zone of protection is also created on the downwind side where deposition can occur and where reduced wind speeds will not pick up additional odor particles. (Figures 6 & 7)

Figure 6 – Windbreaks can act as filters for wind carrying particulates and odor. In addition, the zone of protection created by the windbreak prevents odors from being picked up and encourages dust particles to drop out downwind of the windbreak.

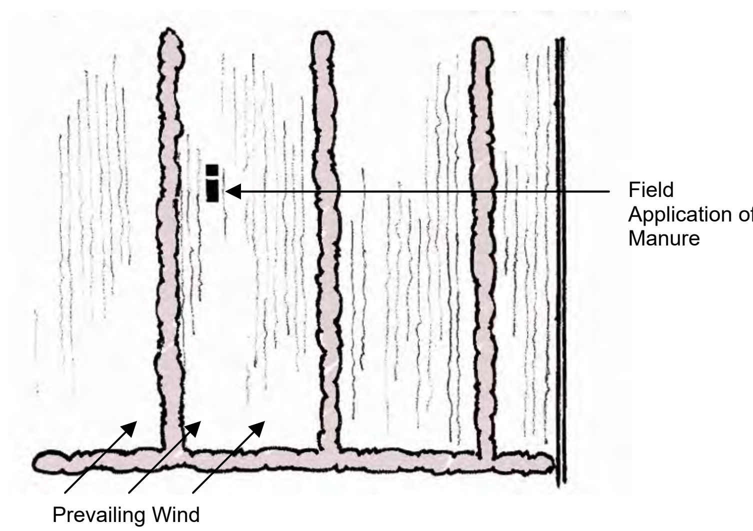


Figure 7 – Windbreak installed to prevent wind erosion. The windbreak also filters air as it moves through the windbreak, encourages deposition of particulates and prevents particulates from being picked up.

Turbulent Zone

In addition to the zone of protection, a turbulent zone is created at the top of a windbreak.

Once odors have been picked up from sources such as a production building or an open manure storage tank, a windbreak can redirect the wind up and over the trees, lifting dust and odors up into the lower atmosphere above people and residences where they would be regarded as offensive. At the same time, the turbulent zone at the peak of the windbreak has the potential to **dilute** and **disperse** odors, reducing their intensity and concentration. (Figure 8)

As wind is pushed up over the windbreak, air compresses and then expands while passing the crest of the windbreak creating an area of turbulent air. (Figure 1) Although not conclusive, the turbulence causes some of the air stream to mix into adjacent layers of air in the lower atmosphere allowing for some odor dispersion. Engineering models have shown that the turbulence contributes to a slower release of particulates into the downwind air stream diluting the odor plume.

Figure 8 – The turbulent zone of a windbreak has the potential to dilute and disperse odors picked up from sources such as manure storage tanks.

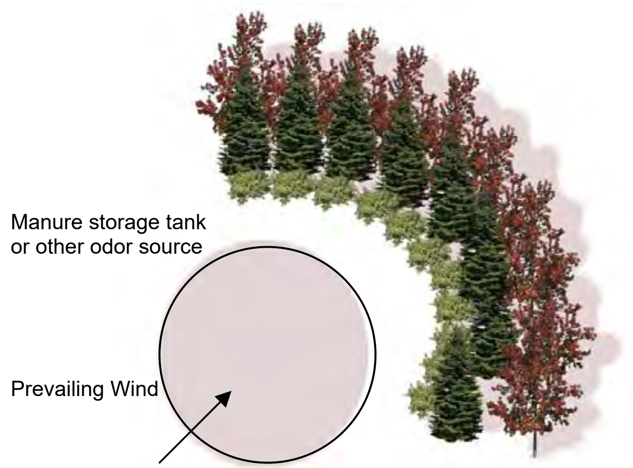


Figure 9 – Windbreak directs air stream into lower atmosphere and turbulent zone, diluting and dispersing odors.

Wedge Shaped Windbreak

Some research has indicated that wedge shaped windbreaks, with the tip of the wedge facing into the prevailing wind, can push airstreams higher into the atmosphere. (Tyndall, 2000)

A row or rows of shrubs, conifers and deciduous trees planted in combination would create a wedge shaped windbreak that would grow quickly, have branches and leaves at ground level and reach great heights.

Key Considerations for Windbreak Design

Understanding the benefits and limitations of using windbreaks to manage odor from animal manure is necessary to determine whether or not a windbreak is appropriate for a given odor management need or management style.

Benefits
For many, windbreaks are a familiar technology. For years NRCS has promoted and landowners have grown windbreaks. People know what they are. Many know how to establish and how to maintain them. Once established, they require regular maintenance to manage grass and weeds, monitor plant health and perform renovation when necessary. However, maintenance is generally minimal.

In addition, one windbreak has the potential to offer multiple benefits. At the same time a windbreak is working to manage odor from livestock facilities, the windbreak can also be working to conserve energy, reduce soil erosion, manage snow, provide shelter for livestock, habitat for wildlife and create visual screens.

As a windbreak screens unsightly facilities, appearance of the operation can be improved by softening buildings and visually breaking up the operation. The aesthetic benefit can be one of the most important benefits of a windbreak. Improved appearance has the potential to help maintain and improve relations with nearby residents.

Finally, compared to other technologies, windbreaks can be a low cost component of an odor management plan.

Limitations
Windbreaks alone will not completely prevent odor problems associated with animal manure. Depending on the odor management needs of a particular site, a windbreak may need to be used in conjunction with other odor management tools such as good housekeeping, food & manure additives, chemical scrubbers and bio-filters.

Another limitation of windbreaks is the time required for a windbreak to become fully functional. Windbreaks designed according to NRCS standards are considered to be at a fully functional height at 20 years. However, partial closure is achieved earlier and some benefit is realized before that point. Windbreaks that include fast growing deciduous trees can be functioning within as little as 5-10 years and reap aesthetic and screening benefits within just a few years. The public relations benefit of these windbreaks can occur immediately.

Planning Considerations

Once the decision has been made to use windbreaks, the following considerations will help determine where windbreaks could be located to effectively manage odor.

- Where are odors coming from?
- When are odors most likely to occur?
- Where are people located for whom odor would be a concern?
- What is the prevailing wind direction?
- From what direction does the wind blow during time(s) of year when odors are likely to be an issue?

The information is then used to identify locations where windbreaks could be located.

Potential locations should then be evaluated against other criteria such as snow deposition, location of utilities and other on-site infrastructure, ventilation requirements, movement of vehicles, aesthetics and possible future development.

The following section outlines design considerations important for locating a windbreak for odor management and selecting vegetation, as well as other general considerations.

Design Considerations

Prevailing Wind Direction

Prevailing wind direction is important in the design of any windbreak. Not only necessary to understanding the movement of odors, knowledge of the prevailing wind direction is also important for managing snow deposition and building ventilation. For accurate local information on prevailing winds in Illinois, refer to the Illinois State Climatologist Office's website - www.sws.uiuc.edu/atmos/statecli/Roses/wind_climatology.htm.

Snow Deposition and Roadways

Windbreaks should be located so snow deposited near them does not interfere with nearby roadways or buildings, inhibit onsite movement of vehicles, nor pose health or safety problems.

Identifying where snow will accumulate is important. Most of the snow deposited near a windbreak is deposited on the leeward side, within a distance that is 1 to 4 times the height of the windbreak. Snow also accumulates on the windward side for a distance of 1 to 2 times the height of the windbreak.

In addition, deep snowdrifts form closer to dense windbreaks. As windbreaks become less dense, snow settles progressively farther away and is distributed more evenly.

Drainage patterns of snowmelt must be taken into consideration. Drainage of snowmelt from the windbreak should not flow into the livestock area or cause erosion.

Building Ventilation

Air movement around buildings should be maintained for animal and worker health and to allow ventilation systems to work properly.

For mechanically ventilated systems, trees can be planted relatively close. The closer the vegetation is to the odor source the more effectively it reduces odors. However, the health of the trees, prevention of back pressure on fans and snow deposition must all be taken into consideration when determining the distance between the ventilation system and the windbreak.

With mechanically ventilated systems, the health of the trees is generally of primary concern. Exhaust from fans increases transpiration in vegetation making them vulnerable to desiccation. In addition, accumulation of debris and the gases exhausted by fans creates a harsh environment for vegetation to grow.

For naturally ventilated systems, the concern is typically with prevailing summer winds. Trees planted in the path of prevailing summer winds may interfere with needed summer air flows. Many producers prefer no vegetation on the side of the building from which prevailing summer winds come.

Root Systems

There is some concern that root systems of vegetation may damage artificial or natural liners of earthen pits or lagoons, resulting in leakage into the surrounding soil and waterways. If planting near such structures, the rooting habits of the species should be considered.

Likewise, location of subsurface drains should be considered during planning. If planting near subsurface drains is unavoidable, non-perforated conduit should be installed in the area where tree planting is planned.

Where concerns exist about competition between a windbreak and an adjacent field for water and nutrients a root plow can be used to sever roots and reduce competition. Root pruning will impact tree growth and must be done with care. Root pruning should be done at the drip line to minimize negative impacts and only one side should be pruned in a given year. Wait until the tree has reached the desired height before root pruning.

Vegetation

Field and farm windbreaks most commonly use conifers. Conifers are trees and shrubs bearing needles and cones and are mostly evergreen. Conifers have a large leaf surface area and generally maintain their branches all the way to the ground. Conifers create the densest windbreaks for blocking winds. These characteristics are useful for capturing particulates and for blocking winds that can pick up odors. However as a group, conifers tend to be slower growing than deciduous trees. The species favored by producers using windbreaks to manage odor are often fast growing deciduous trees such as hybrid willows, poplars and maples.

Deciduous trees, trees that lose their leaves in the winter, tend to grow faster and reach greater heights than conifers. To capture the benefits of conifers, deciduous trees and shrubs, both types of trees as well as shrubs may be planted in combination. Shrubs also tend to grow quickly.

- Tree and shrub species selected must be adapted to the soils, climate and site conditions. For information on species selection refer to the Conservation Tree/Shrub Suitability Index in the Natural Resources Conservation Service electronic Field Office Technical Guide - http://efotg.nrcs.usda.gov/treemenuFS.aspx. For additional information on vegetation characteristics refer to USDA's PLANTS Database at http://plants.usda.gov.

- Diversity of species in a windbreak lessens the negative impact of potential disease or pest outbreaks - problems which can devastate a windbreak composed of only one species. However, trees should be spaced so deciduous trees don't overtop conifers. Deciduous and coniferous trees should not be planted in the same row.

- Maximize particulate trapping by selecting species with high leaf surface roughness (leaf hairs, leaf veins, and small leaf size), complex leaf shapes, large leaf circumference to area ratios and medium to rapid growth rates.

Techniques are available to reduce the amount of time needed to establish a functioning windbreak.

- Supplemental watering and control of competition from grasses and weeds are critical for fast establishment and growth. Mulch, such as landscape fabric, herbicides and mowing are commonly used to control grass and weeds. Mowers can cause considerable damage and mortality to seedlings. Care should be taken if mowing is used.

- Fast growing species may be selected, such as hybrid poplars, willow and some maples. However, producers planting fast growing species need to be aware that their windbreaks will likely require replacement or renovation in 10-20 years. Faster growing tree species are often shorter lived.

- Trees within a row can be planted on a tighter spacing to achieve quicker results. However, thinning and removal of trees will be necessary as the windbreak matures, to prevent trees from dropping their lower limbs and creating holes in the windbreak.

- Larger stock can be used, such as air-root pruned potted planting stock. For more information on air-root pruned potted stock, see "Container grown" planting stock in NRCS practice standard TREE/SHRUB ESTABLISHMENT (612). A complete copy of the standard can be found at http://efotg.nrcs.usda.gov/treemenuFS.aspx.

- Poultry facilities using windbreaks to filter exhaust from fans commonly plant larger stock (8-10') to improve success rates. Seedlings often succumb to desiccation and the accumulation of debris & ammonia exhausted from buildings.

- Staggering tree spacing, so the trees of one row will be planted opposite the openings in the adjacent row, will decrease the time needed for a windbreak to be effective.

Density

All windbreaks impact airflow. Windbreaks promote deposition of dust particles, uplifting and dispersion of odors and filtering of wind. Higher density windbreaks are planted to encourage uplift as well as dispersion and deposition of dust particles. Lower density windbreaks are planted to encourage filtering by allowing more wind to pass through.

Factors that determine density include:

- Tree species
- Growth rates
- Spacing between trees
- Number of rows planted
- Rows that are staggered or are not staggered
- Time of year (Deciduous vegetation)

All of these factors can be manipulated to make a windbreak more or less dense.

Enhancing Aesthetics

Improved aesthetics and improved neighbor relations are often some of the most important benefits windbreaks provide. Windbreaks visually impact the overall rural landscape in addition to improving the appearance of the individual farmstead.

Trees add diversity and visual interest to the landscape and become part of the overall landscape pattern or structure. Vegetation can help soften and visually break up buildings, making them appear smaller and less industrial, as well as screen them from view.

Closer up, characteristics such as the form, color, texture and layout shape the windbreaks appearance and aesthetic. A curvilinear layout can help to blend a windbreak into the landscape. Deciduous trees, coniferous trees, and shrubs planted in the same planting have a different appearance and different texture than a windbreak planted with only coniferous trees or deciduous trees. Showy flowers and brilliant fall foliage add interest during the spring, summer and fall. Colorful fruit and the green of coniferous trees add color to the winter landscape.

Habitat Considerations

Windbreaks enhance wildlife habitat by providing shelter and food. If transfer of disease between wildlife and confined livestock, particularly poultry, is a concern, the risks and benefits of the windbreak need to be evaluated.

An argument exists that windbreaks have the potential to reduce airborne transmission of disease from one facility to another by capturing and preventing pathogens from moving downwind. In addition, there have been instances where raptors have taken up residence in windbreaks helping to keep down rodent populations.

Selecting vegetation that does not provide food or shelter preferred by wildlife may be one way to minimize the potential of disease transfer while realizing the benefits of a windbreak.

NRCS Windbreak Standard 380

For more detailed information on windbreak design refer to NRCS Windbreak/Shelterbelt Establishment Standard (380) and the NRCS Illinois Windbreak Manual. Many of the design considerations mentioned above are discussed in more detail in the standard. All standards referenced in the document are available at http://efotg.nrcs.usda.gov/treemenuFS.aspx.

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EXHIBIT 26

Cannabis Consulting

ORTECH

a Kontrol Energy Company

Why ORTECH

- 40+ years of Experience in Odour Management
- Independent Technical Advice
- Scientific Sampling, Computer Modelling, Analysis and Reporting
- Expert Witness and support services
- Trusted for odour management at: research facilities, greenhouses, industrial buildings, outdoor growing operations
- Experienced in Ensuring Ongoing Compliance with Government Regulations

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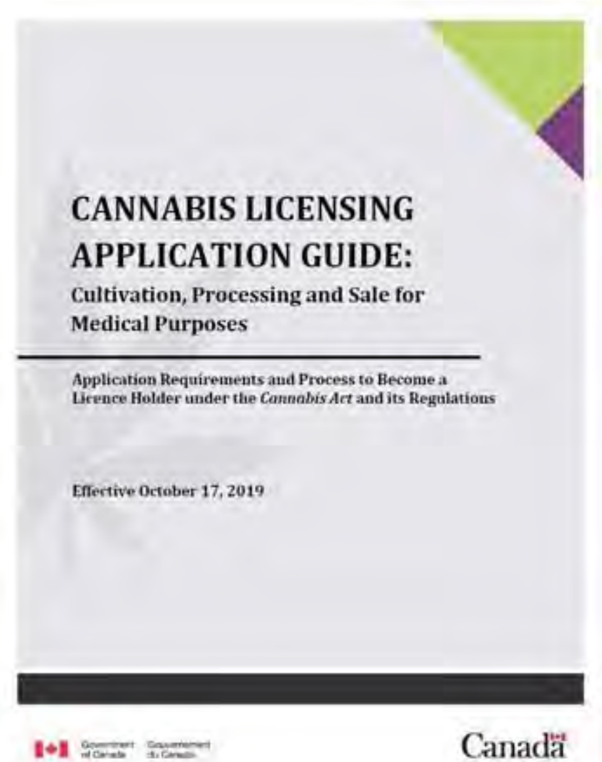
Canadian Approach


CANNABIS LICENSING APPLICATION GUIDE:
Cultivation, Processing and Sale for Medical Purposes

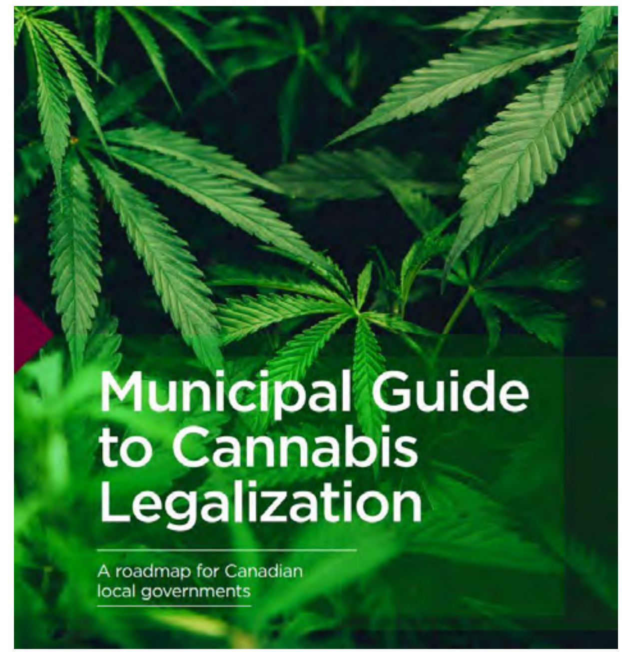
Application Requirements and Process to Become a Licence Holder under the *Cannabis Act* and its Regulations

Effective October 17, 2019

Canada

Municipalities are also responsible for tackling odour nuisance

odour impact assessments and control plans might be included in requirements for rezoning applications or development approvals


Municipal Guide to Cannabis Legalization

A roadmap for Canadian local governments

s.85 of Cannabis Regulation: The building or part of the building where cannabis is produced, packaged, labelled and stored must be equipped with a system that filters air to <u>prevent the escape of odors</u>

In ORTECH's experience, uncontrolled cannabis odors can disperse as far as <u>1000 m from outdoor farms</u> and more than <u>300 m from indoor grow facilities</u>

California Odour Guidelines

- As per, South Coast Air Quality Management District
  - 5 OU is noticeable
  - 5 to 10 OU is enough to trigger complaints
  - 5 or more confirmed complaints/year (3 year average) is considered significant

ORTECH's Experience

- Sampled and collected odour emission data from greenhouses in British Columbia and Ontario, Canada, for one of the largest producers in Canada
- Modelled emissions from indoor and outdoor cannabis growing operations
- Land use zoning studies (odours) for cannabis businesses
- Siting studies (odour assessment) for prospective growers
- Developed odour management plans for indoor grow facilities

ORTECH's Approach

ORTECH has Collected air samples from cannabis facilities and analyzed the air samples in lab to generate odour intensity data - Odour Units/time (OU/s)

ORTECH's in-house odour emissions data **+** Regional meteorological data - Hourly (wind speed, wind direction etc) **+** Terrain data (geographical location and elevation of the land) **+** Surrounding human receptors information (location and elevation)

↓ *Dispersion Modelling*

Minimum Setback distances of the cannabis operations from nearby human receptors can be established by dispersion modelling

Predicted hourly values of odour concentration (OU/m^3) at receptors. These values will be used to compare with the odour guidelines of California. The modelling output will be further analyzed to estimate how many times odour concentration is expected to exceed the odour guideline values.

ORTECH
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https://www.cannabisconsultingservices.ca

Do you need Odour Control? An Engineered Approach to Designing Cannabis Odour Control Solutions.

Does Your Cannabis Extraction Operation need to Register in the Environmental Activity Sector Registry ("EASR")?


QUESTIONS?
Thank you for listening.

EXHIBIT 27

What's it Like to Live 100 feet from 15,000 Cannabis Plants?

by NorthBay biz Staff December 3, 2020 in Columns, Guest Column

Buying a home in Sonoma County turned out to be our worst investment ever

Buying a home in Sonoma County turned out to be our worst investment ever. Cannabis wasn't legal, so a commercial-scale cannabis business in the area wasn't part of our calculation when we purchased our dream home west of Sebastopol. After California legalized cannabis in 2016, Sonoma County allowed our neighbor to grow thousands of new cannabis plants 100 feet from us and other families.

Sonoma County's cannabis ordinance defines the minimum distance between an outdoor cannabis cultivation and a neighbor's property to be 100 feet apart. Your child's swing set could be 100 feet from thousands of smelly cannabis plants or an armed robbery. Your garden, BBQ, patio? Yes, 100 feet from a commercial-scale cannabis field—that's just seven car lengths away.

Our neighbor operates a commercial cannabis cultivation and leases the property from the owners, who don't live there. The overwhelming cannabis odor is one example of how this business violates our right to enjoy our property, while the Sonoma County government disregards our complaints.

We're not the only Sonoma County neighborhood to have a massive, unannounced commercial cannabis business overwhelming the families who live there. Sonoma County's governing philosophy encourages cannabis businesses to proliferate throughout the county, complete the permit process later, wait for families to cobble a scrappy neighborhood opposition, and then ignore them. It's a cannabis-first policy, which Sonoma County fast-tracked by skipping a neighborhood and environmental impact review.

What's it like to live 100 feet from 15,000 cannabis plants? Does cannabis odor affect someone's health? How far does that odor travel in our micro-climates? How are neighborhood wells and watersheds impacted? The California Environmental Quality Act (CEQA) mandates that county officials answer these types of questions to assess the

impacts of a new cannabis ordinance, and act upon its results to ensure it doesn't negatively impact residents, neighborhoods, and the environment.

Instead of abiding by the CEQA, the board of supervisors loop-holed their way around it, and relied on a weak assumption to fast-track cannabis proliferation. They assume cannabis businesses that operate legally inside a neighborhood must be better for the earth than illegal cannabis businesses hiding in the hills. Is that enough to avoid the CEQA?

earth than illegal cannabis businesses hiding in the hills. Is that enough to avoid the CEQA? I don't think so, especially since the supervisors skipped CEQA's neighborhood impact study.

The supervisors claim they care about neighborhoods, as demonstrated during an April 10, 2018, hearing: Supervisor David Rabbitt said, "We need to push [cannabis cultivation] away from the residences."

Supervisor Susan Gorin said, "Move the cultivation away from impacting residential neighborhoods."

Supervisor James Gore said, "I turned-in a grow that was 200 feet from my house."

Supervisor Shirlee Zane said, "We haven't done enough to protect these rural neighborhoods."

Supervisor Lynda Hopkins said, "We really need to focus on the impacts of cannabis cultivation."

Yet today, two-and-a-half years later, the county still approves cannabis permits inside neighborhoods without referencing a CEQA study. To justify these permits, the county writes a "mitigated negative declaration," which includes an outline of questionable environmental recommendations the grower should implement in effort to silence documented neighborhood opposition. These recommendations are not based on science or experience, and lack any plans or timelines to measure their success. For example, the county recommends planting new bushes and trees to reduce (not eliminate) cannabis plant odor wafting around the neighborhood. That unproven idea doesn't work, but the permit is approved regardless. Between our backyard and our neighbor's cannabis plants are several buildings, a hill crest, and three layers of trees. Even Supervisor Hopkins smelled cannabis odor from our kitchen door. The county writes that the new trees will deflect cannabis odor into the atmosphere. This trickery is an astonishingly poor policy, one that places tremendous burden on the residents to prove the adverse impacts of a cannabis business in a neighborhood, making it a cannabis-first policy.

Our neighbor also uses indoor cannabis cultivation sites starting 5 feet from their property lines. Sonoma County's cannabis ordinance defines the minimum distance between an lines. Sonoma County's cannabis ordinance defines the minimum distance between an indoor cannabis cultivation and a neighbor's property to be 0 feet apart. Cannabis cultivation should be at least 1,000 feet from its neighbors. A 1,000-foot setback distance is a primary method to protect neighborhoods. Fooling residents to grow bushes and keeping the setbacks at 100 feet are the result of an irresponsible government promoting a cannabis-first agenda.

Other California counties have a different approach to keep a proper distance between residents and a cannabis business. Yolo County, at two-thirds the population density of Sonoma County's, conducted a CEQA study, in which the environmental impact report concluded that outdoor cannabis plants must be 1,000 feet away from neighboring properties. Why doesn't Sonoma County think the same? Please help shape the county's cannabis ordinance before a commercial cannabis business suddenly appears next to you.

Grace Barresi is one of seven families whose property completely encircles a commercial cannabis cultivation property. She speaks for more than 25 families who are impacted by this site. As of today, this cannabis business is without a county permit, but has been growing one acre of outdoor and indoor plants since 2017. Their lot size is 10 acres (ordinance minimum), and our parcel is 2 acres. We have pleaded with the county to change the ordinance and place commercial cannabis cultivation in more appropriate places. To contact Grace, write to her at 95472grace@gmail.com.

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EXHIBIT 28

The Nasal Ranger: A Hobbyist Weed Farm's Worst Enemy

Have a smelly investigation? The Nasal Ranger is on the case.

// BY CAROLINE DELBERT JAN 15, 2020

ST. CROIX SENSORY, INC.

- The Nasal Ranger helps investigators track strong odors, whether of chemical contaminants or just "bad smells."
- Machines are talented at detecting poisons or at purifying air, but humans are still better at tracking smells.
- Dynamic olfactometry means diluted smelly air is passed to trained human panelists. The Nasal Ranger is a limited mobile version.

The tiny city of Bessemer, in Michigan's remote Upper Peninsula, has spent $3,400 on a marijuana-sniffing instrument called the Nasal Ranger. City officials say that while recreational use is legal in the state, individuals are limited in how many plants they can grow, and the city's strong odor indicates people aren't obeying that part of the law. How does this device, which looks like a combination vape and bullhorn, help an investigator find the source of a smell?

The Nasal Ranger is a field olfactometer, and it uses a method called dilution to threshold: stinky air is sealed and then diluted with purified air that has no odor particles. In lab and manufacturing settings, this air is passed through a panel of qualified human smellers. The NIH explains, "[O]nly assessors who meet predetermined repeatability and accuracy criteria are selected as panelists." The way we sense smells is logarithmic, the same as decibels, meaning our sense of "smelliness" doesn't follow in a linear relationship with the amount of smelly particulate in our air.

Sometimes, a specific odor at, say, a construction site or a workplace can be "bagged" and brought back to a lab environment to be analyzed and presented to panelists. But for use cases like trying to locate a concentrated marijuana plant odor, a field olfactometer lets testers roam and continue to smell on the go. Operators still must qualify as smellers, and the NIH says tracking odors in situ is challenging because of how quickly a skilled smeller can get overwhelmed by surrounding smelly air instead of the isolation of a lab.

The company that makes the Nasal Ranger, St. Croix Sensory, offers a trademarked Odor School program so people using the Nasal Ranger are qualified to operate it. Users should also each have their own custom nose-covering mask portion, because the Nasal Ranger has to make an airtight seal. This all sounds very methodologically mushy, and invites the question: Why don't we just use machines?

Machine olfaction has come a long way, the NIH says, using "Gas Chromatography coupled with Mass Spectrometry." For measuring poisonous compounds in the air, this level of straightforward detection can work really well and help to protect workers or local residents threatened by pollution or mishandling of dangerous materials.

A complex mixture of chemicals makes up almost everything we smell. Have you ever caught a whiff of something that smelled good, before catching a second whiff and realizing it was something nasty? Our brains race to translate olfactory receptor information into smell messages, but scientists don't yet understand how that process works or what's really going on. They're also not sure why certain smells disgust us so much.

Marijuana plants in particular have a strong stench that reminds people of skunk spray. "The smell from commercial cannabis farms, which brings to mind a mixture of rotting lemons and sulfur, is nothing like the wafting cloud that might hover over a Phish show, pot farm detractors say," the *New York Times* reported from California in 2018.

In that piece, the creator of the Nasal Ranger said that flowering cannabis "easily" rates a level 7 on the Nasal Ranger's scale. "Charles McGinley, the inventor of the device, says a Level 7 is the equivalent of 'sniffing someone's armpit without the deodorant — or maybe someone's feet — a nuisance certainly,'" the *Times* reported.

In Bessemer, Michigan, the culprits are likely "hobby farmers" growing more than their legal share. The Nasal Ranger could lead to investigators busting these illegal farms, and residents could have better air quality in return.

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EXHIBIT 29

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Cannabis farms in the US could be causing chronic air pollution

19.09.2019

HEALTH, NEWS

THOMAS BARRETT

Cannabis farms, traffic emissions and the Californian sunshine could be creating the 'perfect storm' for air pollution, according to research published by the Desert Research Institute (DRI).

Since California and Nevada legalised cannabis for recreational use in 2016 and 2017, there has been a proliferation of new farms popping up across the two states but a pilot study, published in *Journal of the Air & Waste Management Association,* suggests this is having a negative impact on air quality.

Researchers visited four cannabis growing farms and found that cannabis plants emit biogenic volatile organic compounds (BVOCs) during growth and reproduction, which when mixed with nitrogen oxide (NOx) traffic emissions and sunlight creates ozone (O3), a toxic air pollutant which is harmful to humans.

Vera Samburova, Ph.D, and lead author of the study said: 'The concentrations of BVOCs and butane that we measured inside of these facilities were high enough to be concerning,

'In addition to being potentially hazardous to the workers inside the cannabis growing and processing facilities, these chemicals can contribute to the formation of ground-level ozone if they are released into the outside air.'

Mike Wolf, permitting and enforcement branch chief for the WCHD Air Quality Management Division added: 'With so much growth in this industry across Nevada and other parts of the United States, it's becoming really important to understand the impacts to air quality.'

The team at DRI now say they hope to find funding for a similar study on a wider scale

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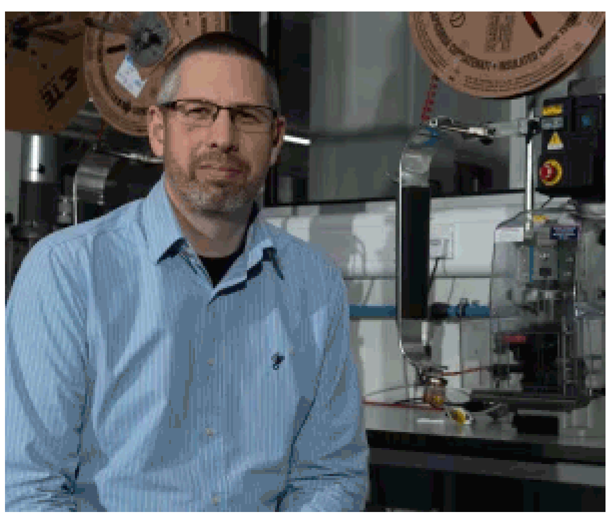

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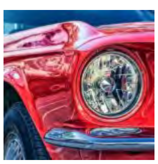

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EXHIBIT 30

Emissions from cannabis growing facilities may impact indoor and regional air quality

Pilot study evaluates potential for air quality impacts at facilities in Nevada and California

Date: September 18, 2019

Source: Desert Research Institute

Summary: Scientists have studied air quality inside of four cannabis growing facilities in Nevada and California. They recorded high levels of BVOCs (biogenic volatile organic compounds) and butane inside each growing facility, which can contribute to the formation of ground-level ozone if released into the outdoors.

FULL STORY

The same chemicals responsible for the pungent smell of a cannabis plant may also contribute to air pollution on a much larger scale, according to new research from the Desert Research Institute (DRI) and the Washoe County Health District (WCHD) in Reno, Nev.

In a new pilot study, DRI scientists visited four cannabis growing facilities in Nevada and California to learn about the chemicals that are emitted during the cultivation and processing of cannabis plants, and to evaluate the potential for larger-scale impacts to urban air quality.

At each facility, the team found high levels of strongly-scented airborne chemicals called biogenic volatile organic compounds (BVOCs), which are naturally produced by the cannabis plants during growth and reproduction. At facilities where cannabis oil extraction took place, researchers also found very high levels of butane, a volatile organic compound (VOC) that is used during the oil extraction process.

"The concentrations of BVOCs and butane that we measured inside of these facilities were high enough to be concerning," explained lead author Vera Samburova, Ph.D., Associate Research Professor of atmospheric science at DRI. "In addition to being potentially hazardous to the workers inside the cannabis growing and processing facilities, these chemicals can contribute to the formation of ground-level ozone if they are released into the outside air."

Although ozone in the upper atmosphere provides protection from UV rays, ozone at ground-level is a toxic substance that is harmful for humans to breathe. Ozone can be formed when volatile organic compounds (including those from plants, automobile, and industrial sources) combine with nitrogen oxide emissions (often from vehicles or fuel combustion) in the presence of sunlight. All of these ozone ingredients are in ample supply in Nevada's urban areas, Samburova explained -- and that impacts our air quality.

"Here in our region, unfortunately, we already exceed the national air quality standard for ground-level ozone quite a few times per year," Samburova said. "That's why it is so important to answer the question of whether emissions from cannabis facilities are having an added impact."

At one of the four cannabis growing facilities visited during this study, the team measured emission rates over time, to learn about the ozone-forming potential of each individual plant. The results show that the BVOCs emitted by each cannabis plant could trigger the formation of ground-level (bad) ozone at a rate of approximately 2.6g per plant per day. The significance of this number is yet to be determined, says Samurova, but she and her team feel strongly that their findings have raised questions that warrant further study.

"This really hasn't been studied before," Samburova said. "We would like to collect more data on emissions rates of plants at additional facilities. We would like to take more detailed measurements of air quality emissions outside of the facilities, and be able to calculate the actual rate of ozone formation. We are also interested in learning about the health impacts of these emissions on the people who work there."

The cannabis facility personnel that the DRI research team interacted with during the course of the study were all extremely welcoming, helpful, and interested in doing things right, Samburova noted. Next, she and her team hope to find funding to do a larger study, so that they can provide recommendations to the growing facilities and WCHD on optimum strategies for air pollution control.

"With so much growth in this industry across Nevada and other parts of the United States, it's becoming really important to understand the impacts to air quality," said Mike Wolf, Permitting and Enforcement Branch Chief for the WCHD Air Quality Management Division. "When new threats emerge, our mission remains the same: Implement clean air solutions that protect the quality of life for the citizens of Reno, Sparks, and Washoe County. We will continue to work with community partners, like DRI, to accomplish the mission."

Story Source:

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Journal Reference:

1. Vera Samburova, Mark McDaniel, Dave Campbell, Michael Wolf, William R. Stockwell, Andrey Khlystov. **Dominant volatile organic compounds (VOCs) measured at four Cannabis growing facilities: pilot study results**. *Journal of the Air & Waste Management Association*, 2019; 1 DOI: 10.1080/10962247.2019.1654038

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EXHIBIT 31

AIR POLLUTION

Growth of legal pot farms drives smog worries

Colorado to launch study of potential air quality effects of indoor cannabis facilities

By **Jason Plautz**, *in Boulder, Colorado*

Atmospheric scientist William Vizuete grew his dozen pot plants in a garage here, on shelves tucked between some bicycles and a lawn mower. The researcher at the University of North Carolina in Chapel Hill wasn't looking for a high—just data. His team aimed to measure the volatile organic compounds (VOCs) released into the air by four varieties of cannabis—including strains dubbed Lemon Wheel, Elephant Purple, and Rockstar Kush—as they grew, rather than when they were smoked.

Those measurements, recently published in *Atmospheric Environment*, are just one product of an emerging effort to understand how expanding pot farms in Colorado and the nine other U.S. states and Washington, D.C., that have legalized recreational marijuana might be affecting air quality. Vizuete's study, for instance, suggested the more than 600 indoor pot farms in Denver could be worsening the city's air pollution, which sometimes violates federal limits. Next month, in a bid to understand that issue, Colorado officials will launch one of the largest studies to date of pot farm emissions.

Those findings could also aid regulators across the nation, who face a dearth of data as they try to evaluate the pot industry's potential effects on indoor and outdoor air quality as well as worker health. "To be able to permit [pot farms], we have to at least estimate their emissions," says Mike Wolf, a regulator in Washoe county in Nevada.

Such estimates have been scarce, largely because the federal government still considers cannabis an illegal industry. That has made it difficult for researchers to obtain funding from federal agencies, including the Environmental Protection Agency (EPA) and the Occupational Safety and Health Administration. Vizuete, for example, had to work in a garage because cannabis plants aren't allowed in the federally funded National Center for Atmospheric Research here, where he had hoped to run the study. Scientists wanting to study pot, he says, "are stuck in a position where we have to cobble this together on our own."

Researchers have long known that VOCs emitted by plants can contribute to smog. VOCs can mix with nitrogen oxides—produced by cars and industrial sources—in sunlight-driven reactions that produce ground-level ozone, a pollutant. Vizuete's study confirmed that pot plants are a rich source of potent VOCs called terpenes, which give cannabis its dank smell. And it suggested the tens of thousands of plants in Denver's indoor farms—which are mostly found along two busy highways—could, under a worst case scenario, double the city's volume of smog-forming VOCs. If the farms "are putting out a significant amount of terpenes, there is not a worse place to put them," Vizuete says. "If I was designing an ozone reactor, this is what I'd do."

Ultimately, researchers will plug the findings into computer simulations that help scientists and regulators understand the factors driving air pollution. Normally, EPA provides those numbers for industrial emissions. But it doesn't recognize pot growing and Urso says agency officials don't like to discuss the matter, leaving states to fill the gap. "EPA has left us holding the bag," Urso says.

If pot farm emissions do pose air quality problems, it's not clear what regulations would require growers to do. Farms are exempt from many clean air rules, although worker safety regulations and some state rules could apply. Placing carbon filters on grow house exhausts could capture up to 98% of volatile emissions, but so far the filters aren't required. The industry, meanwhile, is eager to work with researchers. "We want more data, we want to know how we can promote best practices and be good neighbors," says Morgan Fox of the National Cannabis Industry Association in Washington, D.C.

Researchers want to know more about how pot farms, like this one in Avondale, Colorado, affect air quality.

PHOTO: MATTHEW STAVER/BLOOMBERG VIA GETTY IMAGES

Vizuete's team notes its study—one of the first of its kind—was not definitive. It was small: just three plants each of four of the 620 available cannabis strains. And the plants were "pathetic," says study co-author Christine Wiedinmyer, an atmospheric chemist at the University of Colorado here—nothing like the lush crops grown by professionals.

The Denver study, funded by a state program, will collect more data. It will measure VOC emissions at four farms—two large and two small—over the monthslong cultivation cycle, from planting to processing. The goal is to track emissions across pot varieties, growing conditions, and plant size and age, says project leader Kaitlin Urso of the Colorado Department of Public Health and Environment in Denver.

Some help could soon come from Canada, which recently legalized pot—opening the door to studies that don't have to hide in a garage. But Vizuete says there also "needs to be some leadership from federal agencies" in the United States, including EPA. "Nobody is helped," he says, "by refusing to acknowledge that this is a public health issue." ■

Jason Plautz is a journalist in Denver.

Science

Growth of legal pot farms drives smog worries

Jason Plautz

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EXHIBIT 32

Smoke Exposure and Firefighter Risk in the Wildland Urban Interface

Assistance of Firefighters Grant Program
Fire Prevention and Safety Grants
EMW-2013-FP-00621

Prepared by:
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1.0 Summary

Collaborators with California State University San Marcos and the University Auxiliary Research Services Corporation worked in partnership with the United States Department of Agriculture-Forest Service, CAL FIRE, CAL FIRE Local 2881, the International Association of Fire Fighters, and the National Institute of Standards and Technology to evaluate the physiological and working conditions of wildland firefighters and smoke exposure in the wildland urban interface (WUI). Funding for this work was provided by the Federal Emergency Management Agency (FEMA) Fire Prevention and Safety Program (FPS).

Conditions dictate that wildland firefighters are often required to work for extended periods in intense heat and brutal environmental conditions. Today, a WUI incident represents a dynamic, complex environment where wildland, structure, and vehicle fires often merge. As a result, we do not clearly understand of the risks and hazards this synthesis creates. Moreover, protection standards for firefighters are specific to each incident type, and often overlook the concomitant risks that firefighters face when responding to an incident in the WUI.

This study assesses air pollutants during wildland and urban interface fires, develops protocols and sensor platforms for measuring and assessing smoke exposure in the WUI, monitors the physiological condition of wildland firefighters on duty, and assesses common materials in a WUI incident under controlled laboratory burns and actual WUI incidents to identify and understand constituents of concern in the smoke. Overall, the exposure to wildland firefighters is significant, and often exceeds occupational exposure limits, particularly on those incidents that include combusted materials from the urban environment (e.g. homes, vehicles, and infrastructure). While CO and PM were commonly observed in both the laboratory and field testing, other constituents pose a significant threat to wildland firefighters. In those incidents where manmade materials were included (for both training burns and WUI incidents), key constituents were observed that were otherwise absent or below occupational exposure levels in the other vegetation-only burns. While the laboratory tests provided similar results, the data collected in the field on actual WUI and training fires demonstrated a much more consistent and elevated exposure risk in certain constituents. In general, PM, CO, SO2, VOCs, NO, cyanide, and benzene were commonplace when these combusted materials were included in the smoke exposure, while PAHs, HCN, and HCL were also detected (however these occurrences were typically at lower levels of occurrence and minimal exceedances of occupational levels).

Ninety-five wildland firefighters with CAL FIRE volunteered to participate in this study, including personnel at training events (extended hose lays), controlled burns, and actual wildland fires. The results show that wildland firefighters regularly exceeded safe physiological conditions (regardless of the event type). Nearly 65% of the firefighters had sustained peak heart rates above 200 beats per minute (bpm), with nearly 20% exceeding 220bpm (all but three of the volunteers regularly exceeded the recommended maximum hearts rate for work (220bpm minus your age). Likewise, measured core body temperatures exceeded 102F in roughly 70% of the firefighters, with 10% exceeding 103F. Furthermore, nearly two-thirds of the firefighters started their shifts at or near a level of dehydration. Dehydration rates significantly increased across all firefighters at the end of duty, with only 25% of the firefighters that started off at or near dehydration self-correcting and becoming more hydrated by the end of the shift. Finally, the type of personal protective equipment (PPE) worn by wildland firefighters has a significant influence on their physiology. The results suggest that the traditional double-layer PPE produces significantly higher core body temperatures, higher incidence of dehydration, and higher heart rates than single-layer PPE.

2.0 Literature Review on Primary Constituents of Concern

Today, a WUI incident represents a dynamic, complex environment where wildland, structure, and vehicle fires often merge. As a result, we do not clearly understand of the risks and hazards this synthesis creates. Moreover, protection standards for firefighters are specific to each incident type. This report seeks to rectify this situation by improving our understanding of the exposure risks across the myriad of incident types, providing a synthesis of existing literature and reports associated with wildland, structure, and vehicle fires. This can serve as a springboard for evaluating tools for assessing and predicting hazards, and recommending safeguards for improving health and safety.

The paradigm shift from wildland to WUI firefighting has transformed conventional risk. Traditionally, fire studies focused on the three broad categories: wildland, structure, and vehicle. Each incident type comes with distinctive exposures, hazards, and risks with protocols, tactics, and PPE specific to each scenario. A WUI fire represents a dynamic and complex incident where these incident types merge. Firefighters may respond to a wildland fire, but often focus on community defense where structures and vehicles can become involved. The evolution of modern wildfires fires suggests that this is not only a common scenario, but is a virtual certainty. The result is a transition from a wildland fire (where firefighters may be reasonably prepared and protected) to an atmospheric mix of pollutants that can have severe risks and consequences.

While smoke exposure at some wildfires and prescribed burns can be no more than a nuisance, on occasion it approaches or exceeds legal and recommended occupational exposure limits. The composition of the smoke depends on variables such as fuel type, moisture content, temperature, and wind with different fuels containing variable levels of cellulose, lignin, polyphenols, oils, fats, resins, waxes, and starches. The smoke is a highly variable and complex mixture of carbon dioxide, water vapor, carbon monoxide (CO), particulates (PM), unburned fuel, polycyclic aromatic hydrocarbons (PAHs), nitrogen oxides, trace minerals and diverse hazardous air pollutants (HAPs). While this is daunting in itself, when wildland fires become WUI fires, the range of natural and synthetic materials from structures and vehicles release additional pollutants, many of which are highly hazardous, carcinogenic, and toxic.

Many safeguards for structure and vehicle fires are not part of WUI standards; customary protocols and PPE may actually be incompatible. For example, extended duty on many wildland/WUI fires means that traditional the breathing apparatus used for these incidents would provide only a fraction of the protection needed during a 12-, 16-, or 24-hour shift where exposure can be unpredictable. This device is further limited simply due to the physical constraints it places on the firefighter in the field. Similarly, turnout gear for structure fires is designed to afford adequate protection for an interior attack, not the exterior attack more typical of WUI firefighting. The thick, heavy, urban gear induces serious heat stress for firefighters conducting exterior or vegetative fire suppression. Proper WUI safeguards are imperative.

This project compiled nearly two hundred sources of literature and reports related to exposure hazards and risks related to wildland, structure, and vehicle fires. The goal is to provide an assessment of the types or hazards and exposure risks that can occur in the outside environment for a WUI fire (where traditional wildland, structure, and vehicle fires can occur simultaneously). The findings included herein can be used to inform firefighting agencies and firefighters with responsibility for WUI fires. This synthesis helped identify gaps in information, as well as which constituents of concern we should focus on for our broader exposure study.

2.1 Methods

In order to assess the current understanding of hazards and risks related to wildland, structure, and vehicle fires, we conducted an exhaustive search of the literature and reports available on this topic, with an emphasis on those studies that have been competed since 2000. Our literature search included keyword searches with both and “OR” and “AND” qualifier using combinations of terms, including: firefighter, structure fires, vehicle fires, wildland fires, wildland urban interface fires, smoke, exposure, air pollution, contaminants, and emissions. We searched key databases including: Web of Science, PubMed, Medline, BIOSIS, PubMed, JSTOR, Google Scholar, and the Cal State and University of California Databases with San Diego State University and UC San Diego. We also conducted general Internet searches and key agency contacts including the US Forest Service, the National Institute for Occupational Health and Safety, Centers for Disease Control and Prevention, National Institute of Standards and Technology, and the Motor Vehicle Fire Research Institute. Additional references were identified in key papers that were screened for relevant articles that were not identified in the original search. All articles were compiled in an EndNote database (Version 8), with annotations and digital copies of the source (where available).

2.2 Results

In total, the searches resulted in 2,028 potential articles that met our search criteria. We then evaluated these articles for accessibility and validity, selecting literature that was either published by reputable sources, agencies, or peer reviewed literature. We then read through the articles to identify those that were relevant to this particular study and human exposure. This resulted in 194 sources: 85 for wildland fires, 67 for structure fires, and 49 for vehicle fires (fifteen articles spanned both structure and wildland fire topics). These sources were then further analyzed to identify specific hazards and exposure risks that can reasonably be related to firefighters in the wildland urban interface.

A database was compiled, evaluating each article on several key factors (Table 1):

- The type of study conducted (e.g. whether it was an exposure study, assessment of combustible materials, or an analysis of a particular injury-related incident)
- Whether the study specifically included or referenced firefighting and firefighters
- Whether the study addressed smoke related issues (generally and specifically)
- Key constituents included in the study including hazardous air pollutants (HAPs), polycyclic aromatic hydrocarbons (PAHs), volatile organic compounds (VOCs), particulates, carbon monoxide, carbon dioxide, nitrogen species, sulfur dioxide, benzene, cyanide, and acids (hydrochloric and sulfuric)
- Whether the study included an assessment of heat as part of the analysis
- Whether the study specifically addressed wood and/or wood related products
- Whether the study addressed the use of SCBA or respirators as part of the evaluation
- For vehicle fires, the evaluation also identified whether the study was specific to tunnel fires and/or whether they included tire combustion in the assessment

Appendix A provides a complete table and evaluation criteria for each resource included in this analysis. **Appendix B** provides a complete list of the literature included in the literature review.

Table 1. Number and type of studies that addressed specific categories of combustion constituents

Incident(Type	HAPs	PAHs	VOCs	PM	CO	CO2	NOx	SO2	Benzene	Cyanide	Acids
Structure'Fire'Total	14	8	8	9	16	5	5	3	3	14	4
Vehicle'Fire'Total	4	5	6	2	8	5	2	1	4	3	3
Wildland'Fire'Total	2	8	19	26	25	2	3	1	9	6	2
GRAND(TOTAL((N=194)	**20**	**21**	**33**	**37**	**49**	**12**	**10**	**5**	**16**	**23**	**9**

Table 2. Number and type of studies that included key criteria (discussed above)

Incident(Type	Firefighter(Study	Heat	Wood(Combustion	SCBA(and/or(Respirator(Use	Tunnel(Study	Tire(Fires*
Structure'Fire'Total	27	5	8	4	NA	NA
Vehicle'Fire'Total	8	6	1	1	12	5
Wildland'Fire'Total	49	0	17	4	NA	NA
GRAND(TOTAL((N=194)	**84**	**11**	**26**	**9**	**12**	**5**

*This'criteria'only'applies'to'vehicle'fires'included'in'this'assessment

Results of this review led us to identify the key physiological measurements that we collected on the firefighters as well as the key constituents of concern to assess in our WUI smoke exposure assessment (described in the following sections).

3.0 Laboratory Analysis and Sensor Assessment

Significant research has been conducted to better understand the conditions that fire fighters and occupants are exposed to during structure fires and to a somewhat lesser extent, during wildland fires. Less research has been conducted to understand the exposure to WUI fires. This study was designed to better characterize smoke generated by wildland-urban interface fires to better understand the exposure of fire fighters and the public to WUI smoke. A portable gas and particulate sampling system was developed to collect data both at laboratory- and full-scale for smoke from combinations of structural and vegetative fuels.

This study focuses on the exposure of fire fighters, but the data collected by the sensor package is also applicable to characterizing the exposure of the public during WUI fires. This study extends the work of previous studies (including those conducted by NIST) on the physical and chemical characterization of smoke, laboratory experiments, and field assessments to identify key constituents of smoke [1-16].

3.1 Smoke Sampling

Combustion smoke can be sampled and analyzed using a range of technologies including gravimetric sampling, optical and paramagnetic sensors, gas chromatographs, photoionization detectors, and electrochemical diffusion cells. Some of these techniques can track species or particulate concentrations in real time while others collect an integrated or batch sample which is analyzed off-line to report concentrations. Although batch sampling typically requires less equipment in the field because the sample is returned to the laboratory for analysis, batch samples provide concentrations averaged over the entire collection period, not time-resolved data.

Smoke can be characterized in terms of chemical composition, concentration, and aerodynamic size. Identifying the chemical components of smoke is necessary to determine what compounds, both inorganic and organic, that fire fighters could potentially be exposed to on the fire ground. Organic compounds may include toxic gases (hydrogen cyanide and carbon monoxide), asphyxiants (carbon dioxide [17]), carcinogens (benzene and polycyclic aromatic hydrocarbons [18]) and unburned fuel (soot, vegetation, and volatile organic compounds). Inorganic compounds may include toxic gases (hydrogen sulfide and sulfur dioxide), irritant gases (hydrogen chloride, hydrogen bromide, nitrogen oxides), and particulates (soil). Quantifying how much or the of the specific compounds are present in the smoke is necessary to assess the potential impact of the chemical compounds. For gaseous species concentration is often expressed as parts per million (ppm) or volume percent while solid particulates are reported in mg/m^3.

3.2 Soot and Particulate Sampling

3.2.1 Mass Concentration

Soot and particulate sampling can be conducted using gravimetric filters, either batch or real time, or optical light cell based techniques. The simplest approach is gravimetric batch where a pump is used to pull smoke through a filter media. Filter media can be cellulosic or quartz fibers or polymeric membranes. The filter is weighed before collection, smoke at a known flow rate is pulled through the filter, and the filter is re-weighed after collection. Dividing the total mass collected on the filter by the total volume provides an average concentration. Soot and particulates can also be sampled gravimetrically in real-time using a tapered element oscillating microbalance (TEOM). The TEOM techniques involves causing a small filter to vibrate at a known frequency, and pulling a known volume of smoke sample through the filter media. Although this technology can be deployed to the field, As the mass accumulates on the filter, the frequency of the vibration changes, and the accumulated mass can be calculated from the frequency change in real time. Again, dividing the instantaneous mass by the flow rate provides real-time mass concentration. However, the relatively small EOM filter (< 1.3 cm diameter) can become clogged in high mass concentrations requiring frequent filter changes. For low concentrations of smoke, a single filter can collect for many hours, but for higher concentrations of smoke, such as those in close proximity to active fires, a single filter may only collect for several minutes before necessitating a filter change.

In additional to TEOM techniques, light- or optical-cells can also be used to monitor soot and particulates in real-time. Smoke is pulled into a small volume while a beam of light is transmitted through the smoke. The light source which can be a laser, an incandescent filament, or light emitting diode, is typically in the visible and/or infrared portion of the electromagnetic spectrum. Smoke can either absorb or scatter light within the cell volume. The amount of light adsorbed and scattered is a function of mass concentration, size distribution, index of refraction, and the wavelength of the light. Optical cells can be small portable hand held models or more complex 10 liter cells mounted on an optical board or frame.

3.1.2 Size Distribution

The size distribution of soot and particulates can be conducted using aerodynamic impactors (batch), or optical light cell based techniques (real-time). A pump is used to pull smoke through a multi-stage impactor. At each stage the smoke is accelerated and required to negotiate 90 degree changes in direction. At each stage, the particles with larger aerodynamic diameter are less able to follow the flow lines of the gas and impact a thin foil collection media. As the smoke is accelerated more at each subsequent stages, the smoke particulates are collected on the different foils according to aerodynamic size. The size distribution of the particulates is calculated by weighing the mass of particles on each sizing stage. Some impactors are designed to simulate how deep the particulates would penetrate the human respiratory system. Large particles would be deposited in nose/throat, smaller particles in the bronchial tree, and still smaller particles would be carried deeper into the lungs.

Optical light cell particle counters can use light scattering, light obscuration, or direct imaging to count and/or size smoke particulates. Typically, a pump pulls a smoke sample into a sensing chamber where a high intensity light (LED, laser, or halogen) illuminates the particles. Photo detectors track the scattered light and/or obscured light and the amplitude of the light scattered or light blocked allows particles to be counted and tabulated into standardized counting bins. For direct imaging, the sensing chamber is illuminated by a high intensity light and digital images of the particles are recorded for subsequent analysis by imaging software. While light scattering or light blocking particle counters can display data in real-time, direct imaging counters typically do not report data in real time.

3.2 Gas Species

Combustion smoke gas species can be sampled and analyzed using a range of technologies including light absorption cells, paramagnetic sensors, electrochemical cells, photoionization detectors, and gas chromatographs. Many of these monitors provide real-time or near real-time gas concentrations while others utilize batch collection and off-line analysis.

3.2.1 Light Absorption Optical Cells

Within Carbon monoxide and carbon dioxide, within the smoke can be individually detected using non-dispersive infrared sensors. After passing the smoke through a cold trap to remove water and a filter to remove particulates, smoke is pumped through a small cell. A beam of infrared light is split and transmitted through the sample cell and a reference cell which contains the gas species of interest at a known concentration. Both the sample and reference cells absorb portions of the transmitted light in proportion to the gas species being detected. The ratio of the two signals provides real-time concentration of gas species in the reference cell.

3.2.2 Paramagnetic Detectors

Oxygen concentrations can be tracked in real-time because oxygen has the unique paramagnetic properties which cause a flow of oxygen containing gas to induced an internal magnetic field when placed in an externally applied magnetic field. Since the induced magnetic field is proportional to amount of oxygen molecules, oxygen concentrations can be tracked in real-time. Typically, the smoke is pumped through a cold trap to remove water vapor and a filter to remove particulates.

3.2.3 Electro-Chemical Cells

The gas diffuses into the sensor, through the back of the porous membrane to the working electrode where it is oxidized or reduced. This electromechanical reaction results in an electric current that passes through the external circuit. In addition to measuring, amplifying and performing other signal processing functions, the external circuit maintains the voltage across the sensor between the working and counter electrodes for a two electrode sensor or between the working and reference electrodes for a three electrode cell. At the counter electrode an equal and opposite reaction occurs, such that if the working electrode is an oxidation, then the counter electrode is a reduction.

3.2.4 Photoionization Detectors

Photoionization detectors measure volatile organic compounds and other gases in concentrations. In a photoionization detector high energy photons, typically in the vacuum ultraviolet range, break molecules into positively charged ions. As compounds enter the detector they are bombarded by high energy UV photons and are ionized when the absorb the UV light, resulting in ejection of electrons and the formation of positively charged ions. The ions produce an electric current, which is the signal output of the detector. The greater the concentration of the component, the more ions are produced, and the greater the current. PIDs are non-destructive and can be used before other sensors in multiple-detector configurations.

3.3 Sorbent Tubes

Sorbent tubes are widely used collection media for sampling gases and volatile compounds in air or smoke. Sorbent tubes are small glass tubes packed with various types of sold adsorbent materials. The medium is tailored to the component(s) of interest. Activated charcoal and a crosslinked polystyrene copolymer resin are often used to capture benzene and polycyclic aromatic hydrocarbons, respectively. Smoke is pulled through a sorbent tube and the chemicals are trapped onto the sorbent material during the sampling period. Sorbent tubes are returned to a laboratory for desorption and subsequent analysis. Often the analysis is completed using a gas chromatograph. Once analyzed, often done via a gas chromatograph, the total amount of chemical is reported. Dividing the total amount by the volume pulled by the pump through the sorbent tube provides an integrated value over the entire sampling period.

3.4 Chromatography

Chromatography is an analytical technique which can be used to quantify compounds in smoke. Samples are introduced typically into a small diameter column which is packed with a specific medium. The medium is tailored to the component(s) of interest. The sample is moved through the medium within the column by either a carrier gas or liquid solvent. Compounds move through the medium at different rates because of specific material properties. For example, large molecules may take more time than small molecules to elude from the end of the column. Detectors at the end of the column sense when specific compound emerge as a function of time. The amount of time required for sample to move through medium is dependent on compound, carrier/solvent flow, and length of column. Portable chromatographs and micro-chromatographs can be deployed to the field, but do not provide real-time data. By selecting different medium, columns, carriers/solvents, and detectors, chromatographs can identify a broad range of compounds, but not simultaneously.

4.0 Instrumentation Package

On the fire ground, whether it be an urban, wildland, or wildland-urban interface fire, fire fighters are exposed a range of combustion products. A field deployable instrumentation package would allow smoke to be sampled on the fire ground. Deployment of multiple packages would allow smoke exposure to be characterized at multiple location simultaneously. Smoke sampling technologies, both commercial off-the-shelf systems as well as laboratory prototypes, each system was reviewed to assess the suitability of sensors and monitoring devices for potential precision/accuracy, reliability/repeatability, durability, length of deployment, portability (size/weight), data distribution and communications compatibility, real-time capabilities, and ease of use and interpretation. It was also critical that the selected instruments be compatible with other systems in order to allow all the sampling to be assembled, powered, and deployed in a single rugged system.

4.1.1 Smoke Sampling Capabilities

The system needed to include the capability of monitoring multiple combustion products including toxic and irritant gases, polycyclic aromatic hydrocarbons, volatile organic compounds, particulate materials as well as temperature and relative humidity. Smoke components, sensors, and analysis techniques are tabulated in Table 3.

Table 2. Smoke Components, Sensors, and Analysis Techniques.

Smoke Component	Sample Type	Detection Method	Reported Data
Carbon Monoxide	Real time	Optical Cell – light absorption	Concentration Volume Percent (Parts Per Million)
Carbon Dioxide	Real time	Optical Cell – light absorption	
Hydrogen Cyanide	Real time	Electrochemical Cell	
Hydrogen Chloride	Real time	Electrochemical Cell	
Hydrogen Flouride	Real time	Electrochemical Cell	
Nitric Oxide	Real time	Electrochemical Cell	
Nitrous Oxide	Real time	Electrochemical Cell	
Sulfur Dioxide	Real time	Electrochemical Cell	
Benzene	Integrated Batch	Sorbent Tube Chromatography	Mass Concentration Mg/m3
Polycyclic aromatic hydrocarbons	Integrated Batch	Sorbent Tube Chromatography	
Volatile Organic Compounds	Real time	Photo ionization	

Particulate Material	Integrated Batch	Gravimetric	Average Mass Concentration
	Integrated Batch	Gravimetric	Particle Size Distribution
	Real Time	Optical Cell – Light Scattering	Particle Size Distribution

Smoke monitoring analyzers are commercially available as single gas or multiple gas systems. In order to minimize weight and size as well as power required, multiple-gas analyzers were selected. Two multi-gas systems were configured to monitor carbon dioxide, carbon monoxide, volatile organic com dedicated to tracking one gas or compound or as multiple analyzer

Table 3. Smoke Component and Sample Configuration

Smoke Component		Sample Configuration
Hydrogen Cyanide		Multi-Gas System1
Hydrogen Chloride		
Hydrogen Flouride		
Nitrous Oxide		
Sulfur Dioxide		
Carbon Monoxide		Multi-Gas System 2
Carbon Dioxide		
Nitric Oxide		
Volatile Organic Compounds		
Benzene		Sorbent Tube & portable pump
Polycyclic aromatic hydrocarbons		Sorbent Tube & portable pump
Particulate Material	Average Mass Concentration	Filter & portable pump
	Particle Size Distribution	Cascade Impactor & portable pump
	Particle Size Distribution	Particle Analyzer with built-in pump

4.1.2 Active Smoke Sampling

The key feature of active smoke sampling is that a sample is extracted from the fire conditions or smoke plume. Typically, a pump is employed to pull the sample through the probe at a calibrated flow rate through tubing to a detector. The probe and tubing can be glass, metal, or plastic. The smoke may or may not be conditioned to prepare it for analysis. Filters are used to remove particulates, cold traps to remove water, and specific adsorbents, to scrub carbon dioxide. Gravimetric analysis for particulates almost always requires that a volume be pulled through a filter media in order to separate out the solid component of the smoke. When sampling for multiple compounds, it can be useful to use the same probe to pull all the samples. If multiple probes and sample locations are used, it can introduce uncertainty as to whether or not there was variability in chemical composition related to different sample locations. Since active sampling involves moving a sample from the sampling point to an analyzer, electrical power, either hardwired or battery, is needed.

4.1.3 Passive Smoke Sampling

Rather than using pumps to extract a sample, passive sampling relies on wind or air currents to move or convect the smoke to the detector. The smoke may or may not be well mixed, so multiple sensors located small distances apart may be immersed and thus sampling in smoke of different concentrations. However, since passive sampling does not require a pump to extract a sample, the need for electrical power requirements are significantly reduced.

4.2 Smoke Sampling Package

In order to monitor and track multiple components of smoke which were identified during the early stages of this study, the design of this instrumentation package needed to meet a number of requirements including 1) real-time concentration measurements of 8 different gas species, 2) real-time concentrations of volatile organic compounds, 3) batch sample collection for polycyclic aromatic hydrocarbons and benzene, 4) real-time monitoring of size distribution of particulates, 5) gravimetric measurement of soot and particulate mass concentrations, 6) portable and relatively low weight, 7) battery powered, 8) data logging for real-time data streams, and 9) able to survive brief exposure to flame radiation and embers.

4.2.1 Analyzer Enclosure

The enclosure for the analyzers is a thin wall stainless steel duct of 24 cm (9 inch) diameter and 40 cm (16 inch) long(Figure 1). An end cap at the exhaust or lower end a centered mounting column, battery pack, and exhaust fans (Figure 2). Another end cap at the entrance or upper end is perforated with twenty holes of 2.5 cm (1 inch) diameter. The 20 orifices help ensure that the smoke drawn into the main body of the cylinder is well mixed and prevents large embers from entering (Figure 3).

4.2.2 Multi-Gas Systems

Multi-gas systems 1 and 2 are positioned parallel to and mounted to the center support (Figure 4). Temperature and relative humidity sensors are incorporated into both of the multi-gas systems. As the smoke is pulled into the cylinder and through the perforated end cap, the smoke volume appeared well-mixed within the cylinder. The gravimetric and sorbent tube sampling trains were located after the electro-chemical, photoionization, and light absorption optical cells.

4.2.3 Gravimetric and Sorbent Tube Sampling

Filter holder for gravimetric soot mass concentration and small funnel shaped entrance tip to soot particle size analyzer are mounted in between the multi-gas systems (Figure 5). Sorbent tubes for benzene and polycyclic aromatic hydrocarbons (PAH) are mounted on the opposite side from the multi-gas analyzers (Figure 6). Both sorbent tubes have a filter located before the sorbent tube to remove soot and other particulates. The PAH sorbent tube is larger diameter and filled with white XAD-2 adsorbent (Figure 7). The benzene sorbent tube is a smaller diameter filled with black coconut charcoal (Figure 7).

4.3.4 Pumps, Particle Size Analyzer and Data Acquisition System

Once the stainless steel cylinder has been re-installed over the analyzers, filters, and sorbent tubes, the portable battery-powered pumps are mounted on the outside of the cylinder (Figure 8). Each pump is connected via 6 mm (0.25 inch) diameter plastic tubing to a sample train which includes a filter and sorbent tube. The flow rate for the benzene and polycyclic aromatic hydrocarbon sampling trains were set at 0.2 l/m and 2.0 l/m, respectively. In addition to the sample pumps, the battery-powered particulate sizing analyzer is also mounted on the outside of the cylinder and connected to the sampling tip on the inside of the cylinder by a small diameter 3 mm (0.125 inch) plastic tube (Figure 9). A battery-powered data acquisition system was also mounted on the outside of the cylinder. It was connected to the multi-gas analyzers and other instruments inside the cylinder and the particle analyzer on the outside (Figure 10).

4.3.5 Final Sensor Measurement Matrix

The following table shows the final sensors used to assess smoke samples in both the laboratory and in the field.

Table 4. Wildland-Urban Interface Fire Exposure Selected Measurement Technology

Energy					
	Temperature	Air / Gas	Thermocouple	Chromel-Alumel	
	Thermal Flux	Thermal Radiation	Heat Flux Transducer	Conduction cooled	
Mass					
	Chemical Component	Type of Measurement		Sample Acquisition	GrayWolf Analyzer
	Cabon Monoxide		Opto-chemical	Real Time	IQ-610
			Biomimetic	Assisted Convection	
			Electrochemical		
			Semiconductor		
	Carbon Dioxide		Non-Dispersive Infrared	Real Time Assisted Convection	IQ-610
	Nitrogen Dioxide, NO2		Electro-Chemical Diffusion Cell	Real Time Assisted Convection	IQ-501
	Nitric Oxide, NO		Electro-Chemical Diffusion Cell	Real Time Assisted Convection	IQ-501
	Sulfur Dioxide		Electro-Chemical Diffusion Cell	Real Time Assisted Convection	IQ-501
	Cyanide		Electro-Chemical Diffusion Cell	Real Time Assisted Convection	IQ-610
	Sulfuric Acid H2SO4		Electro-Chemical Diffusion Cell	Real Time Assisted Convection	
	Hydrochloric Acid HCl		Electro-Chemical Diffusion Cell	Real Time Assisted Convection	IQ-501
	Hydrobromic HBr		Electro-Chemical Diffusion Cell	Real Time Assisted Convection	
	Hydroflouric HF		Electro-Chemical Diffusion Cell	Real Time Assisted Convection	IQ-501
	VOC's		Electro-Chemical Diffusion Cell	Real Time Assisted Convection	IQ-610
	Benzene		Sorbent Tubes	Integrated Sample Offline analysis	SKC Sorbent Tube Cat No. 222-3-50
	PAHs		Sorbent Tube/ Foam	Integrated Sample Offline analysis	SKC PUF/XAD/PUF Cat No. 226-129
	Inhalable Coarse Particles PM10		Optical Scattering	Real Time Assisted Convection	PC-3016A
	Inhalable Fine Particles PM 2.5		Optical Scattering	Real Time Assisted Convection	PC-3016A
Weather					
	Temperature			Single Point Real Time	IQ-610
	Wind Speed & Direction			Single Point Real Time	
	Humidity			Single Point Real Time	IQ-610

Figure 1. Stainless steel duct analyzer enclosure.

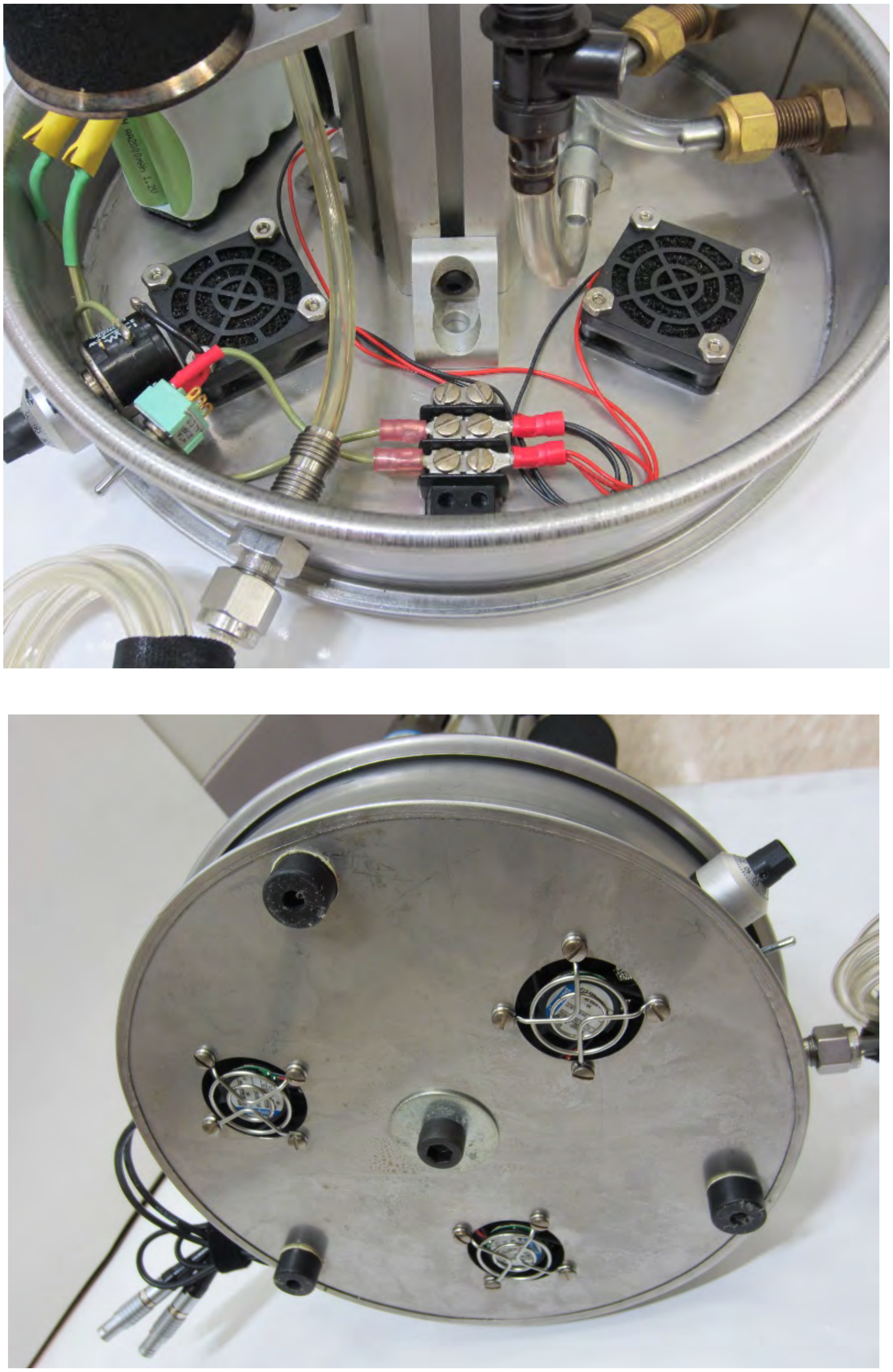

Figure 2. End cap with centered mounting column, battery pack and exhaust fans. Top image sampling side and lower image from exhaust side.

Figure 3.   Perforated entrance plate.

Figure 4. Multi-gas systems 1 and 2 are positioned parallel to and mounted to the center support.

Impact of Ventilation

Figure 5. Filter holder for gravimetric soot mass concentration and small tip for soot particle size analyzer are mounted in between the multi-gas systems

Figure 6. Sorbent tubes for benzene and polycyclic aromatic hydrocarbons (PAH) are mounted on the opposite side from the multi-gas analyzers.

Figure 7. Sorbent tubes for polycyclic aromatic hydrocarbons (top) and benzene (bottom).

Figure 8. Portable battery-powered pumps are mounted on the outside of the cylinder.

Figure 9. Battery-powered particulate sizing analyzer is also mounted on the outside of the cylinder.

Figure 10. A battery-powered data acquisition system was also mounted on the outside of the cylinder.

5.0 Laboratory Testing of WUI Materials

Smoke assessments were conducted at the Fire Research Division of the Engineering Laboratory at the National Institute of Standards and Technology (NIST), located in Gaithersburg, Maryland. Vegetation was collected from areas in southern and northern California (ponderosa pine, California cedar, and chaparral), Texas (grassland), Florida (palmetto) and Colorado (pine). Materials were burned as stand-alone vegetation or mixed with standard PVC, gypsum (wall board), or wooden planks (e.g. standard construction lumber) to simulate a wildland fire or a fire with mixed materials as would be found in a WUI incident. The basic premise was twofold: first to assess the viability of the sensor platform and its ability to assess smoke at wildland incidents, and second, to isolate these materials in a laboratory setting to assess the key constituents of concern. The following figures shows the laboratory conditions and protocols used. The samples were placed into metal bins, with a natural gas burner at the bottom of the material (for initial ignition). The smoke is collected by the shroud located above the material, and then funneled into a chamber where the smoke sensors are able to measure the various constituents.

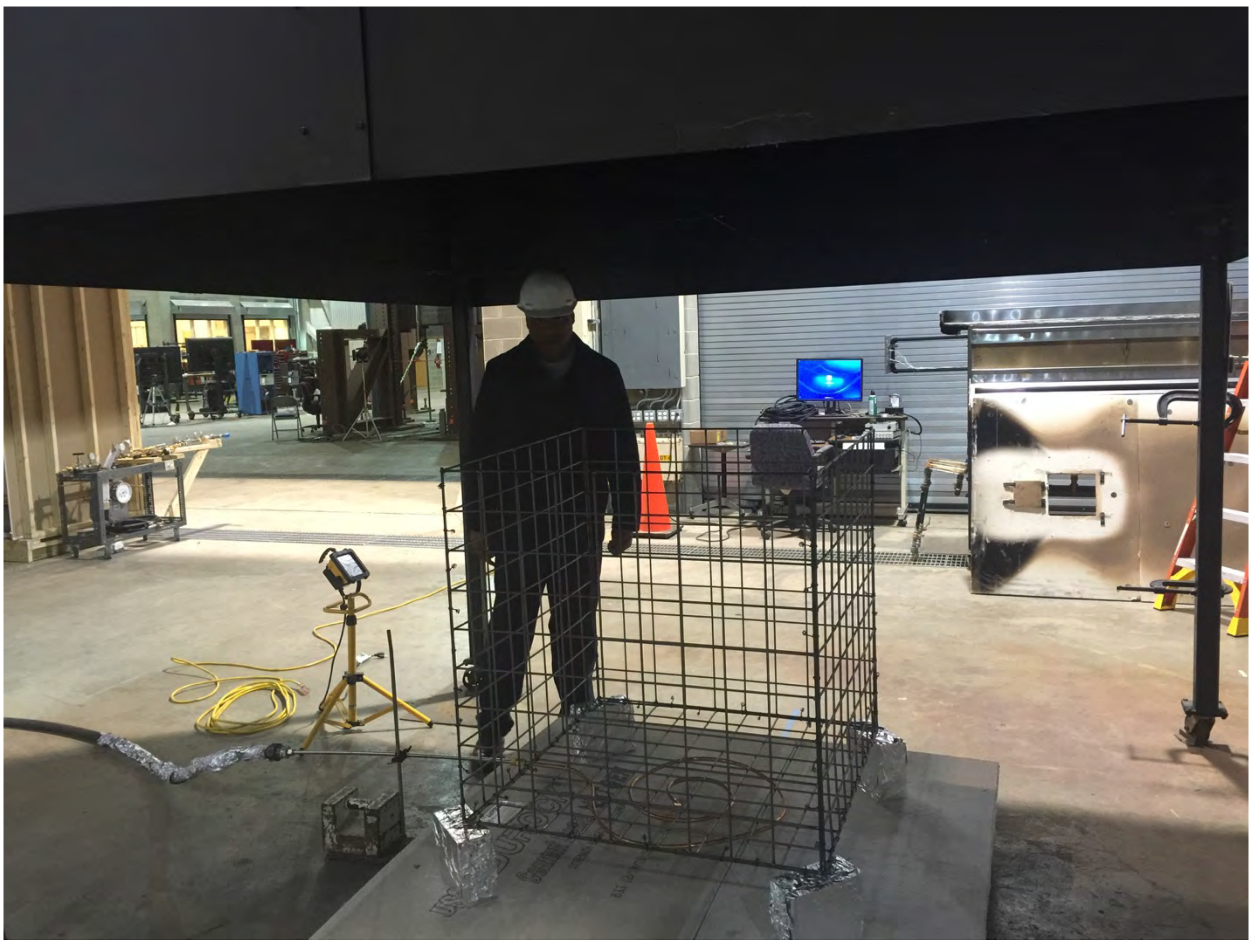

Figure 11. Metal cage and gas coil burner used for vegetation testing.

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Figure 12. Weighing the plant material placed into metal cage.

Figure 13. Metal hood used to collect smoke from the burn, and funnel it to the sensor array.

Figure 14. Sensor platform connected to metal tubes that send smoke through to be analyzed.

Figure 15. Real-time monitoring of material burn.

Figure 16. Active burning of pine, gypsum, and PVC to simulate a WUI fire.

5.1 Laboratory Results

The following tables and figures represent some of the raw data collected during the laboratory sampling. Following the initial testing of the chaparral, it was determined that the sensor array needed to be modified to allow for the detection of higher levels of and increased range for total VOCs. The other gas sensors were also not operating with accurate results. Therefore, limited data were collected on the chaparral. Additionally, some of the plant materials were unusable for burning as they were contaminated with mite outbreaks, or became too dry during the shipping process (no longer reflecting actual vegetation conditions). However, once these issues were resolved, laboratory data were collected on materials sent on the Saw Palmetto, California Cedar, Texas Grass, Ponderosa Pine, and White Pine (with gypsum, PVC, and pine wood being combined to these materials to simulate a WUI fire incident.

Table 5. Fuel packages and mass tested in the fire lab.

Test ID	Fuel Package	Initial Fuel Mass (g)
WETS160112c	Saw Palmetto	23.3
WETS160113a	Saw Palmetto	45.4
WETS160113b	Saw Palmetto	44.4
WETS160113c	Saw Palmetto	55
WETS160113d	Saw Palmetto	54.5
WETS160114a	Saw Palmetto	46.6
WETS160114b	Saw Palmetto	37.7
WETS160114c	Saw Palmetto	47.3
WETS160114d	Saw Palmetto	42.2
WETS160115a	Texas Grass	21.4
WETS160115b	Texas Grass	19.8
WETS160115c	Texas Grass	29.3
WETS160115d	Ponderosa Pine	58.2
WETS160115e	Ponderosa Pine	28.5
WETS160115f	Ponderosa Pine	83.2
WETS160128a	California Cedar	77.6
WETS160128b	California Cedar	91.4
WETS160128c	California Cedar	88.6
WETS160129a	California Cedar + Gypsum (6) + Pine Wood (8)	67.1
WETS160129b	California Cedar + Gypsum (6) + Pine Wood (8)	65.2
WETS160129c	California Cedar + Gypsum (5) + Pine Wood (7) + PVC (2)	86
WETS160129d	Grass + Gypsum (5) + Pine Wood (7) + PVC (2)	59.7
WETS160201a	White Pine	63.1
WETS160201b	White Pine	74
WETS160201c	White Pine	83.9
WETS160201d	White Pine + Gypsum (5) + Wood (7) + PVC	96.1
WETS160201e	Gypsum (22) + Wood (28) + PVC (6)	156.1

In general, there was a variability in the particle size that was observed when non-vegetation materials were added to the burn, with smaller particles showing up earlier in the smoke column with the introduction of gypsum and typically occurring throughout the burn test.

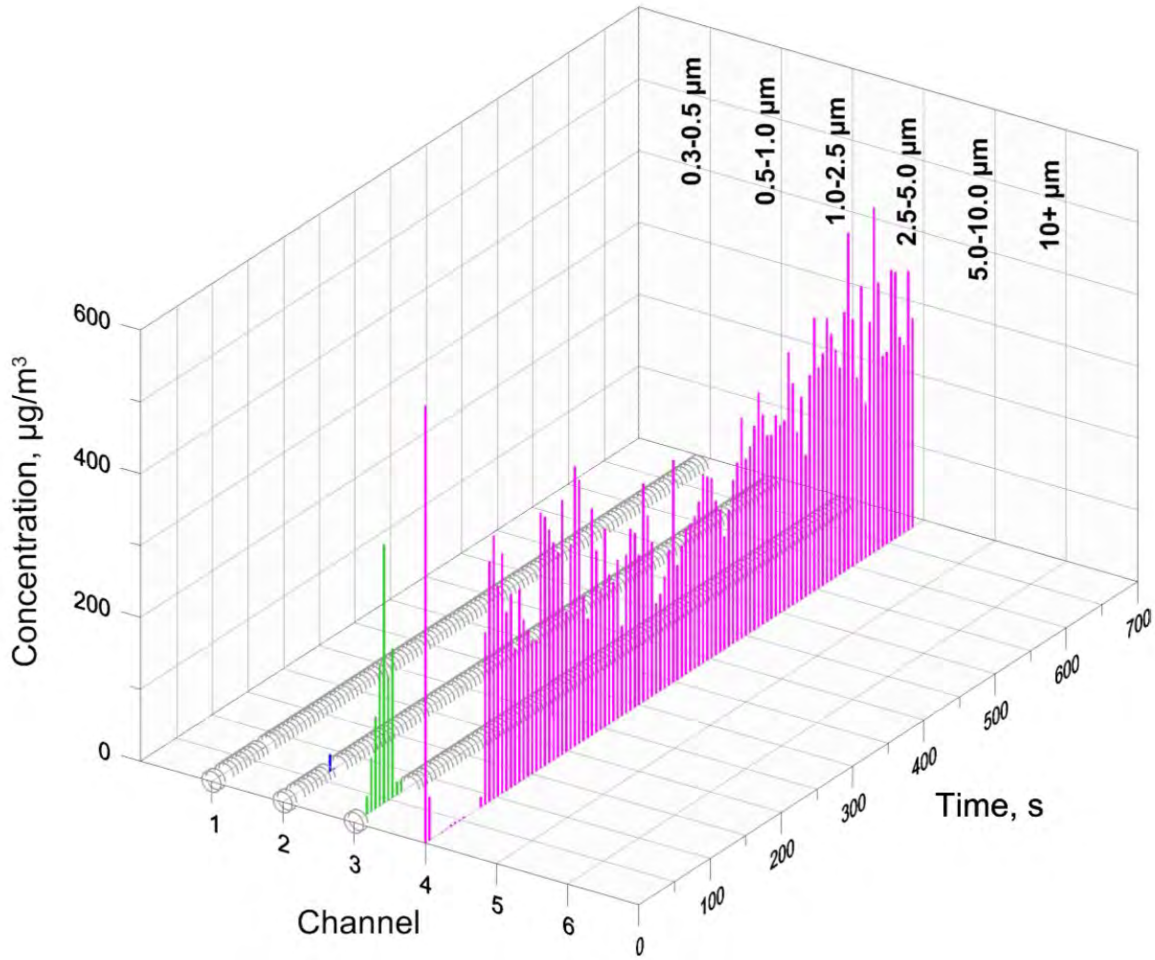


Figure 17. Particle Size Distribution- California Cedar/Gypsum/Pine Wood Test WETS160129b.

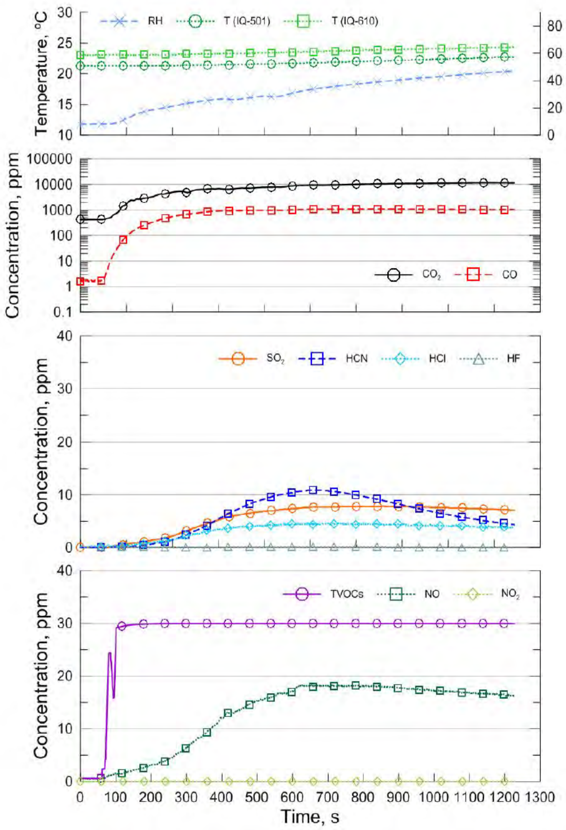
With regard to particle sizes, across all vegetation types, the dominant and persistent particle sizes that were observed throughout the laboratory tests consisted largely of PM 2.5-5.0, with some samples showing period releases of PM 1.0-2.5. Additional particle size distribution figures are provided in Appendix A.

The tests showed that the concentrations of carbon monoxide were generally above 1,000 ppm, and tended to carry a stable concentration throughout the burn. Concentrations of SO_2, NO, HCN, HCI, and HF all peaked at the early stages of the burn and then slowly dissipated, with SO_2 taking longer (in general to dissipate). Concentrations of total VOCs showed a similar pattern of high early concentrations that took longer to dissipate compared to the other constituents. Finally, NO_2 was found in relatively low levels throughout the burns. It is also important to note that the concentrations of total VOCs were likely much higher than what was recorded in the lab tests simply because the sensor had limits to its peak detection capabilities. Graphs of the cone data reports for laboratory testing is provided in Appendix B.

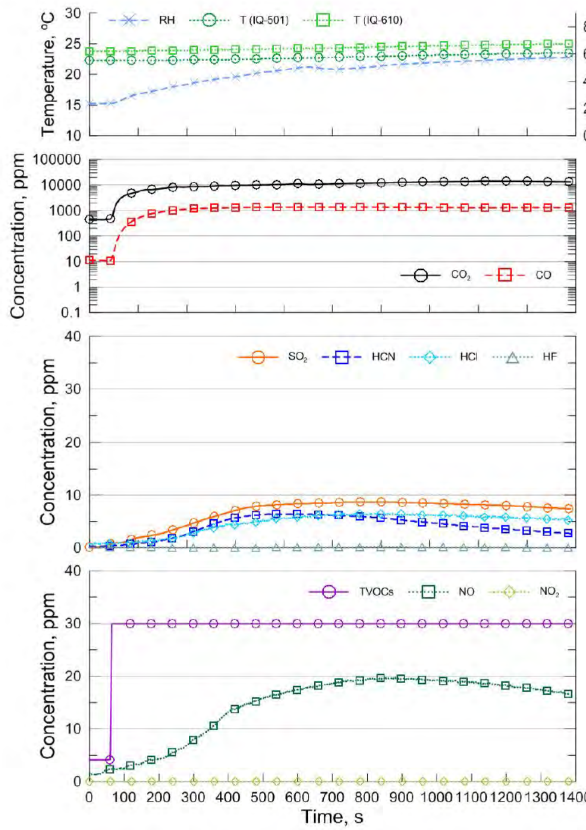
When comparing the data collected from laboratory burns that included just the natural vegetation, versus those that included materials to simulate a WUI scenario, several observations were made. First, not significant differences were detected with regard to the relative humidity, temperature, or concentrations of carbon dioxide or carbon monoxide when WUI materials were introduced to test burns. This was true across all types of vegetation tested. With regard to SO2, concentrations were relatively consistent across both vegetation, and WUI + vegetation burn experiments, however time to reach peak concentrations was often more rapid when WUI materials were introduced into the burn tests. Concentrations of Cyanide for strictly vegetation burns tended to have slightly higher peaks when compared to test burns that included WUI materials. Airborne acids (HCl) were also typically found in higher concentrations when WUI materials were introduced into the test burns, when compared to vegetation alone. With regard to VOCs, no significant differences were observed between test burns with or without WUI materials, however in many cases initial levels of TVOCs were more variable at the beginning of the burn when WUI materials were not present. Finally, NO was typically higher in test burns that included WUI materials when compared to vegetation-only tests (although these differences tended to somewhat variable and only slightly higher).

The following figures show a side-by-side comparison between vegetation-only test burns versus test burns that included WUI materials (including pine board, PVC, and gypsum). Additional graphs of test burns under various conditions are provided in Appendix B.

FIGURE 18. COMPARISON OF WHITE PINE AND WUI MATERIALS

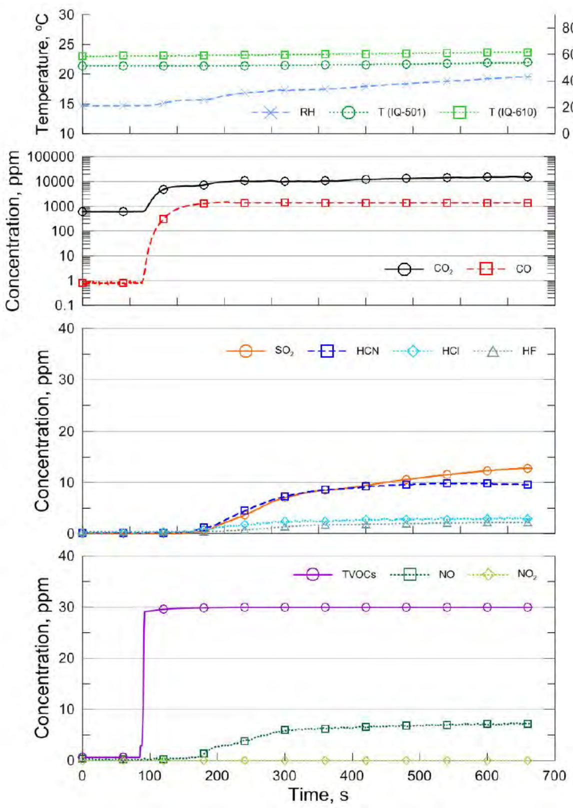


Gas Species Concentration
White Pine **Only**

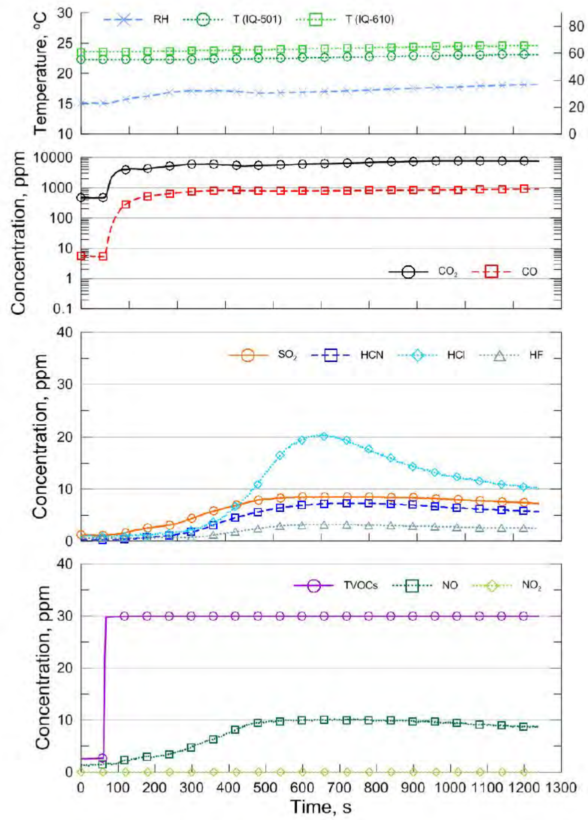


Gas Species Concentration
White Pine and **WUI** Material
Gypsum, Wood Pine, PVC

FIGURE 19. COMPARISON OF TEXAS GRASS AND WUI MATERIALS

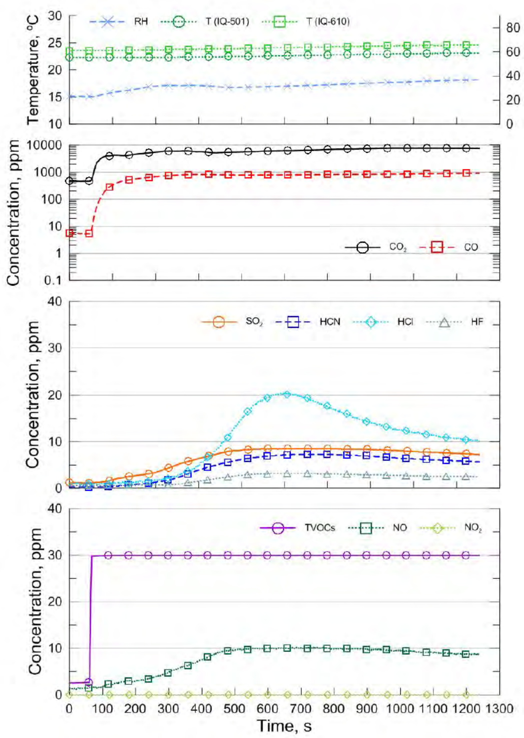


Gas Species Concentration
Grass **Only**

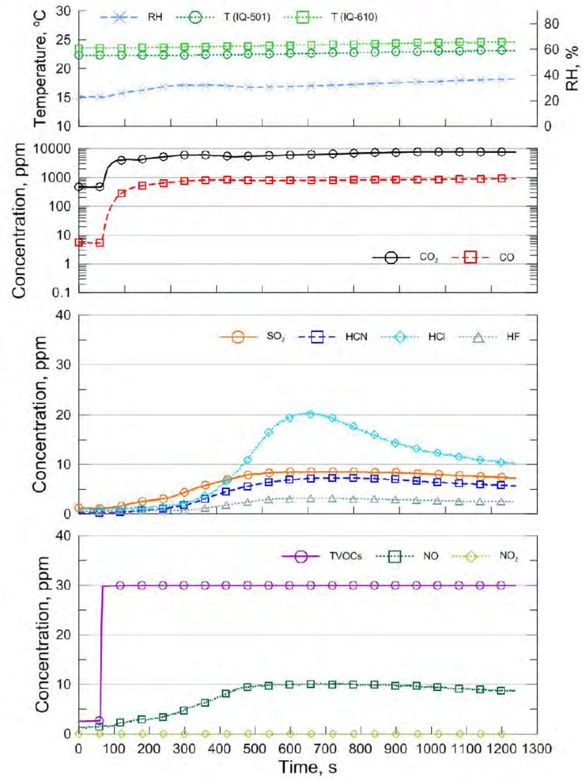


Gas Species Concentration
Grass and **WUI** Material
Gypsum, Wood Pine, PVC

FIGURE 20. COMPARISON OF CALIFORNIA CEDAR AND WUI MATERIALS



Gas Species Concentration
Cedar **Only**



Gas Species Concentration
Cedar and **WUI** Material
Gypsum, Wood Pine, PVC

The data collected through the sorbent tubes included concentrations of both Benzene and PAHs. In general, the Benzene concentrations tended to be significantly higher for those test burns that included both the vegetation and the WUI materials.

Table 6. Benzene Concentration by sample type – Coconut Charcoal Sorbent Tube

Sample	**Sample Volume L**	**Sample Time s**	**Concentration**		**Reportable Limit mg/m3**	**Notes**
			mg/m3	**ppm**		
White Pine WETS160201b	4.49	1348	8.7	2.7	0.22	
White Pine WETS160201c	3.95	1186	12	3.9	0.25	
Ponderosa Pine WETS160115f	3.86	1159	14.0	4.4	0.002	
California Cedar WETS160128c	4.51	1353	4.2	1.3	0.002	
California Cedar/Gypsum/Wood WETS160129b	3.15	944	16.5	5.2	0.002	
White Pine/Gypsum/Wood/PVC WETS160201d	4.58	1374	16	5.1	0.22	
Gypsum/Wood/PVC WETS160201e	4.58	1374	120	38	2.2	Benzene on Backup Sorbent Section - Possible break through
California Cedar/Gypsum/Wood/PVC WETS160129c	3.88	1164	20	6.2	0.26	
Air Blank	3.79	1136	0.79	0.2	0.002	
Burner Blank	3.87	1162	0.52	0.2	0.002	

With regard to PAH concentrations, most of the samples were below the reportable limits under the analysis, with only instance where Phenantherene was recorded in a sample burn that included white pine, gypsum, pine wood board, and PVC. This suggests that PAH concentrations under these laboratory scenarios is somewhat limited and not able to produce detectable results under the volume burned and time allotted (Appendix C).

6.0 Field Assessment of Smoke Exposure

6.1 Methods

During the fire assessments, the sensor platform was placed at or near where firefighters were actively engaged in training activities, suppression, or other duties related to the incident. Data were typically collected for 4 hours where possible (ensuring that no operational impact from the data collection occurred to the fire operations). Sensors were either placed or carried alongside where the firefighters were actively engaged in their duties, with an emphasis on identifying those individuals or teams that were working in conditions where smoke exposure was likely.

Eighteen fire incidents were analyzed during the study, including six controlled burns, seven wildland fire incidents, and five training academy burns. The controlled burns were conducted in Northern California, Riverside, and San Diego County, in grassland areas and mixed grass/shrubland during fire control training courses conducted by CAL FIRE during the spring/summer of 2014-16. The wildland fire incidents included two "typical" wildland fires in southwest Riverside County in mixed chaparral/coastal sage scrub, two incidents in both Riverside and San Diego county that included mixed scrub, grassland, and some wildland urban interface, and three fires in northern California that were dominated by timber (mostly pine and cedar) that included infrastructure, homes, vehicles, etc. from the wildland urban interface (Table 7). The sensors used to collect data at these burns included the same sensor platform used at the NIST burn laboratory, however the sensors were not encased in the steel cylinder as we were attempting to monitor ambient air constituents.

6.2 Results

In general, controlled burns showed limited levels of exposure, with CO and PM being the most common exposure type. While the firefighters were working in the smoke, the occupational exceedances of both PM and CO were commonplace, however the variability of wind gusts seemed to have an effect on the ability of the sensors to accurately collect data on ambient air quality conditions. It was noticed on these incidents (and others) that even in a heavy inversion, when gusts of wind would pass through the sensors, they typically reached at or near zero levels of key constituents. This may be a limitation of the sensors themselves, and may not accurately reflect actual ambient air conditions outside the laboratory. It was thought that encasing the sensors in the same type of metal cylinder that was used in the NIST laboratory experiments, and allowing small fans to pull in ambient air from outside would help stabilize that ambient air conditions in the field, providing for a more accurate assessment of environmental contamination. We were unable to test this hypothesis during this study, but will continue to evaluate this as an option for future studies on wildland smoke exposure.

In those incidents where manmade materials were included (for both training burns and WUI incidents), key constituents were observed that were otherwise absent or below occupational exposure levels in the other vegetation-only burns. While the laboratory tests provided similar results, the data collected in the field on actual WUI and training fires demonstrated a much more consistent and elevated exposure risk in certain constituents. In general, PM, CO, SO2, VOCs, NO, cyanide, and benzene were commonplace when these combusted materials were included in the smoke exposure, while PAHs, HCN, and HCL were also detected (however these occurrences were typically at lower levels of occurrence and minimal exceedances of occupational levels).

With regard to the use of sorbent tubes on actual wildfire incidents, there were both logistical and technological issues that limited our ability to collect reliable data. To overcome those issues, we have investigated the use of optical sensors that can detect PAHs and Benzene in real time. Unfortunately, this method does not allow for a similar analysis as a sorbent tube (as was used in the laboratory testing), with total exposure and air volume sampling not immediately comparable to the data collected by a sorbent tube, it is still valuable to be able to detect levels of PAHs and Benzene on a wildland/WUI incident and determine whether these constituents are present.

Table 7. Controlled burns, training burns, and WUI incidents with key exposures/toxicants found at the incidents exceeding established threshold values for NIOSH (REL-ST) and OSHA (IDLH).

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Fire Type	Main Products Combusted	Atmospheric Conditions	Key Exposures Detected
Controlled Burn			
NorCal1a	Grassland	75F, 48%RH, wind <2mph	CO, PM
GrassV1a	Grassland	72F, 33%RH, wind <1mph	CO, PM
Grassv1b	Grassland/Shrub	71F, 30%RH, wind 4mph	PM
Cleveland	Shrub/Timber	88F, 44%RH, wind 3mph	CO, PM, HCN
Riverside	Grassland/Shrub	68F, 33%RH, wind <2mph	CO, PM, SO2
Training			
Clark1a	Household products, furniture, mattress, carpet, gypsum	84F, 28%RH, wind 3mph	CO, PM, NO2, NO, SO2, VOCs, Cyanide
Clark1b	Plywood, tar shingles, pine	84F, 28%RH, wind 3mph	CO, PM, SO2, HCL
Indio1	Home burn (no furniture or carpet)	79F, 40%RH, wind 5mph	CO, PM, SO2, HCN, HCL, VOCs
Indio2	Home burn (no furniture or carpet)	73F, 44%RH, wind <2mph	CO, PM, SO2, HCN, HCL, VOCs
Riverside1	Home burn (no furniture or carpet)	85F, 34%RH, wind <2mph	CO, PM, SO2, HCN, HCL, VOCs
Riverside2	Home burn (office/home furniture and carpet)	85F, 34%RH, wind <2mph	CO, PM, SO2, HCN, HCL, PAHs, Benzene, VOCs
WUI			
Temecula	Chaparral, Freeway, Utilities	95F, 25%RH, wind 15mph	CO, NO2, Cyanide, PM
Sands	Timber/WUI	75F, 28%RH, wind 7mph	CO, Cyanide, VOCs, Benzene, PM, NO2
Yolo	Grassland/Homes	83F, 35%RH, wind 3mph	CO, PM, NO
Cleveland	Chaparral, Freeway, Utilities, Barn	75F, 34%RH, wind <2mph	CO, PM, Cyanide, VOCs
Calaveras	Timber, Shrubland, homes, vehicles, utilities	80F, 22%RH, wind <2mph	CO, PM, NO, NO2, SO2, Cyanide, HCL, VOCs, Benzene, PAHs
Napa	Timber, Shrubland, homes, vehicles, utilities	71F, 34%RH, wind <2mph	PM, CO, NO, VOCs
Paradise	Timber, shrubland, highway and utility infrastructure	98F, 20%RH, wind 15mph	PM, CO, NO, VOCs

Figure 21. Firefighter exposure at grass fire controlled burns.

Figure 22. Limited respiratory protection provided for wildland and WUI incidents.

Figure 23. Typical timber and shrubland wildfire.

Figure 24. Sensors deployed at WUI incident.

Figure 25. Typical smoke exposure and materials burned at WUI incident.

Figure 26. Typical smoke exposure and materials burned at WUI incident.

Figure 27. Urban materials burn testing conducted at Clark Training Base with CAL FIRE.

Figure 28. WUI training burn smoke exposure sampling.

7.0 Wildland Urban Interface Firefighter Assessment

In conjunction with the FEMA-FPS funded program described herein, our team worked in partnership with the US Forest Service, International Association of Fire Fighters, CAL FIRE, and CAL FIRE Local 2881 to evaluate the physiological conditions of wildland firefighters between through 2014-2015. Wildland firefighters often work for extended periods in intense heat and brutal environmental conditions. It is important to understand how the regular duties and environmental conditions experienced by wildland firefighters influence key physiological conditions including heart rate, respiratory rate, core body temperature, and hydration. Ninety-five wildland firefighters with CAL FIRE volunteered to participate in this study, including personnel at training events (extended hose lays), controlled burns, and actual wildland fires. The results show that wildland firefighters regularly exceeded safe physiological conditions (regardless of the event type). Nearly 65% of the firefighters had sustained peak heart rates above 200 beats per minute (bpm), with nearly 20% exceeding 220bpm (all but three of the volunteers regularly exceeded the recommended maximum hearts rate for work (220bpm minus your age). Likewise, measured core body temperatures exceeded 102F in roughly 70% of the firefighters, with 10% exceeding 103F. Furthermore, nearly two-thirds of the firefighters started their shifts at or near a level of dehydration. Dehydration rates significantly increased across all firefighters at the end of duty, with only 25% of the firefighters that started off at or near dehydration self-correcting and becoming more hydrated by the end of the shift. Finally, the type of personal protective equipment (PPE) worn by wildland firefighters has a significant influence on their physiology. The results suggest that the traditional double-layer PPE produces significantly higher core body temperatures, higher incidence of dehydration, and higher heart rates than single-layer PPE.

A full report on the findings, methods, and recommendations is provided in a separate report.

8.0 Presentations and Workshops

Throughout the research process, we worked closely with partners in the IAFF, CAL FIRE, CAL FIRE Local 2881, NIST, and the US Forest Service. Annual updates were provided at conferences and symposia for both CAL FIRE and the IAFF (Redmond and Alts), as well as presentations given at the NWCG annual conference. In 2014 and through 2015, a symposium was held in Sacramento that included all the major state and federal agencies that deal with wildland and urban interface issues.

The results of that effort are included in a separate report.

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APPENDIX A

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RESOURCE						EXPOSURE TYPE												OTHER INFORMATION				
Incident Type	**Author**	**Year**	**Digital Copy**	**Type of Study**	**Firefighter Study**	**Smoke (generally)**	**HAPs**	**PAHs**	**VOCs**	**PM**	**CO**	**CO2**	**NOx**	**SO2**	**Benzene**	**Cyanide**	**Acids**	**Heat**	**Wood Combustion**	**SCBA and/or Respirator Use**	**Tunnel Study**	**Tire Fires**
Structure	Alarie	2002	No	Exposure Study							X		X			X	X	X				
Structure	Anseeuw et al.	2013	Yes	Exposure Study												X						
Structure	Antonio et al.	2013	Yes	Exposure Study							X					X		X				
Structure	Aubin et al.	1994	No	Exposure Study																		
Structure	Austin et al.	2001	No	Exposure Study	X				X													
Structure	Austin et al.	2001	Yes	Exposure Study																X		
Structure	Bari et al.	2010	Yes	Materials Study				X		X									X			
Structure	Baxter et al.	2010	Yes	Exposure Study	X					X												
Structure	Bernard et al.	1979	No	Exposure Study							X											
Structure	Bertol et al.	1983	No	Exposure Study							X					X						
Structure	Birky et al.	1981	Yes	Exposure Study																		
Structure	Bisby et al.	2005	No	Materials Study																		
Structure	Blomqvist et al.	2003	Yes	Materials Study			X			X												
Structure	Bølling et al.	2009	Yes	Materials Study						X									X			
Structure	Bolstad-Johnson, et al.	2000	No	Exposure Study	X																	
Structure	Boman et al.	2003	Yes	Exposure Study															X			
Structure	Borron et al.	2007	Yes	Exposure Study												X						
Structure	Brandt-Rauf et al.	1989	Yes	Exposure Study	X																	
Structure	Brandt-Rauf et al.	1988	Yes	Exposure Study	X	X	X		X	X	X			X	X	X						
Structure	Burgess et al.	2001	Yes	Exposure Study	X		X	X	X	X	X		X			X	X			X		
Structure	Burgess et al.	1979	No	Exposure Study	X	X																
Structure	Caux et al.	2002	No	Exposure Study	X			X							X							
Structure	Clark et al.	1988	No	Exposure Study		X																
Structure	Cone et al.	2008	Yes	Exposure Study	X	X					X							X				
Structure	Cone et al.	2005	Yes	Exposure Study	X						X									X		
Structure	Currie et al.	2009	No	Exposure Study	X	X	X			X	X		X	X						X		
Structure	DeMarse	2006	No	Strategies/Tactics	X	X																
Structure	Doroudiani et al.	2010	No	Materials Study			X															
Structure	Einhorn	1975	Yes	Materials Study		X																
Structure	Fabian et al.	2011	No	Exposure Study	X		X			X	X			X		X						
Structure	Fabian et al.	2010	Yes	Exposure Study	X	X	X	X	X	X	X	X				X						
Structure	Fabio et al.	2002	No	Exposure Study	X																	
Structure	Gann	2004	No	Exposure Study	X	X																
Structure	Gann	2008	No	Materials Study	X																	
Structure	Gold et al.	1978	No	Exposure Study	X					X	X	X	X			X	X					
Structure	Grabowska et al.	2012	No	Exposure Study							X					X						
Structure	Greven et al.	2011	Yes	Exposure Study	X	X																
Structure	Heggers et al.	1995	No	Exposure Study		X																
Structure	Heimbach et al.	1988	Yes	Exposure Study		X					X							X				
Structure	Horii et al.	2010	No	Exposure Study	X	X	X															
Structure	Hoyeto et al.	1999	No	Exposure Study		X					X					X						
Structure	Irvine et al.	2000	Yes	Materials Study			X															
Structure	Jankovic at al.	1991	Yes	Exposure Study	X	X	X		X		X	X			X	X	X					
Structure	Kumar et al.	2010	No	Materials Study		X																
Structure	Lahn et al.	2003	No	Exposure Study		X																
Structure	Laitinen et al.	2010	Yes	Exposure Study	X	X	X	X	X							X						
Structure	Large et al.	1990	No	Exposure Study	X	X																
Structure	Laumbach et al.	2012	Yes	Exposure Study		X													X			
Structure	Lestari et al.	2012	Yes	Exposure Study					X													
Structure	Lipsett et al.	1994	No	Exposure Study		X																
Structure	Maciulaitis et al.	2013	No	Materials Study		X						X						X	X			
Structure	Mouritz et al.	2009	No	Materials Study																		
Structure	NIOSH	1997	No	Materials Study																		
Structure	NIOSH	1997	No	Incident Analysis	X	X																
Structure	Northcross et al.	2012	Yes	Materials Study			X												X			
Structure	Peters et al.	1974	No	Exposure Study	X	X																
Structure	Pettit et al.	1997	No	Incident Analysis	X	X																
Structure	Pyror	1992	No	Materials Study		X																
Structure	Schoket	1999	Yes	Exposure Study		X		X														
Structure	Sharma et al.	2004	No	Materials Study																		
Structure	Shusterman	1993	Yes	Exposure Study		X																
Structure	Sorathia et al.	1996	Yes	Materials Study				X		X									X			
Structure	Stefanidou et al.	2004	No	Exposure Study		X																
Structure	Stefanidou et al.	2008	Yes	Exposure Study	X	X																
Structure	Tong et al.	2004	No	Exposure Study		X																
Structure	Treitman et al.	1980	No	Exposure Study	X		X		X		X	X	X			X						
Structure	Valavandis et al.	2008	No	Exposure Study		X	X	X														
Vehicle	Ahrens	2013	Yes	Incident Analysis	X																	
Vehicle	Bari et al.	2005	Yes	Exposure Study		X					X	X									X	
Vehicle	Bates et al.	1998	Yes	Incident Analysis																		
Vehicle	Battipaglia	2003	Yes	Materials Study							X	X	X			X	X					
Vehicle	Borgerson et al.	2011	No	Exposure Study	X	X																
Vehicle	Bunn et al.	2004	No	Exposure Study																		

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Vehicle	Capleton et al.	2005	Yes	Exposure Study	X										X							
Vehicle	Chow et al.	2003	Yes	Materials Study																		
Vehicle	Chow et al.	1999	Yes	Exposure Study		X					X										X	
Vehicle	Chow et al.	2001	Yes	Incident Analysis		X															X	
Vehicle	Connell et al.	2008	Yes	Incident Analysis		X												X			X	
Vehicle	Dalrymple	2012	Yes	Incident Analysis																		
Vehicle	Digges et al.	None given	Yes	Materials Study																		
Vehicle	Digges et al.	2008	Yes	Materials Study																		
Vehicle	Digges et al.	2005	Yes	Materials Study	X																	
Vehicle	Dillon et al.	2009	Yes	Materials Study														X				
Vehicle	Duckworth	2008	Yes	Incident Analysis														X			X	
Vehicle	Fabian et al.	2010	Yes	Exposure Study	X	X	X	X	X	X	X	X				X						
Vehicle	Fent et al.	2012	Yes	Exposure Study	X		X	X	X						X					X		
Vehicle	Fent et al.	2011	Yes	Exposure Study	X			X	X		X				X							
Vehicle	Griffith et al.	2005	No	Materials Study		X	X		X		X											
Vehicle	Hirschler et al.	2002	Yes	Materials Study		X												X				
Vehicle	Jafari et al.	2011	Yes	Exposure Study	X	X															X	
Vehicle	Janssens et al.	2008	Yes	Materials Study																		
Vehicle	Jones et al.	2009	Yes	Materials Study														X				
Vehicle	Karlsson et al.	2006	Yes	Exposure Study		X																
Vehicle	Kit et al.	2009	Yes	Exposure Study		X															X	
Vehicle	Kumar et al.	2013	Yes	Exposure Study		X				X												
Vehicle	Laumbach et al.	2012	Yes	Exposure Study		X													X			
Vehicle	Lestari et al.	2012	Yes	Exposure Study					X													
Vehicle	Liu et al.	2007	Yes	Exposure Study		X															X	
Vehicle	Lonnermark et al.	2006	Yes	Exposure Study		X		X	X					X	X		X					
Vehicle	Murray	2003	Yes	Exposure Study		X																X
Vehicle	Murray	2010	Yes	Exposure Study																		X
Vehicle	Okamoto	2009	Yes	Materials Study														X				
Vehicle	Qu et al.	2012	Yes	Exposure Study							X	X									X	
Vehicle	Sanchez et al.	2006	Yes	Exposure Study																		X
Vehicle	Santrock et al.	2001	No	Materials Study		X																
Vehicle	Shakya et al.	2008	Yes	Exposure Study		X																X
Vehicle	Shipp et al.	1995	No	Materials Study		X																
Vehicle	Sidhu et al.	2006	No	Exposure Study		X																X
Vehicle	Stephenson et al.	2005	Yes	Materials Study																		
Vehicle	Stephenson et al.	2006	Yes	Materials Study																		
Vehicle	Stroup et al.	2001	No	Materials Study		X																
Vehicle	Vianello et al.	2012	Yes	Exposure Study																	X	
Vehicle	Wantanabe et al.	2007	Yes	Exposure Study																		
Vehicle	Wichmann	1995	Yes	Exposure Study			X	X													X	
Vehicle	Willson et al.	2006	Yes	Materials Study		X					X	X	X			X	X					
Vehicle	Zhang et al.	2007	Yes	Exposure Study		X															X	
Wildland	Adetona et al.	2011	Yes	Exposure Study	X					X												
Wildland	Adetona et al.	2011	Yes	Exposure Study	X	X																
Wildland	Adetona et al.	2013	Yes	Exposure Study	X	X				X	X											
Wildland	Adetona et al.	2013	Yes	Exposure Study	X	X																
Wildland	Arbex et al.	2010	No	Exposure Study						X												
Wildland	Baldwin et al.	2012	No	Incident Analysis	X	X																
Wildland	Barboni et al.	2010	Yes	Exposure Study	X	X			X						X							
Wildland	Baris et al.	2002	No	Exposure Study		X																
Wildland	Baud	2007	No	Exposure Study												X						
Wildland	Baud et al.	2011	No	Exposure Study							X					X						
Wildland	Beason et al.	1996	No	Exposure Study		X														X		
Wildland	Bizovi et al.	1995	No	Exposure Study	X	X																
Wildland	Blake et al.	2009	No	Exposure Study					X	X												
Wildland	Bolstad-Johnson et al.	2000	No	Exposure Study	X	X																
Wildland	Boman et al.	2003	Yes	Exposure Study															X			
Wildland	Booze et al.	2004	Yes	Exposure Study	X			X	X	X	X				X							
Wildland	Brandt-Rauf et al.	1988	Yes	Exposure Study	X	X	X		X	X	X			X	X	X						
Wildland	Brotherhood et al.	1990	No	Exposure Study	X						X											
Wildland	Burgess et al.	2001	No	Exposure Study	X	X														X		
Wildland	Castaneda et al.	2013	Yes	Exposure Study		X																
Wildland	Caux et al.	2002	No	Exposure Study	X	X		X							X							
Wildland	Cone et al.	2010	No	Exposure Study	X						X									X		
Wildland	Delfino et al.	2009	Yes	Exposure Study						X												
Wildland	DeVos et al.	2009	Yes	Materials Study					X	X	X				X							
Wildland	DeVos et al.	2006	No	Exposure Study	X	X														X		
Wildland	Dost	1991	No	Exposure Study		X		X	X	X												
Wildland	Dunn et al.	2013	Yes	Exposure Study	X						X											
Wildland	Dunn et al.	2009	Yes	Exposure Study	X						X											
Wildland	Edwards et al.	2005	Yes	Exposure Study	X					X												
Wildland	Fabian et al.	2010	No	Exposure Study	X	X																
Wildland	Gann	2004	No	Exposure Study	X	X																
Wildland	Gaughan et al.	2008	Yes	Exposure Study	X	X																
Wildland	Giancasbro et al.	2008	Yes	Materials Study		X													X			
Wildland	Greven et al.	2011	Yes	Exposure Study	X	X																

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Wildland	Greven et al.	2012	Yes	Exposure Study	X																	
Wildland	Greven et al.	2011	Yes	Exposure Study	X	X																
Wildland	Guidotti et al.	1992	No	Exposure Study	X	X																
Wildland	Hall	2004	No	Exposure Study		X																
Wildland	Heji et al.	2013	Yes	Exposure Study	X	X				X	X											
Wildland	Henderson et al.	2011	Yes	Exposure Study		X				X												
Wildland	Huff et al.	1995	Yes	Exposure Study		X																
Wildland	Johnston et al.	2012	Yes	Exposure Study		X																
Wildland	Jordan et al.	2006	No	Materials Study		X													X			
Wildland	Kochi et al.	2010	Yes	Exposure Study		X																
Wildland	Kurmi	2010	Yes	Exposure Study		X													X			
Wildland	Kurmi et al.	2013	No	Exposure Study		X				X									X			
Wildland	Laitinen et al.	2010	Yes	Exposure Study	X	X	X	X	X							X			X			
Wildland	Laitinen et al.	2012	Yes	Exposure Study	X	X		X	X													
Wildland	Larson et al.	1994	No	Exposure Study		X													X			
Wildland	Laurent et al.	2011	Yes	Exposure Study	X	X																
Wildland	Lees	1995	No	Exposure Study	X	X		X	X		X	X			X	X	X					
Wildland	Leonard et al.	2007	Yes	Exposure Study	X	X																
Wildland	Materna et al.	1992	No	Exposure Study	X	X		X	X	X	X				X							
Wildland	McCammon et al.	1999	No	Incident Analysis	X																	
Wildland	McNamara et al.	2012	Yes	Exposure Study	X					X												
Wildland	Miranda et al.	2012	Yes	Exposure Study	X	X			X		X		X									
Wildland	Miranda et al.	2010	Yes	Exposure Study	X				X	X	X		X									
Wildland	Mott et al.	2002	Yes	Exposure Study		X																
Wildland	Naeher et al.	2013	Yes	Exposure Study	X	X																
Wildland	Naeher et al.	2007	No	Exposure Study															X			
Wildland	Naeher et al.	2007	No	Exposure Study		X					X		X		X				X			
Wildland	Neitzel et al.	2009	Yes	Exposure Study	X	X																
Wildland	Ouyang et al.	2012	Yes	Exposure Study	X	X		X														
Wildland	Reinhardt et al.	2004	Yes	Exposure Study	X				X	X	X				X							
Wildland	Reisen et al.	2009	Yes	Exposure Study	X	X			X	X	X											
Wildland	Reisen et al.	2011	Yes	Exposure Study	X	X			X	X	X											
Wildland	Ribeiro et al.	2009	Yes	Exposure Study	X	X																
Wildland	Shaw et al.	2014	Yes	Exposure Study	X																	
Wildland	Simoneit	2002	No	Exposure Study		X													X			
Wildland	Simpson et al.	2010	Yes	Exposure Study		X													X			
Wildland	Slaughter et al.	2004	Yes	Exposure Study	X				X	X	X											
Wildland	Stefanidou et al.	2008	Yes	Exposure Study	X	X																
Wildland	Swiston et al.	2008	Yes	Exposure Study	X					X	X											
Wildland	Terrill et al.	1978	No	Exposure Study		X					X											
Wildland	Townsend et al.	2002	Yes	Exposure Study		X					X											
Wildland	Tzamtzis et al.	2006	No	Exposure Study	X	X																
Wildland	Wang et al.	2011	Yes	Exposure Study						X									X			
Wildland	Ward et al.	1991	Yes	Exposure Study		X				X	X	X							X			
Wildland	Washenit et al.	2001	No	Incident Analysis	X																	

APPENDIX B

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APPENDIX A.

Laboratory Cone Experiments for California Cedar, Texas Grass and white pine, with baseline data collected for ambient air quality in the laboratory and for burn fuel used to ignite vegetation during burn testing (showing minimal contributions to results observed during vegetation and WUI materials burns).

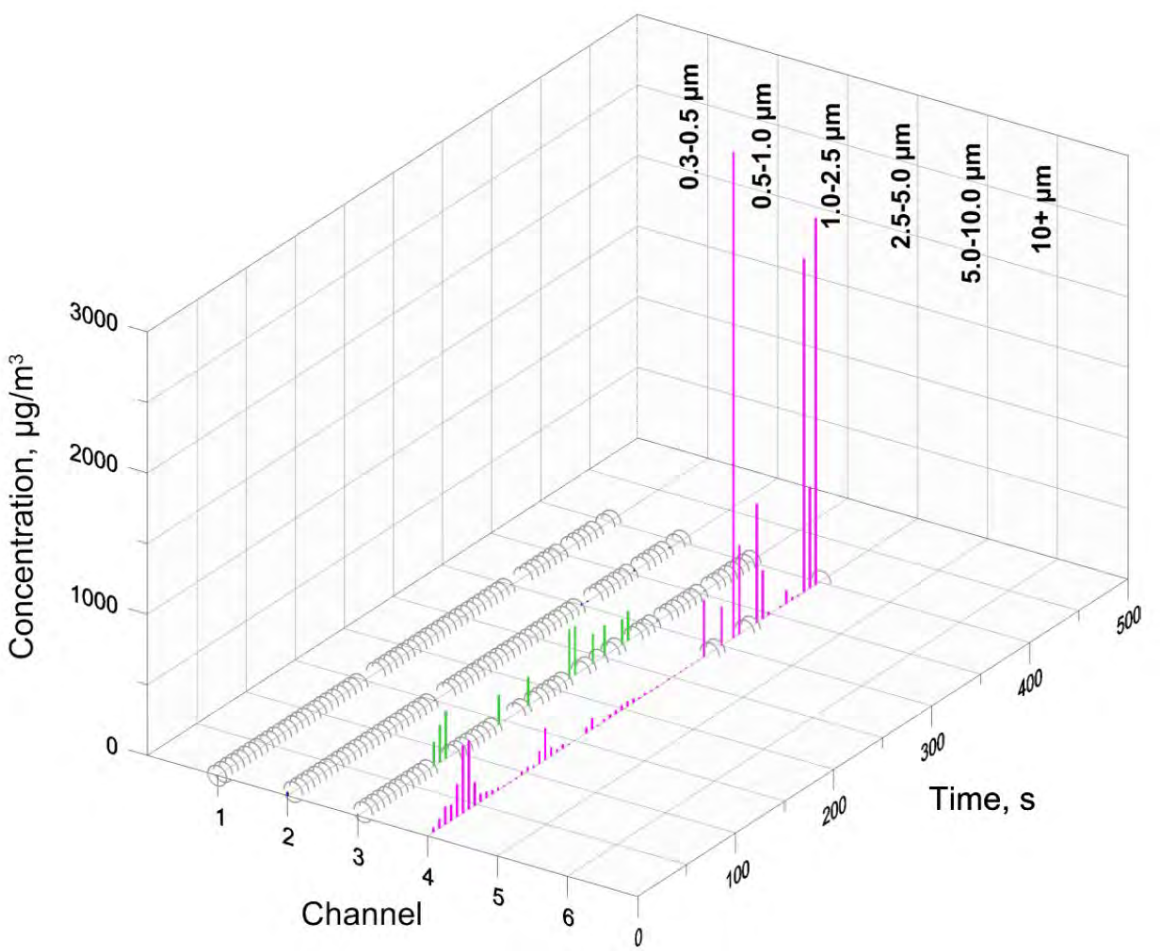
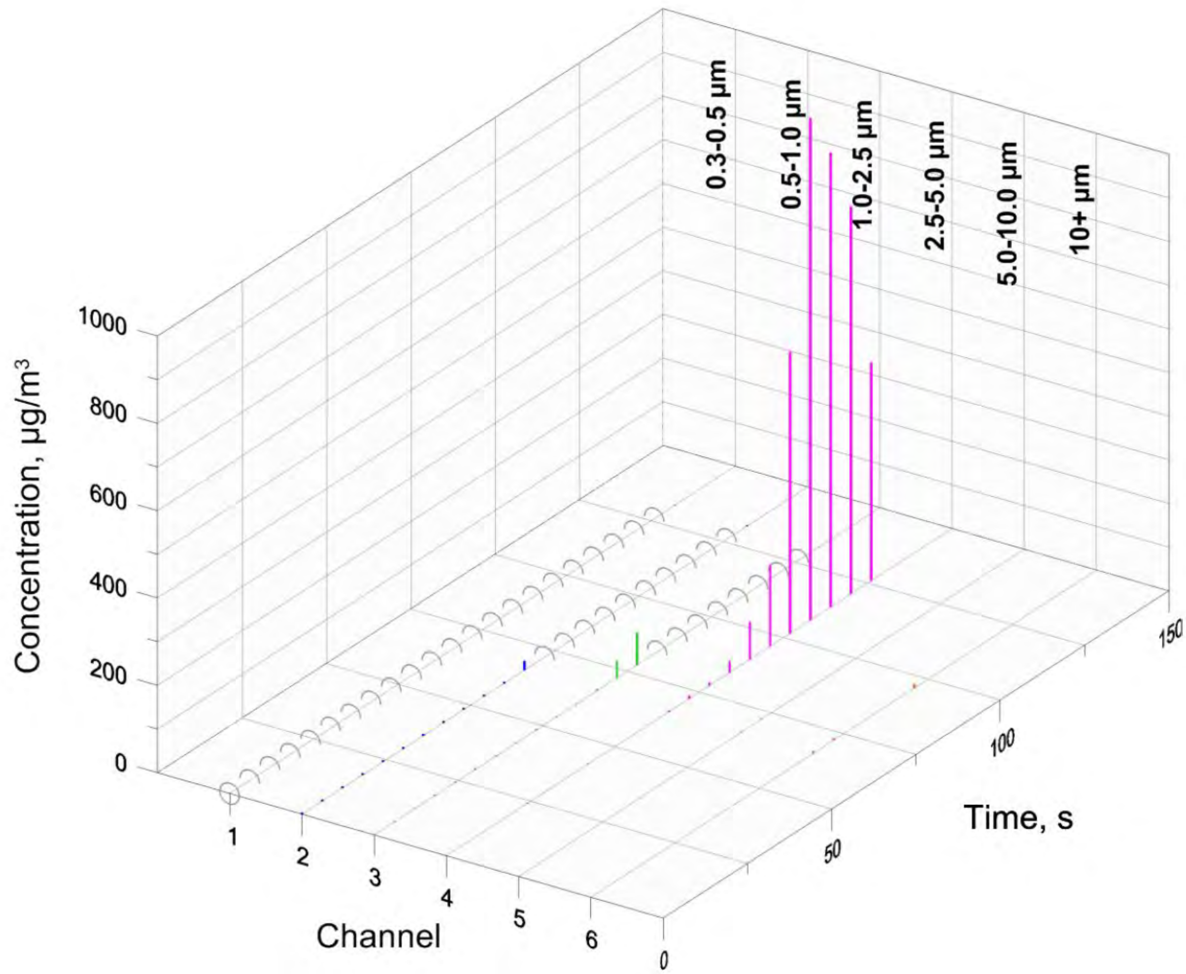


Figure 1. Particle Size Distribution- California Cedar Test WETS160128a.



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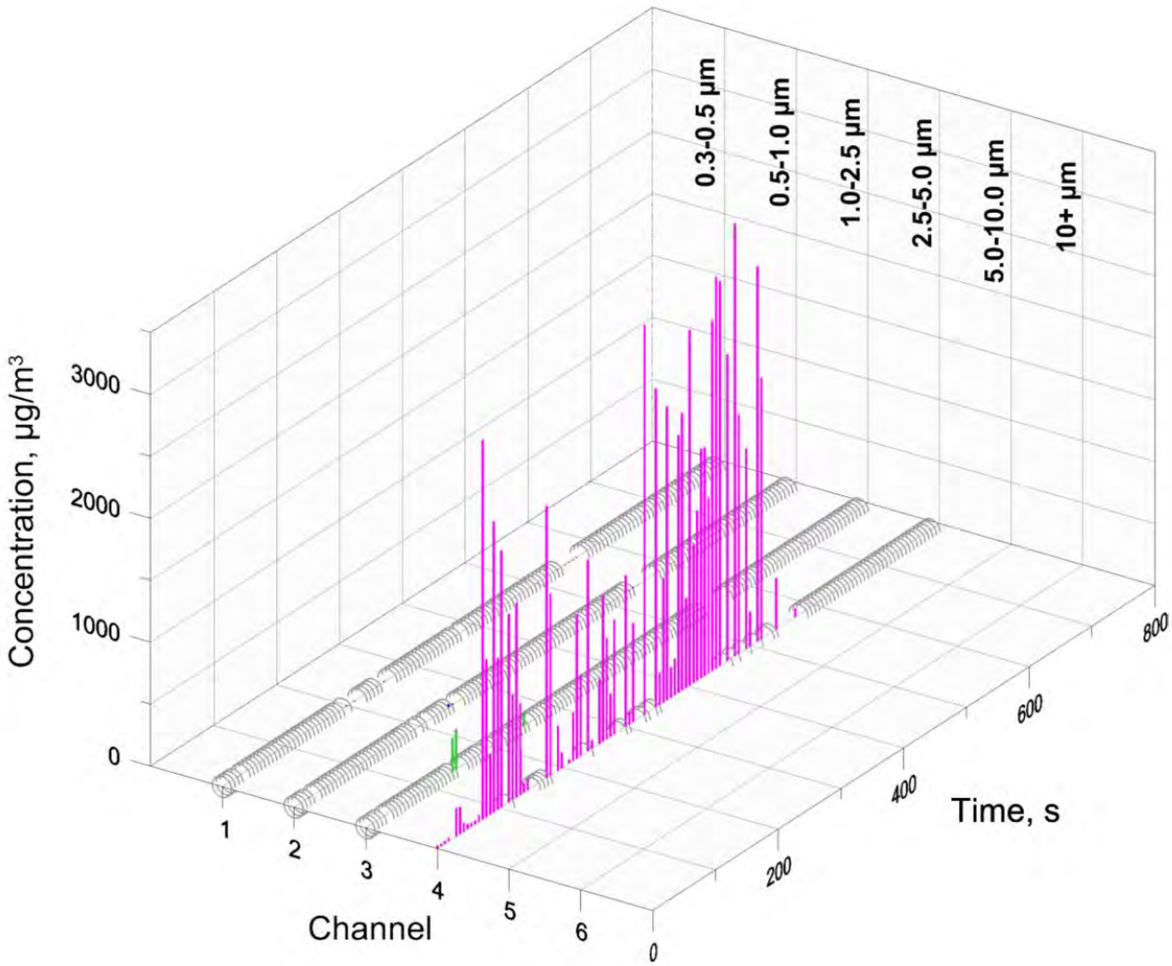

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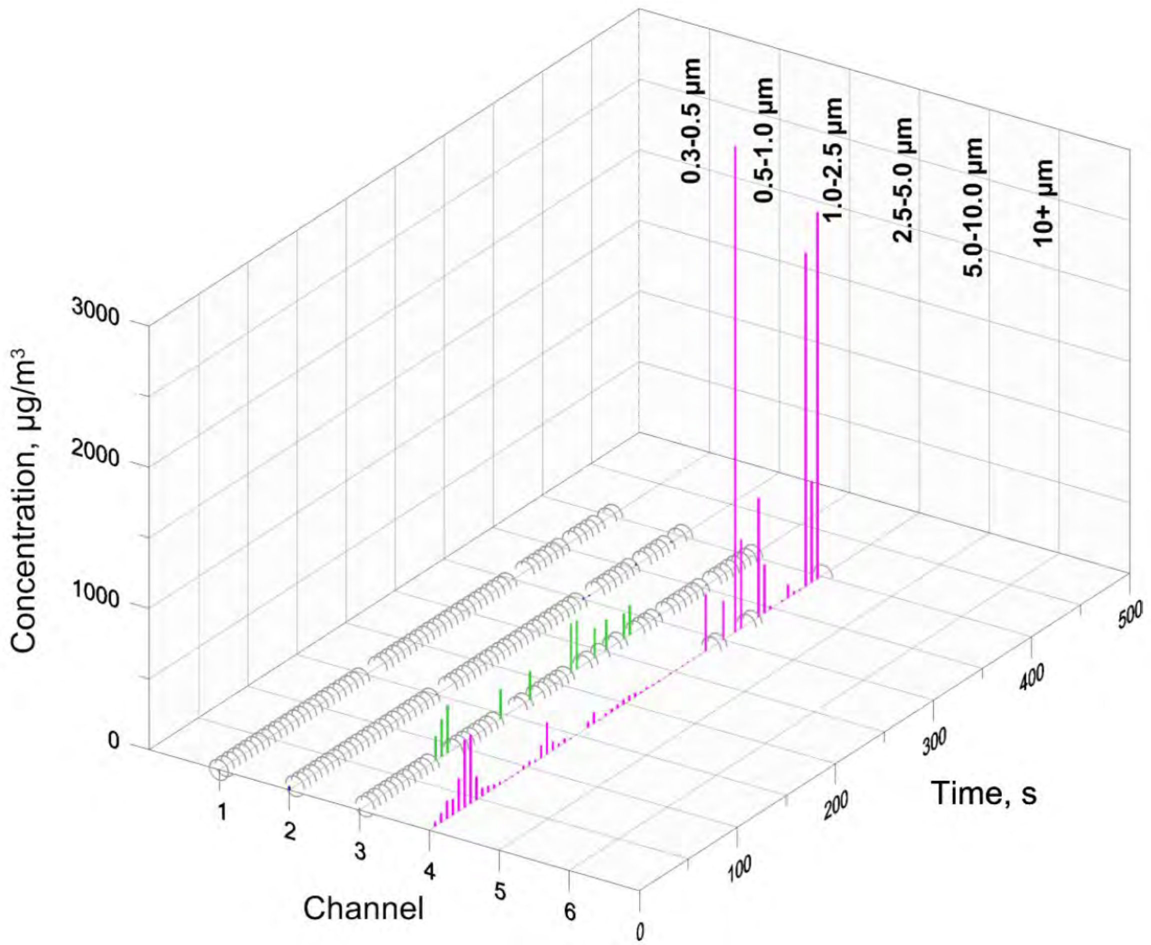
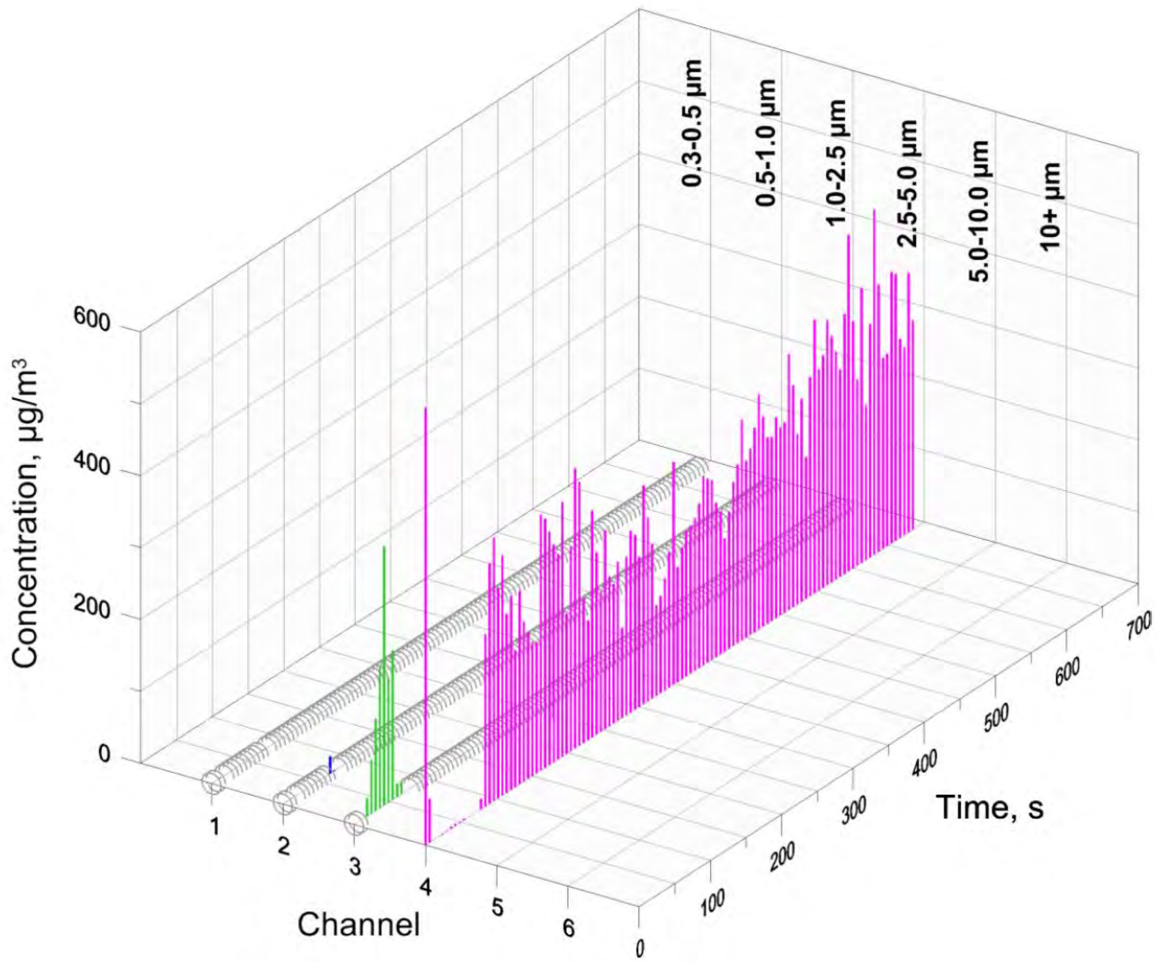


Figure 4. Particle Size Distribution- California Cedar/Gypsum/Pine Wood Test WETS160129a.



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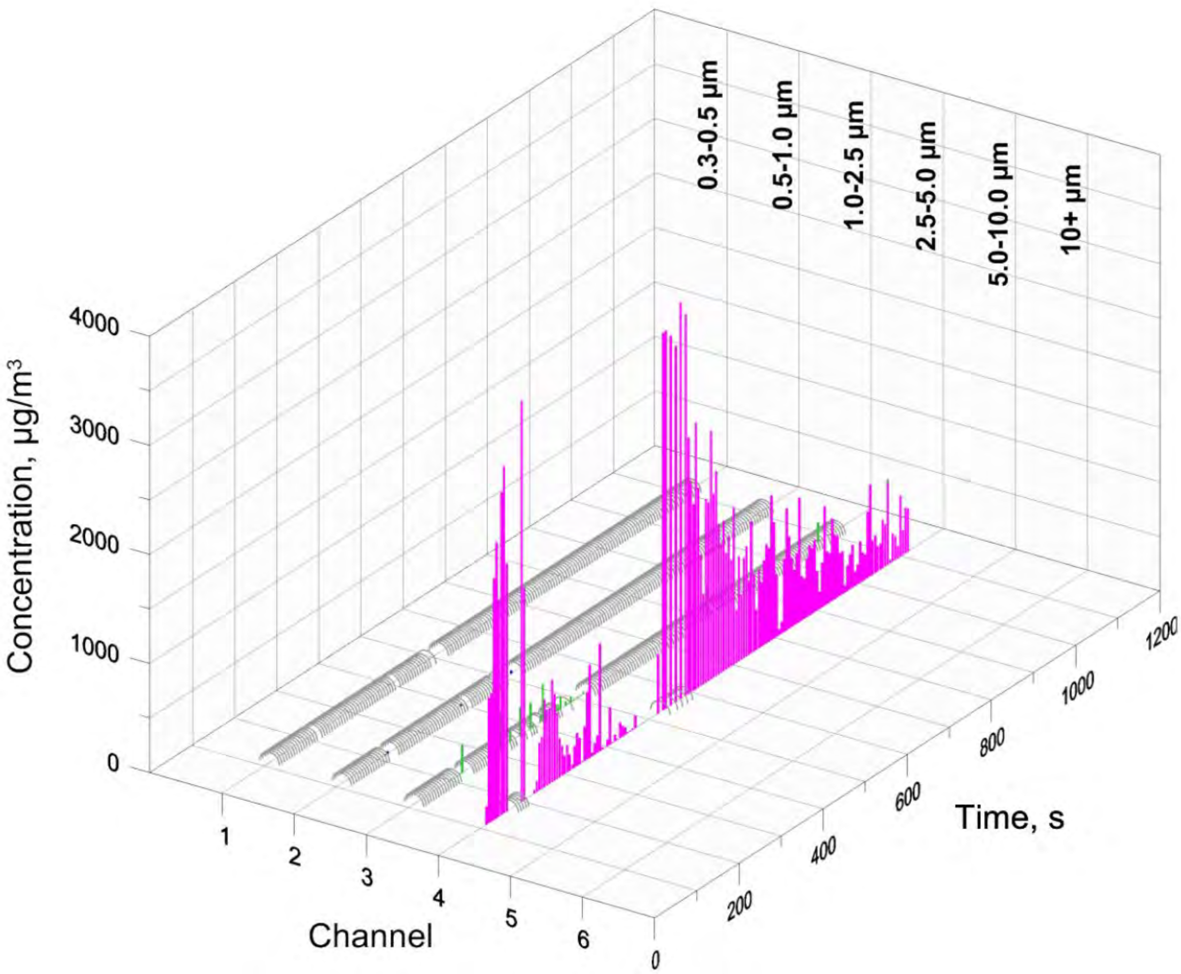

Figure 6. Particle Size Distribution- California Cedar/Gypsum/Pine Wood/PVC Test WETS160129c.

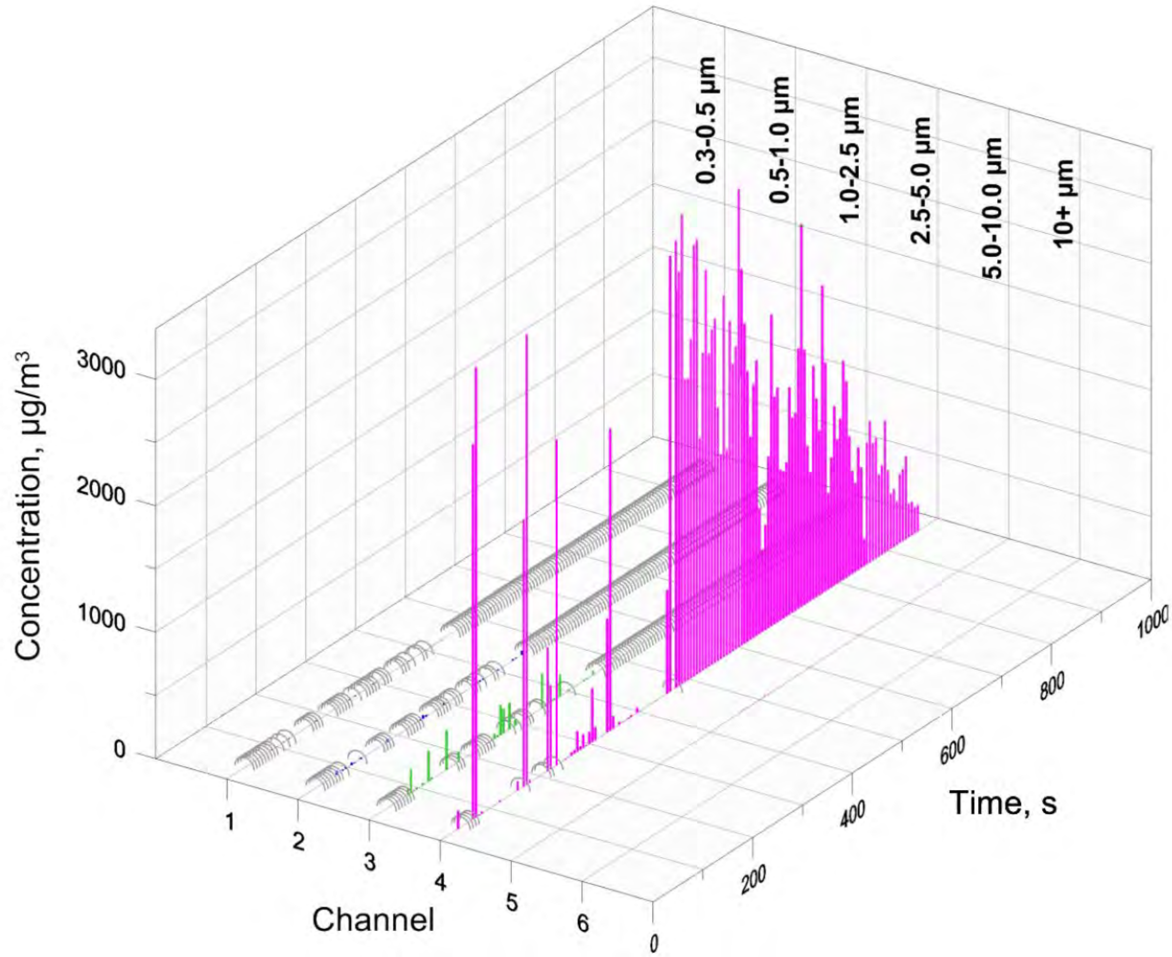

Figure 7. Particle Size Distribution- Texas Grass/Gypsum/Pine Wood/PVC Test WETS160129d.

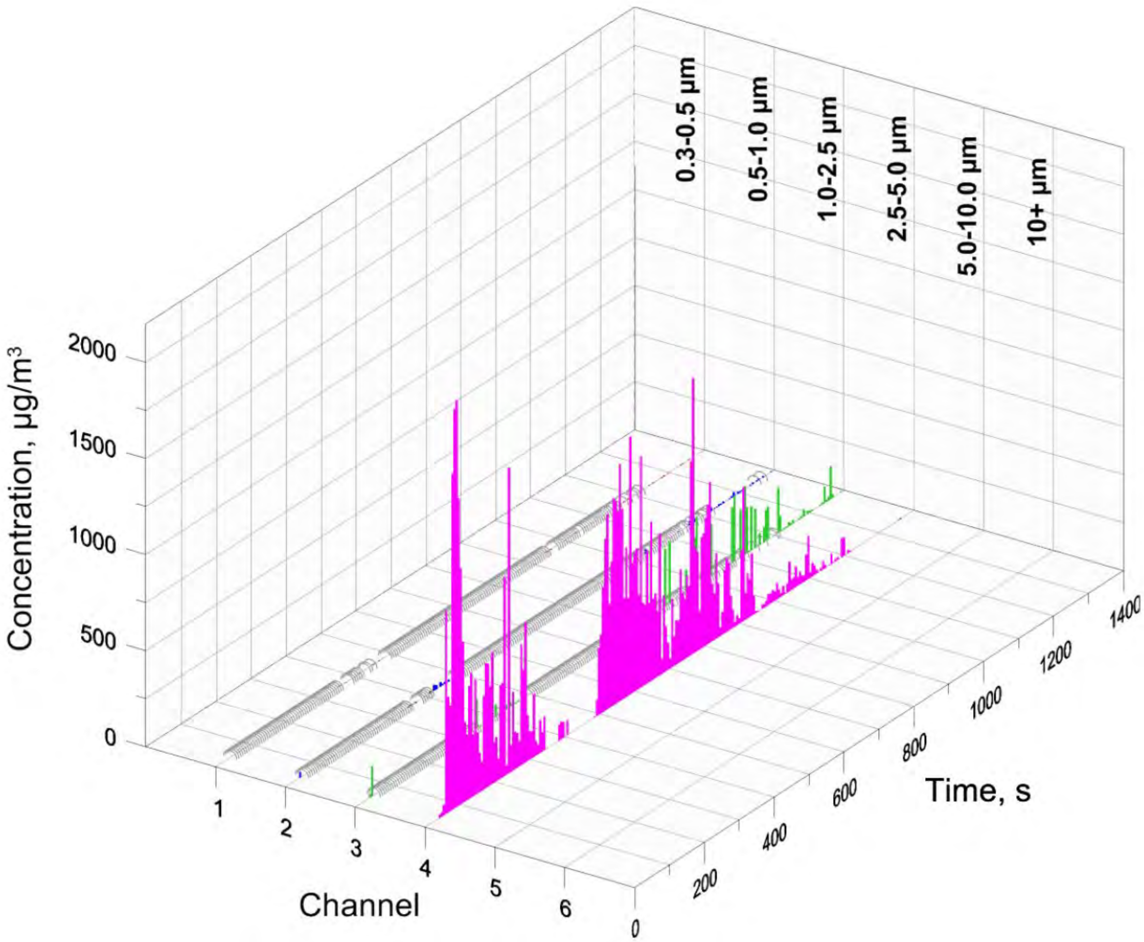

Figure 8. Particle Size Distribution- White Pine Test WETS160201a.

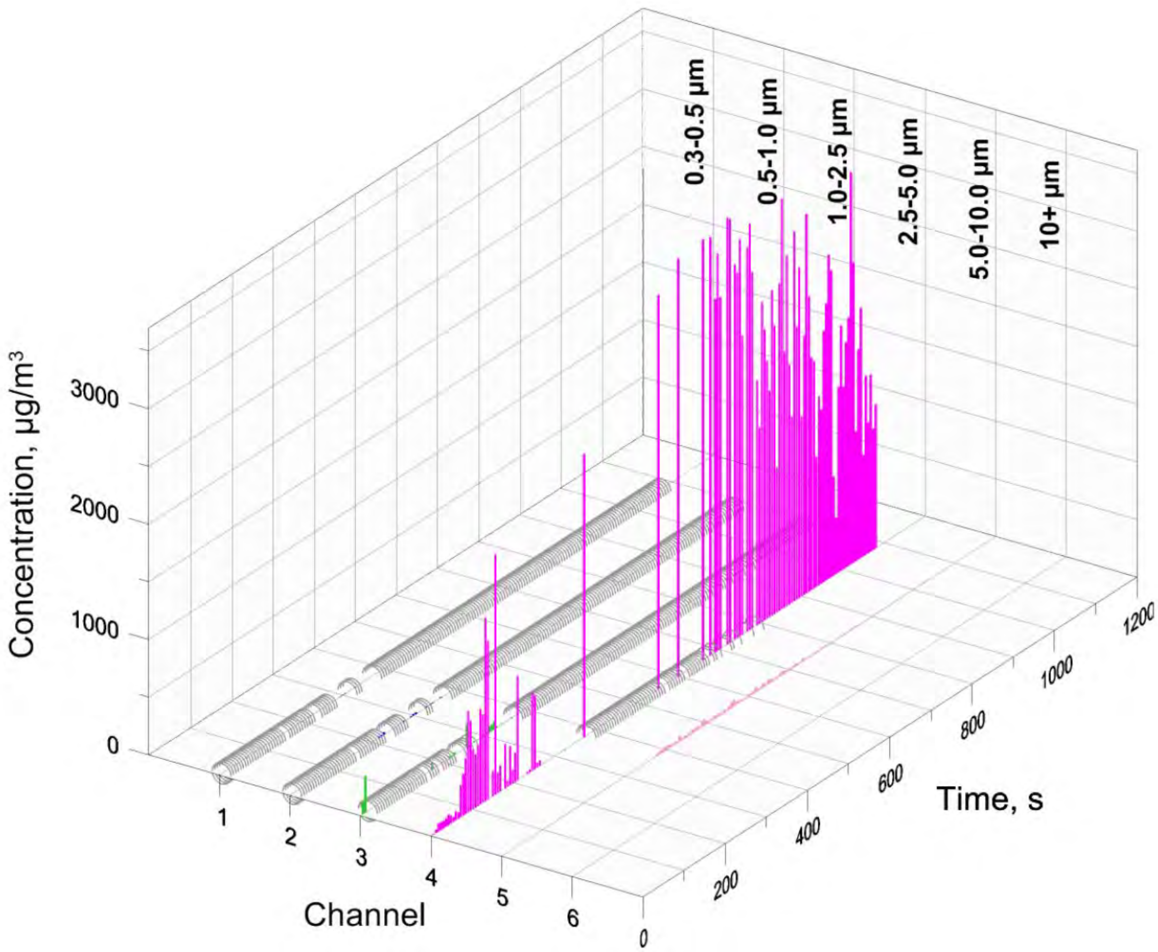

Figure 9. Particle Size Distribution- White Pine Test WETS160201b.

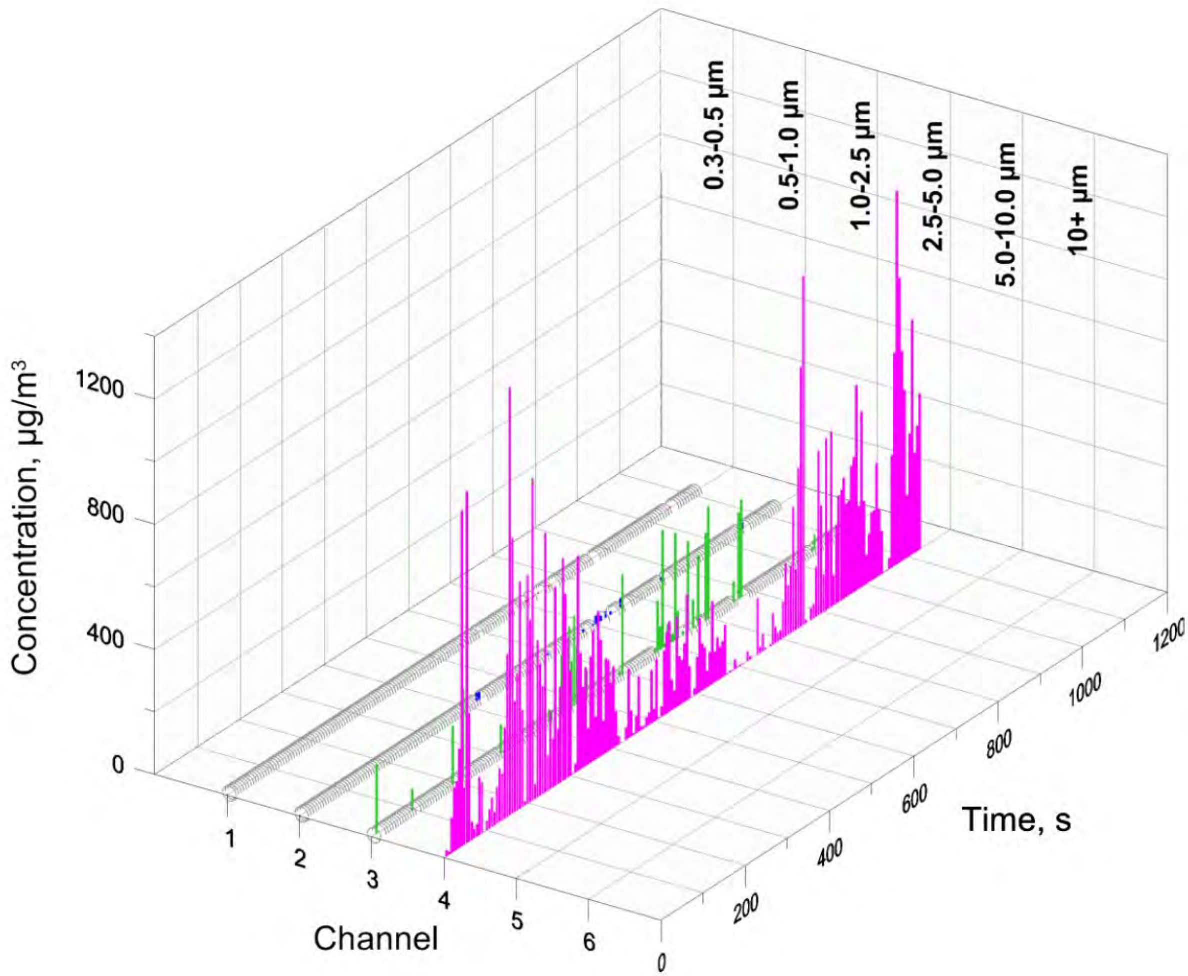

Figure 10. Particle Size Distribution- White Pine Test WETS160201c.

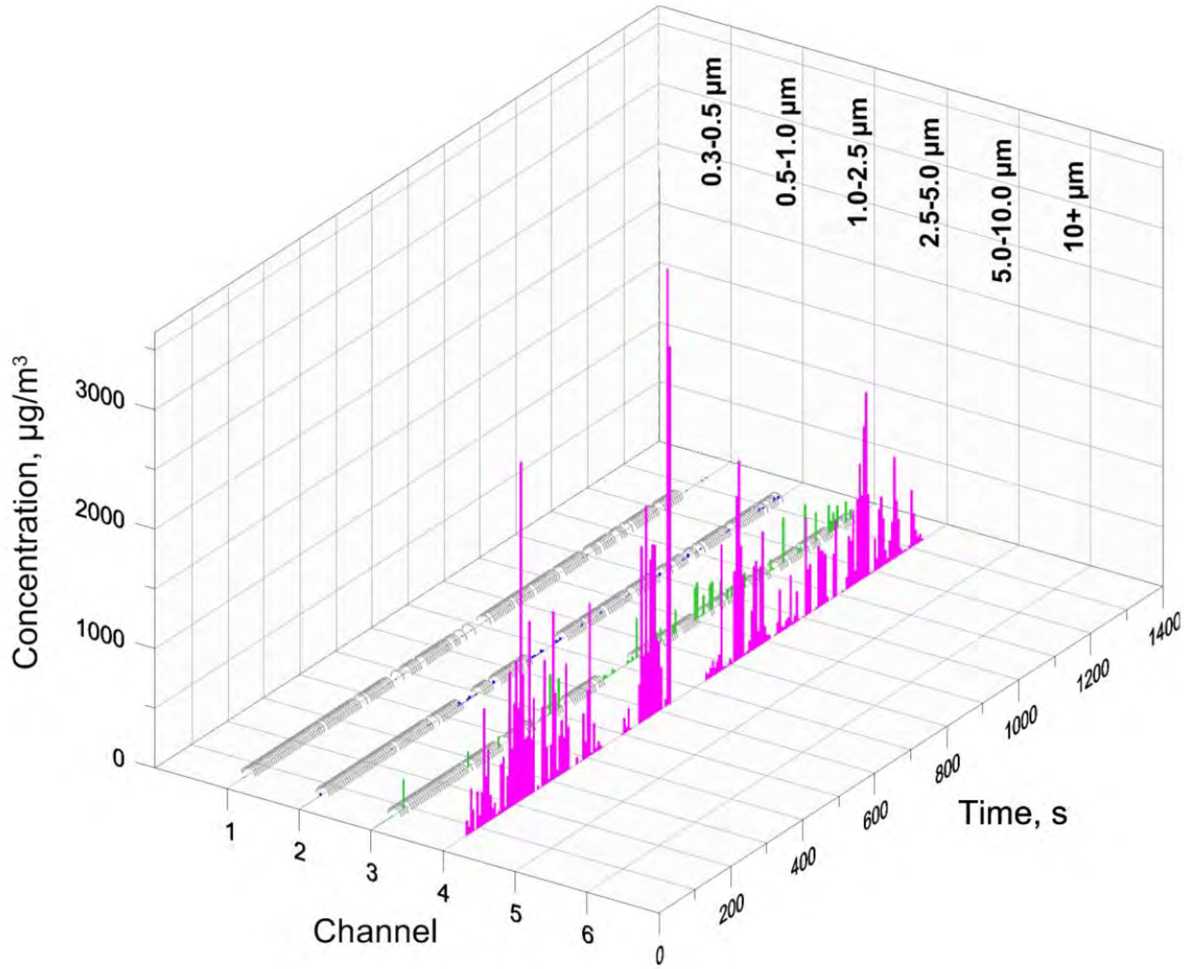

Figure 11. Particle Size Distribution- White Pine/Gypsum/Pine Wood/PVC Test WETS160201d.

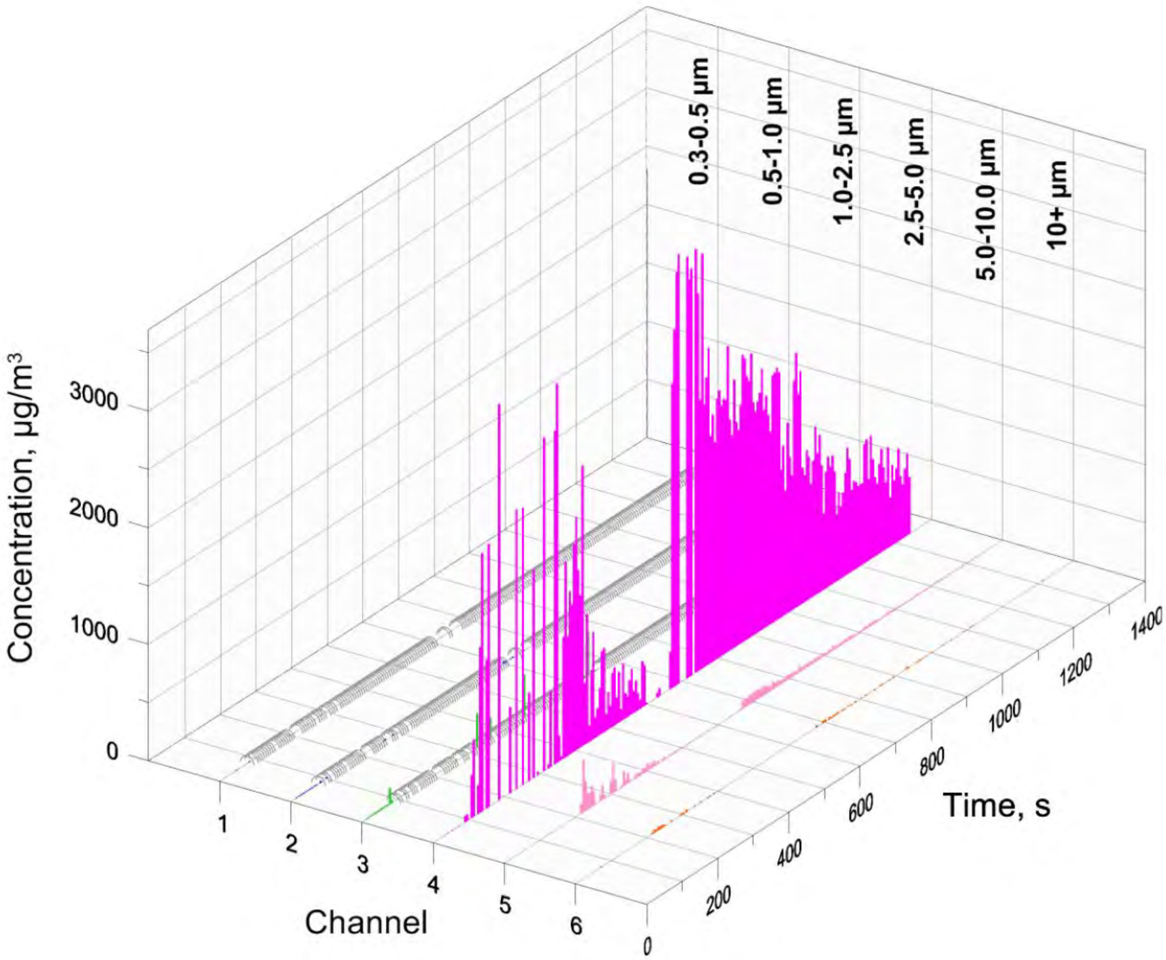

Figure 12. Particle Size Distribution- Gypsum/Pine Wood/PVC Test WETS160201e.

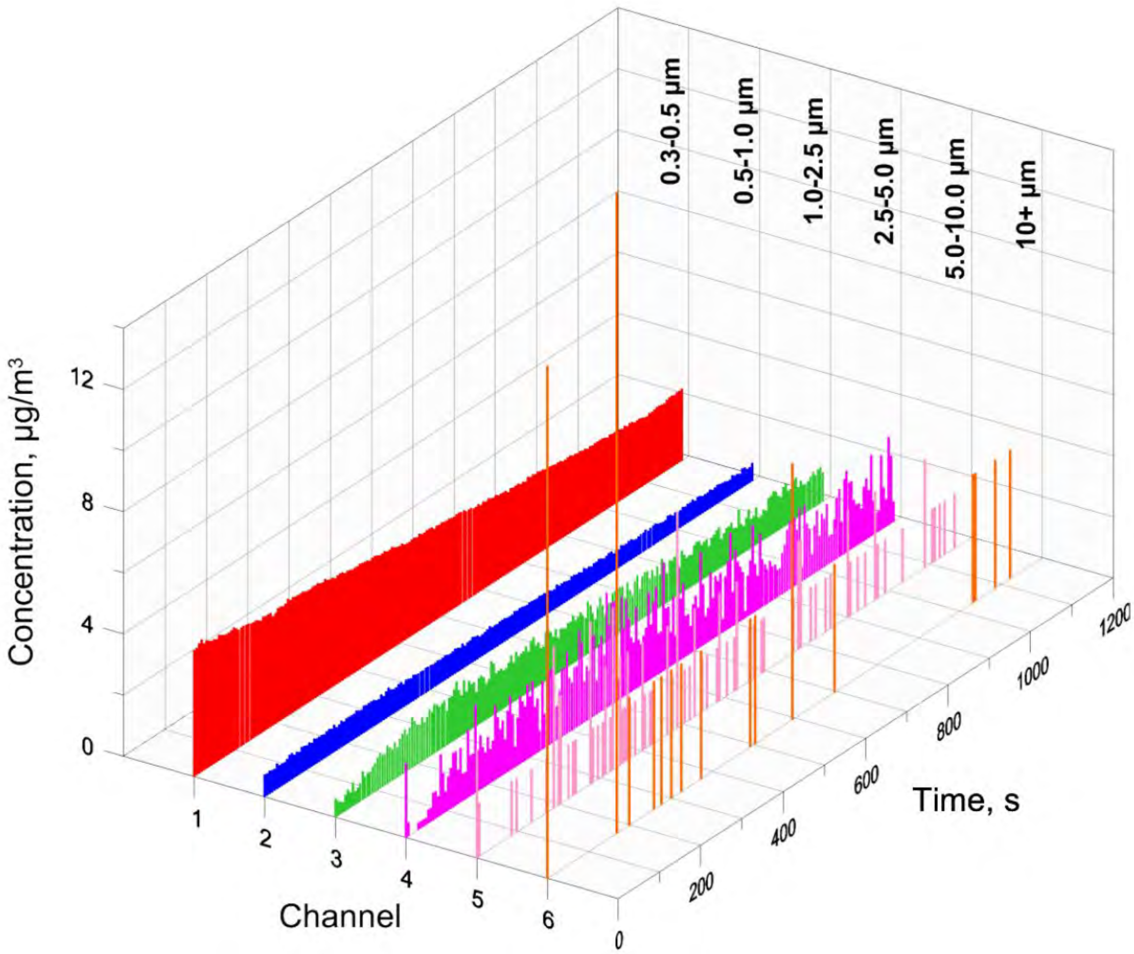

Figure 13. Particle Size Distribution- Air WETS160203_Air.

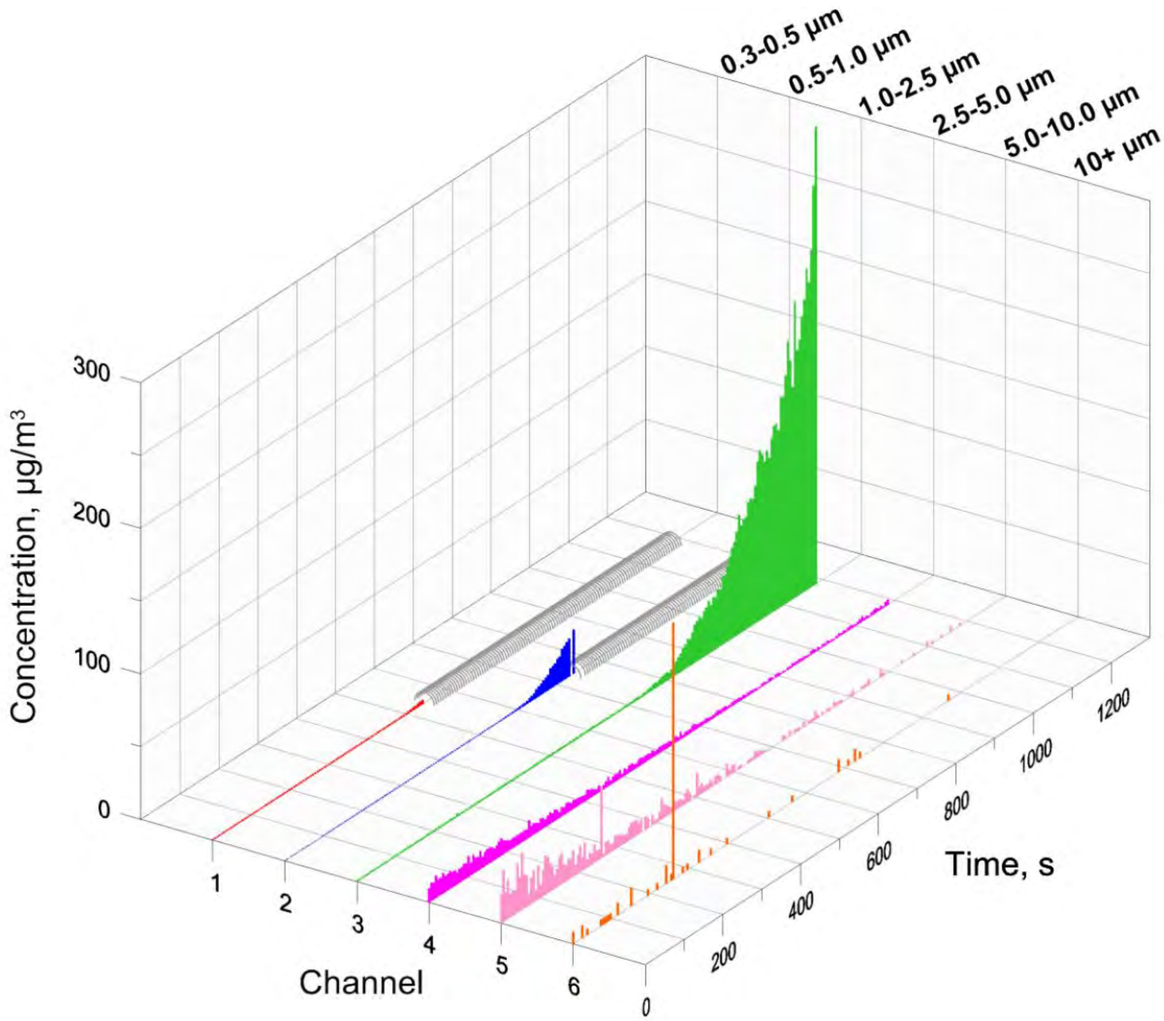

Figure 13. Particle Size Distribution- Natural Gas WETS160203_Burner.

APPENDIX B

Laboratory Cone Data on gas species detected from NIST for vegetation burns and WUI materials (including gypsum, pine wood, and PVC).

Date	Test ID	Fuel Package	Initial Fuel Mass	Mass at Suppression	Peak Heat Release Rate
1/12/2016	WETS160112c	Saw Palmetto	23.3		
1/13/2016	WETS160113a	Saw Palmetto	45.4		
1/13/2016	WETS160113b	Saw Palmetto	44.4		
1/13/2016	WETS160113c	Saw Palmetto	55		
1/13/2016	WETS160113d	Saw Palmetto	54.5		
1/14/2016	WETS160114a	Saw Palmetto	46.6		
1/14/2016	WETS160114b	Saw Palmetto	37.7		
1/14/2016	WETS160114c	Saw Palmetto	47.3		
1/14/2016	WETS160114d	Saw Palmetto	42.2		
1/15/2016	WETS160115a	Texas Grass	21.4		
1/15/2016	WETS160115b	Texas Grass	19.8		
1/15/2016	WETS160115c	Texas Grass	29.3		
1/15/2016	WETS160115d	Ponderosa Pine	58.2		
1/15/2016	WETS160115e	Ponderosa Pine	28.5		
1/15/2016	WETS160115f	Ponderosa Pine	83.2		
1/28/2016	WETS160128a	California Cedar	77.6		
1/28/2016	WETS160128b	California Cedar	91.4		
1/28/2016	WETS160128c	California Cedar	88.6		
1/29/2016	WETS160129a	California Cedar + Gypsum (6) + Pine Wood (8)	67.1		
1/29/2016	WETS160129b	California Cedar + Gypsum (6) + Pine Wood (8)	65.2		
1/29/2016	WETS160129c	California Cedar + Gypsum (5) + Pine Wood (7) + PVC (2)	86		
1/29/2016	WETS160129d	Grass + Gypsum (5) + Pine Wood (7) + PVC (2)	59.7		
2/1/2016	WETS160201a	White Pine	63.1		
2/1/2016	WETS160201b	White Pine	74		
2/1/2016	WETS160201c	White Pine	83.9		
2/1/2016	WETS160201d	White Pine + Gypsum (5) + Wood (7) + PVC	96.1		

2/1/2016	WETS160201e	Gypsum (22) + Wood (28) + PVC (6)	156.1		
2/3/2016	WETS160203_AIR	X	X		
2/3/2016	WETS160203_BURNER	X	X		

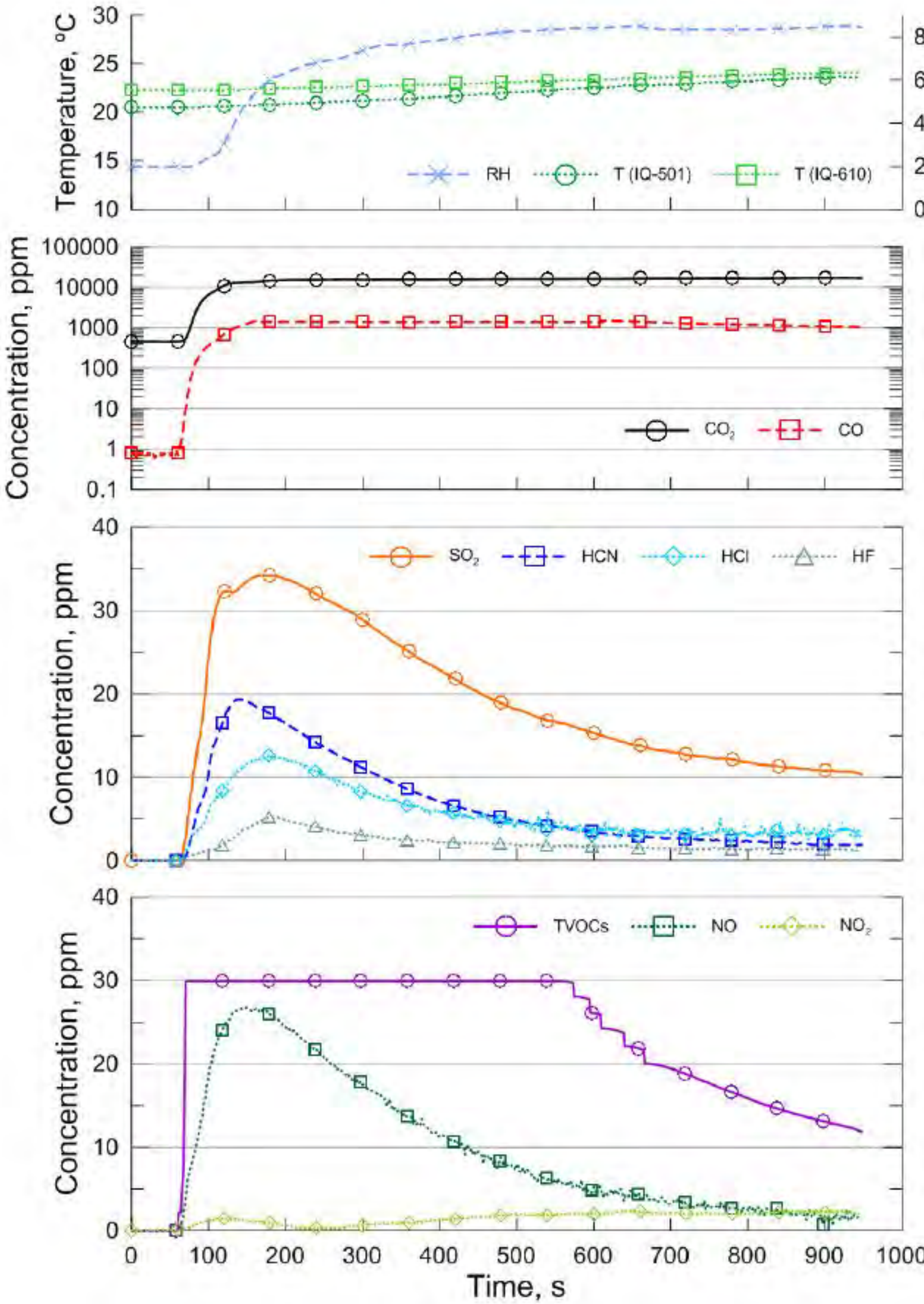

Figure 1. Gas Species Concentrations- Saw Palmetto Test WETS160112c.

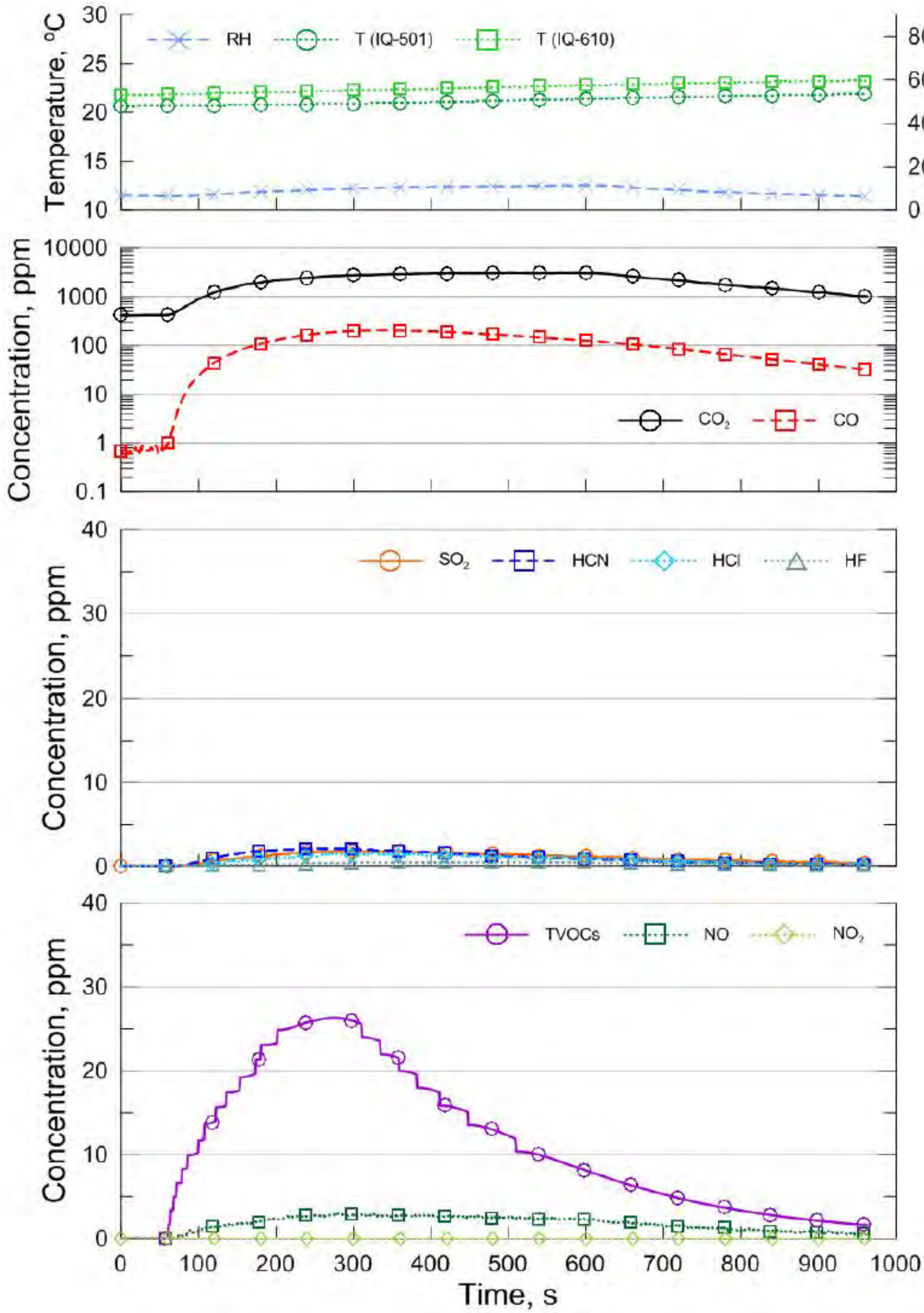

Figure 2. Gas Species Concentrations- Saw Palmetto Test WETS160113a.

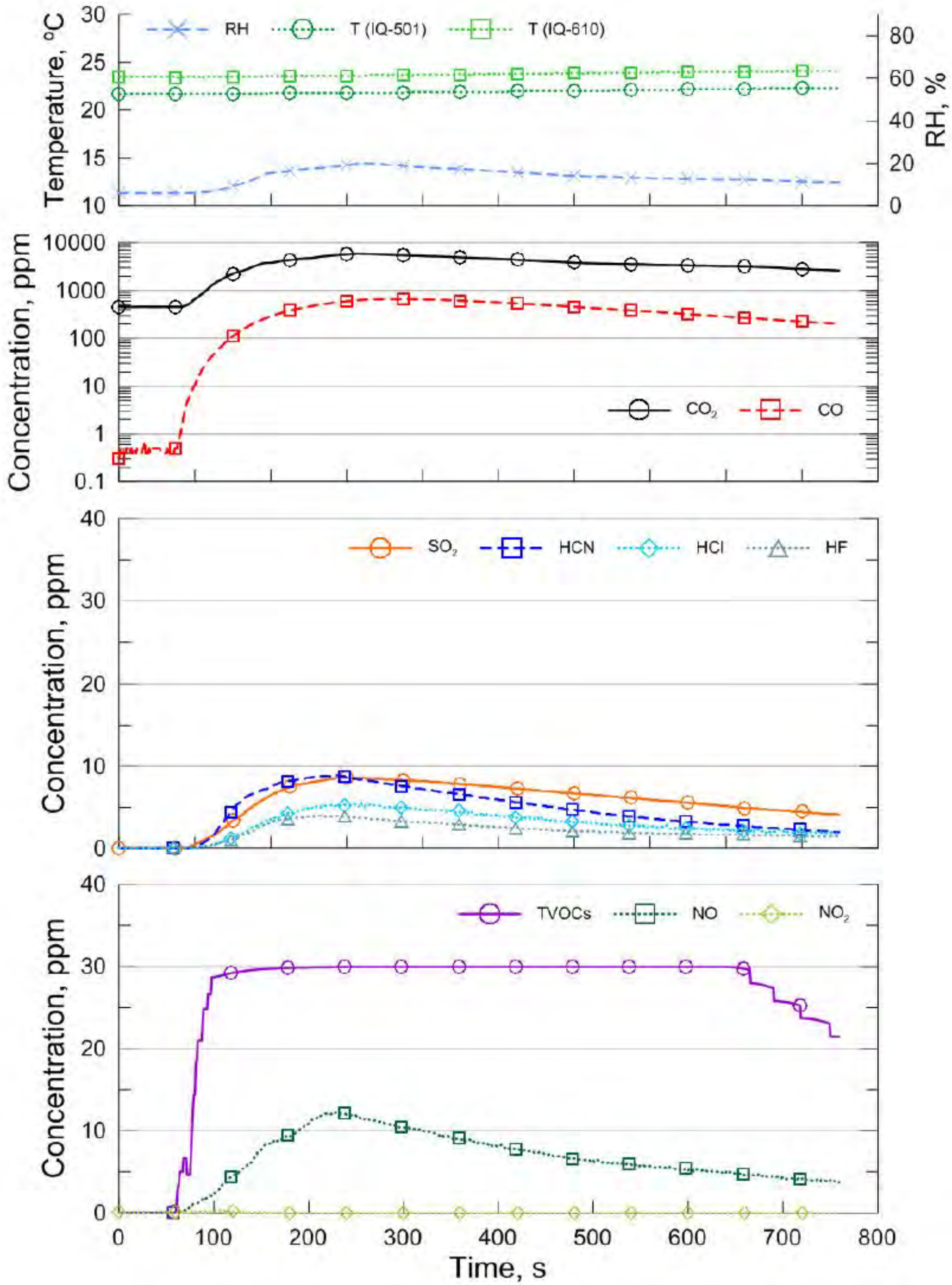

Figure 3. Gas Species Concentrations- Saw Palmetto Test WETS160113b.

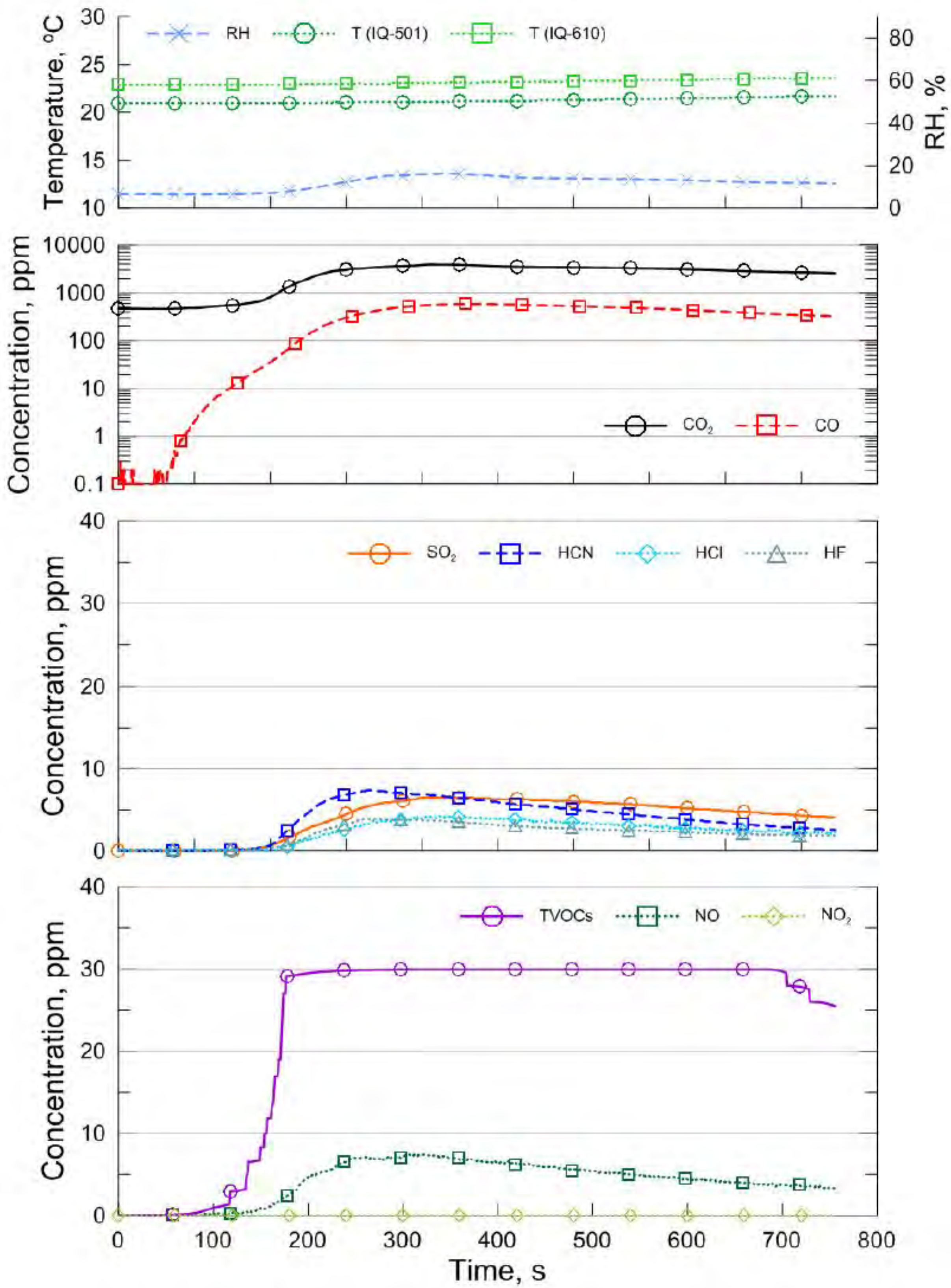

Figure 4. Gas Species Concentrations- Saw Palmetto Test WETS160113c.

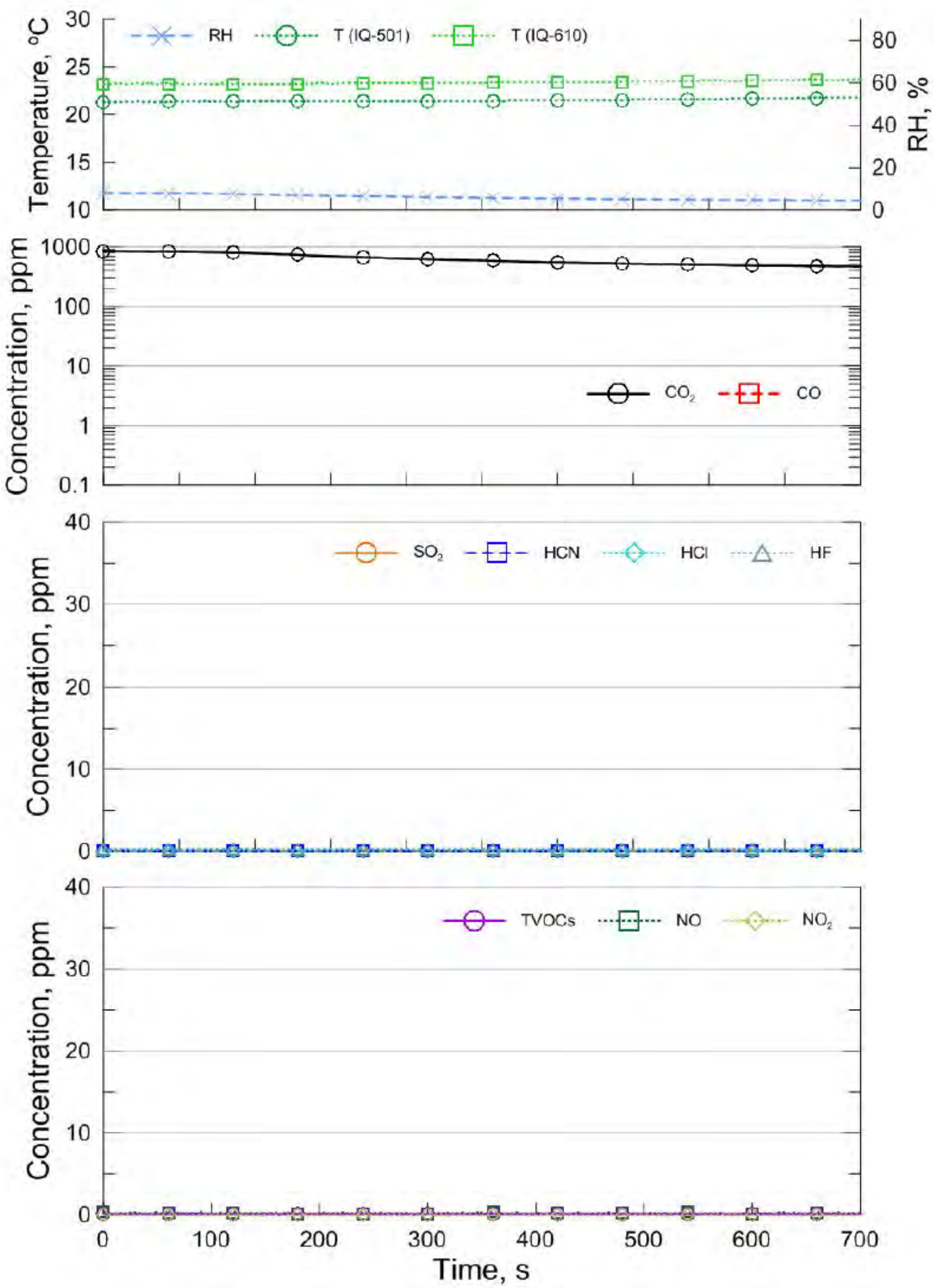

Figure 5. Gas Species Concentrations- Saw Palmetto Test WETS160113d.

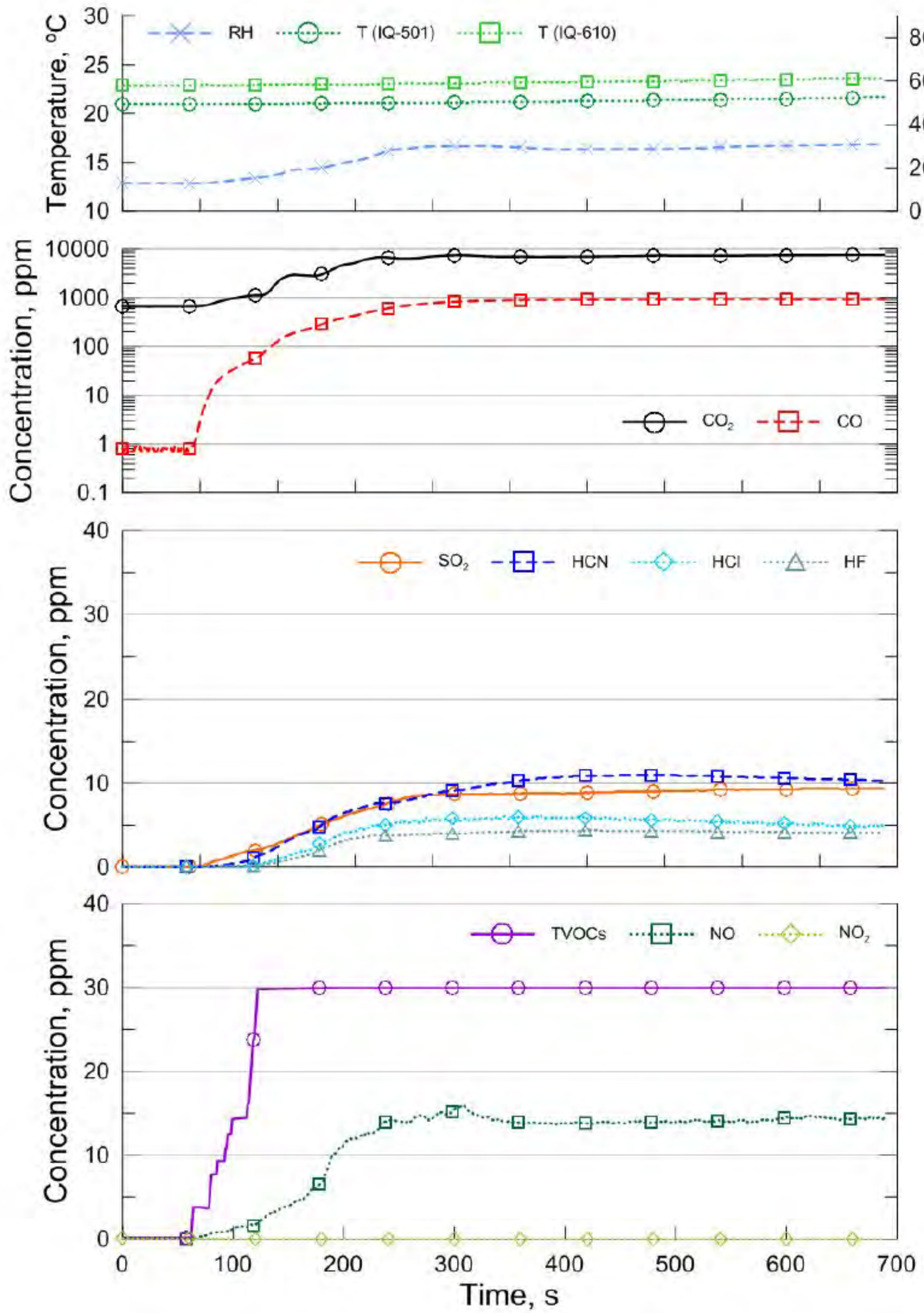

Figure 6. Gas Species Concentrations- Saw Palmetto Test WETS160114a.

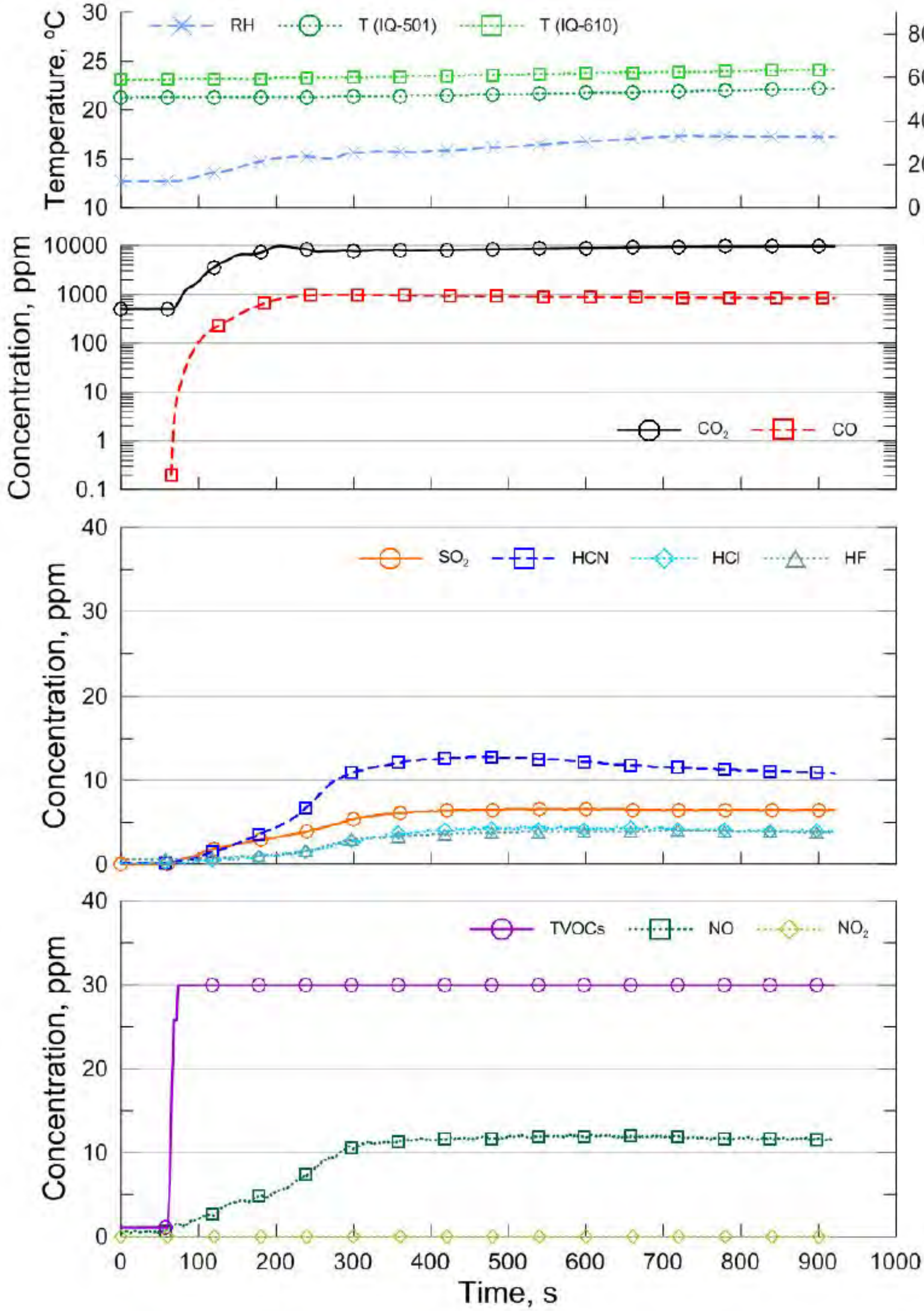

Figure 7. Gas Species Concentrations- Saw Palmetto Test WETS160114b.

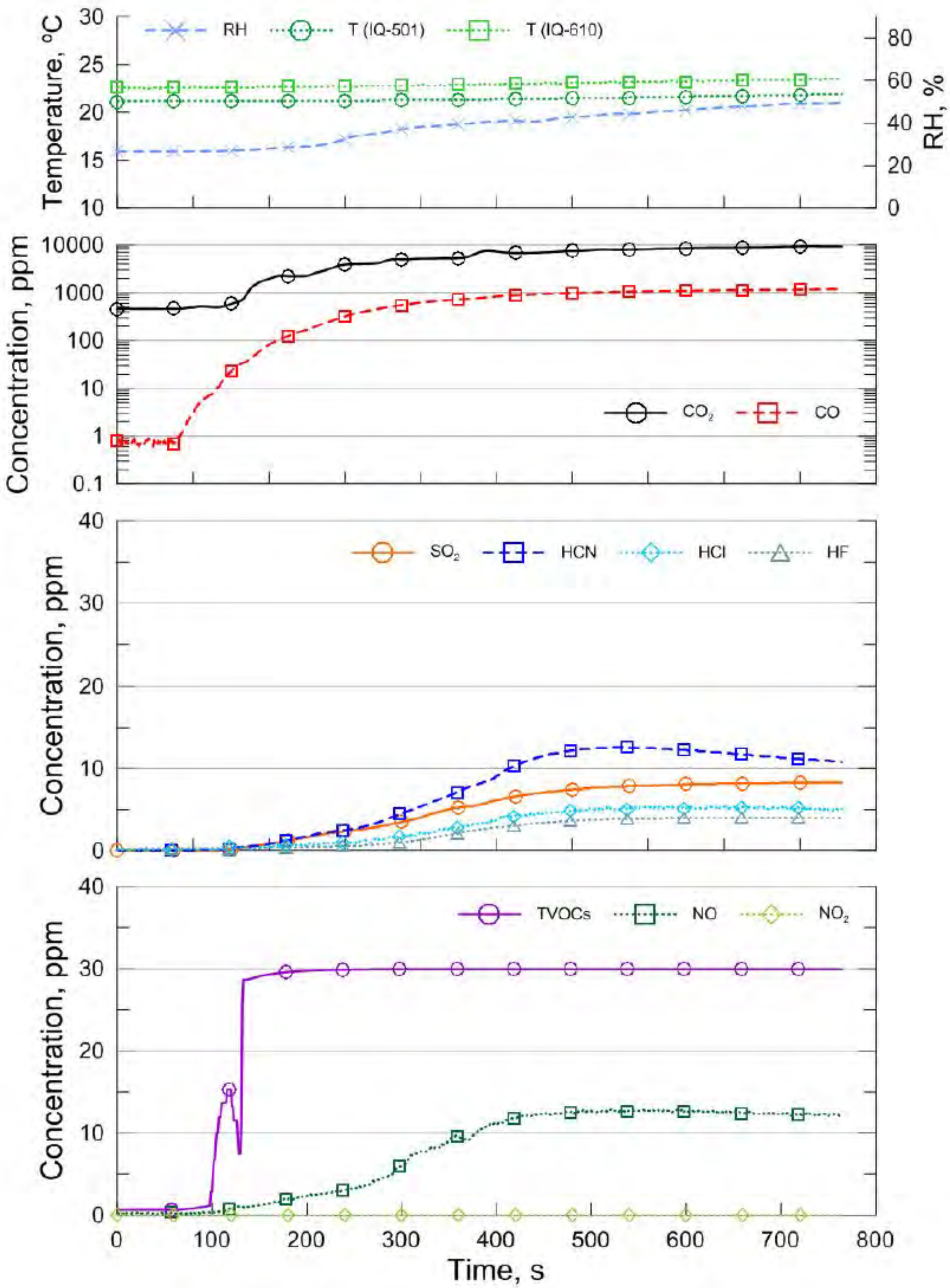

Figure 8. Gas Species Concentrations- Saw Palmetto Test WETS160114c.

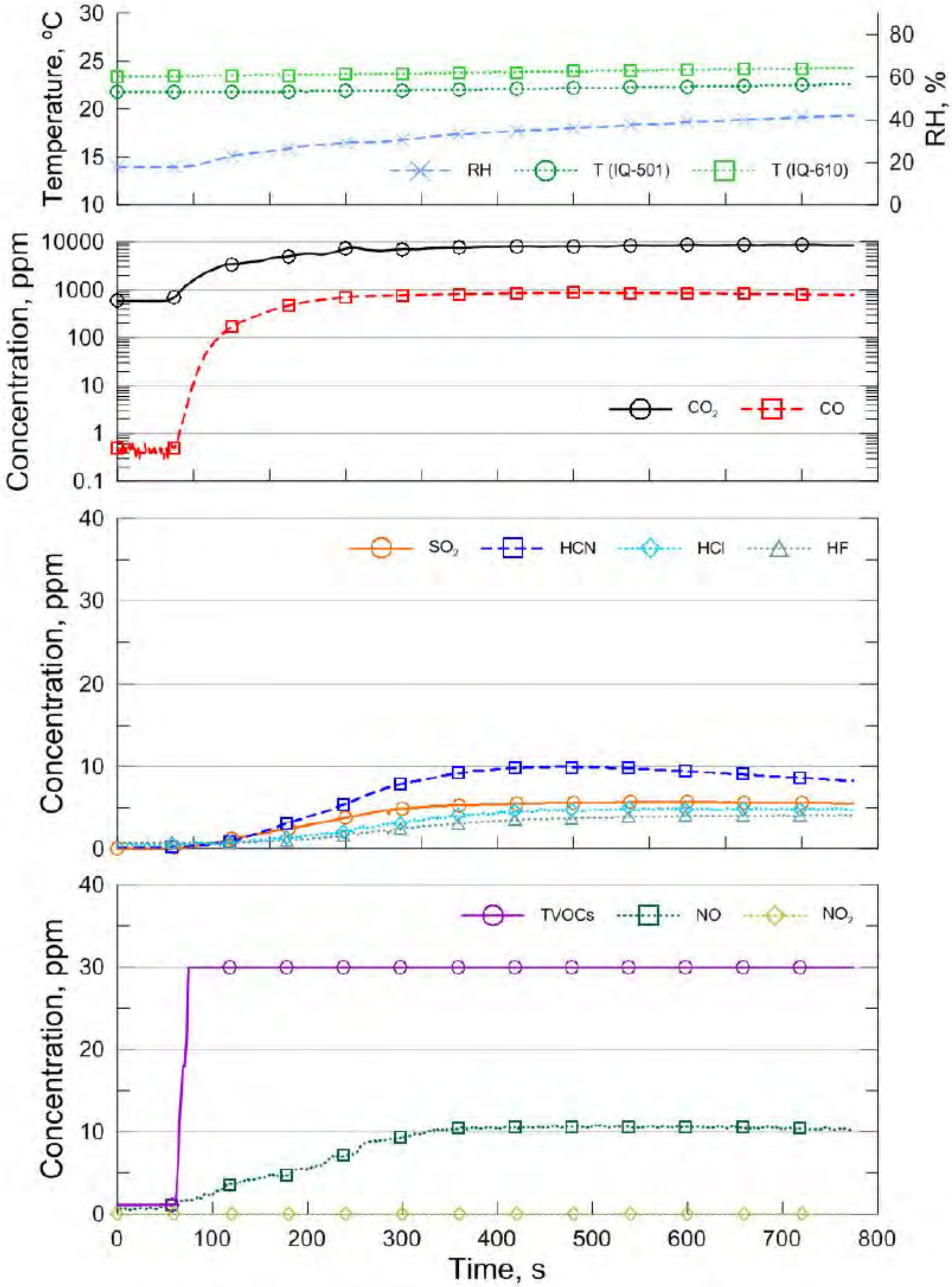

Figure 9. Gas Species Concentrations- Saw Palmetto Test WETS160114d.

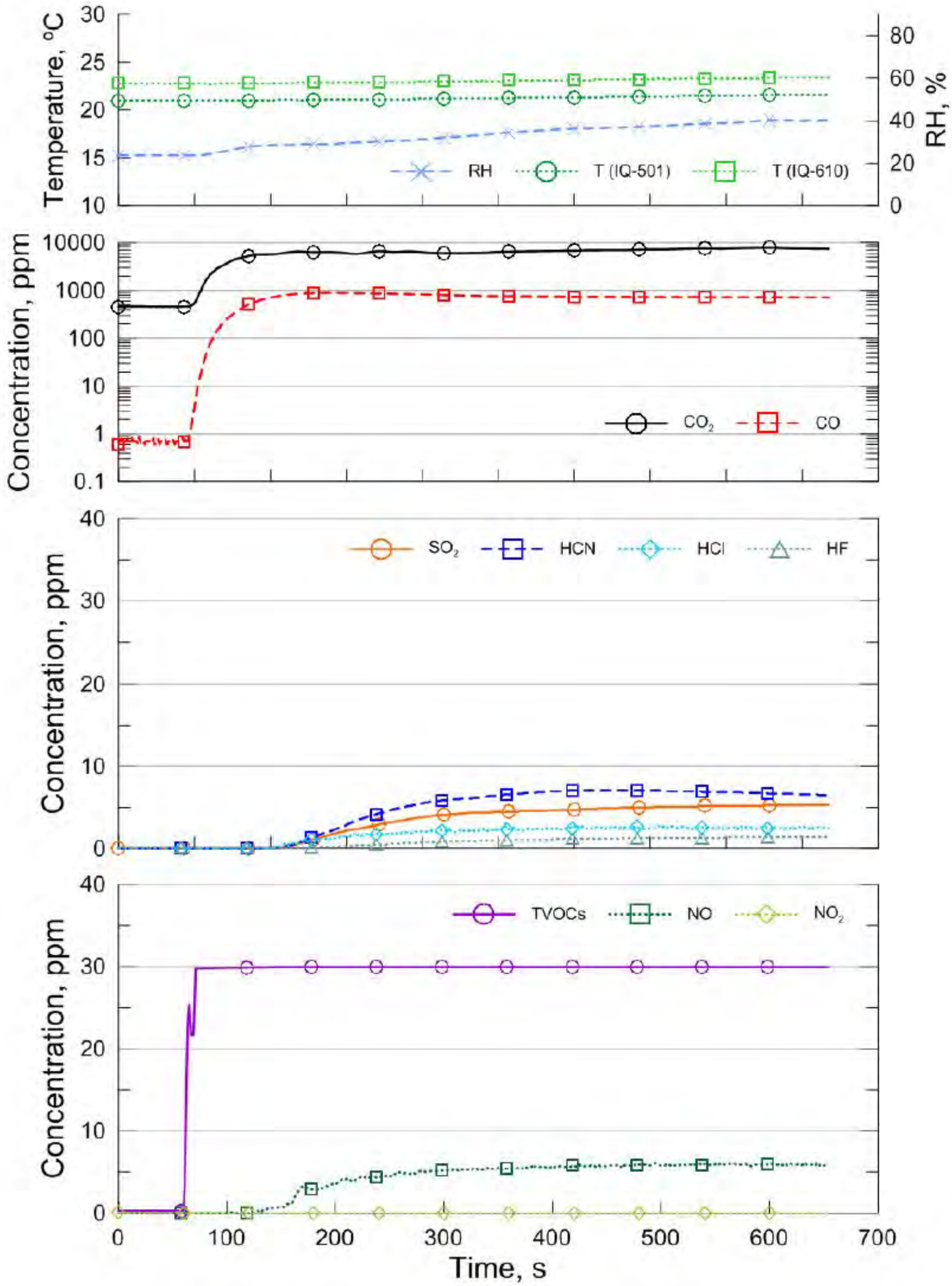

Figure 10. Gas Species Concentrations- Texas Grass Test WETS160115a.

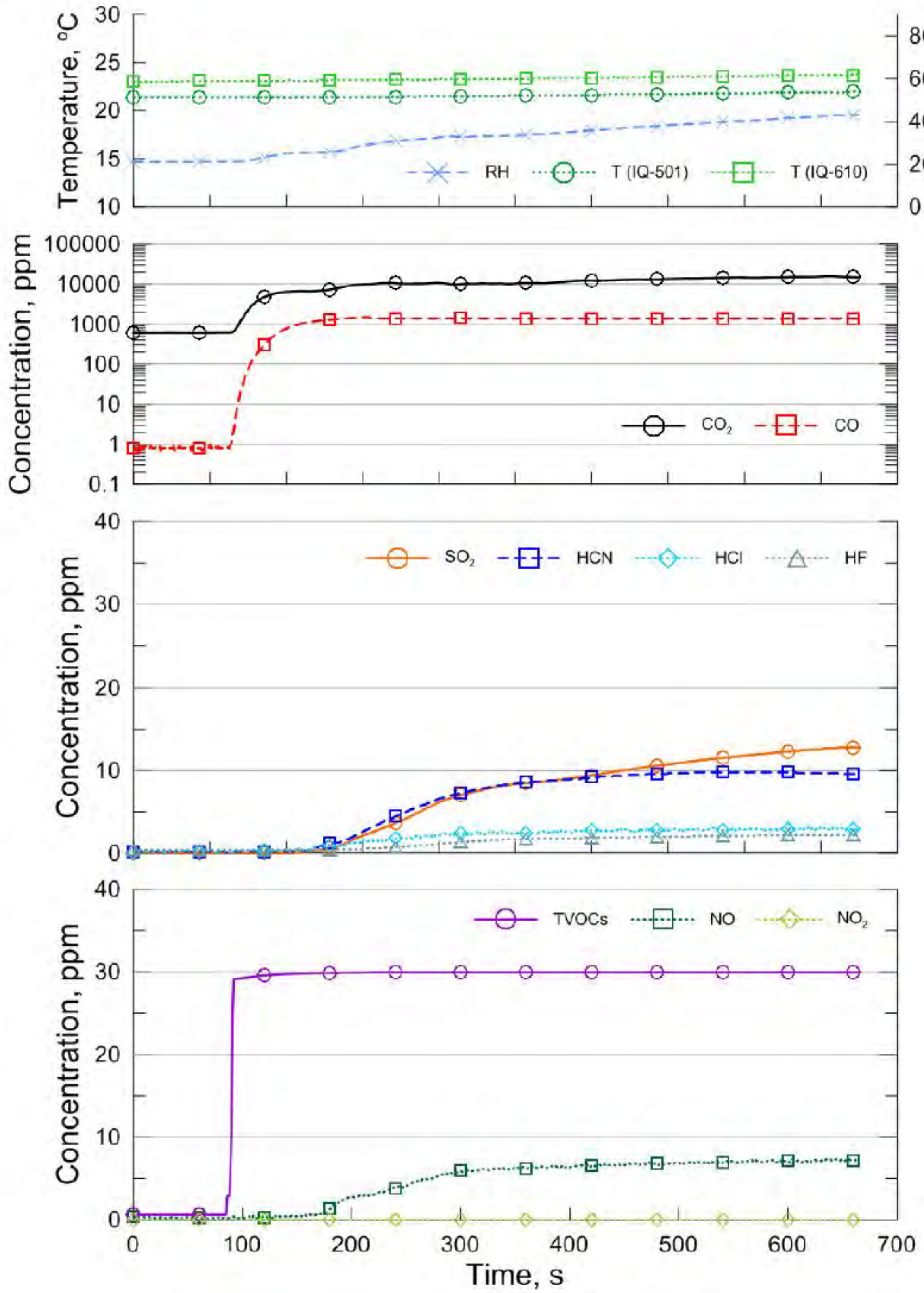

Figure 11. Gas Species Concentrations- Texas Grass Test WETS160115b.

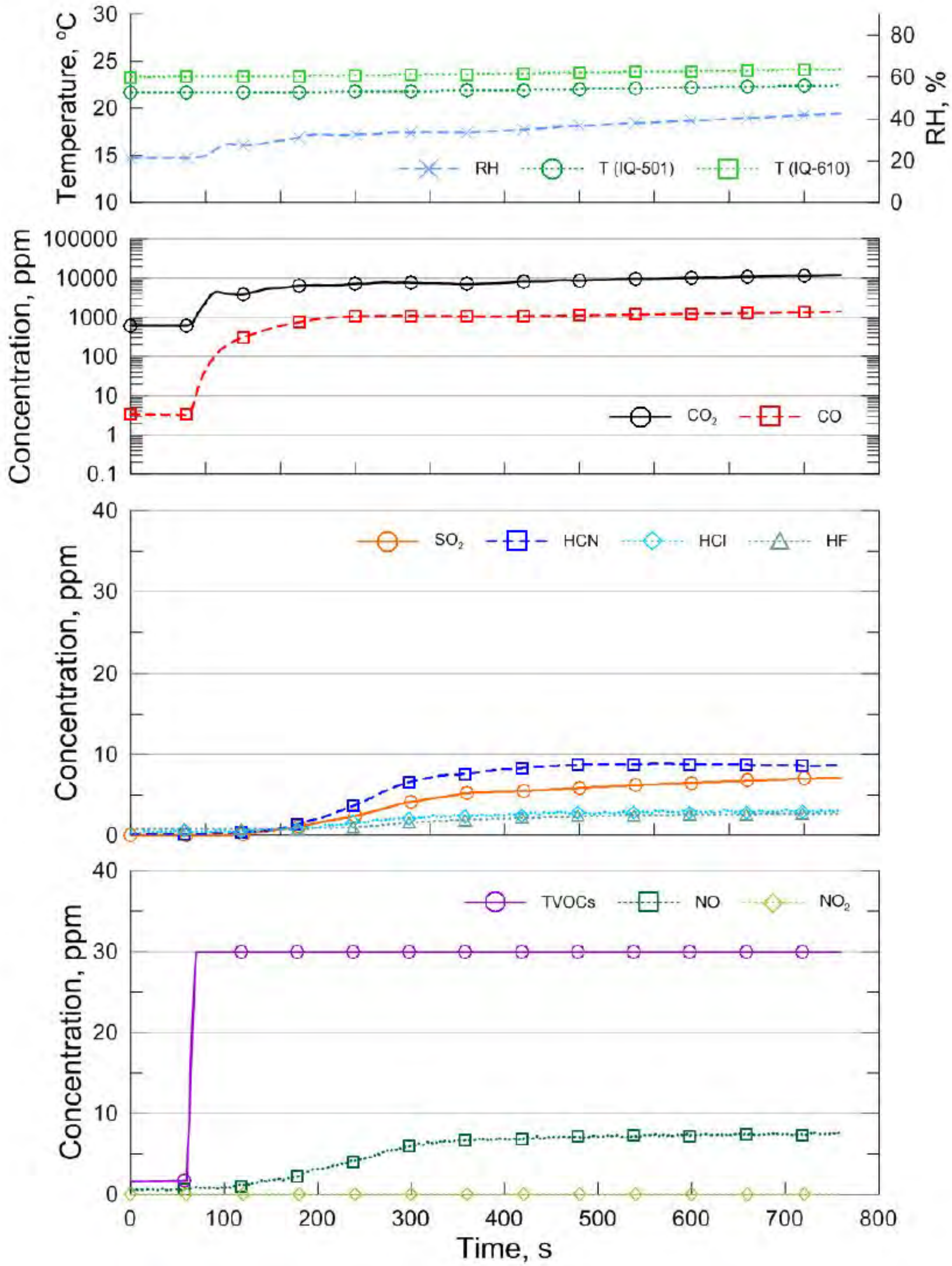

Figure 12. Gas Species Concentrations- Texas Grass Test WETS160115c.

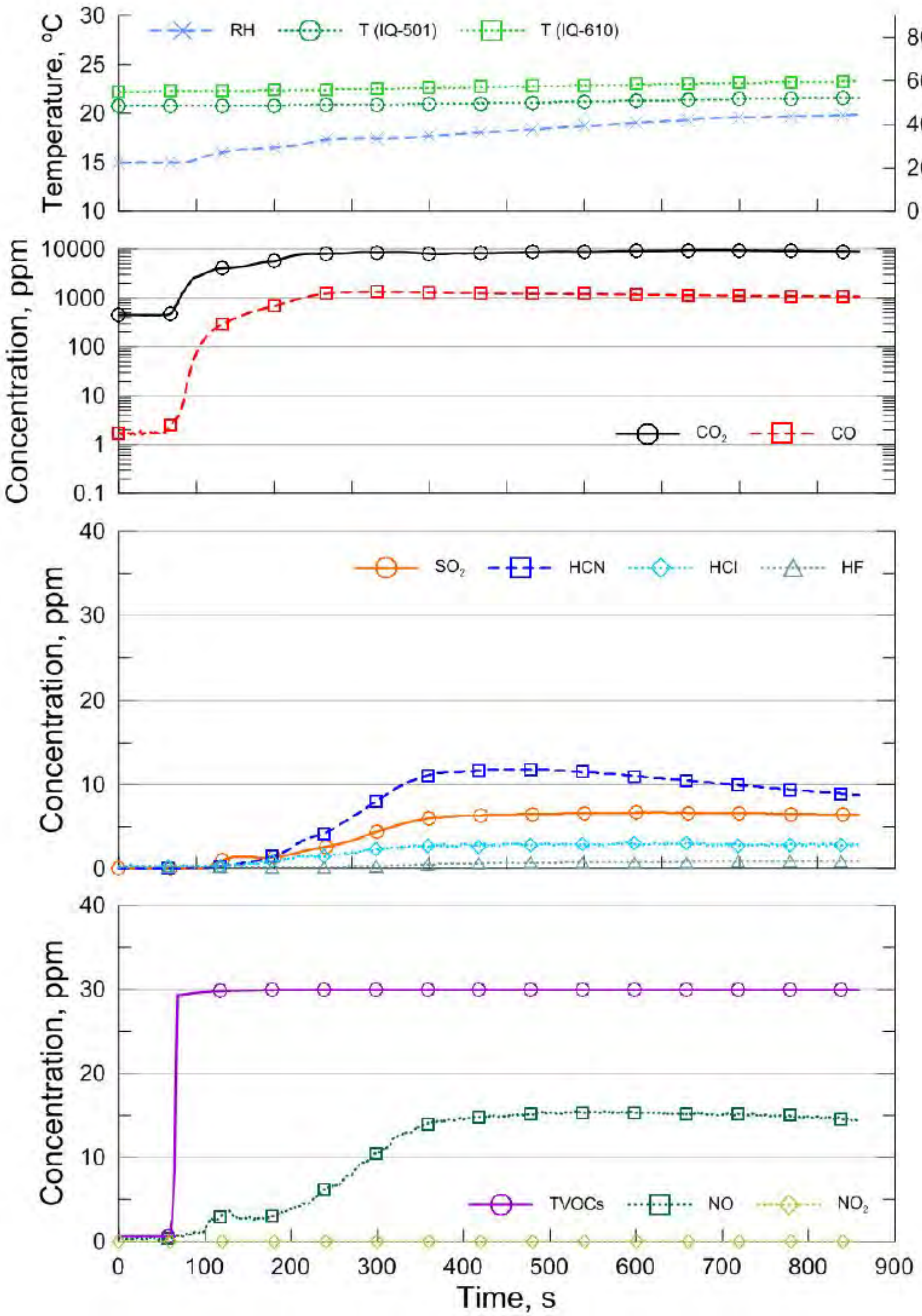

Figure 13. Gas Species Concentrations- Ponderosa Pine Test WETS160115d.

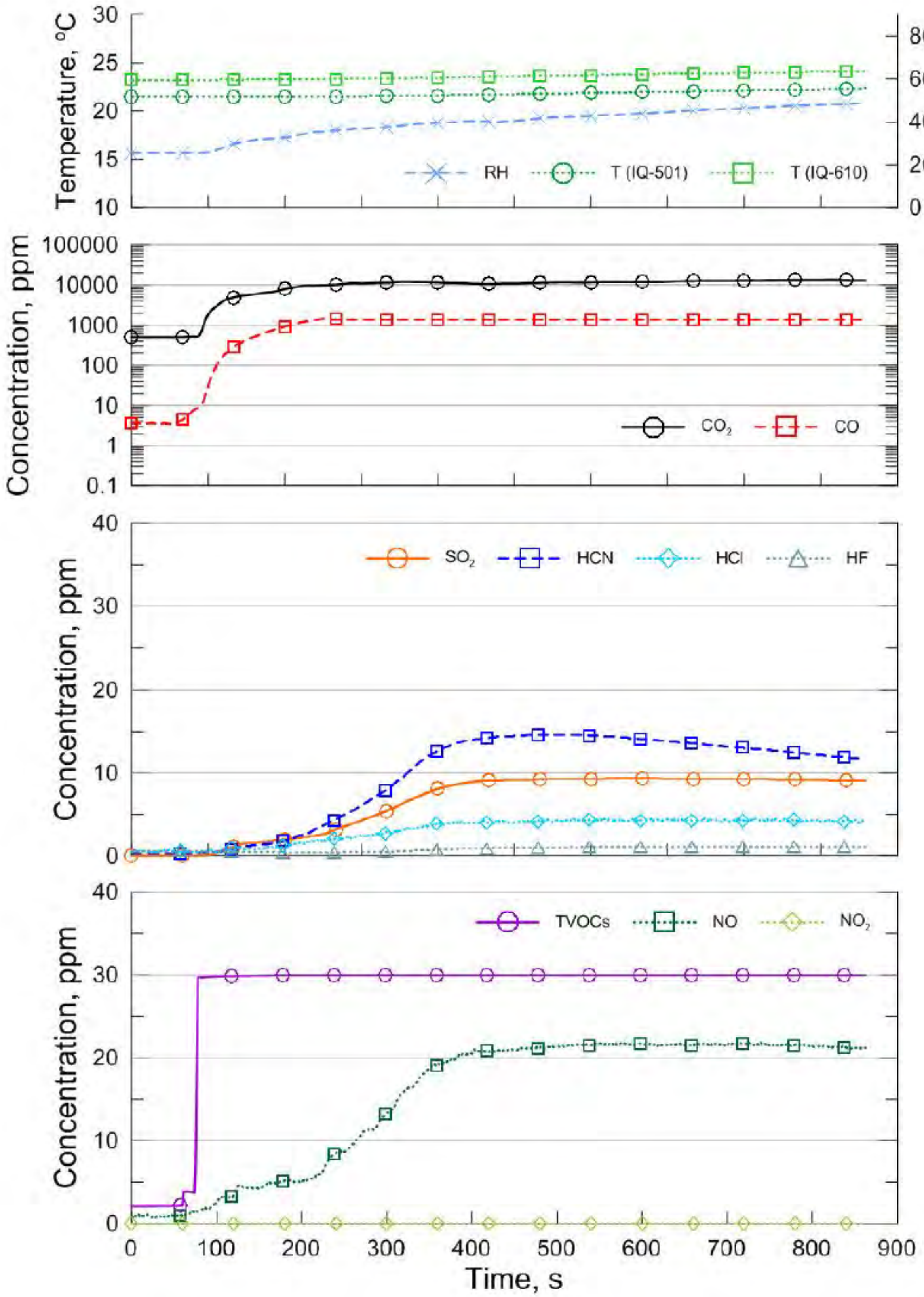

Figure 14. Gas Species Concentrations- Ponderosa Pine Test WETS160115e.

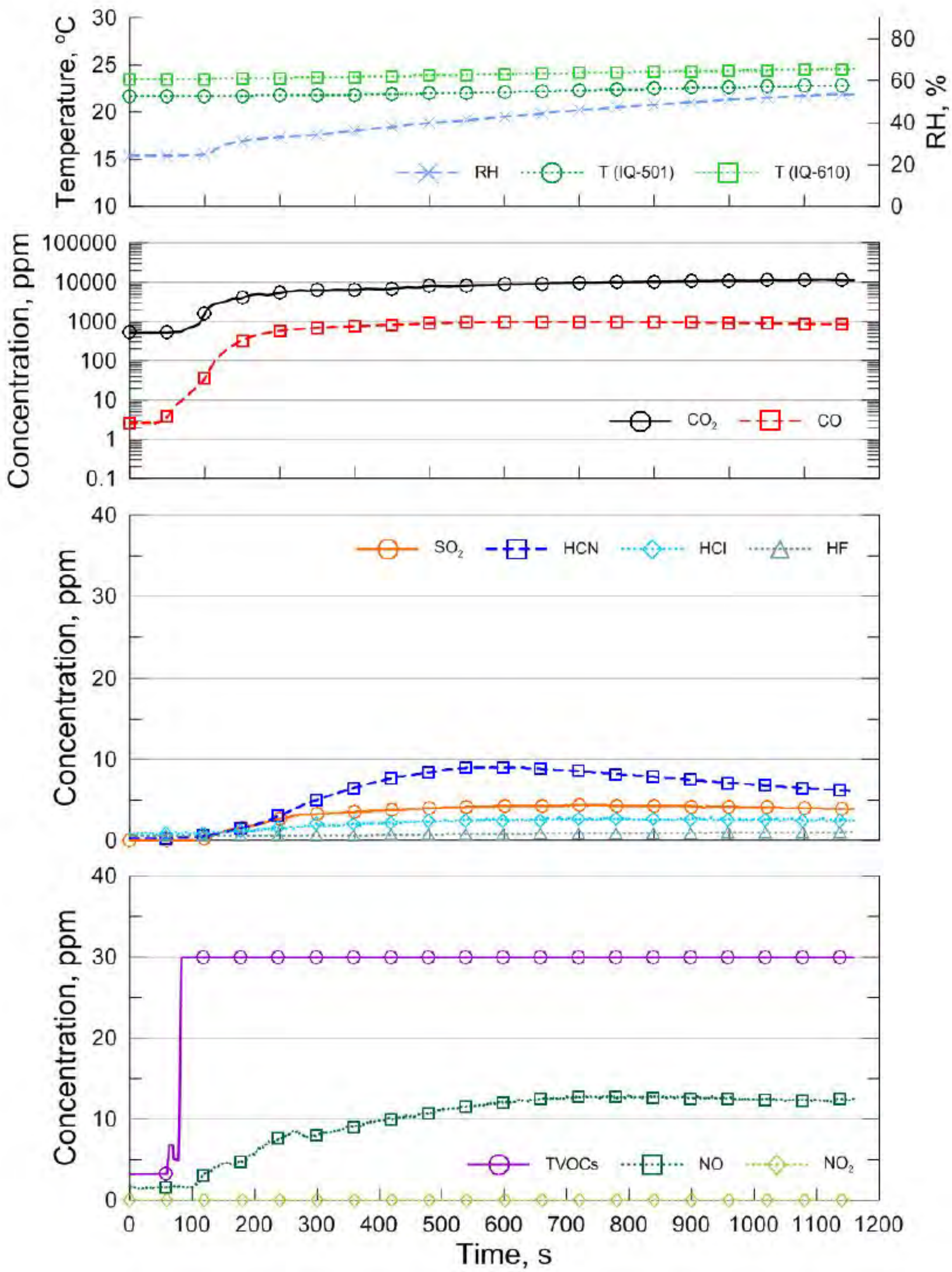

Figure 15. Gas Species Concentrations- Ponderosa Pine Test WETS160115f.

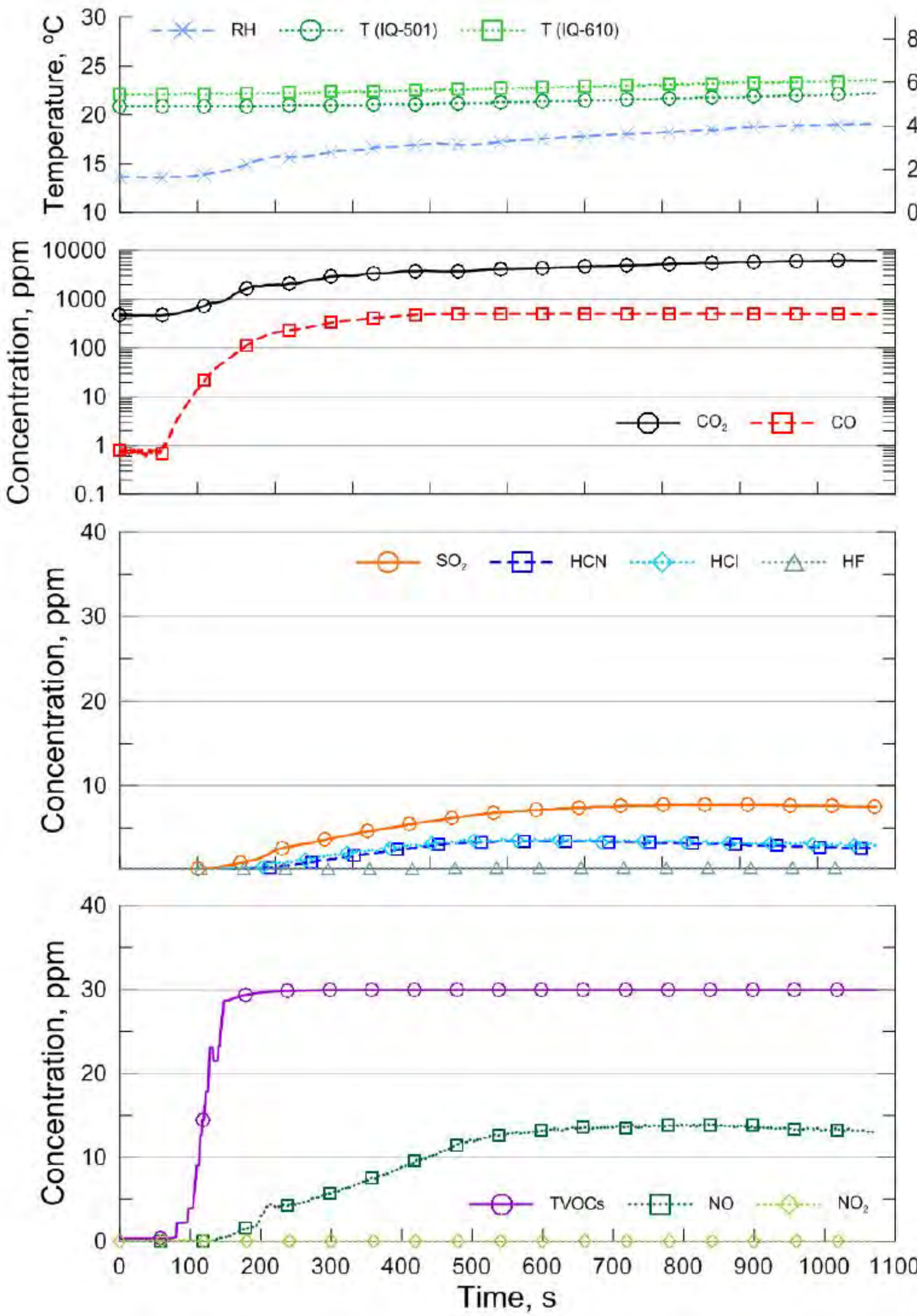

Figure 16. Gas Species Concentrations- California Cedar Test WETS160128a.

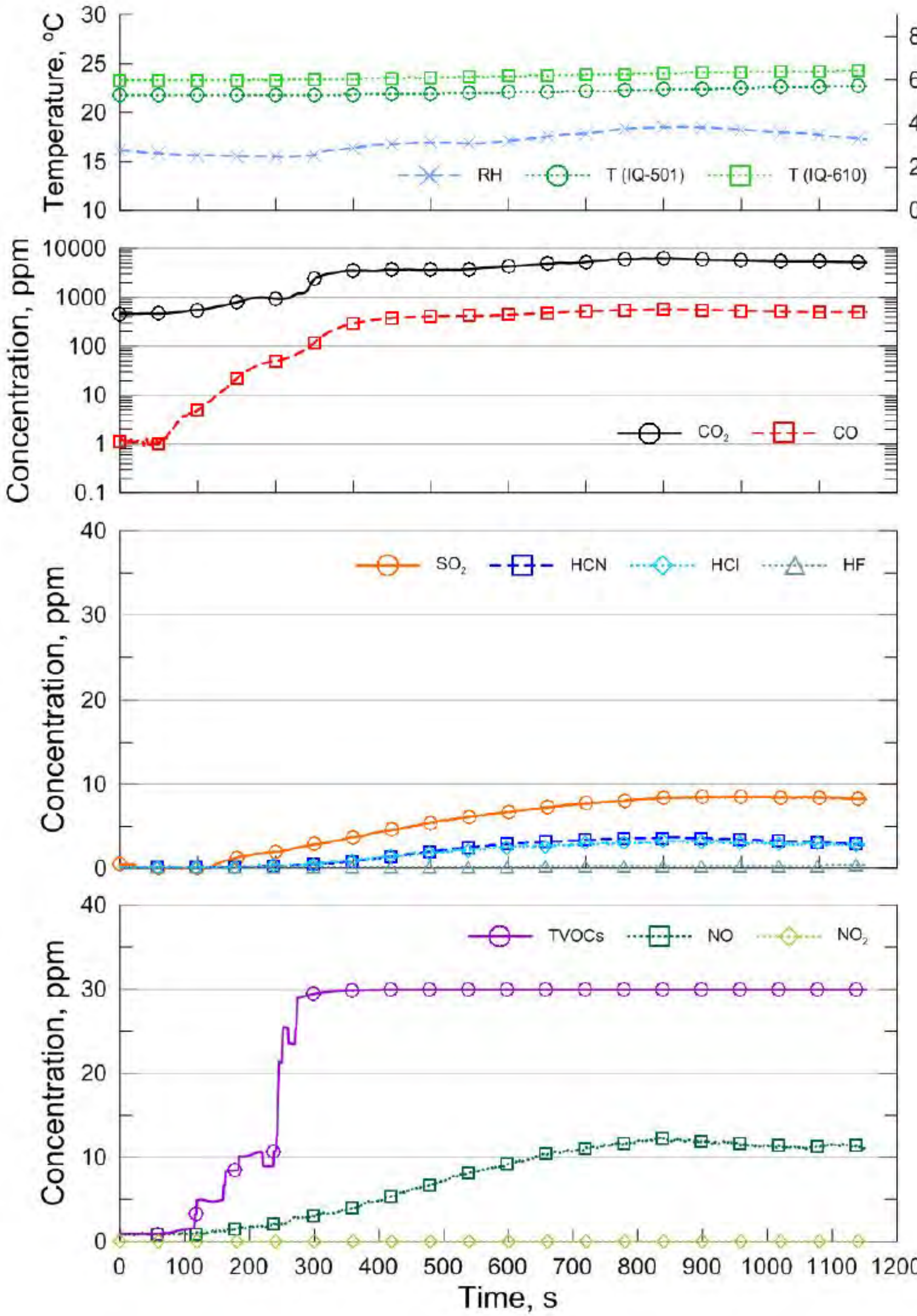

Figure 17. Gas Species Concentrations- California Cedar Test WETS160128b.

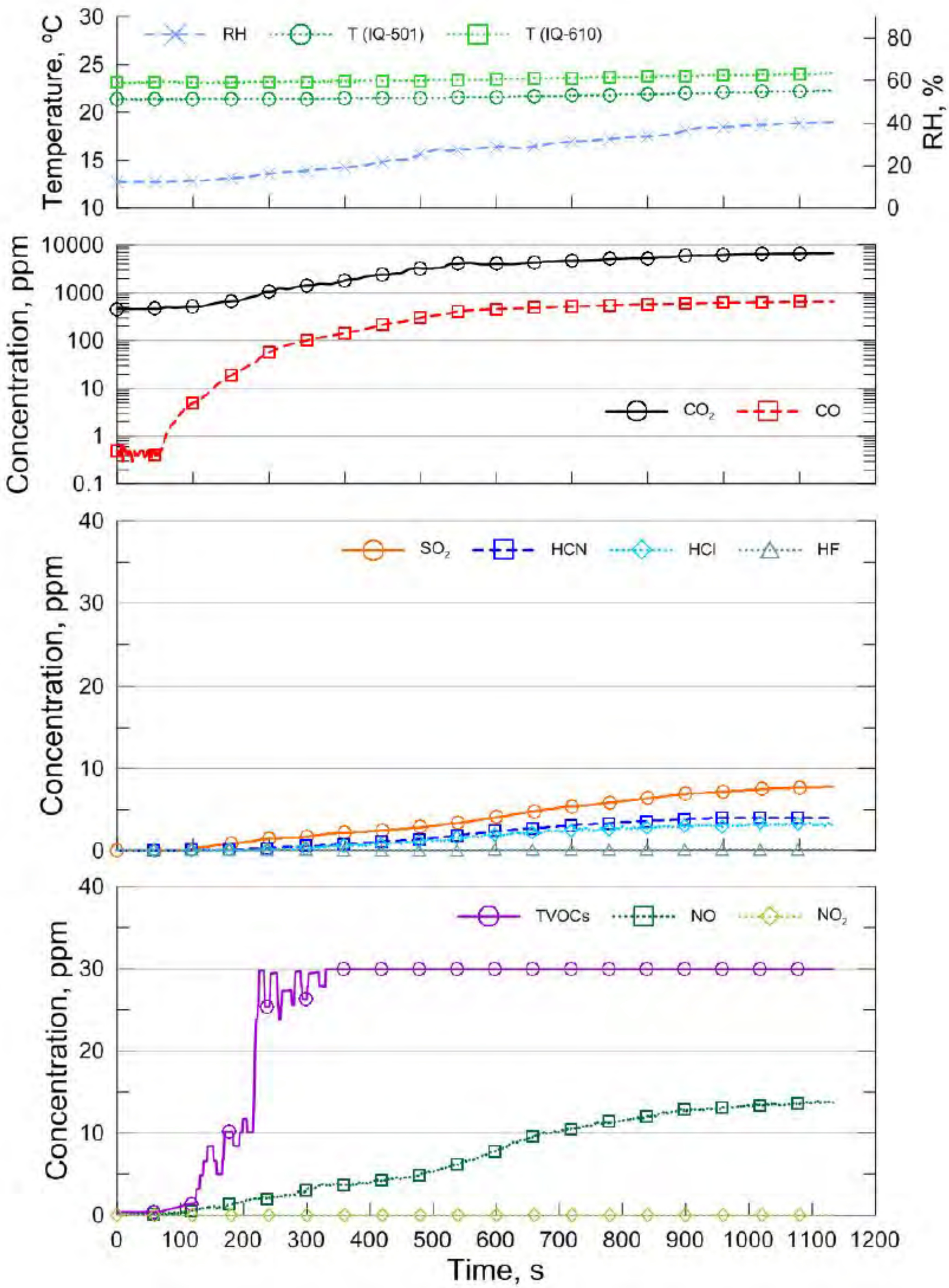

Figure 18. Gas Species Concentrations- California Cedar Test WETS160128c.

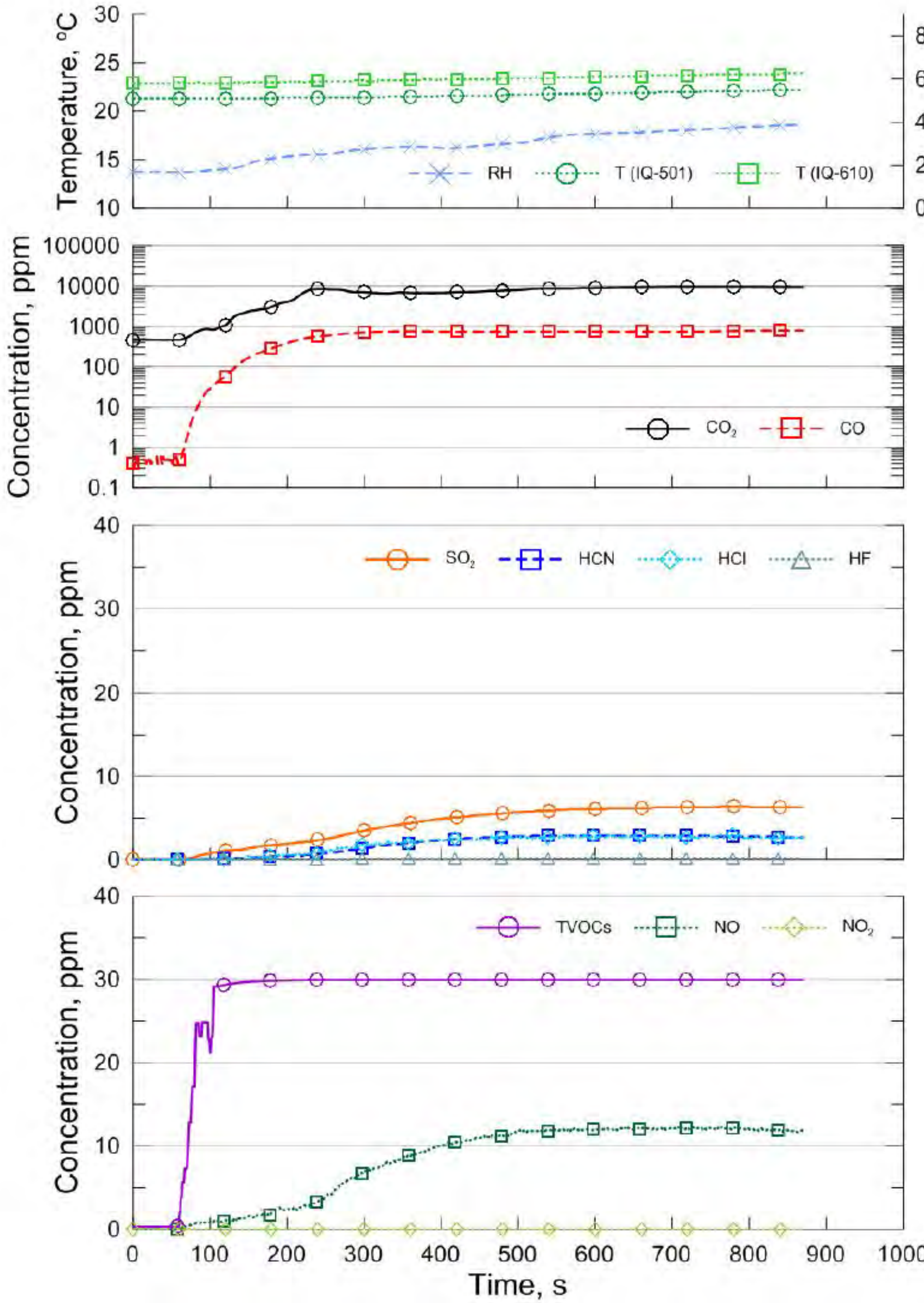

Figure 19. Gas Species Concentrations- California Cedar/Gypsum/Pine Wood Test WETS160129a.

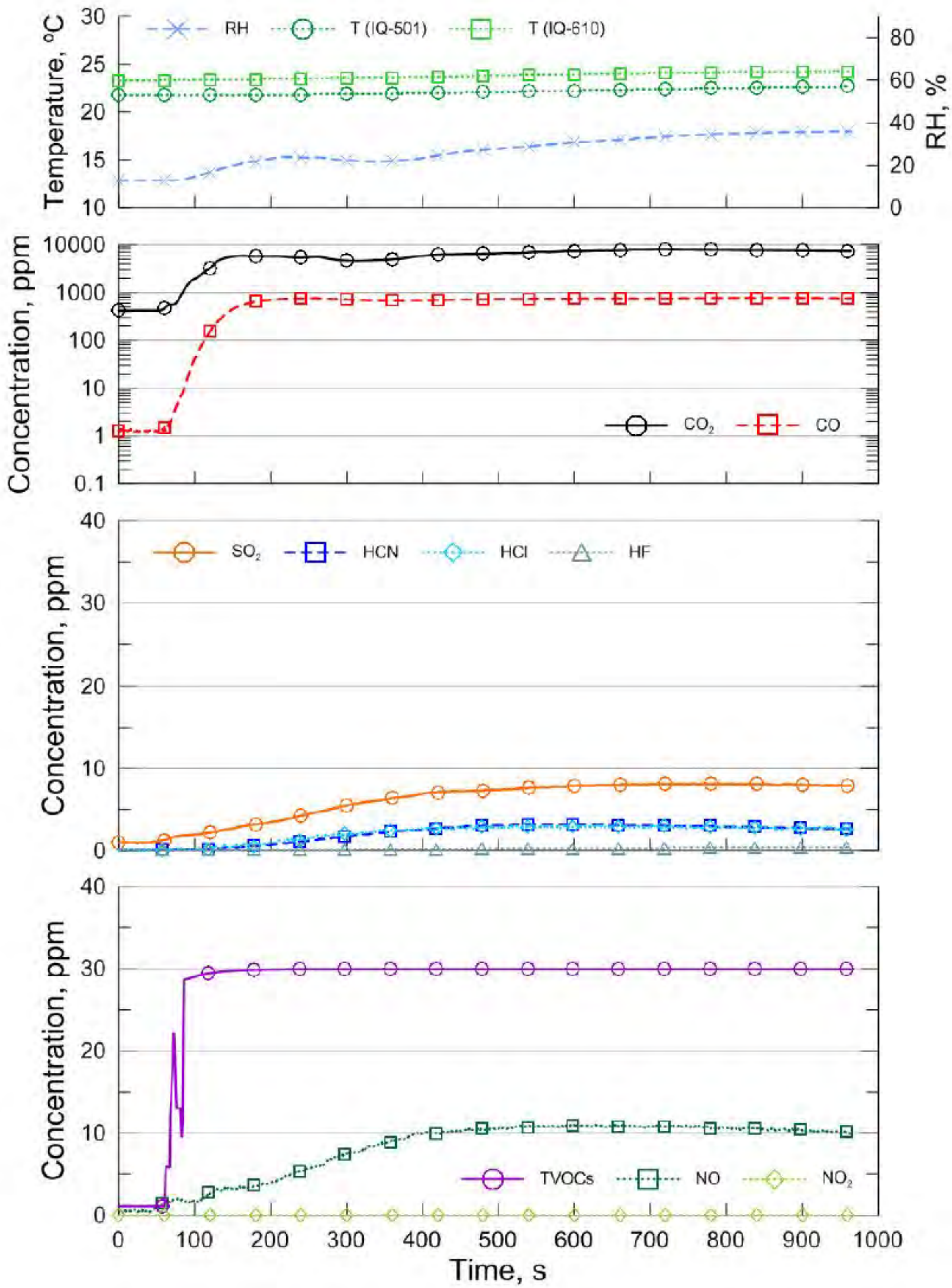

Figure 20. Gas Species Concentrations- California Cedar/Gypsum/Pine Wood Test WETS160129b.

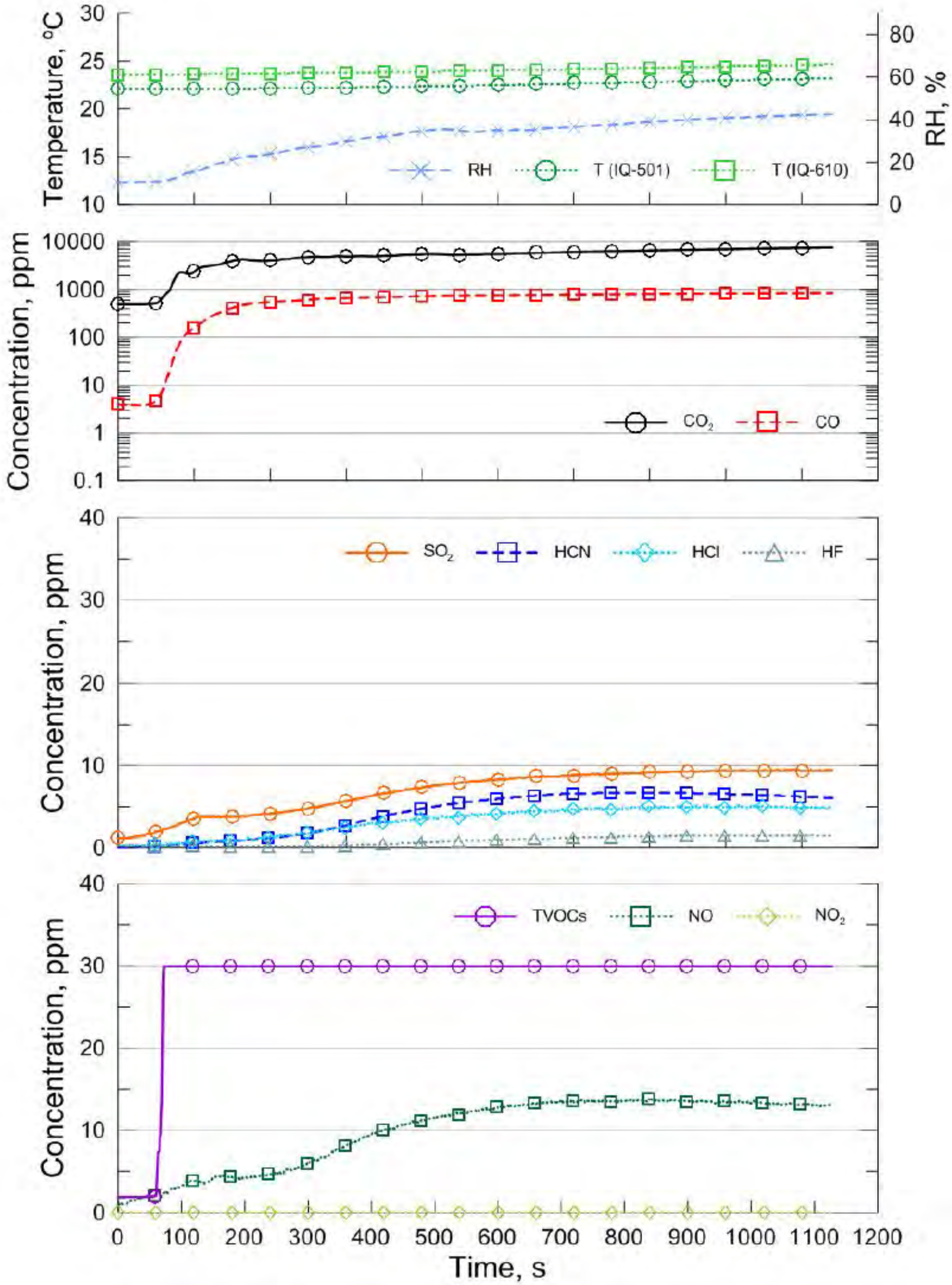

Figure 21. Gas Species Concentrations- California Cedar/Gypsum/Pine Wood/PVC Test WETS160129c.

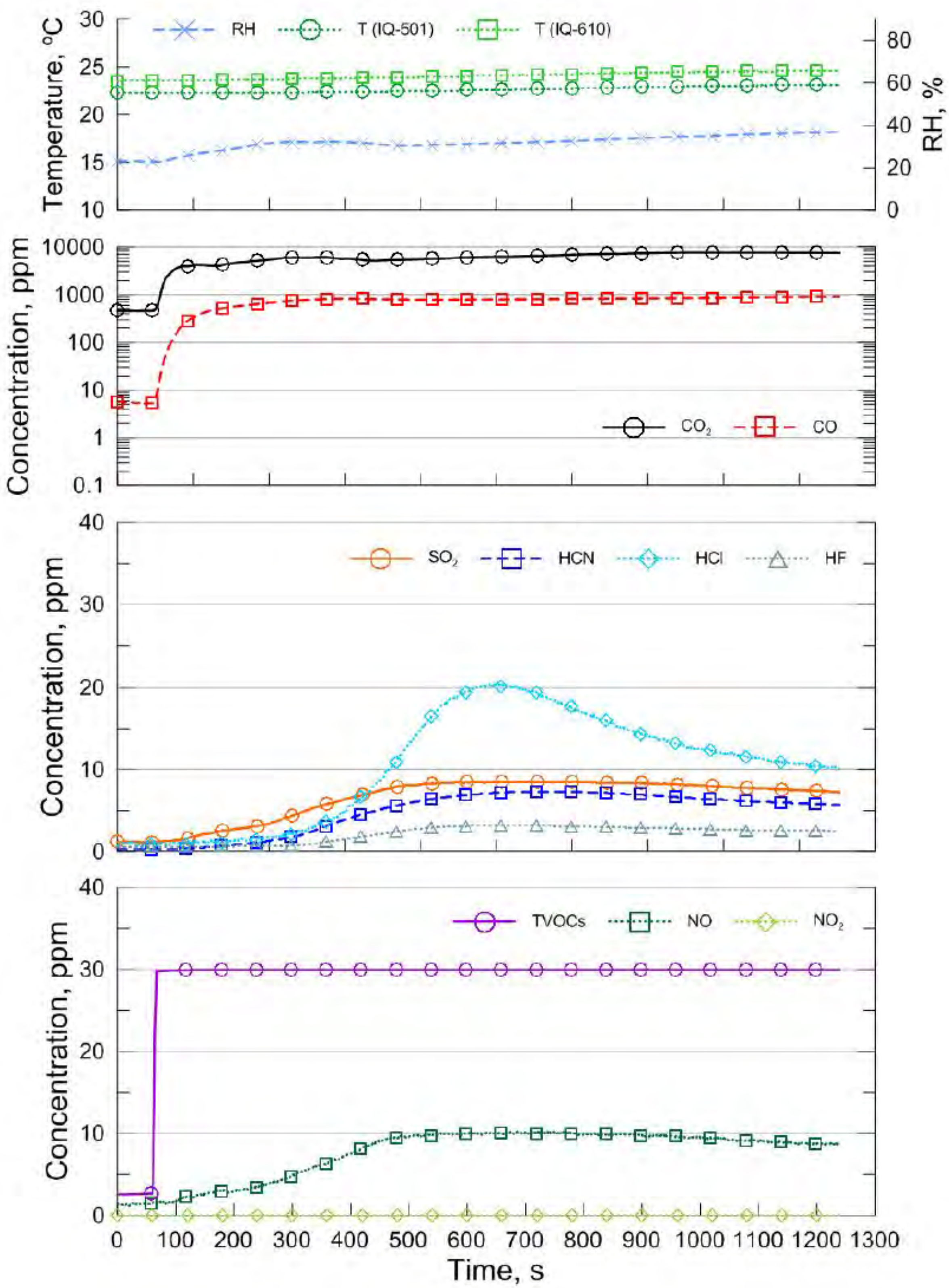

Figure 22. Gas Species Concentrations- Texas Grass/Gypsum/Pine Wood/PVC Test WETS160129d.

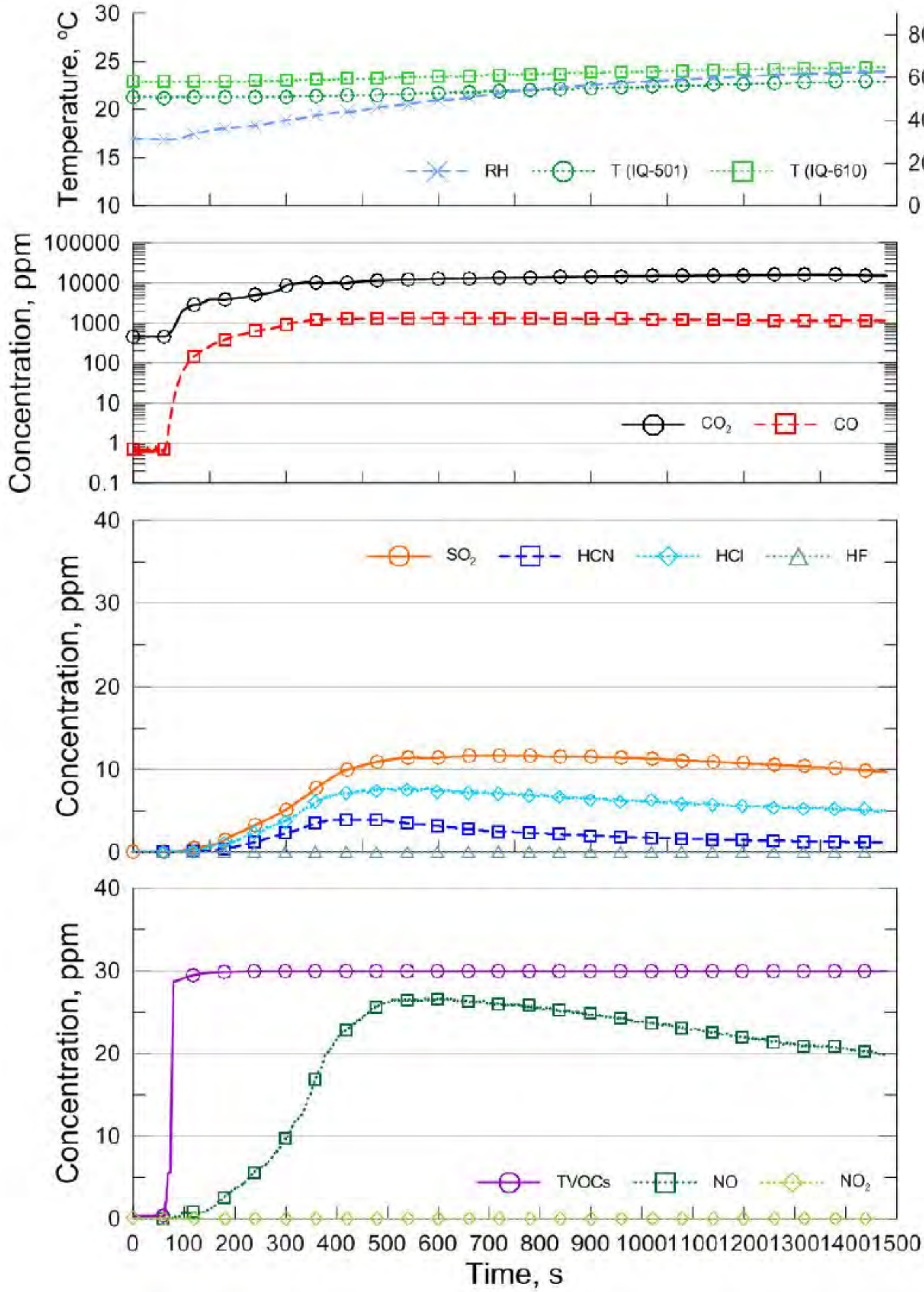

Figure 23. Gas Species Concentrations- White Pine Test WETS160201a.

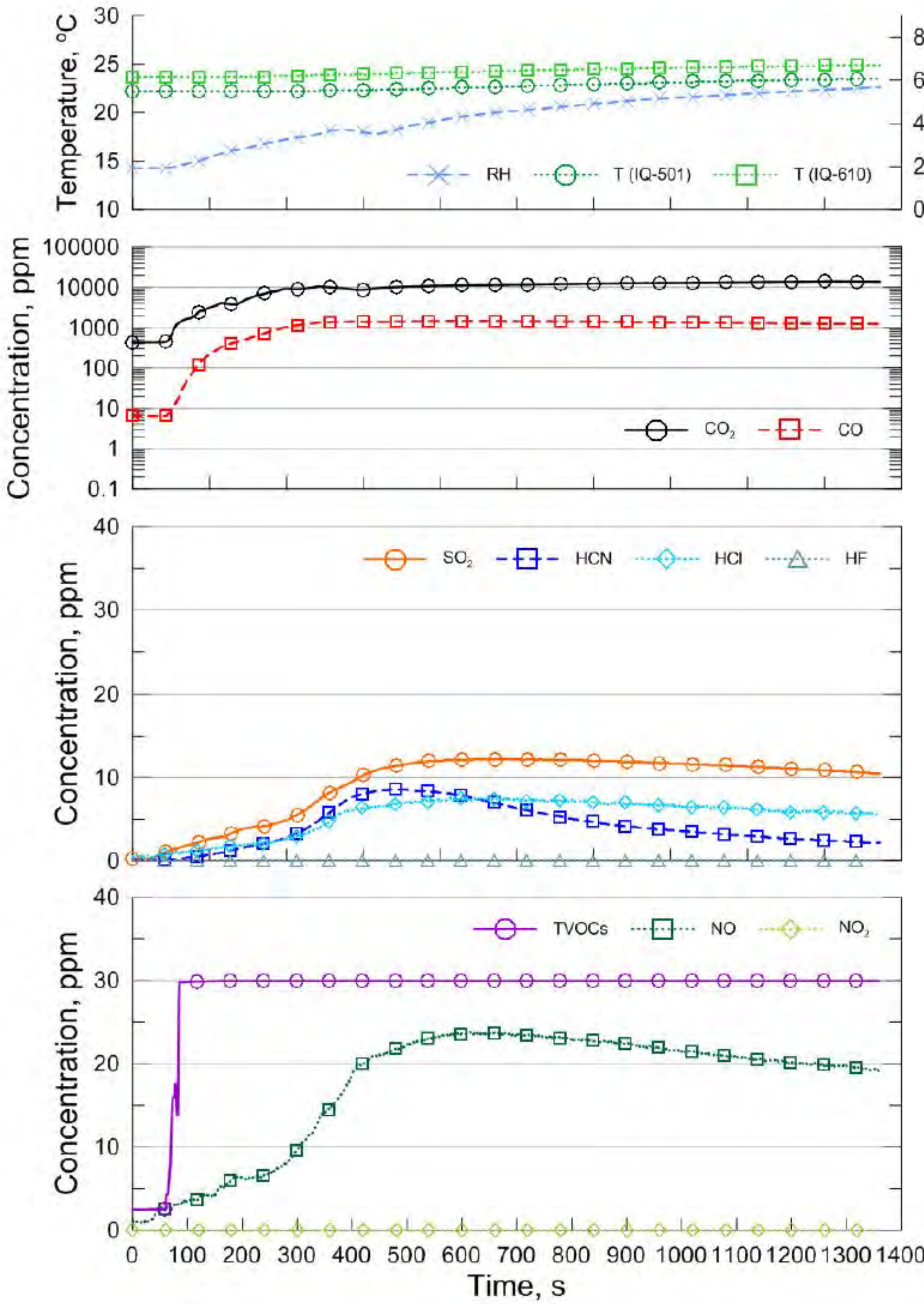

Figure 24. Gas Species Concentrations- White Pine Test WETS160201b.

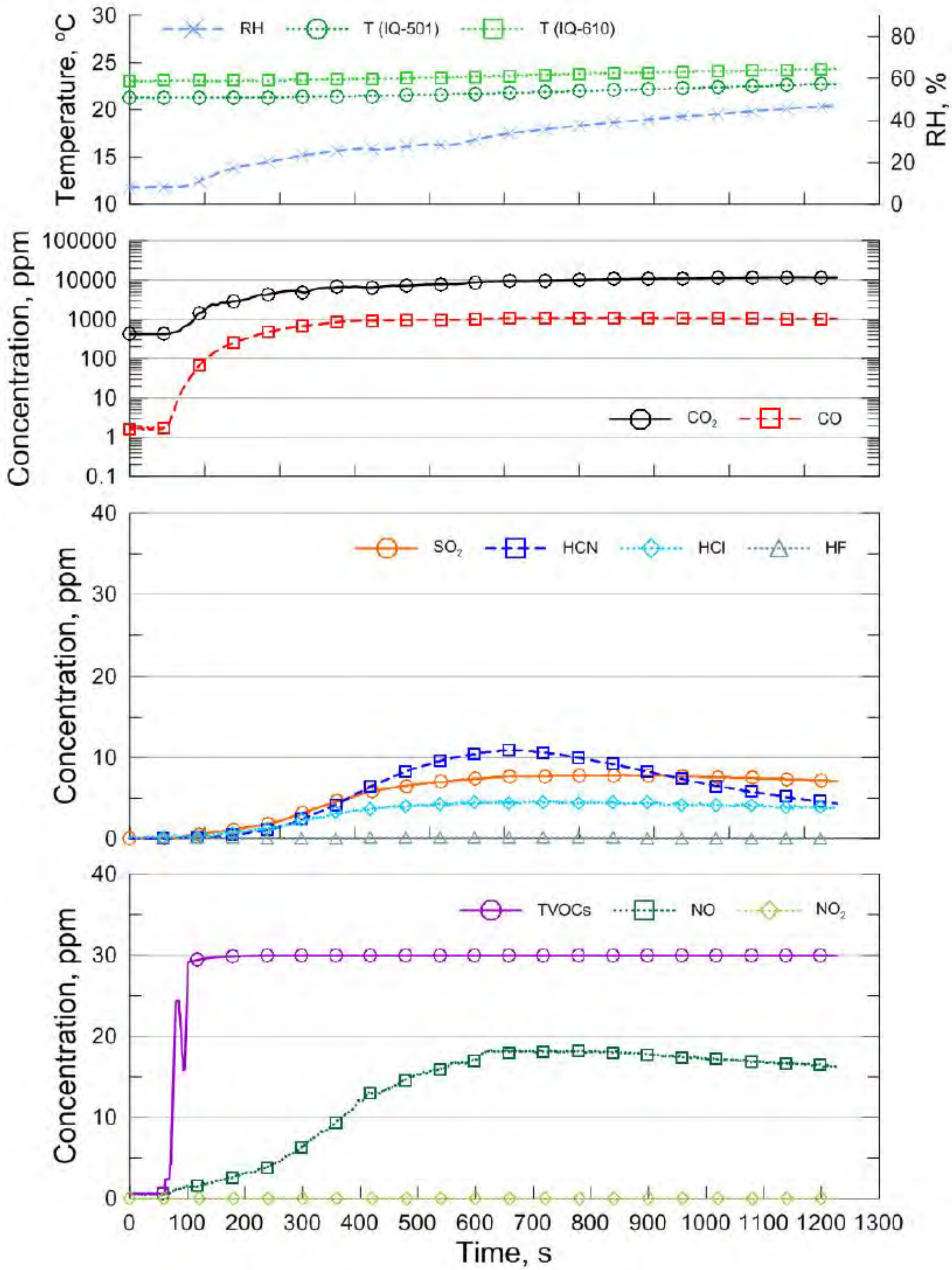

Figure 25. Gas Species Concentrations- White Pine Test WETS160201c.

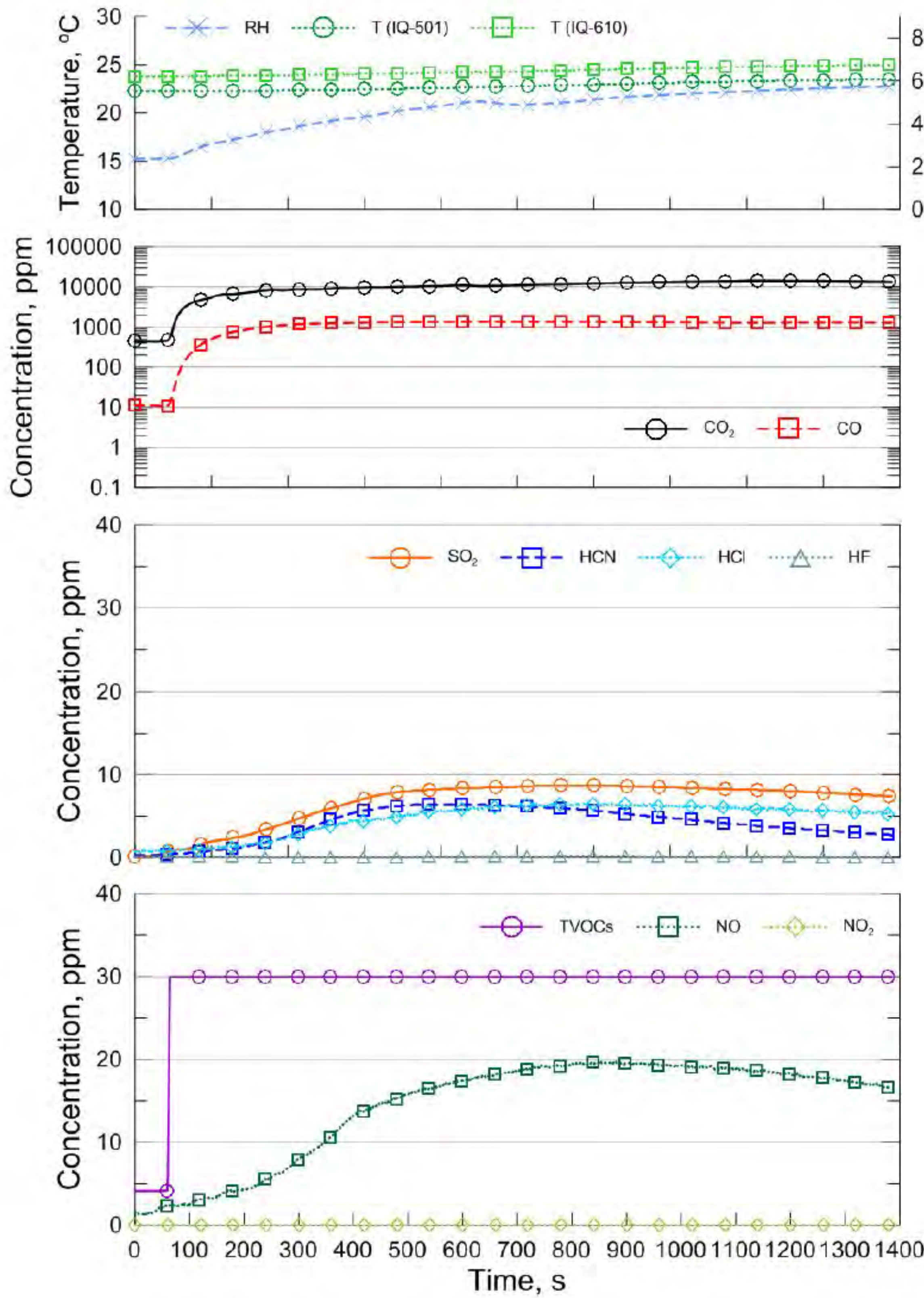

Figure 26. Gas Species Concentrations- White Pine/Gypsum/Pine Wood/PVC Test WETS160201d.

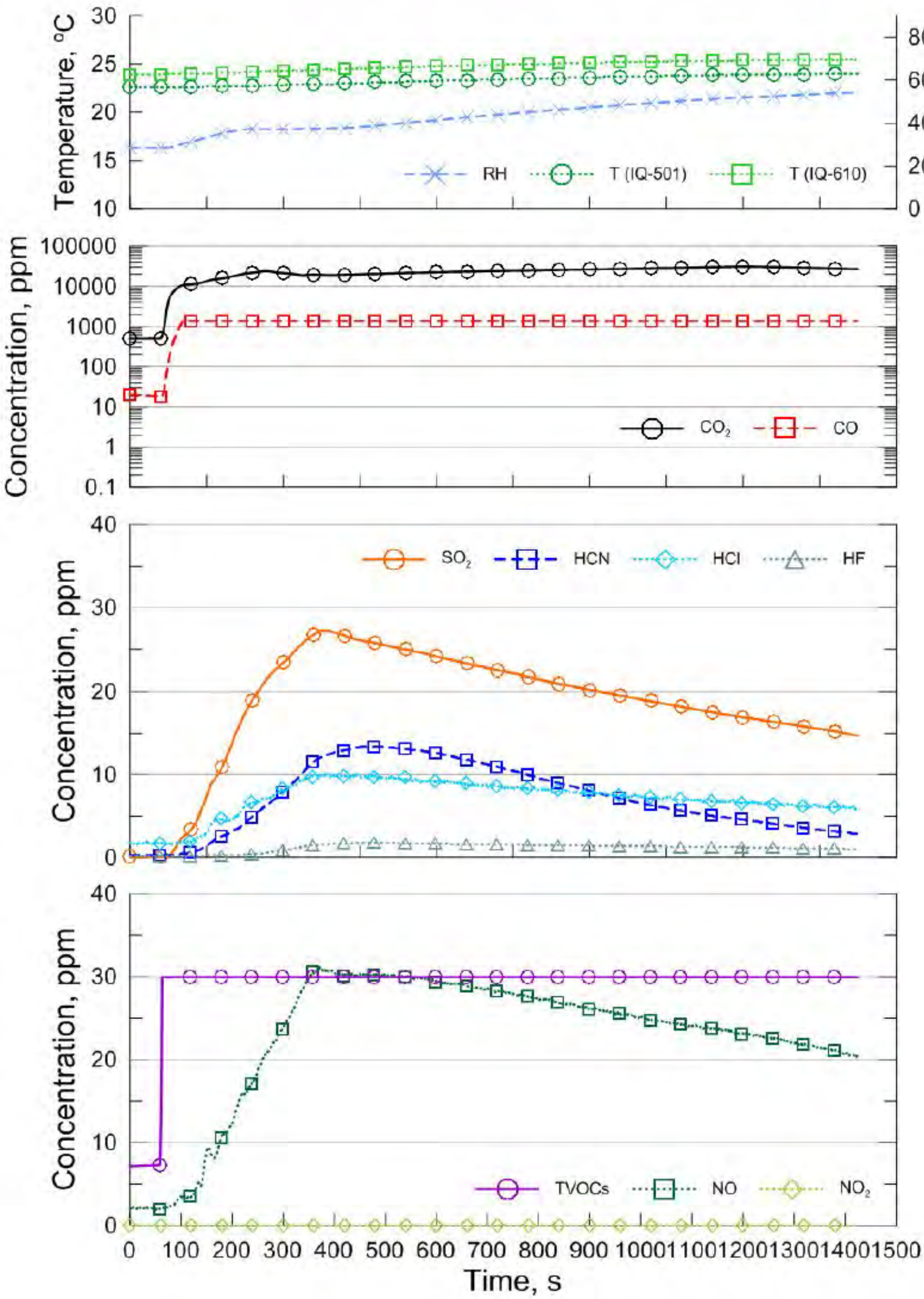

Figure 27. Gas Species Concentrations- Gypsum/Pine Wood/PVC Test WETS160201e.

APPENDIX C

Concentrations of Benzene and PAHs on sorbent tube samples collected during laboratory test burns of vegetation and WUI materials.

Benzene Concentration – Coconut Charcoal Sorbent Tube

Sample	Sample Volume L	Sample Time s	Concentration		Reportable Limit mg/m3	Notes
			mg/m3	ppm		
White Pine WETS160201b	4.49	1348	8.7	2.7	0.22	
White Pine WETS160201c	3.95	1186	12	3.9	0.25	
Ponderosa Pine WETS160115f	3.86	1159	14.0	4.4	0.002	
California Cedar WETS160128c	4.51	1353	4.2	1.3	0.002	
California Cedar/Gypsum/Wood WETS160129b	3.15	944	16.5	5.2	0.002	
White Pine/Gypsum/Wood/PVC WETS160201d	4.58	1374	16	5.1	0.22	
Gypsum/Wood/PVC WETS160201e	4.58	1374	120	38	2.2	Benzene on Backup Sorbent Section - Possible break through
California Cedar/Gypsum/Wood/PVC WETS160129c	3.88	1164	20	6.2	0.26	
Air Blank	3.79	1136	0.79	0.2	0.002	
Burner Blank	3.87	1162	0.52	0.2	0.002	

PAH Concentration - California Cedar/Gypsum/Pine/PVC

Sample	Sample Volume L	Sample Time s	Sample Flow l/m			
California Cedar/Gypsum/Pine/PVC WETS160129c	29.13	1164	1.5			
	Glass Fiber Filter		XAD-2 Sorbent Tube		Reportable Limit (RL)	
	µg/m^3	ppm	µg/m^3	ppm	µg/m^3	ppm
Acenaphthene	< RL	< RL	< RL	< RL	860	0.16
Acenaphthylene	< RL	< RL	< RL	< RL	860	0.14
Anthracene	< RL	< RL	< RL	< RL	860	0.12
Benz[a]anthracene	< RL	< RL	< RL	< RL	860	0.092
Benz[a]pyrene	< RL	< RL	< RL	< RL	860	0.083
Benzo[b]flouranthene	< RL	< RL	< RL	< RL	860	0.083
Benzo[ghi]perylene	< RL	< RL	< RL	< RL	860	0.076
Benzo[k]fluoranthene	< RL	< RL	< RL	< RL	860	0.083
Chrysene	< RL	< RL	< RL	< RL	860	0.092
Dibenz[a,h,j]anthracene	< RL	< RL	< RL	< RL	860	0.075
Fluoranthene	< RL	< RL	< RL	< RL	860	0.10
Fluorene	< RL	< RL	< RL	< RL	860	0.13
Indeno[1,2,3-cd]pyrene	< RL	< RL	< RL	< RL	860	0.076
Napthalene	< RL	< RL	< RL	< RL	860	0.16
Phenanthrene	< RL	< RL	< RL	< RL	860	0.12
Pyrene	< RL	< RL	< RL	< RL	860	0.10

PAH Concentrations – White Pine

Sample	Sample Volume L	Sample Time s	Sample Flow l/m			
White Pine WETS160201b	33.83	1353	1.5			
	Glass Fiber Filter		XAD-2 Sorbent Tube		Reportable Limit (RL)	
	$\mu g/m^3$	ppm	$\mu g/m^3$	ppm	$\mu g/m^3$	ppm
Acenaphthene	< RL	< RL	< RL	< RL	740	0.14
Acenaphthylene	< RL	< RL	< RL	< RL	740	0.12
Anthracene	< RL	< RL	< RL	< RL	740	0.10
Benz[a]anthracene	< RL	< RL	< RL	< RL	740	0.079
Benz[a]pyrene	< RL	< RL	< RL	< RL	740	0.072
Benzo[b]flouranthene	< RL	< RL	< RL	< RL	740	0.072
Benzo[ghi]perylene	< RL	< RL	< RL	< RL	740	0.065
Benzo[k]fluoranthene	< RL	< RL	< RL	< RL	740	0.072
Chrysene	< RL	< RL	< RL	< RL	740	0.079
Dibenz[a,h,j]anthracene	< RL	< RL	< RL	< RL	740	0.065
Fluoranthene	< RL	< RL	< RL	< RL	740	0.089
Fluorene	< RL	< RL	< RL	< RL	740	0.11
Indeno[1,2,3-cd]pyrene	< RL	< RL	< RL	< RL	740	0.065
Napthalene	< RL	< RL	< RL	< RL	740	0.14
Phenanthrene	< RL	< RL	< RL	< RL	740	0.10
Pyrene	< RL	< RL	< RL	< RL	740	0.089

PAH Concentrations – White Pine

Sample	Sample Volume L	Sample Time s	Sample Flow l/m			
White Pine WETS160201c	29.63	1185	1.5			
	Glass Fiber Filter		XAD-2 Sorbent Tube		Reportable Limit (RL)	
	µg/m^3	ppm	µg/m^3	ppm	µg/m^3	ppm
Acenaphthene	< RL	< RL	< RL	< RL	840	0.16
Acenaphthylene	< RL	< RL	< RL	< RL	840	0.14
Anthracene	< RL	< RL	< RL	< RL	840	0.12
Benz[a]anthracene	< RL	< RL	< RL	< RL	840	0.090
Benz[a]pyrene	< RL	< RL	< RL	< RL	840	0.082
Benzo[b]flouranthene	< RL	< RL	< RL	< RL	840	0.082
Benzo[ghi]perylene	< RL	< RL	< RL	< RL	840	0.075
Benzo[k]fluoranthene	< RL	< RL	< RL	< RL	840	0.082
Chrysene	< RL	< RL	< RL	< RL	840	0.090
Dibenz[a,h,j]anthracene	< RL	< RL	< RL	< RL	840	0.074
Fluoranthene	< RL	< RL	< RL	< RL	840	0.10
Fluorene	< RL	< RL	< RL	< RL	840	0.12
Indeno[1,2,3-cd]pyrene	< RL	< RL	< RL	< RL	840	0.075
Napthalene	< RL	< RL	< RL	< RL	840	0.16
Phenanthrene	< RL	< RL	< RL	< RL	840	0.12
Pyrene	< RL	< RL	< RL	< RL	840	0.10

PAH Concentrations - White Pine/Gypsum/Wood/PVC

Sample	Sample Volume L	Sample Time s	Sample Flow l/m			
White Pine/Gypsum/Wood/PVC WETS160201d	34.35	1374	1.5			
	Glass Fiber Filter		XAD-2 Sorbent Tube		Reportable Limit (RL)	
	µg/m^3	ppm	µg/m^3	ppm	µg/m^3	ppm
Acenaphthene	< RL	< RL	< RL	< RL	730	0.14
Acenaphthylene	< RL	< RL	< RL	< RL	730	0.12
Anthracene	< RL	< RL	< RL	< RL	730	0.10
Benz[a]anthracene	< RL	< RL	< RL	< RL	730	0.078
Benz[a]pyrene	< RL	< RL	< RL	< RL	730	0.071
Benzo[b]flouranthene	< RL	< RL	< RL	< RL	730	0.071
Benzo[ghi]perylene	< RL	< RL	< RL	< RL	730	0.064
Benzo[k]fluoranthene	< RL	< RL	< RL	< RL	730	0.071
Chrysene	< RL	< RL	< RL	< RL	730	0.078
Dibenz[a,h,j]anthracene	< RL	< RL	< RL	< RL	730	0.064
Fluoranthene	< RL	< RL	< RL	< RL	730	0.088
Fluorene	< RL	< RL	< RL	< RL	730	0.11
Indeno[1,2,3-cd]pyrene	< RL	< RL	< RL	< RL	730	0.064
Napthalene	< RL	< RL	< RL	< RL	730	0.14
Phenanthrene	1500	0.20	< RL	< RL	730	0.10
Pyrene	< RL	< RL	< RL	< RL	730	0.088

PAH Concentrations - Gypsum/Wood/PVC

Sample	Sample Volume L	Sample Time s	Sample Flow l/m			
Gypsum/Wood/PVC WETS160201e	34.38	1375	1.5			
	Glass Fiber Filter		XAD-2 Sorbent Tube		Reportable Limit (RL)	
	μg/m^3	ppm	μg/m^3	ppm	μg/m^3	ppm
Acenaphthene	< RL	< RL	< RL	< RL	730	0.14
Acenaphthylene	3500	0.56	< RL	< RL	730	0.12
Anthracene	1500	0.21	< RL	< RL	730	0.10
Benz[a]anthracene	1400	0.15	< RL	< RL	730	0.078
Benz[a]pyrene	< RL	< RL	< RL	< RL	730	0.071
Benzo[b]flouranthene	960	0.093	< RL	< RL	730	0.071
Benzo[ghi]perylene	< RL	< RL	< RL	< RL	730	0.064
Benzo[k]fluoranthene	990	0.096	< RL	< RL	730	0.071
Chrysene	1400	0.15	< RL	< RL	730	0.078
Dibenz[a,h,j]anthracene	< RL	< RL	< RL	< RL	730	0.064
Fluoranthene	3200	0.39	< RL	< RL	730	0.088
Fluorene	2000	0.30	< RL	< RL	730	0.11
Indeno[1,2,3-cd]pyrene	< RL	< RL	< RL	< RL	730	0.064
Napthalene	1900	0.76	7300	1.4	730	0.14
Phenanthrene	5500	20	< RL	< RL	730	0.10
Pyrene	2300	0.28	< RL	< RL	730	0.088

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WILDLAND FIREFIGHTER EXPOSURE STUDY:

EVALUATING CORE TEMPERATURE, HEART RATE & HYDRATION

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Abstract

The Wildfire Research Center at San Diego State University and the Wildfire Program at California State University San Marcos worked in partnership with the United States Department of Agriculture-Forest Service, CAL FIRE, and CAL FIRE Local 2881 to evaluate the physiological and working conditions of wildland firefighters between 2012 and 2015.

Conditions dictate that wildland firefighters are often required to work for extended periods in intense heat and brutal environmental conditions. This study will delineate how the regular duties and environmental conditions experienced by wildland firefighters influence key physiological factors including heart rate, respiratory rate, core body temperature, and hydration. Ninety-five CAL FIRE wildland firefighters participated in this study, including personnel at training events, controlled burns, and actual wildland fires. The results reveal that wildland firefighters regularly exceeded safe physiological conditions while performing their duties (regardless of the event type). Nearly 65% of the firefighters had sustained peak heart rates above 200 beats per minute (bpm), while nearly 20% exceeded 220bpm. Virtually every firefighter regularly exceeded the recommended maximum heart rate for work (220bpm minus age). Likewise, measured core body temperatures exceeded 102°F in roughly 70% of the firefighters, with 10% exceeding 103°F. Furthermore, nearly two-thirds of the firefighters started their shifts at or near a level of dehydration. Regardless of their starting status, dehydration rates significantly increased by the end of their duty, with only 25% of the firefighters (that started off at or near dehydration) self-correcting and becoming more hydrated by the end of the shift. Finally, the type of personal protective equipment (PPE) worn by wildland firefighters has a significant influence on their overall physiology. The results suggest that the traditional double-layer PPE produces significantly higher core body temperatures, higher incidence of dehydration, and higher heart rates than single-layer PPE.

1.0 Introduction

Awareness of wildfires as an issue may avoid worldwide focus, but has never been greater in our country's history than now. What were once considered issues of the West are nationally recognized as an increasing threat to all of our communities and ecosystems. As our population continues to grow, decisions on developing and managing the wildland urban interface (WUI) determines our vulnerability and the risks imposed on our firefighters and communities. Given the complexity of land use and natural areas, many firefighters will, at some point in their career, respond to a fire in the wildland and WUI. In the conterminous U.S., the WUI covers approximately 277,668 square miles and has over 45 million housing units.[1] Much of this area is adjacent to the vast areas of federal lands managed by the U.S. Forest Service, Bureau of Land Management, and National Park Service, as well as various state parks, reserves, and open space. The WUI is a modern phenomenon that has become a persistent and permanent presence in the eastern U.S., reaching a maximum of 72% of land area in Connecticut. California, not surprisingly, has the highest number of WUI housing units of any state (5.1 million).

Predictably, as human interaction with our wild areas takes root, we've witnessed an increase in the incidence of fires. On closer inspection the statistics become staggering. Since the 1970s, our nation has endured an increase from an average of three million to an overwhelming seven million acres burned each year – with further increases projected.[2] 2015 was distinguished as the single highest acreage count on record, with over 10 million acres burned in wildland and WUI fires.[3] In California, only about 4% of wildfires are natural events, meaning that well over 95% of our wildfires are the result of human activity.[4] The building and the burning has made the term 'wildland fire' a bit of a misnomer. Large wildfires frequently threaten homes, businesses, and lives, shifting the focus to the urban interface. Further exacerbating the situation, a new paradigm is emerging: we are witnessing a dramatic shift in the frequency and intensity of wild fires due to a variety of factors, again most of which are human-caused.

Recent research suggests that the fire season is much longer than historically observed.[5] In an analysis of the western United States, the numbers and intensity of wildfires have significantly increased since the mid-1980s. Shifting climatic conditions and land use change have combined to produce more frequent wild fires while also increasing the overall annual wildfire season.[6] Even more disconcerting is that recent research suggests that regional temperatures in places like California may increase from 1.7 C to 5.8 C by 2100, depending on the climate model used and the emissions scenarios assumed.[7] If these trends continue, and the concomitant problems associated with drought and climate change suggest the trend is inexorable, it is conservatively predicted that large fires (defined as 500 acres or more) will increase nearly 35% by 2050 and an

1 Radeloff, V., R. Hammer, S. Stewart, J. Fried, S. Holcomb, and J. McKeefry. 2005. The Wildland-Urban Interface in the United States. Ecological Applications 15:799-805.

2 Headwater-Economics. 2011. U.S. Communities Dealing with WUI Fire Fact Sheet. (ICC) 1.1.2011.

3 National Interagency Fire Center. 2016. https://www.nifc.gov/fireInfo/fireInfo_stats_totalFires.html (last accessed 6/10/16)

4 Rahn, M. 2009. Wildfire Impact Analysis: 2003 Wildfires in Retrospect. http:// re.sdsu.edu. San Diego State University. Wildfire Research Report No. 1. Montezuma Press. San Diego, CA.

5 Running, S.W. 2006. Is Global Warming Causing More, Larger Wildfires? Science 313: 927-928.

6 Westerling, A., H. Hidalgo, D. Cayan, and T. Swetnam. 2006. Warming and Earlier Spring Increase Western U.S. Forest Wildfire Activity. Science 940.

7 D. Cayan, A. L. Luers, M. Hanemann, G. Franco, and B. Croes, Scenario of Climate Change in California: Overview. CEC-500-2005-186-SF (2006).

alarming 55% by the end of this century.[8] Future decisions on development and management of the WUI are critical in determining future vulnerability and risks.

The more we gather data the portrait for firefighters darkens. These changing conditions have a direct and negative impact on firefighter exposure as the frequency of high or extreme fire-risk days increases. What this means for the "traditional" concept of wildland firefighting is that the regularity, intensity, and complexity of wildland firefighting is increasing, resulting in associated increases in the risks to firefighters responding to these incidents. The ability to effectively combat wildfires is inextricably linked to firefighter health and safety.

The firefighters response to a wildland or WUI fire, demands strenuous physical work over rugged terrain, often in hot, dry, smokey conditions. Incidents can last hours or weeks, usually requiring consecutive working days and shifts of up to 24 hours long.[9,10,11] While the general impression of wildland firefighting is that the firefighters are working in near constant presence of actual fire, in many incidents a majority of tasks performed during wildfire suppression occur away from the fire or after the fire has been put out (e.g. mop-up). Consequently, it is vital that we understand the physiological conditions of firefighters across a diversity of duties and tasks, and across a range of environmental conditions.

Even a cursory glance forces us to appreciate that the physical demands of wildland firefighting are executed while wearing personal protective equipment (PPE). This can create a highly insulating environment, in addition to individuals carrying an additional 10- to 20-kg (or more) of food, water, safety gear, and equipment. This combination of exertion, psychological stress, weighted personal equipment and hostile environmental conditions creates a demanding work environment that can affect nearly every system of the body. As a result, wildland firefighters

8 Westerling, et al. 2006.

9 Aisbett, B., A. Wolkow, M. Sprajcer, and S. Ferguson. 2012. Awake, Smoky, and Hot: Providing an Evidence-base for Managing the Risks Associated with Occupational Stressors Encountered by Wildland Firefighters. Applied Ergonomics 43: 916–925.

10 Rodríguez-Marroyo J., J. Villa, J. López-Satue, R. Pernía, B. Carballo, J. García-López, et al. 2011. Physical and Thermal Strain of Firefighters According to the Firefighting Tactics Used to Suppress Wildfires. Ergonomics 54: 1101–1108.

11 Cater H., D. Clancy, K. Duffy, A. Holgate, B. Wilison, and J. Wood. 2007. Fatigue on the Fireground: The DPI Experience. Hobart, Australia.

experience the limits of what the human body was meant to endure. Repeated exposure to these conditions can lead to injuries, long-term health effects, and increased morbidity and mortality.

Unfortunately, the majority of the research describing the effects of firefighting have investigated relatively short bouts of activity, or simulated events in controlled or simulated environments. This stands in stark contrast to the often long hours worked on extended attack incidents with chaotic and diverse environmental conditions. These studies certainly provide valuable information about relationships between the working environment and the effects on the human body, but it is likely that the results obtained under these controlled conditions are not necessarily analogous to actual working conditions. They may in fact underestimate the physiological stresses that occur during an actual incident. What is more concerning is that a vast majority of the work on firefighter health and safety tends to focus on urban, structure, and high-rise incidents. As a result, experts in the industry generally agree that wildland firefighting is, in many respects, at least a generation behind with regard to fundamental research and understanding health effects.[12]

The magnitude of physiological strain, cardiovascular impact, and thermal stress experienced by a wildland firefighter are the result of diverse and complex variables including environmental (e.g. work performed, duration, protective equipment, and ambient environmental conditions) and personal factors (e.g. individual characteristics, hydration, physical fitness, and health condition). This project was designed to improve our understanding and provide recommendations to improve the health and safety for those working on wildland and WUI fires.

1.1 Core Body Temperature

Thousands of occupational heat related illnesses (HRI) are documented annually, and hundreds of duty-related civilian causalities that result from environmental heat exposure.[13] In 1986, the National Institute for Occupational Safety and Health (NIOSH) estimated that roughly 5 to 10 million workers in the U.S. experience excessively hot working conditions that may impact health and safety.[14] Higher temperature working conditions and thermal loading of an individual is not only physically dangerous, it also decreases an individual's productivity, decreases their ability to perform tasks, and can lead to a higher incidence of injury.[15,16,17] Once on notice policymakers recognize staffing and liability concerns. This is of particular importance to wildland firefighting

12 Rahn, M. and T. McHale. 2015. A Comprehensive View on the Future of Fighting Wildfires by a Team of Experts. CAL FIRE Local 2881 Symposium. Sacramento, CA.
13 Bureau of Labor Statistics. Last accessed: May 14, 2016. Injuries, Illnesses, and Fatalities databases. 2014 Available at: http://www.bls.gov/iif/
14 National Institutes for Occupational Safety and Health (NIOSH). 1986. Criteria for a recommended standard…Occupational Exposure to Hot Environments Revised Criteria 1986. U.S. Department of Health and Human Services, Public Health Service, Centers for Disease Control, NIOSH, and Division of Standards Development and Technology Transfer. Full report available at: www.cdc.gov/niosh/docs/86-113/86-113.pdf.
15 Lin, R. and C. Chan. 2009. Effects of Heat on Workers' Health and Productivity in Taiwan. Glob Health Action. doi: 10.3402/gha.v2i0.2024.
16 Ramsey, J. 1995. Task Performance in Heat: a Review. Ergonomics. 38(1):154–65.
17 Park, E., K. Hannaford-Turner, and H. Lee. 2009. Use of Personal Protective Equipment in Agricultural Workers Under Hot and Humid Conditions. Ind Health. 47(2):200–1.

given the complex and hazardous working environment that regularly requires rapid response and decision-making.

Studies addressing HRI often focus on physical exertion; those working in an outdoor environment are at particularly high risk, especially for those jobs that require significant exertion and/or endurance.[18] Seasonal wildland firefighters, short duration employees, and those in the early stages of their training (e.g. military) are identified as a relatively susceptible population for HRI.[19,20] Studies on heat exposure have been a key priority for the military since the 1950's when guidelines at training facilities were established to help reduce heat causalities.[21] Additional research with the military also identified that heat stroke is more commonly associated with overweight individuals, and often occurs (regardless of fitness level) within the first two hours of activity.[22] This basic research has helped us understand the human response to stressful working environments. The bad news is that a singular focus and body of literature on wildland and WUI firefighters is lacking. This is unacceptable given the modern dynamic of wildland firefighting.

What we do know, is that the onset of heat stress occurs when a person has either been overexposed to high thermal conditions or has exerted themselves beyond a safe level for the existing thermal environment.[23] This is unfortunately a common scenario for most wildland firefighters.[24] It is well documented that the use of PPE can exacerbate the risk of HRI, even when the subject is operating in conditions that are not considered particularly hot.[25] Studies on firefighters found that PPE profoundly influenced an increase in HRI, with incidence of injury occurring at significantly lower ambient temperatures when compared with the general civilian workforce (~79°F versus ~89°F respectively).[26] Further confounding the situation, dehydration can significantly influence HRI, even in individuals that are generally physically fit and acclimated to the heat.[27] Suitable understanding of the relationships between heat related illnesses and the implications for wildland/WUI firefighters remains limited.

1.2 Heart Rate

Take a moment to consider that heart or cardiovascular disease accounts for almost half of all duty-related fatalities among U.S. firefighters.[28,29] Additionally, it is estimated that for every heart-related fatality, there are an estimated seventeen non-fatal, line-of-duty cardiovascular disease events that occur in the U.S. fire service.[30] The number of cardiac events has been relatively stable since 2005.[31] Many of these fatalities are related to sudden cardiac death during fire

18 Nelson, N., C. Collins, R. Comstock, and L. McKenzie. 2011. Exertional Heat-Related Injuries Treated in Emergency Departments in the U.S., 1997–2006. Am J Prev Med. 40(1):54–60.
19 Maeda, T., S. Kaneko, M. Ohta, K. Tanaka, A. Sasaki, and T. Fukushima. 2006. Risk Factors for Heatstroke Among Japanese Forestry Workers. J Occup Health. 48(4):223–9.
20 Epstein, Y., D. Moran, Y. Shapiro, E. Sohar, and J. Shemer. 1993. Exertional heat stroke: a case series. Med Sci Sports Exerc. 31(2):224–8.
21 Minard, D., H. Belding, and J. Kingston. 1957. Prevention of heat casualties. J Am Med Assoc. 165(14):1813–8.
22 Esptein et al. 1999.
23 National Oceanic and Atmospheric Administration (NOAA). 2005. Heat wave: a major summer killer. Last Accessed 5/10/2016.: www.nws.noaa.gov/om/brochures/heat_wave.shtml
24 Rodríguez-Marroyo et al. 2001.
25 Crockford, G. 1999. Protective Clothing and Heat Stress: Introduction. Ann Occup Hyg. 43(5):287–8.
26 Bonauto, D., E. Rauser, and L. Lim. 2010. Occupational Heat Illness in Washington State, 2000–2009. Washington State Department of Labor & Statistics. Technical Report Number 59-2-2010.
27 Ekbom, B., J. Greenleaf, and L. Hermansen. 1970. Temperature Regulation During Exercise Dehydration in Man. Acta Physiol Scand. 79:475–483.
28 Fahy, R., R. LeBlanc, and J. Molis. 2009. Firefighter Fatalities in the United States – 2008. Quincy, MA: National Fire Protection Association.
29 Kales, S., E. Soteriades, C. Christophi, et al. 2007. Emergency duties and deaths from heart disease among firefighters in the United States. N Engl J Med. 356:1207–1215.
30 Karter M. and J. Molis. 2005. Firefighter Injuries. National Fire Protection Association. Quincy, MA.
31 Fahy, R. 2010. U.S. Fire Service Fatalities in Structure Fires, 1977-2009. NFPA.

ground activities and when responding to, or returning from fires.[32,33]

In an investigation of on-duty cardiac-related fatalities, NIOSH reports "*Firefighting activities are strenuous and often require firefighters to work at near maximal heart rates for long periods. The increase in heart rate has been shown to begin with responding to the initial alarm and to persist through the course of fire suppression activities.*"[34] Additional studies suggest that the risk of dying from coronary heart disease (and related factors) is 10 to 100 times higher during firefighting activities than during non-emergency fire department duties.[35]

Studies within the fire services have documented that typical duties and training activities can often result in near maximal heart rates that are often reached early and maintained for prolonged periods after peak activities. These rigorous duties can trigger heart events in firefighters, especially those with existing or undiagnosed heart problems.[36,37,38] Researchers at the University of Illinois conducted a structure fire study, observing that it was not uncommon for firefighters to reach nearly 190 beats per minute (reaching age-predicted maximal heart rates).[39] Similar studies have documented analogous results during training and active fire scenarios,[40,41,42] while other studies found less than maximal heart rates during firefighter training events.[43]

A paucity of research specific to wildland and WUI firefighting, especially in the areas of cumulative effects and extended duty is unfortunate and likely consequential. One of the limitations of existing studies is that they focus on structure fire incidents that typically have limited durations of less than an hour. Further, some studies that collected real-time data have screeched to a halt once physiological parameters reached advanced levels (e.g. high core temperatures or heart rates). While the safety of the participant is obviously of paramount concern, halting these studies limits insight into actual fire scenarios and the wildland firefighter, where individuals often work for extended periods of time under extreme conditions.

32 Fahy, R. P. LeBlanc, and J. Molis. 2007. What's Changed Over the Past 30 Years? NFPA.
33 Fahy, R. 2005. U.S. Firefighter Fatalities Due to Sudden Cardiac Death. NFPA.
34 NIOSH. 2004. Report Number FACE-F2004-46. http://www.cdc.gov/niosh/face200446.html.
35 Kales, S. E. Soteriades, C. Christophi, and D. Christiani. 2007. Emergency Duties and Deaths from Heart Disease among Firefighters in the United States. New England Journal of Medicine 356(12): 1207-1215.
36 Kales SN, Soteriades ES, Christoudias SG, et al. 2003. Firefighters and on-duty deaths from coronary heart disease: a case control study. Environ Health. 2003; 2:14.
37 Holder, J., L. Stallings, L. Peeples, et al. 2006. Firefighter Heart Presumption Retirements in Massachusetts 1997–2004. J Occup Environ Med. 48:1047–1053.
38 Kales, S., E. Soteriades, C. Christophi, et al. 2007. Emergency Duties and Deaths from Heart Disease Among Firefighters in the United States. N Engl J Med. 356:1207–1215.
39 Smith, D., T. Manning, and S. Petruzzello. 2001. Effect of Strenuous Live-Fire Drills on Cardiovascular and Psychological Responses of Recruit Firefighters. Ergonomics. 44(3): 244-254.
40 Manning, J. and T. Griggs. 1983. Heart Rates in FIre Fighters Using Light and Heavy Breathing Equipment: Similar Near-Maximal Exertion in Response to Multiple Work Load Conditions. Journal of Occupational Medicine. 25(3): 215–218.
41 Duncan, H., G. Gardner, and R. Barnard. 1979. Physiological Responses of Men Working in Fire Fighting Equipment in the Heat. Ergonomics. 22(5): 521-527.
42 Sothmann, M., K. Saupe, D. Jasenof, and J. Blaney, 1992. Heart Rate Response of Fire Fighters to Actual Emergencies: Implications for Cardiorespiratory Fitness. Journal of Occupational Medicine. 34(8): 797-800.
43 Romet, T. and J. Frim. 1987. Physiological Responses to Fire Fighting Activities. Eur J Appl Physiol Occup Physiol. 56(6):633-8.

1.3 Hydration

It is well documented as well as common sense that maintaining healthy levels of hydration is critical to the safety and performance of an individual. Despite the fact that the National Fire Protection Agency (NFPA) has promulgated multiple standards that address hydration, there is a general lack of guidance on how to effectively monitor and maintain healthy levels of hydration, especially during prolonged wildfire incidents where firefighters are exposed to extreme environmental conditions. Although several studies (discussed in Section 4.3) address the methods of hydration, exhaustive protocols do not currently exist and ad libitum hydration seems to dominate the recommended strategies.

The impact to our wildland firefighters is real. Sports medicine research has demonstrated that a loss of fluids (and even minor losses in body mass) is correlated with a decrease in physical ability, concentration, alertness, and performance.[44,45,46] The cumulative effects from excessive heart rates, environmental exposures, and excessive core body temperatures is of genuine concern for wildland and WUI firefighting. It is estimated that the average 200 pound structure firefighter can lose two percent of their body mass within 30 to 60 minutes (depending on work intensity and environmental conditions), causing significant physiological issues.[47] It is not clear however, how extended duty, high levels of activity, and excessive temperatures influence the mental or physiological capabilities of wildland firefighters. Using a sports metaphor, we better understand the sprinter, yet find the marathoner a mystery.

1.4 Personal Protective Equipment (PPE)

Personal protective equipment (PPE) is necessary to protect firefighters from burn and inhalation injuries. That is the good news. The most immediate problem is that the PPE adds to the weight of an already burdened firefighter, adding friction and unwanted heat generation with fabrics that interfere with the body's natural thermoregulation processes (sweating and evaporation). Heat dissipation is significantly impaired by PPE, largely due to the encapsulation of the individual.[48] This can add strain on an individual's respiratory and cardiovascular system. Past studies demonstrate that simply wearing structure PPE (and SCBA) while walking can heighten core temperature and heart rates. The type of PPE (e.g. fully encapsulating versus lesser PPE) can also affect physiological response to work, depending on the level of insulation produced.[49]

FEMA training guidelines recommend that structural firefighters wear lighter weight PPE and limit their turnout use to very short durations to minimize heat stress injuries.[50] No such option exists for the wildland firefighter. It is recognized that the typical urban or structural firefighting

44 Rodrigues, R., B. Baroni, M. Pompermayer, et al. 2014. Effects of Acute Dehydration on Neuromuscular Responses of Exercised and Nonexercised Muscles After Exercise in the Heat. J Strength Cond Res. 28:3531–3536.
45 Maughan, R. 2003. Impact of Mild Dehydration on Wellness and on Exercise Performance. Eur J Clin Nutr. 57: Suppl 2, S19–S23.
46 Pompermayer, M., R. Rodrigues, B. Baroni, et al. 2014. Rehydration During Exercise in the Heat Reduces Physiological Strain Index in Healthy Adults. Rev Bras Cineantropom Desempenho Hum. 16:629637.
47 McEvoy, M. and D. Rhodes. 2015. Hydration and Firefighter Performance. Fire Engineering. 168(4).
48 Smith, D., G. Horn, E. Goldstein, S. Petruzzello, et al. 2008. Firefighter Fatalities and Injuries: The Role of Heat Stress and PPE. Firefighter Life Safety Research Center, Illinois Fire Service Institute. University of Illinois and Urbana-Champaign.
49 Smith, D., S. Petruzzello, J. Kramer, S. Warner, B. Bone, and J. Misner. 1995. Selected Physiological and Psycho-Biological Responses to Physical Activity in Different Configurations of Firefighting Gear. Ergonomics. 38(10): 2065-2077.
50 FEMA. 2002. Introduction to Wildland/Urban Interface Firefighting for the Structural Company Officer. Training Manual, 2002.

companies are more frequently responding to wildland and WUI fires.[51] Unfortunately, many of these companies do not have the resources to carry the lighter weight PPE specifically for WUI firefighting. Understanding the effect PPE has on firefighters, and having flexible, configurable, and adaptive PPE is becoming more important as the incidents of wildland and WUI fires increases across the U.S.

1.5 Goals and Objectives

The goal of our study is to understand the relationship between the wildland and WUI working environment and firefighter health and safety. We will identify areas where tactics, equipment, protocols, or policy can be amended to improve the health and safety of our wildland firefighters. Our aim is to understand the relationship between diverse environmental factors, core body temperature, heat exposure, heart rate, respiration rate, activity, dehydration, and PPE.

2.0 Methods

Our research team was embedded with CAL FIRE and had real-world access to trainings, controlled burns, and actual wildfire incidents to collect data on environmental factors and firefighter physiology. We assessed firefighters while they were actually conducting training activities that generally occurred on extended hoselays of 2,000 feet, controlled burns (of both grasslands and mixed shrub), and on actual wildfire incidents. A primary objective was to ensure that we had no operational impact on wildfire incidents, underscoring that data collection would occur as a byproduct of normal activities. Another objective was to collect data across a diverse cross section of CAL FIRE firefighters with regard to gender, age, experience, and physical condition. We were technically constrained by the additional requirement that we work only with individuals who were willing to volunteer to participate in the experiment. This did not prove to be inhibiting since so many were willing to step forward that candidates were then selected based on a random draw of those firefighters available for each day of the experiment.

A biological use authorization approval was provided through

51 Rahn and McHale, 2015.

San Diego State University by the Institutional Biosafety Committee and Institutional Review Board (IRB) in accordance with 45 CFR 46 and 21 CFR 50. All subjects included in the study were on-duty CAL FIRE firefighters who voluntarily signed a comprehensive research consent form (approved by the IRB). During all phases of the research involving firefighters, the highest level of care and concern was given to the safety and health of the participants. All information collected was protected to ensure the privacy of study participants per human subject protocol requirements. Firefighters involved in the study were identified only by a unique number rather than by name.

This study was designed to be consistent with the methods being used by the U.S. Forest Service in related studies on firefighter exposure. A key goal is that meaningful comparisons can be made. Variables were monitored every second and included: heart rate, respiratory rate, skin temperature, and core body temperature. The BioHarness™ (designed by Zyphr Technology) was used to monitor heart rate, activity, and respiratory rate. This device is generally regarded as a robust and reliable field-based tool for measuring these factors,[52] including use by firefighters during duty and in hot environments.[53,54]

Maximum heart rate for each individual was estimated using the formula HRmax = 220bpm – age,[55] and was calculated based on data collected by the BioHarness. The BioHarness provides a quantifiable measure of activity through use of a tri-axial accelerometer and piezoelectric technology. This estimate of activity, measured in vector magnitude units by the BioHarness, is considered a reliable metric for monitoring personal activity and exertion.[56]

Core body temperature (T_c) was recorded every ten seconds using a CorTemp® Ingestible Core Body Temperature Sensor (designed by HQInc.) that wirelessly transmits core body temperature as it travels through the digestive tract. The sensor's signal passes harmlessly through the body to the CorTemp Data Recorder worn on the outside of the body. Ambient temperature was measured every ten seconds using a USB temperature probe with external high temperature thermistor (Lascar EL-USB) that was attached to the front of the web gear on the firefighter to monitor ambient temperature and radiant heat exposure. Additional ambient conditions and heat stress were recorded every 15 minutes with a Extech HT30 Heat Stress WBGT meter, logging wet blub globe temperature, ambient air temperature, and relative humidity.

Additional data collected on the individual firefighter included rank, shift duration, age, gender, height, weight, Body Mass Index (BMI), hydration levels, nutritional information, PPE (double or single layer), fitness level, and nicotine use. For hydration, we measured urine specific gravity (U_{sg}) before and after the activity period being monitored.[57] A urine sample was collected in the morning before shift and at the end of the monitoring period with a hand-held refractometer used to estimate U_{sg}. For our purposes, a U_{sg} of less than 1.020 was generally considered the

52 Hallstone, J. and A. Kilding. 2011. Reliability and Validity of the Zephyr BioHarness to Measure Respiratory Response to Exercise. Measurement in Physical Education and Exercise Science. 25(4): 293-300.
53 Smith, D., J. Haller, B. Dolezal, C. Cooper, and P. Fehling. 2014. Evaluation of a Wearable Physiological Status Monitor During Simulated Fire Fighting Activities. J. of Occup. And Env. Hyg. 11(7): 427-433.
54 Kim, J. R. Roberge, J. Powell, A. Schafer, and W. Williams. 2013. Measurement Accuracy of Heart Rate and Respiratory Rate during Graded Exercise and Sustained Exercise in the Heat Using the Zephyr BioHarness. Int. J. Sports. Med. 34(6): 497-501.
55 Miller et al. 1993. Predicting max HR. Medicine & Science in Sports & Exercise. 25(9): 1077-1081.
56 Johnstone, J., P. Ford, G. Hiughes, T. Watson, A. Mitchell, and A. Garrett. 2012. Field Based Reliability and Validity of the Bioharness Multivariable Monitoring Device. J. Sports. Sci. Med. 11(4): 643-652.
57 Urinalysis has been shown to be the most valid and reliable method for determining moderate changes in fluid balance. See generally: Armstrong, L.E., Soto, J.A., Hacker, F.T., Casa, D.J., Kavouras, S.A., Maresh, C.M. 1998. Urinary indices during dehydration, exercise, and rehydration." Int. J. Sport Nutr. 8: 345-355.

lowest acceptable level of hydration for firefighters.[58,59] Nutritional information was recorded from each volunteer, documenting food and fluid intake during the 12-hour period prior to the activity, as self-reported by the study participant. Where practical, we collected data on the current fitness of each firefighter using the USFS step test.[60,61] These tests were generally conducted on the volunteers the day before the event when logistically possible.

Once all the data was downloaded, collected, and collated, a "data cleaning" protocol was used to remove any extraneous or anomalous data and gross errors that were a byproduct of sensor faults or other technical errors. This vastly improves the data analysis and subsequent reliability and validity of statistics across all variables. The basic statistics for heart rate, activity, respiration and core temperature was calculated for each minute of the study. A maximum sustained value for heart rate, respiratory rate, and activity was identified during each minute interval as the peak value that was sustained for at least 10 seconds during any given minute. Maximum core temperature was identified during each minute as the peak value sustained for 30 seconds during each minute interval. All data were then combined into a complete time-series spreadsheet and exported into Microsoft Excel (v15), MiniTab (v16), and R (v3.2.5) for analysis.

58 Sawka MN, Burke LM, Eichner ER, et al. American College of Sports Medicine Position Stand: Exercise and Fluid Replacement. Med Sci Sports Exerc. 2007; 39:377390.

59 McEvoy and Rhodes, 2015.

60 Sharkey, B.J. 1979. Physiology of Fitness: Prescribing Exercise for Fitness Weight Control and Health, Human Kinetics Publishers.

61 Sharkey, B. 2003. Work capacity test: administrator's guide. NWCG PMS 307 NFES 1109. Boise, ID: National Wildfire Coordinating Group, National Interagency Fire Center. 28 p.

3.0 Results

Between April 2013 and June 2015, we were able to collect data on 95 firefighters: 25 firefighters at three training events; 30 firefighters at four controlled burns; and 40 firefighters at five wildfire incidents. Of the firefighters monitored, 93 were male and two were female; 26 were wearing double layer PPE while the rest wore single layer; 72 were a rank of Firefighter 1 or 2, 11 were Engineers, and 12 were Captains. Additional summary statistics on the firefighters are provided in Table 1. The average age of the firefighters was 29 years old, with an average height of 5'10" and average weight of 188 pounds. Fifteen firefighters self-identified as using nicotine.

Table 1. Summary Statistics for Firefighters Included in the Study (field instrumentation was limited to a minimum U_{sg} of 1.01 and a maximum of 1.04*).**

Variable	Mean	SE Mean	StDev	Median	Min	Max
Start Hydration (urine specific gravity)*	1.020	0.000692	0.00675	1.02	1.01	1.04
End Hydration (urine specific gravity)*	1.023	0.000802	0.00782	1.024	1.01	1.04
Age (years)	28.71	0.691	6.736	26	21	50
Height (inches)	70.61	0.288	2.807	70	65	79
Weight (lbs)	187.71	2.46	23.94	185	150	265
BMI	26.45	0.294	2.862	25.8	20	37
Max Heart Rate (beats per minute)	199.27	2.13	20.8	202	126	238
Max Core Temperature (Fahrenheit)	102.00	0.0897	0.874	102.15	99.77	103.79

While BMI is not the best indicator of fitness, it still provides a useful assessment of an individual.[62] According to the standard measure of BMI, most of the firefighters in this study would be considered overweight. However it is widely recognized that highly-trained individuals may have an artificially high BMI because of increased muscle mass.[63] Due to this discrepancy, we also conducted the Sharkey Step-Test as a more reliable measure of individual fitness. As a result, most of the firefighters included in this study were considered generally fit, with the step test results showing only a typical negative relationship between the estimated VO_2 Max and age (Figure 1). In addition, no significant relationships were identified between the results of the Step-Test and other factors including heart rates or core temperatures.

62 For BMI calculations, we used the formula provided by the National Institute of Health: National Heart, Lung, and Blood Institute. Last Access 5/15/16. http://www.nhlbi.nih.gov/health/educational/lose_wt/BMI/bmicalc.htm
63 Centers of Disease Control and Prevention. Body Mass Index: Considerations for Practitioners. Last Accessed 5/15/16. http://www.cdc.gov/obesity/downloads/BMIforPactitioners.pdf

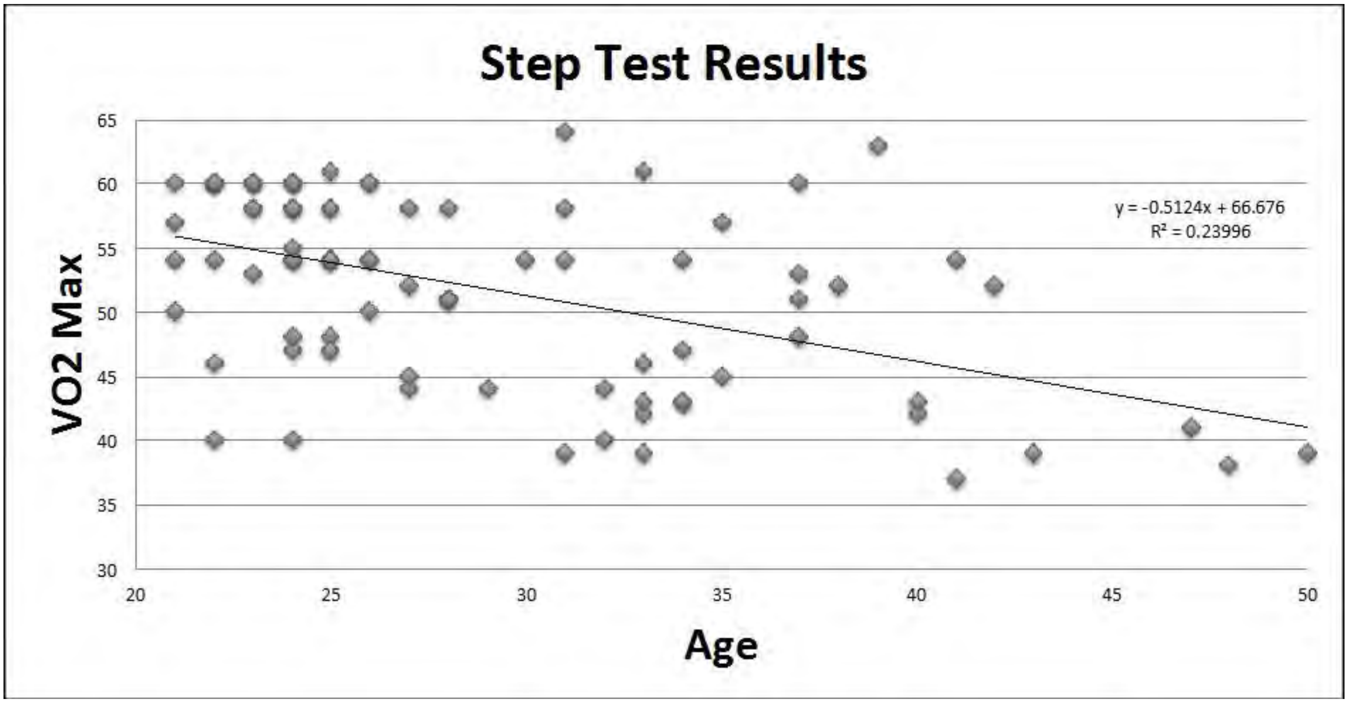


Figure 1. Step test results for 95 firefighters included in the study. Note that as age increases, the estimated VO_2 Max decreases.

To help us understand the potentially complex relationships between the variety of categorical, and continuous numerical data collected, and to summarize results across the firefighters included in the study, a Canonical Correspondence Analysis (CCA) was performed to determine which factors (if any) have the most significant influence on health and safety. The CCA summarizes the responses across all the factors, and expresses the results in terms of changes in heart rate, core temperature, and hydration, and fitness level relative to a variety of factors, including age, height, weight, nicotine use, ambient air temperature, incident type, and activity levels. More than one pattern can change in the response variables, and CCA can identify as many "axes" of change in composition as there are predictors. The strongest pattern (called CCA1) is found first, and subsequent axes characterize successively weaker patterns of change in composition. Randomization tests can be used to identify a significant CCA overall, and to test the significance of each CCA axis. While the CCA did not result in identifying strongly significant relationships (with no significant eigenvalues), maximum core temperature and maximum heart rate did seem to have the highest response levels (Figure 2). This provided additional (albeit limited) insight into the relationships among the data, and helped focus additional analyses that were specific to core temperature and heart rate.

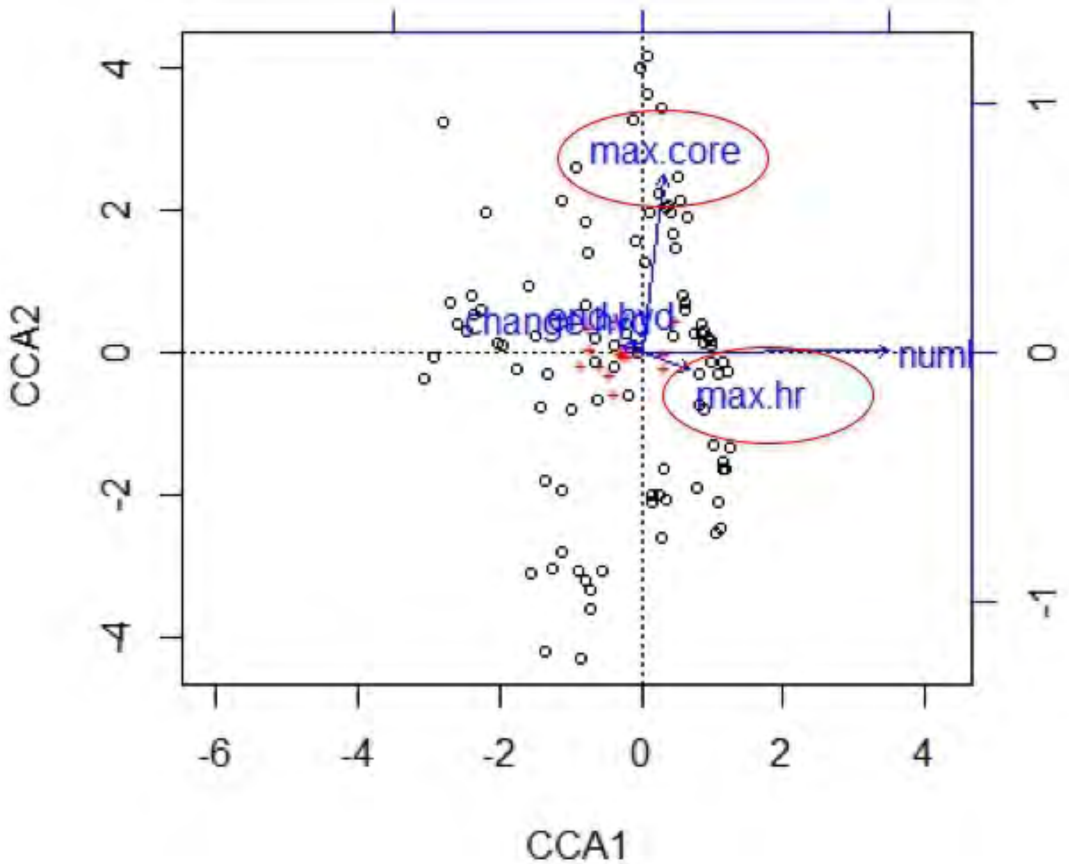


Figure 2. Results of the Canonical Correspondence Analysis showing slight influence related to a firefighter's maximum core temperature and heart rate.

3.1 Core Temperature

The mean core temperature of the firefighters during the study was 99.67°F (SD = 1.11), with a calculated maximum core temperature (per minute) of 99.73°F (SD = 1.13). If one assumes a normal core temperature of 98.7°F, this means that the firefighters generally maintained core temperatures throughout their shift above normal approximately 75% of the time (Figure 3).

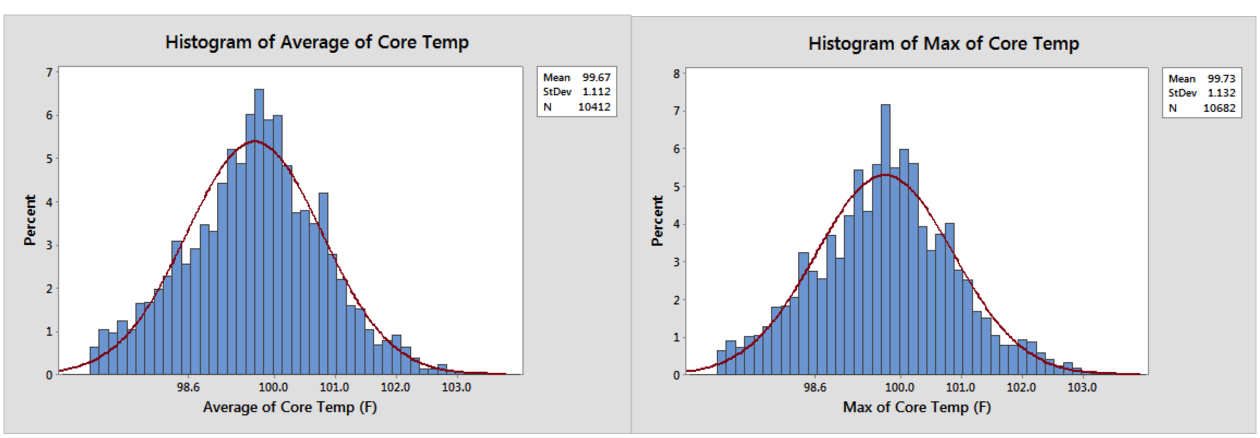


Figure 3. Histograms of the average and maximum core temperatures of firefighters.

Approximately 70% of the firefighters (at some point during their activity) had a maximum sustained core temperature above 102°F, with nearly 10% of them reaching a maximum sustained core temperature above 103°F. One individual reached a maximum core temperature of 103.79°F (notably, this was also the same individual that reached a maximum sustained peak heart rate of 238 bpm-discussed below).

When looking at the average or maximum core temperatures of the firefighters involved in the study, there were no significant relationships observed with regard to age, fitness (BMI and step test results), ambient temperatures, wet-bulb-globe temperatures, or hydration.

We did note a significant difference in core temperature based on the PPE worn, with wearers of single layer PPE having lower core temperatures than that of double layer (discussed in more detail in Section 3.4).

When combining all recorded data into one large dataset, we were able to observe general relationships (using simple linear regression) between average and maximum core temperatures, heart rate, and respiratory rate. The following analyses resulted in noticeable findings:

1) When looking at the average core temperature (°F) and average heart rate (per minute), a significant regression was observed (F (1, 5891)=3084.33, $p<0.0001$) with an R^2 of 22.88%. A firefighters average core temperature is predicted to increase by 0.2°F for every 10bpm increase in average heart rate. Similarly, when looking at the maximum core temperature (°F) and maximum heart rate (per minute), a significant regression was observed (F (1, 164)=3430.53, $p<0.0001$) with an R^2 of 24.34%. A firefighter's maximum core temperature is predicted to increase by 0.2°F for every 10bpm increase in average heart rate. (Figure 4).

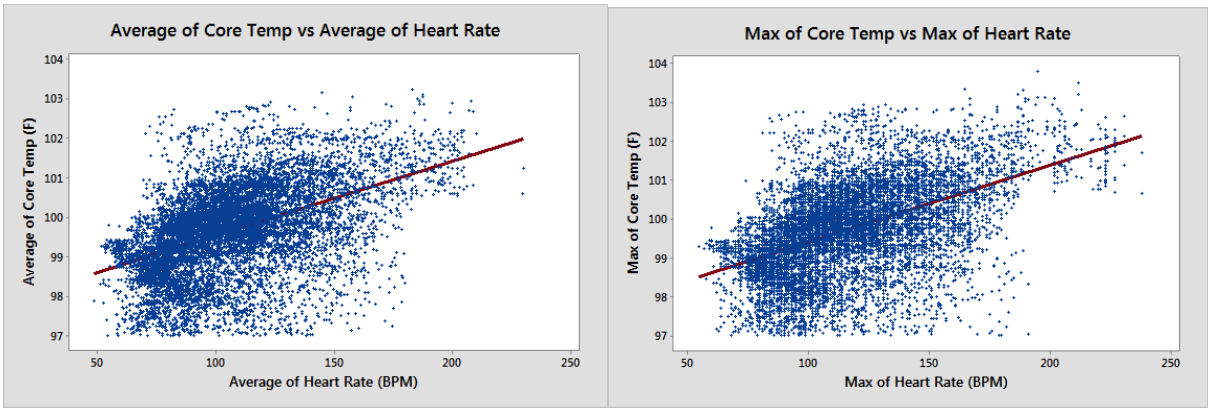


Figure 4. Linear regression of average core temperature v. average heart rate and maximum core temperature v. maximum heart rate.

2) While there were significant relationships observed when looking at the average core temperature (°F) and average respiratory rate (breaths per minute) ($F\ (1,2807)=299.82$, $P<0.0001$, and $R^2=2.8\%$), and the relationship between maximum core temperature and maximum activity level ($F\ (1,127)=213.2$, $P<0.0001$, and $R^2=1.96\%$), the R-squared values are remarkably low, suggesting that while there may be a significant relationship, too little of the data are explained by these relationships (Figure 5).

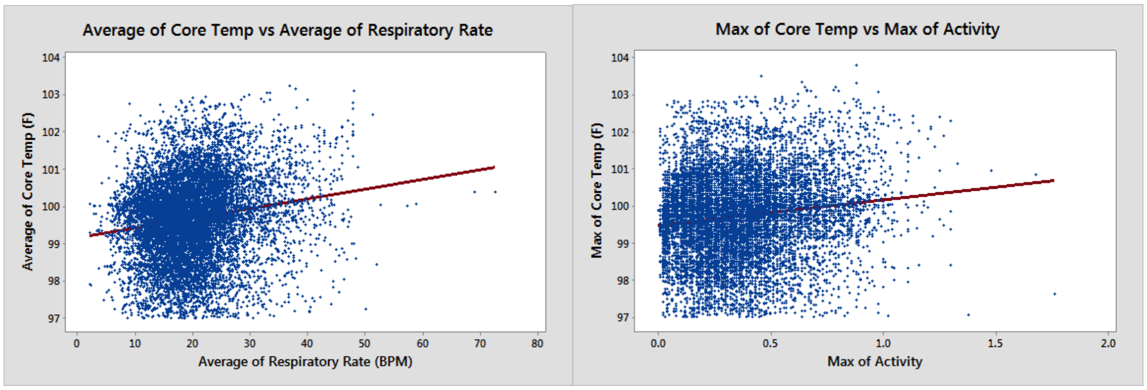


Figure 5. Linear regression of average core temperature v. average respiratory rate and maximum core temperature v. maximum activity level.

3.2 Heart Rate

The mean heart rate of the firefighters (recorded throughout the shift duration) was 108.9bpm (SD = 29.4), with a calculated maximum sustained heart rate (per minute) of 118.5bpm (SD = 29.22). If one assumes a normal resting heart rate of 60bpm, this means that the firefighters generally maintained average heart rates throughout their shift above the resting normal roughly 85% of the time (Figure 6).

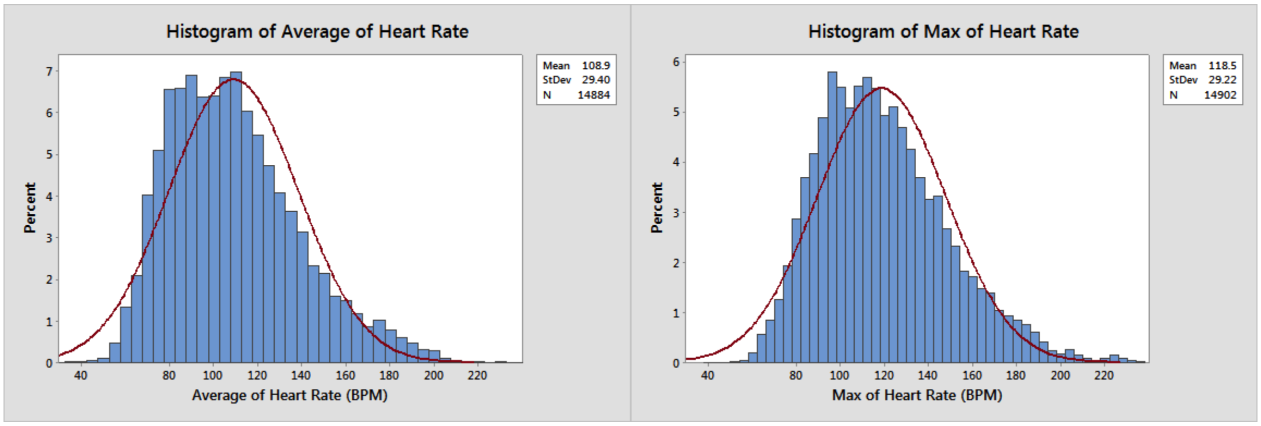


Figure 6. Histograms of the average and maximum sustained heart rates of firefighters.

Approximately 64% of the firefighters (at some point during their activity) had a maximum sustained peak heart rate above 200bpm, with 18% exceeding 220bpm. Similarly, 97% (N=92) of the firefighters regularly exceeded the recommended maximum heart rate for work (85% of the maximum heart rate of 220bpm – age). The firefighters exceeded this recommended threshold, reaching an average sustained peak heart rate that was 123% higher (±14%), with the highest level exceeding 165% for an individual, sustaining a peak heart rate of 238bpm.

When looking at the average or maximum heart rates of the firefighters involved in the study, there was no significant relationships observed with regard to age, fitness (BMI and step test results), ambient temperatures, wet-bulb-globe temperatures, or hydration. While nicotine use did not show any significant relationship to heart rate graphically, there appears to be a somewhat higher heart rate in those individuals that self-reported nicotine use (Figure 7). Furthermore, while there is no significant relationship between hydration levels, it does appear that there may be a nascent relationship with higher levels of dehydration resulting in elevated heart rates (Figure 8). We recognized a significant difference in heart rate levels based on the PPE worn, with wearers of single layer PPE having significantly lower heart rates than that of double layer (discussed in Section 3.4).

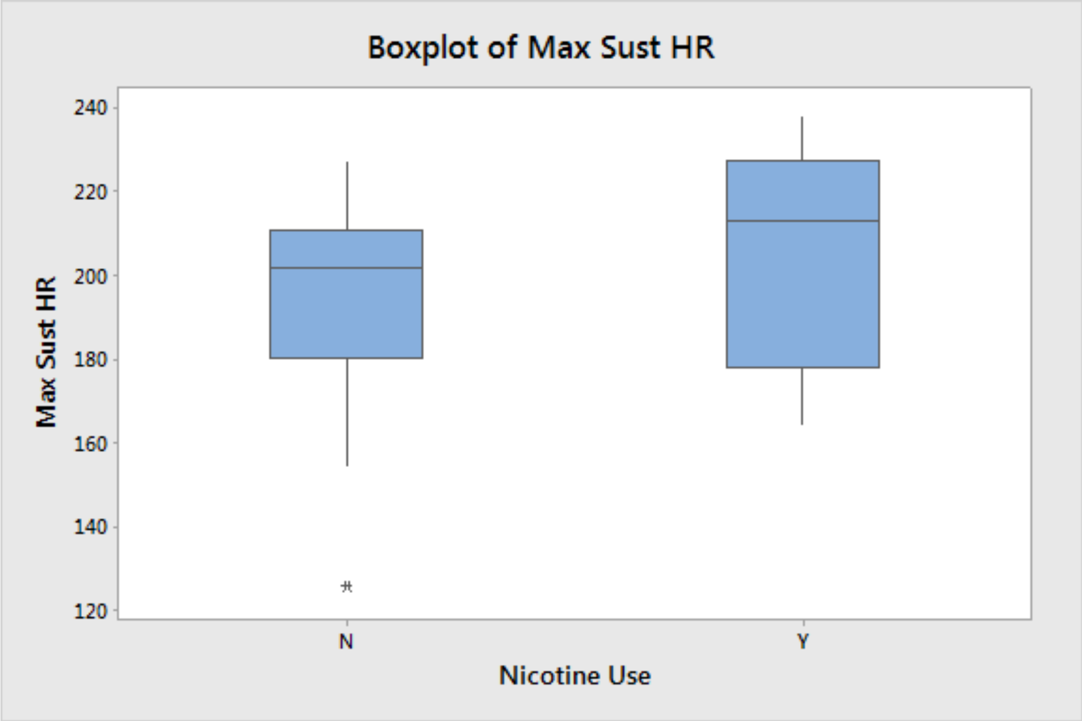


Figure 7. Comparison of maximum sustained heart rate and the reported use of nicotine by firefighters.

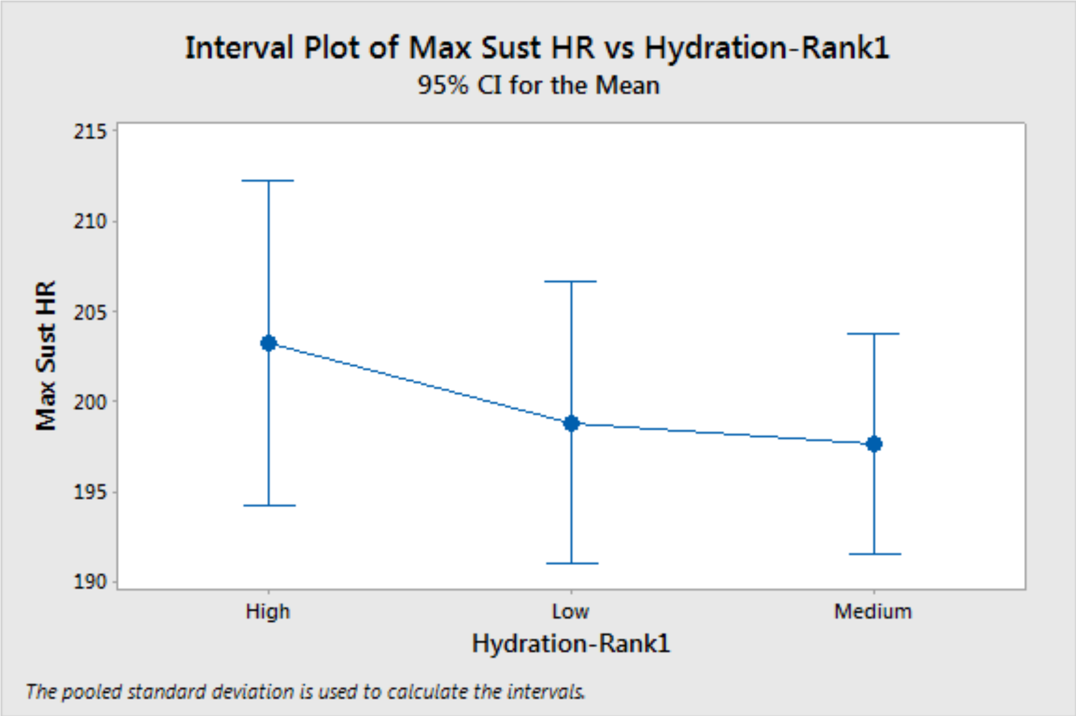
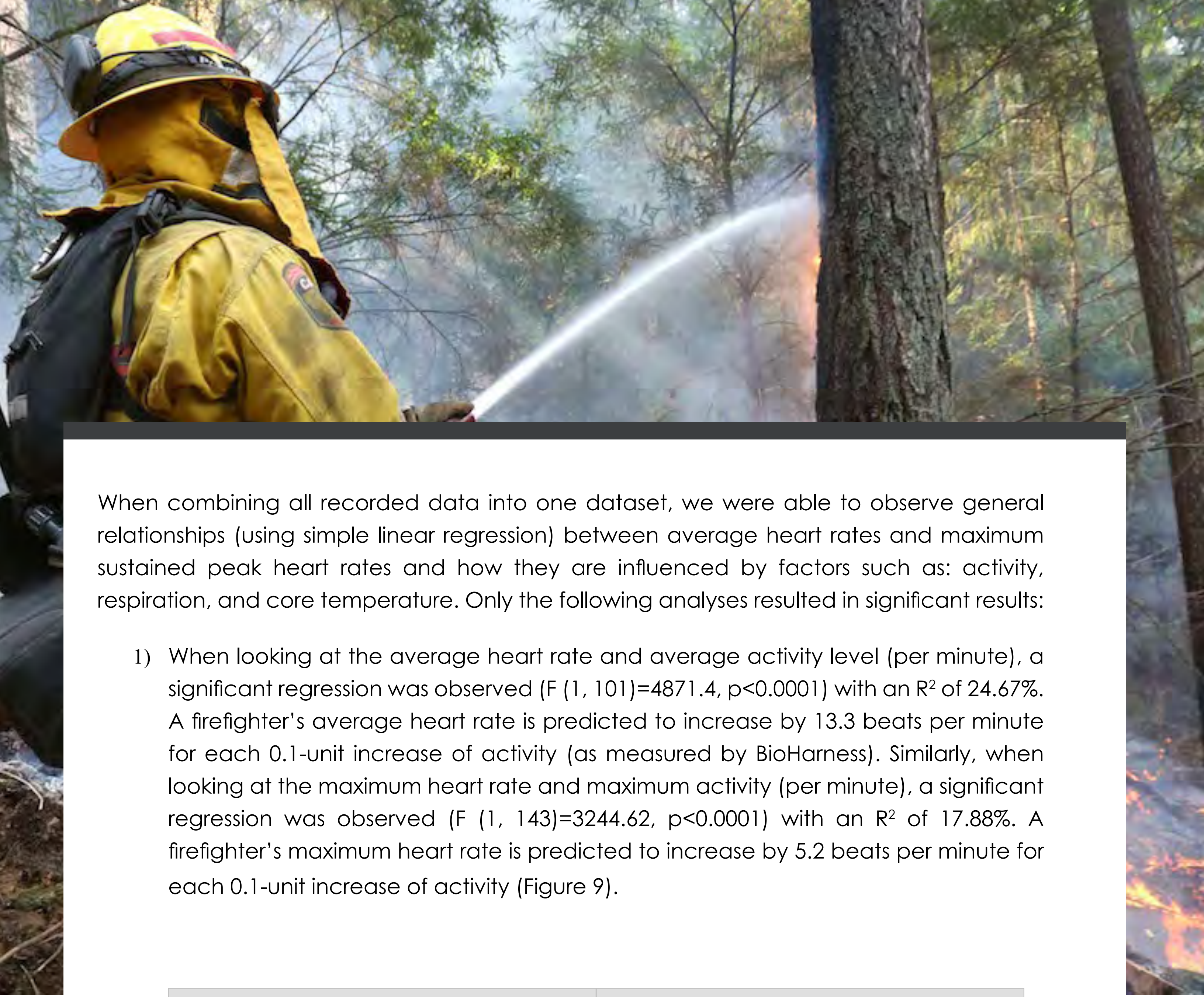


Figure 8. Comparison of maximum sustained heart rate and levels of hydration, where low is considered hydrated, medium is considered near dehydration, and high is dehydrated (U_{sg}>1.2).



When combining all recorded data into one dataset, we were able to observe general relationships (using simple linear regression) between average heart rates and maximum sustained peak heart rates and how they are influenced by factors such as: activity, respiration, and core temperature. Only the following analyses resulted in significant results:

1) When looking at the average heart rate and average activity level (per minute), a significant regression was observed (F (1, 101)=4871.4, $p<0.0001$) with an R^2 of 24.67%. A firefighter's average heart rate is predicted to increase by 13.3 beats per minute for each 0.1-unit increase of activity (as measured by BioHarness). Similarly, when looking at the maximum heart rate and maximum activity (per minute), a significant regression was observed (F (1, 143)=3244.62, $p<0.0001$) with an R^2 of 17.88%. A firefighter's maximum heart rate is predicted to increase by 5.2 beats per minute for each 0.1-unit increase of activity (Figure 9).

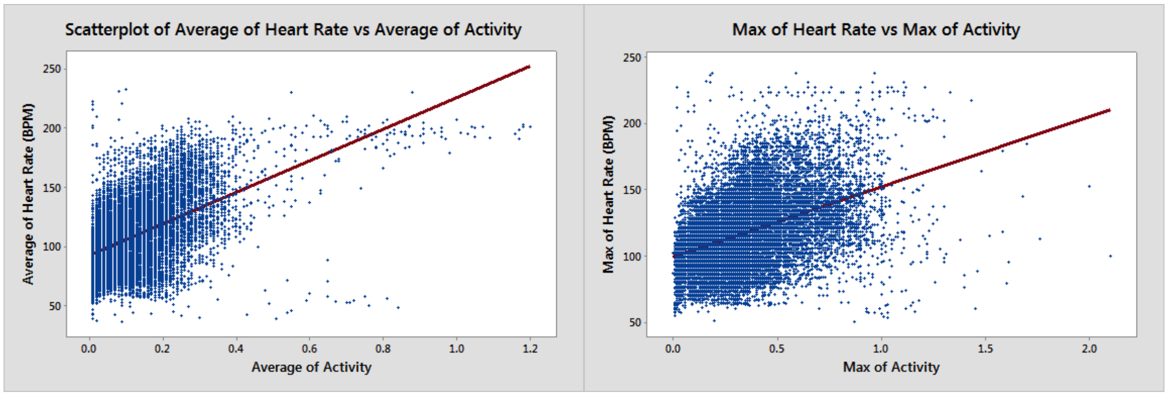


Figure 9. Linear regression of average heart rate v. average activity and maximum heart rate v. maximum activity.

2) When looking at the average heart rate and maximum core temperature (°F), a significant regression was observed (F (1, 377)=3405.35, $p<0.0001$) with an R^2 of 24.21%. A firefighter's average heart rate is predicted to increase by 12.2 beats per minute for each degree increase in maximum core temperature (Figure 10).

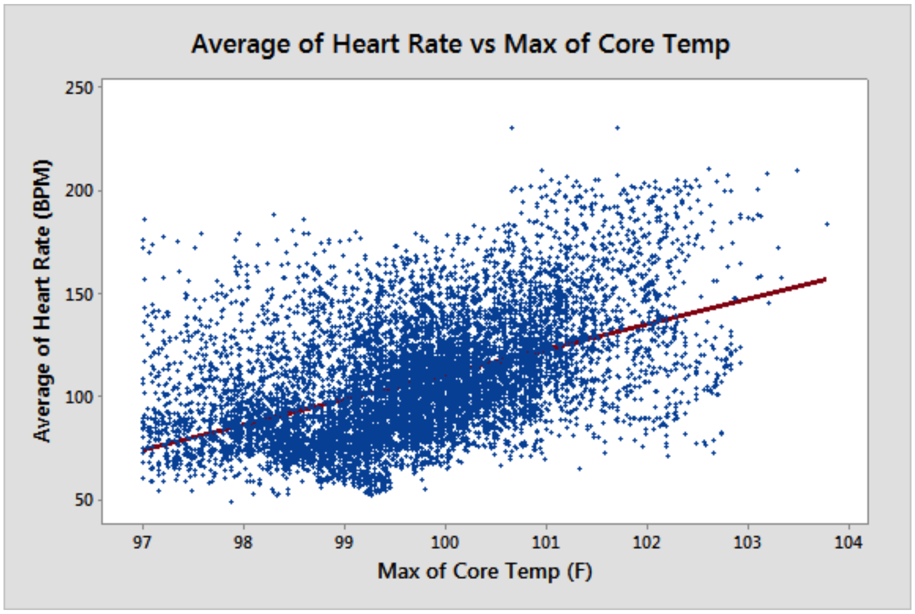


Figure 10. Linear regression of average heart rate and maximum core temperature.

3) When looking at the maximum heart rate (bpm) and maximum respiratory rate (breaths per minute), a significant regression was observed (F (1, 552)=2008.45, $p<0.0001$) with an R^2 of 11.9%. A firefighter's maximum heart rate is predicted to increase by 1.2 beats per minute for each additional breath taken per minute (Figure 11).

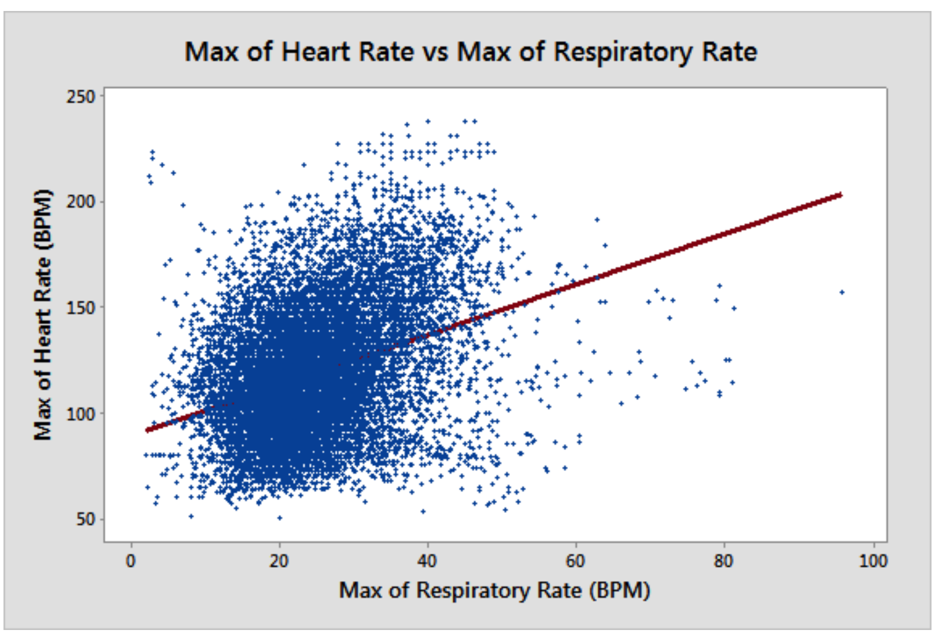


Figure 11. Linear regression of maximum heart rate and maximum respiratory rate.

3.3 Hydration

We recorded hydration on 95 firefighters, with urine samples collected before and after duty. The hand-held refractometer had a scale from 1.01 to 1.04; firefighters with a Usg of 1.02-1.022 were considered "near dehydration," while any values above that level were classified as dehydrated. Nearly two-thirds of the firefighters started their shifts at or near a level of dehydration. Dehydration rates significantly increased across all firefighters at the end of duty. Of those individuals that started off the shift at or near dehydration (N=62), 63% (N=39) were more dehydrated by the end of the shift, 8% (N=5) had no change in hydration, and only 26% (N=16) self-corrected and were better hydrated by the end of the shift. In a paired t-test comparing the mean differences between start and end hydration, there was a significant difference among all firefighters; they all generally ended their shift less hydrated than they started ($t = -3.89$, $df = 94$, $p<0.0001$) (Figure 12).

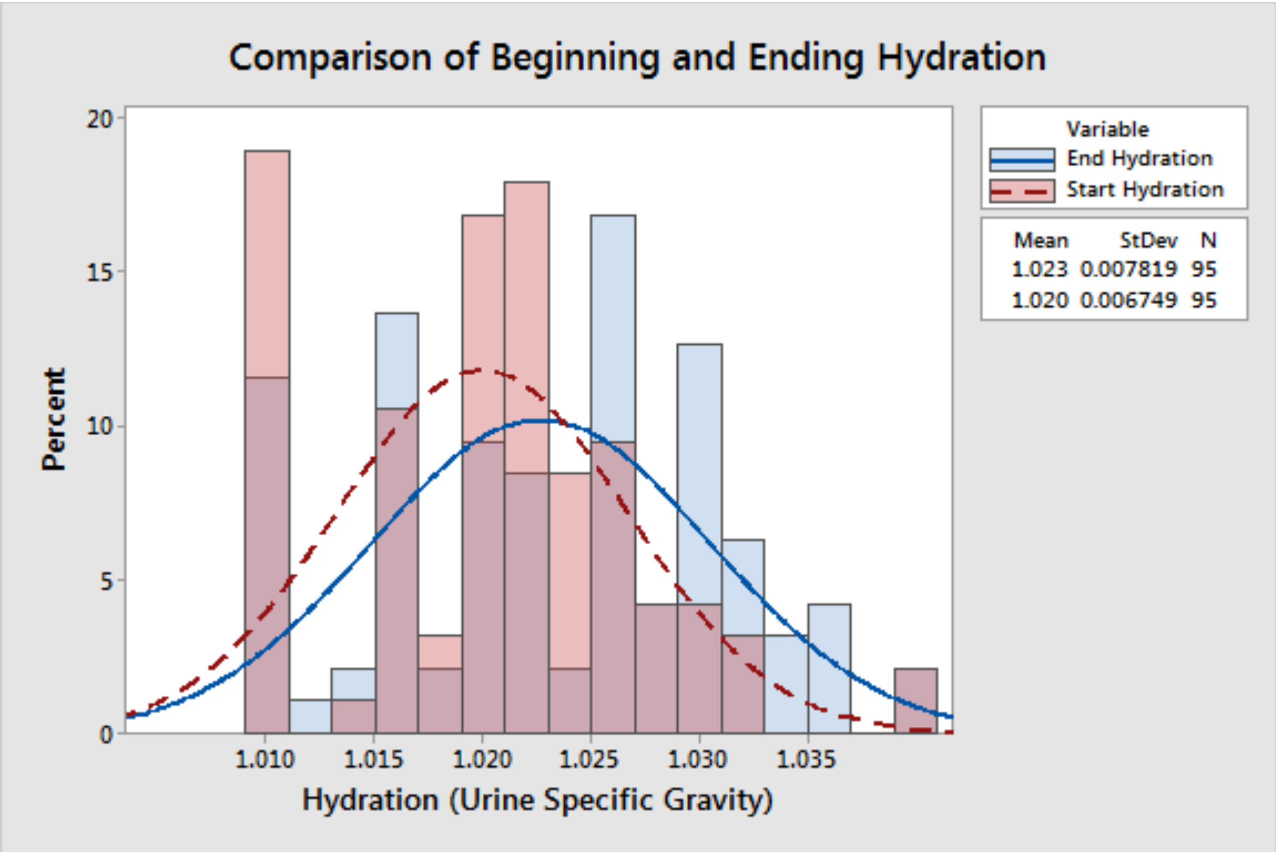
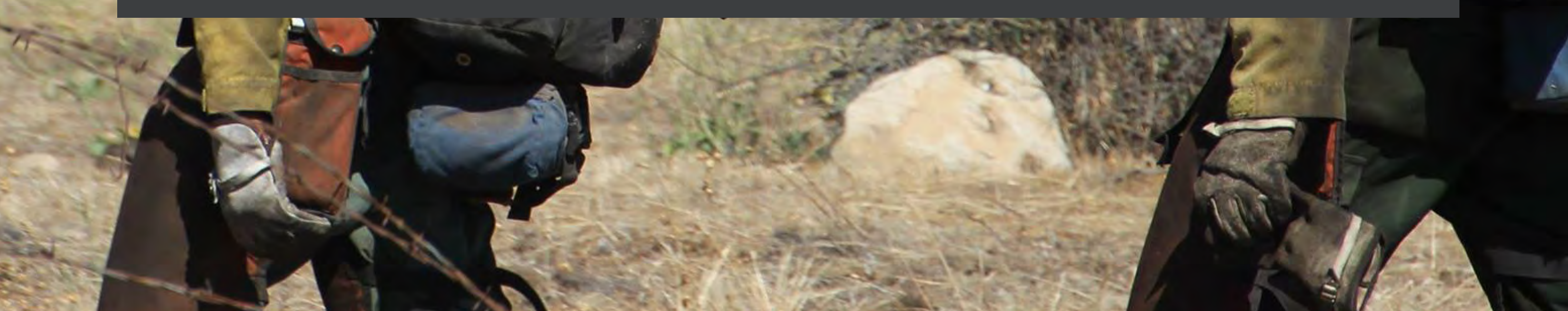


Figure 12. Histogram and summary statistics on the starting and ending hydration for 95 firefighters included in the study.



There were no significant relationships between hydration and other factors including BMI, fitness level, nicotine use, ambient temperature, wet-bulb-globe temperature, and activity. The type of event (actual wildfire, controlled burn, and training exercise) showed no significant influence on hydration levels (Figure 13). There was however a significant difference in hydration levels based on the PPE worn, with wearers of single layer PPE having higher levels of hydration than that of double layer (discussed in Section 3.4).

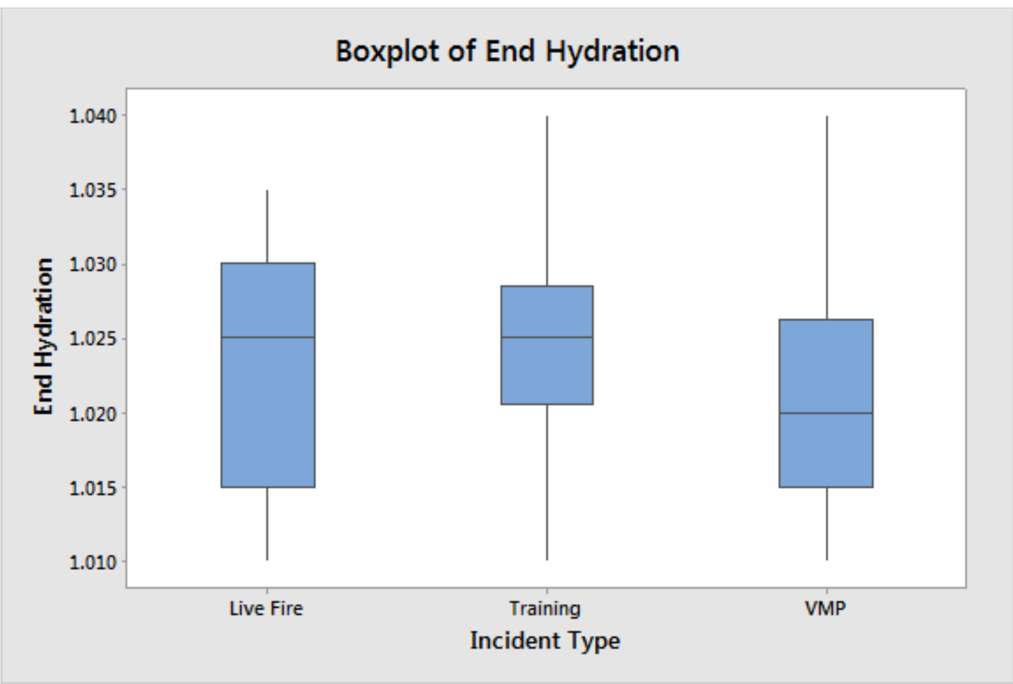


Figure 13. No significant differences were observed between incident types [actual wildfire, training, and controlled burn (VMP)] and the hydration level of the firefighters at the end of the day.

3.4 Personal Protective Equipment (PPE)

During the study, we recorded 26 individuals wearing the CAL FIRE Legacy PPE that consisted of a double-layer PPE jacket with cotton lined sleeves, and 69 individuals wearing the interim garment that consisted of a a single layer top (no sleeve linings) made from Nomex® IIIA material. In addition, each firefighter included in the study was wearing a base-layer that consisted of a cotton under shirt and two layers of pants that included standard issue uniform work pants and wildland firefighter Nomex® IIIA pants (we did not control for socks or underwear). Although the sample sizes were not equivalent, we were able to perform simple statistics to identify potential relationships. The following analyses provided significant results:

1) In a two-sample t-test, firefighters wearing double-layer PPE had significantly higher maximum core body temperatures (102.3°F) than those wearing single-layer PPE (101.9°F), ($t=2.11$, $df=41$, $p=0.041$), (Figure 14).

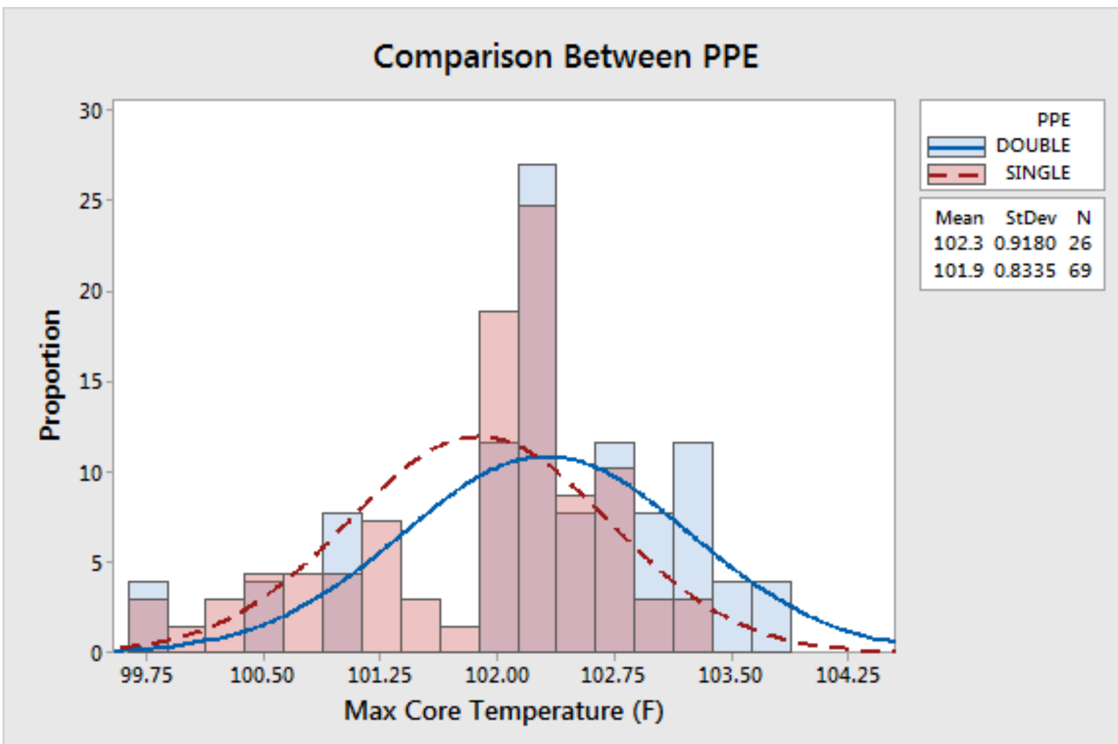


Figure 14. Histograms comparing the distribution of maximum core body temperatures of firefighters wearing double- and single-layer PPE

2) In a two-sample t-test, firefighters wearing double-layer PPE had significantly higher levels of dehydration (1.025U_{sg}) than those wearing single-layer PPE (1.022U_{sg}), (t=2.04, df=41, p=0.048), (Figure 15).

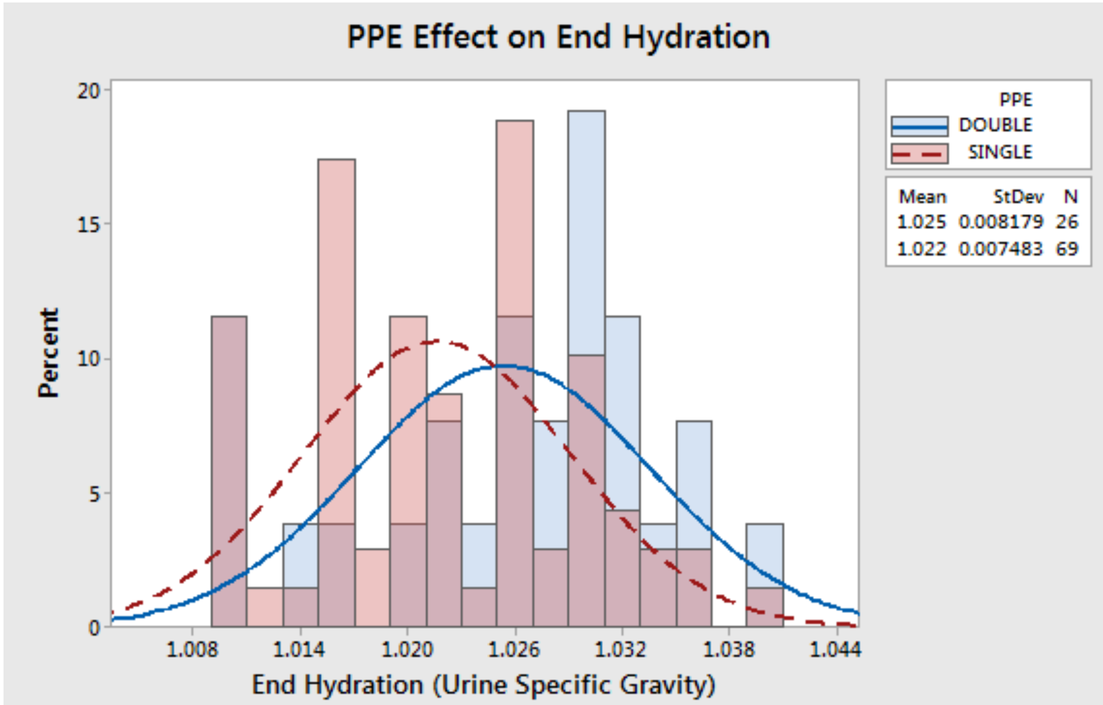


Figure 15. Histograms comparing the distribution of end of shift hydration levels of firefighters wearing double- and single-layer PPE.

3) In a two-sample t-test, firefighters wearing double-layer PPE had significantly higher average sustained heart rates, and maximum sustained peak heart rates than those wearing single-layer PPE, (t=32.2, df=41, p<0.0001; and t=38.4, df=41, p<0.0001 respectively), (Figure 16)

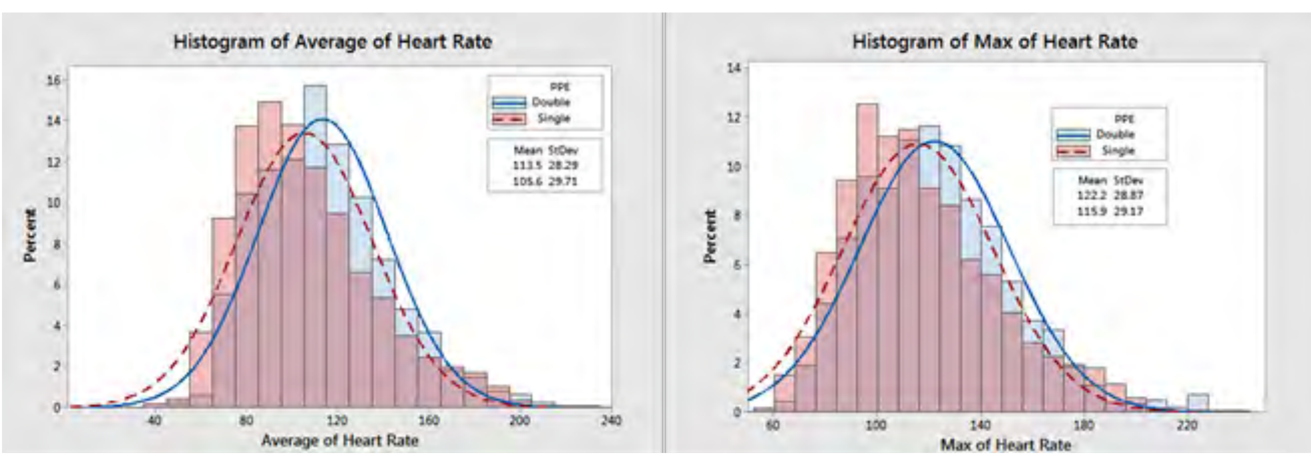


Figure 16. Histograms comparing the distribution of average and maximum heart rates of firefighters wearing double- and single-layer PPE.

4.0 Discussion

An ongoing debate is ensuing throughout the United States that questions the adequacy of modern firefighter staffing, resources, response protocols, and land management. Critical decisions are driven by such malleable and extrinsic factors as public perception, environmental concerns and budgetary constraints. As a result, decisions can be made without adequate empirical support or even any in-depth understanding of the issues. This has led to serious consequences for wildfire/WUI response, community safety, attack effectiveness, and firefighter health and safety. Although firefighting response and effectiveness has vastly improved, many of the basic issues have not been researched and considerable uncertainty remains. Consequently, wildland and WUI fires have not kept pace with the advancements seen in structure and high-rise fires.[64]

The health and safety of our firefighters is secondary only to the protection of the citizens they have sworn to serve, yet our ability to clearly understand how to avoid, minimize, and mitigate risk is confounded. For example, the notion of a discrete fire season and "traditional wildland fire" is antiquated. A paradigm shift is occurring as our country continues to build, and in many instances, recklessly into the WUI. A clear result is an increase to our community risks, and that of our firefighters; every season is wildfire season. The results of this study provide useful insights into how changing environmental conditions, duties, and PPE relate to the health and safety of firefighters. This study also provides recommended steps that can be taken to improve the health and safety of our wildland and WUI firefighters.

No one questions that firefighters experience extreme physical strain. While this is expected on a wildfire (given the dramatic and chaotic working environment), it was surprising that trainings and controlled burns created nearly identical physiological impacts to firefighters. Despite these results (across all incident types), it is important to note that this study has limits. It was not possible to collect data on initial attack firefighters that work under the most extreme conditions, nor was it possible to track

64 Rahn and McHale, 2015.

wildland firefighters over multiple, consecutive days as they worked without reprieve. It can probably be argued successfully that this may be where the largest idiosyncrasies in health and safety impacts occur. Given the extreme physiological responses observed in this study, and the consistency with which they were detected, regardless of incident type, it can safely be assumed that firefighters working under the most extreme of conditions are likely to experience even higher heart rates, core temperatures, and levels of dehydration. The results of this study may explain why there is a high propensity of cardiovascular events in firefighters. As a result, it is increasingly important to identify protocols, tactics, strategies, equipment, and rehabilitation measures that can help mitigate stressors and improve firefighter resilience.

The complex working environment and diversity of intrinsic and extrinsic variables makes this a challenging field of study. A pervasive issue throughout the analyses was that, while there appeared to be significant relationships between various factors, low probability values were confounded by low R-squared values. Basically, while there may be a statistically significant relationship between some variables, there is also considerable variability within that relationship that is not well described by traditional linear models. Although this is not ideal for a regression analysis, this is not an uncommon outcome, particularly when working with large datasets and human physiology. Many studies on humans have R-squared values far less than 50% because people tend to be fairly unpredictable and physiological responses can be complex.[65] The data may contain inherently high amounts of unexplained variability as the low p-values indicate that there is a real (and significant) relationship between predictors and the response variable; pooling the data on all firefighters may explain this discrepancy.

When we look closer at how individuals responded to certain conditions, the distribution of the data still tends to be heteroskedastic. The relationships become clearer, with continued low p-values ($P<0.0001$), but higher R-squared values (of approximately 40%) (Figure 17).

65 REFERENCE NEEDED

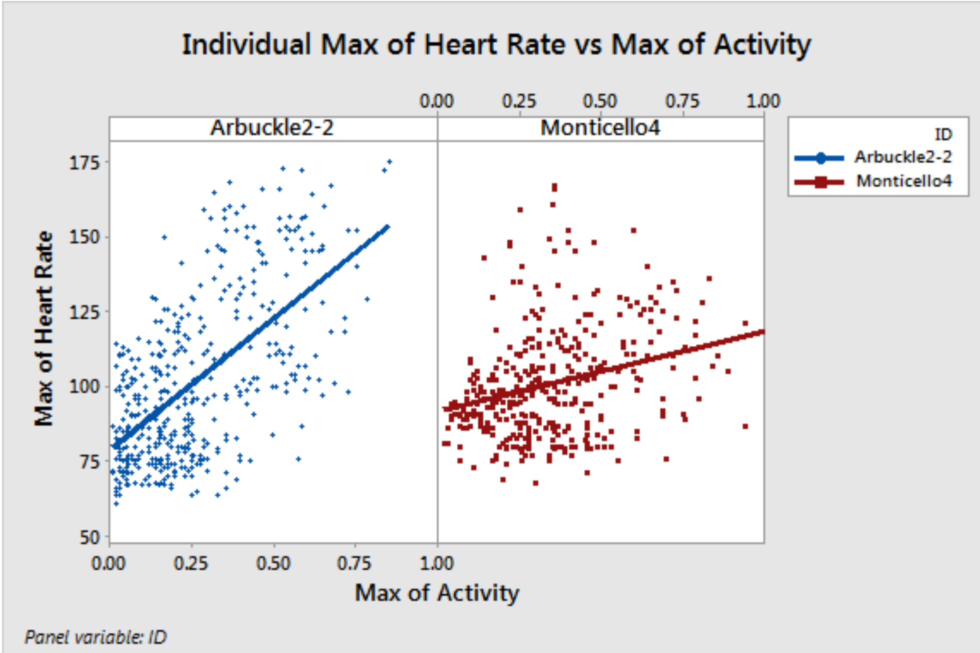


Figure 17. Individual regression results for firefighters showing similarly low p-values, considerably less variability than the overall population, and over twice the resulting R-squared values.

Likewise, data collected on individual firefighters show that there are strong observable relationships within an individual that become convoluted when looking across a cross section of wildland firefighters (Figure 18).

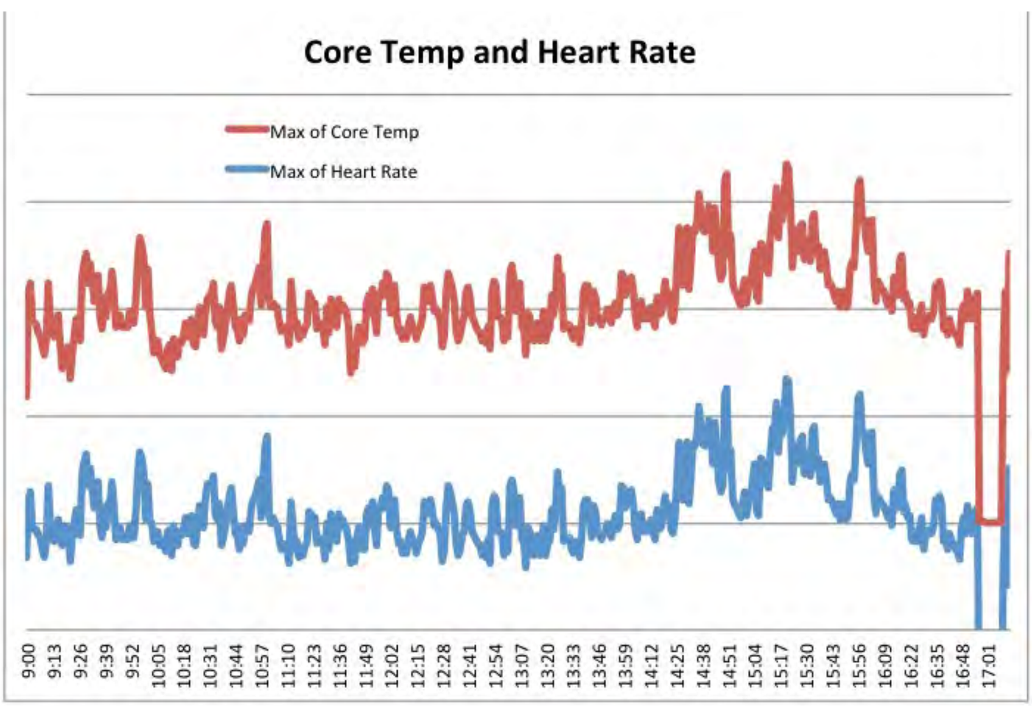


Figure 18. Individual time-series results for an individual firefighter showing the correlation between maximum core temperature and maximum heart rate recorded while on an eight-hour shift.

These results suggest that while we can make reasonable predictions and generalizations across a population of wildland firefighters, ultimately the individual matters. An overall pattern of response to exertion and stress exists, but each firefighter may have a discrete response to activities, environmental conditions, and stressors, confounded by an individual's fitness, physiology, psychology, and acclimation. The following sections specifically address the research results related to core body temperature, heart rate, hydration, and PPE.

4.1 Core Body Temperature

The National Institute for Occupational Safety and Health (NIOSH) recommended a heat exposure standard to the Occupational Safety and Health Administration (OSHA) in 1972, 1986, and 2016.[66,67,68] Despite the history and the large body of evidence that suggests heat stress on a wildland/WUI fire is an occupational hazard, OSHA has not promulgated standards for environmental heat exposure under the U.S. Code of Federal Regulations; uniform heat stress prevention policies do not exist. This is not entirely surprising, particularly given the results of this study. We are only beginning to understand the relationships between environmental and occupational stressors and the resultant health and safety of firefighters. Absent sufficient data and understanding it is not credible to implement exhaustive regulations.

Published empirical and epidemiological data on occupational heat stress are sparse and fragmented, particularly with regard to wildland firefighters. In general, the human body should maintain a core temperature within about 1.8°F of the normal core body temperature, or a maximum of 100.4°F.[69] Again, firefighters included in this study carried core temperatures above this recommended level over half of the time. Heat-related issues can arise from stressors including high air temperatures, humidity, radiant heat, and individual metabolic heat that is generated though physical activity.[70] Results from this study demonstrated that

66 National Institutes for Occupational Safety and Health (NIOSH). 1972. Criteria for a Recommended Standard…Occupational Exposure to Hot Environments.
67 NIOSH 1986.
68 National Institutes for Occupational Safety and Health (NIOSH). 2016. Criteria for a Recommended Standards: Occupational Exposure to Heat and Hot Environments.
69 American Conference of Governmental Industrial Hygienists (ACGIH). Heat Stress and Stain. TLVs. 2009.
70 Weeks, J., B. Levy, and G. Wagner, editors. Preventing Occupational Disease and Injury. Washington, D.C: American Public Health Association Press; 1991.

wildland/WUI firefighters regularly experience high core body temperatures, regardless of whether they are participating in a wildfire, controlled burn, or training incident. In analogous studies conducted by the U.S. Forest Service, it was also found that firefighters regularly exceeded recommended core temperatures during sustained submaximal exercise in the heat.[71] These results have serious implications for the health and safety of our wildland/WUI firefighters.

Although heat related illness (HRI) can occur in an otherwise healthy individual, major risk factors include dehydration, obesity, poor physical fitness, alcohol use, and prior or recent diagnosis of an HRI.[72] These factors also interfere with the ability to acclimate to extreme temperatures. Although this did not seem to be an issue for our test subjects, this study essentially collected data on comparatively fit firefighters – this is certainly an issue worth addressing within the fire services as these factors can potentially contribute to dangerous health circumstances (particularly given that those firefighters willing to volunteer for this study may be predisposed to have higher fitness levels than those that did not volunteer).

The individual's fitness level put aside, adaptation to environmental conditions is universal. However, even though humans are capable of adapting to discrete periods of high heat (e.g. acclimatization), this generally occurs over a 4–6 day period where the individual experiences continuous daily exposure (with peak acclimatization generally occurring in two weeks).[73] Despite this potential evolutionary advantage, it is unlikely that sufficient acclimatization occurs during episodic and intermittent extreme heat events.[74] In contrast to these findings however, sports medicine research suggests that short-term, repeated heat exposures can improve performance and decrease thermal stress and exertion (although subjects in these studies do not experience the extreme environmental, psychological, or physiological

71 Domitrovich, J. 2014. Wildland firefighter health & safety report: No. 14. Tech. Rep. 1351–2811–MTDC. Missoula, MT: U.S. Department of Agriculture, Forest Service, Missoula Technology and Development Center. 10 p.
72 Adelakun, A., E. Schwartz, and L. Blais. 1999. Occupational heat exposure. Appl Occup Environ Hyg. 14(3): 153-4.
73 World Health Organization (WHO). 1969. Technical Report series No 412. Geneva: 1969. Health factors involved in working under conditions of heat stress. Report of a WHO Scientific group.
74 Patz, J., M. McGeehin, S. Bernard, K. Ebi, P. Epstein, A. Grambsch, D. Gubler, P. Reiter, I. Romieu, J, Rose, J. Samet, and J Trtanf. 2000. The Potential Health Impacts of Climate Variability and Change for the United States: Executive Summary of the Report of the Health Sector of the U.S. National Assessment. Environ Health Perspect. 108(4):367–76.

stresses of a wildland firefighter).[75,76] It is worth studying this issue further, particularly for those wildland firefighters that are on an incident for an extended period of time.

Finally, occupational exposure related to climate change effects has received very limited attention, and is an area critical to the everyday experiences of wildland firefighters.[77] From 1979 through 2000, the U.S. death rate attributed to heat exposure was generally around 0.5 deaths per million, however, since 2000, that number seems to have tripled.[78] It is important that agencies are cognizant of changing climatic conditions and the increased risks to wildland firefighters, ensuring that policies, protocols, and technology respond to this change.

4.2 Heart Rate

A high occupational rate of injuries and cardiac-related fatalities among wildland firefighters (compared with other professions) suggests that we need to improve our understanding of the relationship between the working environment and the physiological response by wildland firefighters. While NIOSH reports that structural firefighters often work "*at near maximal heart rates for long periods,*" [79] our study confirms that this is also the case for wildland firefighters. More importantly however, is the fact that wildland firefighters often exceed maximal heart rates across a variety of activities, including training, controlled burns, and actual wildfire incidents. A concomitant concern is the extraordinary length of intensive effort displayed by a wildland firefighter in comparison to a structural firefighter.

While the maximum heart rate was estimated using the formula HR_{max} = 220bpm – age,[80] the American Heart Association provides additional guidance in suggesting that the peak sustained heart rates do not exceed roughly 70-90% of the maximum

75 Garrett, A., R. Creasy, N. Rehrer, M. Patterson, and J. Cotter. 2012. Effectiveness of Short-Term Heat Acclimation for Highly Trained Athletes. European Journal of Applied Physiology 112: 1827–1837.
76 Castle, P., R. Mackenzie, N. Maxwell, A. Webborn, and P. Watt. 2011. Heat Acclimation Improves Intermittent Sprinting in the Heat but Additional Pre-Cooling Offers no Further Ergogenic Effect. Journal of Sports Sciences 29: 1125–1134.
77 See generally: Kjellstrom, T., I. Holmer, and B. Lemke. 2009. Workplace heat stress, health and productivity – an increasing challenge for low and middle-income countries during climate change. Glob Health Action.
Kjellstrom, T., S. Kovats, S. Lloyd, T. Holt, and R. Tol. 2009. The direct impact of climate change on regional labor productivity. Arch Environ Occup Health. 64(4):217–27.
Schulte, P., and H. Chun. 2009. Climate change and occupational safety and health: establishing a preliminary framework. J Occup Environ Hyg. 6(9):542–54.
Hyatt, O., B. Lemke, and T. Kjellstrom. 2010. Regional maps of occupational heat exposure: past, present and potential future. Global Health Action.
Gubernot, D., G. Anderson, and K. Hunting. 2014.
The Epidemiology of Occupational Heat-Related Morbidity and Mortality in the United States: A Review of the Literature and Assessment of Research Needs in a Changing Climate. Int J Biometeorol. 58(8): 1779–1788
78 U.S. Environmental Protection Agency (EPA). 2015. Climate Change Indicators in the United States: Heat Related Deaths. Last accessed 5/15/2016. https://www3.epa.gov/climatechange/science/indicators/health-society/heat-deaths.html
79 NIOSH, 2004.
80 Miller et al. 1993.

heart rate during intense physical activity.[81] We therefore estimated the maximum peak sustained heart rate at 85% of the HR_{max} given that the fitness levels of firefighters is generally higher than the general population. Despite this more generous calculation, we saw a significant number of wildland firefighters exceeding the HR_{max}. On average, firefighters in this study reached an HR_{max} that was 38% higher than recommended (123% ±14%), with one individual sustaining a HR_{max} of nearly 240bpm. Similarly, the U.S. Forest Service has observed comparable results.[82]

The high incidence of cardiac-related injuries and death in wildland firefighters may be related to regularly exceeding recommended cardiac thresholds, however the myriad of other often co-occurring and interrelated risk factors confounds a clear understanding of this relationship (which likely influences the high levels of variability seen in the data). Despite this, it is important to identify strategies for managing and reducing stressors and variables that contribute to potentially dangerously high heart rates and their resultant health and safety implications.

Beyond avoidance, minimization, and mitigation strategies for managing cardiac issues, it is important that agencies are not only aware of how environmental conditions and workload influence heart rate, but also how incident response protocols and industry practices can significantly influence outcomes. In a study of structure firefighters, researchers found that the average peak heart rate for those on the first responding engine were greater than 80% of the age-predicted maximum values when only two firefighters were deployed. In fact, the driver had an average peak heart rate of nearly 90% of age-predicted maximum when there were only two firefighters on the engine. When three and four firefighters were deployed per apparatus the peak heart rate was just above 70% (on average) across the three positions.[83] Similar studies concluded that staffing levels can also have a significant impact on the heart rate of wildland firefighters. Not only did attack effectiveness increase by over 60% as staffing progressed from a two-person to a four-person engine, but this also resulted in significantly lower heart rates, with no firefighters exceeding 195bpm on a four-person engine (while three- and two-person engines experienced peak heart rates above 200 and 220bpm, respectively).[84] This research has been disregarded to the point that we are only now starting to understand the implications of being a wildland firefighter and cardiac health.

4.3 Hydration

Notwithstanding personal statements and self-reporting to the contrary, empirical data reveals that most firefighters included in this study began duty at or near dehydration. While some of them self-corrected during the day, the vast majority were less hydrated at the end of their shift. The enduring conviction that the simple feeling of thirst is a reliable indicator of dehydration remains controversial, although our understanding of this sensation and its role in managing hydration continues to improve. Recent studies in sports medicine have found thirst as one of the most reliable indices for achieving optimal hydration.[85] However, the reliability of thirst diminishes with age[86] and in situations

81 See generally: http://www.heart.org/HEARTORG/HealthyLiving/PhysicalActivity/FitnessBasics/Target-Heart-Rates_UCM_434341_Article.jsp#.V1X7nlfg_Dk
82 George Broyles, U.S. Forest Service. Personal Communication. 2016.
83 Smith, D.L. and R. B. Benedict. 2010. Effect of Deployment of Resources on Cardiovascular Strain of Firefighters. Fire Fighter Safety and Deployment Study. International Association of Fire Fighters, Washington, DC.
84 Rahn, M. 2010. Initial Attack Effectiveness: Wildfire Staffing Study. Wildfire Research Report No. 2, Summer 2010. Montezuma Press, San Diego, CA.
85 Heneghan C, Howick J, O'Neill, et al. The evidence underpinning sports performance products: a systematic assessment. BMJ Open 2012
86 Grandjean AC, Reimers KJ, Buyckx ME. Hydration: Issues for the 21st Century. Nutrition Reviews. 2003;61:261271.

where there is excessive sweating (a phenomenon called "voluntary dehydration").[87] It is also unclear how other extrinsic factors (e.g. smoke exposure, hazardous air pollutants, high core temperatures, thermal insulation, and high ambient temperatures) affect the usefulness of thirst as a motivator in managing personal hydration. Although thirst is certainly not an exclusive, satisfactory indicator of hydration, there is sufficient evidence that it should not be ignored.[88] The challenge is identifying other measures that can be used to monitor and mitigate dehydration in wildland firefighters.

Studies related to firefighter hydration suggest that ad libitum drinking (e.g. at one's pleasure) was an adequate method for maintaining hydration status, even in hot conditions.[89] Yet extra (compulsory) fluid consumption or a pre-shift fluid bolus did not improve firefighter activity or physiological function (although core temperature was lower earlier in their shift), and self-regulation of fluids seemed to influence euhydration.[90,91] We need to develop better standards and protocols to ensure proper hydration.

This is particularly important, since it appears that firefighters may have a propensity toward baseline dehydration.[92] There is a strong imperative to encourage proper hydration before being on an incident. Firefighters also need to be able to better assess and maintain safe hydration levels while on duty, particularly during an extended attack or extreme heat days. This is particularly important given the relationship between hydration levels, core temperature, and heart rate. As a person becomes dehydrated, their blood becomes thicker, and causes the heart to work harder.[93] This can lead to elevated HR_{max}, core temperatures, and a myriad of other issues that can significantly diminish a firefighters health and safety.

87 Ganio MS, Casa DJ, Armstrong LE, et al. Evidenceapproach to lingering hydration questions. Clin Sports Med. 2007;26:116.
88 HewButler T, Verbalis JG, Noakes TD. Updated fluid recommendation: Position statement from the International Marathon Medical Directors Association (IMMDA). Clin J Sport Med. 2006;16:283292.
89 Raines, J., R, Snow, D. Nichols, and B. Aisbett. 2015. Fluid Intake, Hydration, Work Physiology of Wildfire Fighters Working in the Heat Over Consecutive Days. Ann Occup Hyg. 59(5):554-65.
90 Raines, J., R. Snow, A. Petersen, J. Harvey, D. Nichols, and B, Aisbett. 2013. The Effect of Prescribed Fluid Consumption on Physiology and Work Behavior of Wildfire Fighters. Appl Ergon. 44(3): 404-13.
91 Raines, J., R. Snow, A. Petersen, J. Harvey, D. Nichols, and B. Aisbett. 2012. Pre-Shift Fluid Intake: Effect on Physiology, Work and Drinking During Emergency Wildfire Fighting. Appl Ergon. 43(3):532-40
92 Horn G., J. DeBlois, I. Shalmyeva, et al. 2012. Quantifying Dehydration in the Fire Service Using Field Methods and Novel Devices. Prehosp Emerg Care. 16:347–355.
93 INSERT REFERENCE HERE.

It is therefore important to develop self-awareness and evaluative procedures so that firefighters can effectively assess their personal status, and that of their coworkers.

4.4 Personal Protective Equipment (PPE)

The focus of the study was not specifically on PPE. Yet the data collected on firefighters wearing two different types of wildland PPE show that heavier, thicker PPE can significantly and negatively impact the core temperature, heart rate, and hydration of a wildland firefighter. When ambient temperatures are high, the body relies on evaporative cooling; anything that restricts evaporation can interfere with this physiological response and its resulting benefits.[94] Fortunately, ongoing research is working to improve wildland PPE, balancing the need to shield the firefighter from extreme environmental conditions, while also allowing for evaporative cooling and the dissipation of heat. A simple one-size-fits all approach does not avail itself, especially as wildland firefighting continues to tackle the risks associated with the wildland urban interface. The results of this study highlight the significant role that PPE plays with regard to core temperature, hydration, and heart rate.

Firefighters deserve an assessment that properly identifies and prioritizes operational requirements for PPE worn in wildland and WUI environments. This includes an evaluation of the differences involved in a "traditional" wildland fire versus a WUI incident where firefighters are responding to an environment that includes both the wildland and structural firefighting hazards. This combination requires a rethinking of how the NFPA 1977 and NFPA 1971 requirements can be integrated in response to the WUI. The data will identify requirements for wear, comfort and protection in daily use clothing (including base layers and station uniforms) and the combination of wildland/WUI PPE needed for prolonged wear in different geographic, climatic, and environmental conditions.

94 Budd, G. 2008. Wet-bulb globe temperature (WBGT) – its history and its limitations. J Sci Med Sport. 11(1):20–32.

5.0 Conclusions and Recommendations

Based on the results of this study, the following recommendations are provided to improve wildland firefighter health and safety:

- Consider the importance of understanding wildland/WUI firefighting as equal importance to that of structure
- Provide educational programs to firefighters on how individual factors and lifestyle may predispose firefighters to increased risk for heat related injury, dehydration, and cardiac issues
    - Provide education on the effects of obesity, poor physical fitness, alcohol and nicotine use, and prior or recent diagnosis of a heat related injury as they relate to core body temperature and cardiac risk
- Develop education programs on self-assessment and/or monitoring devices used to track personal heart rate, core temperature, and hydration levels
    - Provide training on the early identification of elevated core temperature, heart rate, and dehydration
    - Train firefighters on how to utilize this information to limit and/or avoid heart rates that exceed their age-calculated HR_{max}, core temperatures in excess of 100.4°F, and dehydration
    - Provide recommended best practices to avoid, minimize, and mitigate health and safety concerns, with an emphasis on strategies employed before, during, and after duty (including actual incidents, controlled burns, and training events)[95]
    - Provide education on the signs and symptoms of extreme core temperature, heart rate, and dehydration (heat related injury signs and symptoms)
    - Provide protocols and the measures that should be taken if dangerous levels are reached[94]

The following recommendations are provided to identify future research needs and better characterize and understand health and safety issues:

- Collect additional data on firefighters working under extreme exertion and environmental conditions, in both the wildland and WUI environment, during initial attack and extended deployment

95 See generally: http://www.nifc.gov/PUBLICATIONS/redbook/2016/Chapter07.pdf

- Conduct additional research into nascent factors including nicotine use, caffeine, alcohol consumption, and their potential impact on physiological effects experienced during incidents, and health and safety of wildland firefighters

- Evaluate how specific activities (e.g. hose lays, cutting line, hiking, etc.) are related to the resultant level of activity or exertion (as measured by the BioHarness or similar device) and the resulting effect on core temperature, heart rate, and hydration

- Continue to test and develop rapid, field-based protocols for measuring and monitoring hydration levels, heart rate, and core temperature of wildland firefighters, and novel strategies to identify, avoid, minimize and mitigate these issues

- Conduct studies related to core body temperature and the effects of acclimatization during initial attack, different shift durations, and during extended attack

- Study the relationship between hydration, core body temperature, and heart rate – specifically addressing the role that fluid intake (volume and temperature) plays in reducing core temperature (and heart rate), and identifying strategies and protocols to ensure adequate levels of hydration (and peripheral benefits) for wildland firefighters

    - Study the effects that extended attack has on the hydration levels of firefighters, and identify mitigation measures that can improve healthy hydration levels and rehabilitation on the line and when returning from the field

The following additional recommendations are provided to better inform agencies and policymakers:

- Fire agencies should create clear protocols to monitor and prioritize the health and safety of fire personnel in extreme environmental conditions, and evaluate the impact of reduced attack effectiveness and productivity on fire suppression efforts

- Provide long-term, longitudinal studies on cohorts of career firefighters, to understand how individual physiology, work duties, and exposure incidents may influence cardiac issues and long-term health effects

- As research on PPE continues, it is imperative that any new wildland/WUI ensembles be thoroughly tested in both laboratory and field conditions

- Research on PPE should emphasize collecting data on real world scenarios, prior to wholesale adoption of new garments by an agency, and should include assessments of factors including heart rate, core temperature, and hydration

- Evaluate the need and value of creating a hybrid PPE that can provide enhanced protection (beyond traditional wildland PPE) when responding to a WUI fire incident, and how this PPE may influence factors such as core temperature, heart rate, and hydration

6.0 Acknowledgements

We would like to thank the FEMA-Fire Prevention and Safety grant (EMW-2013-FP-00621) for their support and assistance with this project. In addition, we would like to thank USFS Director of Fire and Aviation Tom Harbor (ret.), James Fortner (USFS Cooperative Fire Program Manager), and George Broyles (USFS Fire and Fuels Project Leader) for their support. We would also like to thank CAL FIRE, Director Ken Pimlott, Executive Management, Chief Curtis Brown (representing CAL FIRE's Research and Development Program) for their partnership and support of this project, along with the nearly 100 firefighters that volunteered to participate in this study. Finally, we wanted to thank President Mike Lopez and CAL FIRE Local 2881 for providing additional logistical and technical support for this research project.

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WILDLAND FIREFIGHTER EXPOSURE STUDY:
EVALUATING CORE TEMPERATURE, HEART RATE & HYDRATION

CAL FIRE Local 2881
SYMPOSIUM

A Comprehensive View on the Future of Fighting Wildfires by a Team of Experts

2015

Written and Compiled by Dr. Matt Rahn and Terence McHale

Dr. Matt Rahn

Dr. Ma ver two decades of experience in applied sciences and policy, with an emphasis on environmental science, sta e science. Having earned both a PhD and JD, Dr. Rahn has focused much of his work on the interface between science and policy al, state and federal programs in collabora wyers, policymakers and scien ts on issues ranging from watershed management, endangered species, land use planning and renewable energy.

As a researcher and educator, Dr. Rahn has been involv e issues throughout his career. Results of this research have helped establish a benchmark for evalua onomic impacts from large-sc es and understanding the total economic burden. He has also led a sta tudy that bec st of its kind to address ho e ter sta ack e eness and health/safe e. He is currently leading a collabora Local 2881, CAL FIRE, US Forest Service, Interna e ters and the Na e of Standards and Technology. This research focuses e ter health and safety ocus on heat stress, heart and respiratory rates and exposure to air contamina es.

Terence McHale

Terry joined Aaron Read & Associates a er serving as Director of the California Fire Founda ant to the California Stat ee on Fire, Police and Emergency Services. Terry has worked with a wide variety of clients to write and lobby legisla anging from the crea ornia Fire ter’s Memorial to the line of consanguinity for heirs. In 2009, he was awarded with the Director’s Achievement Award on behalf of CAL FIRE.

t Aaron Read & Associates, Terry has interview en stories about such interes ornians as Clint Eastwood, Kareem Abdul Jabbar, Gary Condit, Governors Pete Wilson and Gray Davis and the great skier, Spider Sabich. Terry was made an honorar e ter in 2002 for his work in public safety. He has also been awarded the President’s Award from the California Dental Hygienist’s Associa ward from the California Athle rainer’s Associa TA) for the work he has done on their behalf.

Terry has maintained an integral role in managing both the paid and free media messages of campaigns.

A Comprehensive View on the Future of Figh y a Team of Experts

On June 16-17, 2014, CAL FIRE Local 2881 host st C*alif* *atewide Challenges Symposium* in Sacramento, California.

Community experts from the federal, state and local levels accepted invita o a end the symposium. Topics ranged from environmental change, to land management, t e ter sta fety.

The format consisted of individual presenta ollowed by roundtable discussions. No one arrived at the symposium with a pre-set agenda or a preconceiv te outcomes would be.

The idea was simple enough – allow the experts to honestly view the California landscape as it relates to es and encourage common sense conclusions.

The robust discussions were insigh

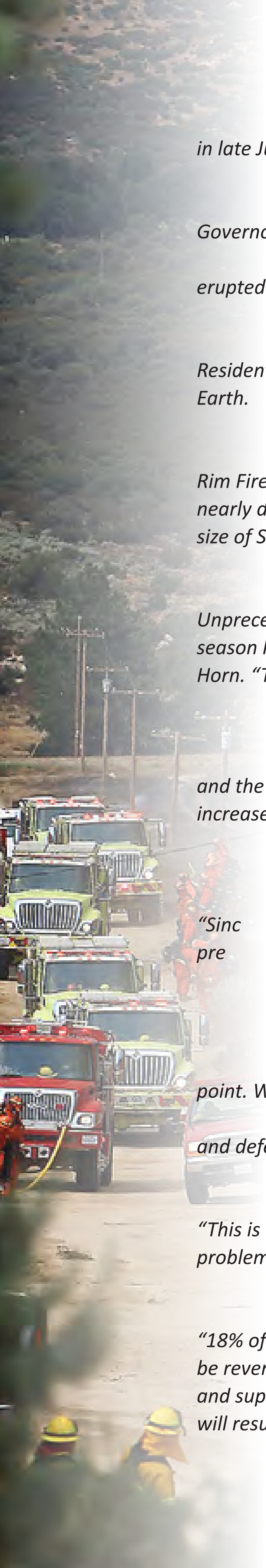
A universal conclusion was that urbaniza ofoundly and permanently changed the California wildland environment and that we are a genera trategies f e suppression and response when es. A concomitant view is that the risks ar terface is abrogated by increased development and natural factors such as drought and global warming, which contribute t vit es that singularly would once have been viewed as cataclysmic.

Costs a ed t es are staggering. An economic s es in San Diego County alone in 2003 and 2007 es ted costs at $4.5 billion and that does not include incalculable, indirect costs, such as lost workdays, business shutdowns, watershed losses or decreased tourism. The economic costs far exceed the cos es.

> *ed consultant to the State Senate Natural Resourc ee, said, " ost $3 billion a year at the federal level, which is half of the Forest Service budget now being spent on suppression. It used to be 15 percent in the 1990s. The economic losses are no y were in the 1980s."*

As more resources are being directed towar es, fewer may be available for research and preven orts.

A failure to develop a strategy f es that includes coopera tween stakeholders, budget a al vagaries and social and business structuring is an invita o disasters that will be devasta t. Lives will be profoundly disrupted and tragic impacts will be felt by public safety and the general public.



on o burn out of control throughout California. Man ed in late June by dry lightning and made worse by parched c all."

~ **NASA, July 1, 2008**

Governor Arnold Schwarzenegger declared a state of emergency…as Santa Ana winds con o whip t open and the hillside looked like a volcano had just erupted ….looked lik wing down the hill.

~ **San Francisco Chronicle, November 16, 2008**

Residents Evacuat t ornia Flames Scorch Dry Earth.

~ **CNN, August 13, 2012**

Rim Fire Hits Yosemite and Explodes into One of California's Larges uolumne Coun nearly doubled in size overnight and stretched over 125,620 acres, or 196 square miles – larger than the size of San Jose.

~ **San Jose Mercury News, August 23, 2013**

Unprecedent ornia: The Januar season have come true … "I've been doing this for twenty years," said San Diego County Supervisor, Bill Horn. "This is the worst I have seen."

~ **CNN, May 16, 2014**

at Up Forest Service Budget, Hampering Preven os ornia and the western United States has skyrocket xpenses have increased from 16% of the Forest Service Budget in 1995 to 42% in 2014 ….

~ **Robert Bonnie, Undersecretary**
Natural Resources and Environment for the U.S. Dept. of Agriculture, March 4, 2015

"Sinc tern United States increased fourf o the pre een years."

Dan Cayan, Research Meteorologist
UC San Diego's Scripps Ins eanography

est and I worry that we are ge point. We have a billion burnable acres in the United States and 250 million of those acres are at risk. 15 ed problem that will not rise to other issues like budget and defense, but it is a bad problem ge "

Tom Harbour, US Forest Service

"This is not jus 's a development problem, a land-use problem and an ecological problem."

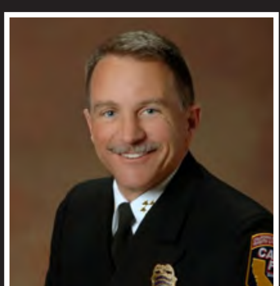
Kevin O'Connor, Int ters

"18% of the country's wildlands are developed and the movement into areas once open and wild will never be reversed. Our goal is a consolidated e ort between all levels of government as we implement preven and suppression measures to protect the lives and property increasingly at risk. Failure to act responsibly will result is economic ruin for c e."

Mike Lopez, President, CAL FIRE Local 2881

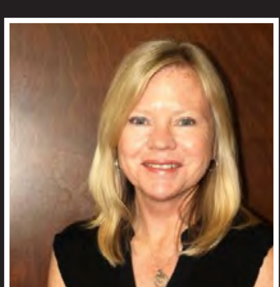
Quotes by Symposium Attendees

Mike Lopez, President CAL FIRE Local 2881: **"When Rick Swan and I sat down to plan the Symposium, our goal was simple – We wanted to get beyond the posturing and hyperbole to begin developing a realistic wildland fire plan for California and the country."**

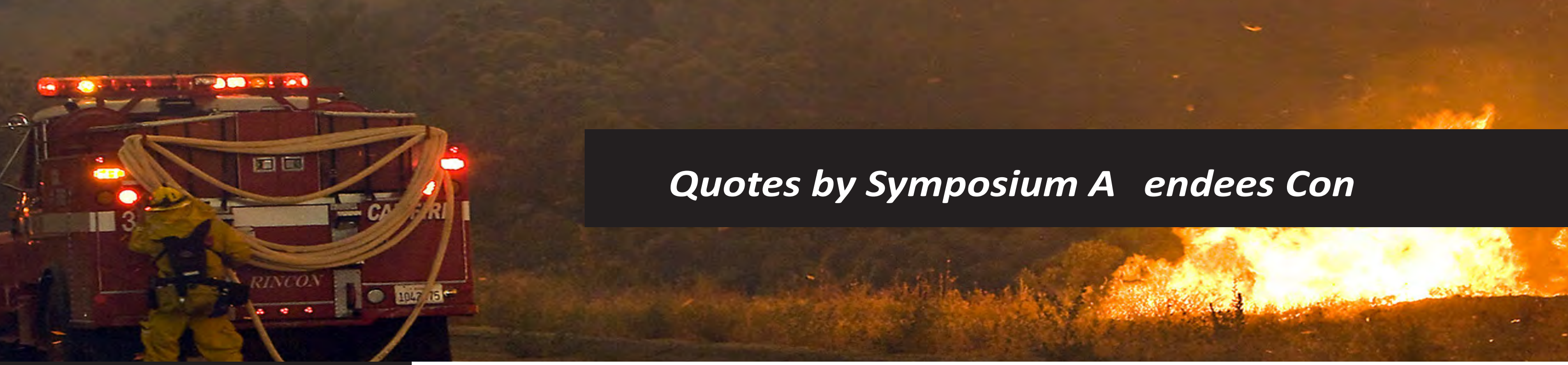


Ken Pimlott, Director of CAL FIRE: **"We keep going down the paradigm of let's throw more stuff at it. But when you look at the cost of rebuilding, it doesn't matter how much you throw at it, you're still going to lose all those things… Go to the Oakland-Berkeley Hills. They rebuilt exactly the way it was. The roads aren't wider and the vegetation is twice what it was."**

Kevin O' Connor, International Association of Fire Fighters (IAFF) Governmental Affairs assistant to the General President:
"Any firefighter west of the Mississippi and south of central North Carolina is going to be a wildland firefighter at some point in their career. Even New York City last year had some significant events."



Karon Green, Chief Consultant to the Assembly PERS Committee, answering a question about encouraging the Legislature to enact policies: **"I look at it as...How do you get it proposed for funding? The more research you have to back up your asks, the more weight it carries."**



Quotes by Symposium A endees Con

Rex Frazier, Personal Insurance Federation of California (PIFC): **"The Insurance industry is looking to firefighters for assistance as we begin to assess a future with fires no one would have predicted possible a decade ago."**

William "Bill" Craven, Chief Consultant of the California Senate Natural Resources Committee: **"A couple of numbers jumped out at me. One is that in California so far, we've had 1,100 fires of various sizes, two times the yearly average. The second is a statistic from NASA… 30 to 60 percent higher projections for fire numbers by the end of the century...Seventeen percent of the California WUI is developed with housing. As population pressures increase, the rest of that WUI is going to be subject to potential development. That is going to make things very dicey in terms of fire policy."**

Tom Harbour, Director of Fire and Aviation Management for the U.S. Forest Service: **"We don't think far enough down the road about how we are going to get out ahead of this wildland fire problem. We can't cut our way out of it and we can't one-more-air tanker our way out of it. It's too big. Choices are going to have to be made. If we don't make them, folks outside of us are going to make them for us….25-year-old staffers on the Hill are going to be making decisions…unless folks like us get together and say, 'We have some ideas.'"**

Deputy Chief (Ret.) Rick Swan, former member of the CAL FIRE's Personal Protective Clothing Committee: **"This whole issue of wildland firefighter PPE (personal protective equipment) and heat stress and smoke and particulates are in such an infant stage of what we should know. We don't know what we are breathing in and how it's affecting us, how that comes back into our bodies. We know what's going on in structural stuff, but what about the intermittent CO exposure? We don't know what that does or how that affects us. We flat out don't know."**

Quotes by Symposium A endees Con

Nelson P. Bryner, Chemical Engineer Leader for the National Institute of Standards and Technology (NIST): **“I think the fact that WUI is a problem has not received much attention until recently. ‘America Burning’ started us down a path that we are still on with 40 years of science. We don’t have 40 years of science for the WUI side.”**

President Chris Mahon, President of Ventura County Professional Firefighters Association: **“Ventura County has had an aggressive prevention program for 30 years. We’ve been working with property owners for a long time. It was difficult program to start, but now it is ingrained in our department. We get great compliance. New people are often skeptical of our program until they experience their first wildfire. Once they have lived through one, they are the first ones out there saying, ‘Hey, can you come tell us what to do?’”**

Dr. Dan Cayan, Scripps Institution of Oceanography (SIO): **“We cannot escape the relationship between a more volatile fire environment and climate change. It must be addressed. The impact on fire safety is significant.”**

Dan Silver, MD, CEO of the Endangered Habitats League: **“Fire departments, from my perspective, facilitate the continued expansion of the WUI by checking boxes. ‘You build it and we’ll defend it.’ Somehow that chain needs to be broken.”**

George Broyles, Fire Test Leader, U.S. Forest Service: **“The landscape in the West has changed quickly and become more susceptible to the conditions which lead to wildland fires.”**

INDEX/DEFINITIONS

CHANGING NOMENCLATURE OF CALIFORNIA FIRES

Fire Season: An an ted term that refers to annual discrete periods where pa erns of temperature, precipita facilitate c es; modern trends indicate that the nomenclature be changed to "**Fire Year"**

EHL: Endangered Habitats League

IAFF: Interna e Fighters

LRA, SRA, FRA: Local-, State-, Federal Responsibility Area

NIST: Na e of Standards and Technology

PIFC: Personal Insurance Federa California

USFS: United States Forest Service

Wildland Fires: This term has become a misnomer. Fire is no longer isolated to wildland ar es now impact highways, houses, businesses, et ely referred to as a wildland urban interf e **(WUI**)

WUI: Wildland Urban Interface

ornia foothills, and the const caused was front page news. People were alarmed. In the last few years, we have grown accustomed to stories of thousands of acres being burned and incomprehensible loss. (Tom Harbour US Forest Service, June 16, 2014)

STATUS AND TRENDS

Since the 1970s, our na ease from three million to an overwhelming seven million acres burned each year – with further increases projected.[1]

The Oakland Hills Fire in 1991 placed an orange glow in the sky that was unfamiliar and, at least momentarily, frightening for Californians. Fire ters who responded have said since then that we "dodged a bullet" as the e nearly escaped into total catastrophe. This singular event exposed ine t we have allowed to con sequent two decades. Recen es hav o strain the great trust that our e ters, the best trained and educated in the world (and certainly not short on courage), will be able to put es.

Given the complexity of our c e ters will, at some point in their career, respond t e in the Wildland Urban Interface (WUI). In the conterminous US, the WUI covers 277,668 square miles and has approximately 45 million housing units.[2] The WUI is widespread in the eastern US, reaching a maximum of 72% of land ar est, California has the highest number of WUI housing units of any state (5.1 million). Between 2007-2011, loc e departments responded to over es each year.[3] There are approximat e ters and 3 e departments in the US.[4] Conserva ely speaking, if roughly 9% of the U.S. is part of the WUI, then at leas e ters are regularly involved in WUI and wildland incidents across 2,709 departments. Despite this, many of these e ters do not generally consider themselv e ters.

The sta e staggering. In Calif es are natural events, meaning that well over es are the r . Of these events, one in six engulfs transporta infrastructure and one in ten includes some type of structure (about 3,000 homes are lost each year in the U.S.)[5] Sadly, 2014 was a hit in the gut when 34 wildla e ters lost their lives. As a result, emphasis has ed from "tr e " to structure defense in the WUI where over 40% of our homes are now located.[6]

If trends con oeful problems associated with drought and global warming suggest the trend is inexorable, it is conserva ely predicted that larg es (de es or more) will increase nearly 35% by 2050 and an alarming 55% by the end of this century.[7] Future decisions on development and management of the WUI ar al in determining future vulnerability and risks. The par om wildland to WUI e ansformed conven

Tr e studies focus on the three broad categories: wildland, structure and vehicle. Each incident type comes with dis e exposures, hazards and risks with protocols, t o each e represen aceted incident where these incident types merge. Fire ters may respond t en focus on community defense where structures and vehicles can become involved. The ev es and the complex matrix of land use and development suggest that this is not only a common scenario, but is a virtual certainty. As a result, we are experiencing a tr om a “tr e (wher e ters and c y be reasonably prepared and protected) to an incident with diverse risks and consequences.

We need to change the way our society think es.

The discussion during the Symposium focused some on the disconnect between the various levels of government. Immediately problema t the same mistakes keep being made. Much of this is ascribable to the curious fact that the federal government does not have an independen e service with an autonomous, opera t person taking charge and assuming the demands of leadership. The federal responsibility f es is sca ered through too many bureaucracies, and too many agencies.

As men eviously e ters consider themselv e ters. Consequently, the training f e an be marginalized both in terms of importance and budge an also be exacerbated by the distances perceived between a forester and a e ter.

e service can some acterized as 100 years of tr unencumbered by progress. For example, Ed Pulaski creat e ool that carries his name, the Pulaski, more than 100 years ago. If Pulaski had been a soldier a century ago, he would not recognize the modern way we conduct war, but sadly his f e trategies and tools would be immediate.

The internecine issues inheren e e problema ers construct a coheren e an be expected to list e ters provide a linear narra e, but a cacophon e specialists providing con es' only adds to the problem. We could resolve many of the problems if we develop a list of ideas as a step toward establishing public policy.

At the end of this document, we will provide a series of ideas that will str e policy and result in more e e prot operty, greater security for our neighbors, and increased health and safety for e ters.

"A couple of numbers jumped out at me. One is that in California so far of various siz ond is a st A … 30 to 60 percen y the end of the century … seventeen percent of California is WUI de t of that WUI is going to be subject to poten velopment. That is going to make things very dicey in t ." ~ William Craven, Chief Consultant, Ca.Natural Resourc ee

BEHAVIOR OF FIRE IN CALIFORNIA

The t e season" has become archaic in the public safety lexicon. The mission has changed due to environmental reasons and the widespread development in previously pris eas. The idea of seasonal e ters ma e realize that the vast es (over 95% in California alone) are the result of human causes rather than natural events. We should also be asking wh e ters fall under the aegis of the Department of the Interior, the Department of Agriculture, BLM and others in a piecemeal approach t es at the federal level. The Fire Service as a professional partner is not there with the U.S. Forestry; and while no one is accusing anyone of anything nefarious, the idea of benign neglect wading toward incompetency is men

Large-sc es hav ant, overlooked ec en exceeding billions of dollars in losses. In the conterminous United States, there are over 45 million homes in 70,000 c WUI[4], with the annual cos es exceeding $14 billion.[8] E e has a unique personality and concomitant economic impacts. In California, the most alarming trend is that half of the twenty larges es in California's recorded history have occurred in only the past decade, with many of these events having an unprecedented physic o the state. The economic, social and environmental costs of es ar en staggering.

For ex e event that consumed much of San Diego County became one of the most cos e incidents in California's history. With three c es (Cedar, Paradise and Ota es consumed a total of 375, 917 acres, 3,241 homes were lost and, sadly, 16 people lost their lives, including e ter. A es, 6,635 crew wer es. The Cedar Fire is s gest recor e in California's history (at over 280,000 acres).

In a comprehensive economic impact assessment, the total ec es in San Diego County is es ted at over $2.45 billion.[9] This equates to a cost of over $6,500 per acre. Surprisingly, the total suppression costs amounted to ***less than 2 percent*** of the en e economic impact, a rela ely negligible cost in contrast to the overall loss. Major categ frastructure ($147.3 million), ecosystems ($61.2 million), lost business and tourism ($365.5 million), unemployment insurance ($400 million), FEMA disaster loans ($170 million), FEMA grants ($137.5), insurance claims ($1.2 billion), and increased medical costs (mainly respiratory/pulmonary cases - $10.7 million). In 2007, San Diego County experienced another large-sc e siege, cos onomic losses.

More recently, the Rim Fire from 2013 became the third larges e in California's history having burned over a quarter-million acres in the Sierra Nevada Mountains near Yosemite Na ark. Over a year passed before e w ed "out" due to a lack of winter rains and several deep-interior inaccessible areas that con o smolder. In comparison to other large-sc es in California, the Rim Fire had rela ely few structures lost (11 residences, 3 commercial buildings, and 98 outbuildings). Bec an resources and ecological value of the a ected area, total economic losses neared $1 billion. In comparison with es in the state, suppression costs were staggering ($127 million or nearly 14% of the total economic loss). Had the Rim Fire reached the Hetch Hetchy reservoir (the main water supply for the Bay Area), economic losses could have made this one of the mos vasta es in the world (see below for further discussion on water resources).

While these case studies provide an interes ecent, large-sc es in California, actual economic and social impacts are not adequately addressed. Further, it does not account for the total losses in ed on our state fr es (both large and small). Finally, not all of the economic impacts or losses are captured in these analyses. It is rela ely easy to quan y economic losses in terms of property, buildings, infrastructure, goods and suppression costs. It is mor o quan y the long-term costs to health and welfare (for both community member e ters), ecosystem services, watershed and water quality degrada . Regardless, we now recognize that large-sc es have become commonplace; the frequency and int es is increasing and the r onomic and societal impacts ar ant.

Experts at the Symposium highlighted that what we don't kno es may exceed what we do understand. Nelson P. Bryner of NIST said they lack data on the WUI. For ex es we know kitchens are the number one loca t fat e caused by upholstered furniture. In the WUI we don't know if its wood shingles tha st ignite or the walls and the lack of reliable informa a e impact on how we plan to a ack.

NIST studies provide some evidence that wooden decks ar t, yet we don't know how many embers it takes to ignite a deck. NIST conducted some wind tunnel experiments and discovered if the embers are spread out, they blow away and won't st e. As studies mature, the idea of how we build a deck will change.

SYMPOSIUM DISCUSSION

Awar es as an issue has never been greater in our country's history than now. What were once generally considered issues of the West are now na ecognized as an increasing threat to all of our c osystems. As a result, the t e' has become a bit of a misnomer. Large es frequently threaten homes, businesses and liv ocus to structure defense. Further exacerba w paradigm is emerging: we are witnessing a drama equency and int es due to a variety of factors, most of which are human-caused.

As our popula ows, decisions on developing and managing the WUI will determine our vulnerability and the risk e ters and c oughout the United States, an ongoing debate is ensuing that ques e ter sta , resources, response protocols and land managemen al decisions are driven by such malleable and extrinsic factors as public percep environmental concerns and budgetary constraints. As a result, decisions can be made without adequate empirical support or understanding of the issues, r onsequences t e/WUI response, community safety, a ack e e ter health and safety.

e esponse and e eness has vastly improved, many of the most basic issues have not been researched and considerable uncertainty remains. As a r es have not kept pace with the advancements seen in structur es. In 1973, the Na Fire Preven trol published a report that was the result of nearly two years of work. Findings and recommenda om this report served as a catalyst f ant changes and advancements in our urban e sector. The results are nothing short of miraculous, especially when you consider that the U.S. popula has increased by about 100 million people, with corollary increases in buildings and homes.

Table 1. Tr es, deaths, injuries, and dollar loss in the United States.

Category	1971[10]	2012[11]
Deaths	7,570	2,385
Property Loss (Adjusted for 2012 dollars)	$12.85 Billion	$7.10 Billion
Number of Fires (structure)	996,900	374,000
Injuries	Tens of Thousands (es te)	13,050

**Data based on Appendix V, America Burning, the Report of the National Commission on Fire Prevention and Control (1973)*
***Data based on US Fire Administration statistics (http://www.usfa.fema.gov/downloads/pdf/statistics/res_bldg_fire_estimates.pdf)*

Unfortunately, c ts at the symposium es te that analogous advancements in es are easily decades behind structur es. For example, we are only st o understand how sta ack e es, yet we do not fully understand the poten s tha e ters face, including exposure to carbon monoxide and hazardous air pollutants. Further, although there are a variety of progr e sciences, they tend to focus on structur e administra e technology e science and educa ograms remain under represented in the e services industry and our educa

The result of the America Burning Report (1973) provided several broad recommenda or wha tely seems to have been a successful na ogram. It is worth highligh ey points here, as they can easily be adapted to meet the wildland/WUI agenda and coincidently follows closely with many of the recommenda t emerged from this symposium:

Table 2. America Burning (1973) key recommendations

There needs to be mor e preven
e services need be er training and educa
Americans must be educat e safety
In both design and materials, the environment in which Americans live and work presents unnecessary hazards
e prot eatures of buildings need to be improved
Important areas of research are being neglected

Again, the purpose of this symposium is to highligh al areas of need and discussion for wildland and WUI es in California (and the United States), and help advance public safety, community prot e ter health and safety. We need to begin a statewide and na e issues that receives the same a en ta t resulted from America Burning (1973). Genera dialogue and awar e issues could have a galvanizing a ect across California and the United States, r tal, economic, and environmental bene

Much like America Burning, the recommenda ein are simple, straigh orwar . Our goal is to highligh al needs (a ers are focusing more carefully on costs), address long-term planning and land-use change and recognize our changing demographics. We need to answer the ques how we are going to con ot amilies, c e. The results of the symposium are provided below, organized int e areas: Climate and Environment, Land Management, Resources and Infrastructure, Fire ter Health and Safety and A ack E eness.

CLIMATE AND ENVIRONMENT

"Wildland re service in the West is s ll based on what used to be a limited re 'season.' But climate change is expanding the 'natural' season, and there is no season for human-c s."

For thousands of years, the frequency and intensity of natur es shaped the dis con a orests and grasslands in many parts of the United States. Ov y of our ecosystems became adapted t es with some plant and animal species becoming dependen e as part of their natural history. However, modern catastr es ar an erent from the historic e regime in California. Today, only a fr es we experience in California are caused by natural events.

As described earlier es can have major economic consequences with large-scale incidents and through aggregat es. Much of that economic toll occurs in our ecosystems where the services that they provide are lost or degraded. According to our panel of experts, the two areas of greatest concern are impacts to our watersheds and air quality. Other key areas include habitat losses, impacts to endanger e species and the r eases in invasive species pos e.

Status and Trends

ally, scien ts have linked climate change to the amount of carbon dioxide in the atmosphere. It used to be 280 parts per million of CO2 concentra -Industrial Rev oday it is around 400ppm. By the end of the century it will be even higher as explained by Meteorologist Cayan.

Iden ying Need f

As more than one speaker not es were a wicked pr e death toll was averaging 9,000 a year. A federal blue-ribbon commission tackled the issue and produced the landmark America Burning Report. In the 40 years since, that r e service and led to be er scien st es in enclosed spaces, be er safety gear f e ters, mor e-resistant building codes and be er preven orts and equipment. As a r e deaths in America have been cut by two-thirds, even as the popula xpanded.

WATER RESOURCES

The rela tween our na s water resources and our wildland areas cannot be overlooked. According to Tom Harbour, probably one of the highest risks lies in watershed management and water quality. Economic assessmen e the majority of the funds allocated to our ecosystems tend to support watershed restora ograms. For example, a er the 2003 Cedar Fire, FEMA provided over $47 million in watershed restora ar a orts. P funds were used to restore habitat and control the poten ollowing winter. It will never be clear how much funding private landowners, tribes and municipal en t on er ontrol measures, but we know this was an extraordinary expenditure.[9]

These impacts pale in comparison to the poten t could have occurred during the 2013 Rim Fire. Poten o the Hetch Hetchy reservoir put at risk the main water supply for the San Francisco area, servicing over 85% of their water needs with over 2.6 million customers. As a prec y measure, the San Francisc erted water from Hetch Hetchy to downstream reservoirs in San Mateo and Alameda coun wev ver $116 million for supplemental water and electrical services as a r ted that if the Rim Fire had actually impacted their water infrastructure, economic losses would have been between $100 and $736 million. We rely on these pris atersheds for a large part of our state and na water supply. We cannot a ord to ignore this risk.

Finally e is a very serious threat. There is a possibility tha e created a hydrophobic layer beneath the surface, increasing the chance of a landslide in subsequent rain events. The lack of aboveground vegeta ompromised root structures can also lead t

AIR QUALITY

Second only to watershed impacts is the threa es have to our air quality. The e ects of smoke exposure on the body are diverse and cover a range of c ye and respiratory tract irrita o more serious disorders, including r xacerba thma and premature death. Concrete data is not available for calcula otal health impacts fr es, but it has been es ted at over $10 million in health care costs for a single large (500+ acres) incident.[9] During the Cedar Fire in 2003 (California's larges e on record), hospitals e antly higher than average numbers of complaints from local residents for illnesses plausibly associated with exposure t e or smoke such as asthma, burns and respiratory distress. There was also an increase in poten elated complaints such as altered neurologic ardiac-related chest pain and palpita [12]

The physical e ects associat e are a result of the types of pollutants found in the smoke, which can be unpredict e fr es is a highly variable and complex mixture of CO2, water vapor, CO tes, unburned fuel, polycyclic aroma ydrocarbons (PAH), nitrogen oxides, trace minerals and diverse toxic cons ariables such as fuel type, moisture content, temperatur erent types of wood and vegeta ontain cellulose, lignin, tannins and other polyphenols, oils, fats, resins, waxes and starches that pr erent compounds when burned, some of which are hazar es bec es, man-made materials (once ignited) release a variety of chemicals, many of which are considered carcinogenic and highly toxic. The c chemical mixture is largely unknown during various stag e, and hazard assessments and decision-making cannot adequately account f e ter and community risk.

CLIMATE CHANGE

Climate change impacts are a growing concern, not just because of the poten eases and risks of es, but also bec es ma ant contributor to carbon emissions. For example, the es ted GHGs fr es in California were roughly 200% higher than the annual car emissions for those same years, or the equivalent of adding 50 million vehicles to the state.[13] In fact, the amount of carbon released by the dead and decaying trees (pos e) may emit more carbon into the atmospher e event itself.[14]

In an analysis of the western United Stat es hav antly incr clima e have combined to produce more frequent and int es while also increasing the over e season.[7] California is also considered a climate change hotspot likely to experience higher than average impacts when compared to the rest of the United States.[15] lty in managing the drama e frequency and intensity over the past decade suggests that historic management and response pr e inadequate.

Recent research suggests that regional temperatures in California may increase from 1.7 C to 5.8 C by 2100, depending on the climate model used and the emissions scenarios assumed.[16] This of course leads to an increase in the number of days of high or extr e risk (as assessed b e risk warning syst tely e season may be longer in California, with predicted increases in the number of Santa Ana wind days under future climate scenarios.[17]

In fact, recent research suggests tha e seasons are already longer than they were historically.[17] There is more uncertainty about how California's future precipita erns will be in y climate change. It is generally predicted that most precipita ter mon or no predicted changes in the total annual precipita wever, most studies suggest that there may be considerable changes in inter-annual and dec ecipita [16] Future climate scenarios also predict decreases in snowfall with more of California's annual precipita oming from rainfall.[18] As the climate warms, the snowpack in the mountains will melt faster, c o happen earlier in the year tely means that the availability of water for vegeta antly reduced during the dry seasons (spring through fall) leading to decreased fuel moisture and incr e risk.[7]

Increased frequency of lightning may occur as a result of climate change.[19] This, of course, has direct implica es that we may already be experiencing. In 2008, ov es were started by over 6,000 dry-lightning strikes in Northern California. The record number of lightning strikes and extreme drought c eated catastrophic c t burned nearly 1.2 million acres, destroyed over 500 structures and killed 15 people.[20]

INVASIVE SPECIES

Biological invasions have been characterized as “self-regenera ”[21] Whether inten accident an be thought of in much the same way as wat [22] Unfortunately, reducing or controlling invasive species requires a dis erent strategy because of:

- The economic value, tr t depend on or involve invasive species
- The diverse entry points or pathways for intr
- Poor understanding of na a, making iden a vasiv
- Problems knowing which species may become invasive
- t t be regulated to combat the problem, like tr oaches to deal with invasive species are similar; they include preven ost recovery (polluters pay a penalty), and pr e or regulatory legisla [23]

es may also augment the current spread of invasive species. This occurs when the normal disturbance regimes under which the na e community evolved are altered. Throughout the western United States, we have witnessed the spread of invasiv asses, which chang e frequency and intensity and shorten the return interv es. This results in a feedback loop wher es advance the spread of invasiv tely leading to a type-conversion of the habitat to a nonna e dominated ecosystem.[24,25] Beyond non-na e grasses and noxious w eats may exist in increased infesta ain beetle species and other insects or pathogens that can decrease ecosystem health and incr e risk. While many of these pathways and rela s are s ves ated, one thing is clear: invasive species must be dealt with in our long-t e management strategy.

The impact to ecosystems is largely uncertain, however some changes are likely. For example, some insect species ins at e risk c egeta ality from insects and pathogens can become a ant contributor t e risk.[26] Further, insect infesta thogens are predicted to increase as a direct result of changing climate.[27] This occurs because future climate scenarios may actually enhance the survivability and spread and by reducing overall health thereby making the biological community more suscep o damage or disease.[28] For example, increasing the winter temperatures in the Sierra Nevada Mountains could make c e suitable for pitch canker, r eased disease and economic losses.[29]

at and Endangered Species

In many of the economic assessments on large-sc es, ecosystem impacts and endangered species antly into the loss es tes and recovery costs. Futur e management plans and response strategies must account for na e habitat and endanger e species.

LAND MANAGEMENT

Land use change and urbaniza easing development into the WUI seems divorced from natural processes and ecosystems. Much like our historic development in the high-risk areas, lik we con o expand our homes, business and infrastructure into the WUI without rigorous constraints or societal acknowledgment of the risk. There seems to be a disconnect between the risks created by our land- te costs incurred by local, state or federal governments.

CAL FIRE is a world-renowned emergency response agency dedicated to prot ver 31 million acres of wildland in California. Today, their role has expanded to cover over 350,000 calls a year for non- e related incidents, including medical aids, hazardous material spills, s ater rescues, search and rescue, es and more.[30] However, when budget r e proposed, the focus is typically on es rather than other areas of CAL FIRE's responsibility.[31] In recent decades, our Governors, Legislature and Legisla e Analyst' ve suggested strategies for coping with the budget impact, focused on e prot ate Responsibility Area (SRA). Generally, these proposals emphasized the development of a new fee for pr ated within the WUI/SRA.

The original goal was to create an SRA fee program t set the roughly $200 million cost of CAL FIRE's e prot esponse budget. However, increases in major disasters and a failing economy led to a substan erent progr al year, the newly implement e preven fee program collected $74,978,000, and spent $58,765,000 on preven administra edly, this program is s tages and the long-term results have yet to be realized. However, the high cos es con ant r state's opera et.

FIREFIGHTER HEALTH AND SAFETY

"Let's review together the combined resources in place for preven "

"There are huge ine w to exist."

"We have allowed benign neglect to become overall incompetence."

"Because of budge ters are being asked to do more with less."

Status and Trends

The ability to e ely comba es is inextricably linked to c e ter health and safety. Ag e industr antly lags behind structur e or example, a considerable amount of research has addressed CO exposure and risk in structur e incidents with aggressive outreach and educa ampaigns.[32] However, analogous research programs on WUI and wild e incidents are more limited. As a result, there is a serious de ent underst e pr and e ter health and safety. Fundamental uncertain based on our fragmentary understanding of the rela s between resources, land management and environmental c eates a situa which sound and well-informed decision-making is extremely challenging, if not impossible.

While smoke exposure a es and prescribed burns can be no more than a nuisance, on occasion it approaches or exceeds legal and recommended occupa xposure limits.[8]
Air Quality abov es create a highly hazardous, carcinogenic and toxic environment for

e ter es become more commonplace, we are recognizing that many safeguards for structure and v es are not part of WUI standards. Customary protocols and personal prot e equipment (PPE) may actually be incompa y situa or example, extended duty on many wildland/WUI es means that an SCBA could provide only a fr ot device is further limited simply due to the physical constrain e t , turnout gear for structur es is designed to a ord adequate prot or an interior a ack, not the exterior a ack more typic e vy, urban gear induces serious heat stress for e ters c xterior or vegeta e suppression. Proper WUI safeguards are impera e.

The typical r e ter are also a leading contributor to the health risks they face. Fire ter en go from a state of sleep to near 100 percent alertness and extreme physical ex a ma er of minutes. When combined with the heavy equipment and gear they carry through extended periods of intense heat and brutal environmental c e ters experience the limits of what the human body was meant to withstand. Repeated exposure to these c an lead to cardiac arrests, where the heart's electrical impulses become rapid (ventricular tachycar entricular [33]

All of the studies from the 1970s to present look at v es, structur es as though they are isolated incidents. But in California, you would be hard-pressed t e (a point made at the symposium by Dr. Ma om California State University San Dieg e ter goes in with standard gear and no SCBA and yet we don't know the answer to the basic ques ou're standing 20 feet from the burning vehicle, what are you being exposed to?

e ter ering from dehydra s to be on the rise, yet the reasons have not been delineated, studied or reviewed at length. The reason may be as simple as the fact that e ters are drinking sports drinks instead of water. NIST points out that we have not yet developed to test for hydra

Studies are now being conducted on the long and short-term e ects of exposure to carbon monoxide, but researchers are hampered by the inability to measure the exposure in r e ter moves in and out of smoke. The roundtable discussion at the symposium triggered concern over the r a xposed to CO and the subsequen e ter to think clearly and act decisively. Poten , a risk management decision is being undermined because people aren't thinking clearly.

Iden

Advancements in technology and assessment methods can help us understand the rela tween the harmful e ects of CO tes, hazardous air pollutants (HAPs) and other threats tha e incident. We need to understand the actual exposure and risks our c e ters face during a e incident. We need to understand how the response, training and prot otocols can be improved to enhance the health and safe e ters and our community. This not only helps protect the e ters, but also contributes to improv ack and response e eness: a health e ter is an e e ter.

ATTACK EFFECTIVENESS

"It is a tribute t ters that, under such extreme c ontrolled quickly"

Status and Trends

Emergency response e eness is driven by four factors: 1) land management pr xis environmental c t resources available t e ters dispatched to an incident. When one variable is unbalanced (e.g. extreme environmental c t sta esult is an inability to e ely cont es.[34]

The availability of adequate resources and sta o comba es also has a direct impact on mee e suppression goals. Suppression failures generally happen when the resources available f ack response are ine t at contr e. This c e esources throughout a region are spread too thin due to excessiv te resources are not pro t the outse e event.

Rahn (2010) conduct s e sta tudy t ack e eness under various sta vels and environmental c ally, the results suggested that by increasing the number e ters on an engine, the e , e eness and the overall ability to poten ontrol a antly increased, thus enhancing emergency response and the ability to protect California fr es. This preliminary study also has serious implica e ter health and safety.

The most st erence was the peak heart rates recorded by a 3-0 engine. During these trials, these e ters traveled nearly ½ a mile longer than a 4-0 engine on the same 2,000-foot hoselay. Furthermore, e ter to a 3-0 engine resulted in faster comple t were up to 50 percent faster. Fire ters on a 3-0 engine also sustained peak heart rates of over 220 beats per minute, well beyond acceptable limits, increasing the risks of complica achycardia. It should be noted tha tudy was conducted under "ideal" c ornia, lacking the intensity, heat and stress that a e creates.

Current research conducted by Rahn (2014-2015) has demonstrated that real-world scenarios are far more serious. Monitoring Calif e ter e incidents has shown tha e ters regularly exceed safe physiological c y individuals sustained peak heart rates above 220 beats per minute, had core body temperatures well above 102 degrees fahrenheit, demonstrated excessively rapid respiratory rates and were exposed to CO levels well beyond occupa ach factor c antly impair a ack e eness, let alone ha e ters experience all factors simultaneously.

NEXT STEPS AND RECOMMENDATIONS

Iden

It is impera e that we improve our understanding of how sta , resources, t echnology can improve a ack e eness.

- We must increase programs that focus on preven ove educa wareness of homeowner responsibility in the WUI. These programs cannot con e serious discussion on how we manage and expand into the WUI.

- We must create a comprehensive policy and management program that adap ely and scien ally informs when and how we suppr es, allo es to be a natural part of the landscape, allows for future developmen e-safe resilient c ovides for ecosystem and watershed-level prot

- Address the issue of inter- and intra-agency coopera t to navigate the LRA, SRA and FRA. We need to address the diverse land managemen e response pr tween and among agencies, the funding mechanisms f e preven esponse and the alloca resour e ters at a local, state and na vel. This discussion should include the concept of a consolidated feder e agency.

- There is a need to create a comprehensiv e/WUI educa aining program that meets the diver e agencies with an emphasis on providing new tools, technologies and opera trategies to meet the evolving risks and demands.

- Develop a be er understanding of future risks related t es and create pr e (rather than just r e) programs to address key areas such as drough , Santa-Ana wind events, landslides, etc.

- A change in the frequency, intensity and dis es has, and will con o occur throughout California. It is impera e that we acknowledge this change and iden y ways to avoid, minimiz ate the risk and impacts.

- We need to develop a long-t e ter health survey that addresses key factors associated with exposure and injuries and a be er understanding of the short- and long-term consequences.

- We need to improve funding for research, especially in key areas that can help improve situa awareness, environmental monitoring (e.g. exposure and risk), communica ot e equipment.

- We need t e ters understand when they are experiencing compromised decision-making (related to factors such as stress, heat, CO exposure, dehydra tc.).

- We need to ensure that policy and decision-making is informed by good science and informa triking a balance between theore al, applied and basic science).

- We need to address ment e eas related to post-trauma tress disorders and suicide rates.

- We need to develop a be er tool for hazard risk assessments f es and implement land management that pr ely protects and plans accordingly.

- We need to understand how the incident command and/or other remote opera an be er serve e ter e ough enhanced monitoring, situa wareness and biometrics.

- Iden e programs that address issues such as greenhouse gas emissions, climate change, ecosystem management, invasive species removal, watershed management, habitat conserva and endangered species programs can align with and facilitate landscape level management for wildland/ es.

- Improve communica oordina tw e and insurance agencies.

- Ensure that current and future regula odes are supported by the best available science and underst

- Improve the communica esearch and technology t e agencies and decisionmakers.

- Improve our understanding of how and where small scale proscribed burns can be a useful management tool and iden e this can assist in improving habitat and ecosystems.

- Work with the building, insurance and development industry to help iden y and implement the best pr able design and materials for cons or retr requirements for resale and/or reconstructed homes within the WUI that do not meet current standards.

- Iden y poten or tax and/or insurance incen es for homeowner preven management programs within the WUI.

- Dev e impact assessment tools that accurately captures the total loss, as well as the “saves” that occur due t e suppr

- Develop a clearinghouse for informa e ter health/safety.

- Create a center or group that can provide independent expert analysis on policies, laws and regula related t es and emergency response services and how they relate t e response agencies and e ters

- Advocate for Blue Ribbon Commission on Wildland/WUI that follows in the spirit of the work done in 1973 – Americ

ADDENDUM - A NATIONAL PERSPECTIVE

FEDERAL GOVERNMENT STRUGGLES WITH FIRE POLICY

"Currently, agencies like the Forest Service must borro coun costs exceeding the budget. 'Fire Borrowing' was intended to be an extraordinar seasons have grown more des ome c e (8 of the last 10 years) - and has created a devast vents agencies from doing needed hazardous fuels removal or vest, leading t form the way we budget f ocate can take place." - Congressman Mike Simpson 2015

2014 IAFF ANNUAL CONVENTION WILDLAND TASKFORCE MEETING, CINCINNATI, OHIO

On July 17, 2014, Dr. Rahn and symposium representa es me e ter experts from across the United States at the 2014 annual conven or the Interna e Fighters (IAFF), and their Wildland Taskforce mee epresenta es of the Taskforce came from across the United States, including Florida, Colorado, Texas, New Mexico, Arizona, Virginia, Washington and many other states. The purpose was to discuss trends and the con ornia, which is being felt almost iden ally, ering loc vor, across the country. The group echoed many of the same issues discussed at the California Symposium. It became clear tha e agencies throughout the US are ba many of the same wildland/WUI issues experienced in California. Topics discussed at the mee the following:

- Changing Environment
- Fire ter Health and Safety
- Community Preparedness
- Fire ter Sta esources
- Naviga ot ement Landscape
- Dealing with Government Bureaucracy

P ts generally agreed with the outcome and recommenda om the California Symposium, but also introduced a variety of challeng sisten tur , the following issues were highlighted during the mee

- ant changes in the frequency and int es have been occurring throughout the rest of the U.S. Fire ter impacts are increasing as a result. We need to recognize that this impacts not just the tr e ters, but also municipal agencies. The con ought and lack of water resour ant issue/concern.
- Develop advanced educa aining programs f e t are accessible to car e ters and diverse agencies throughout the U.S.
- Incen wners to maintain defensible space and resolving con osystem and watershed management.
- Resolve funding, reimbursement and cost recovery mechanisms between local and federal agencies.
- Improve coordina ement pr oss federal, state and local lands. Preven programs are vital but there ar en not enough resources to educate land owners or enforce requirements.
- Land management hurdles must also be overcome, including environmental challenges, legal, regulatory and policy hurdles associated with proscribed burns, brush clearing or other pr e need to iden y streamlined procedures to address environmental clearances to pro t wildland management. Air quality permits/approval seems to be one of the more major hurdles.
- There is a growing disconnect in land use where local government con o permit development in the den to state and feder e agencies., Also, federal fuel management may be placing an increased risk on local c overnment resources.
- There is a disconnect between land management, policies, local land use, and private property. In some cases, homeowners may be unwilling to cooperate or manage their land/property in the WUI.
- There w ant interest in impro e , especially in the areas of e ter tracking, communica ard/exposure iden a
- Minimum wage is being discussed as a living wage argument and the impact on entry-lev e ters is real, and concerns of salary c e daun

, the workgroup expressed an obvious frustra elated t e t stems from inconsistencies across the na onfronted b encies and various regulatory frameworks. Due to the con xpansion of our urban areas, man e departments previously tasked with the primary roles of structural suppression and EMS ar e en this results in con ederal agencies and feder egarding suppression, preven maintenance of lands adjacent to the c

As a member of the Training Program in Na e Coordina oup, the IAFF could help inform the training curriculum to provide for emerging concerns. It is also important to consider developing a na wide "surge capacity" wher al members provide the sta ently the federal government deals with states through a na wide process; individual states need to query their r e local departments as to how they need to work within the federal process to ensure a more streamlined and comprehensive approach.

The workgroup also suggested that we should, as a na verage the work in concert with the 2009 FLAME amework recommended under the Na or a "Na Cohesive Wildland Fire Management Strategy" (April 2014). This can assist in implementa e response preparedness in areas more likely to experience large, long-dura e response preparedness in areas experiencing high rates of structure loss per area burned, and 3) emphasize both structure prot e preven o enhance the e esponse.

DELIVERABLES

At the end of the session, the Taskforce recommended the following deliverables:

IAFF White Paper on Wildland Fire Figh

The Task Force members and f ts agree that the development of an IAFF "White Paper" regar e st step in iden egarding wildland e ould include the IAFF and others to encourage a Federal Blue Ribbon Commission on es (similar to America Burning, 1973).

E raining Requirements

Training requirements across the spectrum regar e valuated by the IAFF Training Department and a database created. An evalua tate and federal requirements will allow the IAFF to address inconsistencies or concerns.

Research Grants

The IAFF should engage stakeholders and iden y priority needs regarding research and seek federal grants to accomplish research int e topics of concern. Such research will directly bene members, their safety and the public.

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EXHIBIT 33

How Smoke from Fires Can Affect Your Health

How Smoke from Fires Can Affect Your Health
Updated January 2017

Smoke may smell good, but it's not good for you

While not everyone has the same sensitivity to wildfire smoke, it's still a good idea to avoid breathing smoke if you can help it. And when smoke is heavy, such as can occur in close proximity to a wildfire, it's bad for everyone.
Smoke is made up of a complex mixture of gases and fine particles produced when wood and other organic materials burn. The biggest health threat from smoke is from fine particles. These microscopic particles can penetrate deep into your lungs. They can cause a range of health problems, from burning eyes and a runny nose to aggravated chronic heart and lung diseases. Exposure to particle pollution is even linked to premature death.


Smoke is made up of a complex mixture of gases and fine particles produced when wood and other organic materials burn.

Some people are more at risk

It's especially important for you to pay attention to local air quality reports during a fire if you are

- **a person with heart or lung disease,** such as heart failure, angina, ischemic heart disease, chronic obstructive pulmonary disease, emphysema or asthma.
- **an older adult**, which makes you more likely to have heart or lung disease than younger people.
- **caring for children, including teenagers,** because their respiratory systems are still developing, they breathe more air (and air pollution) per pound of body weight than adults, they're more likely to be active outdoors, and they're more likely to have asthma.
- **a person with diabetes,** because you are more likely to have underlying cardiovascular disease.
- **a pregnant woman,** because there could be potential health effects for both you and the developing fetus.

How to tell if smoke is affecting you

High concentrations of smoke can trigger a range of symptoms.

- **Anyone** may experience burning eyes, a runny nose, cough, phlegm, wheezing and difficulty breathing.
- **If you have heart or lung disease**, smoke may make your symptoms worse
  - **People with heart disease** might experience chest pain, palpitations, shortness of breath, or fatigue.
  - **People with lung disease** may not be able to breathe as deeply or as vigorously as usual, and may experience symptoms such as coughing, phlegm, chest discomfort, wheezing and shortness of breath.

Protect yourself!

It’s important to limit your exposure to smoke - especially if you are at increased risk for particle-related effects. Here are some steps you can take to protect your health:

Prepare for fire season if you live in a fire-prone area

If you have heart, vascular or lung disease, including asthma, talk with your health care provider.

***5/28/20** This information was developed before the COVID-19 health emergency. Please supplement this information with the latest advice from state, local, Tribal and federal agencies, including the **EPA website (https://www.epa.gov/coronavirus)** and **CDC webpage (https://www.cdc.gov/coronavirus/2019-ncov/index.html)**

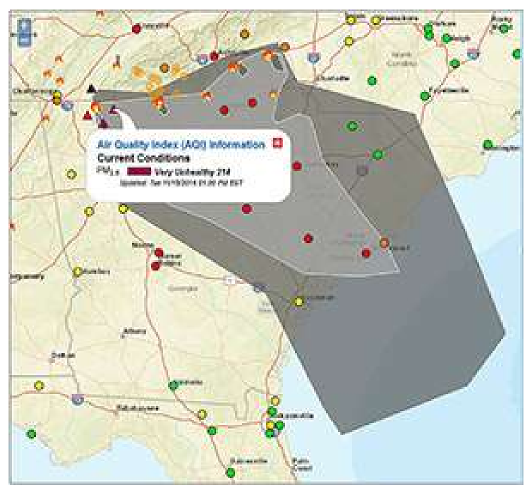
If you have heart, vascular or lung disease, including asthma, talk with your health care provider before fire season to make plans. Discuss when to leave the area, how much medicine to have on hand, and your asthma action plan if you have asthma.

Have a several-day supply of nonperishable foods that do not require cooking. Cooking - especially frying and broiling - can add to indoor pollution levels.

Consider buying an air cleaner. Some room **air cleaners (https://www.epa.gov/indoor-air-quality-iaq/guide-air-cleaners-home)** can help reduce particle levels indoors, as long as they are the right type and size for your rooms as specified by the manufacturer. If you choose to buy an air cleaner, don’t wait until there’s a fire - make that decision beforehand. Note: Don’t use an air cleaner that **generates ozone (https://www.arb.ca.gov/research/indoor/aircleaners/certified.htm)** EXIT AIRNOW. That just puts more pollution in your home.

Have a supply of N-95 or P-100 masks on hand, and learn how to use them correctly (/publications/fire-mask-respirator-and-palm-cards-in-seven-languages/infographic-how-to-use-a-respirator). They are sold at many hardware and home repair stores and online.

During a fire



If you have heart, vascular or lung disease, including asthma, talk with your health care provider.

Pay attention to local air quality reports. As smoke gets worse, the concentration of particles in the air increases - and so should the steps you take to protect yourself. Air quality reports are available through local news media, your local air agency or on **airnow.gov (/)**.

Use common sense to guide your activities. Even if you don’t have a monitor in your area, if it looks or smells smoky outside, it's probably not a good time to mow the lawn or go for a run. And it's probably not a good time for children - especially children with asthma - to be vigorously active outdoors, or active outdoors for prolonged periods of time. If you are active outdoors, pay attention to symptoms. Symptoms are an indication that you need to reduce exposure.

Paper “dust” masks or surgical masks will not protect your lungs from the fine

Dust masks aren't enough! Paper “dust” masks or surgical masks will not protect your lungs from the fine particles in wildfire smoke. Scarves or bandanas (wet or dry) won’t help, either. Particulate masks known as N-95 or P-100 respirators will help, but they must fit well and be used correctly. They are sold at many hardware and home repair stores and online.

If you are advised to stay indoors, take steps to keep indoor air as clean as possible. Keep your windows and doors closed - unless it's extremely hot outside. Run your air conditioner, if you have one. Keep the filter clean to prevent bringing additional smoke inside. Open windows to air out the house when air quality improves. Note: If you don't have an air conditioner, staying inside with the windows closed may be dangerous in extremely hot weather. In these cases, seek alternative shelter, such as with relatives or a cleaner air shelter.

particles in wildfire smoke. Photo Courtesy of California EPA.

Help keep particle levels inside lower. When smoke is heavy for a prolonged period of time, fine particles can build up indoors even though you may not be able to see them. Try to avoid using anything that burns, such as wood fireplaces, gas logs, gas stoves - and even candles. Don't vacuum. That stirs up particles already inside your home. And don't smoke. That puts even more pollution in your lungs, and in the lungs of people around you.

If you have asthma or another lung disease, make sure you follow your healthcare provider's directions about taking your medicines and following your asthma action plan. Have at least a five-day supply of medication on hand. Call your healthcare provider if your symptoms worsen.

If you have cardiovascular disease, follow your healthcare provider's directions and call if your symptoms worsen. If you think you are having a heart attack or stroke, dial 9-1-1.

Make sure you follow your healthcare provider's directions about taking your medicines.

Resources

Get air quality information: If there is an active fire in your area, follow your local news, the airnow.gov (/) website, or your state air quality website for up-to-date information.

Learn more about smoke and health: See *Wildfire Smoke, A Guide for Public Health Officials* (/publications/wildfire-smoke-guide/wildfire-smoke-a-guide-for-public-health-officials).

For information about home air cleaners: Guide to Air Cleaners in the Home (https://www.epa.gov/indoor-air-quality-iaq/air-cleaners-and-air-filters-home)

For a list of certified air cleaning devices: California Certified Air Cleaning Devices (http://www.arb.ca.gov/research/indoor/aircleaners/certified.htm) (Exit AirNow)

Learn the right way to use an N-95 or P-100 particulate respirator mask: Protect Your Lungs from Wildfire Smoke (http://www.bepreparedcalifornia.ca.gov/ResourcesAndLinks/Languages/Documents/English/ENG_ProtectLungsSmoke7208color.pdf) (Exit AirNow)

What to do before, during, and after a wildfire: Centers for Disease Control and Prevention's Wildfire Page (https://www.cdc.gov/disasters/wildfires/index.html) (Exit AirNow)

Only your doctor can advise you about your specific health situation. But EPA's color-coded Air Quality Index can help you protect yourself when particle levels are high. See the *Air Quality Guide for Particle Pollution* (/publications/activity-guides/activity-sheet-for-pm/) for specific steps you can take.

(http://w(https://(https://(https://twitter.com/airnow)facebook.com/airnow)

AirNow.gov - Home of the U.S. Air Quality Index

Home (/) | Site Map (/site-map)

EXHIBIT 34


1-1-S
1-2-S

EXHIBIT 35

EXHIBIT 36

About Content Legend

Legend

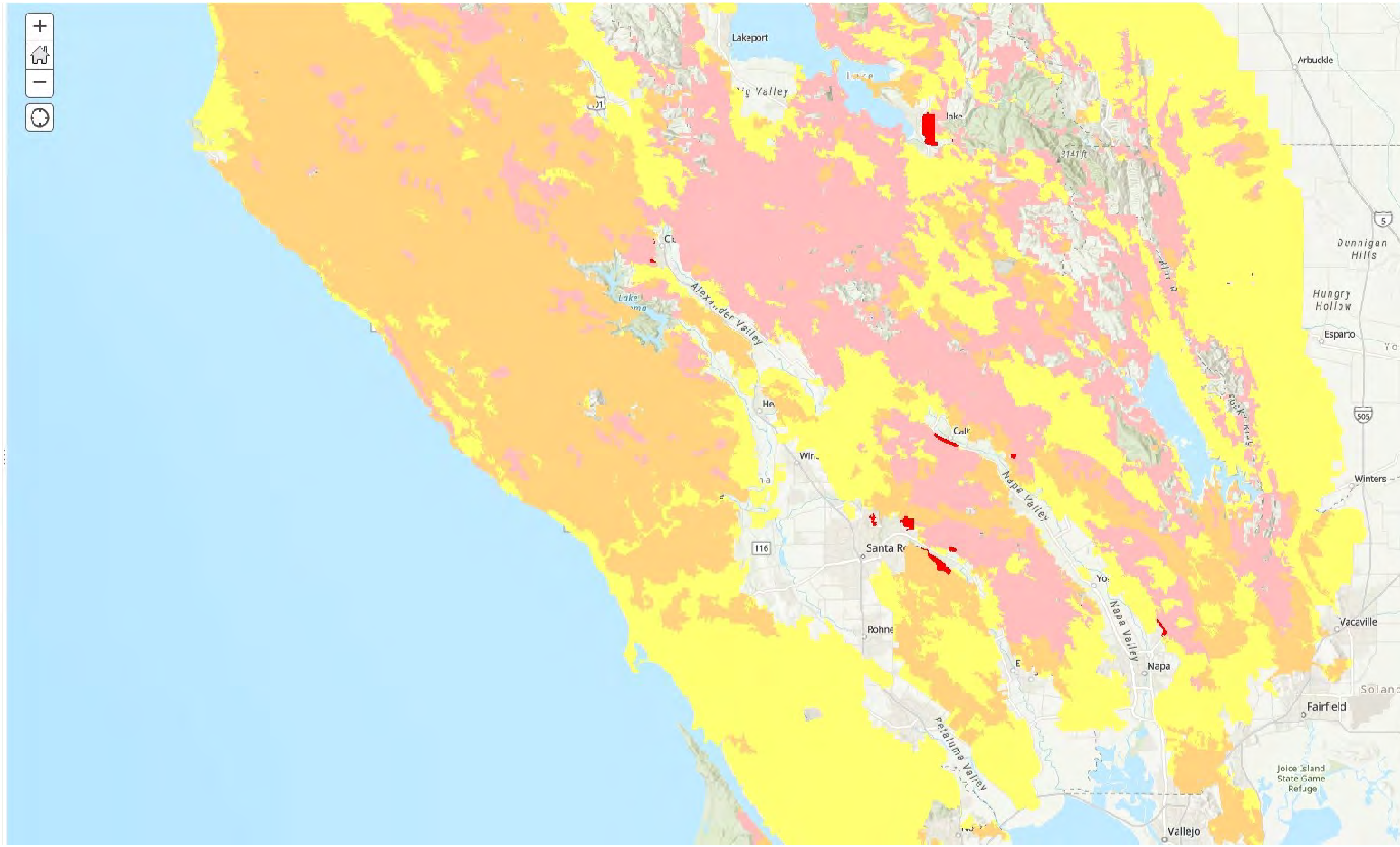
California Fire Hazard Severity Zones (FHSZ)

FHSZ in LRA

- VHFHSZ

FHSZ in SRA

- Very High
- High
- Moderate



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Warming and Earlier Spring Increase Western U.S. Forest Wildfire Activity

A. L. Westerling,[1,2]* H. G. Hidalgo,[1] D. R. Cayan,[1,3] T. W. Swetnam[4]

Western United States forest wildfire activity is widely thought to have increased in recent decades, yet neither the extent of recent changes nor the degree to which climate may be driving regional changes in wildfire has been systematically documented. Much of the public and scientific discussion of changes in western United States wildfire has focused instead on the effects of 19th- and 20th-century land-use history. We compiled a comprehensive database of large wildfires in western United States forests since 1970 and compared it with hydroclimatic and land-surface data. Here, we show that large wildfire activity increased suddenly and markedly in the mid-1980s, with higher large-wildfire frequency, longer wildfire durations, and longer wildfire seasons. The greatest increases occurred in mid-elevation, Northern Rockies forests, where land-use histories have relatively little effect on fire risks and are strongly associated with increased spring and summer temperatures and an earlier spring snowmelt.

Wildfires have consumed increasing areas of western U.S. forests in recent years, and fire-fighting expenditures by federal land-management agencies now regularly exceed US$1 billion/year (*1*). Hundreds of homes are burned annually by wildfires, and damages to natural resources are sometimes extreme and irreversible. Media reports of recent, very large wildfires (>100,000 ha) burning in western forests have garnered widespread public attention, and a recurrent perception of crisis has galvanized legislative and administrative action (*1*–*3*).

Extensive discussions within the fire-management and scientific communities and the media seek to explain these phenomena, focusing on either land-use history or climate as primary causes. If increased wildfire risks are driven primarily by land-use history, then ecological restoration and fuels management are potential solutions. However, if increased risks are largely due to changes in climate during recent decades, then restoration and fuels treatments may be relatively ineffective in reversing current wildfire trends (*4*, *5*). We investigated 34 years of western U.S. (hereafter, "western") wildfire history together with hydroclimatic data to determine where the largest increases in wildfire have occurred and to evaluate how recent climatic trends may have been important causal factors.

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Competing explanations: Climate versus management. Land-use explanations for increased western wildfire note that extensive livestock grazing and increasingly effective fire suppression began in the late 19th and early 20th centuries, reducing the frequency of large surface fires (*6*–*8*). Forest regrowth after extensive logging beginning in the late 19th century, combined with an absence of extensive fires, promoted forest structure changes and biomass accumulation, which now reduce the effectiveness of fire suppression and increase the size of wildfires and total area burned (*3*, *5*, *9*). The effects of land-use history on forest structure and biomass accumulation are, however, highly dependent upon the "natural fire regime" for any particular forest type. For example, the effects of fire exclusion are thought to be profound in forests that previously sustained frequent, low-intensity surface fires [such as Southwestern ponderosa pine and Sierra Nevada mixed conifer (*2*, *3*, *10*, *11*)], but of little or no consequence in forests that previously sustained only very infrequent, high-severity crown fires (such as Northern Rockies lodgepole pine or spruce-fir (*1*, *5*, *12*)].

In contrast, climatic explanations posit that increasing variability in moisture conditions (wet/dry oscillations promoting biomass growth, then burning), and/or a trend of increasing drought frequency, and/or warming temperatures have led to increased wildfire activity (*13*, *14*). Documentary records and proxy reconstructions (primarily from tree rings) of fire history and climate provide evidence that western forest wildfire risks are strongly positively associated with drought concurrent with the summer fire season and (particularly in ponderosa pine–dominant forests) positively associated to a lesser extent with moist conditions in antecedent years (*13*–*18*). Variability in western climate related to the Pacific Decadal Oscillation and intense El Niño/La Niña events in recent decades along with severe droughts in 2000 and 2002 may have promoted greater forest wildfire risks in areas such as the Southwest, where precipitation anomalies are significantly influenced by patterns in Pacific sea surface temperature (*19*–*22*). Although corresponding decadal-scale variations and trends in climate and wildfire have been identified in paleo studies, there is a paucity of evidence for such associations in the 20th century.

We describe land-use history versus climate as competing explanations, but they may be complementary in some ways. In some forest types, past land uses have probably increased the sensitivity of current forest wildfire regimes to climatic variability through effects on the quantity, arrangement, and continuity of fuels. Hence, an increased incidence of large, high-severity fires may be due to a combination of extreme droughts and overabundant fuels in some forests. Climate, however, may still be the primary driver of forest wildfire risks on interannual to decadal scales. On decadal scales, climatic means and variability shape the character of the vegetation [e.g., species populations and their drought tolerance (*23*) and biomass (fuel) continuity (*24*), thus also affecting fire regime responses to shorter term climate variability]. On interannual and shorter time scales, climate variability affects the flammability of live and dead forest vegetation (*13*–*19*, *25*).

High-quality time series are essential for evaluating wildfire risks, but for various reasons (*26*), previous works have not rigorously documented changes in large-wildfire frequency for western forests. Likewise, detailed fire-climate analyses for the region have not been conducted to evaluate what hydroclimatic variations may be associated with recent increased wildfire activity, and the spatial variations in these patterns.

We compiled a comprehensive time series of 1166 large (>400 ha) forest wildfires for 1970 to 2003 from federal land-management units containing 61% of western forested areas (and 80% above 1370 m) (*26*) (fig. S1). We compared these data with corresponding hydroclimatic and land surface variables (*26*–*34*) to address where and why the frequency of large forest wildfire has changed.

Increased forest wildfire activity. We found that the incidence of large wildfires in western forests increased in the mid-1980s (Fig. 1) [hereafter, "wildfires" refers to large-fire events (>400 ha) within forested areas only (*26*)]. Subsequently, wildfire frequency was nearly four times the average of 1970 to 1986, and the total area burned by these fires was more than six and a half times its previous level. Interannual variability in wildfire frequency is strongly associated with regional spring and summer temperature (Spearman's correlation of 0.76, $P < 0.001$, $n = 34$). A second-order polynomial fit to the regional temperature signal alone explains 66% of the variance in the annual incidence of these fires, with many more wildfires burning in hotter than in cooler years.

The length of the wildfire season also increased in the 1980s (Fig. 1). The average season length (the time between the reported first wildfire discovery date and the last wildfire control date) increased by 78 days (64%), comparing 1970 to 1986 with 1987 to 2003. Roughly half of that increase was due to earlier ignitions, and half to later control (48% versus 52%, respectively). Later control dates were no doubt partly due to later ignition dates, given that the date of the last reported wildfire ignition increased by 15 days, but a substantial increase in the length of time the average wildfire burned also played a role. The average time between discovery and control for a wildfire increased from 7.5 days from 1970 to 1986 to 37.1 days from 1987 to 2003. The annual length of the fire season and the average time each fire burned were also moderately correlated with the regional spring and summer temperature (Spearman's correlations of 0.61 ($P < 0.001$) and 0.55 ($P < 0.001$), respectively.

The greatest increase in wildfire frequency has been in the Northern Rockies, which account for 60% of the increase in large fires. Much of the remaining increase (18%) occurred in the Sierra Nevada, southern Cascades, and Coast Ranges of northern California and southern Oregon ("Northern California," in fig. S2). The Pacific Southwest; the Southern Rockies; the Northwest; coastal, central, and southern California; and the Black Hills each account for 11%, 5%, 5%, <1%, and <1%, respectively. Interestingly, the Northern Rockies and the Southwest show the same trend in wildfire frequency relative to their respective forested areas. However, the Southwest's absolute contribution to the western regional total is limited by its smaller forested area relative to higher latitudes.

Increased wildfire frequency since the mid-1980s has been concentrated between 1680 and 2590 m in elevation, with the greatest increase centered around 2130 m. Wildfire activity at these elevations has been episodic, coming in pulses during warm years, with relatively little activity in cool years, and is strongly associated with changes in spring snowmelt timing, which in turn is sensitive to changes in temperature.

Fire activity and the timing of the spring snowmelt. As a proxy for the timing of the spring snowmelt, we used Stewart and colleagues' dates of the center of mass of annual flow (CT) for snowmelt-dominated streamflow gauge records in western North America (*32*–*34*). The annual wildfire frequency for the region is highly correlated (inversely) with CT at gauges across the U.S. Pacific Northwest and interior West, indicating a coherent regional signal of wildfire sensitivity to snowmelt timing (Fig. 2).

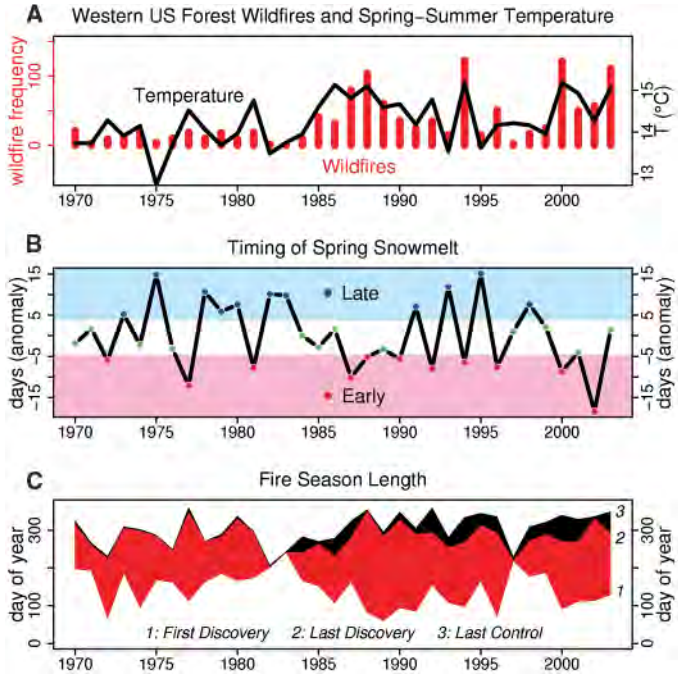

Fig. 1. (**A**) Annual frequency of large (>400 ha) western U.S. forest wildfires (bars) and mean March through August temperature for the western United States (line) (*26*, *30*). Spearman's rank correlation between the two series is 0.76 ($P < 0.001$). Wilcoxon test for change in mean large–forest fire frequency after 1987 was significant ($W = 42$; $P < 0.001$). (**B**) First principle component of center timing of streamflow in snowmelt dominated streams (line). Low (pink shading), middle (no shading), and high (light blue shading) tercile values indicate early, mid-, and late timing of spring snowmelt, respectively. (**C**) Annual time between first and last large-fire ignition, and last large-fire control.

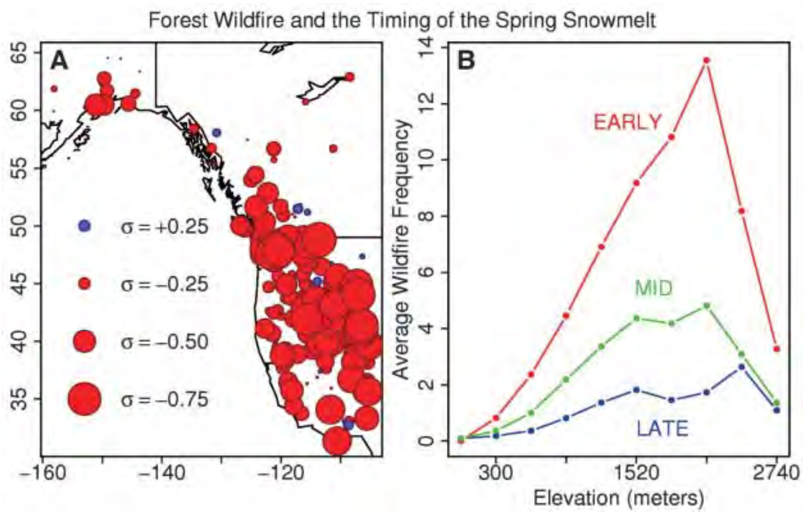

Fig. 2. (**A**) Pearson's rank correlation between annual western U.S. large (>400 ha) forest wildfire frequency and streamflow center timing. *x* axis, longitude; *y* axis, latitude. (**B**) Average frequency of western U.S. forest wildfire by elevation and early, mid-, and late snowmelt years from 1970 to 2002. See Fig. 1B for a definition of early, mid-, and late snowmelt years.

The negative sign of these correlations indicates that earlier snowmelt dates correspond to increased wildfire frequency. Following Stewart *et al*., we used the first principal component (CT1) of CT at western U.S. streamflow gauges as a regional proxy for interannual variability in the arrival of the spring snowmelt (Fig. 1) (*26*, *32*). This signal had its greatest impact on wildfire frequency between elevations of 1680 and 2590 m (Fig. 2), with a nonlinear response at these elevations to variability in snowmelt timing. Overall, 56% of wildfires and 72% of area burned in wildfires occurred in early (i.e., lower tercile CT1) snowmelt years, whereas only 11% of wildfires and 4% of area burned occurred in late (i.e., upper tercile CT1) snowmelt years.

Temperature affects summer drought, and thus flammability of live and dead fuels in forests through its effect on evapotranspiration and, at higher elevations, on snow. Additionally, warm spring and summer temperatures were strongly associated with reduced winter precipitation over much of the western United States (Fig. 3). The arrival of spring snowmelt in the mountains of the western United States, represented here by CT1, is strongly associated with spring temperature (*26*). Average spring and summer temperatures throughout the entire region are significantly higher in early than in late years (Fig. 3), peaking in April. The average difference between early and late April mean monthly temperatures in forested areas was just over 2°C, and it increased with elevation.

Snow carries over a substantial portion of the winter precipitation that falls in western mountains, releasing it more gradually in late spring and early summer, providing an important contribution to spring and summer soil moisture (*35*). An earlier snowmelt can lead to an earlier, longer dry season, providing greater opportunities for large fires due both to the longer period in which ignitions could potentially occur and to the greater drying of soils and vegetation. Consequently, it is not surprising that the incidence of wildfires is strongly associated with snowmelt timing.

Changes in spring and summer temperatures associated with an early spring snowmelt come in the context of a marked trend over the period of analysis. Regionally averaged spring and summer temperatures for 1987 to 2003 were 0.87°C higher than those for 1970 to 1986. Spring and summer temperatures for 1987 to 2003 were the warmest since the start of the record in 1895, with 6 years in the 90th percentile—the most for any 17-year period since the start of the record in 1895 through 2003—whereas only 1 year in the preceding 17 years ranked in the 90th percentile. Likewise, 73% of early years since 1970 occurred in 1987 to 2003 (Fig. 1).

Spatial variability in the wildfire response to an earlier spring. Vulnerability of western U.S. forests to more frequent wildfires due to warmer temperatures is a function of the spatial distribution of forest area and the sensitivity of the local water balance to changes in the timing of spring. We measured this sensitivity using the October-to-September moisture deficit—the cumulative difference between the potential evapotranspiration due to temperature and the actual evapotranspiration constrained by available moisture—which is an important indicator of drought stress in plants (*24*). We used the percentage difference in the moisture deficit for early versus late snowmelt years scaled by the fraction of forest cover in each grid cell to map forests' vulnerability to changes in the timing of spring (Fig. 4) (*26*). The Northern Rockies and Northern California display the greatest vulnerability by this measure—the same forests accounting for more than three-quarters of increased wildfire frequency since the mid-1980s. Although the trend in temperature over the Northern Rockies increases with elevation, vulnerability in the Northern Rockies is highest around 2130 m, where the greatest increase in fires has occurred. At lower elevations, the moisture deficit in early years is increasing from a high average value (i.e., summer drought tends to be longer and more intense at lower elevations), whereas at higher elevations the longer dry season in early years is still relatively short, and vegetation is somewhat buffered from the effects of higher temperatures by the available moisture.

Discussion. Robust statistical associations between wildfire and hydroclimate in western forests indicate that increased wildfire activity over recent decades reflects sub-regional responses to changes in climate. Historical wildfire observations exhibit an abrupt transition in the mid-1980s from a regime of infrequent large wildfires of short (average of 1 week) duration to one with much more frequent and longer burning (5 weeks) fires. This transition was

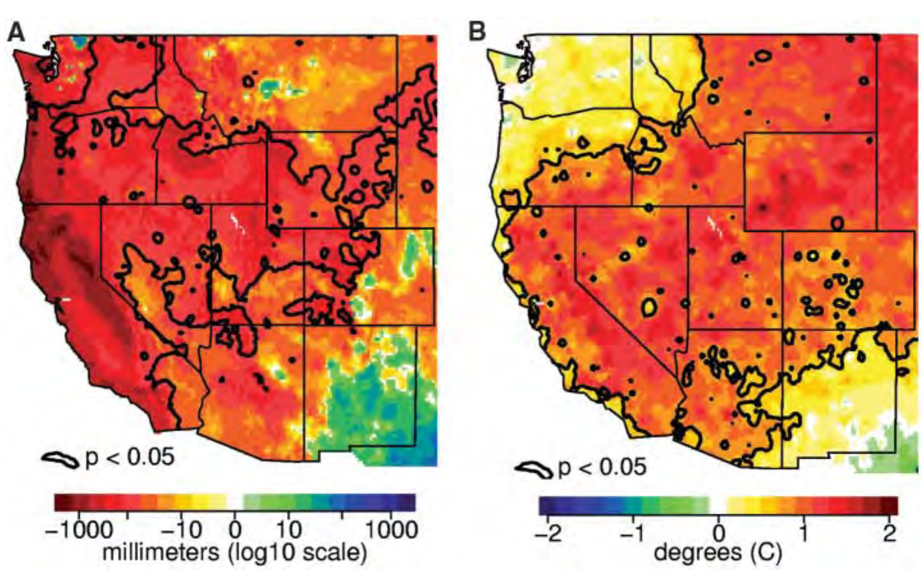

Fig. 3. Average difference between early and late snowmelt years in average precipitation from October through May (**A**) and average temperature from March through August (**B**). Contours enclose regions in which a *t* test for the difference in mean between 11 early and 11 late years was significant ($P < 0.05$). The null hypothesis that precipitation from October through May is normally distributed could not be rejected using the Shapiro-Wilk test for normality ($P > 0.05$ for more than 95% of 24,170 grid cells, $n = 49$ for precipitation; $P > 0.05$ for more than 95% of 24,170 grid cells, $n = 50$ for temperature). See Fig. 1B for a definition of early, mid-, and late snowmelt years.

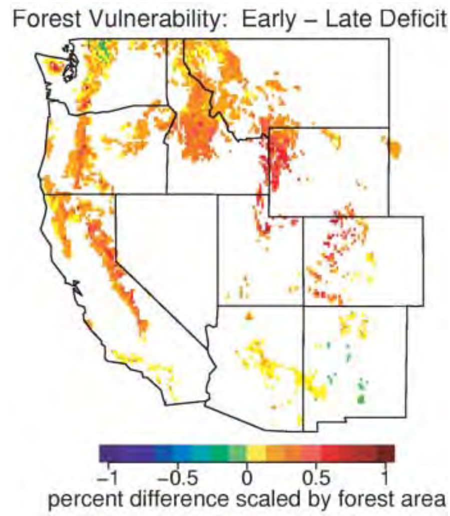

Fig. 4. Index of forest vulnerability to changes in the timing of spring: the percentage difference in cumulative moisture deficit from October to August at each grid point in early versus late snowmelt years, scaled by the forest-type vegetation fraction at each grid point, for 1970 to 1999 (*26*). See fig. S3 for a map of forest vulnerability for 1970 to 2003 over a smaller spatial domain. See Fig. 1B for a definition of early, mid-, and late snowmelt years.

marked by a shift toward unusually warm springs, longer summer dry seasons, drier vegetation (which provoked more and longer burning large wildfires), and longer fire seasons. Reduced winter precipitation and an early spring snowmelt played a role in this shift. Increases in wildfire were particularly strong in mid-elevation forests.

The greatest absolute increase in large wildfires occurred in Northern Rockies forests. This sub-region harbors a relatively large area of mesic, middle and high elevation forest types (such as lodgepole pine and spruce-fir) where fire exclusion has had little impact on natural fire regimes (*1*, *5*), but where we found that an advance in spring produces a relatively large percentage increase in cumulative moisture deficit by midsummer. In contrast, changes in Northern California forests may involve both climate and land-use effects. In these forests, large percentage changes in moisture deficits were strongly associated with advances in the timing of spring, and this area also includes substantial forested area where fire exclusion, timber harvesting, and succession after mining activities have led to increased forest densities and fire risks (*10*, *11*). Northern California forests have had substantially increased wildfire activity, with most wildfires occurring in early years. Southwest forests, where fire exclusion has had the greatest effect on fire risks (*2*, *3*), have also experienced increased numbers of large wildfires, but the relatively small forest area there limits the impact on the regional total, and the trend appears to be less affected by changes in the timing of spring. Most wildfires in the Southern Rockies and Southern California have also occurred in early snowmelt years, but again forest area there is small relative to the Northern Rockies and Northern California. Thus, although land-use history is an important factor for wildfire risks in specific forest types (such as some ponderosa pine and mixed conifer forests), the broad-scale increase in wildfire frequency across the western United States has been driven primarily by sensitivity of fire regimes to recent changes in climate over a relatively large area.

The overall importance of climate in wildfire activity underscores the urgency of ecological restoration and fuels management to reduce wildfire hazards to human communities and to mitigate ecological impacts of climate change in forests that have undergone substantial alterations due to past land uses. At the same time, however, large increases in wildfire driven by increased temperatures and earlier spring snowmelts in forests where land-use history had little impact on fire risks indicates that ecological restoration and fuels management alone will not be sufficient to reverse current wildfire trends.

These results have important regional and global implications. Whether the changes observed in western hydroclimate and wildfire are the result of greenhouse gas–induced global warming or only an unusual natural fluctuation is beyond the scope of this work. Regardless of past trends, virtually all climate-model projections indicate that warmer springs and summers will occur over the region in coming decades. These trends will reinforce the tendency toward early spring snowmelt (*36*, *37*) and longer fire seasons. This will accentuate conditions favorable to the occurrence of large wildfires, amplifying the vulnerability the region has experienced since the mid-1980s. The Intergovernmental Panel on Climate Change's consensus range of 1.5° to 5.8°C projected global surface temperature warming by the end of the 21st century is considerably larger than the recent warming of less than 0.9°C observed in spring and summer during recent decades over the western region (*37*).

If the average length and intensity of summer drought increases in the Northern Rockies and mountains elsewhere in the western United States, an increased frequency of large wildfires will lead to changes in forest composition and reduced tree densities, thus affecting carbon pools. Current estimates indicate that western U.S. forests are responsible for 20 to 40% of total U.S. carbon sequestration (*38*, *39*). If wildfire trends continue, at least initially, this biomass burning will result in carbon release, suggesting that the forests of the western United States may become a source of increased atmospheric carbon dioxide rather than a sink, even under a relatively modest temperature-increase scenario (*38*, *39*). Moreover, a recent study has shown that warmer, longer growing seasons lead to reduced CO_2 uptake in high-elevation forests, particularly during droughts (*40*). Hence, the projected regional warming and consequent increase in wildfire activity in the western United States is likely to magnify the threats to human communities and ecosystems, and substantially increase the management challenges in restoring forests and reducing greenhouse gas emissions.

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Supporting Online Material

www.sciencemag.org/cgi/content/full/1128834/DC1
Materials and Methods
Figs. S1 to S3
References

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Warming and Earlier Spring Increase Western U.S. Forest Wildfire Activity

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EXHIBIT 38

SCENARIOS OF CLIMATE CHANGE IN CALIFORNIA: AN OVERVIEW

A Report From:

California Climate Change Center

Prepared By:
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Guido Franco, California Energy Commission
Bart Croes, California Air Resources Board

WHITE PAPER

Arnold Schwarzenegger, *Governor*

February 2006
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Preface

The Public Interest Energy Research (PIER) Program supports public interest energy research and development that will help improve the quality of life in California by bringing environmentally safe, affordable, and reliable energy services and products to the marketplace.

The PIER Program, managed by the California Energy Commission (Energy Commission), annually awards up to $62 million to conduct the most promising public interest energy research by partnering with Research, Development, and Demonstration (RD&D) organizations, including individuals, businesses, utilities, and public or private research institutions.

PIER funding efforts are focused on the following RD&D program areas:

- Buildings End-Use Energy Efficiency
- Energy-Related Environmental Research
- Energy Systems Integration
- Environmentally Preferred Advanced Generation
- Industrial/Agricultural/Water End-Use Energy Efficiency
- Renewable Energy Technologies

The California Climate Change Center (CCCC) is sponsored by the PIER program and coordinated by its Energy-Related Environmental Research area. The Center is managed by the California Energy Commission, Scripps Institution of Oceanography at the University of California at San Diego, and the University of California at Berkeley. The Scripps Institution of Oceanography conducts and administers research on climate change detection, analysis, and modeling; and the University of California at Berkeley conducts and administers research on economic analyses and policy issues. The Center also supports the Global Climate Change Grant Program, which offers competitive solicitations for climate research.

The California Climate Change Center Report Series details ongoing Center-sponsored research. As interim project results, these reports receive minimal editing, and the information contained in these reports may change; authors should be contacted for the most recent project results. By providing ready access to this timely research, the Center seeks to inform the public and expand dissemination of climate change information; thereby leveraging collaborative efforts and increasing the benefits of this research to California's citizens, environment, and economy.

For more information on the PIER Program, please visit the Energy Commission's website www.energy.ca.gov/pier/ or contact the Energy Commission at (916) 654-5164.

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1.0 Summary of Key Findings and Recommendations

- Climate change impacts will affect all of the sectors considered in this report: sea-level rise, agriculture, snowpack and water supply, forestry, wildfire risk, public health, and electricity demand and supply.
- The more that greenhouse gases (GHGs) accumulate in the Earth's atmosphere over the next century, the greater the warming and the more severe and costly the impacts will be. This study considered three future GHG emissions scenarios—low, medium high, and high emissions—and explored associated climate changes through three modern climate models of differing sensitivity to GHG concentrations.
- Although climate model results are inconclusive as to whether California's precipitation will change over the next century, all climate models show increases in temperature, with the aggregate of several model runs containing a range of warming from 2000 to 2100 from about +2ºC to about +6ºC (+3.6ºF to about +10.8 ºF). Increases in temperature alone would impact the California hydrological cycle, with consequences upon the state's water supply, hydroelectric power supply, agriculture, recreation, and ecosystems.
- Climate change could produce compounding impacts—for instance, in the San Francisco Bay Delta, heightened sea levels and high river inflows from warmer storms would place levee systems in greater jeopardy of flooding.
- Some of the most dramatic climate change impacts will be experienced as increased frequency and severity of extreme events, such as heat waves, wildfires, flooding, and conditions conducive to air pollution formation.
- Even under lower GHG emissions scenarios, some impacts of climate change are inevitable. As a result, although adaptation is not the solution to climate change, it is a necessary complementary strategy to manage some of the projected impacts.
- Although there are many opportunities for California to increase its capacity to cope with many climate change impacts, these can be costly, and they require time and planning.
- More analysis—and in some cases, more information—is needed to better understand the vulnerability of California's health, economy, and environment to climate change. In particular, greater attention must focus on social dimensions of climate change for both assessing and implementing the state's mitigative and adaptive potential. Critical to this work will be evaluating and addressing the distributional and equity implications of climate changes in California.

2.0 Motivation and Overview of The Scenarios Project

Governor Arnold Schwarzenegger's Executive Order S-3-05 of June 1, 2005, called for specific emission reductions and a periodic update on the state of climate change science and the emerging understanding of potential impacts on climate-sensitive sectors such as the state's water supply, public health, agriculture, coastal areas, and forestry. In response to this Executive Order, the California Energy Commission (Energy Commission) and the California Environmental Protection Agency (Cal/EPA) commissioned an assessment of the potential impacts of climate change on key state resources ("the Scenarios Project").

The Scenarios Project was conducted under the direction of the California Climate Change Center ("the Center"), which has engaged in a long-term, California-specific climate research program. The assessment builds on earlier work that came out of the Center and other previous studies. In particular, it extends the work of a recent study that compared the projected impact of climate change in California under differing emissions scenarios (Hayhoe et al. 2004). This assessment draws upon experts within and outside of the Center to produce a collection of separate research reports on the projected impacts of climate change under multiple scenarios across six different sectors: coasts, water resources, agriculture, public health, forestry, and electricity production and demand.

This report summarizes the findings from the individual research reports and compares them with the earlier findings from the Hayhoe et al. (2004) study. This summary report compares the impacts on key sectors under multiple future scenarios of temperature changes and links these impacts to GHG emission trajectories, assuming different climate sensitivities.

3.0 Core Research Papers

This document summarizes and integrates the results of several studies listed in the following table. The California Institute for Energy and Environment (CIEE, associated with the Office of the President, University of California) is conducting an external review on all the papers listed in this table. Dr. Edward Vine is managing the peer review process. These papers are available at www.climatechange.ca.gov/.

Research Papers	
Dan Cayan et al.	Climate Scenarios for California
Dan Cayan et al.	Projecting Future Sea Level
Dennis Baldocchi et al.	An Assessment of Impacts of Future CO_2 and Climate on Agriculture
Brian Joyce et al.	Climate Change Impacts on Water for Agriculture in California: A Case Study in the Sacramento Valley
Josue Medellin et al.	Climate Warming and Water Supply Management in California
Department of Water Resources	Progress on Incorporating Climate Change into Management of California's Water Resources*
Andrew Paul Gutierrez	Analysis of Climate Effects on Agricultural Systems
Timothy Cavagnaro et al.	Climate Change: Challenges and Solutions for California Agricultural Landscapes
James Lenihan et al.	The Response of Vegetation Distribution, Ecosystem Productivity, and Fire in California to Future Climate Scenarios Simulated by the MC1 Dynamic Vegetation Model
Anthony Westerling and Benjamin Bryant	Climate Change and Wildfire in and Around California: Fire Modeling and Loss Modeling
Jeremy Fried et al.	Predicting the Effect of Climate Change on Wildfire Severity and Outcomes in California: A Preliminary Analysis
Max Moritz and Scott Stephens	Fire and Sustainability: Considerations for California's Altered Future Climate
John Battles et al.	Climate Change Impact on Forest Resources
Deborah Drechsler et al.	Public Health-Related Impacts of Climate Change for California
Amy Lynd Luers and Suzanne Moser	Preparing for the Impacts of Climate Change in California: Opportunities and Constraints for Adaptation
Technical Notes	
Sebastian Vicuña et al.	Climate Change Impacts on High Elevation Hydropower Generation in California's Sierra Nevada: A Case Study in the Upper American River
Guido Franco and Alan Sanstad	Climate Change and Electricity Demand in California
Sebastian Vicuña	Predictions of Climate Change Impacts on California Water Resources Using CalSim-II: A Technical Note

* The Department of Water Resources (DWR) coordinated the peer-review process for this paper. It will be available from DWR.

4.0 Introduction

It is now apparent that the increasing atmospheric concentration of GHGs, resulting from human activities, is changing the climate in ways that pose serious risks to California's health, economy, and environment. However, the most severe impacts that are expected with greater temperature rises could be avoided if the rate of GHG emissions is reduced. To help identify the potentially avoidable climate impacts in California, this paper summarizes some of the impacts expected under lower, medium, and higher ranges of projected warmings, as determined by different GHG emissions scenarios and different global climate models.

Linking temperature changes with particular levels of GHG emissions is a useful way to gauge the level of emissions reductions needed to avoid serious climate change impacts. However, current understanding of the climate system permits only limited precision in linking specific temperature changes to specific emission scenarios. Among a collection of more than a dozen national and international global climate models, *all* project increased temperatures as a result of higher emissions of GHG. However, the models differ in their sensitivity to changes in atmospheric GHG concentrations. For example, temperature rises between 1.5°C to 4.5°C (2.7°F to 8.1°F) have been projected for a doubling of CO_2 concentration above pre-industrial levels (IPCC 2001). The range in temperature response is the result of differences in the way that the models represent certain processes of the climate system, such as the way that they simulate clouds and radiation (Stephens 2005).

Society can neither control, nor at present precisely determine, the sensitivity of the earth's climate system to rising GHG concentrations. As a result, society must consider the implications of a range of climate sensitivities when evaluating the risks of climate change and devising policies to manage the one factor we can control: our own GHG emissions.

This paper summarizes the findings of the California Climate Change Center Scenarios Project ("the Project") and compares these new projections with those reported in an earlier study produced by many of the same researchers (Hayhoe et al. 2004). The projections in this summary are based upon three GHG scenarios—a lower emissions, medium-high emissions, and higher emissions scenario. The effect of different estimates of the sensitivity of the climate system to GHG forcing is explored by comparing the temperature projections from three different global climate models—each containing somewhat different representations of some crucial physical processes that result in different levels of climate sensitivity.

The following sections describe the emission scenarios and climate projections, and report on the projected impacts of the specific climate projections across six sectors: coasts, water resources, agriculture, forests/fire, public health, and electricity. The paper concludes with a discussion of the implications of these projections for mitigation and adaptation, and points out some outstanding problems that require further information or research.

5.0 Climate Change Scenarios

5.1. Emission Scenarios

The Intergovernmental Panel on Climate Change's (IPCC's) *Special Report on Emissions Scenarios* (SRES) developed a set of possible future emissions scenarios based on different assumptions about global development paths (Nakicenovic et al. 2000). This report contrasts the results from recent analyses for California of three SRES emissions scenarios—a lower emissions scenario (B1), a medium-high emissions scenario (A2), and a higher emissions scenario (A1fi) (Figure 1):

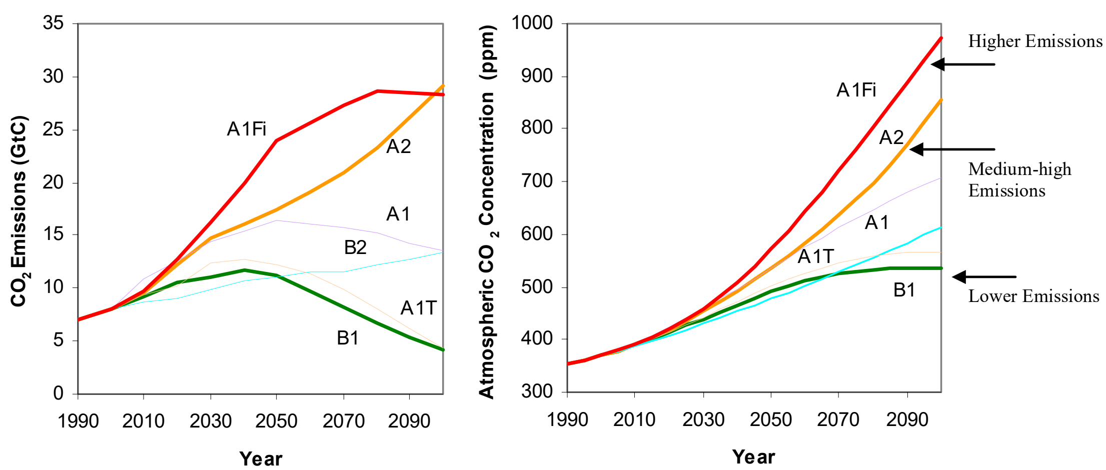

Figure 1. IPCC SRES Emission Scenarios

Six IPCC SRES Emissions Scenarios are presented here. The bold lines represent the three scenarios used in the analysis presented here (B1, A2, A1fi), the other lines represent IPCC scenarios not used in this study, yet presented here to illustrate how the trajectories selected for this study fit within the family of curves developed by the IPCC (Nakicenovic et al. 2000). The trajectories in this figure do not exactly match those in official IPCC documents (Nakicenovic et al. 2000) because the results we report here are based on revised emissions projections subsequently made available by IPCC; these are available at http://sres.ciesin.columbia.edu/. In addition, the authors used a new version of MAGICC available from www.cgd.ucar.edu/cas/wigley/magicc/index.html. However, the differences between this figure and similar figures provided by the IPCC are minor, and do not affect the discussion in this paper.

- The lower emissions scenario (B1) characterizes a world with population growth similar to the highest emissions scenarios, but with rapid changes toward a service and information economy and with the introduction of clean and resource-efficient technologies. The B1 scenario has CO_2 emissions peaking just below 10 gigatonnes per year (Gt/yr) in mid-century before dropping below the current-day level of 7 Gt/yr by 2100. Under the B1 scenario, the CO_2 concentration would double, relative to its pre-industrial level, by the end of this century.
- The medium-high emissions scenario (A2) projects continuous population growth, with slower economic growth and technological change than in the other scenarios. For the medium-high emissions scenario (A2), CO_2 emissions continue to climb throughout the century, reaching almost 30 Gt/yr, about four times the present rate of emissions. By the end of the century CO_2 concentration would reach more than triple its pre-industrial level.
- The higher emissions scenario (A1fi) represents a world of rapid fossil-fuel-intensive economic growth, global population that peaks mid-century then declines, and the introduction of new and more efficient technologies towards the end of the century. The higher emissions scenario (A1fi) rises faster than the A2 scenario, reaching about 25 Gt/yr, more than three times the present rate of emissions, by 2050. The A1fi scenario concludes the century with approximately the same annual emissions as the A2 scenario. However, the A2 and A1fi scenarios differ in two ways that have important implications for the projected changes. First, the emissions pathways of A1fi and A2 diverge by mid-century, with A1fi rising rapidly and then flattening out toward the end of the century. Second, the total cumulative emissions in the A1fi scenario are almost 20% higher at the end of century than in the A2 scenario.

To capture a range of uncertainty among climate models, this chapter reports on projections from three state-of-the-art global climate models (GCMs) that capture a range of climate sensitivities:

- The Parallel Climate Model (PCM1) from the National Center for Atmospheric Research (NCAR) and the U.S. Department of Energy (DOE) groups (Washington et al. 2000), a low-sensitivity model, with a climate sensitivity of approximately 1.8°C (3.2°F)[1]
- The Geophysical Fluids Dynamic Laboratory (GFDL) CM2.1 (NOAA Geophysical Dynamics Laboratory, Princeton New Jersey) model (Delworth et al. 2005), a medium-sensitivity model with climate sensitivity of approximately 3°C (5.4°F)
- The U.K. Met Office Hadley Centre Climate Model, version 3 (HadCM3) (Pope et al. 2000), with a slightly higher climate sensitivity of 3.3°C (5.9°F)

Each of the three GCMs produced a reasonably good simulation of key features of California's observed climate and representations of tropical Pacific ENSO variability.

[1] *Climate sensitivity* is defined as the change in temperature resulting from a doubling of CO_2 concentration above pre-industrial levels.

The models were also chosen for having available simulation datasets at monthly and daily time scales in order to carry out the impact studies undertaken in the scenarios analysis.

Global climate models calculate weather, ocean, and land surface variables over a discrete global grid too coarse to adequately depict the complex structure of temperature and precipitation that characterizes the California setting. The results presented here rely principally on a statistical technique using properties of observed data (Wood et al. 2002), that was employed to correct model biases and "downscale" the model data to a finer level of detail—a grid of approximately 12 kilometers (km) (7 miles). This downscaling technique, which was employed in previous climate change assessments, was used to satisfy study requirements for impact studies, including modeling the water and energy balance. To derive land surface hydrological variables consistent with the downscaled forcing data, a macroscale, distributed, physically based hydrologic model—the variable infiltration capacity (VIC) model (Liang et al. 1994; Liang et al. 1996)—was used.

5.2. Climate Projections

5.2.1. Temperature

Temperatures in California are projected to rise significantly over the twenty-first century. As shown in Table 1 and Figure 2, magnitudes of the warming vary because of the uncertainties in the climate sensitivity, as expressed by differences between models and in the emission scenarios. The rises (2000 to 2100) vary from approximately 1.7°C–3.0°C (3.0°F–5.4°F) in the lower range of projected warming, 3.1°C–4.3°C (5.5°F–7.8°F) in the medium range, and 4.4°C–5.8°C (8.0°F–10.4°F) in the higher range (Cayan et al. 2006a). To comprehend the magnitude of these projected temperature changes, over the next century the lower range of projected temperature rise is slightly larger than the difference in annual mean temperature between Monterey and Salinas, and the upper range of project warming is greater than the temperature difference between San Francisco and San Jose, respectively.[2]

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[2] The difference in annual mean temperatures between Monterey (65.3ºF or 18.5ºC) and Salinas (67.8ºF or 19.9ºC) is 2.5ºF (1.4ºC) and the difference between San Francisco Mission Dolores (63.6ºF or 17.6ºC) and San Jose (71.0ºF or 22ºC) is 7.4ºF (4.4ºC).

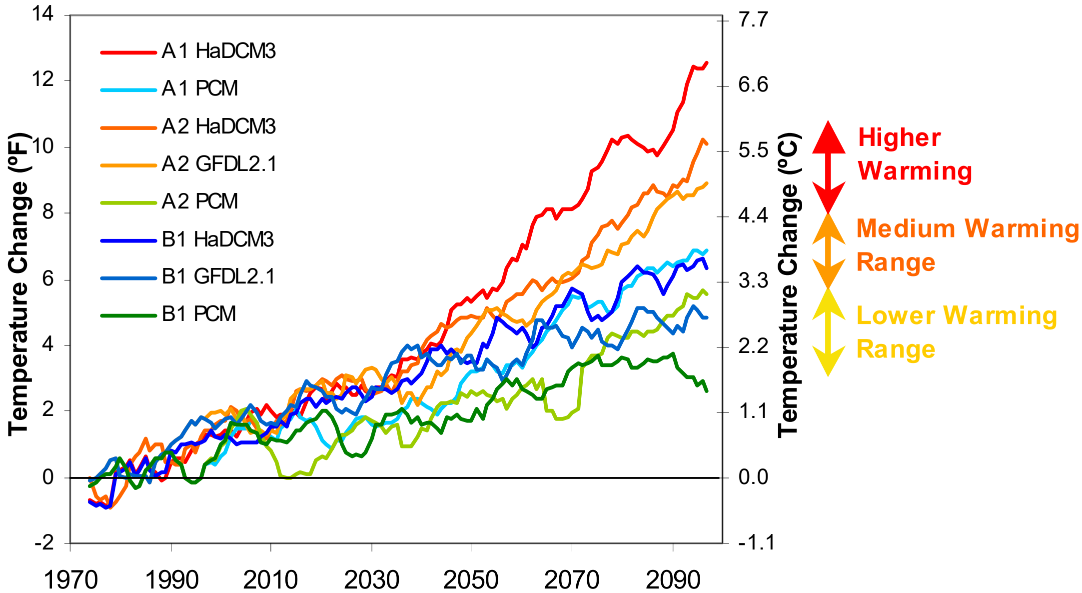


Figure 2. Change in California annual mean temperature

Change in California annual mean temperature (7-year running mean) (°F/°C) by year, from 1970–2099, relative to 1961–1990 average.

An important aspect of the model results is that all of the GHG scenario simulation, (except the low-emission scenario simulated by the low response model) exhibit higher warming in summer than in winter. In the medium-high emission (A2) scenario with the low sensitivity and medium sensitivity models, temperature increases by the end of the twenty-first century are 1.5°C–3.5°C (2.7°F–6.3°F), greater in summer than in winter (Cayan et al. 2006a). This result has important implications for impacts such as ecosystems, agriculture, water and energy demand, and the occurrence of heat waves, which have public health consequences.

5.2.2. Precipitation

There is no clear trend in precipitation projections for California over the next century. However, from the recent IPCC model projections—including several models that were not selected for the present study—there are considerable differences, from wetter to drier, between models and between emissions scenarios. The center of this distribution of simulations yields relatively little change, with a tendency for a slight decrease in precipitation, as is the case for the GFDL and the HadCM3 simulations (Cayan et al. 2006a).

Table 1. Potential warming ranges for California

	GCMs	Lower °C (°F)	Medium °C (°F)	Higher °C (°F)
Projected End of Century Range of Warming*		1.7°C–3°C (3.0°F–5.4°F)	3.1°C–4.4°C (5.5°F–7.8°F)	4.4°C–5.8°C (8.0°F–10.4°F)
Lower GHG Emissions B1	PCM	1.7 (3.0)		
	GFDL	2.2 (4.0)		
	HadCM3		3.1 (5.6)	
Medium-High GHG Emissions A2	PCM	2.6 (4.7)		
	GFDL		3.9 (7.0)	
	HadCM3			4.5 (8.1)
Higher GHG Emissions A1fi	PCM		3.3 (6.0)	
	HadCM3			5.8 (10.4)

*The temperature ranges were defined here for illustration only. The division was made simply by dividing evenly (low, medium, high) range of change in California's average annual temperatures as projected by the three GCM and emissions scenarios reported on in this summary (1.7°C–5.8°C (3.0°F–10.4°F)). The projected warming ranges presented here are for 2070–2099 relative to 1971–2000. However, some of the impacts summarized in this report used a different historical climatological baseline of 1961–1990. The difference between the 1961–1990 and 1971–2000 baselines leads to a small difference in projected temperature rise for the different scenarios and models. The difference in baselines amounts to approximately a 0.2°C (0.36°F) difference in the full range of projected end-of-century temperature rise.

There is no evidence from the projections indicating that the Mediterranean seasonal precipitation regime in California will change. All of the simulations examined here indicate that the very dominant portion of precipitation continues to be derived during winter from North Pacific storms. Summer precipitation changes only incrementally, and actually decreases in some of the simulations, so there is little evidence for a stronger monsoon influence. For the scenarios reported here, each of the model runs is characterized by large interannual to decadal fluctuations of precipitation, but not much change in annual precipitation over the 2000–2100 period. Little change in variability over the period of the model runs is evident in the simulations. The frequency of warm tropical events (El Niños) remains about the same as was exhibited in the historical simulations. As in observations, GCM El Niño events are related to anomalous precipitation patterns near the California region (Cayan et al. 2006a).

6.0 Coastal Sea Level

Coastal observations and global model projections indicate that California's open coast and estuaries will experience rising sea levels during the next century. Sea level rise already has affected much of the coast in Southern California, Central California, and the San Francisco Bay and estuary. These historical trends, quantified from a small set of California tide gages, have approached 2 mm/year (0.08 in/yr), which are rates very similar to those estimated for global mean sea level. So far, there is little evidence that the rate of rise has accelerated, and indeed the rate of rise at California tide gages has actually flattened since about 1980. However, projections indicate that substantial sea level rise, even faster than the historical rates, could occur during the next century.

As discussed in Cayan et al. (2006b), recent climate change simulations project significant global sea level rise during the next century, as the result of thermal expansion as the oceans warm and as runoff from melting land-based snow and ice accelerates. Sea level rise projected from the models increases in proportion to the amount of global warming. By the 2070–2099 period, sea level rise projections range from 13–62 cm (5.1–24.4 in) higher than the 2000 level for simulations following the lower emissions scenario (B1), from 18–76 cm (7.1–29.9 in) for the medium-high emission scenario (A2), and from 21–89 cm (8.5–35.2 in) for the higher emissions scenario(A1fi). These are illustrated in Figure 3, together with the last century of observed sea level at the San Francisco tide gage.

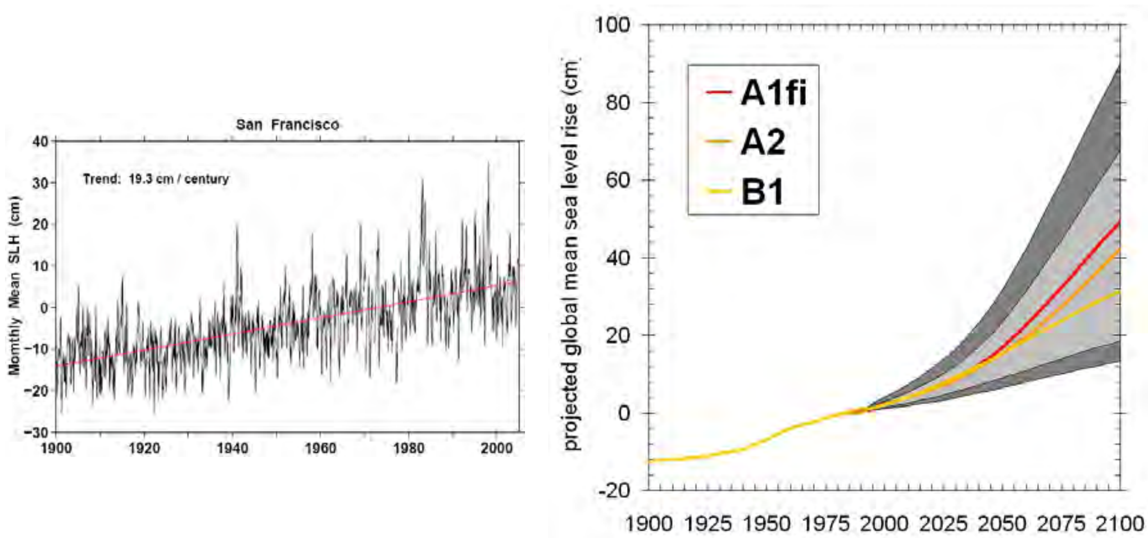


Figure 3. Observed change in sea level rise in San Francisco and projections of global mean sea level rise

Projected sea level rise from climate model estimates for three GHG emissions scenarios, A1fi (higher emissions), A2 (medium-high emissions), and B1 (lower emissions). San Francisco observed sea level, with trend of 19.3 cm/century (7.6 in/century), is shown for comparison. (Cayan et al. 2006b). In the graph on the right, light gray and dark gray represent uncertainty from thermal expansion and ice melt, respectively.

In addition to relatively steady long-term trends and astronomical tides, sea levels along the California coast undergo inter-annual and weather scale fluctuations that carry sea level elevations above and below the predicted tides and trends. These slower sea level rises are crucial because they boost the sea level excursions associated with the shorter term tidal, weather, and climate fluctuations. The most impressive examples of high sea level episodes in recent decades occurred during the winters of the massive El Niño events of 1982–1983 and 1997–1998 (Flick 1998). Thus, much of the potential damage from rising sea levels will occur during the occasions when high water stands due to tides, weather and climate anomalies are made higher (or more frequent) by the gradually rising mean sea levels. Importantly, GCMs include El Niños and La Niñas, as well as longer-lasting Pacific decadal variability, both in historical simulations as well as in projections that are being used to investigate twenty-first century climate changes.

Cayan et al. (2006b) considered two climate models and three emission scenarios to provide a set of future weather and short-period climate fluctuations, and a range of potential long-term sea level rises. Moderate to very large sea level rises were projected. The middle to higher end of this range would substantially exceed the historical rate of sea level rise (15–20 cm (5.9–7.8 in) per century) observed at San Francisco and San Diego during the past 100 years. Using a model of the combined contributions of tides, weather, climate, and long-term global warming on hourly sea levels, the potential for sea level rise impacts was assessed from the occurrence of hourly extremes. Considering a range of scenarios, and a range of possible sea level trends (Figure 4), Cayan et al. (2006b) find that, if warming is near the low end of the temperature range of projections so that sea level rise trends are also near the low end, then the occurrence of extremely high sea level events will increase, but not greatly, and sea level extremes under the various emissions scenarios (B1, A2, A1fi) are not much different from each other. On the other hand, if warming is greater, then sea level rise trends are at the higher end in each scenario, causing extreme events and their duration to increase markedly, especially for the medium-high and higher GHG emissions scenarios (A2, A1fi). Because of uncertainties in the climate sensitivity, it is not clear how rapidly sea levels will rise, even under the lowest emission scenarios. However, the California coast has already experienced rises of sea level that approach 15–20 cm (6–8 in) over the last century, so it seems prudent to consider scenarios where projected rise rates equal or exceed these historical sea level rise rates.

Coastal sea level extremes are also exacerbated by other processes, such as heavy surf from wind-driven waves, and these effects tend to be active during the same storms that causing anomalously high sea levels. Near San Francisco and Crescent City, when sea level fluctuations, above tide predicted levels, reach anomalies that exceed the 99th percentile of their measurements, the average in peak wave height at nearby wave-measuring buoys maintained by NOAA climbs to about double its ambient level. Because wave energy is proportional to the *square* of the wave height, the wave height increase during anomalous sea level episodes is equivalent to a coincident increase in wave energy by a factor of four. This observational evidence indicates that when anomalous sea level is highest, wave energy has an increased likelihood of reaching very high levels. When waves and anomalously high sea level coincide with high tides, the chances for coastal damage are heightened. Continuing increases in mean sea level due to global change makes this problem even more severe.

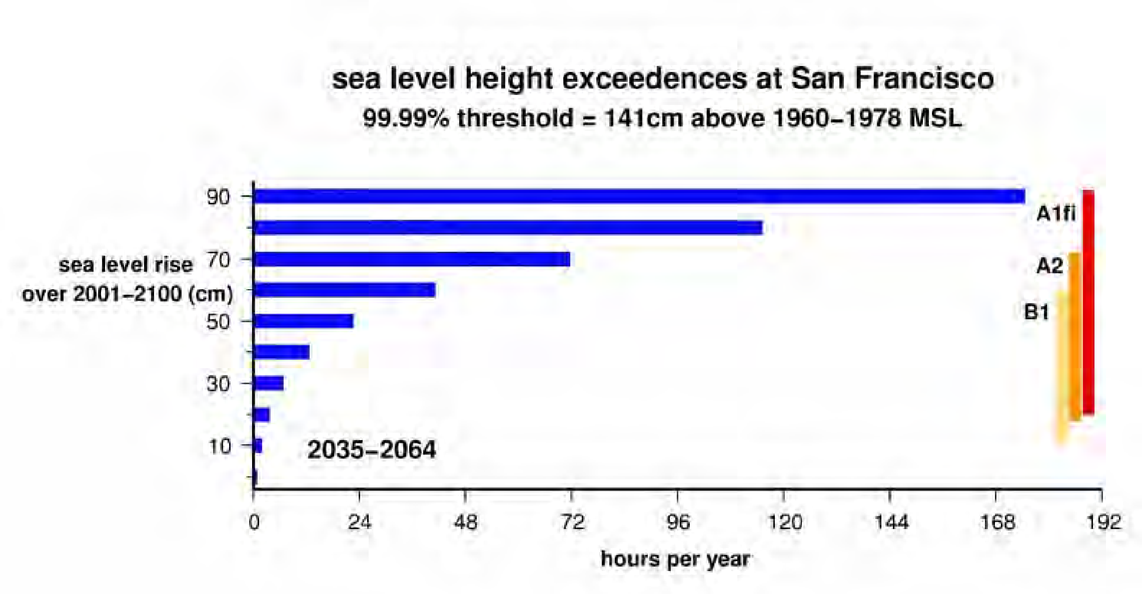


Figure 4. Projected number of hours per year, when San Francisco sea level height (SLH) exceeds 99.99% of its historical threshold

Projected number of hours per year, averaged over 2035–2064, when San Francisco sea level height exceeds historical (1960–19780 99.99 percentile observed threshold. Estimates are calculated from GFDL model weather and ENSO variability superimposed on predicted tides and a range of long term sea level rise as approximated by linear trends, from 0 to 90 cm over 2000–2100. Range of trends that have been estimated from climate models is indicated for three different GHG emission scenarios (Cayan et al. 2006b).

Sea level rise also threatens the Sacramento/San Joaquin Delta of the San Francisco Bay estuary. Historically, major floods have produced breaches in levees that protect low-lying, subsiding island tracts in the Delta and riverine and estuarine margins elsewhere, despite many engineered changes to the rivers. As sea levels rise, flood stages in the Delta would be expected to rise also, putting increasingly more pressure on Delta levees. The threats from sea level rise are particularly significant, because as Mount and Twiss (2005) have noted, the forces that rising sea/river levels bring to Delta levees increase as the *square* of the rises, rather than "just" linearly with the rises. Furthermore, the combination of flood and high sea-level stands are particularly dangerous in the Delta, where it is the combination of sea level and river stages that determine the water height. Storms are primary causes of the highest water levels both from barometric and wind effects on the sea levels and from the (freshwater) floods that they can generate. A count of the number of projected extremely high sea level episodes at San Francisco that coincide with potential storm/flood episodes is depicted in Figure 5 by cases when sea level is unusually high and atmospheric surface pressure is unusually low. This simulation indicates that, at least during the earlier decades of the next century, the largest increases in the frequency of extremely high sea level episodes as sea levels rise will coincide with periods of enhanced storm-flood risks.

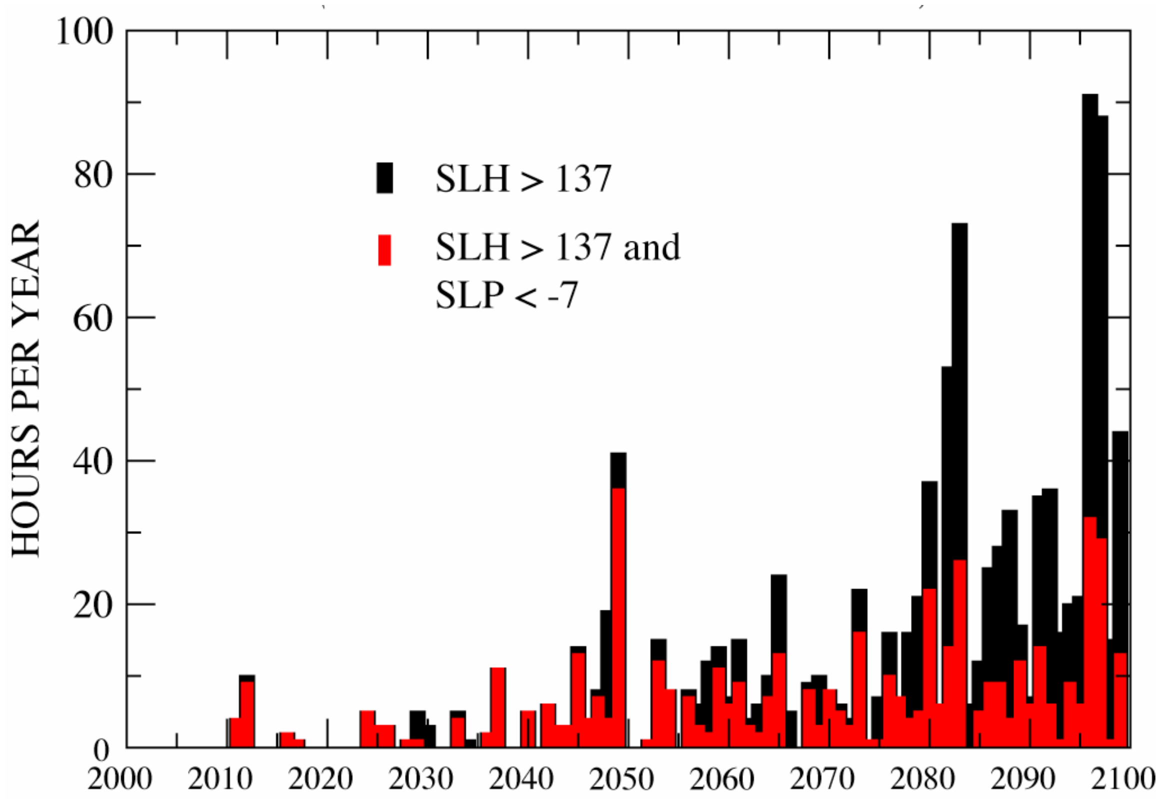


Figure 5. Projected total exceedances of San Francisco hourly sea level height

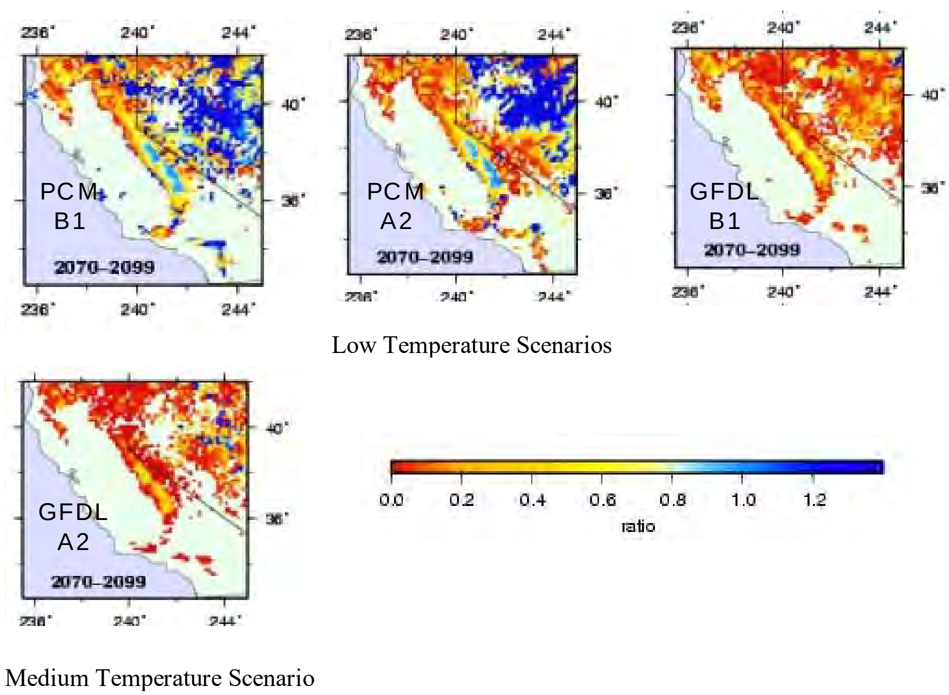
Projected total exceedances of San Francisco hourly sea level height above historical 99.99 percentile (black), and number that are coincident with sea level pressure (SLP) anomalies less than -7 mb. This figure was generated using projected sea level from GFDL model weather and Nino3.4 SST with a linear trend of 30 cm over 2000–2100 (Cayan et al. 2006b).

7.0 Water Resources

Although most climate model simulations project relatively moderate changes in precipitation over this century, rising temperatures are expected to lead to diminishing snow accumulation in mountainous watersheds, including the Sierra Nevada. Warmer conditions during the last few decades across the western United States have already produced a shift toward more precipitation falling as rain instead of snow (Knowles et al. 2005), and snowpacks over the region have been melting earlier in the spring (Mote et al. 2005; Stewart et al. 2005). Delays in snow accumulation and earlier snowmelt will have cascading affects on water supplies, natural ecosystems, and winter recreation.

7.1. Snowpack

The Variable Infiltration Capacity (VIC) distributed land surface hydrology model was used to simulate snowpack throughout the century (Cayan et al. 2006a). Projected reductions in snowpack increase with temperature, with the larger losses of spring snowpack in the higher range of projected warming (Figure 6). Each of the simulations shows losses of spring snow accumulation, largely over the Sierra Nevada, become progressively larger over the twenty-first century. In the Sierra Nevada by the 2035–2064 period, snowpack could decrease 12% to 47% from historical levels under the lower range of projected warming, and decrease 26% to 40% in the higher range of projected warming, with precipitation changes playing a partial role in the reductions for the lower temperature cases. By the end of century, snowpack could decrease by as much as 90% in the higher amount of warming—almost double the losses expected under the lower warming cases.



Source (Cayan et al. 2006a)

Figure 6. April 1 snow water equivalent 2070–2090 fraction of 1961–1990.

7.2. Water Supply

Declining snowpack will aggravate the already overstretched water resources in California. The snowpack in the Sierra Nevada provides natural water storage, equal to about half the storage capacity in California's major human-made reservoirs, holding the winter precipitation in the form of snow and releasing it in the spring and early summer as the snow melts. This loss in storage could mean more water shortages in the futures. However, the full effect of this storage loss will depend in part on whether reservoirs can be managed to capture the earlier snowmelt while not losing flood control capacity or, at the higher elevations, hydropower generation capacity.

Two different methods were used to project the effects of the alternative climate scenarios on water supply. One approach used the VIC model to simulate inflows into major reservoirs in the Sacramento Valley as drivers for their respective water resource management models, CALSIM and CALVIN[3] (Chung et al. 2006; Medellin et al. 2006; Vicuña et al. 2006; Vicuña 2006). The second approach used the Water Evaluation and Planning (WEAP) system (Joyce et al. 2006).

These two approaches differ in how they process the climate change scenarios.[4] Under most scenarios, both modeling approaches project streamflows to decrease slightly by mid-century, with more dramatic changes by the end of the century. Flows into the major Sierra Nevada reservoirs could decline between 25%–30% under the medium range of projected warming and the simulated decline in precipitation—almost double the decrease projected under the lower range of projected warming. However one model run produces a slight increase in precipitation and a corresponding rise in projected streamflows.

The Sacramento Four River Index (also called the *Sacramento 40-30-30 Index*) was used to classify the probability of water year types under the different climate change scenarios.[5]

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[3] CALSIM was used to assess hydrologic impacts in the Central Valley; CALVIN also covers the portions of the state outside the Central Valley

[4] CALSIM and CALVIN require as input a given time series of monthly stream flows—both use a modified version of the historical stream flow over the period 1922–1994. Climate change is incorporated into the given historical series by the "perturbation ratio" method: for a given time period of interest (2035–2064 or 2070–2099), a given stream location, and a particular month, one computes the average ratio of the VIC streamflow in that month over the period of interest to the VIC streamflow for the corresponding month over a base period (1961–1990). The monthly ratios are then used to adjust, or "perturb," the monthly stream flows in the historical series 1922–1994. In contrast, the WEAP approach uses raw time series of precipitation and temperature in a watershed hydrology model and directly generates a time series of streamflows. The perturbation approach is tied more closely than the WEAP approach to the historic inter-annual pattern of year-to-year variation in drought and wetness, although both approaches can generate changes in drought persistence.

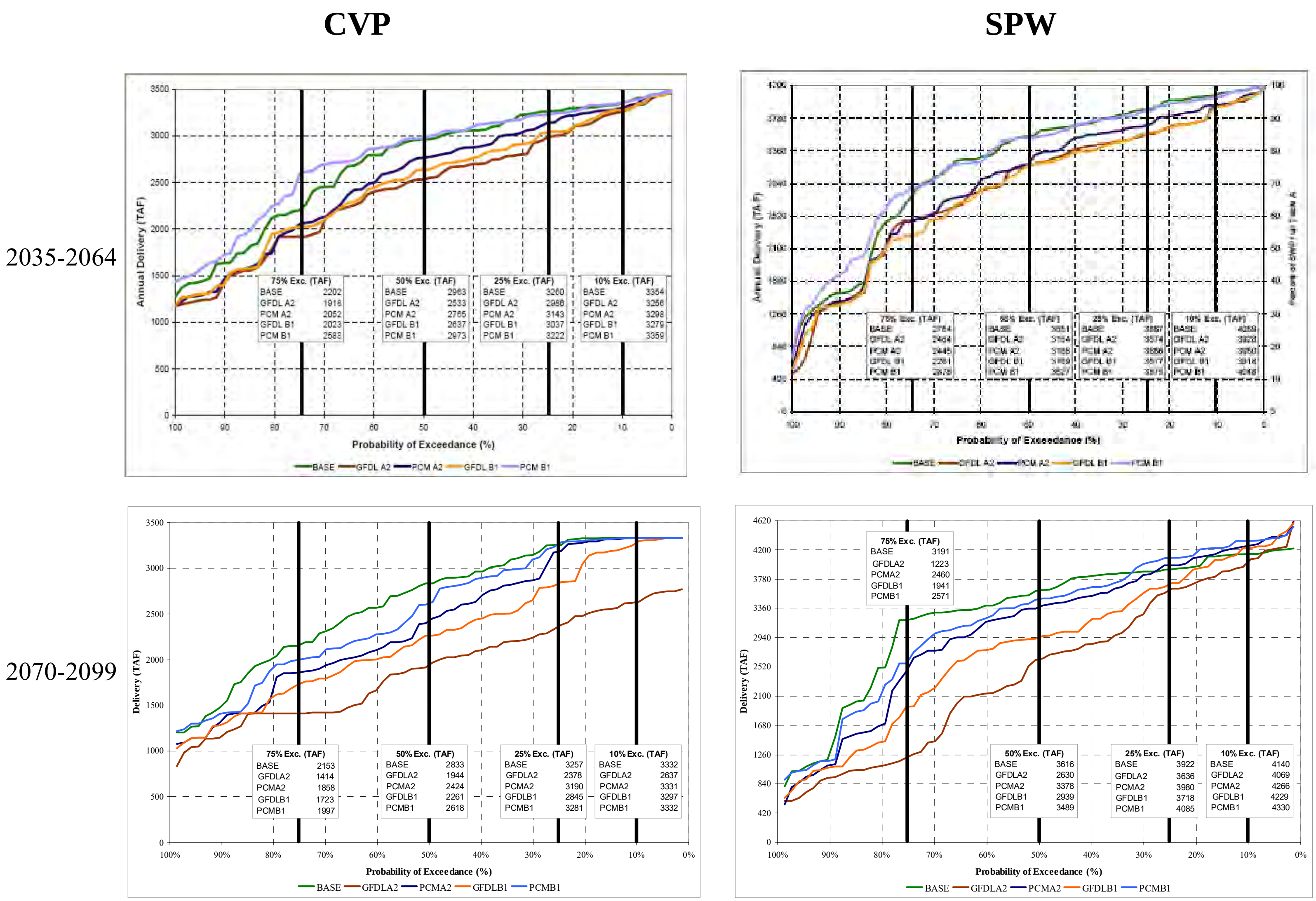
[5] The Sacramento River Index was developed by the State Water Resources Control Board for regulatory purposes, and requires the forecasting by May of each year of the current year's April–July unimpaired runoff in the Sacramento Valley. When a retrospective analysis is conducted using the historical hydrology, as here, the actual April–July runoff is known, but not the prospective forecast, and therefore the index cannot be calculated in exactly the same way. The research here uses the Brekke et al. (2004) retrospective approximation for calculating the index.

This river index classifies the years into five categories: Wet, Above Normal, Below Normal, Dry, and Critical. Because the River Index pays greater attention to the aggregate stream flow then the timing of flow, it is more influenced by changes in precipitation then temperature. The projections for the less dry model (PCM) indicate that toward the end of the century, under the higher-emissions scenario, up to 50% of the years between 2070–2099 could be critically dry years, as compared to 18% in the historical period (Vicuña 2006; Hayhoe et al. 2004). Under the lower-emissions scenario in the less-dry model, little or no change in the frequency of critically dry years is expected. In contrast, from the projections using the drier models (HadCM3 and GFDL), even under the lower-emissions scenarios the frequency of critically dry years would increase, up to twice as often as historical conditions.

CALSIM was used to assess the consequences of the climate change scenarios on carryover storage at CVP and SWP reservoirs and for deliveries to CVP and SWP (Chung et al. 2006; Vicuña 2006). Toward the end of the century, the change in the volume and timing of runoff reduce the ability of the major projects to deliver water to agricultural users south of the Delta. These deliveries fall by 15%–30% under the lower range of projected warming, and 40%–50% under the medium and higher ranges of projected warming (Vicuña 2006) (Figure 7), with the drier model simulations showing the largest decreases. The projected changes in water supply would be further exacerbated by increased demand due to warmer temperatures. By the end of century, warmer temperatures are expected to increase the crop demand between 2% and 13%, in the lower and medium warming cases, respectively; there could be a similar effect on urban demand for outdoor lawn watering (Baldocchi et al. 2006).

7.3. Winter Recreation

Declines in Sierra snowpack will also have widespread implications for winter tourism. Warming could affect the starting and closing dates of the ski season. Toward the end of the century, in lower temperature scenarios, the ski season at lower and middle elevation settings could shorten by as much as a month, while projected climatic changes under the higher temperature scenario suggest that the minimum snow conditions for ski resort operation might never occur, and resorts would be forced to rely entirely on snowmaking or move their operations (Hayhoe et al. 2004).



(Chung et al. 2006; Vicuña 2006)

Figure 7. Exceedance probability plot for Central Valley Project and the State Water Project

7.4 Potential Strategies for Reducing the Impacts on Water Resources

To compensate for the loss of natural storage in the snowpack, the existing man-made storage capacity will have to be managed more effectively, and also augmented. Modern probabilistic seasonal and short-term hydrology forecasting methods and more sophisticated decision algorithms could help reservoir managers better balance the competing demands of storage for water supply, hydropower, and flood control (Yao and Georgakakos 2001).[6] Besides this, it is likely that some form of additional storage will eventually be needed, whether above ground or below ground in the form of enhanced conjunctive use. More generally, it is likely that a portfolio of adaptation responses will be needed, including more conservation and increased efficiency in water use. The transmission systems for moving water around the state will also need to be both firmed up (to protect against seismic risks in the Delta, for example) and also enhanced to provide greater flexibility and connectivity in meeting water users' demands.

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[6] A demonstration project is underway with funding from the CALFED Bay-Delta Program, the National Oceanic Atmospheric Administration (NOAA), and the Public Interest Energy Research Program (PIER). If that project is successful, it will pave the way for the operational use of these new management tools.

8.0 Agriculture

Agriculture, along with forestry, is the sector of the California economy that is most likely to be affected by a change in climate. California agriculture is a $68 billion industry.[7] California is the largest agricultural producer in the nation and accounts for 13% of all U.S. agricultural sales, including half of the nation's total fruits and vegetables. Regional analyses of climate trends over agricultural regions of California suggest that climate change is already in motion. Over the period 1951 to 2000, the growing season has lengthened by about a day per decade, and warming temperatures have resulted in an increase of 30 to 70 growing degree days per decade, with much of the increase occurring in the spring (Feng and Hu (2004). Climate change affects agriculture directly through increasing temperatures and rising CO_2 concentrations, and indirectly through changes in water availability and pests.

8.1. Temperature

Temperature influences crop growth through its impact on photosynthesis and respiration, as well as on growing season length and water use. Temperature also serves as a controlling factor for developmental processes, such as flowering and fruit maturation, which may be threatened if lengthening of the growing season introduces asynchrony between the timing of flowering and the life cycle of important insect pollinators.

Crop growth models show that a warming from a low to a higher temperature generally raises yield at first, but then becomes harmful (Doering et al. 2002). Possible effects of excessively high temperature include: decreased fruit size and quality for stone fruits, premature ripening and possible quality reduction for grapes, reduced fruit yield for tomatoes, increased incidence of tipburn for lettuce, and similar forms of burn for other crops. For example, rising temperatures are likely to produce adverse effects on quantity and quality for a number of California's agricultural products. For example, milk production has been found to decline when temperatures rise above 25°C (77°F), and Hayhoe et al. (2004) projected that in California milk production could decline up to 20% if temperatures rise to the higher warming range. Hayhoe et al. (2004) also projected a decline in wine grape quality as a result of increasing temperatures, where grapes in the major wine growing regions were expected to shift from optimal quality to marginal or impaired as temperatures rise to the higher warming range. Similarly, Baldocchi and Wong (2006) found that as temperatures rise from to the lower and medium warming ranges the number of chill hours declines, threatening the future viability of many species of fruit trees in the state.[8]

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[7] This is the 1998 figure for the total sales of agricultural and processing products in California (Kuminoff et al. 2001).

[8] Tree crops have become an increasingly prominent part of Central Valley agriculture over the three decades; the economic cost associated with the loss of a tree crop due to extreme weather conditions is likely to be significantly larger than that associated with the loss an annual field crop.

8.2. Carbon Dioxide (CO_2)

From a variety of studies in the literature, photosynthesis increases when a plant is exposed to a doubling of CO_2. However, whether this translates into increased yield of economically valuable plant product is uncertain and highly variable. Also, elevated CO_2 levels are associated with decreased concentrations of mineral nutrients in plant tissues, especially a decrease in plant nitrogen, which plays a central role in plant metabolism. Some crops may benefit in quality from an increase in CO_2; for example the fruit flavor of strawberries improves. Some crops are harmed by an increase in CO_2—for example grain protein in crops decreases and, in the case of wheat, breadmaking quality decreases (Cavagnaro et al. 2006).

8.3. Pests and Weeds

Growth rates of weeds, insect pests, and pathogens are also likely to increase with elevated temperatures, and their ranges may expand. A relatively new area of research involves the use of physiologically based dynamic models to fully understand the effects of weather (e.g., temperature, rainfall, solar radiation) on species dynamics. Gutierrez et al. (2006) used a dynamic model to estimate the potential impacts of a pest (pink bollworm, PBW) on cotton cultivation in the state. At the present time this pest is of importance only in the southern desert valleys (e.g., the Imperial and Coachella valleys), because winter frost restricts PBW's invasion to the million acres of cotton grown in the San Joaquin Valley. However, if winter temperatures rise by 2°C to 2.5°C (3.6°F to 4.5°F), as projected under the medium- to higher ranges of projected warming, the distribution of PBW would likely expand northward (Figure 8).

8.4. Potential Strategies for Reducing the Impact on Agriculture

Because of the greater priority being given to urban users in the event of water shortage, the agricultural sector is likely to bear a disproportionate share of water scarcity due to any climate-induced reduction in surface water supply. Farmers will likely respond by increasing their pumping of groundwater where this is available, shifting to higher value/less water-using crops, adopting higher efficiency methods of irrigation, and fallowing some farmland. Over time, new seed varieties could be developed that are better adapted to the changed climate and pest conditions, and entirely new crops may be found to meet pharmaceutical or energy supply needs. However, some of these adaptations may require publicly supported research and development if they are to materialize.

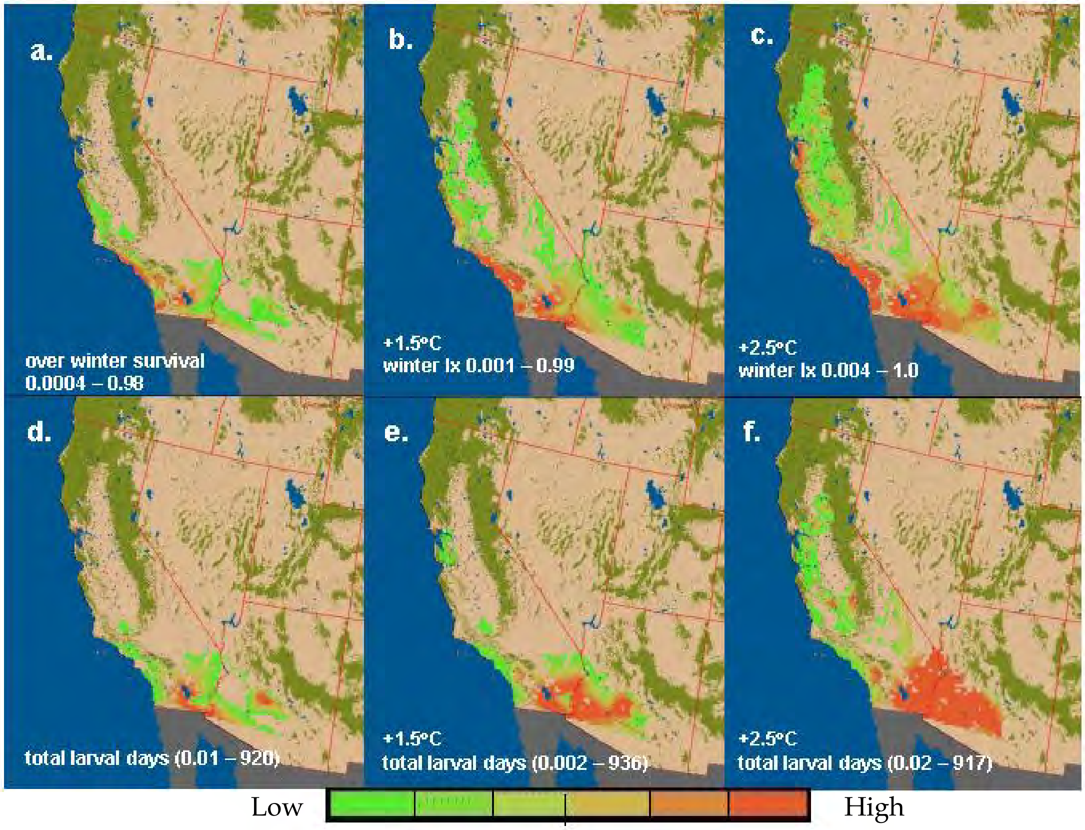


Figure 8. Cotton/pink bollworm (PBW): Predicting areas of favorableness

The effects on winter survival (a-c) and total seasonal pest PBW larval densities (larval days, d-e) under current weather (a,d) and with 1.5ºC (2.7ºF) (b,e) and 2.5ºC (4.5ºF) (c,f) increases in daily temperatures respectively (Gutierrez et al. 2006).

9.0 Forests and Natural Landscapes

Climate changes and increased CO_2 concentrations are expected to alter the extent and character of forests and other ecosystems (Field et al. 1999; McCarty et al. 2001; Aber et al. 2001). The distribution of species is expected to shift; the risk of climate-related disturbance such as wildfires, disease, and drought is expected to rise; and forest productivity is projected to increase or decrease—depending on species and region. In California, these ecological changes could have significant implications for both market (e.g., timber industry, fire suppression and damages costs, public health) and non-market (e.g., ecosystem services) values.

9.1. Natural Landscapes

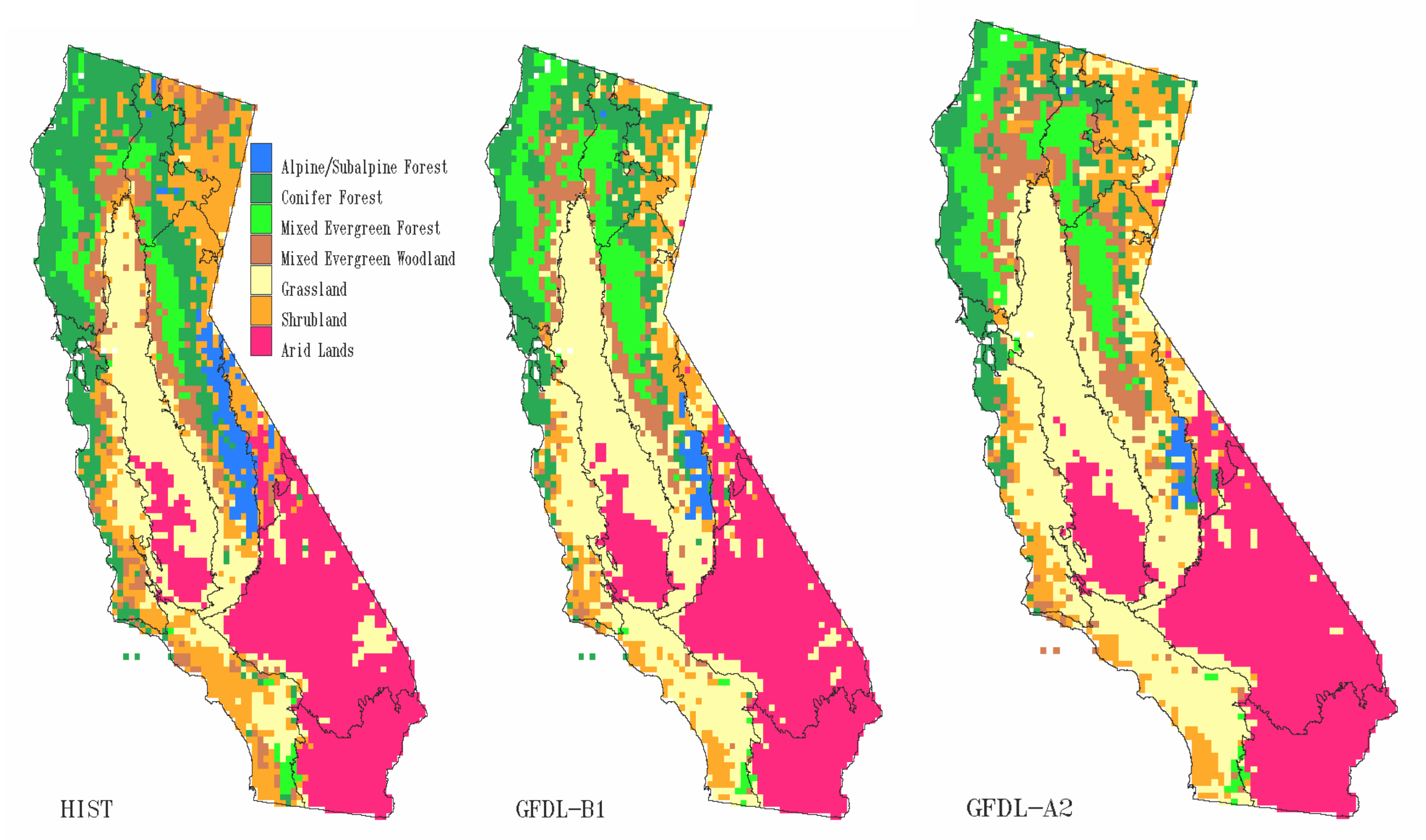
Lenihan et al. (2006) used the MC1 Dynamic Vegetation Model to simulate the response of vegetation distribution and ecosystem productivity to observed historical climate and to project the response to several scenarios of potential future climate change for California (Lenihan et al. 2006; Hayhoe et al. 2004). MC1 simulates lifeform mixtures and vegetation types; ecosystem fluxes of carbon, nitrogen, and water; and fire disturbance. The MC1 projections indicate that the ecosystems most susceptible to temperature rise are the alpine and subalpine forest cover. In addition, changes in fire frequency are expected to contribute to an increase in the expanse of grasslands, largely at the expense of woodland and shrubland ecosystems (Figure 9).

9.2. Wildfires

Fire is an important natural disturbance within many California ecosystems that promotes vegetation and wildlife diversity, releases nutrients and eliminates heavy fuel accumulations that can lead to catastrophic burns. The changing climate could alter fire regimes in ways that could have social, economic, and ecological consequences (McKenzie et al. 2004; Fried et al. 2004; Brown et al. 2004).

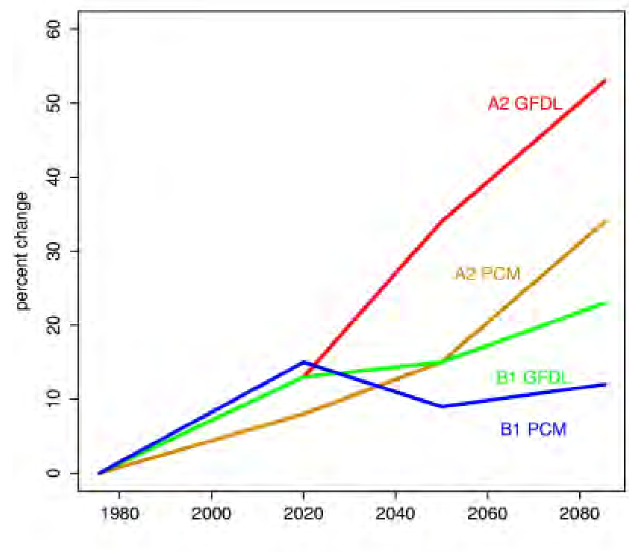
Westerling and Bryant (2006) estimated future statewide wildfire risk from a statistical model based on temperature, precipitation, and simulated hydrologic variables. These are conservative estimates because they do not include effects of extreme fire weather, but implications are nonetheless quite alarming. Projections made for the probabilities of "large fires"—defined as fires that exceed an arbitrary threshold of 200 hectares (approximately 500 acres)—indicate that the risk of large wildfires statewide would rise almost 35% by mid-century and 55% by the end of the century under a medium-high emissions scenario, almost twice that expected under lower emissions scenarios (Figure 10). Estimates of increased damage costs from the increases in fire season severity (Westerling and Bryant 2006) are on the order of 30% above current average annual damage costs.

A second study explored, through a case study in Amador and El Dorado Counties, the effects of projected climate change on fire behavior, fire suppression effort, and wildfire outcomes (Fried et al. 2006). Climate and site-specific data were used in California Department of Forestry and Fire Protection (CDF) standard models to predict wildfire behavior attributes such as rate of spread and burning intensity. The predicted wildfire



(Lenihan et al. 2006)

Figure 9. Vegetation distribution under historical conditions and multiple climate change scenarios at end of century



(Source: Westerling and Bryant 2006)

Figure 10. Percent change in the expected minimum number of large fires per year in California

outcomes were aggregated using the California Fire Economics Simulator version 2 (Fried and Gilless 1999), a stochastic computer model developed for CDF's fire protection planning program. The study found an increase in the projected area burned (10%–20%) and number of escaped fires (10%–40%) by the end of century, under the drier climate scenarios (GFDL). However, the less dry model showed little change.

Neither of these approaches for modeling the effects of climate change on wildfires considers the effects of the potential changes in wind conditions that may result from a changing climate, because the winds produced by GCMs are too coarse to be useful over most of the complex terrain in the California region. However, the strength and direction of winds can greatly influence fire behavior (Fried et al. 2004). Although initial studies suggest that future climate change may decrease early fall Santa Ana Wind conditions in some regions (Miller and Schlegel 2006), further research is needed to more thoroughly characterize potential changes in wind conditions and their possible effects on wildfires in the state.

9.3. Pests and Pathogens

Pests and disease have historically had a significant effect on California forests. The changing climate may exacerbate these effects, by expanding the range and frequency of pest outbreaks. For example, the introduced pathogen, pine pitch canker (*Fusarium subglutinans* f. sp. *pini*), once limited to coastal areas of California has expanded to the El Dorado National Forest in the Sierra Nevada. Rising winter temperature in the Sierra Nevada would make conditions more favorable for pitch canker, and could result in increased disease severity and economic loss (Battles et al. 2006).

9.4. Forest Productivity

Past studies project increases in forest productivity with continued climatic change (Mendelsohn 2003; Lenihan et al. 2003). However increasing evidence suggests that given the uncertainties concerning how trees will respond to elevated CO_2 concentrations (Körner et al. 2006), and the increased risk and susceptibility to catastrophic loss, the implications for the forest productivity and the timber industry may be less optimistic.

The recent assessment by Battles et al. (2006) of the expected impacts of climate change on the California forest sector used an industry standard planning tool to forecast 30-year tree growth and timber yields for forest stands in El Dorado County under a high and medium level of projected warming. Conifer tree growth was reduced under all climate change scenarios. In the medium level of projected warming, productivity in mature mixed-species stands was reduced by 20% by the end of the century. The reductions in yield were more severe (30%) for pine plantations.[9] Projections further indicate that the reduced growth rates could lead to substantial decreases in tree survival rates.

9.5. Potential Strategies for Reducing Impacts on Wildfire Risk and Forestry

Existing fire management strategies will be severely challenged by the interacting effects of expected changes in population and land use, and the projected changes in wildfire frequency and severity resulting from climate change. However, there are actions that can be taken in the near-term to improve our ability to live within California's fire-prone landscapes, while maintaining the functioning and structure of the ecosystems upon which we depend. For example, Moritz and Stephens (2006) suggest: (1) the adoption of a risk-based framework for fire management; (2) the reintroduction of fire to fire-prone ecosystems; (3) the creation of flexible policies that differentiate between the diverse ecosystems in California; and (4) a reevaluation of building and land use planning in the wildland-urban interface.

Battles et al. (2006) point to a number of strategies to offset declining forest yields. For example, silvicultural treatments could be designed to compensate growth losses to climate change with improvements in stand conditions. Planting mixtures of species, maintaining several age classes, reducing tree density, and pruning trees at strategic intervals are examples of cultural practices that could improve timber yields. Retaining a mixture of species and ages in the mixed conifer forests may alleviate some of the risks associated with the projected climatic changes. Single-species stands are at most risk. Spatially mixed forests limit the spread of both pathogens and insects. Decreasing tree densities reduce fuel loads and competition, and promote structures that are more resilient to catastrophic events like fire and epidemics.

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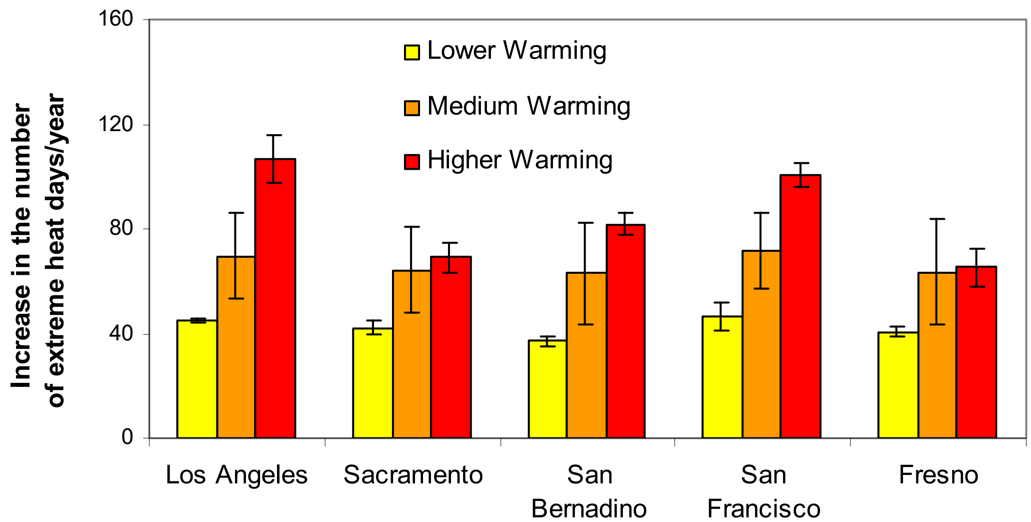
[9] The projections do not consider possible changes in vegetation distribution over the time period. However, Lenihan et al. (2006) analysis suggests that the composition for the study site considered in this study is expected to change very little over the next century.

10.0 Public Health

Climate change will affect the health of Californians by increasing the frequency, duration, and intensity of conditions conducive to air pollution formation, oppressive heat, and wildfires. The primary concern is not the change in average climate, but rather the projected increase in extreme conditions that are responsible for the most serious health consequences. In addition, climate change has the potential to influence asthma symptoms and the incidence of infectious disease.

10.1. Heat-related Deaths

Analyses of various climate change scenarios indicate that the future will have a greater number of extremely hot days and fewer extremely cold days, which may lead to two to six times as many heat-related deaths for the five cities studied (Drechsler et al. 2006). For the higher range of projected warming, the number of days over 31°C (90°F) in Los Angeles and over 35°C (95°F) in Sacramento will increase by up to 100 days by the end of the century—a striking increase over historical rates of occurrence, and almost twice the increase projected under the low-temperature path (Drechsler et al. 2006) (Figure 11).



(Source: Drechsler et al. 2006)

Figure 11. Projected increase in the number of extreme heat days relative to 1961–1990. *Extreme heat* is defined as the average temperature that is exceeded less than 10% of the days during the historical period (1961–1990), or approximately 36 days a year.

Individuals likely to be most affected include the elderly, the already ill, and the economically disadvantaged (CDC 2005a,b; Kilbourne 2002; Kaiser et al. 2001). Other identified risk factors for temperature-related health effects include social isolation, not leaving the home daily, and for heat-related death, living on the upper floors of multi-story buildings (Naughton et al. 2002). The number of deaths attributed to heat have declined over the past 30 years in the United States, primarily due to the increasing number of households with central air conditioning, which appears to be the strongest protective factor (Davis et al. 2003; Donaldson et al. 2003). Kilbourne (2002) suggested that municipal housing codes be modified to require functional air conditioners in rental housing, in addition to existing requirements for heat. The U.S. Department of Commerce expects that air conditioning will be universal in the United States by 2050 (McGheehin and Mirabelli 2001), which will increase demand for electricity for residential cooling—especially on peak demand summer days in the future. In 2100, California will need at least 10% more electricity, compared to today's total generation capacity, for air conditioning alone on peak demand summer days (Miller et al. 2005). Ongoing studies are investigating the contribution of air pollution increases to deaths attributed to heat and refining the air conditioning demand estimates.

10.2. Air Pollution-related Death and Disease

Californians experience the worst air quality in the nation, with over 90% living in areas that violate either the state ambient air quality standard for ozone or particulate matter (PM) (CARB 2005a). The annual health impacts of these standard violations include 8800 premature deaths (3000–15,000 probable range), or 4% of all death; 9500 (4600–14,000) hospitalizations and emergency room visits; 2,800,000 (2,400,000–3,200,000) lost work days; and 4,700,000 (1,200,000–8,600,000) school absence days (CARB and OEHHA 2002, 2005; CARB 2005b). An annual value of $2.2 billion ($1.5–2.8 billion) is associated with hospitalizations and the treatment of major and minor illnesses related to air pollution exposure in California (CARB 2005b). In addition, the value of premature deaths resulting from exposure to air pollution in excess of the state's PM and ozone standards is $69 billion ($34–133 billion) (CARB 2005b). Current motor vehicle and industry control programs cost about $10 billion per year.[10] Ozone (from the precursors methane and nitrogen oxides, NO_X) and PM (especially elemental carbon), and to a lesser extent carbon monoxide and volatile organic compounds (VOCs), contribute to climate change (IPCC 2001).

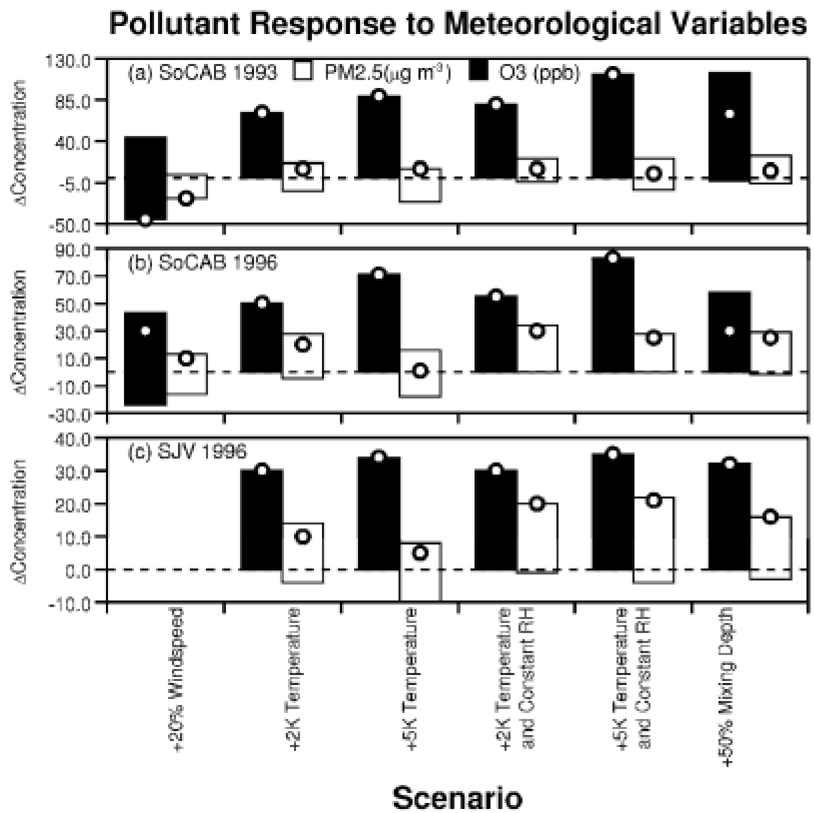
Two recent reports from the National Research Council of the National Academies note that higher temperatures lead to increased emissions and formation of air pollution (NRC 2001, 2004). Maximum ozone levels are about double the current air quality standards and climate change will slow progress toward attainment by increasing emissions, accelerating chemical processes, and increasing summertime stagnation episodes. Model estimates of the effect of altered climate applied to current (2005) pollutant emission patterns show that temperature alone may alter emissions. For the medium-high emissions scenario, summer-time on-road VOC emissions from motor vehicles for the 2005 baseline are estimated to increase by 4% to 5% using temperature

[10] The nationwide annual cost for air pollution control in 2000 was estimated to be $44 billion in 1986 dollars (USEPA 1991). Between 1986 and 2000, nationwide control costs grew about 3.85% annually. Assuming that control costs continued to grow at the same rate from 2000 to 2004, the annual control cost in 2004 is estimated to be about $53 billion in 1986 dollars. Using the Consumer Price Index (CPI), the nationwide annual cost of air pollution control is estimated to be $88 billion in 2004 dollars (the 2005 CPI is not yet available). Assuming California accounts for 12% of this expenditure (proportional to its population), the annual cost of air pollution control for California is about $10 billion.

projections for mid-century and by 13% to 16% for end-of-century temperature projections (Drechsler et al. 2006). These estimates also suggest small decreases in NO_X (Drechsler et al. 2006). Estimates for the low-emissions scenario are similar for mid-century and less than half for 2100. The medium-high emissions scenario results in a positive feedback loop for GHG emissions from on-road motor vehicles, with 4% to 5% increase in methane and 8% to 9% increases in CO_2 by 2100. These emissions estimates are strictly a test of sensitivity to temperature, as they do not take into account future changes in motorist behavior (e.g., increased air conditioning usage or increased miles driven), future growth in the number of vehicles or changes in the fleet mix, future emission controls, or possible technological advances in vehicle design. Constable et al. (1999) estimate that a doubled CO_2 atmosphere will result in a doubling of national biogenic VOC emissions. While California power plants are well controlled, higher temperatures lead to increased NO_X emissions (3% per ˚F, or 1.8% per ˚C) due to increased air conditioning usage (Drechsler et al. 2006).

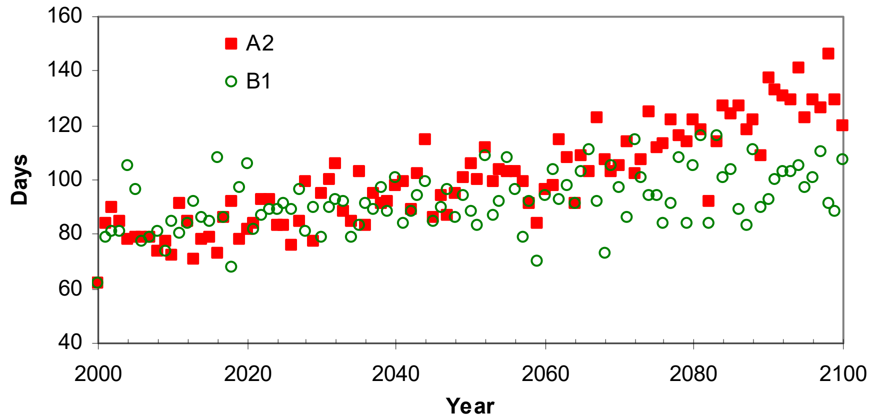
A sensitivity study of three air pollution episodes in the South Coast Air Basin and San Joaquin Valley (Kleeman and Cayan 2006) found that increased temperatures favor the formation of ozone but discourage the formation of ammonium nitrate (a major component of PM). The decrease in PM caused by increased temperatures will be offset by other factors, most notably the increase in background ozone concentrations. The IPCC (2001) estimates that global background ozone concentrations could increase to 40–80 ppb by the year 2100 (up to double the current background value), largely due to emissions outside of California. Background ozone strongly contributes to the nighttime formation of particulate nitrate through the production of N_2O_5 in the upper atmosphere during the evening hours. A preliminary study by Kleeman and Cayan (2006) suggests that if global background ozone levels double, there would be an increase in $PM_{2.5}$ concentrations in California (Figure 12), despite the corresponding increase in temperature. Increased humidity also favors the formation of ozone and ammonium nitrate. Increased wind speed reduces ozone and PM concentrations by enhancing dilution of precursor emissions. Increased mixing depth also reduces PM concentrations, but leads to an increase in surface ozone concentrations because less NO_X is available to titrate the ozone that is produced aloft and mixed to the surface. The converse would be true for lowered wind speeds and mixing heights.

Statistically downscaled climate data from two simulations of one global climate model (GFDL) using two global emissions scenarios (a medium-high (A2) and a lower (B1) scenario), indicates that the number of days meteorologically conducive to pollutant formation could rise by 75% to 85% in the high ozone areas of Los Angeles (Riverside) (Figure 13) and the San Joaquin Valley (Visalia, the high ozone area downwind of Fresno) by the end of the century under a medium-high emissions scenario, but only 25% to 35% under the lower emissions path (Kleeman and Cayan 2006). In addition, global background ozone (primarily formed from the GHG methane and NO_X from fuel combustion) is projected to increase by 4-10 ppb (low scenario) to more than 20 ppb (high scenario) at 2100 (Prather et al. 2003). If background ozone increases by the amount projected for the high scenario, the state 8-hour-average ozone air quality standard of 70 ppb would be impossible to attain in much of California, even with near-zero local emissions. The future trend for PM is not as clear, because increasing temperatures reduce some particle types while others show no change or increase slightly. Rainy days, wildfires, global dust storms, humidity, and other factors also affect PM, and are the subject of ongoing study (Kleeman and Cayan 2006).



(Source: Kleeman and Cayan 2006)

Figure 12. Summary of pollutant response to meteorological perturbations when background ozone concentrations are doubled to 60 ppb during pollution episodes that occurred in: (a) Southern California on September 9, 1993; (b) Southern California on September 25, 1996; and (c) the San Joaquin Valley on January 6, 1996. The bars represent the range of concentration change at any location in the modeling domain in response to the indicated perturbation. The circles represent the concentration change at the location of the maximum concentration for each pollutant.



(Source: Kleeman and Cayan 2006)

Figure 13. Projected days at Riverside meteorologically conducive to exceedances of the 1-hour California ambient air quality standard for ozone of 0.09 ppm.

10.2.1. Wildfires

Wildfires affect public safety and have the potential to significantly impact public health through their smoke. For example, a survey of 26% of all tribal households on the Hoopa Valley National Indian Reservation in northern California showed a 52% increase in medical visits for respiratory problems during a large fire in 1999, compared to the same period of 1998. More than 60% of those surveyed reported an increase in respiratory symptoms during the smoke episode, and 20% continued to report increased respiratory symptoms two weeks after the smoke cleared (Mott et al. 2002). The projected increases in fire season severity could lead (Westerling and Bryant 2006) to more "bad air" days. However, quantitative estimation of the impacts of future wildfire events is extremely difficult. The impacts of any fire are unique to that event, and are influenced not only by the magnitude, intensity, and duration of the fire, but also the proximity of the smoke plume to a population.

10.3. Asthma

Another concern of climate change is the effect on asthma prevalence and attacks. This impact is difficult to predict for several reasons. The most common asthma triggers are dust mites and molds, both of which are higher indoors than outdoors. Both require a relatively humid environment for survival. Consequently, if the climate becomes drier, or drought periods increase, these triggers will become less important. However, both will respond to higher humidity with increased growth, and these triggers may become more significant. Many asthmatics are allergic to various plant pollens. Plants and trees typically have pollination seasons that last a few weeks per year. To the extent that pollen seasons lengthen or become more intense in response to climate change, increased asthma exacerbation could result.

10.4. Infectious Disease

Climate change also has the potential to influence the incidence of infectious disease spread by mosquitoes, ticks, fleas, rodents, and food (Colwell and Patz 1998). More study is needed, because research to date has focused on short-term changes in weather patterns (primarily in ambient temperature and rainfall), rather than long-term changes.

10.5. Potential Strategies for Reducing Public Health Impacts

Some of the public health impacts can be reduced through adaptation measures, but costs are significant and special attention will need to be given to those most vulnerable to the health effects. For example, building climate change considerations into efforts to attain the health-based air quality standards will be necessary in the long-term if the standards are to be met. In addition, heat emergency action plans can help reduce those affected by extreme heat waves (Bernard and McGeehin 2004). Chicago and Milwaukee have developed effective heat emergency plans that could serve as models for California. In both cities, heat-related death rates were considerably lower during the 1999 heat wave, during which the action plans developed in response to the 1995 heat wave were activated (Naughton et al. 2002; Weisskopf et al. 2002). However, Bernard and McGeehin (2004) reviewed heat emergency plans from 18 cities, and found that many plans were inadequate, and that many other at-risk cities had no heat emergency action plans. These findings point to the urgency of developing heat emergency action plans for California before the need arises, and the inclusion of objective criteria for assessing the effectiveness of the plans.

11.0 Electricity Generation and Demand

Changes in temperature and other meteorological variables will affect both the generation of and demand for electricity. The demand for natural gas to warm our homes and buildings will also be affected, most likely resulting in reduced demand in the winter. This section summarizes what is known about the potential effects of climate change on electricity in California and presents some new results for the climate scenarios discussed in previous sections.

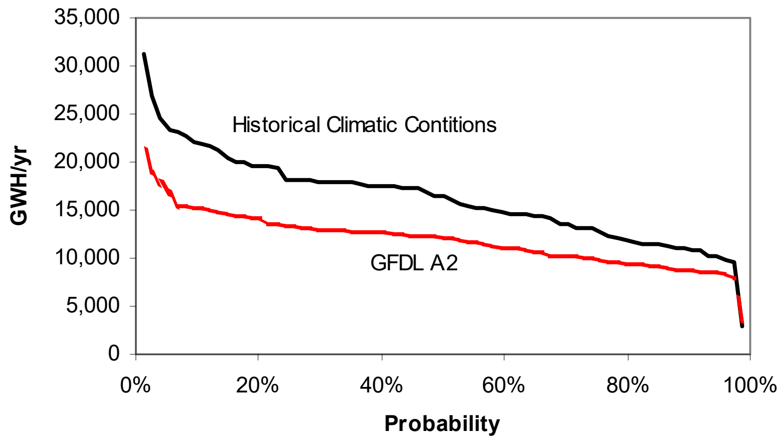
11.1. Electricity Generation: Hydropower

Changes in precipitation levels, should they occur, and changes in the patterns and timing of snowmelt would alter the amount of electricity that hydroelectric facilities could generate. It would also affect seasonal availability, with less water available for hydroelectric generation in the late spring and summer months, when demand is the highest. In addition, there is a high likelihood that changes in precipitation and runoff patterns would lead to changes in broader water policies and end-use priorities, such as water supply and flood control, which could place further limitations on hydroelectric production. Currently, hydropower generation contributes about 15% of California's in-state electricity production, with a range from 9% to 30%, due to variations in climatic conditions. Because it is used predominantly during on-peak periods, hydropower's value outweighs its simple energy contribution. In addition, the state also receives a significant amount of surplus power hydroelectric facilities from the Pacific Northwest, which will also be affected by climate change.

Two recent studies project losses in annual hydropower generation on the order of 10% to 30% by the end of this century, if precipitation levels in California decline (Lund et al. 2003; Vanrheenen et al. 2004). An important caveat about these studies is that they only addressed generation associated with relatively low elevation units, representing about 44% of the total generation capacity from hydropower facilities in the state.

For this study an economic-engineering optimization model of the state water system (CALVIN) was run to estimate the potential impacts of climate change on water resources assuming hypothesized year 2050 level of development with the climate conditions estimated for the end of the century (2070–2099) by the GFDL model for the A2 emissions scenario. As with previous studies, this study indicates that reductions of hydropower generation for relatively low elevation units on the order of 30% would occur, which is a response to a reduction of about 28% in streamflows. Figure 14 presents the frequency distribution of hydropower generation from the major water supply reservoirs modeled in CALVIN. As a point of reference, in the 1990 to 2002 period, California generated from 20,000 gigawatt-hours (GWh) to 51,000 GWh in a given year (Medellin et al. 2006).

Another recent study prepared by the California Department of Water Resources (DWR) used climate projections for the middle of this century (Chung et al. 2006). The DWR modeled the State Water and Central Valley Projects which, as indicated above, represent about 27% of the state's hydroelectric capacity. This study indicates that reductions in electricity generation of approximately 7% would occur for most of lower and medium range of projected warming. However, for the PCM B1 scenario, the least dry scenario, DWR estimated an increase in generation on the order of 4%.



(Source: Medellin et al. 2006)

Figure 14. Probability of producing at a minimum level of generation in a year in major water supply reservoirs modeled in CALVIN: period centered in 2050.

All the studies reported so far address potential impacts on hydropower units that are located in relatively low elevations and served by a large reservoir storage capacity. These can be used to partially offset the trend to an early melting of the snow stored in the Sierra Nevada. Hydropower units in relatively medium and low elevations have little reservoir storage capacity and rely more heavily on the accumulated snow as a natural reservoir. A substantial fraction of the mountain snowpack that supplies water to these units in the spring and summer is located above 1200 meters (3900 feet). This zone is the most vulnerable area to higher temperatures and is expected to experience the most dramatic spring snow losses (Knowles and Cayan 2004). At the present time, the quantitative evaluation of the potential impacts on the medium and high elevation units remains is an unexplored area of study. However, a recent exploratory study of a system owned and operated by the Sacramento Municipal Utility District (SMUD) in the Upper American River Watershed indicates that, as with lower elevation hydro units, electricity generation would go down in response to lower precipitation levels but the existing reservoir system would be able to store enough water to allow generation of electricity in the hot summer months when it is most needed (Vicuña et al. 2006). This occurs despite earlier streamflow runoff caused by climate change. It is unclear how this and other similar systems would respond under scenarios with increased precipitation levels. The most important variables that will determine impacts are storage capacity of the system relative to the volume of stream inflows and the timing of runoff as it compares to the pattern and timing of energy demand.

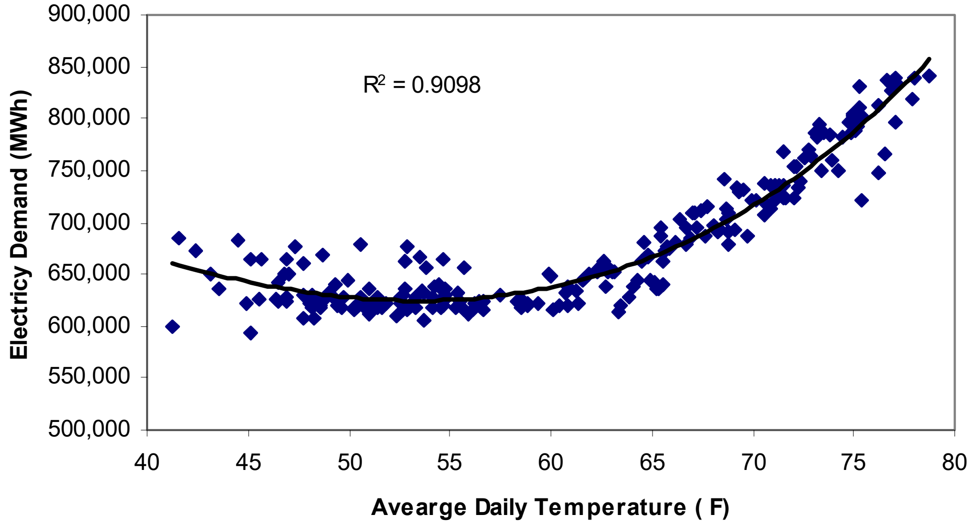
It is important to emphasize that even relatively small changes in in-state hydropower generation result in substantial extra expenditures for energy generation, because this "free" generation must be purchased from other sources. For example, assuming a decrease of 10% from the current average in-state generation level from this renewable energy source, and assuming a price of about 10 cents per kilowatt-hour, this decrease would result in an additional $350 million per year in net expenditures to purchase sufficient electricity to replace the electricity that otherwise would be generated using hydroelectric resources.

11.2. Electricity Demand

One of the few papers that have been published on the potential effect of climate change on electricity demand in California, (Baxter and Calandri 1992) indicates significant increases in electricity requirements. This study was guided by energy forecast models that were developed for or by the Energy Commission to estimate electricity demand taking into account increased population and economic activity. Under their worst-case scenario (a 1.9ºC (3.4ºF) increase), electricity requirements in 2010 would increase by about 7,500 GWh, and would require an additional peak capacity of 2,400 MW. This trend would represent an increase of about 2.6% and 3.7% in energy and peak generation capacity, respectively, from their 2010 base case.

Since it is impossible to know how the energy system and socioeconomic conditions in the state will evolve in the next 100 years, the study described below investigates how future climate projections would affect electricity demand assuming the current infrastructure and demographics. In practice, higher temperatures will increase the penetration of air conditioning units for cooling, but, more important, this approach fails to consider the trend toward more development in the interior parts of California that experience higher temperatures. For these reasons, actual impacts could be higher than what is reported in this section.

Figure 15 shows daily demand of electricity for the area serviced by the California Independent System Operator (CalISO) in 2004 as a function of the simple average of daily temperatures in San Jose, Sacramento, Fresno, and Los Angeles. Figure 15 only includes demand during weekdays, and excludes holidays.

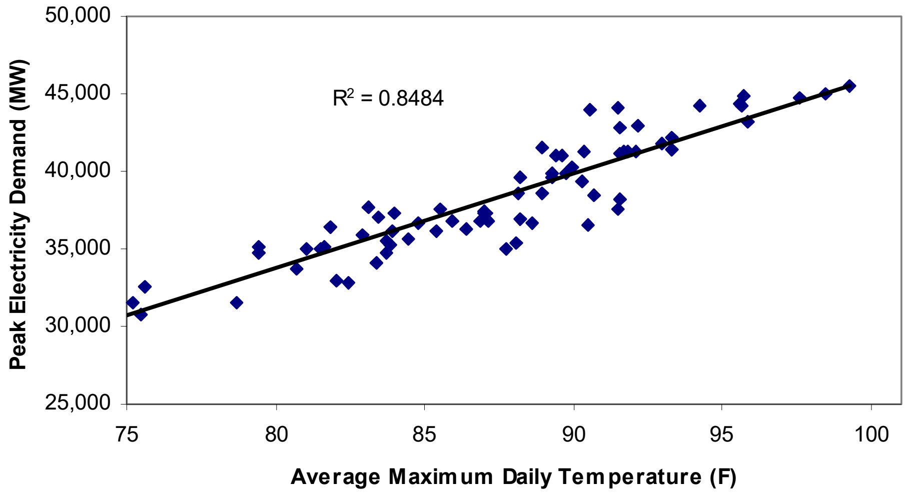


(Source: Franco and Sanstad 2006)

Figure 15. Electricity demand in the CalISO area as function of average temperatures: 2004

Peak electricity demand occurs mostly in the summer months, and it is a strong function of maximum daily temperatures. Figure 16 presents the daily peak energy demand in the CalISO region as function of the average daily maximum temperature measured in San Jose, Sacramento, Fresno, and Los Angeles. It only includes non-holiday weekdays. Electricity consumption during weekends and holidays tends to be lower.

Franco and Sanstad (2006) used these relationships between demand and temperature, to estimate the impact of higher temperatures on annual electricity and peak summer demands (see Table 2). Estimated changes in electricity demand were determined from multiple temperature projections as reported by Cayan et al. (2006a) for grid points close in the cities listed in the previous paragraphs. To calculate changes in peak demand, they used averaged maximum annual temperatures for the periods listed in Table 2.



(Source: Franco and Sanstad 2006)

Figure 16. Peak electricity demand in the CalISO area as a function of maximum daily temperature: June-September 2004

Table 2. Estimated incremental changes in annual electricity and peak load demands for lower, higher, and medium range of projected warming relative to 1961 to 1990 base period

Time Period	Projected Warming Range	Change in Annual Electricity Demand (%)	Change in Peak Demand (%)	Climate Model	Emission Scenario
2005–2034	Low	0.9	1.4	PCM	Low (B1)
		2.5	1.5	GFDL	Low (B1)
		1.2	1.0	PCM	Medium-High (A2)
	Medium	2.9	3.6	GFDL	Medium-High (A2)
	High	3.4	4.8	HadCM3	Higher (A1fI)
2070–2099	Low	3.1	4.1	PCM	Low (B1)
		5.8	7.3	GFDL	Low (B1)
		5.3	5.6	PCM	Medium-High (A2)
	Medium	11.0	12.1	GFDL	Medium-High (A2)
	High	20.3	19.3	HadCM3	Higher (A1fI)

Annual expenditures of electricity demand in California represent about $28 billion (U.S. EIA 2005). Therefore, even the relatively small increases in energy demand shown in Table 2 would result in substantial extra financial expenditures for energy services in the state. For example, assuming a linear increase in electricity expenditures from the recent historical period, a 3% increase in electricity demand by 2020 would translate to about \$1.2 billion nominal dollars a year in additional electricity expenditures.

11.3. Potential Strategies for Reducing Impacts on Electricity Sector

The impacts of climate change on the electricity system will depend in part on how the electricity system evolves in the future. For example, an increased penetration of photovoltaic (PV) systems would reduce the impacts of peak demand because this energy source closely matches the diurnal demand for electricity (Borenstein 2005), but other technologies could also be used to satisfy an increased demand. Energy efficiency programs will reduce electricity demand counteracting some of the negative effects of increased ambient air temperatures. Finally, reducing the heat island effect with the use of more reflective surfaces (e.g., for roofs and pavement) and planting trees that provide shade to homes and buildings will also allow the state to better cope with the expected temperature increases.

12.0 Implications for Mitigation and Adaptation

Continued climate change would have widespread impacts on California's economy, ecosystems, and the health of its citizens. The analyses summarized in Figure 17, however, suggest that many of the more severe impacts projected under the medium and higher warming ranges could be avoided by following the lower emissions pathway. However, if the actual climate sensitivity to GHGs reaches the level of the more sensitive global climate models employed here, an even lower emissions path than the B1 scenario may be required to avoid the medium warming range. How much would GHG emissions have to be reduced to stay below the lower emissions pathway (B1) and insure against temperatures rising to the medium and higher warming ranges presented in this study? The Governor's Executive Order #S-3-05 calls for an 80% reduction in GHG emissions below 1990 levels by 2050. If the industrialized world were to follow California's lead, and assuming the industrializing nations followed the B1 pathway, global emissions would remain below the lower emissions scenario (B1),[11] increasing the likelihood that California and the world would be on track to avoid the more severe impacts by preventing temperatures from rising to the medium warming range.[12] This estimate of the impact of an 80% reduction by the industrialized world has on global emissions depends crucially on the development patterns of the developing world. The SRES B1 scenario assumes development proceeds with a "high level of environmental and social consciousness" with a transition to "alternative energy systems" (Nakicenovic et al. 2000). Emission reductions targets such as the one set by the Governor's Executive Order could spur the innovation necessary to lead the world to a transition to alternative energy systems.

However, even if global emissions stay below the lower emissions scenario (B1), some impacts from climate change are inevitable. Evidence indicates that even if actions could be taken to immediately curtail GHG emissions, the potency of GHGs that have already built up, their long atmospheric lifetimes, and the inertia of the Earth's climate system could result in average global temperatures rising an additional 0.6°C (1.1°F) (Wigley 2005; Meehl et al. 2005). As a result, some impacts from climate change, in California and across the globe, are now unavoidable. Consequently, although it is not the solution to global warming, it is becoming clear that adaptation is an essential complementary strategy to manage some of the projected impacts of climate change.

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[11]This was calculated as follows: (1) Organisation for Economic Co-operation and Development (OECD) population and total emissions were based on SRES B1 IMAGINE runs (Nakicenovic et al. 2000). OECD total emission in 1990 were 2.83 GtC; (2) Eighty percent below this value is 566 MtC; (3) Total global emissions was calculated by adding the 566 MtC to the total emissions for non-OECD countries, as projected by SRES B1. This value is approximately 10 GtC; (4) This 10 GtC/yr was compared to the global emission projected in the B1 scenario (approximately 11 GtC/yr).

[12] As illustrated in Figure 1, beyond 2050, global emissions will need to decrease substantially below 10 GtC/yr to stay on the B1 pathway out to the end of the century. The SRES B1 pathway assumes global emissions decrease to 4.23 GtC/yr by 2100. However, stabilizing atmospheric concentrations will require even lower emissions as natural uptake is estimated between 0.7–2.9 GtC/yr (IPCC 2001).

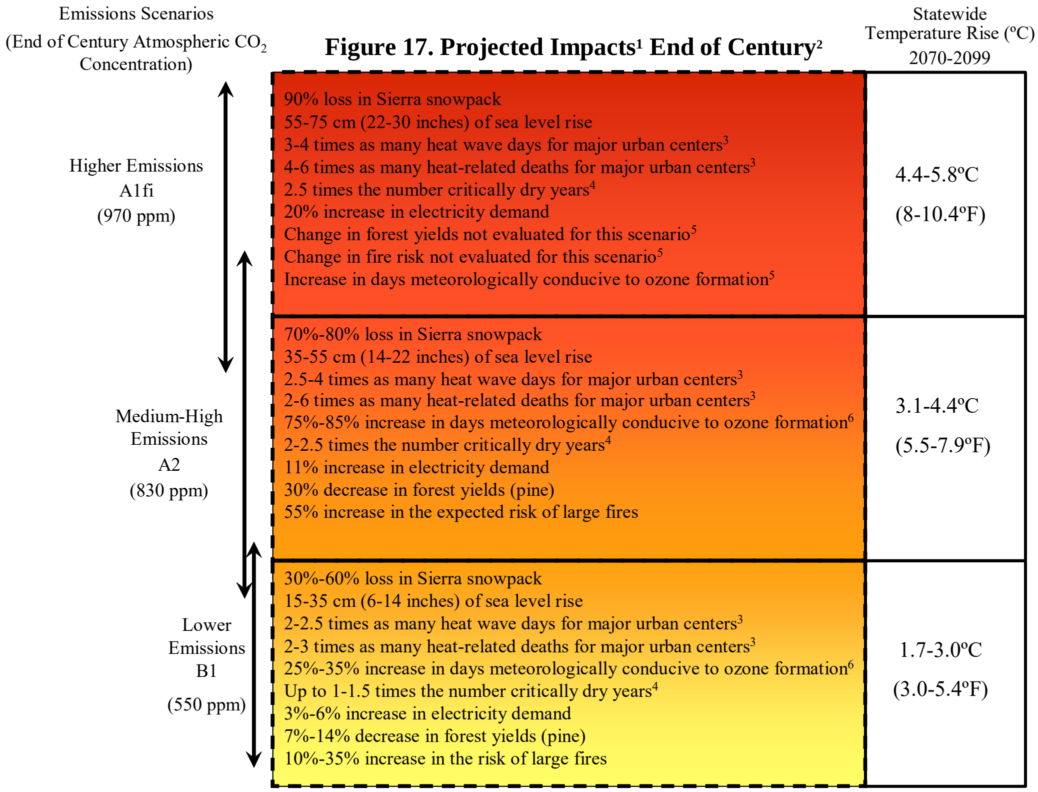

Figure 17. Projected impacts[1] end of 21st century.[2] Impacts presented relative to 1971–2000.

[1] The impacts summarized in this figure reflect projections from different models, based on the current scientific understanding of the relevant social and biophysical processes. Because our scientific understanding is still developing in some key processes that would affect the sectors studied, we provide here some guidance to our levels of confidence of these projections. We assign high confidence to the direction of change in all of impacts described in Figure 17. However, in some sectors we have less confidence in the magnitude of change, because the projections are based on specific assumptions about future development patterns or societal response to projected changes. For example, changes in the number of heat-related deaths could decrease if different assumptions were made about the effectiveness of adaptation measures such as air conditioner use. Furthermore, neither the projection for heat-related deaths nor the projected increases in energy demand take into account population growth, and thus the magnitude of the impact may be significantly higher than the projections presented here. Similarly, the projections for wildfire risk may be conservative, in that they assume constant population and existing vegetation, land-use, and management patterns.

[2] The projected warming ranges presented here are for 2070–2099, relative to 1971–2000. However, some of the impacts summarized in this report used a different historical climatological baseline of 1961–1990. The difference between the 1961–1990 and 1971–2000 baselines leads to a small difference in projected temperature rise for the different scenarios and models. The difference in baselines amounts to approximately a 0.2°C (0.36°F) difference in the full range of projected end-of-century temperature rise.

[3] Los Angeles, San Bernardino/Riverside, San Francisco, Sacramento, and Fresno.

[4] Measures for the San Joaquin and Sacramento basins.

[5] Impacts expected to be more severe as temperatures rise. However, the higher range of projected warming was not assessed for the project.

[6] For high ozone locations in Los Angeles (Riverside) and the San Joaquin Valley (Visalia).

While there are many opportunities for California to increase its capacity to cope with the projected changes, these often can be costly and require time and planning. Furthermore, there are critical limits to adaptation, especially in addressing the threats of abrupt climate changes or in dealing with those impacts on natural, unmanaged species and ecosystems, which may not be able to keep up with the increasingly rapid and severe climate changes expected if emissions go unabated. In addition, managing the impacts of climate change may be particularly challenging when different kinds of changes are experienced together. For example, how would California manage in years where it was subjected simultaneously to an extreme heat wave, an energy blackout, and widespread wildfires, during an extended drought? While at present we are unable to predict the probability and all of the consequences of such an event, in preparing for change we must consider the potential compounding effects of multiple impacts.

Finally, the ability to cope and adapt is differentiated across populations, economic sectors, and regions within the state. As a result, without appropriate mitigating actions, climate change will likely aggravate existing equity issues within California and the rest of the United States. For example, the most vulnerable populations to the health impacts of climate change are children, elderly people, and the poor—the same groups that already face the greatest health and environmental risks.

In order to realize the state's adaptive and mitigative response potential, the state will need to continue to generate public discussion, build awareness, and foster the political will necessary to manage climate change.

13.0 The Need for Climate Change Information for California

There are key unknowns in the cascade of effects of climate change that inhibit better planning and policy actions. For example, better monitoring is needed of California's climate and climate-sensitive sectors to detect and understand a complex chain of impacts. In particular, more work is needed on ecological impacts both in terrestrial and aquatic systems, in the development of more detailed, probabilistic climate projections for the state, and to determine how climate changes and environmentally related policies might impact the California economy, recreation, and tourism. A more comprehensive analysis of the effects of climate change on energy supply and demand, within and outside of California, is needed. The effect of climate change on water resources, including more quantitative understanding of water supply and water demand for the rich complex of agricultural and natural ecosystems in the state is still not well understood. A geographically detailed analysis of the impacts of sea level rise on the California coast and the San Francisco Bay and Delta will be needed to assess potential impacts and conduct planning on local and regional scales. The impact of climate and climate change on temperature-related deaths, air pollutant emissions and quality impacts, and other aspects of human health will require more data and further study. Population growth, urbanization, and technological innovation are among a number of important factors that directly affect these areas. Given the serious potential consequences of climate change on the state's resources, the research community should continue to produce the tools, methods, and information that will be needed to develop robust coping or adaptation strategies in California.

Moreover, additional information is needed to help identify and understand the social and institutional constraints to managing climate change. The international and some national research efforts increasingly have turned away from simple impact assessments towards a "vulnerability" assessment approach that focus on identifying what makes certain populations and sectors susceptible to impacts of climate change. The vulnerability framework considers climate change within the context of multiple interacting stresses—such as population growth, land-use change, and institutional change. California's climate research should begin to include this research framework to identify the most vulnerable populations and regions of the sate, and develop strategies to build their resilience to climate variability and change, and related stresses.

14.0 References

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EXHIBIT 39

Union of Concerned Scientists

REPORTS & MULTIMEDIA / FEATURE

Infographic: Wildfires and Climate Change

Visualizing the Connection in Five Sets of Photos and Charts

Published Sep 8, 2020

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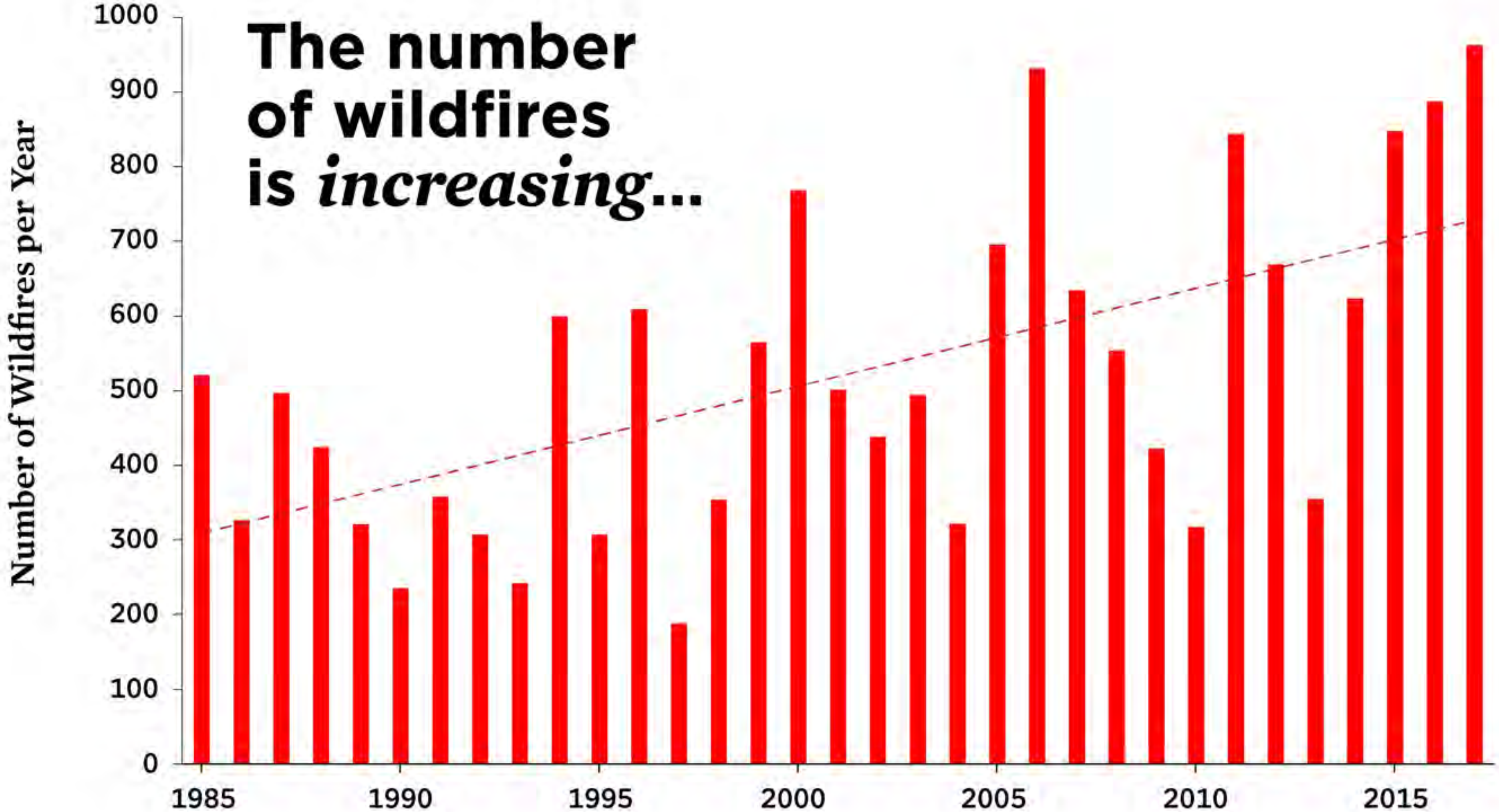
Every year, millions of acres of land are consumed by fire in the United States. By raising temperatures, melting snow sooner, and drying soils and forests, climate change is fueling the problem. Here’s what we know.

#1: Wildfires are getting worse


The number
of wildfires
is *increasing*...
Number of Wildfires per Year
1000
900
800
700
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500
400
300
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1985
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1995
2000
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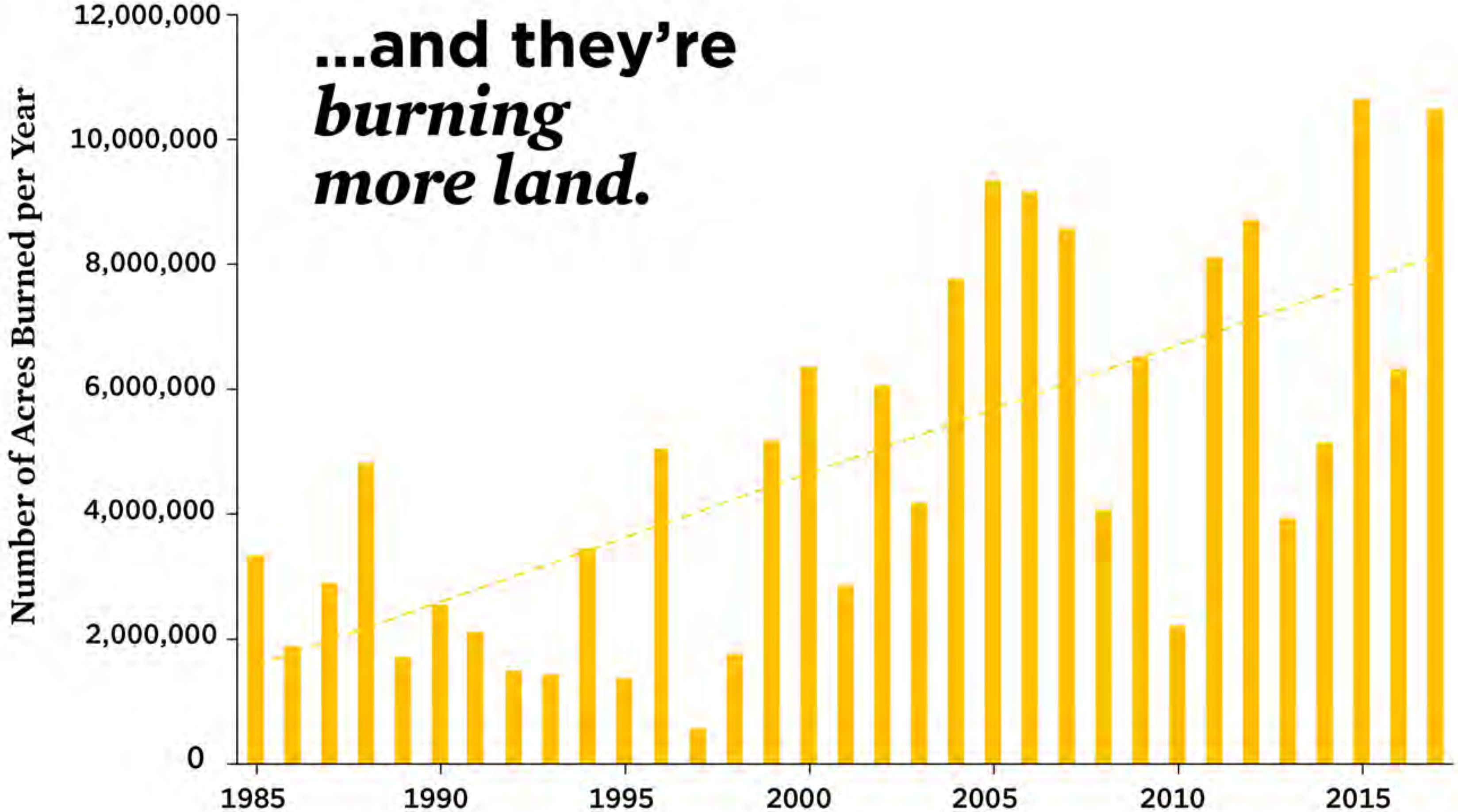
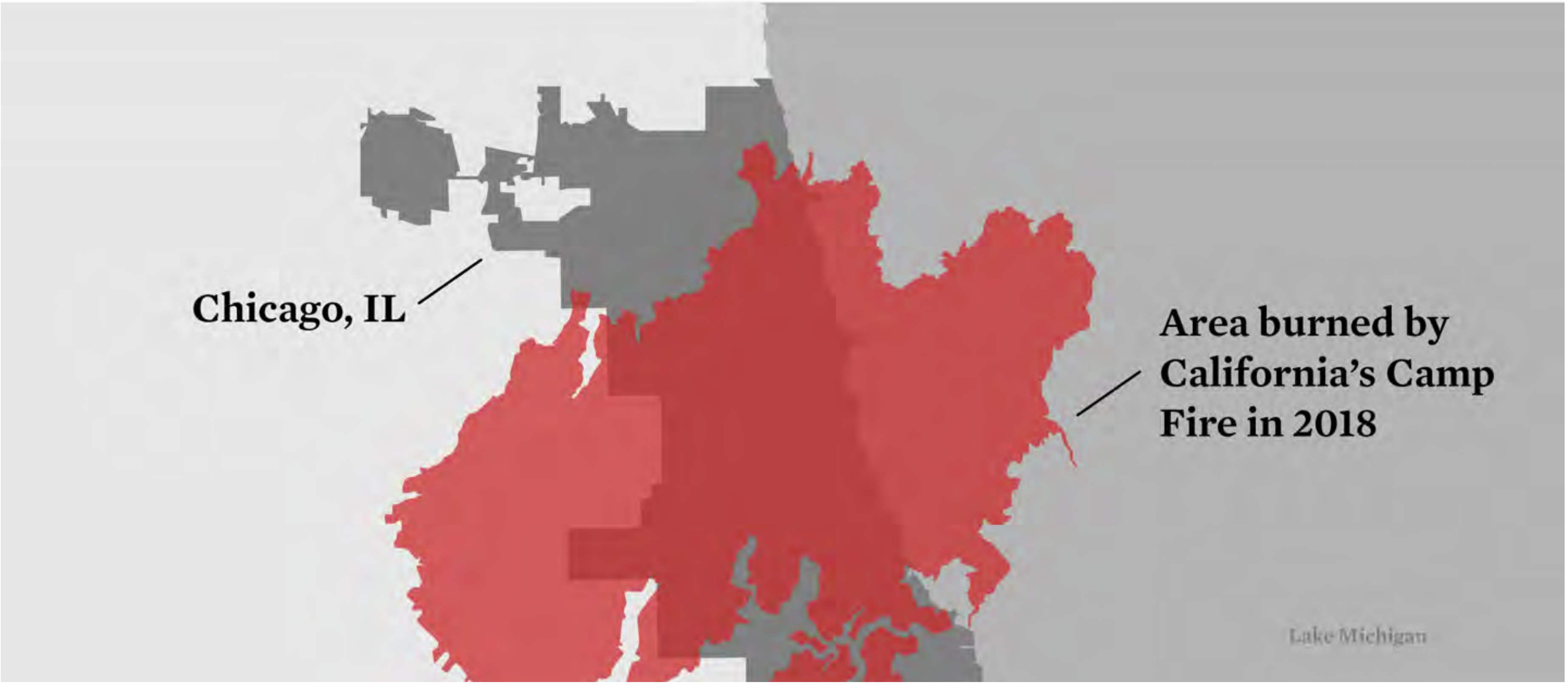
2010
2015

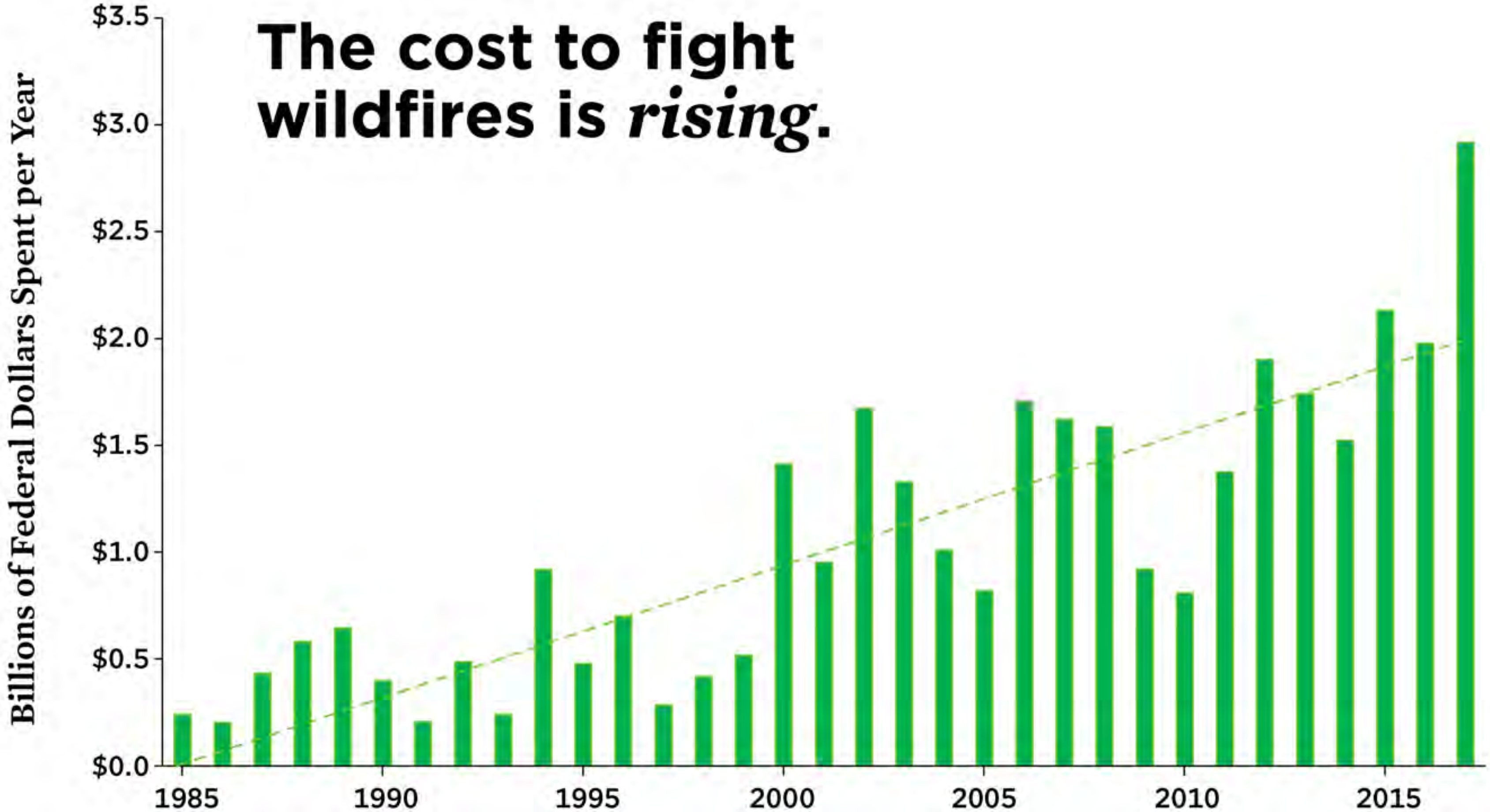


Data from the Monitoring Trends in Burn Severity program. MTBS only includes large fires in the United States (>500 acres for the eastern US, >1000 acres for the west). Prescribed fires removed.

Since 2015, the United States has experienced, on average, roughly 100 more large wildfires every year than the year before. This changes region by region, and year to year, but generally we’re seeing more wildfires, more acres burned, and longer, more intense fire seasons.

#2 Wildfires are causing more harm





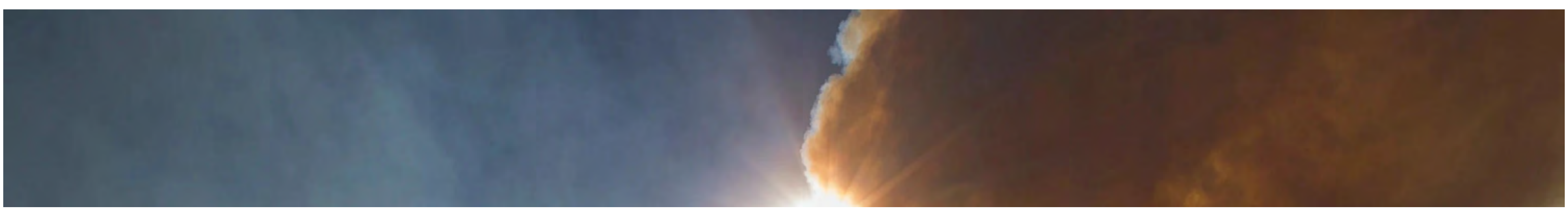
The cost to fight wildfires is *rising*.
Billions of Federal Dollars Spent per Year
$3.5
$3.0
$2.5
$2.0
$1.5
$1.0
$0.5
$0.0
1985
1990
1995
2000
2005
2010
2015

On left, the perimeter of the massive Camp Fire is overlayed on Chicago. Federal suppression costs from the National Interagency Fire Center.

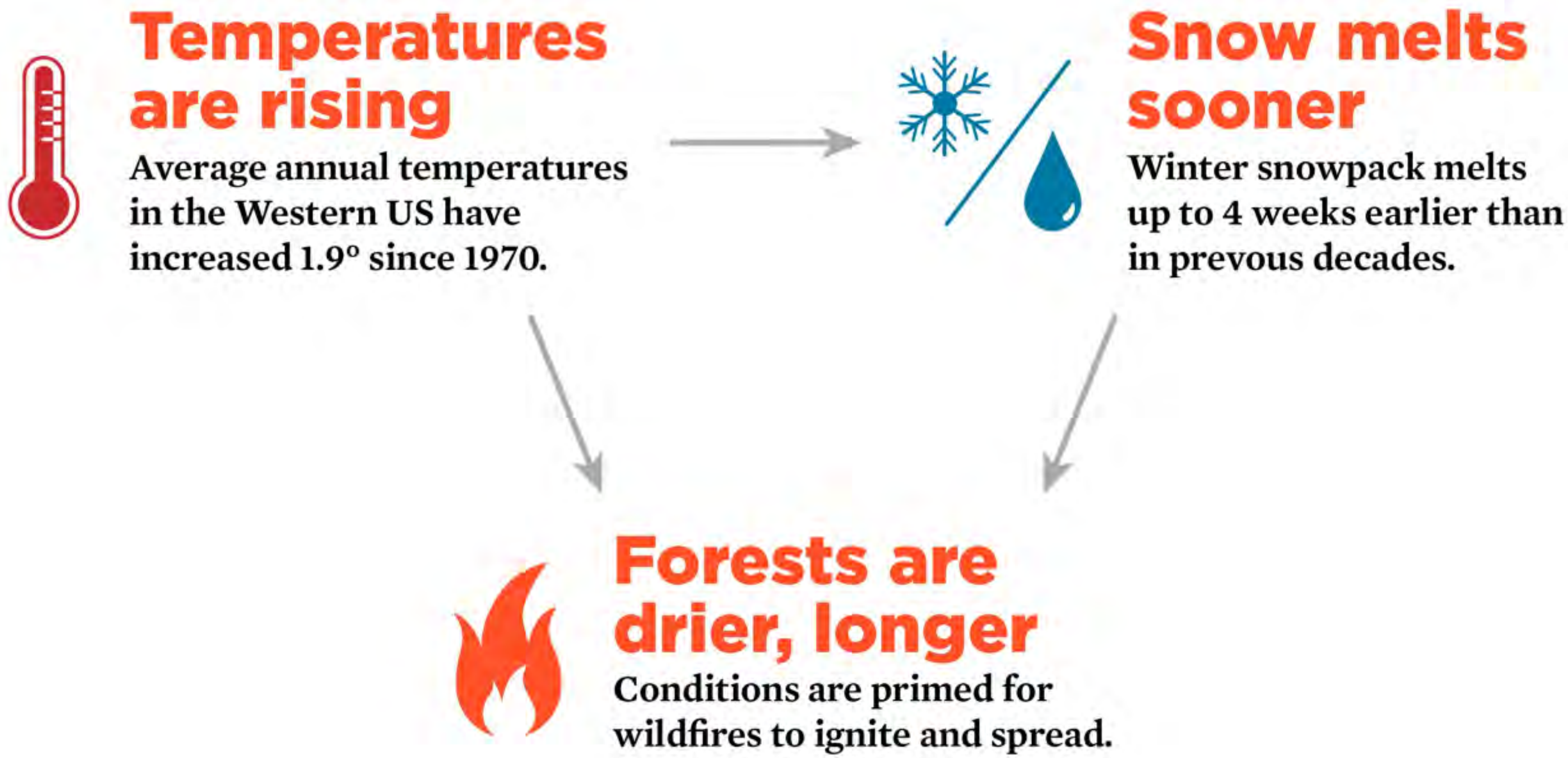
Wildfires are dangerous and destructive. The historically large Camp Fire of 2018 caused at least ninety deaths, destroyed more than 18,000 structures, and covered an area roughly the same size as the Chicago metropolitan area.

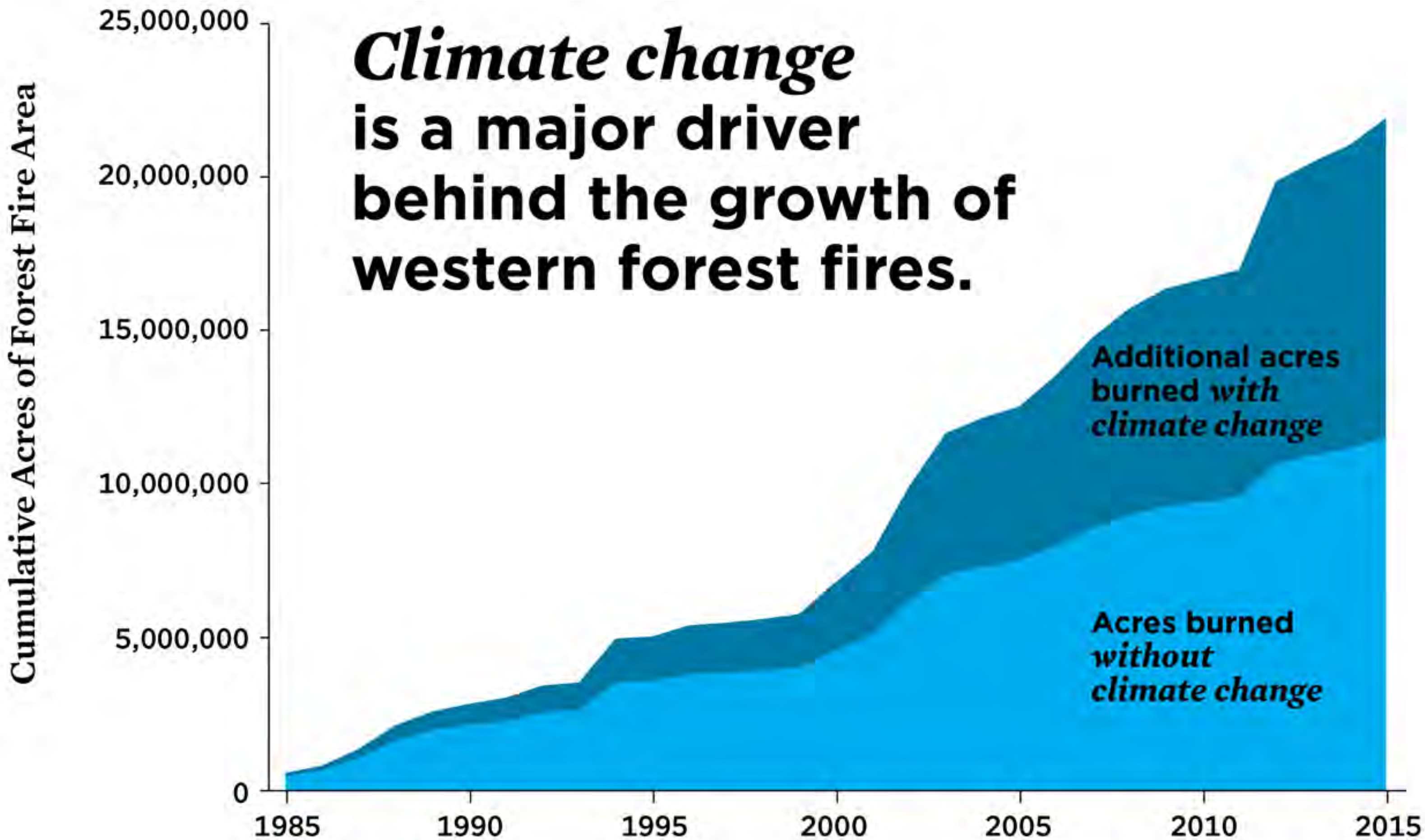
They're also expensive. Between 2014 and 2018, the federal government spent an average of *2.4 billion dollars* fighting wildfires every year. Even when adjusted for inflation, that's more than twice what we spent 20 years earlier (1994-1998).

And as the forests burn, they release carbon dioxide and other global warming gases, worsening climate change. As wildfires burn more land, emissions go up.



#3: Climate change is a key driver


Temperatures are rising
Average annual temperatures in the Western US have increased 1.9° since 1970.
Snow melts sooner
Winter snowpack melts up to 4 weeks earlier than in prevous decades.
Forests are drier, longer
Conditions are primed for wildfires to ignite and spread.



Data shown are from John T. Abatzoglou and A. Park Williams, Impact of anthropogenic climate change on wildfire across western US forests, which models forest fire area as a function of fuel dryness both with and without climate change.

Fire has historically been a natural part of many wild landscapes. But global warming has changed some of the underlying variables that make wildfires more or less likely to occur every year.

Warmer temperatures increase the likelihood that fires will burn more intensely. They also cause snow to melt sooner, and lead to drier soils, forests, and plants, which act as kindling. Increased droughts, unusual rain patterns, and insect outbreaks that lead to large stands of dead trees are also connected with climate change—and they all make wildfires more likely.

#4 Management matters

Other factors also influence wildfire risk—especially management and development decisions in fire-prone areas near forests.

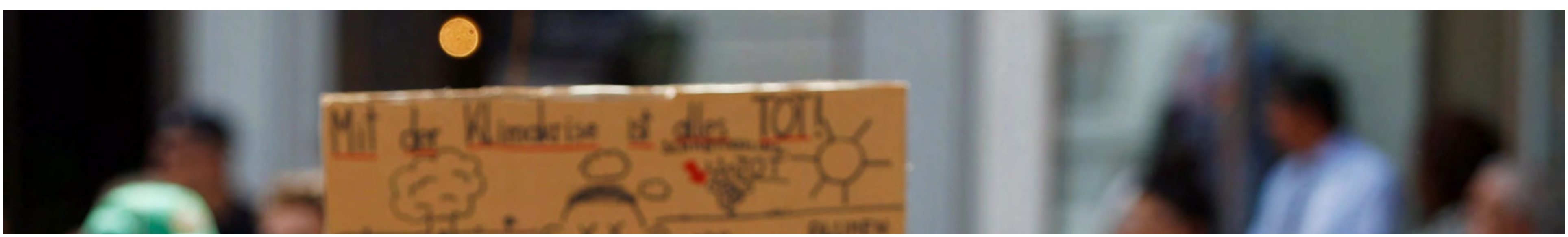
In the western United States, forests historically evolved with frequent, low-intensity fires that removed underbrush, debris, and fallen timber. This allowed for larger trees and made massive fires much less common.

But for the past century, almost all fires have been suppressed, even small ones. This has allowed forests to maintain denser growth and more potential fuel, leading to larger and more intense wildfires.

In addition, development near and into previously wild areas has increased fire risk and made fire-fighting more costly, challenging, and dangerous.

Government agencies have tried to lower forest density through prescribed burning (purposefully lit, low-intensity fires) and thinning (the physical removal of brush, vegetation and dead trees), but have struggled to do so at scale.

On smaller landscapes in the southeast, land managers conduct far more frequent prescribed burns. These fires bring their own risks, including poor air quality, and the chance of growing to be a damaging wildfire. But by mimicking smaller "natural" fires, prescribed burns can benefit forest ecology, and help mitigate at least some of the increased wildfire risk presented by climate change.



#5 Action is possible

In the near term, ecologically-sound forest and fire management could help limit fire risks.

But in the long-term, *climate action* is the best tool we have. When we reduce global warming emissions, we slow the growth of climate risks, including wildfire. Until then, summers will continue getting hotter, forests will get drier, and more and more people will face the threat of wildfire.

INFOGRAPHIC

Printable infographic

Download this hi-res PDF to handout or display.

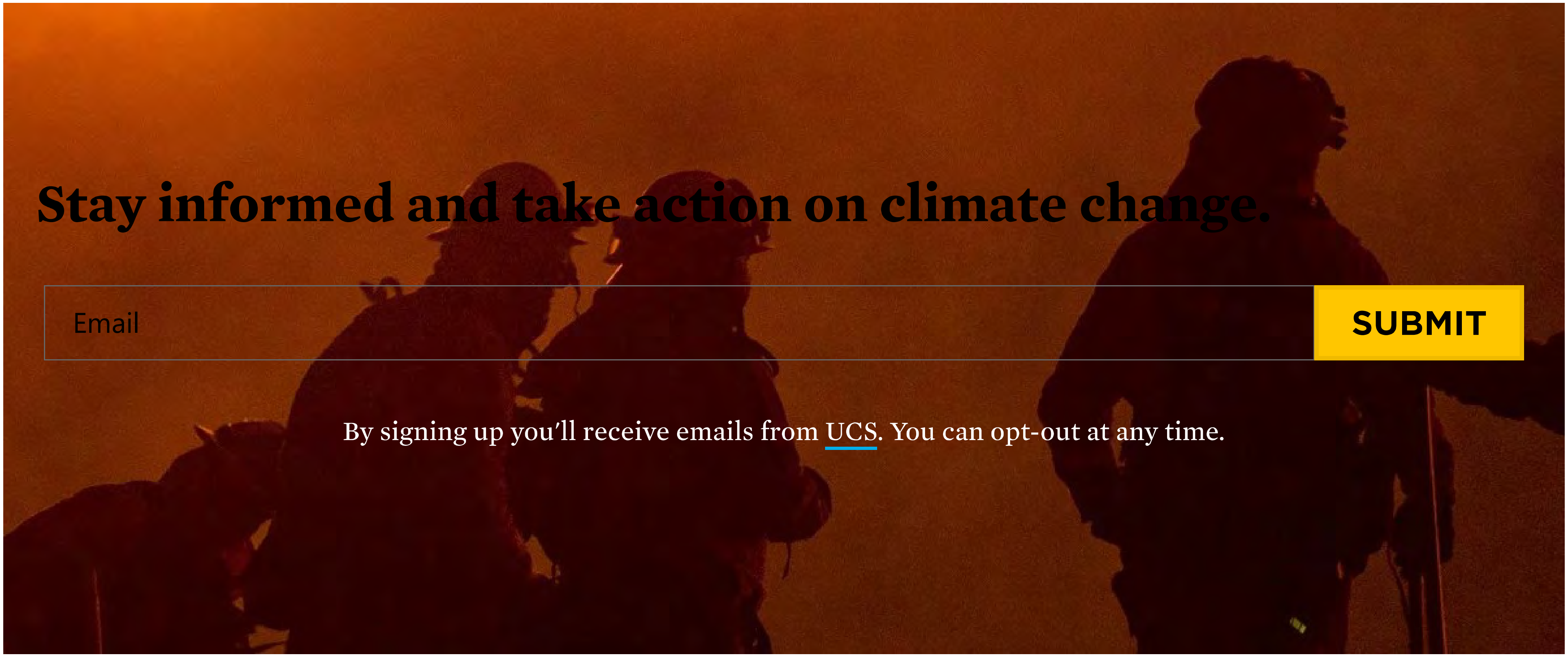
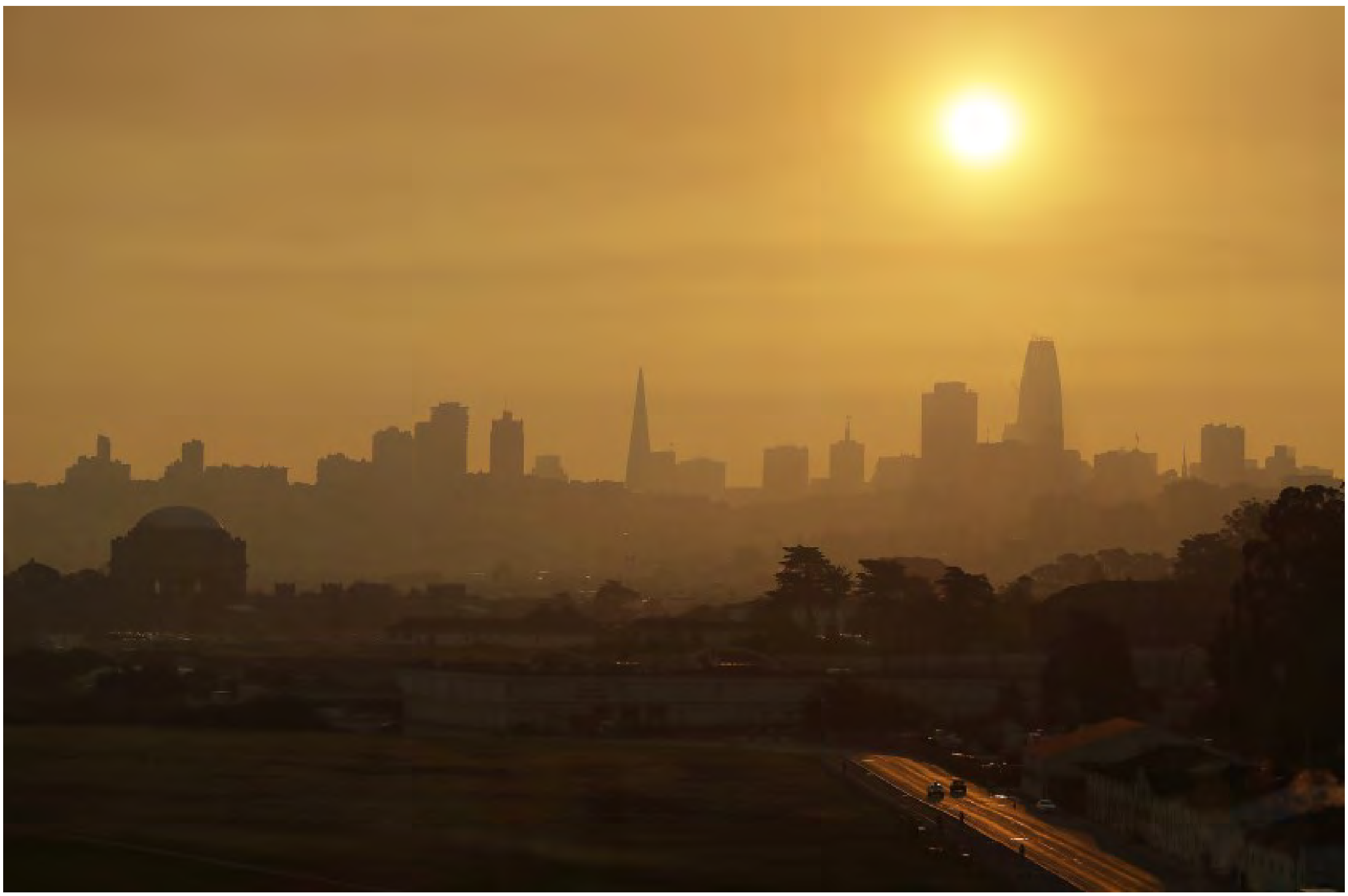


Photo credits: Burning car and home, and burnt neighborhood by Josh Edelson/Getty. Smoke plume by David McNew/Getty. Firefighter carrying drip torch courtesy of the National Park Service. Protesters by Leonhard Foeger/Reuters.

EXHIBIT 40

CALIFORNIA

How climate change is fueling record-breaking California wildfires, heat and smog



Smoke and haze from wildfires hovered Thursday over San Francisco, as much of California was blanketed in smoke from a siege of wildfires and poor air quality. (Eric Risberg / Associated Press)

By SUSANNE RUST, TONY BARBOZA

SEP. 13, 2020 6 AM PT

In 2001, a team of international scientists projected that during the next 100 years, the planet's inhabitants would witness higher maximum temperatures, more hot days and heat waves, an increase in the risk of forest fires and "substantially degraded air quality" in large metropolitan areas as a result of climate change.

In just the past month, nearly two decades after the third United Nations Intergovernmental Panel on Climate Change report was issued, heat records were busted across California, more than 3 million acres of land burned, and in major metropolitan areas, such as Los Angeles and San Francisco, air pollution has skyrocketed.

"This shouldn't come as a surprise to anyone," said Michael Gerrard, director of the Sabin Center for Climate Change Law at Columbia University. "Maybe we underestimated the magnitude and speed" at which these events would occur, he said, but "we've seen this long freight train barreling down on us for decades, and now the locomotive is on top of us, with no caboose in sight."

In a matter of weeks, California has experienced six of the 20 largest wildfires in modern history and toppled all-time temperature records from the desert to the coast. Millions are suffering from some of the worst air quality in years due to heat-triggered smog and fire smoke. A sooty plume has blanketed most of the West Coast, blotting out the sun and threatening people's lungs during a deadly pandemic.

California is being pushed to extremes. And the record heat, fires and pollution all have one thing in common: They were made worse by climate change. Their convergence is perhaps the strongest signal yet that the calamity climate scientists have warned of for years isn't far off in the future; it is here today and can no longer be ignored.

"What we've been seeing in California are some of the clearest events where we can say this is climate change — that climate change has clearly made this worse," said Zeke Hausfather, a climate scientist at the Breakthrough Institute, an Oakland-based think tank. "People who have lived in California for 30, 40 years are saying this is unprecedented, it has never been this hot, it has never been this smoky in all the years I've lived here."

CALIFORNIA
Los Angeles suffers worst smog in almost 30 years
Sep. 10, 2020

Unprecedented, yes. But not unexpected.

Since the 1980s, government and oil industry scientists have been anticipating the events that have transpired across the state this past month.

As one 1988 internal Shell Oil Co. document noted, “by the time the global warming becomes detectable it could be too late to take effective countermeasures to reduce the effects or even to stabilize the situation.”

“I’m only sorry that in 1989, I could not get an audience for what I wanted to communicate,” said Jim Hansen, a retired NASA researcher and early climate change scientist, of testimony he made to Congress about the issue.

Record temperatures

Each of the extremes Californians are living through right now is fueled, at least in part, by the gradual warming of the planet, which is accelerating as greenhouse gas emissions continue to rise.

California summers are 2.5 degrees warmer than they were in the 1970s and are on track to heat up an additional 4.5 degrees by the end of the century if the world’s current emissions trajectory continues, said Hausfather.

While precise attribution studies on the extreme heat waves in California in recent weeks will take time to complete, he said, they are clear examples of how climate change compounds natural weather variability to increase the likelihood of what once would have been a rare event.

“In a world without climate change, it still would have been a hot August; we still would have had some fires. But it’s clear that climate change has made things notably worse,” he said. “An extreme heat event that would have been 100 degrees is now 102.5 or 103 degrees, and that is actually a pretty big difference in terms of the impacts on people.”

During the mid-August heat wave, Death Valley soared to 130 degrees, one of the hottest temperatures ever recorded on Earth.

Another ferocious heat wave over the Labor Day weekend brought Death Valley-like heat to other areas. Los Angeles County had its hottest temperature on record when Woodland Hills hit 121 degrees Sept. 6. At Cal Poly San Luis Obispo, it reached 120 degrees, the highest reading since record-keeping began in 1869, in an area that is less than 10 miles from the Pacific Ocean.

CALIFORNIA

A sizzling summer: Hottest August on record in California

Sep. 10, 2020

John Lindsey, a marine meteorologist with Pacific Gas and Electric, said the mercury rose to unprecedented levels in San Luis Obispo due to hot, downslope winds blowing from the northeast. They are known locally as Santa Lucia winds and can increase temperatures by 5.5 degrees for every 1,000 feet they descend.

“It was just rip-roaring hot,” said Lindsey, who has forecast weather along the Central Coast since 1991. “You just don’t expect Death Valley temperatures along coastal California.”

Lindsey, who acknowledges that he was a bit of a climate skeptic in the past, said seeing the increase in seawater temperatures, in particular, over many years "was a real epiphany or wake-up call."

"By now, there's no doubt in most people's minds that the atmosphere is warming and the ocean is warming," he said. "With the way greenhouse gases are increasing, in my mind, there's no doubt that we're causing this. It's human activity that's causing this. So I'm concerned about the future. And that's somebody who's very skeptical."

Global warming has increased the odds of unprecedented heat extremes across more than 80% of the planet and "has doubled or even, in some areas, tripled the odds of record-setting hot events" in California and the Western U.S., said Stanford University climate scientist Noah Diffenbaugh.

An unprecedented firestorm

When it comes to wildfires, "what we've had in California over the last three to four weeks is unprecedented in our historical experience," Diffenbaugh said.

"This is more extreme than any other year in living memory," he said, and is consistent with the impact of global warming.

Research by Diffenbaugh and colleagues that was published last month found that the number of days with extreme wildfire weather in California has more than doubled since the early 1980s, primarily due to warming temperatures drying out vegetation.

"It means that even with no change in the frequency of strong wind events, even with no change in the frequency of lightning, the risk of wildfire and risk of large, rapidly growing wildfires goes up as a result of the effect of that warming," he said.

California wildfires map: What's burning now

And it's that atmospheric warming that has set the stage for the fires raging throughout the western U.S., said Park Williams, a hydroclimatologist at Columbia University's Lamont-Doherty Earth Observatory.

"If we think of the atmosphere as a giant sponge that's always trying to extract water from the landscape, then temperature increases the sponginess," he said.

As soils become drier, heat waves become more intense. That's because the energy in the atmosphere is no longer being used in evaporation but is just building up heat. And as heat increases and soils — and, therefore, fuel for fires — dry out, the risk grows, laying the foundation for the type of wild and destructive fires we are now observing.

"That's why, I think, you keep reading quotes from these firefighters who say they are seeing fire behavior unlike anything they've seen before," he said. "As we go out in the future, in a world with this exponentially growing risk … we're going to see fires far different than we've seen before."

He noted that fires are not unusual in California — they are an integral part of the state's history and landscape. Bad forest management, combined with human behavior — intentional and unintentional starting of fires — have contributed to the problem. But the effect of climate change is real and growing.

"We have seen the rapid warming of California summers really turbocharge the type of conditions that are suitable for rapid growth of wildfires," Hausfather said. "We see fires growing from essentially nothing to a quarter of a million acres in one day. And that's because the conditions are ripe, and temperature plays a large role."

John Abatzoglou, associate professor in the Department of Management of Complex Systems at UC Merced, agreed.

“What we are seeing play out does indeed have human fingerprints on it, including those from climate change,” he said.

“We can see how warm and dry years catalyze these fires,” he said, adding, however, that for fires to start, “they need to have ignitions. But the heat and dryness have absolutely set the table for widespread fire activity.”

Dreadful air quality

It was no coincidence that ozone pollution levels in downtown Los Angeles spiked to their highest levels since the mid-1990s on a day in which temperatures reached an all-time high for the county, said Cesunica Ivey, an assistant professor of chemical and environmental engineering at UC Riverside who studies air quality.

The global rise in temperatures observed over decades is also occurring locally, she said, “and these frequently occurring heat waves, this upward trend in basin-wide average temperature, is contributing to ozone exacerbation.”

CALIFORNIA

Rarely have so many Californians been exposed to such gloomy, unhealthy air

Sep. 10, 2020

Southern California regulators have seen decades of progress fighting smog stymied in recent years by hotter weather and stronger, more persistent inversion layers that trap pollution near the ground. Their efforts are being hindered by rising temperatures from climate change, according to air quality experts.

That's because hotter weather speeds up the photochemical reactions that turn pollutants from vehicle tailpipes and other sources into ozone, the invisible, lung-damaging gas in summer smog. Studies show that ozone levels are about two parts per billion higher than they would be without global warming.

What precisely is driving changes such as elevated smog levels can be hard to tease out in the middle of an extreme event because so much is happening at once, with multiple hazards piling on top of each other in a vicious feedback loop.

The recent heat spells, for instance, both fueled smog formation and led to power outages. Gov. Gavin Newsom suspended air quality rules on power plants and other polluters to ease strain on the grid, allowing more emissions to sully the air. The COVID-19 pandemic has added an additional layer of complexity at a time when Californians are trying to protect their homes, lungs and bodies from threats that seem to be coming from all sides.

"When you add COVID, extreme heat, wildfires and air pollution all together, they're all detrimental to public health, and it just makes things worse," said Yifang Zhu, a professor of environmental health sciences at UCLA Fielding School of Public Health who studies air pollution and its effects. "These stressors are happening at the same time. So the impact is cumulative and maybe even synergistic to each other."

That cascading effect, in which one extreme compounds another, is a feature of global warming that experts have long warned about.

Ivey, of UC Riverside, said she and other scientists aren't surprised to see so many extremes hitting simultaneously, "but to see it playing out is scary."

"It's one of those moments where ozone converged with record acres burned and a heat wave," she said. "If the writing isn't on the wall, then I don't know what to tell folks."

Global warming is also fueling increases in wildfire pollution, a mix of soot particles and gases that can fuel ozone formation and dramatically worsen smog. Those added emissions are only going to get worse as the severity and frequency of fires increases.

“People may not directly connect local air pollution to global climate change, but they are intertwined,” said Zhu. “They are two sides of the same coin.”

What this year’s extreme heat, fire and air quality degradation is showing, said Columbia’s Williams, is that we are, in a sense, blindly stepping off a cliff from a world in which we could somewhat predict what was going to happen, based on decades and centuries of data.

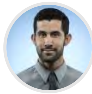
“We’re finding that we’ve lost complete control,” he said. “The baselines we’ve used for decades no longer apply. There really isn’t a normal anymore.”

CALIFORNIA CLIMATE & ENVIRONMENT FIRES

Susanne Rust

Twitter Instagram Email Facebook

Susanne Rust is an award-winning investigative reporter specializing in environmental issues. She is based in the Bay Area.



Tony Barboza

Twitter Instagram Email Facebook

Tony Barboza is a reporter who covers air quality and the environment with a focus on Southern California. He has been on staff at the Los Angeles Times since 2006, is a graduate of Pomona College and completed a Ted Scripps Fellowship in Environmental Journalism at the University of Colorado. News tips? Send messages or documents privately using the Signal smartphone app: (213) 421-1511.

CORONAVIRUS, VACCINES AND PANDEMIC

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EU regulator to issue decision on AstraZeneca shot after review of blood clots

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COVID-19 vaccine questions answered

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Cases statewide »

3,608,923 confirmed	56,363 deaths

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EXHIBIT 41

Land **2015**, *4*, 140-156; doi:10.3390/land4010140

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Review

Land Use and Wildfire: A Review of Local Interactions and Teleconnections

Van Butsic *, Maggi Kelly and Max A. Moritz

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Abstract: Fire is a naturally occurring process of most terrestrial ecosystems as well as a tool for changing land use. Since the beginning of history humans have used fire as a mechanism for creating areas suitable for agriculture and settlement. As fires threaten human dominated landscapes, fire risk itself has become a driver of landscape change, impacting landscapes through land use regulations and fire management. Land use changes also influence fire ignition frequency and fuel loads and hence alters fire regimes. The impact of these changes is often exacerbated as new land users demand alternative fire management strategies, which can impact land cover and management far from where land use change has actually occurred. This creates nuanced land use teleconnections between source areas for fires and economic cores, which demand and fund fire protection. Here we will review the role of fire and fire risk as a driver of land use change, the ways land use changes impact drivers of fire, and suggest that the integration of land use teleconnections into the fire/land use discussion can help us better understand and manage the complex interactions between fire and land use.

Keywords: wildfire; land use change; teleconnections; wildland urban interface (WUI); fire risk; regulations

1. Introduction

The human relationship to fire is complex, and it varies substantially across the globe [1]. Humans have used fire as a tool for modifying landscapes for millennia, clearing land for agriculture, improved hunting, and settlement [2–5]. At the same time, human land use changes have had profound impacts on fire regimes by changing fuel loads and ignition rates, leading to altered fire patterns in many parts of the world [6]. Fire management, in response to human settlement on fire prone landscapes, has often led to ever greater manipulation of fire regimes, with near complete exclusion of fire in some systems resulting in massive changes to natural ecosystems [7,8].

Natural controls on fire activity are dominated by climate variation [9], which can manifest itself at a variety of scales. Fire regimes—namely the sizes, frequencies, intensities, and seasonalities of fire—are typically quantified (*i.e.*, through their statistical distributions) at the regional scale. There are three primary constraints underpinning the spatial and temporal patterns of fire activity: (1) the availability of resources to burn (fuel loads); (2) conditions conducive to combustion (length and intensity of fire season); and (3) ignitions (primarily human sources and lightning) [10]. More local factors, especially topography, can also emerge as an important influence in some fire-prone ecosystems. Therefore, a combination of global, regional, and local factors determines the characteristics of fire regimes.

Land use changes are also driven by forces acting at multiple scales [11]. Global, national, and region wide economic conditions are the largest drivers of aggregate land use change [12,13]. For the individual decision maker, however, local conditions—Including physical conditions of the land, the location of a given piece of land, and the nuanced preferences of the landowner can impact land use decisions [14,15]. Together, global and local drivers interact to create land use systems.

At both global and local scales land use decisions impact fire regimes. At the global scale, land use change contributes to climate change, which in turns impacts the regional climate variation that regulates fire regimes [16,17]. Locally, land use changes impact both fuel loads and ignitions, the primary regulators of local fire conditions. Hence, land use change has become a key driver of fire in many systems across multiple scales.

Beyond interactions across scales, land use and fire may also form unique teleconnections [18,19]. Teleconnections describe interactions that take place between non-adjacent locations, for example between urban centers and distant farms. We hypothesize here that teleconnections may exist between land use and fire due to funding mechanisms which directly link local land use change to distant fire management decisions and because management goals of local and distant actors may differ.

We believe that a *land systems science* framework for understanding the complex role of fire in society may be a valuable contribution to our understanding of human fire relationships. This is urgently needed, especially given the important role that land use plays in different fire-related problems across the globe [20]. Here, we attempt to synthesize the relationships between fire, its risk, and management, and land use change. We start by reviewing past research on the impacts of fire, fire risk and fire management on land use change as well as the impacts of land use change on fire ignitions and fuel loads. We will then offer a land change science perspective on fire and land use interactions drawing heavily on the idea of land use teleconnections [18]. In this section we focus on a short case study of teleconnections between land use and fire, fire risk, and fire management in California. Our goal is to demonstrate how a land change science perspective can broaden the suite of interactions that are evaluated within the land change/fire system. The inclusion of teleconnections within this system suggests the need to coordinate land change and fire management across large spatial scales and between non-adjacent areas.

2. Fire, Fire Risk, and Fire Management of Risk as Drivers of Land Use Change

2.1. Fire as a Tool for Changing Landscapes

Human use of fire to convert landscapes has ranged from localized and targeted applications to impacts across vast regions. For example, early Polynesian colonization of the south island of New Zealand coincided with apparent fire-driven changes in vegetation types, erosion rates, and lake chemistry [21]. Likewise, in North America the use of fire to increase game and grazing was a common strategy of native population and early settlers alike [5]. More recent tropical deforestation and conversion to agricultural is often accomplished through the use of fire, which can have devastating effects in rainforests [22,23]. Throughout history, and even today, fire is clearly an effective landscape-altering tool.

To describe how human use of fire on the landscape changes with increasing levels of industrialization, a general model of phases in a "pyric transition" has been proposed [1,6]. At one end of the spectrum is an uninhabited landscape with some existing background level of fire; intermediate stages see increasing fire activity as humans modify the landscape to suit their needs (*i.e.*, land clearing, soil productivity, cooking and heating); and on completely urbanized landscapes of industrialized cultures, fire has been largely eliminated as a tool to convert landscapes and fossil fuels replace biomass as a source of energy for doing work. Spatial changes in fire, such as concentration in some areas and elimination in others, may also occur along this hypothetical gradient in development. One could imagine the pyric transition taking different forms in different cultures, though few quantitative demonstrations of it exist to date.

2.2. Fire Risk and the Management of Fire Risk as Drivers of Land Use Change

Fire risk and the management of this risk are also a driver of land use change, both by changing human behavior and by changing the regulatory framework in which land use change takes place. Individual tolerance for fire risk can impact land use change. Economic studies [24,25] of land use change have shown that some risk averse landowners are less likely to develop fire prone areas, although this aversion is often balanced by the fact that many fire prone areas also have natural amenities that are desired by home owners (for instance fire prone steep slopes may also offer wonderful views) [26,27]. While it is a common assumption in many fire prone areas that landowners typically rebuild after a fire, empirical evidence suggest that this is not always the case, and indeed a re-wilding of some previously subdivided land may take place after fires [28].

Local and state governments have often used fire risk and public safety as a lever to impact the planning and development process [29]. In the state of California, the state government has mapped areas of very severe fire hazard (VSFH) in municipalities and these areas can be under special development regulations [30]. In some municipalities local zoning has made these areas out of bounds for development, while in others it may be more difficult for developers to insure homes built in VSFH zones. While this policy has been criticized as not being strong enough to deter land use change [24,31], the intention of the regulation was to do just that.

Likewise, the state of California recently passed a law requiring local authorities to include wildfire safely as part of general plans [32]. While this law has only recently passed, the goal is to force communities to think about how wildfire may impact future land use changes. At a smaller scale many municipalities now require that new developments have plenty of egress and regress for firefighting equipment and in addition many localities now enforce strict vegetation guidelines as another way to reduce fire risk [33]. All of these land use planning measures can impact the land-use change process by limiting areas where residential development can take place, the arrangement this development takes (for instance development densities), as well as vegetation near these developments.

The goal of many of these regulations is to change development patterns in fire prone areas—especially in the wildland urban interface (WUI). Thus far, however, there is little empirical evidence that these land use regulations actually reduce fire risk. While a few studies demonstrate how different housing arrangements may impact fire risk [34–36], more comprehensive analysis of such policies is an area of great research need.

Fire risk can also influence land use change through fire management. Often, increased land use intensity (especially increased housing density) results in an increased demand for fire management. In many systems this means manipulating fuel loads through prescribed burns, mastication, and the removal of fuels [37]. Fuel management can result in land use change by leading to type conversion of natural systems—the conversion of an ecosystem from one dominant vegetation type to another [38]. For instance, management of vegetation in chaparral-dominated systems is typically performed by masticating or burning shrubs. Non-native grasses can quickly invade the treated area and become the dominant vegetation type—indicating a type conversion from shrubs to grass [39,40]. This land cover change can then result in a land use change if livestock are brought in to graze the newly established grasses, which has historically constituted "range improvement" in much of the American West. In this setting fire risk leads to a land use transformation from a natural shrubland system to a low intensity agricultural system.

Vegetation management to reduce fire risk can change land use in forested systems in complex ways. In the United States, fire suppression efforts within Forest Service land was originally meant to protect these lands as productive timber stands. In some forests, suppression has increased to the point of total exclusion, at times increasing forest biomass [8]. In these forests a dense understory has grown which has increased the risk of catastrophic fires. In order to reduce this risk, the understory is now being manually cleared in many forests. In some forests, this cleared understory is being used as a source of biofuel to generate electricity. Thus, fire risk can led to a complex change where fire management can transform forest production and use.

An unintended consequence of intentionally reducing fire risk, through both government-subsidized fire suppression and fuels reduction projects, may actually be increased development and human exposure to losses on some fire-prone landscapes [20]. This is because fire risk is only marginally and temporarily reduced through these publicly funded activities, which could promote the perception that such development is acceptable and reasonably safe. Similar to the "safe development paradox" observed to operate on flood-prone landscapes [41], fire risk management can have somewhat perverse outcomes that feed back to cause further land use change and ultimately increased exposure to losses.

3. The Impacts of Land Use Change on Drivers of Fire Risk

Land use change is not only driven by fire and fire risk, it feeds back and impacts fire regimes through changing ignition frequency, fuel loads, and once again management. The overall impact of land use change on drivers of fire risk is often specific to the location, ecosystem, land use system, and underlying climate of a particular place, and thus it can be difficult to generalize across multiple systems, although some general trends have emerged. While fuel loads and ignition are often good indicators of fire risk, this relationship can also be complicated through fire suppression, fuels management and a host of other factors [20]. Indeed, in some cases high fire frequency can be correlated with low fire risk, if fires are started in areas with low chances of spreading [42,43]. Therefore, we present the impact of land use change on ignition frequency and fuel loads, with the understanding that the total impact of these drivers on fire risk may be complex.

3.1. Land Use Change and Ignition Frequency

The trend in much of the world is towards landscapes with more ignitions [44], and these ignitions are often associated with increased land-use intensity [45,46]. This is because in most areas humans are responsible for starting most fires. Although the majority of human caused ignitions are accidental, arson is also a major cause of fire globally and tends to increase with land use intensity. Interestingly, the correlation between increased ignitions and land use intensity may date back to pre-European settlement [47] in North America. Across many land uses increased intensification through the expansion of roads [48,49] has been identified as a major cause of increased ignitions.

In regions with high fire risk, ignitions may be highest at intermediate housing densities [50–52] making the WUI particularly fire prone. Within the WUI, different land uses and densities may lead to different ignition frequencies although the absolute density, which leads to maximum ignitions seems to vary across regions. Some researchers have found isolated houses within the WUI lead to the most ignitions [53,54] while others have found clustered houses have more ignitions [50]. In areas of very high housing densities, ignition rates may be low because even though there are ample sources of ignitions, most materials simply are not flammable. Likewise, at very low housing densities most ignitions tend to be from natural causes such as lightning strikes. Thus, there is strong empirical evidence for a humped shaped relationship between ignitions and housing density, with the peak of the function at intermediate densities.

Changing agricultural uses can also change ignitions. Agricultural abandonment may increase fire at times [55] if abandoned fields are fire prone. This may be especially true in Mediterranean climates where shrublands may burn more frequently than active agricultural lands [56]. Likewise shrubland fires may be larger than others in agricultural lands [57,58]. Conversely there is also evidence that increased livestock density may increase ignitions [59] especially if farmers use burning to spur vegetation regrowth. There is evidence that farm size may influence ignitions, with larger farms having more fires, although it is not clear if these fires are accidental or not [60]. This relationship may actually change seasonally and geographically [61].

3.2. Land Use Change and Fuel Loads

Land use change can increase or decrease the amount of fuel on the landscape, relative to natural systems. Low density housing can lead to increased fuel loads if houses are not designed with flame resistant materials, if homeowners plant flammable vegetation near their homes, or if the natural ecosystems housing replaces have low fuel loads. Alternatively, small scale fuel treatments associated with increased housing density can decrease fuel loads [62,63] although different ownership types may be more or less likely to manage fuels. Increased land use intensity can result in decreased fuel loads, as is the case in dense cities where most buildings are built from non-flammable concrete and steel.

Changes in agricultural systems can also impact fuel loads. The decline of traditional grazing agriculture has increased fuel loads in Portugal [48] and Spain [55] and is associated with land abandonment and shrub encroachment [64] in other Mediterranean countries. However, grazing techniques are also used frequently to reduce fuel loads in natural areas. Likewise, as farms increase intensity from grazing to row crops, typically fuels decrease. Agricultural abandonment and forest regrowth may lead to increased fuel loads, as seen in some areas of Eastern Europe.

4. Fire and Land Use Feedbacks and Teleconnections—A Case Study of California Fire Management

Thus far we have reviewed the relationships between fire and land use change by focusing on how fire and fire risk can impact land use change and how changing landscapes can impact ignitions and fuel loads, common drivers of fire risk. Most of the research reviewed here has been concerned with the local interactions between fire and land use (Figure 1). In this section we expand this local perspective by hypothesizing that land use changes in one location can impact fire, and eventually land use, in distant locations.

Figure 1. Conceptual model of interactions between land use changes and fire risk. Fire risk can drive land use change by creating the need for alternative vegetation management activities, such as type converting flammable fuels and landscape planning, such as laws that dictate suitable areas for subdivision based on wildfire risk. Land use change can in turn impact fire risk by impacting fuel loads and ignitions. Combined, these impacts interact on the landscape and thus inform both future land use change decisions and future fire risk. This creates a feedback-laden system where the actions in one time period may impact future actions.

The land use change fire nexus fits well within the emerging concepts of land use teleconnections [18]. Land use teleconnections are a way to describe the connections between land use in areas that are not necessarily geographically close to each other, but none-the-less exert forces on each other [65,66].

Fire and climate teleconnections have been well documented [67–70], as climatic forces distant from actual fires can impact fire frequency and size. We hypothesize that similar connections may occur between land use and fire: Land use decisions in one place may impact fire management in distant places. Likewise, local fire management decisions may impact distant land use decisions as well. Here we will describe land use and fire management within California's fire management system and then hypothesize that at least three potential teleconnections exist within this system.

4.1. California's Fire and Land Management System

California is one of the most fire prone places in the United States and over 1000 homes are lost to wildfire in the state every year. Fire was used frequently by the Native Californians and widespread on the landscape in pre-European-American settlement era. Some estimates of prehistoric annual area burned in California (up to 1.8 million ha annually) are much higher than current rates and some researchers claim many Californian ecosystems have a fire deficit [71]. Low and moderate-severity fires are not as societally challenging or expensive as larger, catastrophic fires that can do widespread damage especially in WUI areas.

Responsibility for fire protection falls broadly into three categories and is determined by whether land is within a municipality, the intensity of its use, and if it is owned by the federal government. Local responsibility areas (LRAs) include all incorporated lands in the state, such as villages, towns and cities as well as unincorporated areas in intensive agricultural uses (such as row crops, but excluding most pasture and rangelands). Within the LRAs municipal fire agencies typically are responsible for controlling fire and managing vegetation and funds for fire management are generated through local property taxes and sometimes local bond measures. Unincorporated areas of the state with housing densities under three dwellings per acre, including private, county, and state owned land, as well as low intensity agricultural lands are part of the state responsibility area (SRAs). Fire management in the SRA is performed by CALFIRE the California statewide fire agency (although in a minority of counties CALFIRE contracts out fire protection to county governments). Funding for CALFIRE comes from both the state general fund, as well as the fire prevention fee, a fee of ~$150.00 charged to landowners for each habitable structure owned in the SRA. The fire prevention fee was first applied to SRA land in 2013 and how these funds are used and indeed whether the fee should be in place at all are contentious issues. Finally, federal responsibility areas (FRAs) include all of the federally managed lands in the state including national forest, national park, BLM, national monument and military lands. Money for fire prevention activities in these areas usually comes from federal sources (Figure 2).

Land use change is generally determined by market forces interacting with local, state, and federal land use regulations. Within LRA's municipalities are generally responsible for land use planning, although some LRA land that is in intense agricultural use is subject to planning by the county government. Planning in SRA land is typically done at the county level, although each county is required by California state law to have a general plan which meets a number of health, safety and environmental goals. Finally, federal lands are managed to meet the goals of the federal government. The ability of local actors to influence federal management is a point of contention throughout the state. All development decisions in the state are subject to federal environmental laws such as the endangered species act.

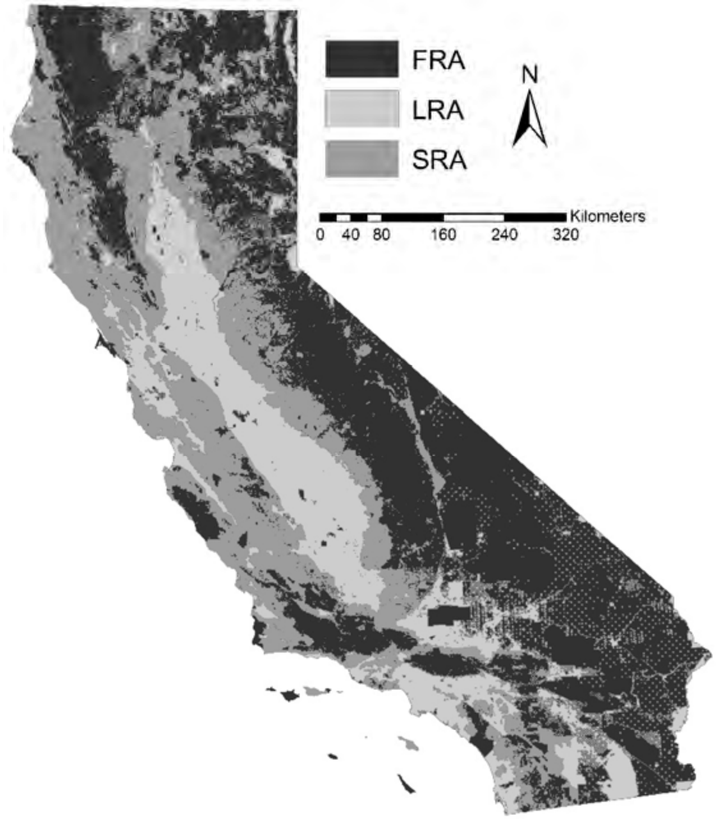

Figure 2. State, Local and Federal, Responsibility Areas, in the state of California (all data provided by CalFire [72]).

Probably the most striking land use changes in California since the 1950's have been the expansion of housing into formerly agricultural and natural areas [73]. Much of this growth has taken place in the WUI [74,75] creating dynamic patterns of land use change where the LRA, SRA and FRA land meet. In many ways, growth in California's WUI is likely typical of much of the rest of the US [76] and therefore may be a useful lens to look at broadly applicable teleconnections. Likewise, conditions in other locations globally, for instance connections between land use and fire management in Australia after the 2009 Victoria fires, may have similar dynamics [77,78].

4.2. Hypothesized Local Feedbacks and Teleconnections

Within this regulatory land use and fire framework, we hypothesize a number of interesting land use teleconnections exists (Figure 3). In particular, the establishment of the fire prevention fee in 2013 creates a unique link between local land use decisions, the statewide fire management budget, and ultimately fire management and land uses throughout the state. We focus here on land use change dynamics, and how these may form both local and teleconnections with fire.

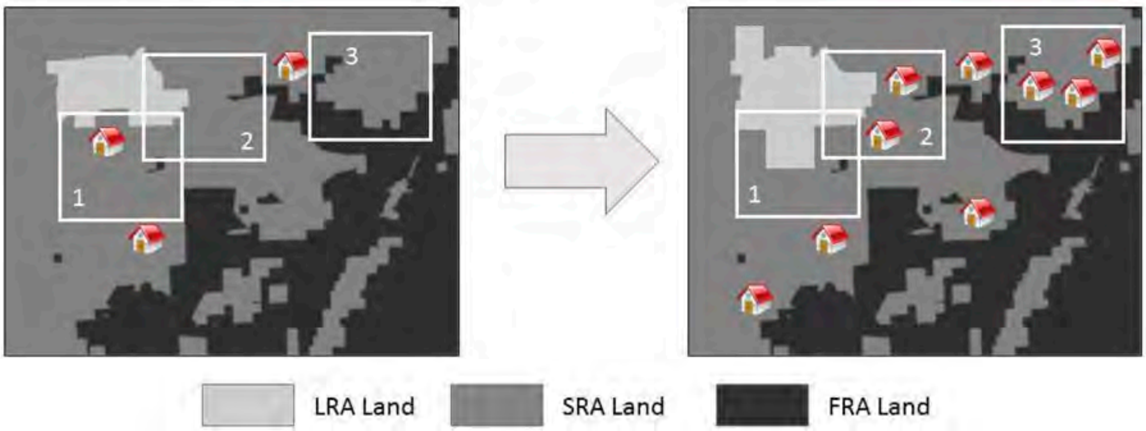

Figure 3. Dynamics of land use change and fire. In box 1, a low-density rural housing in the State Responsibility Area (SRA) is annexed by Local Responsibility Area (LRA) community. In this process SRA fire management loses funds as SRA fees are no-longer collected in this area. In box two SRA land develops at a low enough density so that it does not switch to LRA management. This will increase firefighting revenue for Calfire, but may also increase fire risk as low-density housing is correlated with high fire risk in much of the state. Given the location of this development this may also increase fire risk for areas within the LRA. Box three shows increased housing density near Federal Responsibility Area land. These new homeowners may demand more stringent fuels management within the FRA, although management decisions may be undertaken from within goals of the broader public in mind.

4.2.1. Teleconnection 1: Annexation of SRAs by Municipalities Leads to Potential Changes in Fire Management Statewide

When municipalities annex outlying areas for development, these lands will switch from SRA to LRA classification, because municipalities are generally responsible for their own fire protection. This change in administration has multiple impacts on the management of land and its potential uses. Locally, the annexation may impact land use decisions and potentially fire risk. If the annexed areas develop at densities higher than the SRA designation, a common reason why annexation would take place, we may expect fire risk will change as well. Likewise, these changes may impact the fire risk to nearby SRA land, which may ultimately impact local SRA management. Finally, properties that are annexed no longer need to pay the fire prevention fee (although land owners may be required to pay new local taxes for fire management), therefore reducing funds to statewide fire management.

The main teleconnection is the impact of local administrative changes on funding for the statewide fires protection program. Annexation reduces funding for statewide fire protection for SRAs since fire prevention fees are shared across the state. The strength of this teleconnection may be exacerbated since the fire prevention fee is based on the number of dwellings on a property, not the size of the property. Areas of the SRA which are relatively densely populated—For instance some WUI areas surrounding larger cities—Contribute more to the SRA fire prevention funding on a per acre basis than areas with fewer structures. These areas may also be the most likely to be annexed because they are often adjacent to municipalities. Over time, we expect that land use change which drives annexation of more densely populated SRA areas may lead to fewer SRA fess on a per acre basis for the properties remaining in the SRA. While this dynamic will likely reduce SRA fees on a per-acre basis, if fire risk is most highly associated with low density development which may be common in annexed properties, the average fire risk to SRA parcels may be lowered after annexation as well. In sum, the connection between annexation, SRA fees and statewide fire management is complex. What is clear, however, is that local decisions to annex land can have impacts on fire management well beyond local areas.

4.2.2. Teleconnection 2: SRA Administration May Encourage Local Low Density Development, Increase Statewide Fire Management Funds but Potentially Costs As Well

If land in the SRA converts from low intensity agriculture or forestry to low intensity housing (anything below three dwellings per acre), the property can stay in SRA, as long as it is not annexed by a municipality. In such a case the landowner now must pay the SRA fee for any structures built, increasing SRA fees statewide. This creates an interesting local incentive for counties to develop at low densities: Counties can gain increased tax revenue from the new structures, but as long as the density of these structures are low enough, fire protection remains the responsibility of the state (or at least partially—Many low density communities split firefighting duties between state and local authorities). Locally, there are many potential dynamics of these incentives. For one, counties gain tax revenue while taking on little firefighting costs. Likewise, in the common case where low-density housing is fire prone, nearby LRAs may end up spending more on fire management if SRA areas become more hazardous.

The local decision to develop at low densities in SRAs also has statewide implications as well, creating land use teleconnections. The initial implication is an increase in revenue for statewide fire management because all new structures will be required to pay the fire prevention fee. These fees can be used anywhere in the state and therefore may impact land far away from the structure on which the fee was levied. However, if a county allows a large amount of low-density SRA developments, and this development is commonly associated with increased fire risk, over time the cost of fire management may outweigh the fees generated by the new structures. If this is the case, the county may become a "sink" for SRA fees—More may be spent locally on fire management then are contributed via SRA fees. This would imply that SRA in a different part of the state are subsidizing this areas fire management and in turn are receiving less fire management then they would in the absence of the new low density development. The teleconnection between new SRA developments and statewide fire management can therefore increase or be a drain on state fire management resources depending on how the new developments impact fire risk.

4.2.3. Teleconnection 3: Local, State and Federal Land Use and Fire Management Decisions Interact across Administrative Boundaries

Finally, we hypothesize that there are strong land use teleconnections between land use change on LRA and SRA lands, and fire management and land use change on FRA lands. Federal lands management in the west is often contentious and in California competing land uses outside of the FRA demand alternative land uses and fire management strategies within FRAs. California, like other states has seen an increase in housing density in areas around federal forest and parks [79]. As homes are built closer to wildlands, there may be a heightened demand to prevent fires from spreading from FRA land to SRA or LRA land. These concerns may also be held by timberland owners near FRAs who have recently lost valuable timber when fire has spread from FRA land to SRA land. In this way, there is a local connection between land use decisions near the FRA and management within the FRA. Likewise, if development around FRA's is at typical WUI densities, these developments likely increase the chance for fires, which may spread from SRA or LRA lands to federal property. FRA managers therefore have an incentive to try to reduce fire in non-FRA land close to FRAs, especially fires ignited by humans. Thus, there are strong local connections between FRAs, SRAs and LRAs.

Teleconnections exists between FRA, SRA, and LRA lands because management of FRA land is also influenced by non-local actors and the experience of federal land managers far from California. For example, policies to suppress or let burn wildfire in the FRA are informed not simply by what would be optimal locally, but with management of the full portfolio of federal land in mind. Therefore, even though suppression of a given fire may benefit local actors, this may not be the choice of made by federal agencies with massive land holdings. Goals that may be less important than fire protection to local landowners—Such as biodiversity production and aesthetic quality—often play a large role FRA management. This creates a tension between the scale at which fire prevention activities should take place, and the balance of local *versus* national interest on federally managed lands.

5. Future Research Directions and Policy Implications

Fire and land use are parts of a coupled system, and research discovering and incorporating these dynamics is limited. We have reviewed a number of manuscripts that answer directional questions such as "what is the impact of housing density on fire ignitions/fuel loads" or "what regulations have been put in place to encourage fire safe land use" however far fewer have attempted to address such questions jointly. To do so requires a coupled systems approach that addresses both the natural side of fire and land use—For example how fires spread through different fuels and over different terrain—As well as the human dimensions of land use change and fire management—Such as land use planning decisions and vegetation management. Previous attempts to model the fire and land use system have typically combined spatially explicit land use change and fire behavior models in order to assess the impact of land use change on fire risk [52,80]. While these models have been useful in showing many of the dynamics of the coupled systems they could still be improved by more fully integrating feedbacks between human and natural systems, uncertainty over time and space, and by being more explicitly grounded in theories of human behavior.

Second, as we have pointed out, there may be strong teleconnections between land use and fire decisions. Modeling these teleconnections will require expanding the approaches currently used in the coupled-systems literature to account for interactions between distant places. Modeling and quantifying interactions from possibly distant drivers is difficult, although there are a number of recent examples within the land use literature which may give guidance to researchers interested in the fire and land use teleconnections [12,81]. That being said, developing new approaches that are able to account for land use/fire teleconnections should be a priority area of research.

There is a mature literature demonstrating the strong local connections between land use change and fire. From a policy perspective, then, our review supports the quite obvious policy measure that fire should be taken into account in any land-use planning endeavor [20]. And yet, to our knowledge integrating wildfire and land use planning is quite rare. While the State of California now requires wildfire planning in its county plans, and some Australian regions have similar laws [82] our research indicates that many regions still do not coordinate land use planning and wildfire prevention. This is perhaps due to the outdated thought that fire is a destructive force to be eliminated, rather than a force that can be planned for [83]. In light of the strong impacts of land use change on fire and *vice versa*, our view is that large gains to public safety could be made through better coordination between planning and firefighting agencies.

The presence of teleconnections between fire and land use change may indicate that coordination of fire and planning at the local level may be insufficient. This is especially true in an area like California where firefighting funds may come from local, state, or federal sources. In such situations land use change can impact firefighting resources in distant places and hence there may be a need for more concentrated planning and fire management at the state level. Or at the least funding for statewide programs may be better off separated from local land use decisions. This could be done by guaranteeing that local SRA fees are returned to the county they originate.

6. Conclusions

Fire and land use have been connected throughout history. Here we provide a relevant review of many of these connections, including the impacts of fire on land use and land use regulations, and also the impacts of land use on fire ignitions and fuel loads. While our review is not exhaustive, it does suggest that even though there are clear feedbacks between land use and fire, they are still often studied as a closed rather than coupled system. This may be changing however, as recent research has shown promise in this area [20,84,85]. We suggest that future research into fire and land use as a coupled system is necessary to provide pathways to a future where we co-exist with fire as a natural process, and when possible, better plan how and where we build.

Furthermore, as the case study of California fire management demonstrates, teleconnections between distant places can also impact the fire land use nexus. With funding, land use, and management decisions often being decided by forces outside of local jurisdiction, useful research must take a broader view of the connections between fire and land use. This means adapting research techniques, such as modeling land use change and fire risk, such that they can account for forces that may be acting from outside of the traditional study areas.

Author Contributions

All authors contributed to the development, research, and writing of this manuscript.

Conflicts of Interest

The authors declare no conflict of interest.

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EXHIBIT 42

Human-started wildfires expand the fire niche across the United States

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Human-started wildfires expand the fire niche across the United States

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The economic and ecological costs of wildfire in the United States have risen substantially in recent decades. Although climate change has likely enabled a portion of the increase in wildfire activity, the direct role of people in increasing wildfire activity has been largely overlooked. We evaluate over 1.5 million government records of wildfires that had to be extinguished or managed by state or federal agencies from 1992 to 2012, and examined geographic and seasonal extents of human-ignited wildfires relative to lightning-ignited wildfires. Humans have vastly expanded the spatial and seasonal "fire niche" in the coterminous United States, accounting for 84% of all wildfires and 44% of total area burned. During the 21-y time period, the human-caused fire season was three times longer than the lightning-caused fire season and added an average of 40,000 wildfires per year across the United States. Human-started wildfires disproportionally occurred where fuel moisture was higher than lightning-started fires, thereby helping expand the geographic and seasonal niche of wildfire. Human-started wildfires were dominant (>80% of ignitions) in over 5.1 million km^2, the vast majority of the United States, whereas lightning-started fires were dominant in only 0.7 million km^2, primarily in sparsely populated areas of the mountainous western United States. Ignitions caused by human activities are a substantial driver of overall fire risk to ecosystems and economies. Actions to raise awareness and increase management in regions prone to human-started wildfires should be a focus of United States policy to reduce fire risk and associated hazards.

anthropogenic wildfires | fire starts | ignitions | modern fire regimes | wildfire causes

The United States has experienced some of the largest wildfire years this decade, with over 36,000 km^2 burned in 2006, 2007, 2012, and 2015 (1). There is national and global concern over how fire regimes have changed in the past few decades and how they will change in the future (2–4). In the western United States, there is strong evidence that regional warming and drying, including that directly attributed to anthropogenic climate change, are linked to increased fire frequency and size and longer fire seasons (5–9). However, the role that humans play in starting these fires and the direct role of human-ignitions on recent increases in wildfire activity have been overlooked in public and scientific discourse because of the difficulty in ascribing a cause, either human- or lightning-started (10). Humans primarily alter fire regimes in three ways: changing the distribution and density of ignitions, shifting the seasonality of burning, or altering available fuels (2, 3). Geographic variability in regional and continental-scale fire activity in the United States is strongly tied to proxies for these human-caused changes, including population and road density, and different land-use and development patterns (10–15). Although changing climate and fuels also influence fire regimes across the United States (10, 16, 17), there can be no fire without an ignition source. Here, we explore the role that human-started wildfires play in modern United States fire regimes.

Ignitions are often presumed to be saturated (18, 19), and therefore have limited ability to predict fire activity. However, several studies suggest that humans play an important role in redistributing ignitions (20–22), particularly where lightning rarely occurs or where lightning is not concurrent with dry conditions (23). The human–fire connection in the modern era appears strongest at intermediate levels of development, as fires become less likely in the landscape beyond a certain population density, level of urbanization, or dependence on fossil fuels (11, 13, 24). Overall, humans expand the spatial and temporal "fire niche" by introducing ignitions into landscapes when fuels are sufficiently dry enough to ignite and carry fire, but when lightning is rare. Human ignitions are therefore a critical force acting to expand how the fire niche is realized across United States ecoregions.

National-scale analysis of human alteration of the fire niche is critical given that the annual expense of fighting wildfires has exceeded $2 billion in recent years, and the accrued direct and indirect impacts of wildfire on infrastructure and communities could be 30 times that amount (25). Policies that govern wildfire management and response are also directed at the national level, demanding analysis at a national scale (10, 22, 26). Although recent human influence on fire regimes has been studied at local (13) to regional scales (14), human influence nationally remains poorly understood (10). National policies can strongly influence fire regimes (27) and, with sufficient information on human ignitions, policy directives could target human behavior in ways that remediate increasing trends in wildfire risk.

Here, we ask how human ignitions have altered the spatial extents, seasonality, and temporal trends in wildfire across the coterminous United States. We analyze over 1.5 million records of both human- and lightning-started fires in the United States from

Significance

Fighting wildfires in the United States costs billions of dollars annually. Public dialog and ongoing research have focused on increasing wildfire risk because of climate warming, overlooking the direct role that people play in igniting wildfires and increasing fire activity. Our analysis of two decades of government agency wildfire records highlights the fundamental role of human ignitions. Human-started wildfires accounted for 84% of all wildfires, tripled the length of the fire season, dominated an area seven times greater than that affected by lightning fires, and were responsible for nearly half of all area burned. National and regional policy efforts to mitigate wildfire-related hazards would benefit from focusing on reducing the human expansion of the fire niche.

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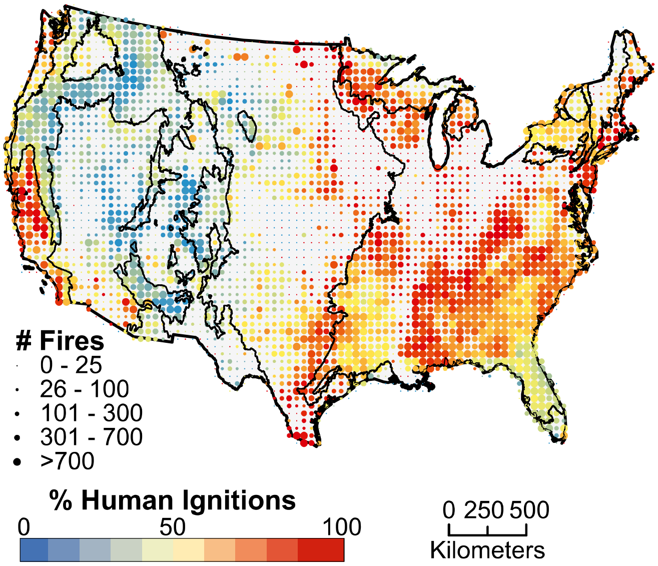

Fig. 1. The total number of wildfires (dot size) and the proportion started by humans (dot color: red indicating greater number of human started fires) within each 50 km × 50-km grid cell across the coterminous United States from 1992 to 2012. Black lines are ecoregion boundaries, as defined in the text.

1992 to 2012 (28). All of these wildfires necessitated an agency response to manage or suppress them, and therefore posed a threat to ecosystems or infrastructure; this record does not include intentionally set prescribed burns or managed agricultural fires. To our knowledge, this is the most comprehensive assessment of the role of human-started wildfires across the United States over the past two decades. We compare: (*i*) the spatial extents of human- vs. lightning-started wildfires, (*ii*) the seasonality of human vs. lightning wildfires, (*iii*) the climate niche for human- vs. lightning-started wildfires, and (*iv*) 21-y trends in large human vs. lightning wildfires. Our analysis documents the pronounced expansion of wildfire extent, seasonality of wildfires, and increasing numbers of large wildfires through time as a result of human-related ignitions across the United States.

Human-Related Ignitions Vastly Expanded the Extent of Wildfire

Human-started wildfires represented 84% of the 1.5 million wildfires included in this analysis (n = 245,446 lightning-started fires; n = 1,272,076 human-started wildfires). The eastern United States and western coastal areas were dominated by human-started wildfires, whereas lightning-started fires dominated the mountainous regions of the western United States (Fig. 1, Table 1 and Table S1). Here we define a fire regime as dominated by either human or lighting ignitions when one cause accounts for more than 80% of the number of fires in a given 50 × 50-km grid cell. Based on this definition, 5.1 million km^2, or 60% of the total land area of the coterminous United States, was dominated by human-started wildfires, whereas only 0.7 million km^2, or 8% of the area, was dominated by lightning-started fires. In addition to expanding the numbers of fires, humans also expanded the total area burned. Human-started wildfires burned a total of 160,274 km^2, or ∼44% of the total area burned from 1992 to 2012 (Table 1).

Human-Related Ignitions More Than Tripled the Length of the Wildfire Season

Human ignitions dramatically expanded the wildfire season in the United States, particularly during spring. The length of the human-started wildfire season [defined as the interquartile range (IQR) of human-ignited fires] was 154 d, more than triple that of the lightning wildfire season (IQR = 46 d) (Fig. 2 and Table 1). This national-scale expansion is driven by earlier (spring) human-started fires in eastern ecoregions coupled with later (late summer or fall) human-started fires in western ecoregions (Table S2). The median discovery date for human-started fires was over 2-mo (May 20th) earlier than lightning-started fires (July 25th). Summed across the 21-y record, the most common day for human-started fires by far was July 4th, US Independence Day, with 7,762 fires starting that day over the course of the record (Fig. 2), whereas, the most common day for lightning-started fires was July 22nd. Of all lightning-ignited fires, 78% occurred in the summer (June–August), 9% in the spring (March–May), and 12% in the fall (September–November). In contrast, human-ignited wildfires were more evenly distributed throughout the year, with 24% in summer, 38% in spring, 19% in fall, and 19% in winter. This pronounced expansion of the wildfire season was also evident spatially (Fig. 3), with human-ignited wildfires occurring predominantly in spring in the eastern United States and in the fall and winter in Texas and the Gulf states. See Table S1 for state-level analysis. When lightning-started fires were rare (<5% and >95% quantile; i.e., before May 13th or after September 16th), humans ignited 842,289 wildfires, effectively increasing the number of wildfires 35-fold compared with the 24,081 lightning-ignited wildfires during these spring, fall, and winter seasons.

Table 1. The number of wildfires, total burned area (ha), and fire season length (IQR, in days), by ecoregion (ordered by percent human-caused fires) and within the coterminous United States from 1992 to 2012

	No. of fires			Area burned (ha)			Length (IQR, days)		
Ecoregion	Human	Light	Human caused (%)	Human	Light	Human caused (%)	Human	Light	Human expansion (%)
MC	87,274	2,855	97	2,143,282	253,210	89	85	45	189
NF	61,673	2,574	96	302,561	82,721	79	51	79	N/A
ETF	815,499	44,859	95	3,827,045	829,293	82	167	66	253
MWCF	14,586	925	94	19,251	27,291	41	67	52	129
GP	134,944	17,586	88	3,992,557	2,564,955	61	148	47	315
SSH	7,504	2,167	78	340,873	254,418	57	55	41	134
TWF	4,832	1,917	72	357,150	350,477	50	98	52	188
NAD	55,422	52,044	52	2,394,677	8,880,691	21	92	40	230
NFM	76,735	94,017	45	1,895,622	5,731,733	25	75	36	208
TS	13,607	26,502	34	754,393	1,152,064	40	85	39	218
CONUS	1,272,076	245,446	84	16,027,412	20,126,852	44	154	46	335

CONUS, Coterminous United States; ETF, Eastern Temperate Forests; GP, Great Plains; MC, Mediterranean California; MWCF, Marine West Coast Forests; NAD, North American Desert; NF, Northern Forests; NFM, Northwest Forested Mountains; SSH, Southern Semiarid Highlands; TWF, Tropical Wet Forests; TS, Temperate Sierras.

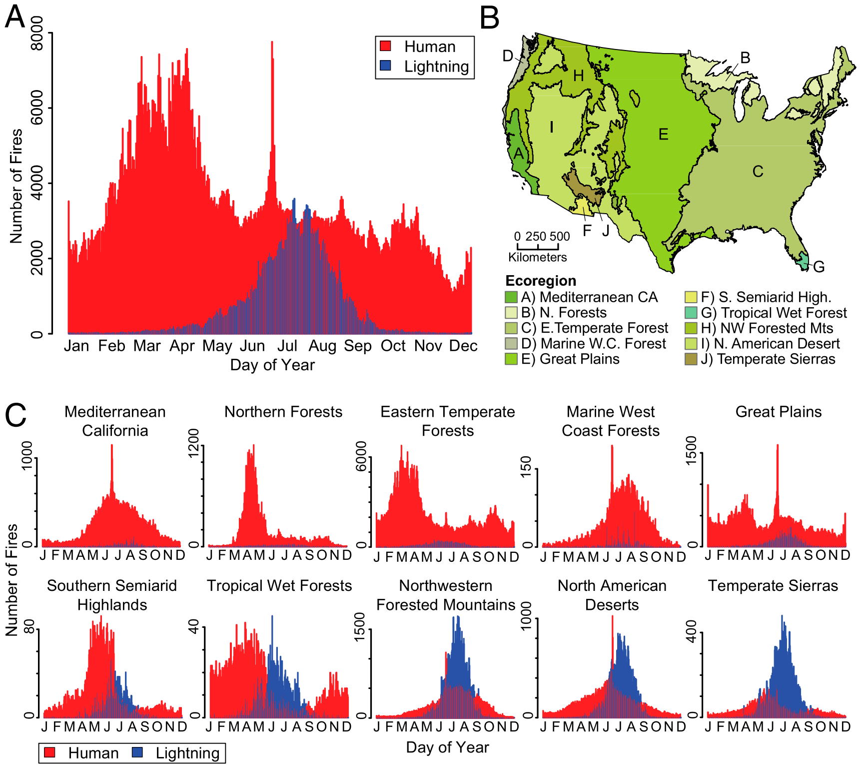

Fig. 2. Frequency distributions of human and lightning-caused wildfires by Julian day of year. (*A*) Frequency distribution of wildfires across the coterminous United States from 1992 to 2012 (n = 1.5 million); (*B*) map of United States ecoregions; (*C*) frequency distributions of wildfires by ecoregions, ordered by decreasing human dominance.

Human-Driven Expansion of the Fire Niche

Humans greatly expanded the natural fire niche (Fig. 4), which we calculated as the co-occurrence of the average monthly lightning density and 1,000-h dead fuel moisture. Regions and seasons of moderate to high lightning-started fire density (>0.4 fires per 1,000 km^2 per month) had a median lightning-strike density of 0.19 (IQR: 0.065–0.57) strikes per square kilometer per month and a median 1,000-h fuel moisture of 11.9% (IQR: 9.25–15.6%) (Fig. 4*A*). In contrast, regions and seasons of moderate to high human-started fire density (>0.4 fires per 1,000 km^2 per month) had a median lightning-strike density of only 0.11 (IQR: 0.025–0.39) strikes per square kilometer per month and a median 1,000-h fuel moisture of 17.8% (IQR: 15.95–19.25%) (Fig. 4*B*). The median fuel moisture and lightning conditions when human-started wildfires occurred were significantly different from those values for lightning-started fires (P < 0.0001). Areas and months of moderate to high human-caused fire density had approximately 40% fewer lightning strikes, and nearly 50% higher fuel moisture levels (based on median values) than for moderate to high lightning-caused fire density. Additional exploration of the fire niche for human-started and lightning-started fires relative to lightning density, fuel moisture, and net primary production (NPP), a proxy for fuels, is provided in Figs. S1 and S2.

Increasing Trends in Large Human-Started Wildfires

During the 21-y time period, there were significant increasing trends in large wildfires ignited by both lightning (n = 4,312; Theil-Sen estimated slope = 12.2; P = 0.001) and humans (n = 4,143; Theil-Sen estimated slope = 3.6; P = 0.004) (Fig. S3). There was a strong dichotomy in human vs. lightning trends seasonally (Fig. 5). Overall trends in lightning-caused fires were primarily driven by increasing numbers of large summer fires (Fig. 5*B*), whereas overall trends in human-caused fires were primarily driven by increasing numbers of large spring fires (Fig. 5*D*). Spatially, lightning-caused fires increased the most in the Northwest Forested Mountains ecoregion (Fig. S4*A*), whereas human-caused wildfires increased the most in the Great Plains ecoregion (Fig. S4*B*).

Discussion

Humans, the keystone fire species (29), play a primary role in spatially and temporally redistributing ignitions and resulting wildfires. We document that over 84% of the government-recorded

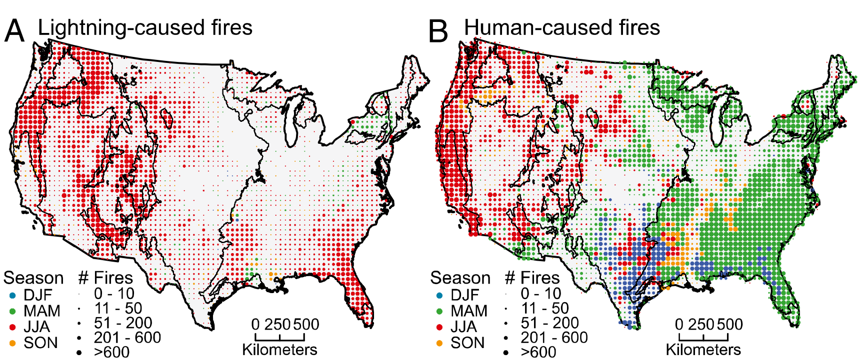

Fig. 3. Comparison of seasonality for (*A*) lightning- vs. (*B*) human-ignited wildfires. Human ignitions expand the seasonal fire niche considerably into spring and fall months. Colors show the season with the maximum ignitions caused by lightning and human within each 50 km × 50-km grid cell. Size of dot indicates the number of unique lightning and human fires between 1992 and 2012. Ecoregion boundaries are overlaid for visualization.

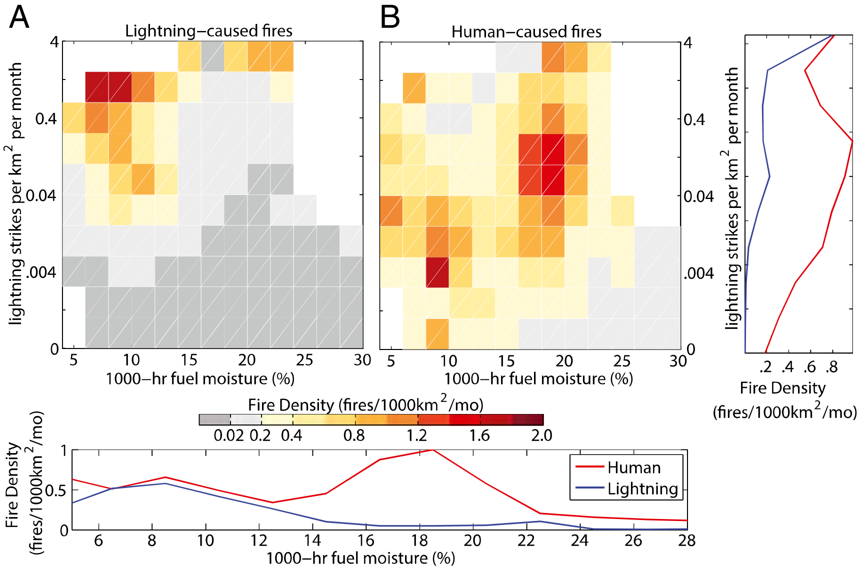

Fig. 4. Human vs. lightning fire niche relative to fuel moisture and lightning density, with greatest resulting wildfire density represented by dark red. (*A*) Lightning-started fires occur in areas with high lightning-strike density and dry fuels. (*B*) Human-started wildfires expand the fire niche to include areas with low lightning-strike density as well as areas with higher fuel moisture. Graphs on the bottom and far right show histograms of 1,000-h dead fuel moisture and lightning strikes, respectively, for human- and lightning-started fires.

wildfires were started by people from 1992 to 2012. Sixty percent of the total land area of the coterminous United States was dominated by human-started wildfires, whereas only 8% of the area was dominated by lightning fires. Humans tripled the length of the wildfire season, extending burning into the spring, fall, and winter months. During the spring, fall, and winter, people added more than 840,000 wildfires, a 35-fold increase over the number of lightning-started fires in those seasons. This expansion of the fire-niche was caused by human-related ignitions under higher fuel moisture conditions, compared with lightning-started fires. Moreover, during this 21-y record, large human-started wildfires increased significantly.

There was a strong national east–west dichotomy in the spatial distribution of human-started wildfires. Although human-started wildfires were pervasive across the United States (Fig. 1), the expansion of human-started wildfires relative to lightning-started fires was most dramatic in the eastern United States and central and southern California (Figs. 1 and 2*C*). Recent work for California confirms the important role of humans, with anthropogenic variables explaining half of the variability in fire probability over the past four decades (30). In contrast, lightning-started fires were found primarily in the intermountain west and Florida and occurred predominantly in the summer, reflecting national lightning strike patterns (31) (Fig. 2*C*). This finding supports other studies of human vs. lightning ignition sources that have found an important distinction between eastern and western United States fire patterns (10, 21) and drivers (32). Some explanations for this distinction include higher population and housing densities, lower proportions of public land, and more extensive land use and development in the eastern United States (33, 34), all of which could lead to more sources of anthropogenic ignitions. Synchrony between lightning activity and the seasonal nadir of fuel moisture in the western United States also likely contributes to these geographic differences. However, even with a projected increase in the number of lightning strikes as a result of anthropogenic climate change (50% by 2100) (35), humans would still remain the dominant ignition source across the majority of the United States land area. The majority of the wildfires requiring agency suppression in the east can be attributed to escaped fires from debris burning occurring in the spring months (or winter in Texas and the Gulf Coast) (Fig. 3). Between 1992 and 2012, wildfires caused by debris burning tended to be small (median

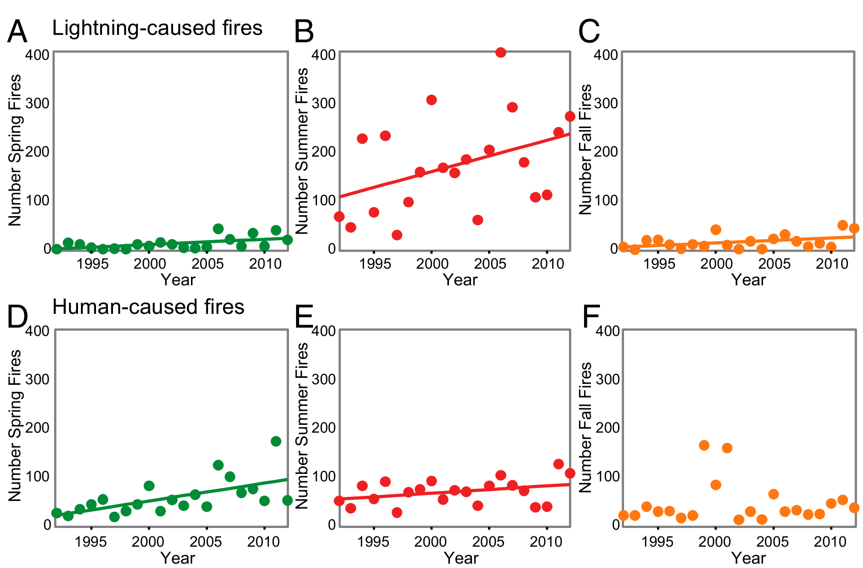

Fig. 5. Trends in the number of large wildfires verified by MTBS records from 1992 to 2012 for lightning-started fires (*A*–*C*) vs. human-started fires (*D*–*F*) in the spring (green: *A* and *D*), summer (red: *B* and *E*), and fall (orange: *C* and *F*). Where trend lines are shown, Theil-Sen estimated slopes are significantly different from zero ($P < 0.05$).

fire size 0.4 ha, IQR: 0.14–1.62 ha), but still an important source of risk to surrounding ecosystems. At finer scales, there are also notable patterns in human- vs. lightning-started wildfires (Fig. S5). Increased wildfires can follow road networks (36), the wildland–urban interface (13), and boundaries between agricultural and forested areas (37), highlighting just a few examples of how human activities and cultural drivers provide ignitions that substantially change the distribution of fire across the United States (38).

Our findings reinforce the strong imprint of people on fire regimes through changes in wildfire seasonality, which has been documented globally (39). In the past few decades, early onset of warmer and drier conditions has promoted greater fire activity across the western United States (6, 7, 40). However, our study highlights the equally important role of human ignitions in changing modern fire regimes by increasing the fire season length to encompass the entire year. The vast majority (78%) of lightning-started fires occurred during the summer months, whereas 76% of human-started fires occurred during the spring, fall, and winter months. Moreover, this trend varies substantially by ecoregion, reflecting again the principle dichotomy between the eastern and western United States (Fig. 3). Human-started fires extend the fire season earlier in the east, and later in the west (Fig. 3 and Table S2). Observations suggest that climate change has extended the duration of the fire weather season across most of the globe, including parts of the United States by a couple of weeks over the past three decades (5, 9), whereas we show that human ignitions in the United States increased the length of the fire season by more than three mo. There was also a notable mark of American culture on the distribution of wildfires, with the peak day of wildfires occurring on July 4th, concurrent with Independence Day fireworks displays (Fig. 2). Indeed, Americans start over twice as many wildfires on July 4th as any other summer day. A similar cultural mark has also been demonstrated globally with a marked decline in wildfires on Sunday compared with other weekdays (41).

Thus, at the national scale, human ignitions dramatically expand the spatial and seasonal niche of fire. The key components that define the fire niche are ignition sources, fuel mass, and desiccation. By exploring the fire niche along these axes, our results show that lightning fires are primarily constrained to areas with a lightning-strike density of greater than 100 strikes per grid cell per month (0.04 strikes/km^2 per month) and are concurrent with drier fuels (< 15% fuel moisture) (Fig. 4). Human ignitions expand fires into regions with higher fuel moisture (Fig. 4) and higher NPP (Figs. S1 and S2), suggesting that humans create sufficient ignition pressure for wetter fuels to burn. As a consequence, human ignitions have expanded the fire niche into areas with historically low lightning-strike density, such as Mediterranean California, or low concurrence of lightning and dry conditions, such as Eastern Temperate Forests (Fig. 1).

Over the past two decades, there was a significant increase across the United States for both human- and lightning-caused large fires (Fig. S3). The significant increase in large lightning fires is driven primarily by fires in summer months (Fig. 5) in the Northwest Forested Mountains ecoregion of the western United States (Fig. S4). This finding is consistent with other studies that have demonstrated an increase in large fires across the western United States (6, 7, 40), likely as a consequence of changes in climate and fuels rather than ignitions. In contrast, the significant trend in human-caused fires is primarily driven by an increase in large fires during spring months (Fig. 5) in the Great Plains ecoregion of the United States (Fig. S4). This increasing trend suggests that earlier springs as a result of climate change (42, 43) may be interacting with human ignition sources to increase the risk of large fires in the central United States.

The strong year-to-year variability in human ignitions (Fig. S3 and S4) may reflect the degree to which human choices can affect fire regimes. However, interannual climate variability also influences fuel moisture, NPP, and short-term weather conditions that enable the spread of human-ignited wildfires (44). There was a significant temporal correlation between large human- and lightning-started fires (R = 0.75). This pattern has been observed previously in the western United States (23) and suggests that large-scale climate drivers affect the frequency of both human- and lightning-caused fires. It is unknown how human actions will be affected by hotter and drier conditions, potentially increasing or decreasing ignitions from land use, recreation, and other sources. Increased public awareness and focused policy and management, particularly in years with elevated fire risk associated with climatic anomalies, are needed to reduce the number of human-caused ignitions.

In conclusion, we demonstrate the remarkable influence that humans have on modern United States wildfire regimes through changes in the spatial and seasonal distribution of ignitions. Although considerable fire research in the United States has rightly focused on increased fire activity (e.g., larger fires and more area burned) because of climate change, we demonstrate that the expanded fire niche as a result of human-related ignitions is equally profound. Moreover, the convergence of warming trends and expanded ignition pressure from people is increasing the number of large human-caused wildfires (Fig. 5). Currently, humans are extending the fire niche into conditions that are less conducive to fire activity, including regions and seasons with wetter fuels and higher biomass (Figs. 3 and 4). Land-use practices, such as clearing and logging, may also be creating an abundance of drier fuels, potentially leading to larger fires even under historically wetter conditions. Additionally, projected climate warming is expected to lower fuel moisture and create more frequent weather conditions conducive to fire ignition and spread (45), and earlier springs attributed to climate change are leading to accelerated phenology (42). Although plant physiological responses to rising CO_2 may reduce some drought stress (46), climate change will likely lead to faster desiccation of fuels and increased risk in areas where human ignitions are prevalent.

Uncertainty remains regarding how anthropogenic climate change will alter wildfire activity geographically and seasonally (47, 48), particularly in areas where human-caused fires dominate. Moreover, the current wildland–urban interface, where houses intermingle with natural areas, constitutes 9% of the United States total land area (33) but is projected to double by 2030, predominantly in the intermountain West (49). This expected development expansion will increase not only ignition pressure, but also the vulnerability of new infrastructure. Human-driven expansion of the spatial and temporal distribution of ignitions makes national- and regional-scale policy interventions and increased public awareness critical for reducing national wildfire risk.

Materials and Methods

For this analysis, we used the publically available US Forest Service Fire Program Analysis-Fire Occurrence Database (FPA-FOD) (28). This comprehensive dataset includes United States federal, state, and local records of wildfires (both on public and private lands) that were suppressed from 1992 to 2012, a total of ~1.6 million records. Previous studies have focused on the western United States (20), federal lands (22), or records from just one agency (21). Each entry includes at minimum the location, discovery date, and cause of the wildfire. We excluded 114,191 wildfires with an unknown cause and analyzed the spatial, seasonal, and temporal patterns of human- vs. lightning-started wildfires. In total, 1,517,522 wildfires were included in the analysis. Human-started wildfires were caused by a variety of sources, including the US Forest Service-designated categories of equipment use, smoking, campfire, railroad, arson, debris burning, children, fireworks, power line, structure, and miscellaneous fires (28). Spatially, we calculated the proportion of human- vs. lightning-caused wildfires within equal-area 50 × 50-km grid cells across the coterminous United States. This grid size corresponds roughly to the size of an average United States county. For each grid cell, we calculated the season (winter, spring, summer, or fall) when the majority of human-caused and lightning-caused wildfires were started. All spatial analyses were conducted in the Albers-Conical equal-area projection. To determine the seasonal distribution of wildfires, we plotted the distribution of human- and lightning-started fires by the day of year for the coterminous United States and for individual ecoregions. We used the level 1 ecological regions of North America, developed by the Commission for Environmental Cooperation (50). We calculated the length of the human- and lightning-caused fire seasons as the IQR of the Julian day of recorded fire ignition: that is, the difference between the first and third quartiles.

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We determined how humans expanded the fire niche by comparing the lightning-strike density (i.e., natural ignition pressure) and fuel-moisture conditions under which actual human- and lightning-started fire events occurred. We obtained daily 1,000-h dead fuel moisture data from the surface meteorological data (51) on a 4-km grid from 1992 to 2012, and computed monthly averages across the 21-y study period. We obtained 4-km gridded monthly lightning-strike data from the Vaisala National Lightning Detection Network (https://www.ncdc.noaa.gov/data-access/severe-weather/lightning-products-and-services) and averaged the data over the 21-y study period. To account for fuel limitations, we also explored the fire niche as a function of fuel amount (approximated by NPP). We used MODIS mean annual NPP data (1-km resolution, from 2002 to 2015) (52) for this purpose. These three datasets were aggregated to the common 50 × 50-km grid cell. We calculated the number of human- and lightning-started fires by grid cell using the FPA-FOD dataset (28). We excluded any grid cells from subsequent analyses that did not report at least one lightning-caused or human-caused wildfire over the period of record. We tested whether fire niche expansion (as determined by fuel moisture and lightning-strike density) caused by human ignitions was significant based on Mann–Whitney tests between human- vs. lightning-started fires.

To assess trends in human- vs. lightning-caused wildfires through time, we used only large fires that were independently verified by the Monitoring Trends in Burn Severity (MTBS) project (53). We specifically focused on these large fires (>400 ha in the west, >200 ha in the east; $n = 8,455$) for comparability with previous research, which has examined temporal trends in the western United States and the link to climate warming (6, 7, 40), but has not investigated the relative contribution of human-started fires at a national scale. In addition to overall temporal trends, we tested for significant trends by ignition source versus season (spring, summer, fall) and versus ecoregion based on the level I ecological regions of North America (50). We explored a similar analysis using all available FPA-FOD data, but changes in reporting frequency through time for some states precluded a robust temporal analysis. We tested for trends in wildfire numbers through time using the nonparametric Theil-Sen estimator (54) and tested for trend significance using nonparametric Mann–Kendall tests (55).

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EXHIBIT 43

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March 20, 2019

Planning Commission of Monterey County
Monterey County Resource Management Agency
Attn: Mike Novo
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Sent via email: novom@co.monterey.ca.us

Re: Paraiso Springs Resort, Project No. PLN040183

Dear Mr. Novo and Commissioners,

Our office has reviewed the Final Environmental Impact Report ("FEIR") and the Recirculated Draft Environmental Impact Report ("DEIR") for the proposed Paraiso Springs Resort Development ("Project") and respectfully submits the following comments. We request that you consider our comments prior to certifying the FEIR. We spoke with County Counsel and staff on March 20, 2019 and alerted them we would be submitting comments prior to your consideration of the FEIR at your March 27, 2019 Planning Commission meeting.

The Attorney General's Office submits these comments pursuant to the Attorney General's independent power and duty to protect the environment and natural resources of the State from pollution, impairment, or destruction, and in furtherance of the public interest. (See Cal. Const., art. V, § 13; Gov. Code, §§ 12511, 12600-12612; *D'Amico v. Bd. of Medical Examiners* (1974) 11 Cal.3d 1, 14-15.)[1] In the wake of the State's deadliest wildfires this past year and the increased occurrence of fires anticipated throughout the State in coming years, it is particularly important that local jurisdictions carefully review and consider new developments in fire prone areas. This is particularly important for new developments proposed in the wildland urban interface or in other relatively undeveloped and remote areas, like the area where the Project is proposed.

Paraiso Springs Resort, LLC, proposes to develop a spa resort along the floor of a canyon in the foothills at the end of rural Paraiso Springs Road in a "very high fire sensitivity

[1] This letter is not intended, and should not be construed, as an exhaustive discussion of the FEIR's and DEIR's compliance with the California Environmental Quality Act ("CEQA") or the Project's compliance with other applicable legal requirements.

zone." The Project site is bordered to the east by grazing and farm land, and to the north, south and west by the Santa Lucia Mountains. (DEIR 2-1.) The Project site was previously operated as a commercial hot springs resort beginning in 1874. (DEIR 3-137.) The site has seen several fires over the years that have destroyed various structures on the Property, including a fire in 1891 that destroyed one of the more substantial buildings on the property, a fire in 1928 that destroyed the hotel, the bathhouse, a garage, the dance hall, and some other smaller buildings, and another major fire in 1954 that destroyed the rebuilt hotel and annex. (DEIR 2-15, 3-137-3-138.)

Paraiso Springs Road, the sole ingress and egress to the site,[2] is a narrow, two-lane road varying in width from 16 to 22 feet that dead ends at the Project site. (DEIR 2-45.) The road currently serves approximately 90 vehicles per day associated with single-family residences and local vineyards. (DEIR 3-329.) The Project would include the development of 103 hotel rooms, 77 multi-bedroom timeshare units, three restaurants, entertainment facilities, and various spa amenities at the end of this narrow two-lane rural road. (DEIR 2-17 – 2-18.) It is anticipated that there would be several hundred people at the resort on peak days. With the Project at 100% occupancy, there would be over 400 additional vehicle trips per day on the road. (DEIR 3-336.)[3] Additionally, because of parking limitations at the proposed Project site and limitations with the capacity of the rural access road, the Project proposes to shuttle in many of the guests and 90% of all employees from a parking lot nearly two miles away. (DEIR 3-335 – 3-336.)

Monterey County, as the lead agency, has prepared a FEIR for the proposed Project. Despite the acknowledgment that the Project is located in a "very high fire sensitivity zone," the FEIR fails to adequately address the risk of fire in several important respects.[4]

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[2] In response to CalFire's comments on the DEIR, the FEIR suggests that there is a service road for ingress and egress at the rear of the development. (FEIR, Response to comment letter No. 18, 2-12.) The response cites to maps within the DEIR. (*Ibid.*) These maps show service roads *within* the development, but these roads do not appear to provide ingress and egress *to the Project site.*

[3] We note that several commenters questioned whether the traffic analysis for the Project underestimated the trips that will be associated with the Project. (See, e.g., FEIR, Comment Letter 10 (p 20-23).) While we have not evaluated the adequacy of the traffic analysis, we are concerned that the number of visitors accessing the site may be even higher than anticipated in the FEIR, which would exacerbate our concerns regarding the risks associated with wildfires and the FEIR's inadequate analysis of those risks.

[4] We understand that LandWatch submitted comments to the County on January 15, 2019 raising many of these same issues. The FEIR does not include a response to these comments.

I. THE FEIR MUST ANALYZE THE INCREASED RISK OF WILDFIRE THAT WILL RESULT FROM THE PROJECT.

The FEIR does not, but should, analyze the increased risk of wildfire that will result from siting the proposed development within a high fire sensitivity zone. The DEIR discussed emergency access to the site in the event of fire and onsite measures to provide fire protection.[5] However, the DEIR did not disclose that locating new development in a high fire sensitivity zone will itself increase the risk of fire and, as a result, increase the risk of exposing existing residents in the area as well as guests and employees of the resort to an increased risk of fire. (See CEQA Guidelines Section 15126.2, subd. (a) [requiring the evaluation of potentially significant environmental impacts of locating development in areas susceptible to hazardous conditions such as wildfire risk areas, especially as identified in hazard maps and risk assessments].)[6] It is well-accepted that building in wildland areas increases the risk and severity of fires.[7] The California

[5] A preliminary fire protection plan was prepared for the Project. (DEIR 2-55.) Fire protection elements include hydrants, sprinkler systems, and the use of fire-resistant building materials. (DEIR 2-55 – 2-56.) The Project also includes vegetation management for defensible space. (See e.g., DEIR 3-81 – 3-80.) Cal Fire's Department of Forestry and Fire Protection commented on, among other issues, the adequacy of the vegetation management discussed in the DEIR. (FEIR Comment Letter 18.) In response to these comments, the FEIR simply refers back to the DEIR and does not provide any additional commitments or project modifications. (FEIR, Responses to Comment Letter 18, 2-12.)

[6] Our comments are based on the CEQA Guidelines in effect prior to the recent 2019 update, but it is worth noting that the update confirms and clarifies the need to consider wildfire risks as part of the environmental review for new developments subject to CEQA.

[7] See, e.g., Rapid Growth of the U.S. Wildland-Urban Interface Raises Wildfire Risk (February 6, 2018) (https://www.pnas.org/content/pnas/115/13/3314.full.pdf); *New York Times*, Climate Change is Fueling Wildfires Nationwide, New Report Warns (November, 2018) (https://www.nytimes.com/interactive/2018/11/27/climate/wildfire-global-warming.html); *Scientific American*, Living on the Edge: Wildfires Pose a Growing Risk to Homes Built Near Wilderness Areas (https://www.scientificamerican.com/article/living-on-the-edge-wildfires-pose-a-growing-risk-to-homes-built-near-wilderness-areas/); *USDA*, Wildfire, Wildlands, and People: Understanding and Preparing for Wildfire in the Wildland-Urban Interface (January 2013) (https://www.fs.fed.us/rm/pubs/rmrs_gtr299.pdf). While these articles and reports largely focus on the risks of locating housing within fire-prone areas, the same risks would appear to apply for commercial establishments offering overnight lodging. The issue with locating development in these areas is that most fires are human induced, so bringing people into wildland areas creates an increased risk that fire will occur. (*Ibid.*) In addition, the risks of fire are exacerbated because development in wildland areas alters the natural environment (e.g., it fragments native vegetation, introduces nonnatives species, and disturbs soils). (See Rapid Growth of the U.S. Wildland-Urban Interface Raises Wildfire Risk (February 6, 2018) (https://www.pnas.org/content/pnas/115/13/3314.full.pdf).) Further, fire management in developed wildland areas is more challenging because it is more difficult to fight fires in these

Supreme Court has confirmed that this kind of risk must be considered as part of the CEQA analysis for a proposed project. (*California Building Industry Assn. v. Bay Area Air Quality Management Dist.* (2015) 62 Cal.4th 369, 388 [holding that while CEQA does not require consideration of the environment's effect on a project, it does require analysis of the project's impacts on the existing environment].)

Concerns regarding the Project's impact on the occurrence of widlfires were raised in public comments on the DEIR. For example, Lois Panziera noted that "[w]hen more people are added to a high severity fire area, the potential for fires will occur." (FEIR, Letter 7, Comment 75.) In response, the FEIR simply refers back to the DEIR. (FEIR 2-58 – 2-59.) However, as explained above, the DEIR did not address the increased risk of fires that will result from locating new development within a high fire sensitivity zone. The County should address these issues prior to certifying the FEIR.

II. THE FEIR SHOULD ADDRESS EVACUATION IN THE EVENT OF FIRE.

Based upon the onsite fire fighting infrastructure (sprinkler systems, etc.) and the Project proponent's commitment to develop a fire protection plan, the DEIR concludes that the "occupants would be protected to the extent possible in the case of fire" such that the potential impacts associated with wildfire hazards would be less than significant. (DEIR 3-215 – 3-216.) The DEIR describes emergency access *to* the site, but does *not* address: (i) the evacuation of employees and guests in the event of a fire, (ii) the increased challenges that existing users of the sole ingress and egress road will face in the event of an evacuation due to the added users on the road, or (iii) the increased challenges that firefighters and emergency responders would face accessing the site and preventing the spread of a wildfire due to the simultaneous evacuation of guests and employees from the Project and neighboring areas. The EIR should include a more robust discussion of the fire hazards and describe the evacuation plan for guests and employees, as well as neighboring residents and existing users of Paraiso Springs Road. (See *Clews Land & Livestock, LLC v. City of San Diego* (2017) 19 Cal.App.5th 161, 194 [discussing whether or not the EIR adequately considered the risk of fire to future users of the project site, including acceptable evacuation plans]; *California Clean Energy Committee v. County of Placer* (Cal. Ct. App., Dec. 22, 2015, No. C072680) 2015 WL 9412772 [concluding that the EIR failed to adequately evaluate evacuation issues associated with the project].)

In response to public comments, including from CalFire's Department of Forestry and Fire Protection, asking about evacuation plans (see Comment Letter 18 starting on FEIR 2-11), the FEIR promises that a final Fire Protection Plan that includes evacuation procedures will be developed. (FEIR 2-12.) Meaningful analysis of the risk of fire and evacuation plans should not be deferred until after the FEIR is certified and the Project is approved. (See CEQA Guidelines

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landscapes and fire management strategies that allow natural fires to burn are not an option. (*Ibid.*; see also *USDA*, Wildfire, Wildlands, and People: Understanding and Preparing for Wildfire in the Wildland-Urban Interface (January 2013) (https://www.fs.fed.us/rm/pubs/rmrs_gtr299.pdf).)

Section 15126.4(a)(1)(B).) While the deferment of mitigation measures may sometimes be appropriate, here no basis has been provided for why the evacuation plan was not already prepared as part of the DEIR or FEIR, nor have any performance standards or potential mitigation measures been identified. (*Ibid*; see also, e.g., *San Joaquin Raptor Rescue Center v. County of Merced* (2007) 149 Cal.App.4th 645, 671 [mitigation measure that included development of a post-FEIR management plan was found to be improperly deferred mitigation where no basis was provided for why the development of mitigation measures needed to be deferred to future plans and, no specific criteria, performance standards, or potential mitigation measures were set forth in the EIR].) In addition, based on the discussion in the DEIR, we are concerned that the Fire Protection Plan, when it is developed, may not adequately address the totality of issues related to evacuation (see above).

III. THE PROJECT MUST COMPLY WITH THE REQUIREMENTS FOR STATE RESPONSIBILITY AREAS.

The Project is located in a State Responsibility Area, which is an area for which the Board of Forestry and Fire Protection has designated the State to be financially responsible for preventing and suppressing fires. (Pub. Resources Code, § 4102.) Local jurisdictions may adopt standards for wildfire protections in State Responsibility Areas, but those standards must be at least as stringent as the State's minimum standards and be certified by the State. (Pub. Resources Code, § 4117.) Monterey County has adopted standards for this purpose. (Monterey County Code, §§ 18.56.010 – 18.56.100.) The proposed Project does not appear to comply with these standards.

First, Paraiso Springs Road is a dead end road that terminates at the proposed Project location. Both the County and State standards limit dead end roads to a cumulative length not to exceed 5,280 feet. (Monterey County Code § 18.56.060(11); Cal. Code. Regs., tit. 14, § 1273.09.) The Paraiso Springs Road that would serve as the sole ingress and egress for the Project is 1.9 miles long or 10,032 feet according to Google maps, nearly double the allowable limit. The FEIR and DEIR do not address the Project's failure to comply with the length limitation for dead end roads in State Responsibility Areas.

Second, the width of Paraiso Springs Road will not comply with the local or State standards. State standards generally require a minimum of two 10-foot traffic lanes. (Cal. Code Regs., tit. 14, § 1273.01.)[8] The Project proposes to widen "*the majority of* Paraiso Springs Road to either 18 or 20 feet wide." (DEIR 3-340.) However, the FEIR explains that the road will only be widened "where feasible". (FEIR 2-10). The Project proponent should commit to widening not just a majority of the road, but the entirety of the road, to a distance that complies with the applicable standards.

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[8] The County requires that all roads have a minimum of two 9-foot traffic lanes. (Monterey County Code, § 18.56.060(3).) Therefore, the State's more stringent requirement would control.

IV. THE PROJECT SHOULD PROVIDE PROXIMAL ACCESS TO A FIRE STATION.

Despite a request from the local fire district, the Project proponent has declined to construct a small fire station onsite, concluding that it would be "incompatible with resort operations." (DEIR 3-307.) The closest fire station is nine miles away, which the program Google Maps reports is an 18-minute drive. The DEIR claims the fire station is within the 15 minutes recommended by the applicable Monterey County General Plan. (DEIR 3-307.) Public comments on the DEIR noted the Project site is not within a 15-minute response time from the Soledad fire station. (See, e.g., Letter 7, Comment 74 starting on FEIR 2-33 and Letter 8, Comment 5 starting on FEIR 2-61). Rather than provide factual support for the DEIR's claim that the fire station is within 15 minutes from the Project site or revise the Project so that it complies with the Monterey County General Plan recommendation, the FEIR simply restates the DEIR's conclusion that "the project would not warrant construction of new or expanded facilities in order to maintain … response times…." (FEIR 2-11). The FEIR should be revised to accurately reflect the distance of the nearest fire station to the Project site and should require compliance with the policy prescribed by the General Plan—preferably with construction of a fire station onsite as requested by the local fire district.

We appreciate your consideration of our comments and respectfully request that you defer certification of the FEIR and approval of the Project until you more fully address the risks of wildfire associated with the Project. If you have any questions or would like to discuss our comments, please feel free to contact us.

Sincerely,

NICOLE U. RINKE
Deputy Attorney General
HEATHER C. LESLIE
Deputy Attorney General

For XAVIER BECERRA
Attorney General

SA2019300293

EXHIBIT 44

Texas Wildfire Mitigation Project

HOW DO POWER LINES CAUSE WILDFIRES?

Power lines have caused more than 4,000 wildfires in Texas in the past three and a half years. Power lines can ignite wildfires through a variety of mechanisms.

Downed lines– Just like homes and office buildings, power distribution systems contain protective devices (e.g. fuses, circuit breakers) that detect short-circuit fault conditions and operate to limit damage to the system. These devices are intended to clear faults quickly, but in as many as 30% of cases in which a single energized line conductor breaks and falls to earth, surface contact resistance causes the resulting fault to draw too little electrical current to blow a fuse or trip a circuit breaker. Such a condition is known as a high-impedance fault, sometimes abbreviated as a HiZ (pronounced "high zee") fault. A line with a HiZ fault can remain energized on or near the earth for an arbitrarily long period of time, often multiple tens of minutes, during which it produces high-energy, high-temperature arcing. The image below shows a downed-conductor, HiZ arcing fault on a 7,200-volt power line. It is common for a downed line conductor to remain energized and arcing until a customer calls the utility company to report a lights-out condition, which may occur only after several tens of minutes. An arcing downed conductor readily ignites proximate vegetation and other materials, particularly if it occurs in an area of elevated fire risk. Even if conventional protection finally operates, the period of arcing already may have started a fire.

Texas Wildfire Mitigation Project

Reducing the risk of wildfires caused by power lines

Vegetation Contact – Trees and other vegetation intruding into power lines can cause fires in multiple ways. A tree falling across a line can tear the line down and result in a downed line. A branch spanning two line conductors for a sufficient period of time may ignite the branch and also may produce high-energy, high-temperature Jacob's Ladder arcs multiple feet in length. If the branch remains in contact and arcing, it can cause progressive damage that eventually breaks the line. The picture below shows a tree branch that contacted a line intermittently, over a 24-hour period, and eventually burned the line down.

Conductor Slap – Power lines are designed with sufficient clearance between conductors to keep them from contacting each other under most operating conditions. Certain unusual circumstances, however, can cause line conductors to slap together. Conductor slap creates high-energy arcing and ejects hot metal particles capable of igniting ground-level combustibles. In addition, where line conductors are made of aluminum, the ejected particles may burn as they fall.

In conjunction with line monitoring efforts at multiple utility companies, TEES has documented multiple instances of a phenomenon known as fault-induced conductor slap (FICS). FICS occurs when a fault at this phenomenon. By contrast, TEES technology detects and reports FICS, enabling corrective action. Correct diagnosis is important because field research shows that a line span that experiences one episode of FICS likely will experience additional episodes in the future, unless the condition is identified and corrected. Detecting an episode of FICS, perhaps during a period of modest fire risk, enables corrective action that eliminates subsequent episodes, which otherwise might have occurred at times of high risk.

Repetitive Faults – Each power line fault creates some risk of fire. Most faults are isolated events (e.g. animal contact, etc.) that do not repeat. Some faults, however, will occur multiple times unless a utility takes corrective action. Repetitive faults can be caused by vegetation, conductor slap, or equipment that is in the process of failing, such as a cracked insulator. TEES intelligent monitoring detects repetitive faults and notifies utilities, providing them with information to aid in locating the underlying problem.

Apparatus Failures – Many power line components (e.g., switches, insulators, transformers, …) provide trouble-free service for decades. A typical circuit may have hundreds or even thousands of components, making it impractical to inspect or test all components on a frequent basis. Components eventually fail. As they do, they often go through an pre-failure period, during which they continue to serve load until progressive deterioration causes complete failure. Pre-failures often involve arcing and sparking at levels too small to be detected by conventional technologies. Over time the arcing and sparking may increase in intensity and, under the right conditions, can ignite proximate combustibles. More commonly these pre-failures cause progressive damage that eventually evolves into high-energy arcing or even burns conductors in two, resulting an energized wire on the ground, which provides a ready source of ignition, as discussed above.

EXHIBIT 45

CAL FIRE NEWS RELEASE

California Department of Forestry and Fire Protection

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RELEASE DATE: June 8, 2018

CAL FIRE Investigators Determine Causes of 12 Wildfires in Mendocino, Humboldt, Butte, Sonoma, Lake, and Napa Counties

Sacramento – After extensive and thorough investigations, CAL FIRE investigators have determined that 12 Northern California wildfires in the October 2017 Fire Siege were caused by electric power and distribution lines, conductors and the failure of power poles.

The October 2017 Fire Siege involved more than 170 fires and burned at least 245,000 acres in Northern California. About 11,000 firefighters from 17 states and Australia helped battle the blazes.

CAL FIRE investigators were dispatched to the fires last year and immediately began working to determine their origin and cause. CAL FIRE investigators continue to investigate the remaining 2017 fires, both in October and December, and will release additional reports as they are completed. The cause of four Northern California fires were released on May 25.

Below is a summary of the findings from the 12 completed investigations:

The **Redwood Fire**, in Mendocino County, started the evening of Oct. 8 and burned a total of 36,523 acres, destroying 543 structures. There were nine civilian fatalities and no injuries to firefighters. CAL FIRE has determined the fire started in two locations and was caused by tree or parts of trees falling onto PG&E power lines.

The **Sulphur Fire**, in Lake County, started the evening of Oct. 8 and burned a total of 2,207 acres, destroying 162 structures. There were no injuries. CAL FIRE investigators determined the fire was caused by the failure of a PG&E owned power pole, resulting in the power lines and equipment coming in contact with the ground.

The **Cherokee Fire**, in Butte County, started the evening of Oct. 8 and burned a total of 8,417 acres, destroying 6 structures. There were no injuries. CAL FIRE investigators have determined the cause of the fire was a result of tree limbs coming into contact with PG&E power lines.

The **37 Fire**, in Sonoma County, started the evening of Oct. 9 and burned a total of 1,660 acres, destroying 3 structures. There were no injuries. CAL FIRE investigators have determined the cause of the fire was electrical and was associated with the PG&E distribution lines in the area.

more

The **Blue Fire**, in Humboldt County, started the afternoon of Oct. 8 and burned a total of 20 acres. There were no injuries. CAL FIRE investigators have determined a PG&E power line conductor separated from a connector, causing the conductor to fall to the ground, starting the fire.

The Norrbom, Adobe, Partrick, Pythian and Nuns fires were part of a series of fires that merged in Sonoma and Napa counties. These fires started in the late-night hours of Oct. 8 and burned a combined total of 56,556 acres, destroying 1355 structures. There were three civilian fatalities.

> CAL FIRE investigators determined the **Norrbom Fire** was caused by a tree falling and coming in contact with PG&E power lines.
>
> CAL FIRE investigators determined the **Adobe Fire** was caused by a eucalyptus tree falling into a PG&E powerline.
>
> CAL FIRE investigators determined the **Partrick Fire** was caused by an oak tree falling into PG&E powerlines.
>
> CAL FIRE investigators determined the **Pythian Fire** was caused by a downed powerline after PG&E attempted to reenergize the line
>
> CAL FIRE investigators determined the **Nuns Fire** was caused by a broken top of a tree coming in contact with a power line.

The **Pocket Fire**, in Sonoma County, started the early morning hours of Oct. 9 and burned a total of 17,357 acres, destroying 6 structures. There were no injuries. CAL FIRE has determined the fire was caused by the top of an oak tree breaking and coming into contact with PG&E power lines.

The **Atlas Fire,** in Napa County, started the evening of Oct. 8 and burned a total of 51,624 acres, destroying 783 structures. There were six civilian fatalities. CAL FIRE investigators determined the fire started in two locations. At one location, it was determined a large limb broke from a tree and came into contact with a PG&E power line. At the second location, investigators determined a tree fell into the same line.

CAL FIRE's investigations have been referred to the appropriate county District Attorney's offices for review in eight of the 12 fires – Sulphur, Blue, Norrbom, Partrick, Pythian, Adobe, Pocket and Atlas – due to evidence of alleged violations of state law.

Californians are encouraged to remain vigilant and prepared for wildfire. For more information on how to be prepared, visit www.readyforwildfire.org or www.fire.ca.gov

# # #

EXHIBIT 46

Roads and Wildfires

Ignition Point for the Command 24 Fire of July 2000, near Hanford, Washington. Looking south along Highway 24.

Pacific Biodiversity Institute

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Roads and Wildfires

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May 2007

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Roads closed by wildfire in Southern California.

Executive Summary

This report explores that relationship between roads and wildfires. This relationship is not as simple as it first appears. An adequate understanding of this relationship is critical to informed decisions on how to manage wildfires in the western United States. Some have argued that building more roads across public land would give firefighters critical access needed to quickly control wildfires before communities and natural resources were threatened. “Roads are not only crucial in fighting forest fires but also in promoting forest health,” said Matt Raymond, chief of staff to US Congressman Rick Hill, Montana (Environmental News Network, 2000). But we have found that the facts do not line up behind the rhetoric.

While it seems reasonable to assume that building new roads would reduce wildfire risk, we discovered ample evidence to the contrary. This report examines the relationship between roads and wildfires. We examine the role that roads play in fire ignitions, the role that roads play in providing access and the role that roads play as fire breaks. We use Geographic Information System (GIS) analysis to examine the spatial relationship between roads and wildfires across the conterminous US and in individual major fires. To conduct this analysis we overlaid wildfire and road databases that have been compiled by federal and state agencies.

Our examination of the spatial relationship of roads to wildfires we found that 88% of all wildfires nationwide are caused by humans. Of these human-caused wildfires, 95% occurred within ½ mile of a road. Over 90% of all wildfires from all causes occurred within ½ mile of a road. We found that there was an extremely significant relationship

between fire occurrence and distance from the nearest road. Areas that are very close to roads have many times more wildfire occurrences than areas distant from roads. We discovered that less than 3% of all wildfires start in wilderness or backcountry areas more than 2 kilometers (about 1.24 miles) from a road.

We examined whether roads enable wildfire ignitions, by providing access to humans who start the vast majority of wildfires. Our analysis revealed that human-caused wildfires occur much more commonly next to roads than would be predicted by random occurrence across the landscape. Nationwide, over 53% more wildfires occur in the zone closest to roads (the first 200-meters) than would be predicted by a random distribution. In road distance zones that are further from roads, there are many fewer wildfire occurrences than would be predicted by random occurrence. All these results are highly statistically significant. Our analysis provides extremely strong evidence that road access is a significant contributing factor in the probability of occurrence of wildfires.

We also examined whether these results hold up for individual western States. In Washington State the relationship between human-caused wildfire occurrence and distance from road was actually stronger than in the US in general. Sixty-nine percent of the human-caused wildfires were within 200-meters of a road and over 96% were within ½ mile of a road. In Arizona over twice as many wildfires occur in the zone closest to roads (the first 200-meters) than would be predicted by a random distribution.

From this spatial analysis, we conclude that the existing high density of roads throughout most of the conterminous US and the high rates of human-caused wildfire ignition enabled by roads creates a situation where nearly all wildfires originate near roads.

We also tackle some fundamental questions regarding the effectiveness of building new roads to control fires. Examination of how actual wildfires have ignited and progressed in relation to roads reveals that roads often do not serve as effective firebreaks. The access provided by roads often appears to have an insignificant effect on the ability of firefighters to control large fires. Current road systems increase risk of human-caused fire. In contrast, areas that are distant from roads have significantly less human-ignited fires.

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Introduction

It has been argued that building more roads across public land would give firefighters critical access needed to quickly control wildfires before communities and natural resources were threatened. During the 2000 wildfire season, Montana governor Mark Racicot and US Congressman Rick Hill denounced the proposal by President Bill Clinton and the US Forest Service to ban road building within over 58 million acres of national forest land. "Roads are not only crucial in fighting forest fires but also in promoting forest health," said Matt Raymond, chief of staff to Hill (Environmental News Network, 2000). In January 2001, a Roadless Area Conservation Rule enacted by the Forest Service to protect undeveloped National Forest land from logging and road building led to increased debate. A July 16, 2002 letter from US Congressman Scott McInnis opposing legislation to codify the Roadless Rule declared that if the rule were codified, "Hundreds of millions of adjacent areas of valuable timber, homes, and other infrastructure assets would be placed at peril."

While it seems reasonable to assume that building new roads would reduce wildfire risk, we discovered ample evidence to the contrary. This report examines the relationship between roads and wildfires and the role that roads play in fire ignitions. We use Geographic Information System (GIS) analysis to examine the spatial relationship between roads and wildfires more closely. We also tackle some fundamental questions regarding the effectiveness of building new roads to control fires. We examine how several major wildfires were ignited and how they progressed in relation to roads during the last decade. We discuss the role that roads play in the ignition of these fires and whether roads served as effective firebreaks. We also discuss whether the access provided by roads had a significant effect on the ability of firefighters to control these large fires.

How do most fires start?

According to the National Interagency Fire Center (www.nifc.gov), during the 10-year period between 1988 and 1997, over 88% of all wildfires were human-caused. The human causes of wildfires include debris burning, arson, careless smoking, equipment use, ignition related to vehicle collisions or malfunctions, ignition from electrical transmission lines, ignition related to railroads, children's activities, etc.

We also analyzed of the National Fire Occurrence database of 976,032 wildfires occurring in the conterminous US during and 11-year period from 1986 to 1996. These results are similar, but break down the cause of the fires into more specific causes (Table 1). Once again, the vast majority of fires are of human origin and less than 15% are from lightning.

Table 1. Causes of 976,032 wildfires occurring in the US during an 11-year period from 1986 and 1996.

Cause	Percent of All Fires
Debris burning (logging slash, fields, trash, etc.)	23.9%
Incendiary (Arson)	18.4%
Lightning	14.7%
Miscellaneous human activities	11.4%
Equipment use	7.8%
Unknown	7.6%
Smoking	5.3%
Children	5.3%
Railroad	2.9%
Campfires	2.5%

Prior studies have indicated that the majority of these human-caused fires start along road systems and spread through roaded landscapes. In an analysis of 20th century fire, the Sierra Nevada Ecosystem Project (Busse and McKelvey 1996) reported that, "the location of multiple-burn sites indicated that they were associated with busy roads." This study suggests that most human-caused wildfires start in or right next to vehicles, making roads a primary contributing cause.

Many of the large fires that dominated the news in the last three years have been human-caused fires that started next to roads. Examples of major fires that were started next to roads include the 2003 Southern California fires (over 500,000 acres), the 2002 Rodeo and Chediski fires in Arizona (468,000 acres), the Hayman fire in Colorado (138,114 acres). These and other fires are discussed in more detail later in this paper.

The spatial relationship between roads and wildfires

Methods

We examined the spatial relationship between wildfires and roads by mapping wildfire fire occurrence locations (both natural and human-caused) and their proximity to roads across the conterminous United States. For this analysis, we used wildfire occurrence information developed by federal, state and local agencies. This data was compiled, reviewed, and corrected by a US Forest Service research team (Schmidt et al 2002). The fire occurrence location data covers all fires that the USFS research team was able to obtain that had reasonably accurate locations during the period from 1986 to 1996. The fire occurrence data contains information about the cause of each fire, its location and other useful information.

We gathered road data from federal and state agencies to create a comprehensive road database for the United States (Figure 1). This road GIS database contains nearly all major and minor roads that are passable by 2-WD vehicles. Some minor roads (especially on private land) and many 4-WD tracks are not included in this GIS road layer.

How far is the nearest road?

From the road location data, we generated a proximity to road GIS layer that records the proximity to the nearest road in 200-meter increments. Nearly 40% of the land area in the conterminous United States is currently within 200-meters (about 1/8 of a mile) from a road (Figure 2). Nearly 84% of the land area in the conterminous US is within 800-meters (about ½ mile) of a road. Only about 4% of the conterminous US is over 2000-meters (1.24 miles) from a road. It is obvious from the map of roads of the US and this proximity analysis that we have built roads to nearly every location in the lower 48 states. Many minor roads and 4-WD tracks and other vehicle accessible areas (agricultural fields, parking lots, etc.) are not included in this analysis. It is literally possible to drive a vehicle very close to nearly all locations in this country (except for Alaska).

The fact that the vast majority of the conterminous US is in close proximity to a road is highly relevant to the wildfire issue. Fire fighters usually have very good road access to wildfire ignition points. There are also abundant roads throughout the landscape to use as firebreaks or staging locations for firefighting efforts. But despite these facts, many fires spread rapidly and quickly overwhelm suppression efforts. We will see later in this paper many examples where the easy access provided by roads and the ample opportunity to use roads for firebreaks did not prevent many of the largest and most disastrous fires that have swept across parts of the western US in the last decade.

Figure 1: Map showing all roads in the United States

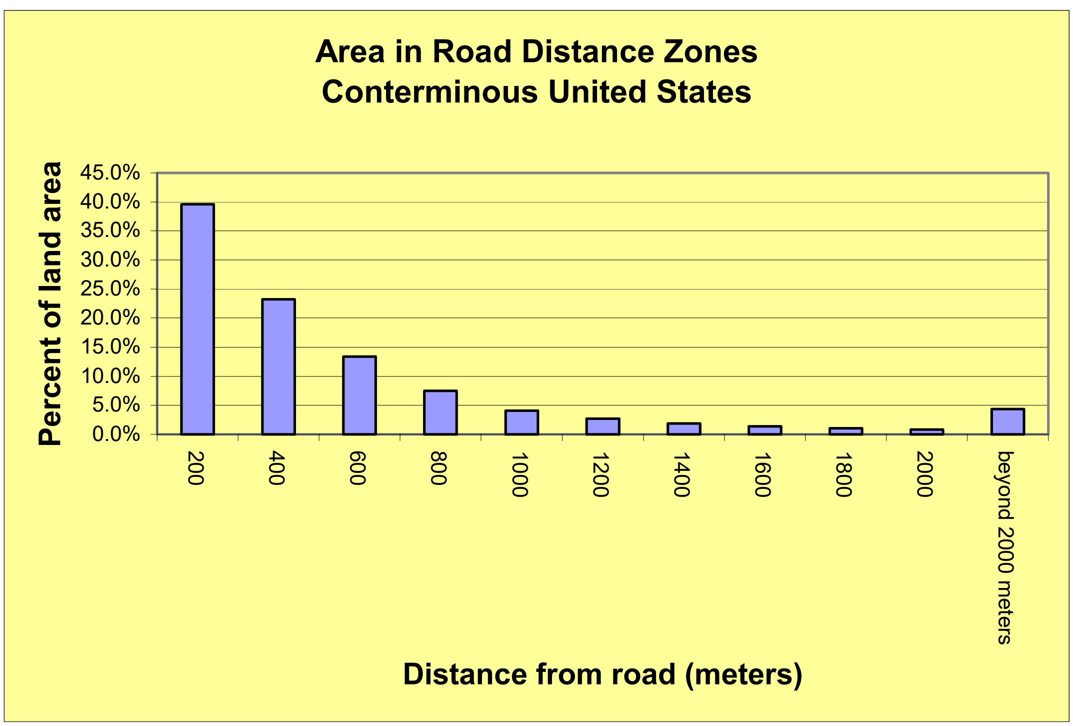

Figure 2. Area in the conterminous United States in progressive distance zones from the nearest road.

How are wildfire occurrences distributed in relationship to roads?

To determine the spatial relationship between wildfire occurrences and roads we overlaid fire occurrence data for the conterminous US on the road proximity data. Through this process, we determined the proximity of each fire occurrence to the nearest road. The results of this overlay were then analyzed to determine the road distance distribution for all the fires segregated by cause of fire.

The results of this analysis are quite startling. 94.9% of human-caused wildfires in the conterminous US (lower 48 states) occur within 800-meters (about ½ mile) of the nearest road. 60.7% of human-caused wildfires occur within the first 200-meters (about 1/8th mile) from the nearest road (Figure 3). Because the vast majority of wildfires are human-caused, the statistics for all fires (including those caused by lightning and from unknown causes) is similar. 90.1% of all wildfires (from all causes) in the conterminous United States occur within 800-meters of a road and 55.3% occur within 200-meters of the nearest road.

A statistical analysis of these results indicates that they are highly significant. Using linear regression analysis, we determined that there is a highly significant relationship between the number of fires and distance from road. They are strongly negatively correlated and 99.17% of the variation in the number of fires can be explained by distance from road (r-squared value of .9917, F 953.77, p-value <.0001). This means that there is an extremely high likelihood that human-caused fires will occur close to roads.

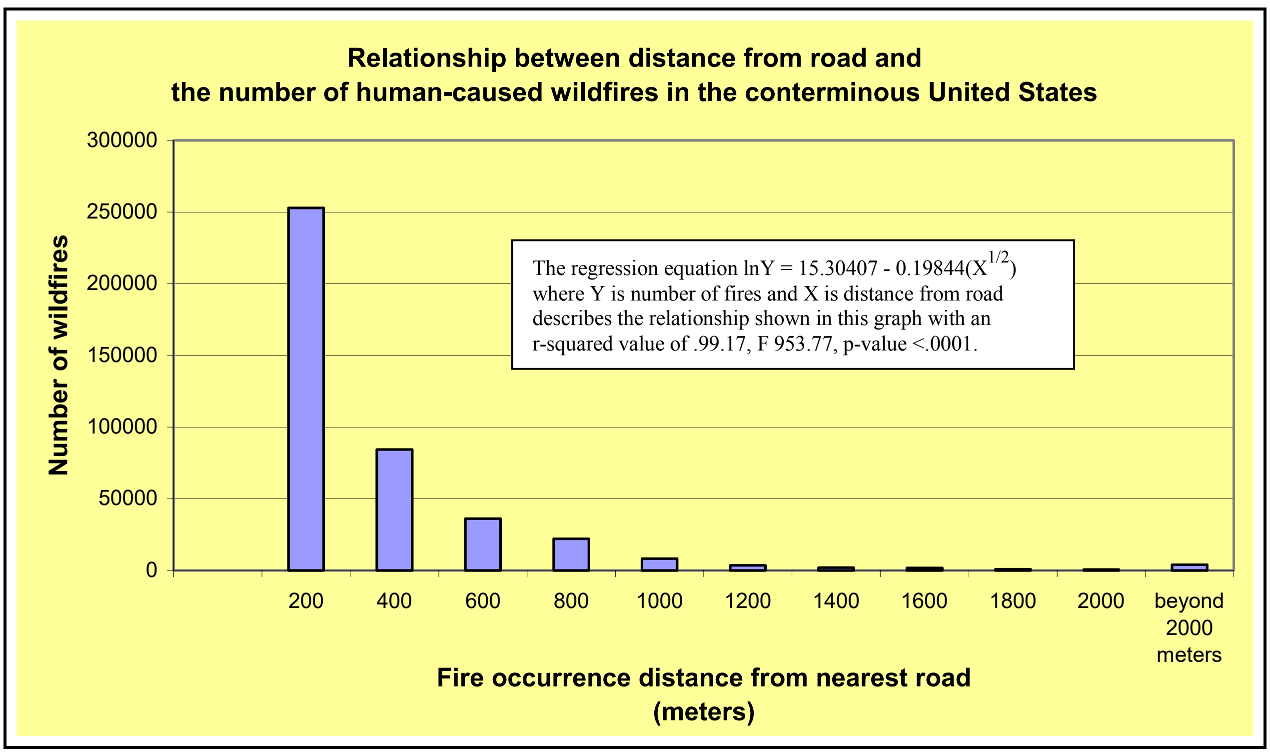

Figure 3: The number of human-caused wildfire occurrences in the conterminous United States vs. distances from nearest road.

Do Roads Enable Wildfire Ignitions?

To determine whether roads enable human-caused wildfire ignitions, therefore promoting higher levels of fire activity than would be expected if human-caused fire activity was randomly distributed across the landscape we compared the observed wildfire occurrence road proximity to what would be expected from a random distribution of wildfires (where the expected number of wildfire occurrences in a road proximity zone would be proportional to the overall area of that zone in relationship to the area of the conterminous US).

The results of this analysis clearly show that human-caused wildfires occur much more commonly next to roads than would be predicted by random occurrence across the landscape (Table 2). Over 53% more wildfires start in the zone closest to roads (the first 200-meters) than would be predicted by a random distribution. In road distance zones that are further from roads, there are many fewer wildfire occurrences than would be predicted by random occurrence. In areas over 1600-meters from a road the occurrence of human caused fires is 78% less than would be predicted by random occurrence. A statistical analysis of these results (Appendix 2) indicates that our results are highly significant (chi-squared value is 64730 with 10 degrees of freedom - extremely significant with $p<.0001$). This analysis provides extremely strong evidence that road access is a significant contributing factor in the probability of occurrence of human-caused wildfires.

Table 2. Occurrence of Human Caused Wildfires in the Conterminous US in Relationship to Distance from Road.

Distance from road (200 meter wide zones)	Percent of land area	Occurrence of human-caused fires	Increase (or decrease) in occurrence over that predicted by random fire occurrence proportional to the area in the road distance zone
0 - 200	39.6%	60.7%	53.3%
201 - 400	23.2%	20.3%	-12.8%
401 - 600	13.4%	8.7%	-35.5%
601 - 800	7.5%	5.3%	-29.4%
801 - 1000	4.1%	2.0%	-51.3%
1001 - 1200	2.7%	0.8%	-68.7%
1201 - 1400	1.9%	0.5%	-74.1%
1401 - 1600	1.4%	0.4%	-70.6%
1601 - 1800	1.1%	0.2%	-78.6%
1801 - 2000	0.8%	0.2%	-78.2%
beyond 2000 meters	4.3%	1.0%	-77.7%

Do These Results Hold Up In Western States?

We tested this data to see whether the strong relationship between wildfire occurrence and distance to the nearest road held up in western states where there are fewer roads and a significant amount of unroaded area. We selected two states (Arizona and Washington) that contained relatively large amounts of wilderness and sparsely roaded land for this test.

In Washington State the relationship between human-caused wildfire occurrence and distance from road was actually stronger than in the US in general (Figure 4). Sixty-nine percent of the human-caused wildfires were within 200-meters of a road and 96.2% were within 800-meters of a road. For all wildfires (including lightning–caused fires), 62.4% of the wildfire occurrences were within 200-meters of a road and 91.4% were within 800-meters of a road. This is very significant, since Washington State contains over 16.8 million acres (27.1% of the state) of unroaded land (Pacific Biodiversity Institute, unpublished data).

In Washington State, we examined the occurrence of human-caused fires compare to that expected by random occurrence proportional to the area in road distance zones. This analysis clearly shows that the same relationship that was described in our nation-wide study applies to this northwestern state. Human-caused wildfires occur much more commonly next to roads than would be predicted by random occurrence across the landscape (Table 3). Over 45% more wildfires occur in the zone closest to roads (the first 200-meters) than would be predicted by a random distribution. In road distance zones that are greater than 200-meters from roads, there are many fewer wildfire occurrences than would be predicted by random occurrence. A statistical analysis of these results (Appendix 3) indicates that our results are highly significant (chi-squared value is 3682 with 10 degrees of freedom - extremely significant with p<.0001). This analysis provides extremely strong evidence that road access is a significant contributing factor in the probability of occurrence of human-caused wildfires.

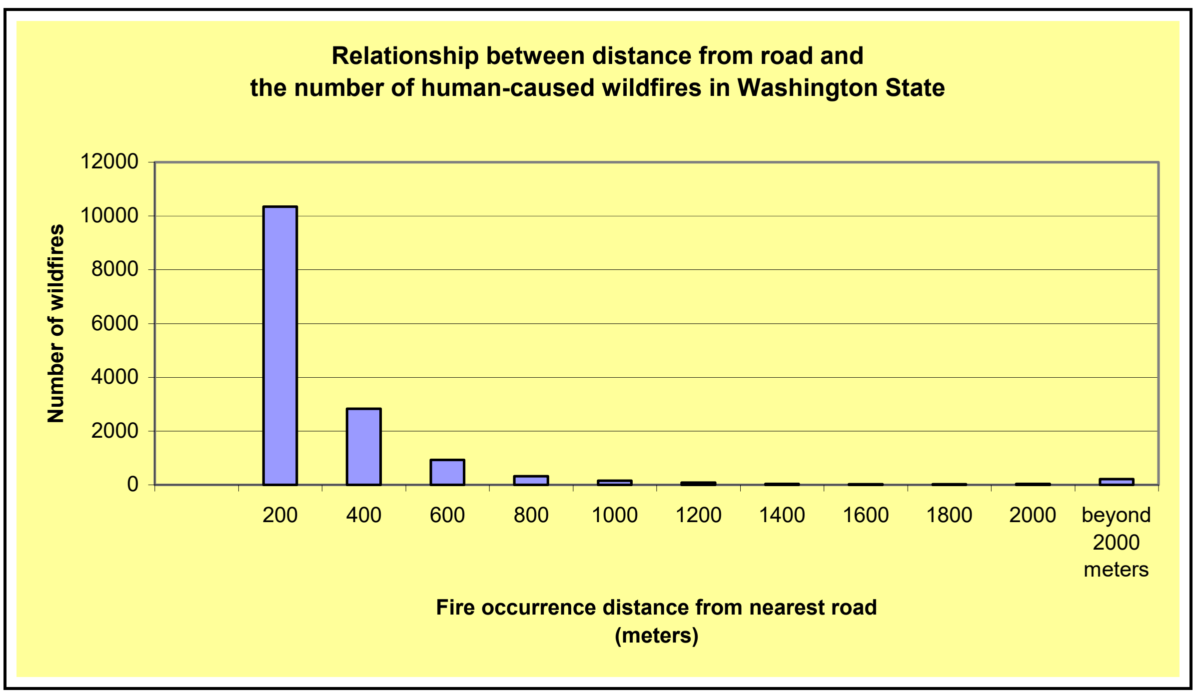

Figure 4: The number of human-caused fire occurrences in Washington State vs. distances from nearest road.

Table 3. Occurrence of Human Caused Wildfires in Washington in Relationship to Distance

Distance from road (200 meter wide zones)	Percent of land area	Occurrence of human-caused wildfires	Increase (or decrease) in occurrence over that predicted by random fire occurrence proportional to the area in the road distance zone
0 - 200	47.4%	69.0%	45.7%
201 - 400	19.4%	18.9%	-2.6%
401 - 600	9.8%	6.2%	-36.9%
601 - 800	5.6%	2.1%	-62.0%
801 - 1000	3.2%	1.0%	-67.2%
1001 - 1200	2.0%	0.5%	-73.9%
1201 - 1400	1.3%	0.3%	-80.0%
1401 - 1600	0.9%	0.2%	-79.5%
1601 - 1800	0.7%	0.1%	-79.4%
1801 - 2000	0.6%	0.2%	-63.7%
beyond 2000 meters	9.1%	1.4%	-84.3%

In Arizona nearly 54% of all human-caused wildfire occurrences were within 200-meters of a road and over 90% of the human-caused wildfire occurrences were within 800-meters of a road (Figure 5). Because lightning-caused wildfires are much more frequent in Arizona 46.8% of wildfires from all causes occurred within 200-meters of a road. But 83.8% of all fires were still within 800-meters of a road. Arizona has fewer roads and lightning-caused fires are more frequent than in Washington State.

We examined the occurrence of human-caused fires in Arizona compare to that expected by random occurrence proportional to the area in road distance zones. This analysis clearly shows that the same relationship that was described in our nation-wide study also applies to this southwestern state. Human-caused wildfires occur much more commonly next to roads than would be predicted by random occurrence across the landscape (Table 4). Over 100% more wildfires occur in the zone closest to roads (the first 200-meters) than would be predicted by a random distribution. In road distance zones that are greater than 400-meters from roads, there are many fewer wildfire occurrences than would be predicted by random occurrence. A statistical analysis of these results (Appendix 4) indicates that our results are highly significant (chi-squared value is 11225 with 10 degrees of freedom - extremely significant with $p<.0001$). This analysis provides extremely strong evidence that road access is a significant contributing factor in the probability of occurrence of human-caused wildfires.

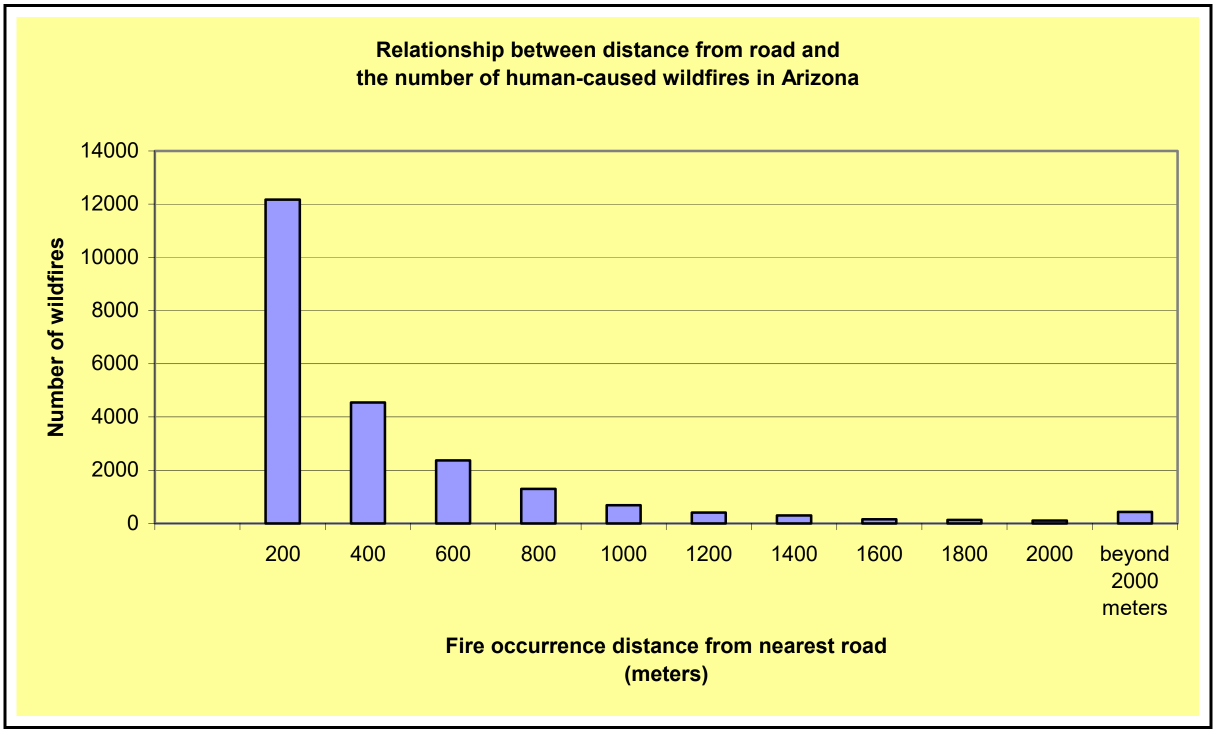

Figure 5: The number of human-caused fire occurrences in Arizona vs. distances from nearest road.

Table 4. Occurrence of Human Caused Wildfires in Arizona in Relationship to Distance from Road.

Distance from road (200 meter wide zones)	Percent of land area	Occurrence of human-caused wildfires	Increase (or decrease) in occurrence over that predicted by random fire occurrence proportional to the area in the road distance zone
0 - 200	26.9%	53.8%	100.2%
201 - 400	16.2%	20.1%	24.3%
401 - 600	11.3%	10.5%	-7.2%
601 - 800	8.4%	5.7%	-31.4%
801 - 1000	6.4%	3.1%	-52.1%
1001 - 1200	5.0%	1.8%	-64.4%
1201 - 1400	4.0%	1.3%	-66.6%
1401 - 1600	3.2%	0.7%	-78.7%
1601 - 1800	2.6%	0.6%	-78.3%
1801 - 2000	2.2%	0.5%	-79.0%
beyond 2000 meters	13.8%	1.9%	-86.0%

Wildfires in Wilderness or Backcountry Areas

It should be noted that nationwide less than 3% of all wildfires start in wilderness or backcountry areas more than 2 kilometers (about 1.24 miles) from a road. Human-caused fires are less than 77% as likely to occur in these wilderness and backcountry areas than would be predicted by random occurrence. This trend is even stronger in western states like Washington and Arizona where wildfires are 84 and 86% (respectively) less likely to occur in the backcountry than would be predicted by random occurrence. In these states, despite the fact that a significant portion of each state is wilderness and unroaded land only about 4% of all wildfire occurrences (including lightning) are over 2 kilometers from a road.

From this analysis, we can conclude that the existing high density of roads throughout most of the conterminous US and the high rates of human-caused wildfire ignition enabled by roads creates a situation where nearly all wildfires originate near roads. Very few wildfires originate in backcountry areas. The argument that we need to build more roads to be able to better suppress wildfires does not stand up to the results presented in this analysis.

In order to further evaluate the policy of road building as a fire prevention strategy, it is necessary to look at the record from past fires. The following section of this report analyzes the effect that road systems have had on the ignition and behavior of some of the prominent wildfires in the last decade. So what is the track record of the existing dense road network in preventing and controlling wildfire?

Examples From Recent Wildfires

To better assess the relationship between roads and wildfires, we examine some of the largest and most destructive wildfires that have occurred in the last decade. The first group of wildfires that we examine includes large human-caused wildfires or fire complexes that start near roads and then spread rapidly across densely roaded landscapes. Next, we examine a set of wildfires fires that were caused by lightning, but spread rapidly through densely roaded landscapes and had good road access to the ignition location. The last set of fires that we examine are human-caused fires that start near or on a road and then spread into wilderness, roadless areas, or sparsely roaded landscapes.

Examples of large human-caused fires that started near roads and then spread rapidly across dense road networks

Southern California Fires, October 2003

A series of 15 wildfires swept across southern California in late October and early November 2003. Humans started all of these fires and arson is suspected for most of the fires. These fires burned more than 750,000 acres. According to the San Bernardino Fire Information Joint Information Center and the California Department of Forestry and Fire Protection, 3,640 homes, 33 commercial properties, and 1,141 other structures were destroyed by these fires (Figure 6). There were 22 fatalities attributed to this group of fires.

These wildfires burned largely through open terrain covered with brush and grass. Most of the land that burned was not forested. The strong Santa Ana winds that initially drove these fires, caused the fires to spread rapidly across this open terrain.

In many cases, roads proved to be ineffective fire breaks. The fires even swept across six lane freeways and interstate highways in multiple cases (Figures 7-9). Many roads were closed to all traffic due to the fact that they were engulfed by the wildfires.

Most of the fire ignition locations were adjacent to roads. There are over 3100 miles of roads within the perimeters of these fires (Figure 10). The average road density in the fire area is 2.67 miles of road per square mile. There was good road access throughout most of the fire area.

Figure 6. A few of the 3,640 homes that burned in subdivisions with dense road networks during the October 2003 wildfires in southern California.

Figure 7. Spot 5 satellite image illustrating overburn of Interstate 8 by the Cedar Fire, October 2003.

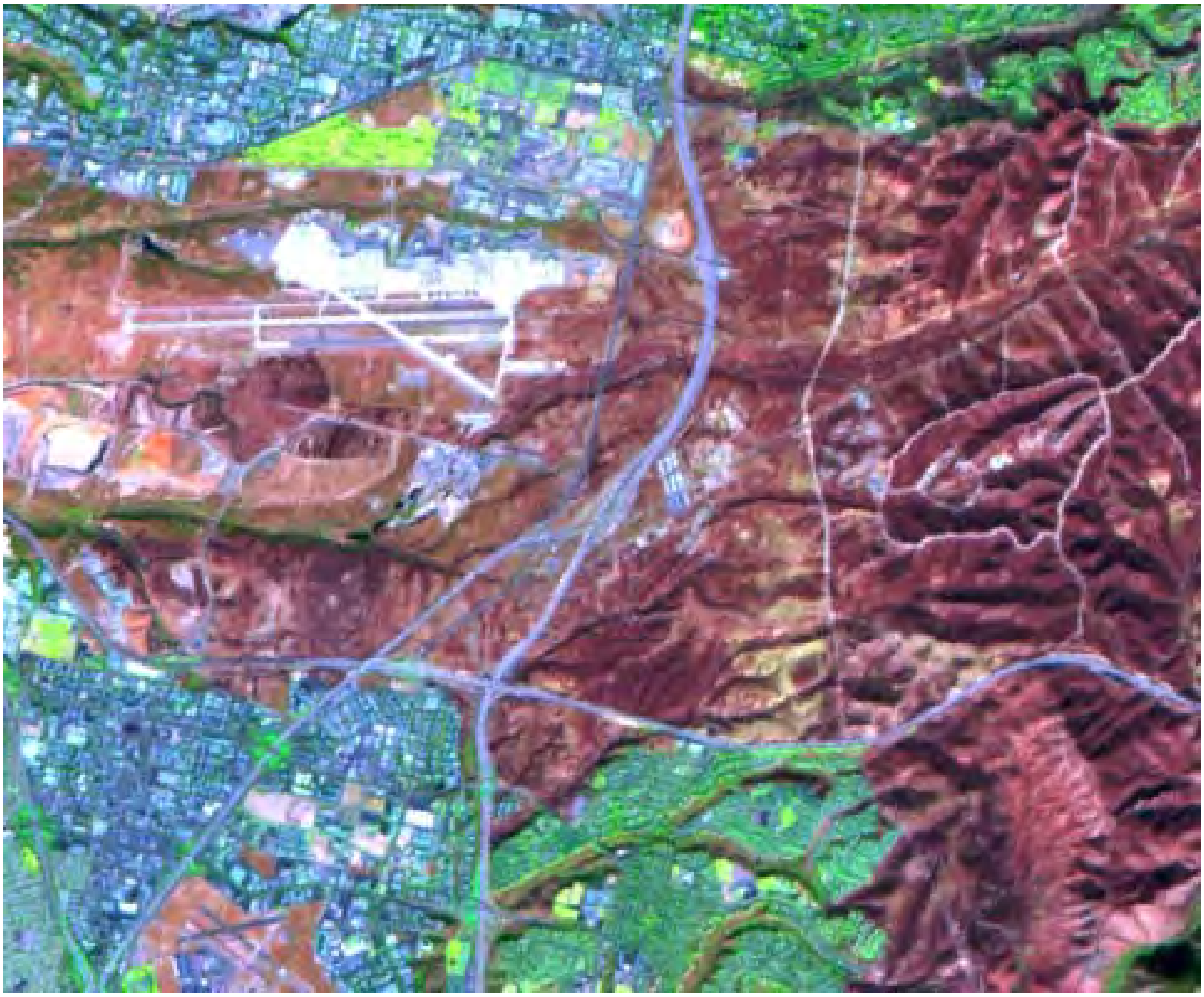

Figure 8. Overburn of freeways and major highways, Cedar Fire, October 2003.


Figure 9. Satellite image of Simi Fire showing overburn of roads and subdivisions, October 2003.

Rodeo-Chediski Fire, Arizona, 2002
The Rodeo and Chediski Fires were human-caused fires that started on roads in the White Mountain Apache Indian Reservation in Arizona on June 18 and June 20, 2002. Together, they burned a total of over 468,000 acres of ponderosa pine forest, pinyon-juniper woodlands, and non-forested land.

Most of the Rodeo-Chediski Fire Complex was densely networked with roads (Figure 10). Over 2,140 miles of logging and multi-use roads existed within the perimeter of the fire (Morrison and Harma 2002). The fire crossed one state highway and several major roads. The density of roads within the fire perimeter is nearly 3 miles of road per square mile. In many places the fire crossed over 25 roads before reaching its final perimeter. Road access to the fire ignition points and ample road access throughout the fire area did not prevent this fire from becoming the largest in recent Arizona history and one of the largest and most destructive fires in our nation's history. This fire eventually destroyed over 500 structures in and near the communities of Aripine, Linden, Overgaard, Pinedale, and Show Low (Figure 11).

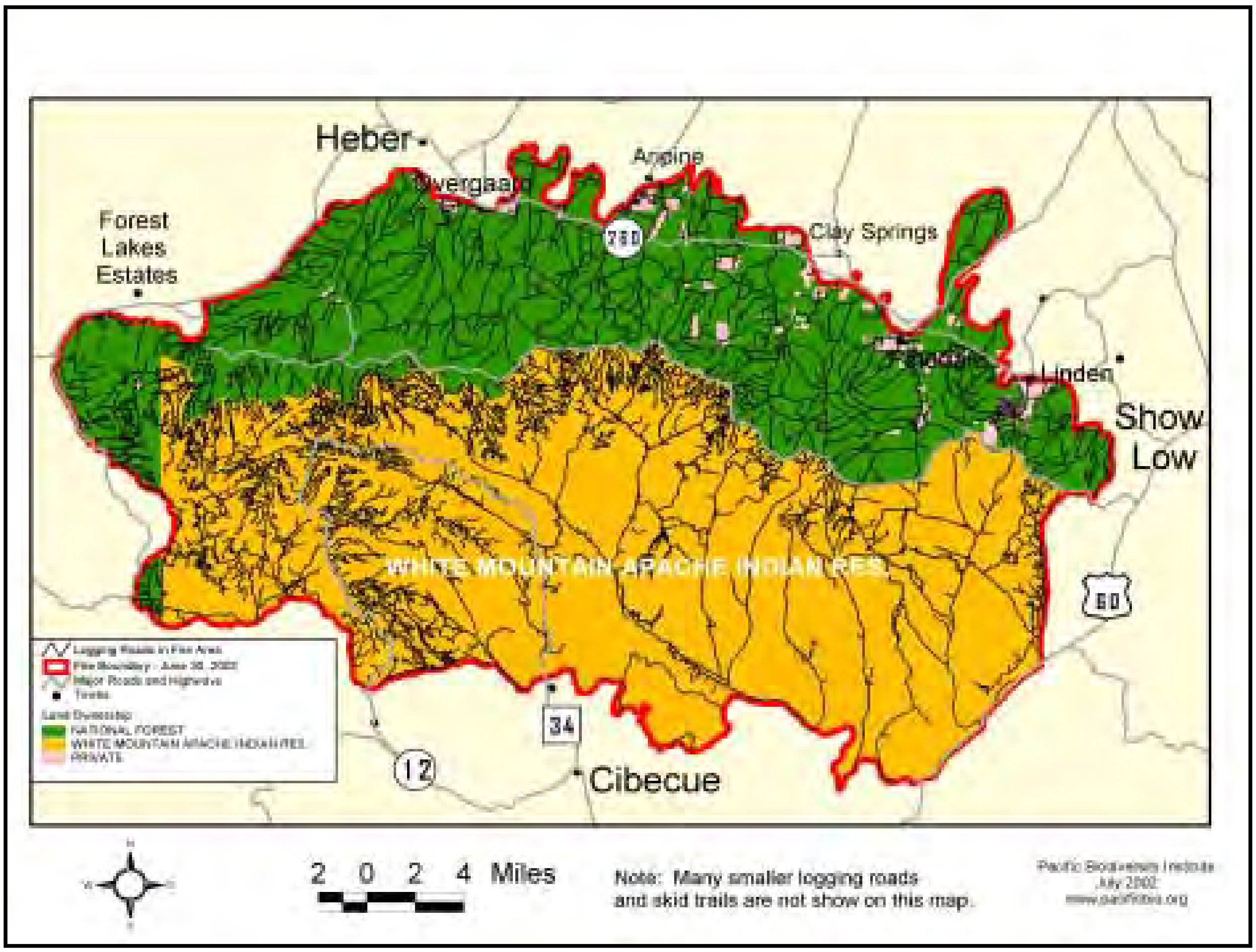

Figure 10. Network of logging roads and other roads in the Rodeo-Chediski Fire Area, Arizona, as of June 30, 2002 (Morrison and Harma 2002).

Figure 11. Remains of three of the homes destroyed in a subdivision with high road density by the Rodeo-Chediski Fire Complex. (Photo Credit: Peter Morrison, August 2002)

Hayman Fire, Colorado, 2002

The Hayman Fire was ignited on June 8, 2002 by a Forest Service employee (convicted of arson) in a campground accessible by road. The fire burned 138,114 acres southwest of Denver, Colorado. Before it was over, the Hayman Fire destroyed 133 homes, 1 commercial building and 466 outbuildings.

The fire was subject to an intensive post-fire study and assessment (Graham 2003). Approximately 426 miles of road were within the fire perimeter including two state highways (Figure 12). The average road density within the burn area was 1.8 miles per square mile. There was ample road access to the fire ignition location and to most parts of the fire area.

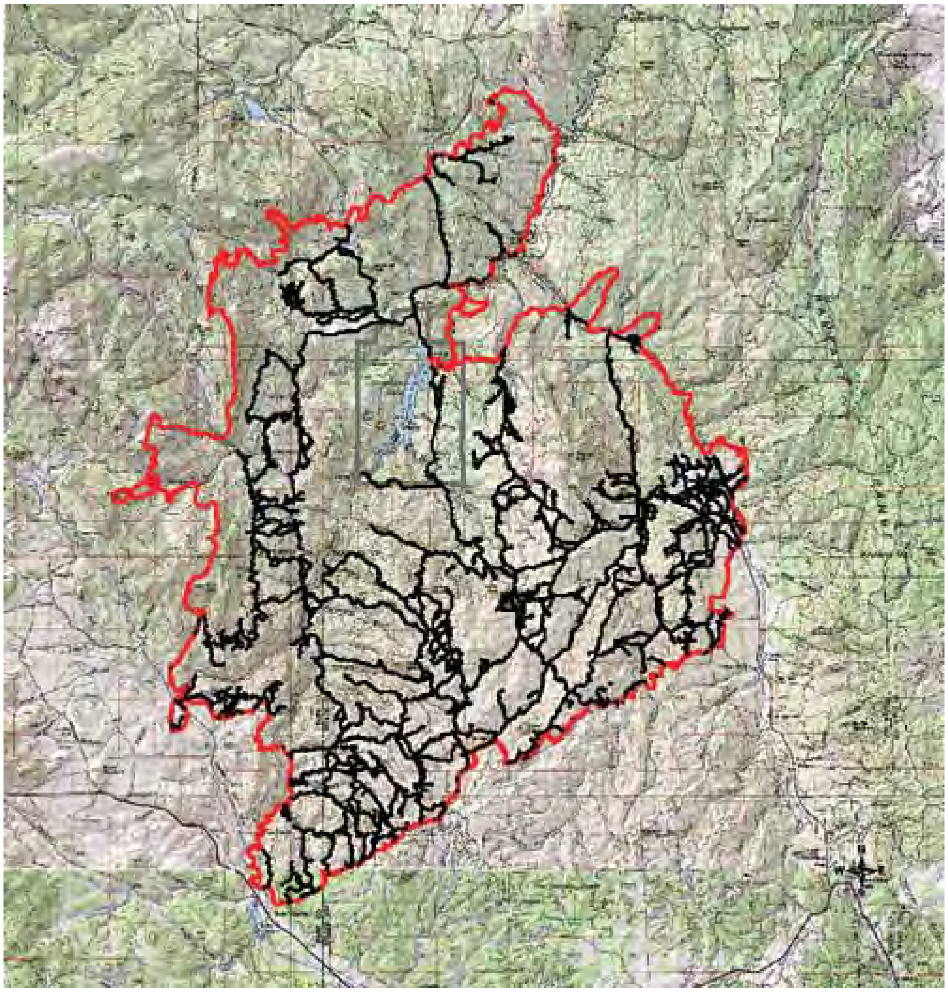

Figure 12. Road network within the Hayman Fire perimeter. Red line is fire perimeter; black lines are roads (McHugh and Finney 2003).

The Jasper Fire, Black Hills National Forest, South Dakota, 2000

The Jasper Fire was one of the large fires that swept through heavily roaded and managed landscape in the year 2000 (Figure 13). This fire was caused by arson along US Highway 16 in an area of very high road density due to logging and thinning activities (Figure 14) (Morrison et al 2000). The fire burned very rapidly in this actively managed forest and in several days burned 83,510 acres. "This has been a very actively managed area," said Sharon Kyhl, acting public-affairs officer for the Black Hills National Forest. “The Jasper Fire area has been logged and thinned recently” Kyhl said (Miller 2001).

The Final Environmental Impact Statement on salvage logging of the fire area aptly describes the existing road network in the fire area: “There are approximately 508 miles of roads within the perimeter of the fire, or about 4 miles of road per square mile of land. Included in this total are 31 miles of arterial roads, 67 miles of collector roads, and 409 miles of local (non-system or two-track) roads” (USDA Forest Service. 2001). The excellent road access to the fire ignition point and the dense road network throughout the fire area were ineffective in controlling this fire (Figure 15). As noted by the Forest Service, the extensive logging and thinning that had been conducted in the area also did nothing to prevent this fire from developing into an enormous firestorm (Figure 13).

Figure 13. Convection cloud of smoke from Jasper Fire, August 26, 2000. *Photo by Cissie Buckert*

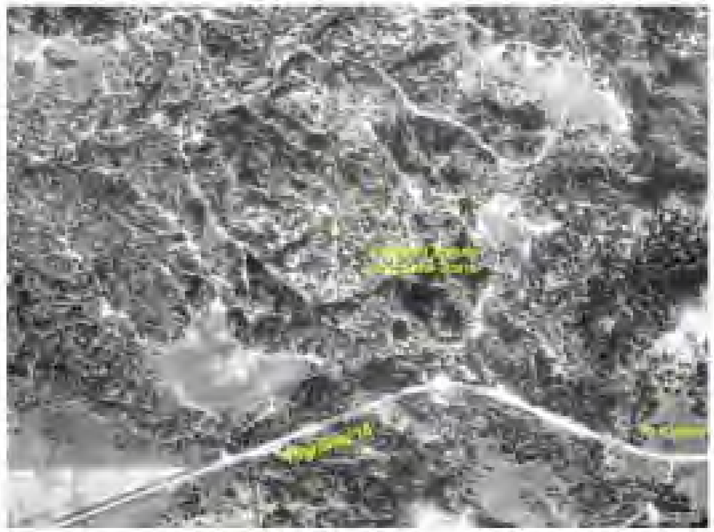

Figure 14. Digital Orthophoto of area to the north of Highway 16, near the ignition point. This area is crisscrossed with skid trail and roads. It has been recently logged and thinned (Morrison et al 2000).

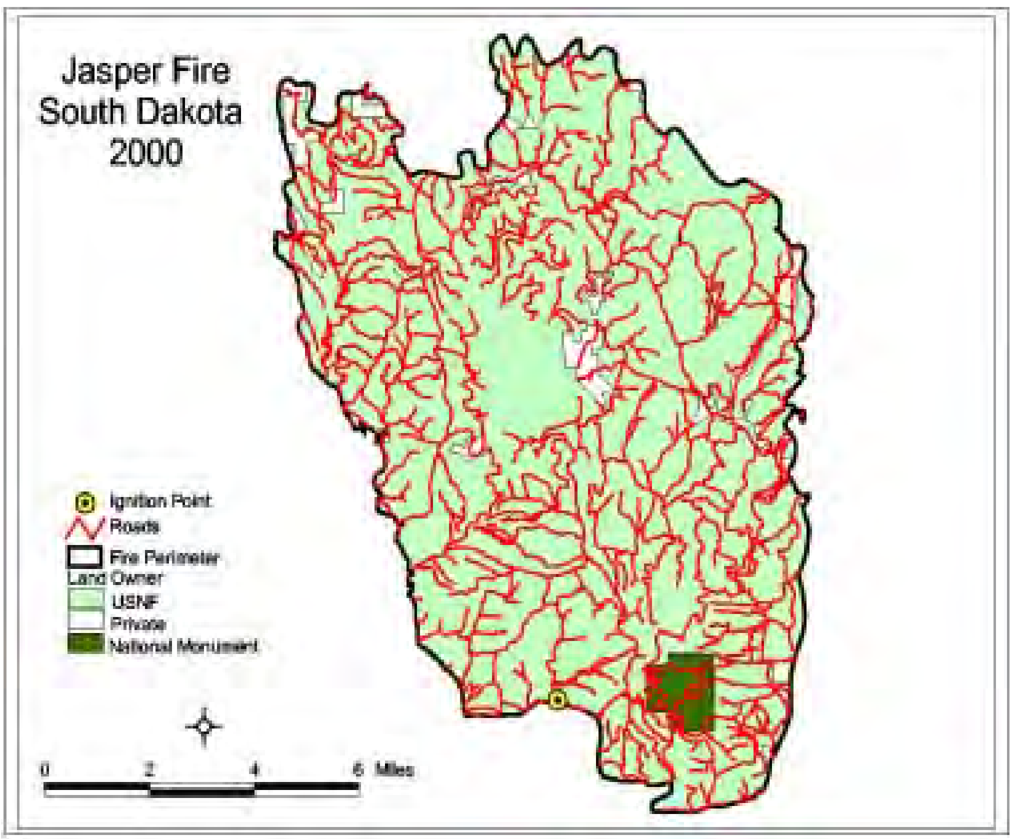

Figure 15. Jasper Fire, South Dakota. This map shows the fire perimeter in relation to the fire ignition point and roads (Morrison et al 2000). Note the dense road network throughout the fire area.

Examples of wildfires that were caused by lightning, but spread rapidly across densely roaded landscapes.

The Valley/Skalkaho Complex, Bitterroot National Forest, Montana, 2000
The largest fire complex during the year 2000, the Valley/Skalkaho Complex was ignited in an intensely roaded landscape managed for grazing and timber production. It burned primarily through parts of the Bitterroot National Forest, Darby Lumber Company land and land owned by the State of Montana. Over 213,000 acres were burned in one of Montana's largest fire events.

The fires in this complex blazed across hundreds of roads before containment. Extensive road access and road/firebreaks did not play a significant role in prevention or control of one of the largest fires in Montana's history. There are 1,645 miles of roads within the fire perimeter. The average road density in the fire area exceeded 5 miles of road per square mile.

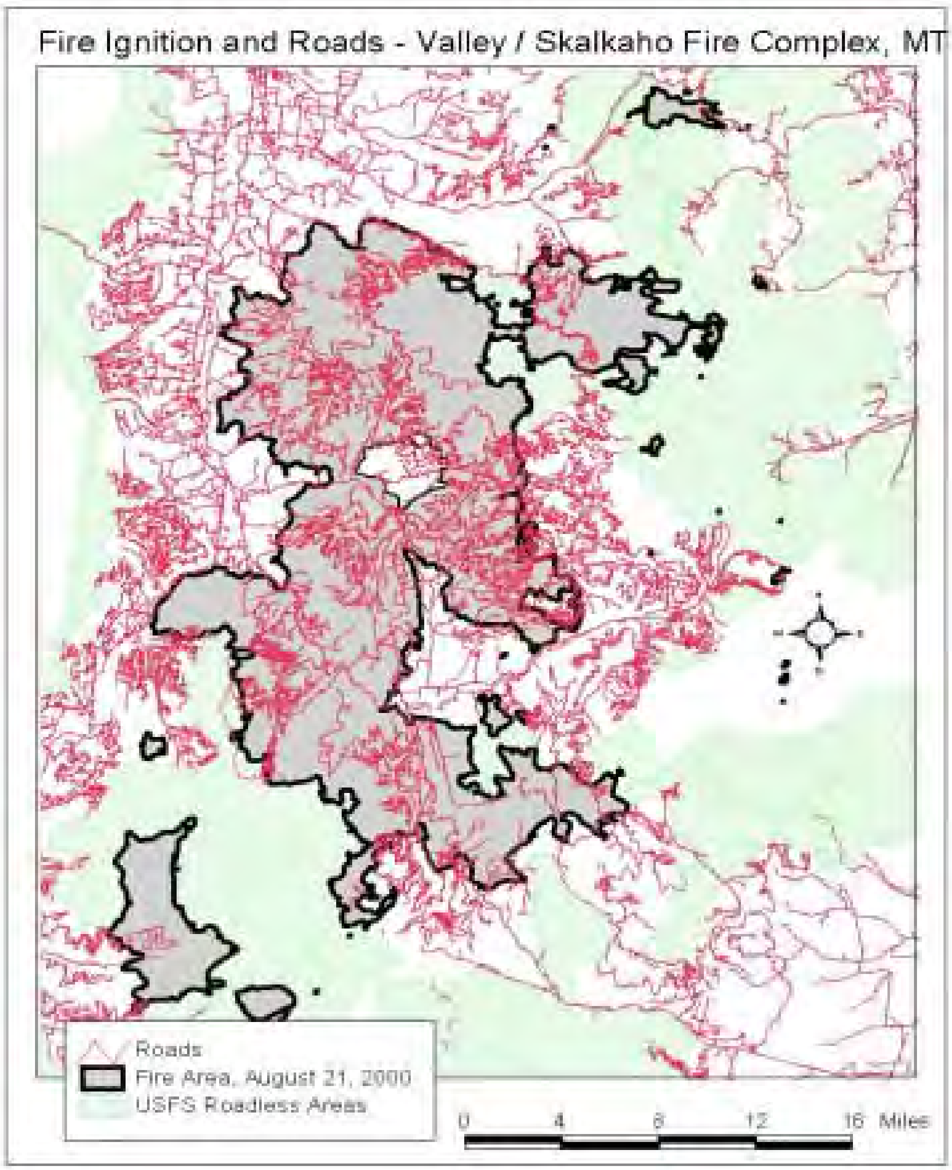

Figure 16. The Valley/Skalkaho Fire Complex, Montana, 2000 in relation to roads (Morrison et al 2000).

Moose Fire, Montana, 2001

The Moose Fire, ignited by lightning on August 15, 2001, burned through portions of the Flathead National Forest in northern Montana. Roads and clear-cuts characterize the landscape where this fire spread and gained intensity. Despite the fact that most of the initial burn area was accessible by a dense network of logging roads, neither road access nor thinned forests prevented this fire from growing to 71,000 acres. There are 211 miles of road within the fire area - a road density of 1.9 miles per square mile.

"*There was adequate access by ground and by helicopter for the initial attack resources. Initial attack fire engines drove right to the fire."* Moose Fire webpage

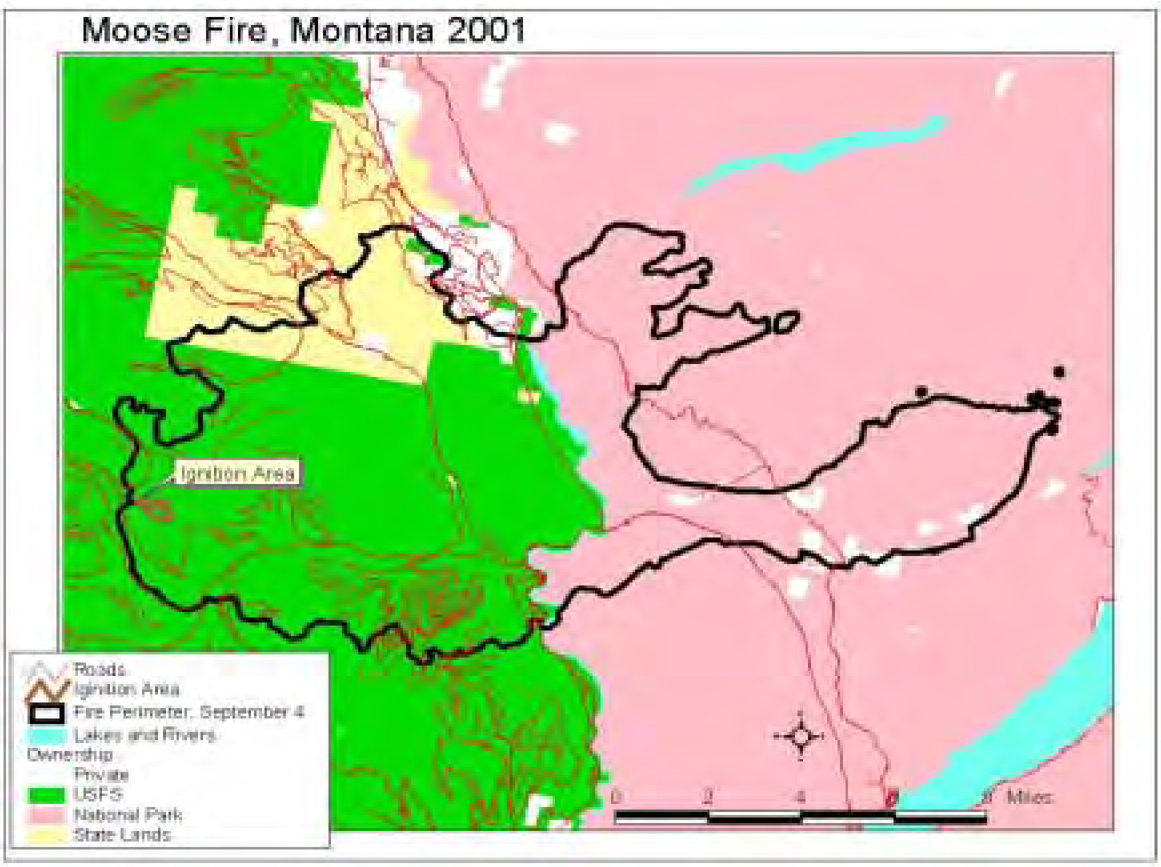

Figure 17. Moose Fire, Montana, 200, in relation to the ignition point and roads (Morrison et al 2001).

The Tyee Fire, Wenatchee National Forest, Washington State. 1994

The Tyee Fire started near a logging road in an area that had recently been thinned. It proceeded to burn across a densely roaded landscape and across previously constructed fire breaks to become one of Washington State's largest wildfires in recorded history, burning over 140,000 acres. There were over 240 miles of roads within the fire perimeter (Figure 18). During the course of fire's course, it burned over more than 30 roads before it reached its eastern perimeter. More roads would not have helped in the control of this fire.

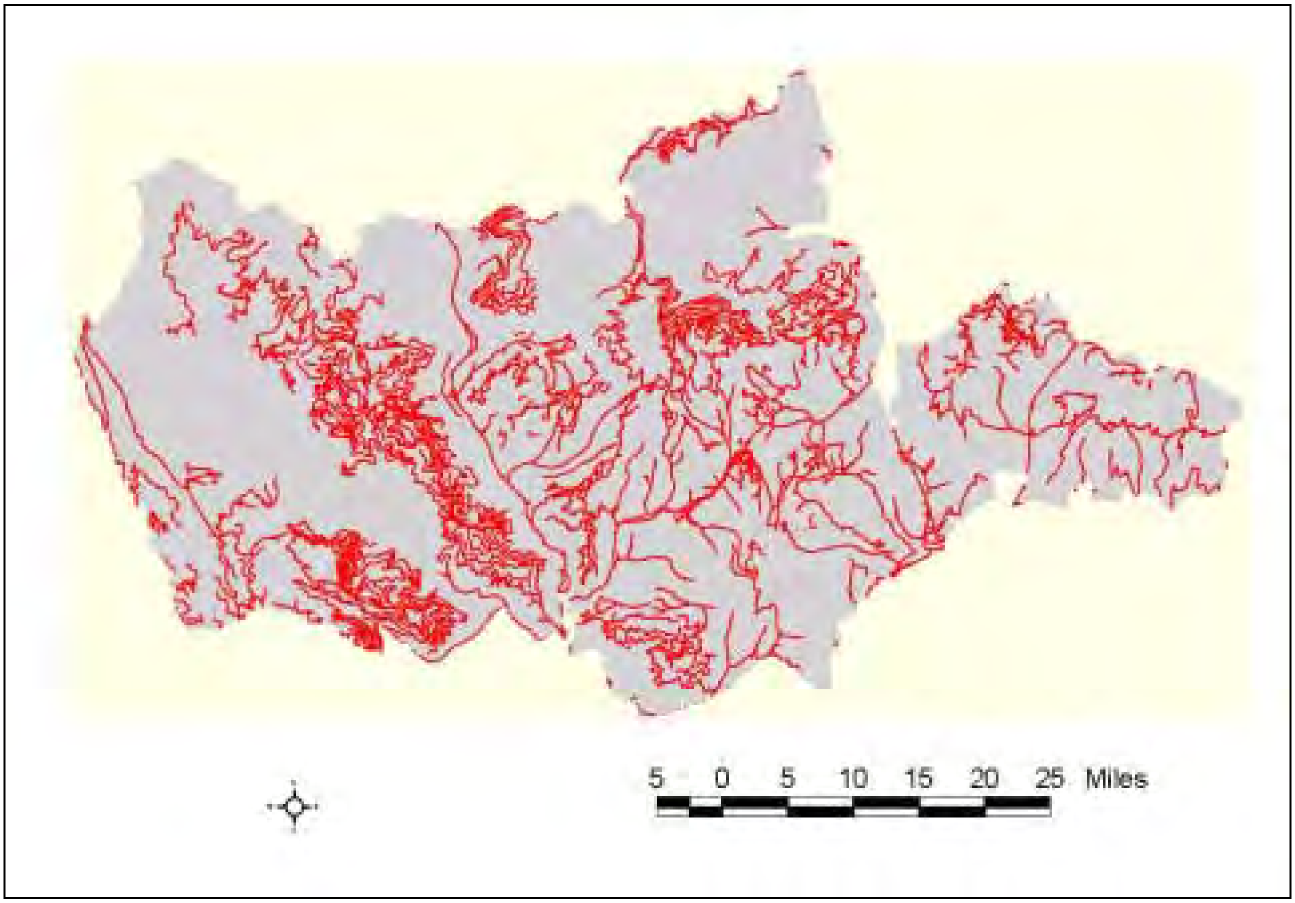

Figure 18. The 1994 Tyee Fire in Washington State illustrating the road network that existed within the fire perimeter.

Examples of human-caused fires that start near or on a road and then spread into roadless areas, wilderness or sparsely roaded landscapes.

Hanford Fire, Washington State, 2000
A fatal automobile collision ignited a brush fire that grew to burn 190,000 acres of land near the Hanford Nuclear Reservation. The Hanford Fire was one of the largest in the nation in the summer of 2000, and received much media attention due to its proximity to the Hanford Nuclear Facility. The Hanford fire is an example of a human-caused fire in a roaded and non-forested area (Figure 13) (Morrison et al 2000). Perhaps aiding the ignition, snow fences along both sides of the highway were buried in tumbleweed over ten feet deep, prior to the blaze.

Figure 18. Ignition Point for the Command 24 fire of July, 2000 near Hanford, Washington. Along Highway 24, looking south towards the Hanford Site.

Thirty-Mile Fire, Okanogan National Forest, Washington, 2001
Road access was directly implicated in the cause of the Thirty-Mile Fire in Okanogan National Forest, Washington. The fire was the result of an unattended campfire next to a major road, which then spread into remote country up the Chewuch River. Firefighters had immediate road access to the location where the fire started and the area where it initially spread. Although the initial fire remained alongside a road with good access, this did not prevent it from growing to over 9,000 acres, killing four firefighters and injuring several others. As the fire grew, it swept up the slopes of extremely steep canyons. No roads existed on these slopes due to the steepness of the terrain. In the Thirty-Mile fire, good road access to the fire initiation site did not prevent a great tragedy or help bring what started as a small blaze under control (Morrison et al 2001).

Figure 19: The Thirty-Mile Fire, Washington, 2000 illustrating the fire ignition point and roads (Morrison et al 2001).

Trough Fire, Mendocino National Forest, California, 2001
This human-caused fire began along a road in a densely roaded area of the Mendocino National Forest and burned into Snow Mountain Wilderness. The Trough fire burned over 67 miles of roads before it burned into the Wilderness (Morrison et al 2000).

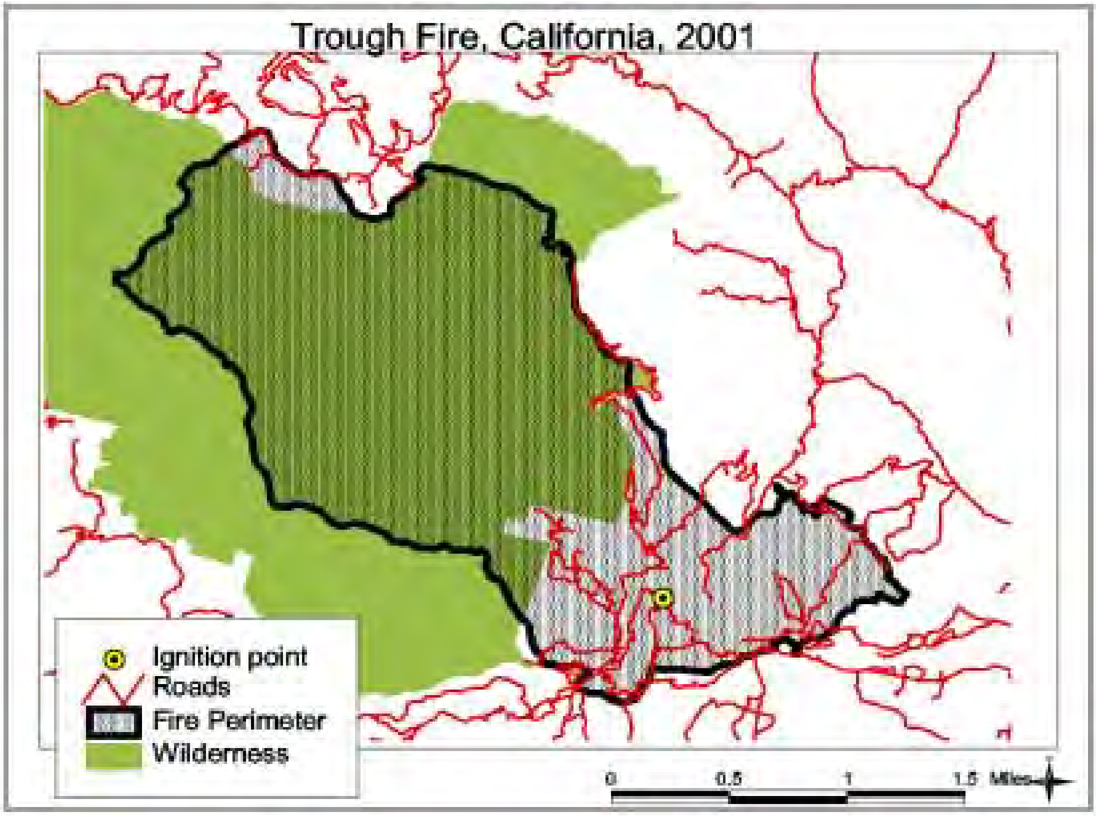

Figure 20. Trough Fire, Northern California, 2001, illustrating the fire ignition point and roads (Morrison et al 2001).

Figure 21. Aerial photograph of landscape conditions near ignition point of Trough Fire. Vegetation is brush and oak woodland. Pre-fire photo is from the US Geological Survey, 1996.

Discussion

What have other researchers found?

In order to recognize the full effect that roads have on wildfires, we must not only examine how and where fires ignite, but also where they burn and how severely they burn. Pew and Larsen (2001) analyzed the spatial and temporal patterns of human-caused wildfires on Vancouver Island. They found that the probability of a section of land burning was negatively correlated with distance from roads. In other words, as the number of roads per given area increased, the probability of fire increased as well.

McHugh and Finney (2003) analyzed the relationship between road density and fire severity in the 2002 Hayman Fire in the Colorado Front Range. They could not find any significant relationship between road density and fire severity. Areas with more road access did not experience any less fire severity.

Does the access provided by roads help fire suppression efforts?

The effectiveness of roads as access points is dependent upon many factors. When roads are used as access points for firefighters, fire lines are often created as a suppression tactic.

In addition, many wildfires in western forests are initially attacked with air-deployed fire crews – making the presence or absence of roads largely moot. Air-deployed fire crews are often used even when the fire is near a road because this is generally the fastest way to get an initial-attack crew to the ignition site. Deployment of water and fire retardant by helicopter and air-tanker has increasingly been used as a general firefighting strategy during and after initial attack. In the Final Environmental Impact Statement (FEIS) on the US Forest Service Roadless Rule (USDA Forest Service 2000), fire management trends were used to determine the effect that the Roadless Rule would have on fire suppression capability. According to the FEIS, "The analysis revealed that a national prohibition on road construction and reconstruction would not result in an increase in wildland fires escaping initial attack. A review of fire occurrence data for inventoried roadless areas further revealed that 98% of all fires ignited inside inventoried roadless areas would be successfully controlled at a relatively small size… The effect of the road construction prohibition on the fire suppression program is expected to be negligible."

Do roads form effective fuel breaks?

The effectiveness of roads as access points and fire breaks is dependent upon many factors. In other cases, roads are themselves used as fuel breaks. According to Green (1977), these fire lines may be totally ineffective in the case of severe fires, whose flames may reach 200 feet and cross fuel breaks that are miles wide.

The recent (October 2003) fires in Southern California fires provided many examples where fires burned across major highways. In at least in one case, these fires burned across an interstate highway (Figure 22).

Figure 22. The Simi Fire burned through brush and across State Route 118, a six-lane freeway (the Ronald Reagan Freeway) running the length of the Simi Valley on October 27, 2003.

Although fuel breaks may be effective in the case of a slower, cooler fire, this type of wildfire does not often pose a threat to communities. Ironically, large, hot burning fires that are affected little by fuel breaks such as roads are the primary impetus for the road building strategy.

Will building new roads help to defend communities against wildfire?

The current network of road systems through US forestland in the US is already very dense. We currently have over 7 million miles of roadway crisscrossing the country. It is rare to find a location that is more than one mile from a road. The few remaining roadless areas are remote backcountry sites, which are usually distant from human population centers and rural communities. Wildfires that do start in the remaining roadless and wild parts of our landscape rarely burn so far as to pose a severe threat to human life or property. In a report by The Wilderness Society entitled, “Roadless Areas Pose no Threat to Communities at Risk from Wildfire”, (The Wilderness Society 2003) a spatial analysis revealed that less that one-tenth of one percent of inventoried roadless land was located within the community protection zone (a one-half mile zone around a community where access fuel removal is deemed important). Clearly, inventoried roadless areas pose little threat to communities.

Wildfires that do start in the remaining roadless and wild parts of our landscape rarely burn so far as to pose a severe threat to human life and property. Our Wilderness Areas and roadless areas are characterized by very steep slopes, sparse and unproductive forests (usually with little commercial value) and high-elevation ecosystems. The health of these ecosystems is highly dependent on wildfire. Few natural resources are at stake in these remote areas and significant ecological benefit occurs as wildfires renew these ecosystems.

What are the financial costs of building fire-access roads across the remaining unroaded parts of our federal lands?
During the last century, roads were built into most of the land feasible for road building and into many other areas with great effort and expense. In 1996 alone, $95 million was appropriated to the Forest Service for the construction and reconstruction of wildland roads. Additionally, $81 million was appropriated for road maintenance. (Wildlands CPR, 2003, What is a Forest Road?) These figures do not include money spent by the federal government to reverse damage done to the environment when roads have blown out and spilled sediment into waterways and homes.

The remaining wild and roadless areas on federal land occupy the most rugged part of the landscape in the US. In many of these areas, it is difficult, if not impossible, to build roads due to the rugged nature of the terrain.

The feasibility of building a road network to provide access to the remaining roadless parts of our landscape needs to be carefully examined by proponents of this strategy. In Washington State, over 70% of the remaining federal forest roadless areas are comprised of slopes over 30 percent in steepness (Pacific Biodiversity Institute unpublished data). Other western states are similar. The cost of building roads through this terrain would be exceedingly costly. Furthermore, the US Forest Service currently does not have sufficient funding to maintain much of it's existing road system and recognizes that many roads must simply be closed because they are unnecessary and too expensive to maintain. The costs of maintaining a greatly expanded road system would be immense given the increased cost of road maintenance in steep, rugged and unstable terrain. But to expand the road system on account of providing better firefighting access would be of questionable merit at best, and at its worst, a prelude to increased conflagration.

What are the environmental costs of building new roads?

Wilderness and roadless areas are characterized by very steep slopes, sparse and unproductive forests, (usually with little commercial value) and high-elevation ecosystems. Before the advent of fire suppression in the early 1900s, the health of these ecosystems was dependent on regular occurring wildfires, which cleaned the forest of excess fuel, and initiated the process of new growth. Commercial developments are few in these remote areas and most of the land is not sufficiently productive to support commercially viable timber stands. Therefore, there is little risk to our society to allowing natural wildfires to continue to play their historically important role in these remote areas. Significant ecological benefits would result as a result from allowing wildfire to return to these ecosystems.

The cost of an expanded road system mounts when considered from an ecological perspective. Trombulak and Frissell (2000) discuss many of the ecological impacts of roads on native ecosystems, fauna, flora and biodiversity.The long-term environmental degradation includes surface erosion and landslide activity due to the steepness of the terrain. West of the Cascades, approximately 25% of recent landslides were tied to road failures while 75% of landslides were caused by roads east of the Cascades. (Wildlands CPR). In the Alder Creek watershed in the western Cascade Range of Oregon, I found that 343 times more landslide-related erosion occurred as a result of road failures than in the surrounding forest (Morrison 1975). Erosion and sedimentation due to roads often results in fishery and aquatic ecosystem degradation. Invasive weed species, which are known to proliferate along new roads, would pose a threat in some of the few remaining areas where pristine, weed-free ecosystems prevail. Roads also cause extensive disruption to many terrestrial wildlife species that are sensitive to human disturbance.

Many Endangered and Threatened species are intolerant of human disturbances associated with roads. Additionally access would be provided for logging, mining, poaching and off–road vehicle abuse.

Road maintenance would involve yearly grading and clearing of downfall. Roadside corridor disturbance opens up the canopy and disturbs the soil, resulting in a flush of deciduous vegetation and leaf litter, which raises the fire risk.

It is clear that the costs of an extended fire road network in the remaining roadless areas goes beyond the direct expenses of constructing the roads and the dubious advantages to firefighting, for they would also cause widespread environmental damage and ecological disruption. It would likely pose increased risks to many endangered species.

Conclusion: Building more roads is not the solution to the wildfire issue.

There is ample evidence to demonstrate that most human-caused wildfires start along roads and that these fires constitute the vast majority of the wildfires that burn across our country. Wildfires blast through heavily roaded landscapes with ease and regularity. While roads do improve access for firefighters, those same roads provide access to careless drivers, campers, and arsonists. The great increase in human-caused wildfire ignition due to an expanded road system greatly outweighs the benefits derived from increased access for firefighters. The financial and environmental costs of such a system would be tremendous. Construction and maintenance of this hypothetical road system would cost billions of dollars and have a distinctly negative impact on some our most fragile ecosystems.

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Appendix 1 - All wildfire occurrences in conterminous US in Wildfire Occurrence Database (Schmidt et al 2002) in relationship to distance from road.

	Human Cause		Lightning Cause		Unknown Cause		All Causes	
Distance from road	Number of fires	% of total	Number of fires	% of total	Number of fires	% of total	Number of fires	% of total
200	252927	60.7%	50928	38.3%	23116	55.1%	326971	55.3%
400	84392	20.3%	24087	18.1%	7817	18.6%	116296	19.7%
600	36053	8.7%	14052	10.6%	4551	10.9%	54656	9.2%
800	22088	5.3%	9921	7.5%	3364	8.0%	35373	6.0%
1000	8285	2.0%	6613	5.0%	1354	3.2%	16252	2.7%
1200	3487	0.8%	4560	3.4%	544	1.3%	8591	1.5%
1400	2021	0.5%	3427	2.6%	290	0.7%	5738	1.0%
1600	1694	0.4%	2640	2.0%	232	0.6%	4566	0.8%
1800	940	0.2%	2148	1.6%	173	0.4%	3261	0.6%
2000	763	0.2%	1732	1.3%	94	0.2%	2589	0.4%
beyond 2000 meters	4017	1.0%	12991	9.8%	407	1.0%	17415	2.9%
Total Fires	416667		133099		41942		591708	
Percent greater than or equal to 1/2 mile from a road		5.1%		25.6%		7.4%		9.9%
Percent within 1/2 mile from a road		94.9%		74.4%		92.6%		90.1%

Appendix 2 – Observed and Expected Values for all human-caused wildfire occurrences in conterminous US in the Wildfire Occurrence Database (Schmidt et al 2002) in relationship to distance from road.

Distance from road	Area in conterminous US (hectares)	Proportion of US in road distance zone	Observed # of wildfires	Expected # of wildfires	Chi-squared value
200	308223736	0.395993547	326971	234313	36642
400	180858153	0.232359332	116296	137489	3267
600	104478840	0.134230241	54656	79425	7724
800	58421214	0.075057243	35373	44412	1840
1000	31754395	0.040796779	16252	24140	2577
1200	20835574	0.026768713	8591	15839	3317
1400	14565869	0.018713647	5738	11073	2570
1600	10749008	0.013809896	4566	8171	1591
1800	8219678	0.010560314	3261	6249	1428
2000	6544399	0.008407982	2589	4975	1144
beyond 2000 meters	33704586	0.043302306	17415	25622	2629
Total	**778355452**	**1**	**591708**	**591708**	**64730**
	chi-squared value is 64730 with 10 d.f. - highly significant with p<.0001				

EXHIBIT 47

BOARD OF FORESTRY AND FIRE PROTECTION
THE NATURAL RESOURCES AGENCY
STATE OF CALIFORNIA

KEITH GILLESS, CHAIR
Wade Crowfoot, *Secretary*
Gavin Newsom, *Governor*

P.O. Box 944246
SACRAMENTO, CA 94244-2460
(916) 653-8007
(916) 653-0989 FAX
BOF Website (www.bof.fire.ca.gov)

October 23, 2020

Linda Schiltgen
Deputy County Counsel
County of Sonoma
Linda.Schiltgen@sonoma-county.org

Re: BOF Certification Questions: Sonoma County Responses

Dear Ms. Schiltgen:

The Board is in receipt of your letter dated October 18, 2020, and addressed to Board of Forestry and Fire Protection (Board) Chair Keith Gilless and Vice Chair Darcy Wheeles. It has been distributed to the Board members for consideration. Because your letter provides responses to questions posed by Board staff, please accept this response by Board staff on their behalf.

<u>Background</u>

A brief summary is appropriate for context. For several months, the Board, its staff, and representatives from the County of Sonoma (Sonoma County) have been engaged in discussions relative to the potential certification of Sonoma County's local fire safe ordinance as equaling or exceeding the Board's Fire Safe Regulations (14 CCR § 1270 et seq.). Board members and staff have expressed concerns about portions of Sonoma County's ordinance that either omit standards included in the Fire Safe Regulations or set standards that, on their face, appear to be less stringent than the Fire Safe Standards. At the September 22, 2020, Joint Committee Meeting of the Board, Board staff were directed to provide Sonoma County with a list of specific questions posed by both Board members and staff, that, if answered, would allow Board staff to properly evaluate the local ordinance and enable staff to make a recommendation to the Board in favor of certification. By letter dated October 12, 2020, Board staff issued those questions to Sonoma County. By your letter dated October 18, 2020, Sonoma County provided its responses for Board staff consideration.

When being presented with the myriad of issues related to certification, it is important not to lose sight of the fundamental task before the Board. The Board is reviewing the Sonoma County ordinance pursuant to 14 CCR § 1270.04 to decide whether to exercise its discretion "to certify [the ordinance] as equaling or exceeding [the Board's regulations] when they provide the same practical effect."[1] While it is generally not difficult to determine whether a particular provision of an ordinance equals or exceeds a corresponding provision in the Board's regulations, the same cannot be said for determining whether a local ordinance that fails to equal or exceed the Board's regulation nonetheless provides the *same practical effect*. To aid in this determination, the Board's regulations provide a detailed definition of the term *same practical effect*. With these tools, the Board must evaluate each provision of a local ordinance and compare it to the corresponding provision in the Board's regulations to determine whether the local ordinance provision equals or exceeds the Board's regulation or provides the same practical effect. Still, the task before the Board is challenging and requires careful and deliberate consideration, especially when applying the complex definition of *same practical effect*.

Summary of Staff Findings

At its core, the Board's task is fundamentally a very narrow inquiry: *For each substantive requirement in the Fire Safe Regulations, does the local ordinance have a provision that equals or exceeds or has the same practical effect as that Fire Safe Regulation standard?*

Board staff have completed their review of Sonoma County's responses and continue to have significant concerns that the ordinance does not satisfy the Board's standards for certification. Sonoma County's responses pertaining to standards for existing roads and for ingress/egress that allows concurrent civilian evacuation are of particular concern. Accordingly, Board staff lack an evidentiary basis to support a recommendation for certification. Board staff have enclosed an updated matrix, dated to reflect the upcoming November 3, 2020, Joint Committee Meeting of the Board, that provides more specific observations and staff recommendations.[2]

This is an appropriate point to address Sonoma County's position that if the Board does not certify its ordinance, then Sonoma County is prevented from enjoying the benefits of the portions of its ordinance that it believes clearly equal or exceed the Fire Safe Regulations. The Board would like to reiterate to Sonoma County that certification of its ordinance by the Board is not required for Sonoma County to apply its own standards that go above and beyond the state minimum standards. Board certification is a creature of regulation, the benefit of which is to publicly document a mutual understanding of the Board and the local jurisdiction that a local ordinance equals or exceeds the Fire Safe Regulations. Under Public Resources Code § 4290, subdivision (c), the Board's minimum standards do not supersede any Sonoma County

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[1] References in this letter to the "equal or exceed" standard includes this "same practical effect" standard.

[2] The attached November 3, 2020, matrix represents Board staff's current evaluation and recommendations to the Board, and supersedes any prior matrix, whether final or draft, including the deliberative draft September 4th matrix, which apparently Sonoma County misunderstood to be something more than merely an informal tool to facilitate productive discussion in advance of the September Board meeting.

ordinance that equals or exceeds the minimum state standards.[3] Thus, if Sonoma County has stricter, greater, or enhanced requirements in its ordinance, the lack of certification by the Board does not preclude Sonoma County from deciding to apply these stricter requirements.

Turning now to Sonoma County's responses, it is worth mentioning that it is unnecessary for Board staff to address each individual response. The purpose of the exercise is to provide Board staff sufficient information so that it may complete its evaluation of Sonoma County's ordinance and issue a recommendation for the Board's consideration. As noted above, the certification determination is made in light of the language of the local ordinance and any documents incorporated by reference. Supplemental information, such as Sonoma County's responses, merely illuminates the local jurisdiction's interpretation of its ordinance and how it equals or exceeds the Fire Safe Regulations.

In any event, Sonoma County's responses reflect a number of recurring issues of concern to Board staff that can be summarized generally without focusing on the content of specific responses or specific sections of the ordinance. Board staff have consistently expressed concerns that the Sonoma County ordinance and Administrative Policy do not articulate specific minimum standards for each type of road referenced in the ordinance and Administrative Policy[4] nor does it articulate what standards govern the fire official's assessment that a road provides concurrent civilian evacuation. Board staff's questions were particularized and specific attempts to identify those standards so that Board staff could evaluate where they equal or exceed the Fire Safe Regulations.

Detailed Discussion

Board staff acknowledge that some of Sonoma County's responses on certain other issues resolved Board concerns or provided additional clarity. This letter focuses on major issues that preclude the Board staff from issuing a recommendation in favor of certification. Board staff refer interested parties to the staff-prepared final matrix for the November 3, 2020, Board meeting for a more comprehensive discussion of portions of the ordinance that equal or exceed the Fire Safe Regulations.

Sonoma County's ordinance and responses to staff questions on the following topics are inadequate. Sonoma County's responses do not provide the requested citations nor identify the specific standards that Sonoma County contends apply. Instead, the responses reiterate

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[3] It is necessary to acknowledge that the statute does not include a "same practical effect" standard. A local ordinance applied pursuant to Public Resources Code § 4290(c), without obtaining Board certification, must "equal" or "exceed" the Fire Safe Regulations in the ordinarily understood sense of those words. Thus, a non-certified local ordinance applied by a local jurisdiction is potentially subject to a stricter legal standard than is required for certification under 14 CCR § 1270.04.

[4] The ordinance and Administrative Policy contemplate new roads, existing roads, existing public roads, existing private roads, and existing roads approved on a discretionary basis and a ministerial basis. Sonoma County is entitled to have as many subcategories as it chooses, but each must have an established standard that equals or exceeds the Fire Safe Regulations.

positions that, while not unimportant, are nonetheless irrelevant to the narrow certification inquiry before the Board.

We will first address the various arguments that are not relevant to and therefore do not inform staff's analysis.

Sonoma County Argument 1: Some portions of the ordinance equal or exceed the Fire Safe Regulations

Sonoma County's introductory paragraph includes a chart outlining several provisions showing how its ordinance equals or exceeds the Fire Safe Regulations. This general claim is reiterated in response to several questions.

The Board acknowledges that many elements of Sonoma County's standards clearly equal and exceed the minimum standards of the Fire Safe Regulations. This has been well established in documents provided for Board consideration, as well as testimony at several Board and Joint Committee Meetings this year. However, exceeding the Fire Safe Regulations in certain aspects does not excuse an ordinance's failure to equal or exceed other standards imposed by the Fire Safe Regulations.

Thus, the Board's determination that one provision of a local ordinance equals or exceeds the Fire Safe Regulations has no bearing on the Board's consideration of other unrelated provisions of the local ordinance. This argument is an unnecessary distraction and does not inform whether all provisions satisfy the certification standard. As such, the Board does not focus on these statements when applying the certification standard.

Sonoma County Argument 2: Takings / Inability to secure easements for expanding roads

Another argument advanced in Sonoma County's preliminary comments asserts that the Fire Safe Regulations effect an unconstitutional "taking" of private property for public use because they make a landowner individually responsible for upgrading existing roads that serve other parcels. Other variations of this argument suggest that the Fire Safe Regulations encourage Not-In-My-Backyard (NIMBY) opposition to prevent development or allow a landowner to extort a neighbor by refusing to sell an easement to facilitate road widening to comply with state standards. These arguments are also reiterated in response to several questions seeking clarity about Sonoma County's standards and how they equal or exceed the Fire Safe Regulation.

The Fire Safe Regulations have not been legally challenged, let alone invalidated, as being unconstitutional in any sense. They are binding as minimum standards on Sonoma County, notwithstanding speculative practical inconveniences at the local level. It is Sonoma County's prerogative to impose those burdens on individual landowners instead of exercising other options at its disposal, such as eminent domain. In any event, the issue of who bears financial responsibility for upgrading existing roads that serve as access to new building construction has no bearing on whether road standards in Sonoma County's ordinance – such as minimum road widths – equal or exceed the corresponding standard in the Fire Safe Regulations. As such, the Board does not focus on this argument when evaluating the ordinance for compliance with its certification standard.

Sonoma County Argument 3: Fire Safe Regulation Exception Process

Another argument advanced in Sonoma County's preliminary comments asserts inadequacies in the Fire Safe Regulations' "exception process" (14 CCR § 1270.06), including a loophole authorizing local jurisdictions to waive any requirement in the Fire Safe Regulations. This argument is reiterated in response to several questions.

While the Board appreciates Sonoma County's comments and will certainly takes these into account to consider whether regulatory changes are warranted to address this point, Sonoma County's concerns regarding 14 CCR § 1270.06 do not have bearing on the present issues related to certification of Sonoma County's ordinance, for multiple reasons. First, Sonoma County adopted its own "exceptions to standards" provision, § 13-23, in its ordinance. Notwithstanding certain staff comments in the matrix, the Board may determine that these provisions equal or exceed the minimum standards in § 1270.06. Second, assuming for the sake of argument that 14 CCR § 1270.06 allows for "behind closed doors" determinations, or fails to provide a thorough open and public process, this is irrelevant as to whether *other* sections of Sonoma County's ordinance equal or exceed the Board's minimum standards. Finally, to the extent Sonoma County finds the minimum standards in 14 CCR § 1270.06 unsatisfactory, the regulation expressly states that local jurisdictions "may establish additional procedures or requirements for exception requests." Thus, to the extent Sonoma County believes that the Board's exception standards in § 1270.06 are deficient, Sonoma County may remedy these by imposing additional requirements. Consequently, the Board does not focus on this argument when evaluating the ordinance for compliance with its certification standard.

Sonoma Ordinance Issue 1: Existing Road Standards

We now turn to Sonoma County's discussion of the specific standards and citations in response to the Board staff's questions relating to existing road standards and the concurrent evacuation requirement. Sonoma County's responses continue to make conclusory statements about the quality of its ordinance and Administrative Policy. Board staff are repeatedly told that these documents have "clear standards" and a "strict set of requirements," but do not reference actual standards or citations. Board staff needs this information to properly evaluate the ordinance for certification. Without it, Board staff are compelled to conclude that no such standards exist and recommend to the Board that Sonoma County's ordinance does not satisfy the certification standard for existing roads.

Throughout the certification process, Sonoma County has repeatedly maintained that Public Resources Code section 4290 and the Fire Safe Regulations do not apply to existing roads. Sonoma County's position is incompatible with the plain language of PRC § 4290,[5] the Fire Safe Regulations,[6] and opinions and letters issued by the Attorney General of California.[7] More importantly, the Fire Safe Regulations themselves – which constitute the basis for the certification determination – clearly provide no exemption for existing roads, and it is these regulations that the Sonoma County ordinance must equal or exceed. This represents a fundamental and intractable disagreement between the Board and Sonoma County. Sonoma County's position on existing roads, standing alone, is a legitimate basis for determining that the ordinance does not equal or exceed the Fire Safe Regulations.

Moreover, Sonoma County's position has a discernible impact on it characterizes its ordinance, and the amount of effort necessary for Board staff to parse its assertions for accuracy and compliance with the certification standard. Specifically, any assertion Sonoma County makes about "roads" requires the Board to evaluate whether Sonoma County intends to apply that standard to existing roads.

Setting aside this fundamental disagreement as to the applicability of the Fire Safe Regulations, Sonoma County has argued that, in the alternative, even though it believes existing roads are exempt, Sonoma County's Administrative policy nonetheless applies to existing roads and equals or exceeds the Fire Safe Regulations.

Board staff have reviewed the ordinance and Administrative Policy in great detail. The only specific standard identified in the Administrative Policy is a 12-foot width requirement for existing private roads. On its face, this falls short of the minimum road standard in 14 CCR § 1273.01. That is a significant obstacle to Board certification. More concerning, however, is that the policy provides no standards for other types of existing roads. As noted before, the Administrative Policy contemplates a public/private distinction, as well as a discretionary/ministerial distinction. No standards for these types of existing roads exist in the ordinance or Administrative Policy. Until these deficiencies are remedied to the Board's satisfaction, Sonoma County's ordinance and Administrative Policy is conclusively ineligible for certification. As Sonoma County's responses fail to provide the requested information with sufficient detail, Board staff can only conclude that no such standards exist and recommend to the Board that the ordinance does not meet the certification standard.

Additionally, Sonoma County's reliance on the Administrative Policy as setting the exclusive standard for existing roads raises concerns beyond the road width issues. The Fire Safe

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[5] "These regulations apply to the perimeters and access to all residential, commercial, and industrial building construction within state responsibility areas… ." (Emphasis added.)

[6] See 14 CCR § 1270.02 which includes the same language in fn5 and includes an exemption for roads that is limited to agricultural, mining, and timber-related operations.

[7] See, e.g., AG Opinion No. 92-807 (1993); AG letter to Monterey County Planning Commission (Oct. 25, 2019).

Regulations set other standards for roads, such as grade, surface requirements, radius, turnouts, turnarounds, and dead end roads. However, the Administrative Policy is silent on those issues, and Sonoma County's responses do not identify what standard, if any, apply for those existing road requirements, and where they can be located in the ordinance or Administrative Policy.

In this respect, Sonoma County's response to Question 1.1.3.3 is emblematic. The Board staff posed a direct request seeking specific information: "For convenience and reference, please complete the following table by filling in the specific ordinance section or Administrative Policy section that addresses the specified SRA Fire Safe Regulation." One axis of the referenced table identified (with citations) all of the above-referenced road requirements in the Fire Safe Regulations that Sonoma County's ordinance must equal or exceed. Along the other axis, the table identified all of the categories of existing roads referenced in the Administrative Policy. Sonoma County's task was to provide an ordinance or Administrative Policy citation in each box.

Board staff believed the table provided the best and simplest opportunity for Sonoma County to provide the information necessary to support certification with respect to requirements for existing roads. Sonoma County's response does not provide any relevant or informative citations. For two columns, Sonoma County cross-referenced six of its other responses to unrelated questions. The County responses did not comply with the call of the question to provide a citation, nor could any relevant citations or standards be discerned from the referenced answers. In fact, some of the cited responses made no mention of the relevant terms. With respect to the remaining categories of existing road standards (public/private and ministerial/discretionary), Sonoma County referenced provisions of its ordinance that apply to *new* roads.[8] These citations are also unresponsive to the call of the question because §13-25(f) of the ordinance clearly states that existing road standards are governed by the Administrative Policy.

In the last couple of weeks, Sonoma County has advanced a new argument indicating that its adoption of an optional appendix from the California Fire Code satisfies the requirement for establishing road requirement standards that satisfy the Fire Safe Regulations. As Board staff made clear in a prefacing comment to Question 2.2 and subsequent follow up questions, compliance with the California Fire Code does not ensure compliance with the Fire Safe Regulations. Those standards are relevant only to the extent that they equal or exceed the Fire Safe Regulations. The Board staff's follow up questions on this point quoted a number of the appendix standards which Sonoma County revised so that the standard may also be satisfied by compliance "with the Sonoma County Fire Safe Standards or as approved by the fire code official." The reference to the Sonoma County standard is a circular reference to the very

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[8] If Sonoma County intends the particular referenced ordinance provisions to apply both to new roads and existing roads, the ordinance and Administrative Policy will require substantial revision.

standard that Sonoma County has been unable to identify to Board staff. Additionally, it appears that the fire code official has unfettered discretion to impose any standard – including a lesser standard or no standard at all. Sonoma County's responses do not contradict this reasoning or clarify the requirements. Board staff stand by the position that Sonoma County's adoption of the California Fire Code Appendix is meaningless in connection with establishing that the Sonoma County ordinance and Administrative Policy provide minimum standards that equal or exceed the Fire Safe Regulations' road requirement standards.

Again, Sonoma County has had repeated opportunities to identify and provide citations for these standards. Sonoma County repeatedly declines to do so. Until Sonoma County can provide direct and adequate responses to the Board's important questions, the Board has no evidentiary basis to support a decision to certify the Sonoma County ordinance.

Sonoma County Ordinance Issue 2: Concurrent civilian evacuation

A distinct component of the Fire Safe Regulations that is somewhat related to the road conditions issue is that emergency access requirements must accommodate ingress and egress for emergency vehicles *and concurrent civilian evacuation*. Board members and staff have asked Sonoma County on prior occasions to clarify how Sonoma County's ordinance and Administrative Policy satisfy this requirement.

The Administrative Policy states, in an introductory paragraph, that a Fire Inspector will perform an evaluation to "confirm that the proposed development equals or exceeds the below requirements, and the proposed development shall be safely accessed and served in the case of a wildfire, with adequate ingress, egress and the capacity for concurrent evacuation and emergency response."

We acknowledge and appreciate that Sonoma County confirms in its responses that the concurrent evacuation standard is an additional standard to equaling or exceeding "the below requirements." However, Sonoma County does not articulate what standards guide the Fire Official in making that determination.

The first requirement following that statement in the Administrative Policy highlights the importance of that query. The requirement sets a road width standard for existing private roads at 12-ft plus 1-foot of vegetation clearance on both sides. This leads Board staff to question how a 12-foot road, which falls short of the Fire Safe Regulation road width requirement, could be certified as ensuring concurrent civilian evacuation during a wildfire. Nor does this section of the Administrative Policy provide guidance as to what standards guide the Fire Official in making a subjective determination. Absent clarification – which did not occur in response to the Board staff's questions – the Board is appropriately reluctant in determining that the ordinance and Administrative Policy equal or exceed the Fire Safe Regulations.

In addition, Sonoma County routinely refers Board staff to §§ 13-62 and 13-63, in response to Board staff's concerns about the lack of specific articulable standards in the ordinance and Administrative Policy. Sonoma County's reliance is misplaced, however, as those sections merely confer discretionary authority to require compliance with additional fire safety measures. Critically, permissive authority provides no assurances to the Board that additional requirements will be imposed at the level contemplated by the Fire Safe Regulations.

Conclusion

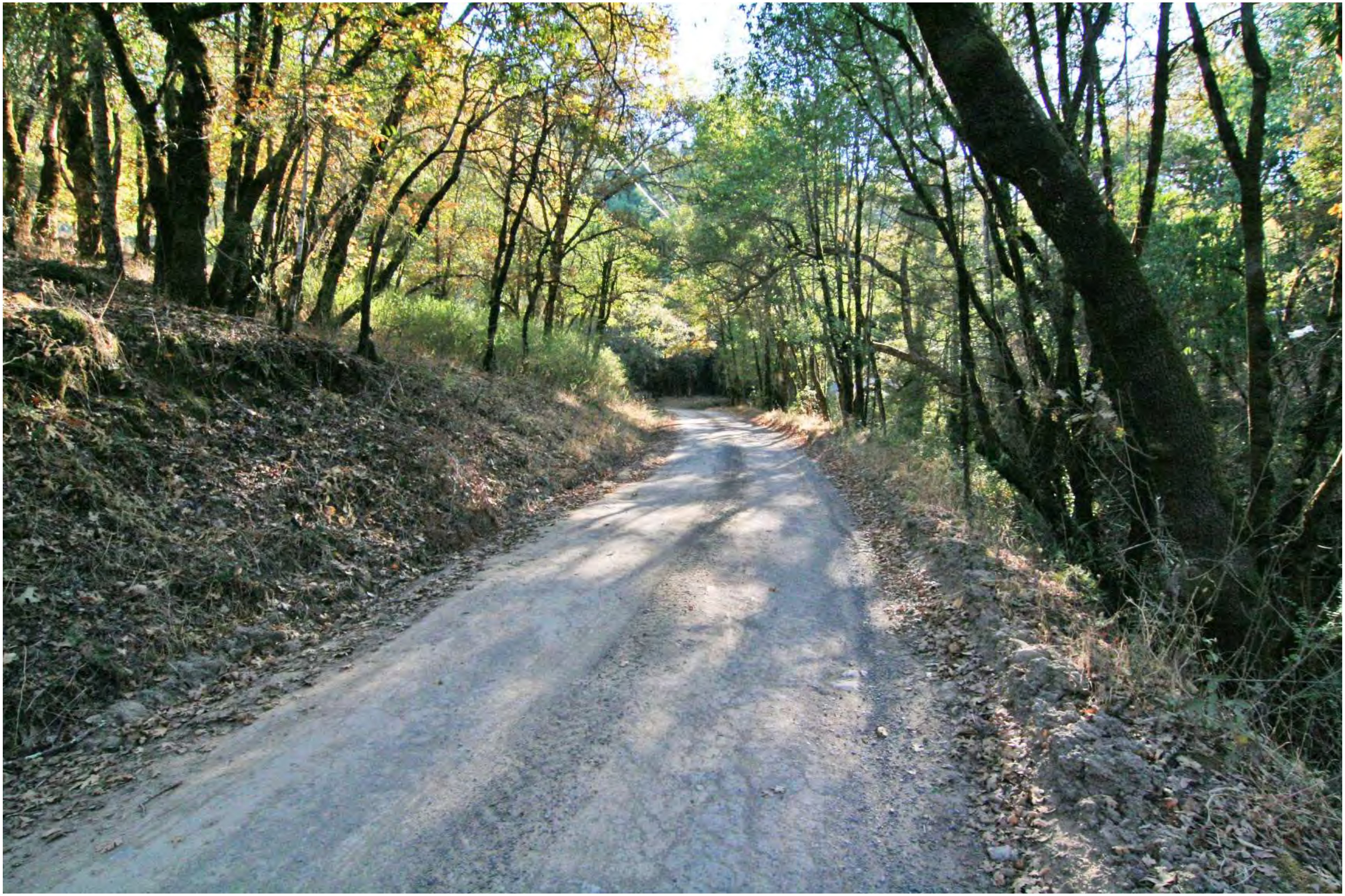
In conclusion, Sonoma County's responses to questions issued by Board staff fail to resolve a number of significant concerns expressed by Board members and staff over the preceding months. The question before the Board at the November 3, 2020, Board meeting is whether the Sonoma County ordinance equals or exceeds the substantive requirements in the Fire Safe Regulations. At this time, the Sonoma County ordinance and Administrative Policy include requirements that fall short of the Fire Safe Regulations and omit standards that are required as a counterpart to other provisions of the Fire Safe Regulations. Until Sonoma County addresses these infirmities, Board staff lack a basis to recommend, and the Board lacks a legal basis to certify, the ordinance as equaling or exceeding the Fire Safe Regulations.

Consistent with our prior communications and correspondence, this letter reflects only the position of Board staff. We wish to be transparent with Sonoma County regarding our ongoing concerns and how we intend to advise the Board in advance of the November Board meeting. Ultimately, the Board will be responsible for making its own assessment on the question of whether the Sonoma County ordinance should be certified as equaling or exceeding the Fire Safe Regulations. Similarly, we respect the right of Sonoma County to disagree with Board staff positions expressed in this letter or the enclosed matrix when the matter is considered by the Board's Joint Committee on November 3, 2020.

Respectfully,

Jeff Slaton
Senior Board Counsel
Board of Forestry and Fire Protection
Jeffrey.Slaton@bof.ca.gov

EXHIBIT 48



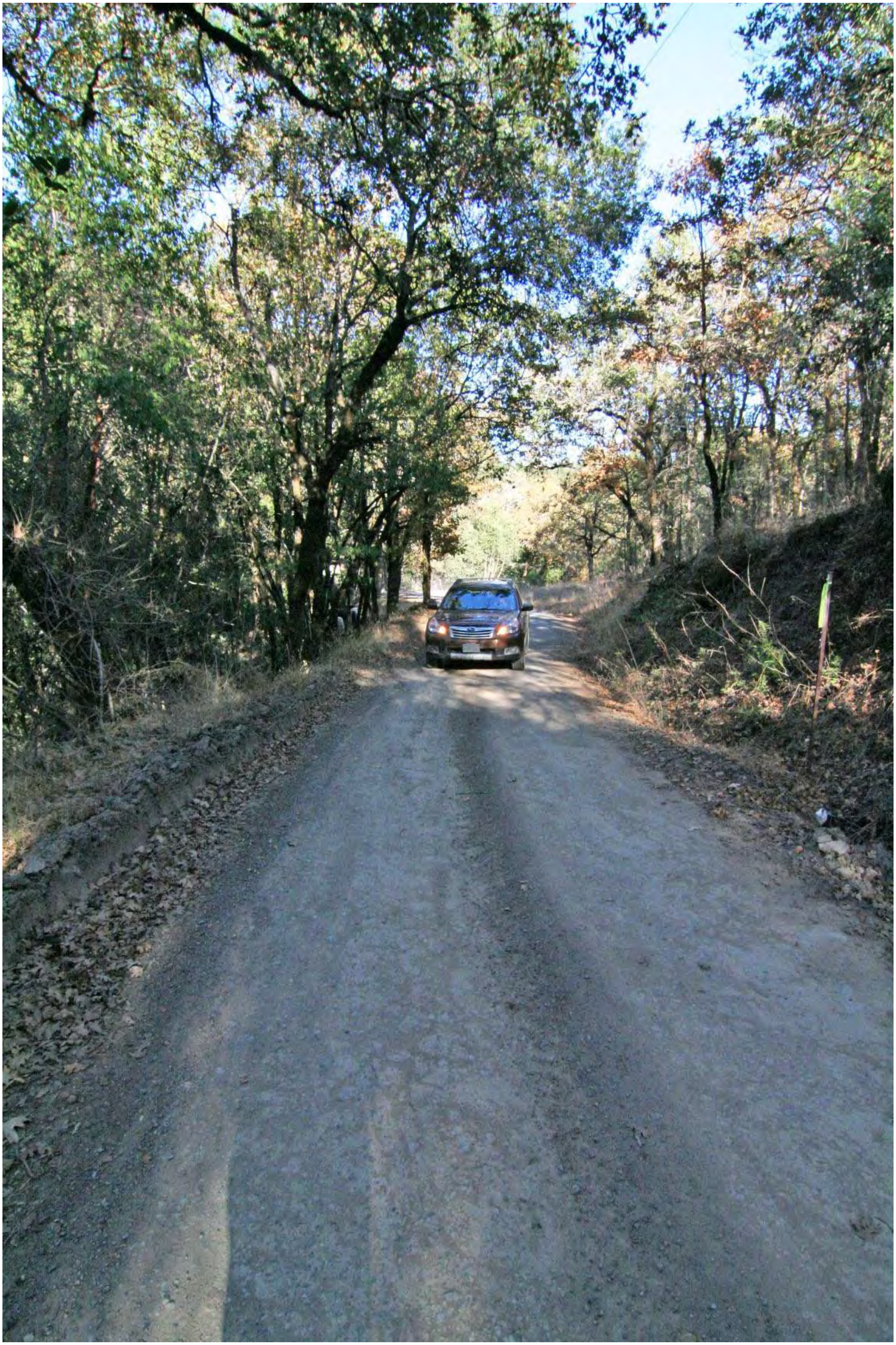
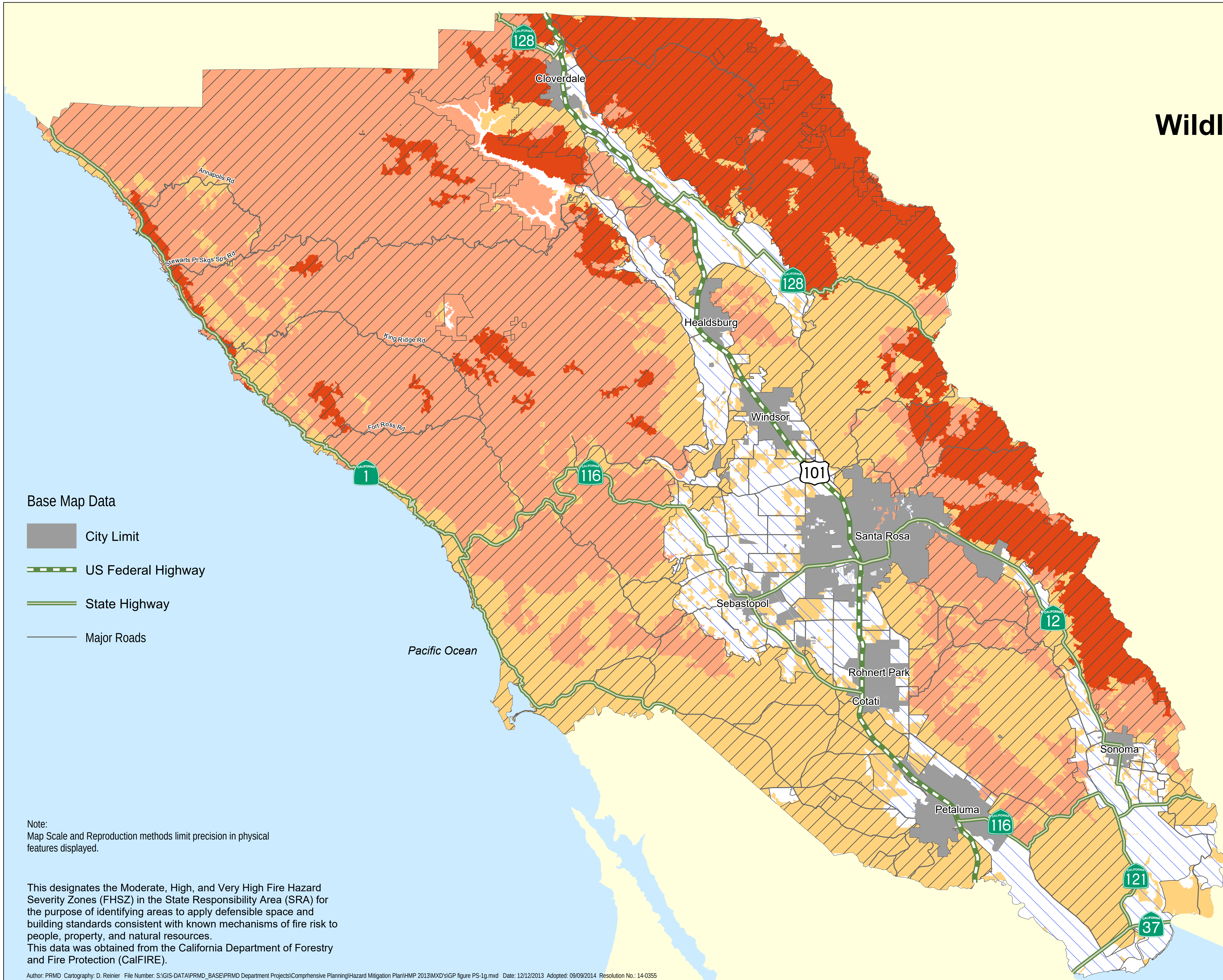


EXHIBIT 49

Figure PS-1g

Wildland Fire Hazard Areas



Fire Protection Responsibility Areas

- LRA - Local Responsibility Area
- SRA - State Responsibility Area

FRAP Fire Hazard Severity Zones

- Very High
- High
- Moderate

Base Map Data

- City Limit
- US Federal Highway
- State Highway
- Major Roads

Note:
Map Scale and Reproduction methods limit precision in physical features displayed.

This designates the Moderate, High, and Very High Fire Hazard Severity Zones (FHSZ) in the State Responsibility Area (SRA) for the purpose of identifying areas to apply defensible space and building standards consistent with known mechanisms of fire risk to people, property, and natural resources.
This data was obtained from the California Department of Forestry and Fire Protection (CalFIRE).

Sonoma County General Plan 2020
Public Safety Element

Permit and Resource Management Department
2550 Ventura Avenue, Santa Rosa, California 95403
707-565-1900
FAX 707-565-1103

Sonoma County General Plan

Author: PRMD Cartography: D. Reinier File Number: S:\GIS-DATA\PRMD_BASE\PRMD Department Projects\Comprhensive Planning\Hazard Mitigation Plan\HMP 2013\MXD's\GP figure PS-1g.mxd Date: 12/12/2013 Adopted: 09/09/2014 Resolution No.: 14-0355

EXHIBIT 50

USGS
science for a changing world

Post-Wildfire Playbook

Release Date: NOVEMBER 13, 2018

New post-wildfire resource guide now available to help communities cope with flood and debris flow danger.

Wildfires burns hundreds of thousands of acres in Oregon each year. After such fires, there can be an increased risk of flooding or debris flows. High intensity wildfires can destroy protective vegetation and alter soil so it is less able to absorb rainfall and snowmelt.

Post-Wildfire Playbook

New post-wildfire resource guide now available to help communities cope with flood and debris flow danger.

Landslides cause about $3.5 billion in damage in the U.S. each year, and claim between 25 to 50 lives. Weeks after the December 2017 Thomas Fire burned the hills above Montecito in Southern California, a debris flow swept through the town, killing more than 20 people.

Communities in areas that have had a wildfire often have questions about what can be done to prevent or prepare for flooding or debris flows, or where to find help with recovery. A task force of state and federal agencies in 2018 compiled a comprehensive guide to help community leaders and emergency management officials in Oregon find answers to these questions. Below is a selection of some commonly asked questions and their answers:

1. ***What is a debris flow?*** A debris flow is a moving mass of mud, sand, soil, rock and water that travels down a slope under the influence of gravity. Debris flows have been recorded at speeds of 35 to 40 miles an hour, much faster than a person can run. Debris flows can sweep up trees, boulders, cars, houses and anything else in their path. Such objects serve as battering rams, knocking down structures in their path.
2. ***Why might a community be at increased risk for flooding or debris flows after a wildfire occurs nearby?*** Depending on how severe a wildfire is, it may bake soil so that a hard crust is formed that repels water. Severe fires can also destroy vegetation that would slow and absorb rainfall, naturally preventing a sudden rise in water level in nearby streams and rivers. With vegetation gone and soils not able to absorb rainfall as they would normally, runoff is greater, making flooding more likely. Debris flows are also more likely when trees and brush that would normally shield the soil from water erosion are killed and consumed by fire.Sediment eroded from newly burned areas

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Partners

The Oregon Department of Forestry

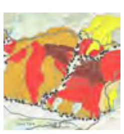
U.S. Army Corps of Engineers

U.S. Forest Service (USFS)

USDA Natural Resources Conservation Service (NRCS) can also fill stream and river channels, causing them to overflow their banks more easily.

3. ***If prior wildfires near a community have not caused any flooding or debris flows, does that mean an area is low-risk for such disasters?*** Everyone lives in an area with some flood risk. The fact that a flood hasn't occurred within recorded history does not mean one won't happen in the future. Every wildfire is different. Lack of flooding or debris flows from past wildfires is not a reliable way to gauge a community's risk after a wildfire. The most recent wildfire may have been larger in size, burned more intensely, burned in steeper terrain or burned more of a particular drainage or landslide-prone area. Rainfall or snowmelt might also be heavier after a new wildfire than after previous ones. Recent construction could also have increased flood risk by reducing the land area that can absorb rainfall. All those factors could create hazards which were not caused by earlier wildfires.
4. ***Can anything be done to prevent destructive post-wildfire flooding and debris flows?*** Communities can take steps to minimize damage from post-wildfire floods and debris flows. The first step is to reduce the risk of a high-intensity wildfire by treating overstocked forestlands near the community to be less vulnerable to high-intensity wildfire through thinning and periodic controlled burns. Through proper planning, communities can also ensure that buildings, roads and other infrastructure are not placed in high-risk areas, such as floodplains and the mouths of steep canyons. Engineering options, such as building retaining walls to channel debris away from populated areas, are also possibilities. These can be expensive and require careful planning to ensure they don't displace damage from one populated area to another.
5. ***Who should I contact in the event of a flood?*** For virtually all emergencies, including flooding, county emergency management offices are the first sources of information, the first responders, and the designated authorities for deciding upon and announcing evacuations.
6. ***What about flood insurance?*** Government agencies cannot advocate for or against flood insurance. We can provide you with information so you can learn as much possible and make an informed decision for yourself. Flood preparation and insurance information is available at FEMA's FloodSmart website: http://www.floodsmart.gov.

Related Content



Date published: JUNE 23, 2018
Status: Active

Emergency Assessment of Post-Fire Debris-Flow Hazards

Estimates of the probability and volume of debris flows that may be produced by a storm in a recently burned area, using a model with characteristics related to basin shape, burn severity, soil properties, and rainfall.

Wildfire can significantly alter the hydrologic response of a watershed to the extent that even modest rainstorms can produce dangerous flash floods and debris flows....

Contacts: Jason Kean, Dennis Staley
Attribution: Natural Hazards, Landslide Hazards Program, Geologic Hazards Science Center

Date published: JUNE 5, 2018
Status: Active

Post-Fire Flooding and Debris Flow

Fast-moving, highly destructive debris flows triggered by intense rainfall are one of the most dangerous post-fire hazards. The risk of floods and debris flows after fires increases due to vegetation loss and soil exposure. Cases of sudden and deadly debris flow are well documented along the western United States, particularly in ...

Attribution: California Water Science Center

Date published: MARCH 2, 2016

Post-Wildfire Landslide Hazards

Post-fire landslides are particularly hazardous because they can occur with little warning, can exert great force on objects in their paths, can strip vegetation, block drainage ways, damage structures, and endanger human life. Our focus is to develop tools and methods for the prediction of post-wildfire landslide activity and hazard delineation.

Attribution: Natural Hazards, Wildfire Hazards

Date published: DECEMBER 30, 2004

Post-Fire Debris Flow Hazards Shown on New USGS Maps

The U.S. Geological Survey (USGS) has posted new maps on the Internet showing basins with the greatest potential for producing mudslides as a result of the devastating October fires in Southern California.

Attribution:

JANUARY 29, 2018

USGS Joins Efforts in Montecito to Assess Debris-Flow Aftermath

A team of USGS geologists provide science support following Montecito post-fire debris-flow event.

Attribution: Natural Hazards, Landslide Hazards Program

EXHIBIT 51

Post-Fire Debris Flow Facts

Debris Flows, Mudflows, Mudslides, and Landslides

Californians who live on or below hillsides -- especially in areas impacted by recent wildfires -- should be aware that the rainy season increases the possibility of potentially dangerous debris flows, a geologic hazard that is often identified in the news as mudflows or mudslides.

A debris flow is a fast-moving mass of material -- slurries of water, rock, soil, vegetation, and even boulders and trees – that moves downhill by sliding, flowing and/or falling.

Debris flows range from a few square yards to hundreds of acres in area, and from a few inches to 50 feet deep. Even smaller ones can be locally dangerous: Imagine trying to walk through a 3-inch deep mass of wet concrete moving at 30 mph.

Conditions that contribute to debris flows:

- Steep slopes
- Heavy rainfall
- Wildfire
- Weak or loose rock and soil
- Earthquakes
- Changes in surface or sub-surface runoff patterns
- Improper construction and grading

Areas impacted by fires are particularly prone to debris flows. The burning of vegetation and soil on slopes more than doubles the rate that water will run off into watercourses.

Debris flow, mudflow, mudslide: why so many names?

They are different kinds of landslides.

A debris flow is far more powerful and dangerous than a mudslide or mudflow. It can move faster and farther, and it's strong enough to carry enormous boulders and entire trees, not to mention cars, k-rails, and sandbags.

Common sight in Montecito after January 2018 debris flows

Many people use the different names interchangeably. However, scientists use each name to talk about a particular kind of landslide. In fact, there are several dozen different kinds of landslides. Scientists have all these names because it helps in understanding the process. Each name gives information about how that landslide moves, where and when it occurs, and what kind of material it carries. When scientists hear the name "debris flow", they know this means a fast-moving, destructive landslide that can kill people.

What is the difference between large, slow-moving landslides and debris flows?

Large, slow-moving **landslides** composed of rock and soil can cause extensive property damage but usually do not result in loss of life.

Bluebird Canyon after a slow moving landslide

Generally, the movement of such large slides is slow. It takes weeks or months for precipitation to percolate through the soil and lubricate a landslide to start detectible movement.

Debris flows are typically more dangerous because they are fast-moving, triggered by short, intense periods of rainfall, and can cause both property damage and loss of life.

The January 2018 Montecito debris flows, in an area of Santa Barbara County impacted by the Thomas fire in December, caused at least 21 fatalities, destroyed more than 100 homes, damaged more than 300 other homes, and shut down Highway 101 for nearly two weeks. California Geological Survey scientists estimated the Montecito debris flow as having speeds of 10-15 mph, being up to 25-30 feet deep, and capable of carrying boulders as large as a tow truck.

What can residents do?

First and foremost, it is critical that residents heed evacuation warnings from local officials. Debris flows can destroy everything in their path. They kill people. The only way to stay safe is to not be in their path.

In the absence of an official notice, residents should pay attention to evolving conditions around their homes, and be aware of the following:

- **Be ready for debris flows for 2-5 years after a wildfire.**
  Don’t worry about every storm, it takes an intense rain (typically about ½ inch per hour – like being in a thunderstorm) on a recently burned slope to trigger a debris flow.
- **Pay attention to official weather forecasts.**
  Just a few minutes of intense rain can start a debris flow. The National Weather Service will issue a flash flood watch or warning for your area when rainfall is anticipated to be intense. Also – and this is important -- it’s the rain in the mountains that will start the debris flow, even if it's not raining - or only sprinkling - where you live.
- **Don’t rely on what you’ve seen in past debris flows.**
  Debris flows can hit new areas or return to previous areas; they might be smaller - or larger - the next time. Whatever happened before, the next time could be different.

- **Get out before the storm arrives.**
  Debris flows move fast! If you wait to see if a debris flow is coming your way, it will be too late to leave safely. You cannot outrun a debris flow.
- **If you must shelter in place, choose your spot in advance and stay alert.**
  Find the highest point nearby (such as a second story room or the roof) and be ready to get there at a moment's notice. Listen and watch for rushing water, mud, and unusual sounds. Survivors describe sounds of cracking, breaking, roaring, or a freight train in advance of a debris flow.
- **Never underestimate a debris flow.**
  Debris flows can start in places they've never been before. They can leave stream channels and plow through neighborhoods. When a debris flow is small, people can control it with walls, k-rails, sandbags. When a debris flow is big enough, nothing can stop it.
- **Expect other flood dangers.**
  Storms that can cause debris flows can also cause more common flooding dangers.
- **Turn Around, Don't Drown!®**
  Never drive, walk, or bicycle through a flooded road or path. Even a few inches of water can hide currents that can sweep you away. Also, the water level can rise before you finish crossing. According to FEMA, a foot of water can float vehicles.
- **Debris flows can also occur in the absence of fire during heavy winters.**
  Be aware that the soil may be waterlogged and that more rain can trigger debris flows.
- **Watch for new springs or seeps and excess surface erosion on slopes on and around your property.**
  If there are nearby streams, do they appear muddier than normal?
- **Avoid sleeping in lower-floor bedrooms on the sides of houses that face slopes.**
  Debris flows can bury people sleeping in lower-floor bedrooms adjacent to hazardous slopes.
- **Sign-up for emergency alerts from your local emergency management agency.**

More about what we do:

The California Geological Survey (CGS) is one of DOC's divisions.

CGS creates a wide variety of landslide maps for different purposes. We provide geologic analysis, input and advice regarding post-fire debris flows and related hazards when requested by the Governor's Office of Emergency Services (CalOES) and the California

Janis Hernandez of CGS stands under a boulder wedged into tree branches about 10 feet high by the Montecito debris flow

Department of Forestry and Fire Protection (CAL FIRE).

Over the past 15 years, CGS has been called upon 40 times to provide input on post-fire geologic hazards.

Our geologists with expertise in slope stability and landslide hazards typically work hand-in-hand with other technical specialists such as hydrologists and engineers to assess post-fire impacts. We use a number of tools to assess the potential for post-fire debris flows, including geologic, soils, climatologic and topographic information; aerial imagery and satellite data; and hydrologic and debris flow models developed by agencies such as the US Geological Survey. This information is coupled with aerial reconnaissance and on-the-ground observations of site-specific conditions to develop an understanding of vulnerable areas and risks.

Based upon this information, our geologists develop summary reports noting the areas where property and lives may be at risk to geologic hazards such as debris flow. This information is transferred via CalOES to the appropriate agencies to inform emergency response plans and mitigation measures.

Special thanks to Dr. Suzanne Perry, Disaster Scientist, U.S. Geological Survey.

EXHIBIT 52

permit SONOMA

PROPOSED
Mitigated Negative Declaration

Publication Date:	December 11, 2020
Public Review Period:	12/11/20 to 1/11/21
State Clearinghouse Number:	
Permit Sonoma File Number:	**UPC19-0002**
Prepared by:	Southisone S. Garner
Phone:	(510) 845-7549

Pursuant to Section 15071 of the State CEQA Guidelines, this proposed Mitigated Negative Declaration and the attached Initial Study, including the identified mitigation measures and monitoring program, constitute the environmental review conducted by the County of Sonoma as lead agency for the proposed project described below:

Project Name:	**UPC19-0002, Gordenker Ranch Cannabis Cultivation**
Project Applicant/Operator:	Timothy Crites representing CSCF, LLC. (cultivation) & Joseph Pearson representing WWCMC, Inc. (processing)
Project Location/Address:	110 Trinity Road, Glen Ellen
APN:	053-110-001, 053-130-009 (part)[1]
General Plan Land Use Designation:	Land Intensive Agriculture (LIA)
Zoning Designation:	LIA B6 100, LG/MTN RC50/25 SR
Decision Making Body:	Sonoma County Board of Supervisors
Appeal Body:	N/A
Project Description:	See Item III, below

[1]A lot line adjustment divided APN 053-130-009 into two parts, one of which was combined with APN 053-110-001, and the other part combined with the adjoining parcel to the north (APN 053-100-015). The parcel maps have not been updated to reflect this.

ENVIRONMENTAL FACTORS POTENTIALLY AFFECTED:

The environmental factors checked below would be potentially affected by this project, involving at least one impact that is a "Potentially Significant Impact" or "Less than Significant with Mitigation" as indicated in the attached Initial Study and in the summary table below.

Table 1. Summary of Topic Areas

Topic Area	Abbreviation	Yes	No
Aesthetics	VIS		No
Agricultural & Forestry	AG		No
Air Quality	AIR	Yes	
Biological Resources	BIO	Yes	
Cultural Resources	CUL		No
Energy	ENE		No
Geology and Soils	GEO		No
Greenhouse Gas Emission	GHG		No
Hazards and Hazardous Materials	HAZ		No
Hydrology and Water Quality	HYDRO		No
Land Use and Planning	LU		No
Mineral Resources	MIN		No
Noise	NOISE	Yes	
Population and Housing	POP		No
Public Services	PS		No
Recreation	REC		No
Transportation	TRAF		No
Tribal Cultural Resources	TCR		No
Utility and Service Systems	UTL		No
Wildfire	WILD		No

RESPONSIBLE AND TRUSTEE AGENCIES

The following lists other public agencies whose approval is required for the project, or who have jurisdiction over resources potentially affected by the project.

Table 2. Agencies and Permits Required

Agency	Activity	Authorization
California Department of Food and Agriculture (CDFA)	Issuance of state cannabis license	Medicinal and Adult-Use Cannabis Regulation and Safety Act
State Water Resources Control Board (SWRCB)	General Construction Permit	National Pollutant Discharge Elimination System (NPDES)
San Francisco Bay Regional Water Quality Control Board (SFBRWQCB)	Discharge or potential discharge to waters of the state	California Clean Water Act (Porter Cologne) – Waste Discharge requirements, general permit or waiver
California Department of Fish and Wildlife (CDFW)	Lake and streambed alteration notification/ agreement	Fish and Game Code, Section 1600 et seq.
Bay Area Air Quality Management District (BAAQMD)	Stationary air emissions/ Green House Gas Emissions/ Emergency backup generator/Building demolition	BAAQMD Rules and Regulations (Regulation 2, Rule 1 – General Requirements; Regulation 2, Rule 2 – New Source Review; Regulation 9, Rule 8 – NOx and CO from Stationary Internal Combustion Engines; Regulation 11, Rule 2 – Asbestos Demolition, Renovation and Manufacturing); and other BAAQMD administered Statewide Air Toxics Control Measures (ATCM) for stationary diesel engines

ENVIRONMENTAL FINDING:

Based on the evaluation in the attached Initial Study, I find that the project described above will not have a significant adverse impact on the environment, provided that the mitigation measures identified in the Initial Study are included as conditions of approval for the project, and a Mitigated Negative Declaration is proposed. The applicant has agreed in writing to incorporate identified mitigation measures into the project plans.

Southisone S. Garner 12/11/2020

Prepared by: Southisone S. Garner Date:

12 / 11 / 2020 12 / 11 / 2020

Applicant: Timothy Crites representing CSCF, LLC Date:
Joseph Pearson representing WWCMC, Inc.

permit SONOMA

Initial Study

I. INTRODUCTION:

Sonoma County has received an application from CSCF, LLC (CSCF) for a Use Permit to allow commercial cannabis cultivation at 101 Trinity Road, Glen Ellen, California. Sonoma County has also received an application from WWCMC, Inc. (WWCMC) for a Use Permit to allow a centralized cannabis processing center at 101 Trinity Road, Glen Ellen, California. The two Use Permit Application requests are from two separate legal entities (CSCF for cultivation; WWCMC for processing) but because their operations would be located on the same parcel, Permit Sonoma has determined that they should be evaluated for CEQA purposes as one project.

CSCF is requesting approval for the construction of a greenhouse/nursery/propagation/head house facility that would support operation of 10,000 square feet of mixed-light cultivation canopy area in four greenhouses ("rooms"), 5,000 square feet of indoor wholesale nursery canopy area, a 5,880 square-foot head house, a 5,880 square-foot utility room, and 10,890 square feet of greenhouse propagation. In addition, CSCF is requesting 28,560 square feet of outdoor cultivation (in two areas; one for 15,720 square feet of canopy and the other for 12,840 square feet of canopy). The greenhouse "rooms," nursery, processing, head house, utility room, and propagation, would be in one structure, with an additional 5,880 square feet of plenum space divided equally at each end of the building.

WWCMC is requesting approval of a use permit for converting an existing barn structure into a centralized cannabis processing center (only nine such facilities are authorized in the County). Existing land uses surrounding the project site include a quarry to the east (that is ceasing operations and has applied for an outdoor cannabis cultivation permit, currently under the penalty relief program), State Highway 12 to the west (and a residential subdivision west of Highway 12), rural residences to the south, and a vineyard to the north (that has applied for an outdoor cannabis cultivation permit, currently under the penalty relief program). The quarry property to the east and the vineyard property to the north are both owned by the same owner of the project property (Gordenker Turkey Farms).

A referral letter was sent to the appropriate local, state, and interest groups who may wish to comment on the project.

This report is the Initial Study required by the California Environmental Quality Act (CEQA). The report was prepared by Southisone S. Garner, Contract Project Planner with MIG. Information on the project was provided by the two project applicants, GDCF, LLC and CSCF, LLC. Other reports, documents, maps, and studies referred to in this document are available for review at the Permit and Resources Management Department (Permit Sonoma).

Please contact Southisone S. Garner, Contract Planner, at (510) 845-7549 for more information.

II. SITE LOCATION

The project site is on a 29.2-acre parcel (APN 053-110-001 plus an approximate 9.53-acre portion of APN 053-130-009, combined as a result of a 2015 lot line adjustment) located east of State Highway 12, off of Trinity Road, near Glen Ellen. The project site has a General Plan Land Use Designation of Land Intensive Agriculture and is zoned Land Intensive Agriculture (LIAB6 100, LG/MTN RC50/25 SR). The site currently contains a residence and an accessory dwelling unit, a barn (that replaced a former barn destroyed in the 2017 Nuns Fire), a few agriculture structures or partial structures remaining from the 2017 Nuns Fire, a concrete pad, and a 150,000-gallon water storage tank. The project is currently authorized to operate under the County's Penalty Relief Program. Parcels in the project area range from approximately 23 acres to 263 acres east of Highway 12 and north of Trinity Road, but on the other side of Trinity Road they are smaller (two acres to 28 acres). Immediately west of Highway 12 and north of West Trinity Road the parcels generally range between one to 1.5 acres (in a residential area) but farther west toward Dunbar Road the parcels again become larger. Figure 1 shows the project site vicinity. Figure 2 shows the project site aerial.

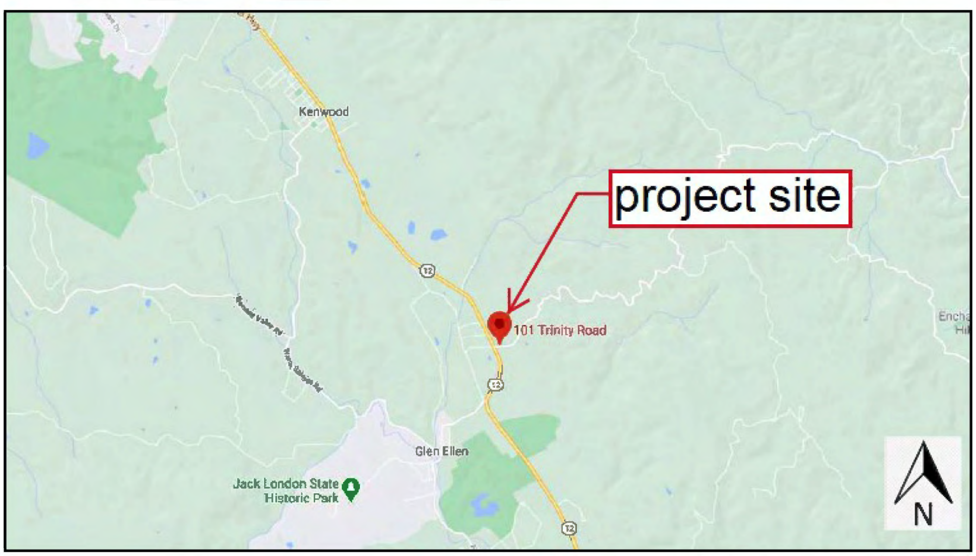


Figure 1. Project Site Vicinity
(Source: Google Maps)

Figure 2. Project Site Aerial
(Source: Google Maps)

III. PROJECT OVERVIEW

The project proposes a commercial cannabis cultivation operation consisting of outdoor cannabis cultivation, mixed-light cannabis cultivation (in greenhouses), indoor wholesale nursery, and propagation to occur in a greenhouse/nursery/ propagation/head house facility. In addition, a centralized processing center would be located in an existing barn farther to the north. The project would also construct fencing, a hammerhead turnaround and a roadway turnout, driveway and interior access road modifications (as determined necessary by the County), a 24-space parking lot, and other infrastructure needed to support the operation, including a proposed backup generator and fuel storage area, a new electrical transformer, and a propane tank and pad, all near the proposed processing building ("existing" barn), a fire hydrant and dedicated water pipe connecting to the water storage tank, and ADA restroom. The project would disturb an area of approximately 173,700 square feet, or roughly four acres of total disturbance.

The operation would employ a maximum of 17 employees (12 full-time, and five additional seasonal employees during harvest). The site would be closed to the public and would not contain any retail components. The proposal includes the construction of supporting infrastructure including a new septic tank and a wastewater pipeline to convey project wastewater off the site to a permitted leachfield on the adjacent northern parcel.

The project construction activities would include earthwork, grading, and construction of the greenhouse/nursery/propagation/head house facility. The project construction is proposing a maximum cut of 4,004 cubic yards (CY), and a maximum fill of 4,108 CY.

The project would be located in a scenic landscape unit, as designated by the Sonoma County Zoning Ordinance.[2] The project site also has a Riparian Corridor designation by the Sonoma County General Plan.[3]

IV. EXISTING FACILITY

The property is partly undeveloped. In addition to the existing residence and accessory dwelling unit, other on-site structures include former agricultural structures and remains of structures burned in the 2017 Nuns Fire east of the site's center where the proposed project cannabis facilities would be located. Figure 3 shows the overall site plan.

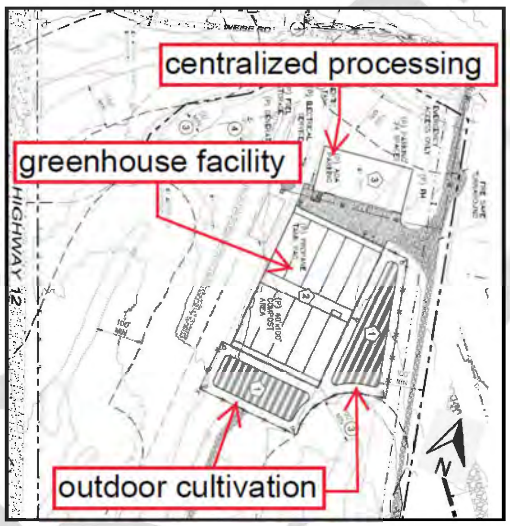


Figure 3. Overall Site Plan
(Source: Adobe Associates, Inc.)

V. SETTING

The project site is in the southeastern part of Sonoma County near the community of Glen Ellen, adjacent to State Highway 12. The site is approximately six miles north of Sonoma and about 3 miles southeast of Kenwood (and approximately 13 miles southeast of downtown Santa Rosa). To the west are the Sonoma Mountains. To the east are the Mayacamas Mountains. The site is an area characterized by large parcels east of Highway 12, with smaller

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[2] Sonoma County. "Proposed Scenic Landscape Units," https://sonomamap.maps.arcgis.com/apps/webappviewer/index.html?id=84689931cabc4c3785312f3fcebae18f, accessed 9/28/20.

[3] Sonoma County. General Plan 2020 Open Space Scenic Resource Areas, Figure OSRC-1, https://sonomacounty.ca.gov/PRMD/Long-Range-Plans/General-Plan/Open-Space-Scenic-Resource-Areas/, accessed 9/28/20.

residential parcels west of Highway 12. Though the site has a relatively level grade, the slope increases farther to the east, as elevation increases into the mountains. The project parcel is zoned Land Intensive Agriculture (LIA) B6 100, LG/MTN RC50/25 SR. The project site is not in the boundaries of a specific plan; however, the site is subject to the Taylor/Sonoma/ Mayacamas Design Guidelines. The area around the project site has some development with generous amounts of open space. There are vineyards and ranches along Highway 12 both to the north (toward Kenwood) and to the south (toward Sonoma).

The project site contains a 150,000-gallon water tank. The project would receive groundwater from a private well on a neighboring parcel, for which an existing water pipeline is already in place. Though the existing residence and accessory dwelling unit are served by on-site private septic systems, the project would not include a septic system but proposes to install a pipeline to convey project wastewater to an adjoining parcel with a permitted leachfield.

Access to the site is from Trinity Road, via State Highway 12. Weise Road, north of the project site, is a private road, and would only be available for emergency access to the site. Public access is not proposed.

Calabazas Creek is approximately 2,500 feet west of the project site. Sonoma Creek is about 1.3 miles southwest of the project site (by straight line).

Existing Uses: The project site is located on a 29.2-acre parcel that has a residence, an accessory dwelling unit, a barn (built as a replacement for the former barn destroyed in the 2017 Nuns Fire), agricultural structures and remains of structures burned in the 2017 Nuns Fire, a concrete pad, and a 150,000-gallon water storage tank. The property has a history of agricultural and ranching uses, including raising chickens, and grazing for goats and cattle. Similar activities have recently occurred (livestock and poultry). The site also has a one-acre vegetable garden.

Topography and Drainage: The topography of the project site is relatively level with slopes averaging about six percent. The parcel ranges in elevation from about 325 feet at the lowest point (near Highway 12) to approximately 360 feet above mean sea level (msl) at the highest point (near the eastern project boundary). The outdoor and mixed-light cultivation sites are proposed in an area where former agricultural buildings were located and where the ground has already been leveled. The northern third of the project site drains north toward a seasonal wetland swale that connects to an unnamed ephemeral creek that flows west into Calabazas Creek. The southeastern third of the site flows south into a long and wide seasonal wetland swale that flows through a culvert under Trinity Road before connecting to the south branch of Calabazas Creek. The southwestern third of the site flows west into seasonal wetland swales or directly into a roadside drainage ditch along Highway 12.

Vegetation: The parcel consists of annual grassland, oak woodland, mixed forest, seasonal wetland, and riparian woodland, with ruderal or disturbed habitat remaining after the 2017 Nuns Fire. Grasslands and seasonal wetlands were also affected by the fire but have generally recovered. The riparian woodland habitat was generally unaffected.

VI. PROJECT DESCRIPTION

Proposed Buildings and Uses: The project proposes to construct a greenhouse/nursery/propagation/head house facility, modifications to an existing barn to convert it into a centralized cannabis processing center, a 24-vehicle parking lot, other driveway and access improvements as determined necessary by the County, and two outdoor cultivation areas. Chemical storage (pesticide and fertilizer) would be contained in a separate room in the head house. The operation would be required to maintain permits from the Fire Prevention Division, Certified Unified Program Agency (CUPA) of Sonoma County and the Agricultural Commissioner, as applicable. Figure 4 shows the proposed greenhouse and processing facilities details on the site.

Employees and Hours of Operation: The cannabis operation would employ up to 12 full-time staff, with up to five part-time seasonal staff.

Outdoor harvesting activities and mixed-light cultivation activities would be conducted seven days a week, 24-hours per day, as needed. Deliveries and shipping and outdoor processing activities, including drying and trimming, would be limited to the hours of 8:00 AM to 5:00 PM.

Cultivation Operation: The project proposes two outdoor areas and mixed-light cultivation in four greenhouse "rooms" within the greenhouse/nursery/propagation/head house facility. Fencing would be constructed around the outdoor and mixed-light cultivation area (see below under Security for more details). The proposed structure would follow a design similar to a "Venlo style" greenhouse (see Figure 5). Each room would be made up of three 14-foot wide sections (for a room width of 42 feet) (see Figure 6), and the sidewall height would be approximately 16 feet (not including the roof ridge). The west side of the structure would have a solid wall, and the other three sides would use either glass or rigid plastic (e.g., clear hard poly). Interior rooms would be divided by glass or rigid plastic walls, with curtains or a similar mechanism to isolate and control light when needed. The outdoor cultivation areas would total 28,560 square feet of canopy (one area with 15,720 square feet, and the other area with 12,840 square feet). The cannabis plants would be cultivated in grow bags that are in ground or in raised beds.

The mixed-light cultivation portion of the operation would occur in four greenhouse rooms; each room would be approximately 5,880 square feet with a canopy area each of 2,500 square feet. The greenhouses would use high efficiency LED lights to supplement daytime light, as necessary.

The indoor wholesale nursery portion of the operation would occur in two fully enclosed rooms within the greenhouse; each room would be 5,880 square feet with a canopy area each of 2,500 square feet.

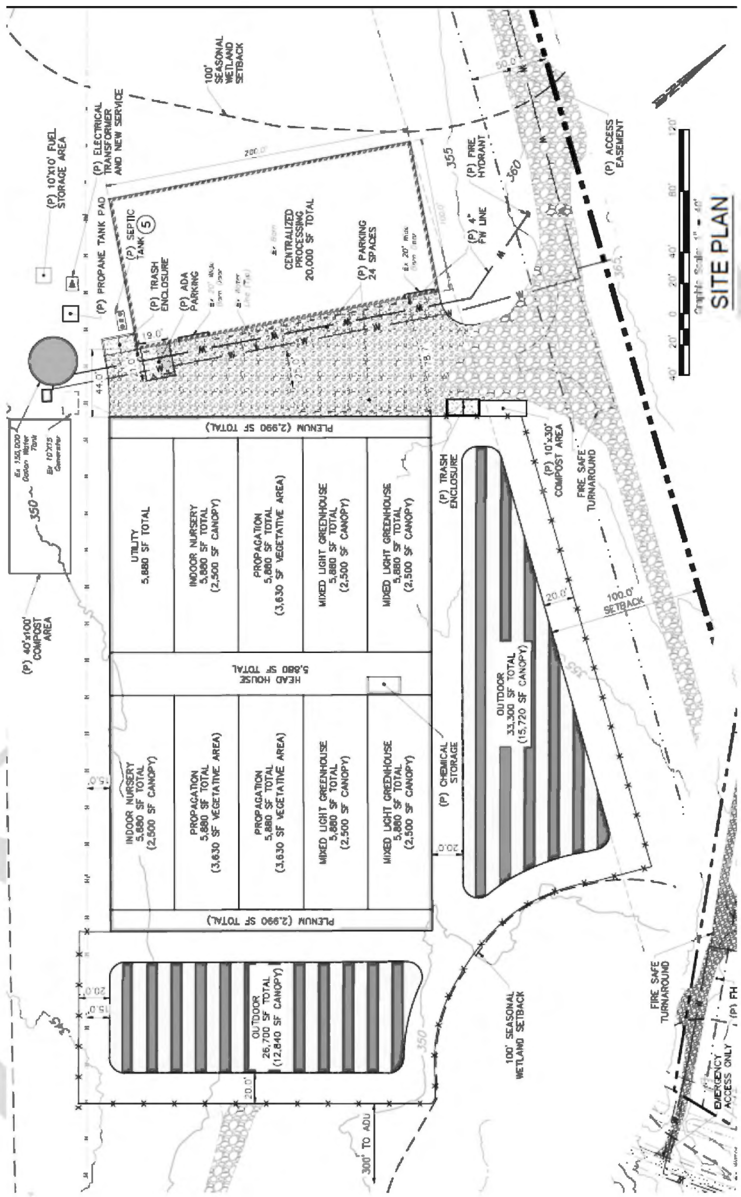

Figure 4. Greenhouse and Processing Facilities Detail
(Source: Adobe Associates, Inc.)

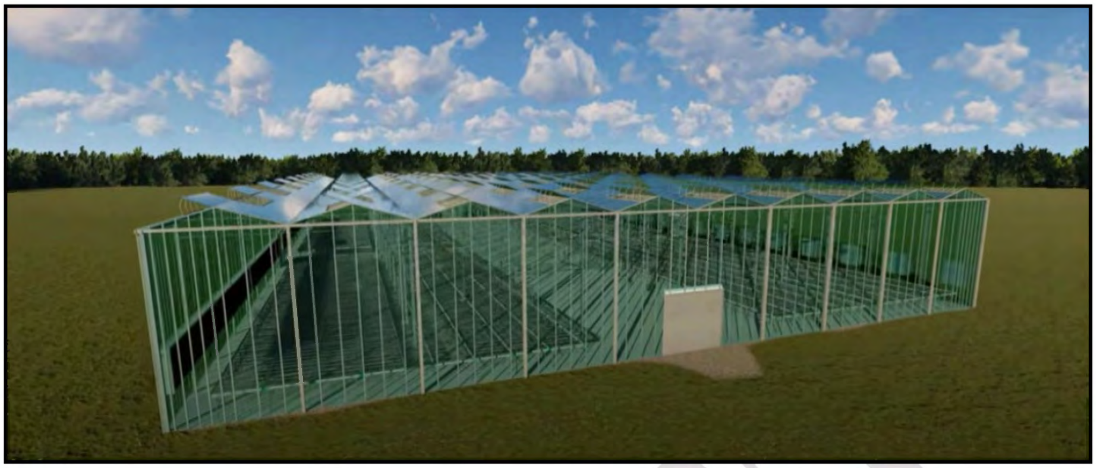

Figure 5. Example "Venlo style" Greenhouse
(Source: Applicant)

Figure 6. Conceptual Layout – Exterior View
(Source: Applicant)

Processing: Harvested cannabis from the outdoor cultivation areas would be stored in the greenhouse/nursery/propagation/head house facility or taken to the centralized processing center. Either activated carbon filters or an odor neutralizing agent would be used in the greenhouse and processing building interiors or exhaust systems to filter odors. Where possible, exhaust air would be directed toward the interior of the parcel to reduce off-site odor effects.

Security: Access to the property would be controlled by a coded gate. Security fencing would be installed around the outdoor cultivation areas with motion-activated lighting and cameras.

Access: On-site circulation is via an existing gravel driveway. The driveway would lead to the parking lot, which would provide access to the greenhouse/nursery/propagation/head house facility and the centralized processing center.

Parking: On-site parking would be provided between the greenhouse/nursery/propagation/ head house facility and the centralized processing center and would accommodate 24 vehicles.

Sewage Disposal: The residence and accessory dwelling unit are connected to existing septic systems. However, these systems would not be used for the proposed project, which proposes to collect wastewater in a new on-site septic tank before conveying it off-site through a proposed pipeline to a permitted leachfield on the adjacent northern parcel.

Water Supply: The project site contains an 150,000-gallon water storage tank. A water pipeline currently transports water to the project site from an adjacent parcel with an existing, permitted well. No changes are proposed for this system.

Energy Supply: The project proposes installation of a new electrical transformer near the proposed emergency backup generator. Electrical power for the operation would be supplied by Sonoma Clean Power.

Waste Management: All cannabis waste generated on-site would be securely stored indoors before being rendered unusable and composted for reuse in the cultivation operation. The compost area for WWCMC would be approximately 40 feet by 100 feet and located south of the water tank and west of the greenhouse/nursery/propagation/ head house facility. CSCF is proposing a smaller compost enclosure of approximately 10 feet by 30 feet. Cannabis green waste would be ground up and mixed with soil and/or mulch to create a mixture that consists cannabis and non-cannabis waste prior to composting.

Landscaping: The project proposes to plant a mix of native trees and shrubs along the western and southern sides of the project site. All vegetation would be native, and drought and fire resistant.

Construction: Construction activities (demolition, site preparation, grading, and building construction) would take approximately 152 working days (about six months). Preliminary cut and fill requirements have been estimated at a maximum cut of 4,004 cubic yards (CY), and a maximum fill of 4,108 CY, for a net fill of 104 CY. The area proposed for outdoor cultivation and the buildings contained or still contain remaining agricultural buildings or partial structures, so minimal ground disturbance would be necessary beyond clearing the project site for the proposed, new activities. No trees are proposed for removal. Erosion control best management practices (BMPs) mandated by Sonoma County would be required during construction. In addition, dust control measures mandated by Sonoma County would be implemented throughout construction.

VII. ISSUES RAISED BY THE PUBLIC OR AGENCIES

A referral packet was drafted and circulated to inform and solicit comments from selected relevant local and state agencies, and to special interest groups who were anticipated to take an interest in the project.

The project planner has received responses to the referral from the following agencies: Sonoma County Public Health Division Environmental Health & Safety Program, Permit Sonoma Natural Resources Geologist, Permit Sonoma Project Review Health Specialist, Permit Sonoma Fire and Emergency Services Department, Sonoma County Department of Transportation & Public Works, Permit Sonoma Grading & Storm Water (G&SW) Section, the Northwest Information Center, State Water Resources Control Board, Native American Heritage Commission, Middletown Rancheria, Stewarts Point Rancheria Band of Kashia Pomo Indians, and Lytton Rancheria. The referral responses included several project use permit conditions of approval.

VIII. OTHER RELATED PROJECTS

Five other applicants have submitted cannabis cultivation applications within three miles of the project site, ranging from an 1,891 square-foot medical cannabis dispensary to one-acre of outdoor cultivation. These projects are currently being processed through the County cannabis permit program. Two of the projects are operating under Penalty Relief.

IX. EVALUATION OF ENVIRONMENTAL IMPACTS

This section analyzes the potential environmental impacts of this project based on the criteria set forth in the State CEQA Guidelines and the County's implementing ordinances and guidelines. For each item, one of four responses are given:

No Impact: The project would not have the impact described. The project may have a beneficial effect, but there is no potential for the project to create or add increment to the impact described.

Less Than Significant Impact: The project would have the impact described, but the impact would not be significant. Mitigation is not required, although the project applicant may choose to modify the project to avoid the impacts.

Potentially Significant Unless Mitigated: The project would have the impact described, and the impact could be significant. One or more mitigation measures have been identified that will reduce the impact to a less than significant level.

Potentially Significant Impact: The project would have the impact described, and the impact could be significant. The impact cannot be reduced to less than significant by incorporating mitigation measures. An environmental impact report must be prepared for this project.

Each question was answered by evaluating the project as proposed; that is, without considering the effect of any added mitigation measures. The Initial Study includes a discussion of the potential impacts and identifies mitigation measures to substantially reduce those impacts to a level of insignificance where feasible. All references and sources used in this Initial Study are listed in the Reference section at the end of this report.

The project applicants, CSCF, LLC and WWCMC, Inc., has agreed to accept all mitigation measures listed in this Initial Study as conditions of approval for the proposed project, and to obtain all necessary permits, notify all contractors, agents and employees involved in project implementation and any new owners should the property be transferred to ensure compliance with the mitigation measures.

1. AESTHETICS

Except as provided in Public Resources Code Section 21099, would the project:

a) Have a substantial adverse effect on a scenic vista?

Comment:
The project is in an area designated as SR (Scenic Resources Combining District) and identified as a Community Separator on Sonoma County General Plan Figure OSRC-1, Scenic Resource Areas. Highway 12 is a Scenic Corridor adjacent to the western project boundary. The remainder of the project site is designated as Community Separator.

Pursuant to the Sonoma County Zoning Regulations,[4] structures located within scenic corridors shall be subject to setbacks of thirty percent (30%) of the depth of the lot to a maximum of two hundred feet (200') from the centerline of the road, with development restricted within the setback. The proposed project structures would be located approximately 600 feet from the centerline of Highway 12.

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[4]Sonoma County Code, Article 64 Scenic Resources Combining District, https://library.municode.com/ca/sonoma_county/codes/code_of_ordinances?nodeId=CH26SOCOZORE_ART64SRSCRECODI, accessed 9/25/20.

The project is also is designated as a Community Separator. Generally, according to the Zoning Regulations (Section 26-64-020, Community separators and scenic landscape units), structures located within community separators and scenic landscape units need to:

(1) be sited below exposed ridgelines;

Explanation: The proposed project structures would not be sited on an exposed ridgeline.

(2) use natural landforms and existing vegetation to screen them from view from public roads (on exposed sites, screening with native, fire resistant plants may be required). In addition, cuts and fills should be discouraged; where practical, driveways should be screened from public view; and utilities should be placed underground, where economically practical;

Explanation: Existing trees near Highway 12 and the distance of structures from Highway 12 would obscure views. As discussed in the Project Description, no existing on-site trees are proposed to be removed, and the project proposes to plant a row of trees and shrubs, along with a fence with vines, as screening for potential views from public vantage points along Highway 12. As required by the County, utilities would be placed underground, to the extent practical.

The proposed project is in the Taylor/Sonoma/Mayacamas Mountains combining zone and would be required to follow those local development guidelines, which are *"intended to reduce the visual impacts of residential related development within the Scenic Landscape Units of Taylor, Sonoma, and Mayacamas Mountain areas as visible from public roads."*[5] Although the project is not residential, it would comply with other relevant requirements such as site planning (siting), lighting, landscaping, etc., some of which are also covered in the County Code requirements for cannabis projects. The project would be consistent with the following Taylor/Sonoma/Mayacamas Mountains local development standards:

b. Siting Criteria. All features of site development that are subject to these standards shall, to the extent feasible, be located to be substantially screened when viewed from public roads. The term "viewed" shall mean what is visible to a person of normal eyesight from public roads.

Explanation: The project location would provide for natural screening due to existing vegetation and distance from public roads.

[5]Sonoma County Code, Section 26-90-120 – Taylor/Sonoma/Mayacamas Mountains, https://library.municode.com/ca/sonoma_county/codes/code_of_ordinances?nodeId=CH26SOCOZORE_ART90LOARDEGU_S26-90-120TASOMAMOMT, accessed 9/25/20.

d. Use of existing vegetation and site features.

1. Existing vegetation or existing topographic features shall be used, where feasible, to substantially screen site development as seen from public roads.

Explanation: The existing trees and other foliage and the distance of project structures from Highway 12 provide substantial screening.

2. Grading and removal of trees and other mature vegetation should be minimized. Avoid removal of specimen trees, tree groupings, and windbreaks.

Explanation: The project does not propose to remove any trees or other mature vegetation. Proposed net grading would be minimal (approximately 104 cubic yards of net fill; 4,004 cubic yards of cut, and 4,108 cubic yards of fill).

3. The applicant shall provide the Department with a site plan indicating if any vegetation is proposed, or topographic features proposed to be removed as well as vegetation to be retained and used to substantially screen the site development.

Explanation: The project submitted a preliminary landscaping plan with its application materials that shows the vegetation (trees and shrubs) proposed to be planted along the western and southern sides of the project site in order to screen the development.

4. Where existing topography and vegetation would not screen structures from view from public roads, landscaping shall be installed consisting of native vegetation in natural groupings that fit with the character of the area in order to substantially screen structures from view.

Explanation: The trees and shrubs proposed in the landscaping plan would include a mix of native trees, shrubs, and fencing with vines; all vegetation would be native, and drought and fire resistant.

e. Ridge-line Development. On hills and ridges, no portion of a single-family dwelling, appurtenant structure(s), or any portion of a structure shall appear against the sky when viewed from public roads.

Explanation: The proposed project structures would not be sited on an exposed ridgeline.

f. Roads and Driveways. The grade and alignment of each new access road, including any driveway, related to the construction of any single-family dwelling and/or appurtenant *structure(s) shall be located and designed to minimize the visibility of each road and road cut, as viewed from public roads.*

Explanation: No new roads or driveways are proposed.

g. Grading.

1. All exposed slopes and disturbed soil resulting from site development shall be graded so as to be gently sloping and blend with the natural topography.

2. Regraded slopes and disturbed soils shall be revegetated with indigenous plants, or other plants with similar massing and coverage characteristics suitable to minimize soil erosion.

Explanation: Proposed net grading would be minimal (approximately 104 cubic yards of net fill; 4,004 cubic yards of cut, and 4,108 cubic yards of fill). The project site does not have exposed slopes and is currently gently sloping.

The guidelines also provide for Architectural Standards (including items to maintain the rural character, building materials and exterior colors, windows and window treatments, lighting, and landscaping. As part of the County's standard development process, County Code Section 26-90-040 (Permit requirements for all Local Area Guidelines and Standards) requires design review for projects within a LG (Local Guidelines) combining zone. The project would be required to submit plans for administrative design review, which would demonstrate project compliance with these items. In addition, as discussed in section 4.d, project lighting would be required to comply with County Code Section 26-88-254(f)(19), which stipulates provisions to minimize light impacts on neighboring properties,

Because public viewpoints of the site from Highway 12 and Trinity Road would be limited due to the natural vegetation and distances, as shown on Figures 5 through 8, and with project compliance with the County Code (for cannabis projects), General Plan policies for Scenic Resources districts, and the Taylor/Sonoma/Mayacamas Mountains local development guidelines (including Design Review), the project would not have significant impacts on a scenic vista.

Significance Level: Less than Significant Impact

b) Substantially damage scenic resources, including, but not limited to trees, rock outcroppings, and historic buildings within a state scenic highway?

Comment:
As discussed in section 4.a, the project site is located adjacent to Highway 12, which is a state-designated scenic highway in this area. However, there are no scenic resources that would be affected by the project because the site is essentially obscured from views along

Highway 12 due to existing trees and vegetation and the distance between Highway 12 and proposed project structures (approximately 600 feet).

Significance Level: Less than Significant Impact

c) **Substantially degrade the existing visual character or quality of public views of the site and its surroundings? (Public views are those that are experienced from publicly accessible vantage point). If the project is in an urbanized area, would the project conflict with applicable zoning and other regulations governing scenic quality?**

Comment:
As discussed in section 4.a, the project parcel is adjacent to Highway 12; however, the area where the proposed project structures would be located is approximately 600 feet from Highway 12 and mostly obscured by existing vegetation. In addition, the project proposes to add a vegetative screen of trees and shrubs, along with a fence with vines, along the west side of the project site to augment screening.

There are rural properties on the remaining sides of the project parcel, with a mixture of residential and agricultural structures, fields with crops, and forested areas. Figures 7 through 9 show publicly accessible vantage points from Highway 12; Figures 10 and 11 show publicly accessible vantage points from Trinity Road at the project entrance.

Figure 7. View of project site looking northeast from Highway 12 at Trinity Road. (Source: Google Maps)

Figure 8. View of project site along Highway 12 heading northwest (existing building on project site in distance). (Source: Google Maps)

Figure 9. View of project site looking southeast from Highway 12 at Weise Road. (Source: Google Maps)

Figure 10. View of project site from Trinity Road.
(Source: Google Maps)

Figure 11. View of project site from driveway along Trinity Road.
(Source: MIG, Inc. site visit)

The proposed project is not subject to any area or specific plan and is consistent with the land use designation (Limited Intense Agriculture) and zoning (LIA Limited Intense Agriculture) for the site. Section 4.a discusses project consistency with General Plan policies and the Taylor/Sonoma/Mayacamas Mountains local development guidelines.

Following County Visual Assessment Guidelines, public viewpoints were considered for determining the project's visibility to the public. Based on the Visual Assessment Guidelines, Table 1: Site Sensitivity, the project location would be considered "High" because:

"The site or any portion thereof is within a land use or zoning designation protecting scenic or natural resources, such as General Plan designated scenic landscape units, coastal zone, community separators, or scenic corridors. The site vicinity is generally characterized by the natural setting and forms a scenic backdrop for the community or scenic corridor. This category includes building and construction areas within the SR designation located on prominent hilltops, visible slopes less than 40 percent or where there are significant natural features of aesthetic value that are visible from public roads or public use areas (i.e. parks, trails etc.). This category also includes building or construction sites on prominent ridgelines that may not be designated as scenic resources but are visible from a designated scenic corridor."[6]

The project proposes new structures; however, neither the proposed structures nor the outdoor cultivation areas would be visible from public viewpoints and therefore would not represent a noticeably distinctive or substantial visual change from the current project site. Based on County Visual Assessment Guidelines, Table 2: Visual Dominance, the project would be considered "Inevident" because:

"Project is generally not visible from public view because of intervening natural land forms or vegetation."

The project's visual effect on the visual character or quality of the site and its surroundings was determined based on County Visual Assessment Guidelines, Table 3: Thresholds of Significance for Visual Impact Analysis.

[6]Sonoma County. "Visual Assessment Guidelines and Procedure," https://sonomacounty.ca.gov/PRMD/Regulations/Environmental-Review-Guidelines/Visual-Assessment-Guidelines/, accessed 9/26/20.

Table 3. Thresholds of Significance for Visual Impact Analysis

Sensitivity	Visual Dominance			
	Dominant	***Co-Dominant***	***Subordinate***	***Inevident***
Maximum	Significant	Significant	Significant	Less than significant
High	Significant	Significant	Less than significant	Less than significant
Moderate	Significant	Less than significant	Less than significant	Less than significant
Low	Less than significant	Less than significant	Less than significant	Less than significant

Considering the project site's "High" sensitivity and the project's "Inevident" visual dominance, the project would be considered to have a less than significant effect on the existing visual character or quality of the site and its surroundings.

Significance Level: Less than Significant Impact

d) Create a new source of substantial light or glare which would adversely affect day or nighttime view in the area?

Comment:
The proposed project would include security lighting that could introduce new sources of exterior light and possible glare. In addition, proposed indoor cultivation operations would include lighting. Security and safety lighting could affect some nighttime views, which might be noticeable from nearby residences with unobstructed sight lines. However, the effects of these new sources of light or glare would be reduced due to compliance with the provisions of County Code Section 26-88-254(f)(19), which requires: *"All lighting shall be fully shielded, downward casting and not spill over onto structures, other properties or the night sky. All indoor and mixed light operations shall be fully contained so that little to no light escapes. Light shall not escape at a level that is visible from neighboring properties between sunset and sunrise."* As discussed in the project description, the proposed greenhouse/nursery/propagation/head house facility would follow a design similar to a "Venlo style" greenhouse and would use a solid wall on the west side of the structure and curtains or a similar mechanism for interior rooms to isolate and control light as needed. In addition, the project proposes using automated blackout curtains to enclose the structure

so no internal light can escape at a level visible from surrounding properties between sunset and sunrise.

As part of the County's standard development process, County Code Section 26-90-040 (Permit requirements for all Local Area Guidelines and Standards) requires design review for projects within a LG (Local Guidelines) combining zone. The proposed project is subject to the Taylor/Sonoma/Mayacamas Mountains local guidelines. Design review of the project, which would include review of project lighting provisions, would ensure project compliance with County lighting standards.

Significance Level: Less than Significant Impact

2. AGRICULTURE AND FOREST RESOURCES

In determining whether impacts to agricultural resources are significant environmental effects, lead agencies may refer to the California Agricultural Land Evaluation and Site Assessment Model (1997) prepared by the California Department of Conservation as an optional model to use in assessing impacts on agriculture and farmland. In determining whether impacts to forest resources, including timberland, are significant environmental effects, lead agencies may refer to information compiled by the California Department of Forestry and Fire Protection regarding the state's inventory of forest land, including the Forest and Range Assessment Project and the Forest Legacy Assessment project; and forest carbon measurement methodology provided in Forest Protocols adopted by the California Air Resources Board.

Would the project:

a) Convert Prime Farmland, Unique Farmland, or Farmland of Statewide Importance (Farmland), as shown on the maps prepared pursuant to the Farmland Mapping and Monitoring Program of the California Resources Agency, to non-agricultural use?

Comment:
The parcel is designated by the Sonoma County Permit Sonoma GIS Cannabis Site Evaluation Tool[7] as "Other Land" with a very small amount of "Grazing Land" at the southeastern project boundary. The proposed outdoor cultivation areas and on-site structures would be located in an area designated as Other Land and therefore would not convert prime farmland, unique farmland, or farmland of statewide importance.

Significance Level: No Impact

[7]Sonoma County Permit Sonoma GIS Cannabis Site Evaluation Tool, https://sonomacounty.maps.arcgis.com/apps/webappviewer/index.html?id=0b784d90045941798d780f288b6f7003, accessed 8/31/20.

b) Conflict with existing zoning for agricultural use, or Williamson Act Contract?

Comment:
The project site is zoned Land Intensive Agriculture, which allows for activities that protect lands suitable for animal husbandry and production of food, fiber, and plant materials, and that are generally used for these activities. The project would be consistent with and would not conflict with the Land Intensive Agricultural zoning classification because a commercial cannabis operation is a permitted use in a Land Intensive Agricultural District.[8] The project site is not under a Williamson Act Contract.

Significance Level: No Impact

c) Conflict with existing zoning for, or cause rezoning of, forest land (as defined in Public Resources Code Section 4526) or timberland zoned Timberland Production (as defined by Government Code Section 51104(g)?

Comment:
The project site is not in a Timberland Production zoning district as designated by the County, nor does the project propose rezoning of forest land.

Significance Level: No Impact

d) Result in the loss of forest land or conversion of forest land to non-forest use?

Comment:
As discussed in section 2.c, the project would not result in the loss of forest land or conversion of forest land to non-forest use.

Significance Level: No Impact

e) Involve other changes in the existing environment which, due to their location or nature, could result in conversion of farmland, to non-agricultural use or conversion of forest land to non-forest use?

Comment:
As discussed in section 2.a, proposed project activities would be located on land designated as "Other Land," as shown on the Permit Sonoma GIS Cannabis Site Evaluation Tool. This

[8] Sonoma County. General Plan 2020 Land Use Element, "Agricultural Land Use Policy," pp. LU-62 through LU-64, http://sonomacounty.ca.gov/WorkArea/DownloadAsset.aspx?id=2147542561, accessed September 3, 2020.

area on the project property has been previously disturbed with farm structures that were mostly burned in the 2017 Nuns Fire, and no agricultural activity on this part of the property would be disrupted by the proposed project.

Significance Level: No Impact

3. AIR QUALITY

Would the project:

a) Conflict with or obstruct implementation of the applicable air quality plan?

Comment:
The proposed project lies within the jurisdiction of the Bay Area Air Quality Management District (BAAQMD). The following discussion considers whether the proposed project would conflict with or obstruct implementation of an applicable air quality plan maintained by BAAQMD.

In April 2017, the BAAQMD adopted its *2017 Clean Air Plan: Spare the Air, Cool the Climate* (*Clean Air Plan*), which provides the BAAQMD's framework for ensuring air quality standards would be attained and maintained in the Bay Area in compliance with state and federal requirements. The BAAQMD 2017 *Clean Air Plan* is a multi-pollutant plan focused on protecting public health and the climate. Specifically, the primary goals of the *Clean Air Plan* are to:

- Attain all state and national quality standards;
- Eliminate disparities among Bay Area communities in cancer health risk from toxic air contaminants; and
- Reduce Bay Area greenhouse gas (GHG) Emissions to 40 percent below 1990 levels by 2030, and 80 percent below 1990 levels by 2050

The *Clean Air Plan* includes increases in regional construction, area, mobile, and stationary source activities and operations in its emission inventories and plans for achieving attainment of air quality standards. Chapter 5 of the *Clean Air Plan* contains BAAQMD's strategy for achieving these climate and air quality goals. This control strategy is the backbone of the *Clean Air Plan*. It identifies 85 distinct control measures designed to comply with state and federal air quality standards and planning requirements and protect public health by reducing emissions of the ozone precursors, Particulate Matter (PM), and Toxic Air Contaminants (TACs), and by reducing greenhouse gases (GHG) emissions. The 85 control measures identified in the *Clean Air Plan* are grouped by nine economic based "sectors": Agriculture, Buildings, Energy, Natural and Working Lands, Stationary Sources, Super GHGs, Transportation, Waste, and Water. Most of the 85 control measures implemented at the local and regional level by municipal government and BAAQMD and are not directly applicable to the proposed project. The proposed project would not conflict with or obstruct implementation of the *Clean Air Plan* because: 1) It does not include significant sources of ozone precursor emissions, PM, or TACs (see also discussion b) and c) below); 2) it would not exacerbate or increase disparities in cancer risks from TAC emissions; and 3) the project is required, pursuant to the County Code (Section 26-88-254(g)(3)), to provide electrical power through a combination of on-grid 100 percent renewable energy, an on-site zero net energy renewable energy system, or purchase of carbon offsets for power obtained from non-renewable resources, which would reduce GHG emissions from the project consistent with state reduction goals (see also Section 8, Greenhouse Gas Emissions).

Significance Level: Less than Significant Impact

b) Result in a cumulatively considerable net increase of any criteria pollutant for which the project region is non-attainment under an applicable Federal or State ambient air quality standard?

Comment:
The federal and state governments have established ambient air quality standards for "criteria" pollutants considered harmful to the environment and public health. National Ambient Air Quality Standards (NAAQS) have been established for carbon monoxide (CO), lead (Pb), nitrogen dioxide (NO_2), ozone (O_3), fine particulate matter (i.e., particles that are 2.5 microns in diameter and smaller, or $PM_{2.5}$), inhalable coarse particulate matter (i.e., articles between 2.5 and 10 microns in diameter, or PM_{10}), and sulfur dioxide (SO_2). California Ambient Air Quality Standards (CAAQS) are more stringent than the national standards for the pollutants listed above and include the following additional pollutants: hydrogen sulfide (H_2S), sulfates (SO_X), and vinyl chloride. In addition to these criteria pollutants, the federal and state governments have classified certain pollutants as hazardous air pollutants (HAPs) or toxic air contaminants (TACs), such as asbestos and diesel particulate matter (DPM).

The San Francisco Bay Area Air Basin (SFBAAB) is an area of non-attainment for national and state ozone, state PM_{10}, and national and state $PM_{2.5}$ air quality standards. Regarding cumulative impacts, the BAAQMD CEQA Air Quality Guidelines[9] state:

[9]BAAQMD. "CEQA Air Quality Guidelines," May 2017, p. 2-1, https://www.baaqmd.gov/~/media/files/planning-and-research/ceqa/ceqa_guidelines_may2017-pdf.pdf?la=en, accessed 9/25/20.

"SFBAAB's non-attainment status is attributed to the region's development history. Past, present, and future development projects contribute to the region's adverse air quality impacts on a cumulative basis. By its very nature, air pollution is largely a cumulative impact. No single project is sufficient in size to, by itself, result in nonattainment of ambient air quality standards. Instead, a project's individual emissions contribute to existing cumulatively significant adverse air quality impacts. If a project's contribution to the cumulative impact is considerable, then the project's impact on air quality would be considered significant. In developing thresholds of significance for air pollutants, BAAQMD considered the emission levels for which a project's individual emissions would be cumulatively considerable. If a project exceeds the identified significance thresholds, its emissions would be cumulatively considerable, resulting in significant adverse air quality impacts to the region's existing air quality conditions. Therefore, additional analysis to assess cumulative impacts is unnecessary."

Short-Term Construction Emissions: Project construction would generate short-term equipment exhaust and fugitive dust emissions from ground disturbance, construction equipment use, worker vehicle trips, and/or material deliveries associated with activities such as site preparation, grading, utility trenching, paving, building/structure demolition, building/structure construction, building/structure remodeling, and application of architectural coatings. Estimated cut and fill on the project site would be limited to 104 cubic yards (CY) of net fill (4,004 CY of cut and 4,108 CY of fill).

For all projects, BAAQMD recommends implementation of eight "Basic Construction Mitigation Measures" to reduce construction fugitive dust emissions level. These basic measures are also used to meet BAAQMD's best management practices (BMPs) threshold of significance for construction fugitive dust emissions (i.e., the implementation of all basic construction measures renders fugitive dust impacts a less than significant level). The County would implement these BMPs through Mitigation Measure AIR-1.

Long Term Operations Emissions: Once operational, the proposed cannabis project may result in emissions of criteria air pollutants from the following sources of pollutants:

- Small "area" sources including landscaping equipment and the use of consumer products such as paints, cleaners, and fertilizers that result in the evaporation of ozone-precursors and other pollutants into the atmosphere during product use.
- Energy use and consumption from the combustion of natural gas in water and space heating equipment, as well as cannabis processing activities.
- Mobile sources such as agricultural equipment and vehicles travelling to and from the proposed project (customers, vendors, workers), including dust generated from travel on paved and unpaved roads, etc.
- Stationary sources such as a back-up generator that emit criteria air pollutants and TACs, including diesel PM.

- Other fugitive dust sources associated with cannabis harvesting and cannabis processing activities.

County Code Section 26-88-254(g)(5) permits cultivation and harvesting activities to be conducted seven days a week, 24 hours a day; deliveries, shipping, cannabis processing (e.g., drying and trimming) and shipping would occur 8:00 AM to 5:00 PM. Project-related vehicle trips would vary seasonally but would be limited, with an estimate maximum average daily trip total of 52, including trips expected during the harvest season.[10] This amount of vehicle trips would not generate significant emissions.

In addition, the BAAQMD *CEQA Air Quality Guidelines* contain screening criteria to provide lead agencies with a conservative indication of whether a proposed project could result in a potentially significant air quality or greenhouse gas impact. Consistent with BAAQMD's guidance, if a project meets all the screening criteria, then the project would not be expected to result in a significant air quality impact and a detailed air quality assessment would not be required for the project. Project consistency with BAAQMD screening criteria is summarized in Table 4, below.

[10]W-Trans, "Traffic Impact Study for the Gordenker Ranch Cannabis Cultivation Project," prepared for the County of Sonoma, March 20, 2020.

Table 4
Project Consistency with BAAQMD Construction and Operational Screening Criteria

Screening Criterion	Requirement	Project Consistency
1) Land Use Type and Size	Project is below all applicable construction (11 acres, 259,000 square feet of building space, or 540 employees) and operational screening size criteria (72 acres, 541,000 square feet of building space, or 1,249 employees) for general light industry use	The proposed project would have 60,000 square feet of outdoor cultivation space (for a maximum canopy of 28,560 square feet), 23,520 square feet of mixed-light cultivation space (for a maximum canopy of 11,400 square feet), and cultivation and processing structures totaling no more than 90,560 square feet. The proposed project would have a maximum of 17 employees at harvest.
2) Basic Construction Measures	Project design and implementation includes all BAAQMD *Basic Construction Mitigation Measures*	The proposed project would incorporate all BAAQMD Basic Construction Mitigation Measures (BAAQMD, 2017, Table 8-2); see Mitigation Measure AIR-1.
3) Demolition	Demolition activities are consistent with BAAQMD Regulation 11, Rule 2: Asbestos Demolition, Renovation, and Manufacturing	The project would include limited demolition activities, however, as discussed in section 9, Hazards and Hazardous Materials, project notification of BAAQMD would be required prior to demolition.
4) Construction Phases	Construction does not include simultaneous occurrence of more than two construction phases (e.g., grading, paving, and building construction would occur simultaneously)	The proposed project does not include simultaneous occurrence of more than two construction phases.
5) Multiple Land Uses	Construction does not include simultaneous construction of more than one land use type	The proposed project includes construction of only one land use type.
6) Site Preparation	Construction does not require extensive site preparation	The proposed project would not include extensive site preparation or extensive grading (approximately 104 cubic yards of net fill).
7) Material Transport	Construction does not require extensive material transport and considerable haul truck activity (greater than 10,000 cubic yards).	The project would not require material transportation greater than 10,000 cubic yards.
8) Carbon Monoxide Hotspots	A) Project is consistent with the applicable congestion management program, regional transportation plan, and local congestion management agency plans; and	The project would not result in significant traffic impacts, conflict with an applicable congestion management program or plan, nor increase traffic volumes above BAAQMD CO hotspot screening levels.

	B) The project traffic would not increase traffic volumes at affected intersections to more than 44,000 vehicles per hour, or more than 24,000 vehicles per hour where vertical and/or horizontal mixing is substantially limited (e.g., tunnel, parking garage, bridge underpass, natural or urban street canyon, below-grade roadway).	
Source: MIG Air Quality and Greenhouse Gas Methodology from BAAQMD, 2017 (Table 3-1, Table 8-2, Page 3-5)		

As shown in Table 4, the proposed project would be consistent with BAAQMD operational screening criteria and would therefore not result in a significant air quality impact from operations.

The BAAQMD screening criteria do not consider stationary sources or other fugitive dust sources such as tilling; however, the project proposes to use grow bags for outdoor cultivation and would not require soil tilling. Sonoma County Code Section 26-88-254(g)(3) prohibits the use of generators for indoor and mixed light cultivation, except for portable, temporary use in emergencies only (i.e., they would not generate pollutants as a matter of routine operation). The California Air Resources Board (CARB) sets emissions limits for both stationary and portable diesel- and gasoline-fueled emergency generators greater than 50 horsepower, and the use of such equipment requires a permit to operate from BAAQMD. In addition, potential dust from harvesting and processing would be temporary and intermittent throughout the year.

Short-Term Construction Emissions: Project construction activities would last approximately six months (an estimated 152 working days) and would generate short-term equipment exhaust and fugitive dust emissions from ground disturbance, construction equipment use, worker vehicle trips, and/or material deliveries associated with activities such as site preparation, grading, utility trenching, paving, building/structure demolition, building/structure construction, building/structure remodeling, and application of architectural coatings. Grading would generally be balanced, with approximately 4,004 cubic yards cut and 4,108 cubic yards of fill (net 104 cubic yards of fill). Construction period ground-disturbing activities would be required by County Code Section 26-88-254(g)(2) to *"utilize dust control measures on access roads and all ground disturbing activities."* As discussed above, BAAQMD recommends implementation of eight "Basic Construction Mitigation Measures." The applicant would implement these BMPs and other standard County requirements for controlling dust through Mitigation Measure AIR-1.

Because the proposed project would not individually exceed any BAAQMD CEQA significance thresholds with application of Mitigation Measure AIR-1, the project's cumulative air quality impact would be less than significant with mitigation incorporated.

Significance Level: Less than Significant with Mitigation Incorporated

Mitigation:
Mitigation Measure AIR-1:

a. The following dust control measures shall be included in the project specifications on all grading and building plans:
    1) Water or alternative dust control shall be sprayed to control dust on construction areas, soil stockpiles, and staging areas during construction as directed by the County.
    2) Trucks hauling soil, sand and other loose materials over public roads shall cover their loads or keep the loads at least two feet below the level of the sides of the container or wet the load sufficiently to prevent dust emissions.
    3) Paved roads shall be swept as needed to remove soil that has been carried from the project site.

b. The following BAAQMD Best Management Practices (BMPs) shall be included in the project:
    1) Water all exposed surfaces (e.g., parking areas, staging areas, soil piles, graded areas, and unpaved access roads) two times per day during construction and adequately wet demolition surfaces to limit visible dust emissions.
    2) Cover all haul trucks transporting soil, sand, or other loose materials off the project site.
    3) Use wet power vacuum street sweepers at least once per day to remove all visible mud or dirt track-out onto adjacent roads (dry power sweeping is prohibited) during construction of the proposed project.
    4) Vehicle speeds on unpaved roads/areas shall not exceed 15 miles per hour.
    5) Complete all areas to be paved as soon as possible and lay building pads as soon as possible after grading unless seeding or soil binders are used.
    6) Minimize idling time of diesel-powered construction equipment to five minutes and post signs reminding workers of this idling restriction at all access points and equipment staging areas during construction of the proposed project.
    7) Maintain and properly tune all construction equipment in accordance with manufacturer's specifications and have a CARB-certified visible emissions evaluator check equipment prior to use at the site.
    8) Post a publicly visible sign with the name and telephone number of the construction contractor and County staff person to contact regarding dust complaints. This person shall respond and take corrective action within 48

hours. The publicly visible sign shall also include the contact phone number for the BAAQMD to ensure compliance with applicable regulations.

Monitoring:
Mitigation Monitoring AIR-1: County staff shall ensure that the construction period air quality measures are listed on all site alteration, grading, building or improvement plans prior to issuance of grading or building permits.

c) Expose sensitive receptors to substantial pollutant concentrations?

Comment:
Sensitive air quality receptors include specific subsets of the general population that are susceptible to poor air quality and the potential adverse health effects associated with poor air quality. In general, children, senior citizens, and individuals with pre-existing health issues, such as asthmatics, are considered sensitive receptors. The California Air Resources Board (CARB) considers schools, schoolyards, parks and playgrounds, daycare facilities, nursing homes, hospitals, and residential areas as sensitive air quality land uses and receptors (CARB, 2005). The nearest sensitive air quality receptors to the perimeter of the proposed project site would include existing residences approximately 600 feet to the west, across Highway 12; the nearest school is Dunbar Elementary School, at 11700 Dunbar Road, Glen Ellen, about one-half mile northwest of the project site.

As discussed in section 3.b, the proposed project would not include significant stationary, mobile, or other sources of emissions. In addition, the proposed project would comply with the property setbacks contained in County Code Section 26-88-254(f), which require cultivation areas and structures (for cannabis cultivation, drying, trimming, etc.) to be located at least 100 feet from property lines, 300 feet from occupied residences and businesses, and 1,000 feet from schools, public parks, childcare centers, and alcohol and drug treatment facilities. The less than significant nature of project emissions sources and the distance between proposed project operations and facilities and any nearby sensitive receptors would ensure that project construction and operation would not result in substantial concentrations of criteria air pollutants or Toxic Air Contaminants (TACs) at sensitive receptor locations.

Significance Level: Less than Significant Impact

d) Result in other emissions (such as those leading to odors adversely affecting a substantial number of people)?

Comment:
According to the 2016 Medical Cannabis Land Use Ordinance Negative Declaration (Sonoma County 2016, page 20): *"Cannabis cultivation operations are associated with a strong odor,*

especially outdoor cultivation operations during the final phase of the growing cycle (typically in late Summer, early Fall). Generally, the larger the size of the cultivation activity and the proximity to sensitive uses, the greater the potential for odor to be evident. Outdoor cultivation has a greater potential for odor than indoor or mixed light because it is not contained and would not have opportunity for a filtered ventilation system."

Much of the strong odor associated with cannabis cultivation and processing, as well as commercial cannabis products, comes from a class of aromatic, organic compounds known as terpenes. Terpenes are not specific to cannabis; they are among the most common compounds produced by flowering plants, vary widely between plants, and are responsible for the fragrance of many flowers typically associated with non-objectionable odors, such as lavender. Different strains of cannabis emit a wide variety of odors with differing levels of potency. The odor may be detectable beyond the cultivation site property boundaries depending on the size of the facility and the specific climatic and topographic conditions that prevail near the cultivation site. In general, cannabis odors tend to lessen during cooler temperatures and worsen with higher temperatures, and wind patterns have the potential to increase or decrease the intensity of cannabis odors depending on whether winds are blowing towards or away from nearby receptors. As noted in the County's 2016 IS/ND, outdoor cultivation has the greatest potential to expose receptors to odors particularly during the final phase of the growing cycle (i.e., typically late summer or early fall); however, indoor and mixed light cultivation can affect surrounding receptors if ventilation systems are ineffective. Indoor cultivation can also result in flowering at different and/or multiple times of the year.

The distinctive odor generated by cannabis cultivation, processing, and manufacturing may or may not be perceived as objectionable, offensive, or a nuisance, depending on the particular individual's olfactory sensitivity. The BAAQMD *CEQA Air Quality Guidelines* (BAAQMD 2017, page 7-1), state that odors are generally regarded as an annoyance rather than as a health hazard. Individual reactions to odors can range from physiological (e.g., irritation, anger, anxiety) to physiological (e.g., circulatory and respiratory effects, nausea, vomiting, headache), but the ability to detect odors varies considerable from person to person and is considered to be subjective. An odor that is offensive to one person may not be offensive to another person. Unfamiliar odors are more easily detected and are more likely to cause complaints than familiar odors, as a person can become desensitized to almost any odor over time (this is known as odor fatigue). In general, the quality and intensity of an odor would influence a person's reaction. The quality of an odor indicates the nature of the smell experience (flowery, putrid, etc.). The intensity of an odor depends on its concentration in the air. When an odor sample is progressively diluted, the odor concentration decreases. As this occurs, the odor intensity weakens and eventually becomes low enough where the odor is no longer detectable. The BAAQMD *CEQA Air Quality Guidelines* contain odor screening distances for a variety of lands uses typically associated with odors such as wastewater treatment plants, landfill and composting facilities, and chemical manufacturing facilities. The recommended screening distance for most of these facilities is one mile. New odor sources located further than one mile from sensitive receptors would not likely result in a significant odor impact; however, cannabis facilities are not listed as a type of land use in the BAAQMD odor screening criteria, and the BAAQMD *CEQA Air Quality Guidelines* state these screening distances should not be considered "as absolute screening criteria, rather as information to consider along with odor parameters" (BAAQMD, 2017, page 3-4).

The proposed project would not result in significant odor impacts for the following reasons:

- The proposed project would not result in the continuous generation of odors. Rather, odors would be intermittent and only generated during certain times of year (e.g., flowering periods, harvesting, processing periods).
- County Code Section 26-88-254(g)(2) requires all indoor, greenhouse, and mixed-light cultivation operations and any drying, aging, trimming and packing facilities to be equipped with odor control filtration and ventilation system(s) to control odors humidity, and mold. The project would either include activated carbon filters to filter odors from greenhouse and processing building interiors or would employ mist and/or vapors as needed to eliminate residual odors upon exhaust. Thus, potential objectionable odors would be controlled at the source. In addition, where possible, exhaust air would be directed toward the interior of the parcel to reduce off-site odor effects.
- The proposed project would comply with all setback requirements contained in County Code Section 26-88-254(f), which requires cultivation areas and structures for cannabis cultivation, drying, trimming, etc. to be located at least 100 feet from property lines, 300 feet from occupied residences and businesses, and 1,000 feet from schools, public parks, childcare centers, and alcohol and drug treatment facilities. These setbacks would serve to dilute and disperse odors according to prevailing meteorological conditions and reduce odor intensity at nearby receptor locations.
- The proposed project is not bordered by a substantial number of people. As discussed in section 3.c, the nearest sensitive air quality receptors to the perimeter of the proposed project site would include existing residences approximately 600 feet to the west, across Highway 12, and the nearest school would be approximately one-half mile from the project site. Although these individual receptors are more likely to be affected by any potential project odors than non-sensitive receptors, the dispersed nature of these receptors and the fact that for the main concentration of residences Highway 12 intervene (with air turbulence from traffic) make it unlikely that a substantial number of people could be affected at the same time in the event odors are generated by the proposed project.

For the reasons outlined above, the proposed project would not be expected to result in the creation of objectionable odors that would affect a substantial number of people.

Significance Level: Less than Significant Impact

4. BIOLOGICAL RESOURCES

The applicant submitted a Biological Assessment prepared by Wiemeyer Ecological Sciences, dated May 16, 2018,[11] that addressed potential project impacts on special-status plant and animal species and habitats. A literature search was conducted for the Biological Assessment, which included searches of the California Natural Diversity Database (CNDDB) and the California Native Plant Society (CNPS) Inventory of Rare and Endangered Plants, among other sources. Subsequently, a separate creek evaluation dated June 25, 2020 was prepared by Lucy Macmillan, Environmental Scientist.

Regulatory Framework

The following discussion identifies federal, state, and local environmental regulations that serve to protect sensitive biological resources relevant to the California Environmental Quality Act (CEQA) review process.

Federal

Federal Endangered Species Act (FESA)

FESA establishes a broad public and federal interest in identifying, protecting, and providing for the recovery of threatened or endangered species. The Secretary of Interior and the Secretary of Commerce are designated in FESA as responsible for identifying endangered and threatened species and their critical habitat, carrying out programs for the conservation of these species, and rendering opinions regarding the impact of proposed federal actions on listed species. The U.S. Fish and Wildlife Service (USFWS) and the National Oceanic and Atmospheric Administration's National Marine Fisheries Service (NOAA Fisheries) are charged with implementing and enforcing the FESA. USFWS has authority over terrestrial and continental aquatic species, and NOAA Fisheries has authority over species that spend all or part of their life cycle at sea, such as salmonids.

Section 9 of FESA prohibits the unlawful "take" of any listed fish or wildlife species. Take, as defined by FESA, means "to harass, harm, pursue, hunt, shoot, wound, kill, trap, capture, or collect, or to attempt to engage in any such action." USFWS's regulations define harm to mean "an act which actually kills or injures wildlife." Such an act "may include "significant habitat

[11] Wiemeyer Ecological Sciences, "Biological Assessment, Turkey Parcel, 101 Trinity Road, Glen Ellen, CA 95442, APN: 053-130-009 & 053-110-001," May 16, 2018.

modification or degradation where it actually kills or injures wildlife by significantly impairing essential behavioral patterns, including breeding, feeding or sheltering" (50 CFR § 17.3). Take can be permitted under FESA pursuant to sections 7 and 10. Section 7 provides a process for take permits for federal projects or projects subject to a federal permit, and Section 10 provides a process for incidental take permits for projects without a federal nexus. FESA does not extend the take prohibition to federally listed plants on private land, other than prohibiting the removal, damage, or destruction of such species in violation of state law.

The Migratory Bird Treaty Act of 1918 (MBTA)

The U.S. Migratory Bird Treaty Act (MBTA) (16 USC §§ 703 et seq., Title 50 Code of Federal Regulations [CFR] Part 10) states it is "unlawful at any time, by any means or in any manner, to pursue, hunt, take, capture, kill; attempt to take, capture or kill; possess, offer for sale, sell, offer to barter, barter, offer to purchase, purchase, deliver for shipment, ship, export, import, cause to be shipped, exported, or imported, deliver for transportation, transport or cause to be transported, carry or cause to be carried, or receive for shipment, transportation, carriage, or export any migratory bird, any part, nest, or egg of any such bird, or any product, whether or not manufactured, which consists, or is composed in whole or in part, of any such bird or any part, nest or egg thereof…" In short, under the MBTA it is illegal to disturb a nest that is in active use, since this could result in killing a bird, destroying a nest, or destroying an egg. The USFWS enforces the MBTA. The MBTA does not protect some birds that are non-native or human-introduced or that belong to families that are not covered by any of the conventions implemented by the MBTA. In 2017, the USFWS issued a memorandum stating that the MBTA does not prohibit incidental take; therefore, the MBTA is currently limited to purposeful actions, such as directly and knowingly removing a nest to construct a project, hunting, and poaching.

The Clean Water Act (CWA)

The CWA is the primary federal law regulating water quality. The implementation of the CWA is the responsibility of the U.S. Environmental Protection Agency (EPA). However, the EPA depends on other agencies, such as the individual states and the U.S. Army Corps of Engineers (USACE), to assist in implementing the CWA. The objective of the CWA is to "restore and maintain the chemical, physical, and biological integrity of the Nation's waters." Section 404 and 401 of the CWA apply to activities that would impact waters of the U.S. The USACE enforces Section 404 of the CWA and the California State Water Resources Control Board enforces Section 401.

Section 404

The Army Corps of Engineers (Corps) regulates "Waters of the United States", including adjacent wetlands, under Section 404 of the federal Clean Water Act. Waters of the United

States include navigable waters, interstate waters, territorial seas and other waters that may be used in interstate or foreign commerce. Potential wetland areas are identified by the presence of (1) hydrophytic vegetation, (2) hydric soils, and (3) wetland hydrology. All three parameters must be present, under normal circumstances, for an area to be designated as a jurisdictional wetland under the Clean Water Act. Areas that are inundated for sufficient duration and depth to exclude growth of hydrophytic vegetation are subject to Section 404 jurisdiction as "other waters" and are often characterized by an ordinary high-water mark (OHWM). The discharge of dredged or fill material into a Waters of the U.S. (including wetlands) generally requires a permit from the Corps under Section 404 of the Clean Water Act.

"Waters of the State" are regulated by the Regional Water Quality Control Board (Water Board) under the State Porter-Cologne Water Quality Control Act. Waters of the State are defined by the Porter-Cologne Act as any surface water or groundwater, including saline waters, within the boundaries of the State. RWQCB jurisdiction includes "isolated" wetlands and waters that may not be regulated by the ACOE under Section 404 (such as roadside ditches).

Section 401

Section 401 of the Clean Water Act specifies that any activity subject to a permit issued by a federal agency must also obtain State Water Quality Certification (401 Certification) that the proposed activity will comply with state water quality standards. If a proposed project does not require a federal permit but does involve dredge or fill activities that may result in a discharge to Waters of the State, the Water Board has the option to regulate the dredge and fill activities under its state authority through its Waste Discharge Requirements (WDR) program.

State

California Endangered Species Act (CESA)

Provisions of the California Endangered Species Act (CESA) protect state-listed threatened and endangered species. The California Department of Fish and Wildlife (CDFW) is charged with establishing a list of endangered and threatened species. CDFW regulates activities that may result in "take" of individuals (i.e., "hunt, pursue, catch, capture, or kill, or attempt to hunt, pursue, catch, capture, or kill"). Habitat degradation or modification is not expressly included in the definition of "take" under the California Fish and Game Code (CFGC), but CDFW has interpreted "take" to include the killing of a member of a species which is the proximate result of habitat modification.

Fish and Game Code 1600-1602

Sections 1600-1607 of the California Fish and Game Code (CFGC) require that a Notification of Lake or Streambed Alteration Agreement (LSAA) application be submitted to CDFW for "any activity that may substantially divert or obstruct the natural flow or substantially change the bed, channel, or bank of any river, stream, or lake." CDFW reviews the proposed actions in the application and, if necessary, prepares a LSAA that includes measures to protect affected fish and wildlife resources, including mitigation for impacts to bats and bat habitat.

Nesting Birds

Nesting birds, including raptors, are protected under California Fish and Game Code (CFGC) Section 3503, which reads, "It is unlawful to take, possess, or needlessly destroy the nest or eggs of any bird, except as otherwise provided by this code or any regulation made pursuant thereto." In addition, under CFGC Section 3503.5, "it is unlawful to take, possess, or destroy any birds in the orders Falconiformes or Strigiformes (birds-of-prey) or to take, possess, or destroy the nest or eggs of any such bird except as otherwise provided by this code or any regulation adopted pursuant thereto." Passerines and non-passerine land birds are further protected under CFGC 3513. As such, CDFW typically recommends surveys for nesting birds that could potentially be directly (e.g., actual removal of trees/vegetation) or indirectly (e.g., noise disturbance) impacted by project-related activities. Disturbance during the breeding season could result in the incidental loss of fertile eggs or nestlings, or otherwise lead to nest abandonment. Disturbance that causes nest abandonment and/or loss of reproductive effort is considered "take" by CDFW.

Non-Game Mammals

Sections 4150-4155 of the California Fish and Game Code (CFGC) protects non-game mammals, including bats. Section 4150 states "A mammal occurring naturally in California that is not a game mammal, fully protected mammal, or fur-bearing mammal is a nongame mammal. A non-game mammal may not be taken or possessed except as provided in this code or in accordance with regulations adopted by the commission." The non-game mammals that may be taken or possessed are primarily those that cause crop or property damage. Bats are classified as a non-game mammal and are protected under the CFGC.

California Fully Protected Species and Species of Special Concern

The classification of "fully protected" was the California Department of Fish and Wildlife's (CDFW's) initial effort to identify and provide additional protection to those animals that were rare or faced possible extinction. Lists were created for fish, amphibians and reptiles, birds, and mammals. Most of the species on these lists have subsequently been listed under the California Endangered Species Act (CESA) and/or Federal Endangered Species Act (FESA). The Fish and Game Code sections (fish at §5515, amphibians and reptiles at §5050, birds at §3503 and §3511, and mammals at §4150 and §4700) dealing with "fully protected" species state that these species "…may not be taken or possessed at any time and no provision of this code or any other law shall be construed to authorize the issuance of permits or licenses to take any fully protected species," although take may be authorized for necessary scientific research. This language makes the "fully protected" designation the strongest and most restrictive regarding the "take" of these species. In 2003, the code sections dealing with "fully protected" species were amended to allow the CDFW to authorize take resulting from recovery activities for state-listed species.

California Species of Special Concern (CSC) are broadly defined as animals not listed under the FESA or CESA, but which are nonetheless of concern to the CDFW because they are declining at a rate that could result in listing or because they historically occurred in low numbers and known threats to their persistence currently exist. This designation is intended to result in special consideration for these animals by the CDFW, land managers, consulting biologists, and others, and is intended to focus attention on the species to help avert the need for costly listing under FESA and CESA and cumbersome recovery efforts that might ultimately be required. This designation also is intended to stimulate collection of additional information on the biology, distribution, and status of poorly known at-risk species, and focus research and management attention on them. Although these species generally have no special legal status, they are given special consideration under the CEQA during project review.

Porter-Cologne Water Quality Control Act

The intent of the Porter-Cologne Water Quality Control Act (Porter-Cologne) is to protect water quality and the beneficial uses of water, as it applies to both surface and ground water. Under this law, the State Water Resources Control Board develops statewide water quality plans, and the Regional Water Quality Control Boards (RWQCBs) develop basin plans that identify beneficial uses, water quality objectives, and implementation plans. The RWQCBs have the primary responsibility to implement the provisions of both statewide and basin plans. Waters regulated under Porter-Cologne, referred to as "waters of the State," include isolated waters that are not regulated by the U.S. Army Corps of Engineers (USACE). Projects that require a USACE permit, or fall under other federal jurisdiction, and have the potential to impact waters of the State are required to comply with the terms of the Water Quality Certification Program. If a proposed project does not require a federal license or permit, any person discharging, or proposing to discharge, waste (e.g., dirt) to waters of the State must file a Report of Waste Discharge and receive either Waste Discharge Requirements (WDRs) or a waiver to WDRs before beginning the discharge.

Local

Sonoma County General Plan

The *Sonoma County General Plan 2020* Land Use Element and Open Space & Resource Conservation Element both contain policies to protect natural resource lands including, but not limited to, watershed, fish and wildlife habitat, biotic areas, and habitat connectivity corridors.

Riparian Corridor (RC) Combining District

The Sonoma County Riparian Corridor (RC) combining zone is established to protect biotic resource communities, including critical habitat areas within and along riparian corridors, for their habitat and environmental value, and to implement the provisions of the General Plan Open Space and Resource Conservation and Water Resources Elements. These provisions are intended to protect and enhance riparian corridors and functions along designated streams, balancing the need for agricultural production, urban development, timber and mining operations and other land uses with the preservation of riparian vegetation, protection of water resources, floodplain management, wildlife habitat and movement, stream shade, fisheries, water quality, channel stability, groundwater recharge, opportunities for recreation, education and aesthetic appreciation, and other riparian functions and values.

Sonoma County Tree Protection Ordinance

The Sonoma County Tree Protection Ordinance (Sonoma County Code of Ordinances, Chapter 26, Article 88, Sec. 26-88-010 [m]) establishes policies for protected tree species in Sonoma County. Protected trees are defined (Chapter 26, Article 02, Sec. 26-02-140) as the following species: big leaf maple (*Acer macrophyllum*), black oak (*Quercus kelloggii*), blue oak (*Quercus douglasii*), coast live oak (Quercus *agrifolia*), interior live oak (*Quercus wislizenii*), madrone (*Arbutus menziesii*), oracle oak (*Quercus morehus*), Oregon oak (*Quercus garryana*), redwood (Sequoia sempervirens), valley oak (*Quercus lobata*), California bay (*Umbellularia californica*), and their hybrids.

Would the project:

a) Have a substantial adverse effect, either directly or through habitat modifications, on any species identified as a candidate, sensitive, or special status species in local or regional plans, policies, or regulations, or by the California Department of Fish and Wildlife or U.S. Fish and Wildlife Service?

Comment:

Based on site visits conducted by Darren Wiemeyer on March 10, March 30, and May 17, 2017, plus a follow-up site visit performed on April 3, 2018 to ascertain site conditions after the 2017 Nuns Fire, the Biological Assessment concluded that site habitats consist of *"annual grassland, oak woodland, mixed forest, seasonal wetland, riparian woodland, ephemeral drainages and a perennial stream (tributary to Calabazas Creek)."* [12] The "perennial" stream identified in the Biological Assessment in the northern part of the site (near Weise Road) was later evaluated by Lucy Macmillan, who determined that because

[12] Wiemeyer May 16, 2018.

the creek did not have water flowing during her June 25, 2020 site visit, the creek would be more appropriately classified as "an ephemeral drainage that carries water during stormwater events and not a perennial feature."[13]

The Biological Assessment determined that the on-site grassland and ruderal habitat did not support special-status plant species, and much of the ruderal habitat was the result of historical and current agricultural practices. Some ruderal habitat was also related to cleanup efforts following the 2017 Nuns Fire, including debris removal, soil testing and removal, grading activities, and installation and maintenance of erosion and sediment control materials. Most of the project site was disturbed by the 2017 Nuns Fire and/or subsequent cleanup activities.

Because the project site is limited to an area previously disturbed by historical agricultural practices and the 2017 Nuns Fire, the Biological Assessment (p. 19) determined that the site's *"annual grassland and ruderal habitat do not support special-status plant species and will not result in impacts to special-status plant species."* During the site visits, no special-status plant species or special-status animal species were observed, though the Biological Assessment determined that the site does contain habitat suitable for several special-status animal species.

Results of the CNDDB search indicated that special-status plant species likely to occur on the project site or in the vicinity of the project site include: Sonoma sunshine (*Blennosperma bakeri*), dwarf downingia (*Downingia pusilla*), Napa false indigo (*Amorpha californica var. napensis*), Cobb Mountain lupine (*Luinus sericatus*), two-fork clover (*Trifolium amoenum*), Jepson's leptosiphon (*Leptosiphon jepsonii*), Franciscan onion (*Allium peninsulare var. franciscanum*), narrow-anthered brodiaea (*Brodiaea leptandra*), and fragrant fritillary (*Fritillaria liliacea*). The Biological Assessment determined that due to lack of suitable habitat, none of these species would likely occur on most of the project site. However, the riparian woodland and ephemeral tributary have moderate suitability to support special-status plant species because the riparian corridor remains essentially intact with mostly native species, though during the field surveys, none were observed.

Special-status animal species habitat occurs on the property but is focused in areas of oak woodland and riparian woodland. The ephemeral tributary north of the project site may support Rainbow trout (*Oncorhynchus mykiss*) and California roach (*Hesperoleucus symmetricus*), but the Biological Assessment noted that other fish species such as coho salmon (*Oncorhynchus kisutch*), steelhead (*Oncorhynchus mykiss irideus*), Sacramento sucker (*Catostomus occidentalis*), and Pacific lamprey (*Lampetra tridentata*) would be less

[13] Lucy Macmillan, Environmental Scientist, "Creek Evaluation at Gordenker Turkey Farm Properties, 101 and 585 Trinity Road and 12201 Highway 12 Properties, APNs 053-130-009, 053-100-015, and 053-110-001, Glen Ellen, California," June 25, 2020.

likely to occur in the ephemeral tributary. Amphibians would be likely to use the riparian corridor, and Pacific chorus frog was observed during field surveys.

The following special-status animal species were identified as having potential for being impacted by project activities on-site:

- Shark-shinned hawk (*Accipiter striatus*), CDFW – Watch List: potential loss of foraging habitat due to project but not considered a significant impact; however, construction activities could disturb species if nesting at the site.
- Grasshopper sparrow (*Ammodramu savannarum*), CDFW - Species of Special Concern: potential loss of foraging habitat due to project but not considered a significant impact; however, construction activities could disturb species if nesting at the site.
- Golden eagle (*Aquila chyrysaetos*), CDFW - Fully Protected: no suitable nesting habitat on-site, and species not observed on the site; possible loss of foraging habitat due to project but determined there will be no significant impact.
- Burrowing owl (*Athene cunicularia*), CDFW - Species of Special Concern: limited suitable habitat, and species not observed on the site nor were burrows observed; possible loss of foraging habitat due to project but determined there will be no significant impact.
- Ferruginous hawk (*Buteo regalis*), CDFW - Watch List: very limited suitable habitat and species not observed on the site; potential loss of foraging habitat due to project but determined there will be no significant impact.
- Swainson's hawk (*Buteo swainsonii*), State – Threatened: very limited suitable habitat and species not observed on the site; potential loss of foraging habitat due to project but determined there will be no significant impact.
- Western yellow-billed cuckoo (*Coccyzus americanus occidentalis*), Federal - Threatened; State – Endangered: very limited suitable habitat and species not observed on the site; potential loss of foraging habitat due to project but determined there will be no significant impact.
- White-tailed kite (*Elanus leucurus*), CDFW - Fully Protected: suitable foraging and nesting habitat on-site but species not observed on the site; possible loss of foraging habitat due to project but determined there will be no significant impact, however, construction activities could disturb species if nesting at the site.
- American peregrine falcon (*Falco peregrinus anatum*), Federal – Delisted; State – Delisted; CDFW - Fully Protected: no suitable nesting habitat on-site and species not observed on the site; possible loss of foraging habitat due to project but determined there will be no significant impact.
- Bald eagle (*Haliaeetus leucocephalus*), Federal – Delisted; State – Endangered; CDFW – None: no suitable nesting habitat on-site and species not observed on the site;

possible loss of foraging habitat due to project but determined there will be no significant impact.

- Purple martin (*Progne subis*), CDFW – Species of Concern: potentially suitable nesting habitat in the mixed forest areas but very limited nesting habitat in the riparian woodland and oak woodland habitat; species not observed on the site; possible loss of foraging habitat due to project but determined there will be no significant impact, however, construction activities could disturb species if nesting at the site.
- Bank swallow (*Riparia riparia*), State – Threatened: limited yet potentially suitable nesting habitat but species not observed on the site; determined there will be no significant impact.
- Northern spotted owl (*Strix occidentalis caurina*), State and Federal – Threatened; CDFW - Species of Special Concern: limited suitable habitat and species not observed on the site; potential loss of foraging habitat due to project but determined there will be no significant impact.
- American badger (*Taxidea taxus*), CDFW - Species of Special Concern: very limited potentially suitable habitat and no species observed at the site nor were burrows observed; loss of annual grassland and ruderal habitat at the site, but proposed locations for development would be unlikely to become occupied by this species; determined there will be no significant impact.
- Special-Status Bat Species: all bat species have state protection during nesting and roosting seasons:
  Townsend's Big-Eared Bat (*Corynorhinus townsendii*) - Conservation Status: State - Candidate Threatened; CDFW - Species of Special Concern
  Western red bat (*Lasiurus blossevillii*) – Conservation Status: CDFW – Species of Special Concern
  Hoary Bat (*Lasiurus cinereus*) – Conservation Status: None
  Fringed Myotis (*Myotis thysanodes*) – Conservation Status: None
  Long-legged Myotis (*Myotis volans*) – Conservation Status: None
  Yuma Myotis (*Myotis yumanensis*) – Conservation Status: None
  There is suitable foraging habitat for bats on-site though no bat species were observed at the site; determined there will be no significant impact.
- California giant salamander (*Dicamptodon ensatus*), CDFW - Species of Special Concern: suitable habitat though this species typically is found in wetter environments surrounded by forest habitats; species not observed at the site; development setbacks and erosion and sediment control measures during construction activities would prevent significant indirect impacts to this species habitat, therefore, determined there will be no significant impact.
- Western pond turtle (*Emys marmorata*), CDFW - Species of Special Concern: very limited suitable breeding habitat and species not observed at the site; development setbacks and erosion and sediment control measures during construction activities

would prevent significant indirect impacts to this species habitat, therefore, determined there will be no significant impact.

- Foothill yellow-legged frog (*Rana boylii*), State – Candidate Threatened; CDFW - Species of Special Concern: suitable habitat but species not observed at the site; development setbacks and erosion and sediment control measures during construction activities would prevent significant indirect impacts to this species habitat, therefore, determined there will be no significant impact.
- California red-legged frog (*Rana draytonii*), Federal – Threatened; CDFW - Species of Special Concern: very limited suitable breeding habitat but the unnamed tributary and riparian woodland provide suitable foraging, refuge and dispersal habitat; species not observed at the site; development setbacks and erosion and sediment control measures during construction activities would prevent significant indirect impacts to this species habitat, therefore, determined there will be no significant impact.
- Red-bellied newt (*Taricha rivularis*), CDFW - Species of Special Concern: the unnamed tributary and riparian woodland provide suitable habitat, but species not observed at the site; development setbacks and erosion and sediment control measures during construction activities would prevent significant indirect impacts to this species habitat, therefore, determined there will be no significant impact.
- Steelhead, or steelhead trout (*Oncorhynchus mykiss*), Federal – Threatened: the unnamed tributary is not a known steelhead stream but exhibits necessary habitat requirements for spawning habitat and more suitable spawning habitat may exist upstream; species not observed at the site; development setbacks and erosion and sediment control measures during construction activities would prevent significant indirect impacts to this species habitat, therefore, determined there will be no significant impact.
- Coho salmon (*Oncorhynchus kisutch*), Federal - Endangered; State – Endangered: the unnamed tributary exhibits necessary habitat requirements for spawning habitat and more suitable spawning habitat may exist upstream, but species not observed at the site; development setbacks and erosion and sediment control measures during construction activities would prevent significant indirect impacts to this species habitat, therefore, determined there will be no significant impact.

California freshwater shrimp (*Syncaris pacifica*), Federal - Endangered; State – Endangered: potentially suitable habitat but species not known to occur in Calabazas Creek and unlikely to occur in the unnamed tributary; species was not observed at the site; development setbacks and erosion and sediment control measures during construction activities would prevent significant indirect impacts to this species habitat, therefore, determined there will be no significant impact.

Although the project does not propose to remove trees on-site, several special-status bird species and native birds could be disturbed during construction activities if nesting were initiated before the beginning of construction. Because most of the construction impacts from project development would be confined to an area of non-native grassland and ruderal habitat, project impacts on special-status species would largely be limited to potential inadvertent destruction or disturbance of nesting birds on and near the project site as a result of construction-related tree and/or vegetation removal and site disturbance. The following mitigation measure would reduce potential project impacts on nesting birds to a less than significant level.

Level of Significance: Less than Significant with Mitigation Incorporated

Mitigation:

Mitigation Measure BIO-1: Nesting Birds

The following measures shall be taken to avoid potential inadvertent destruction or disturbance of nesting birds on and near the project site as a result of construction-related vegetation removal and site disturbance:

(a) To avoid impacts to nesting birds, all construction-related activities (including but not limited to mobilization and staging, clearing, grubbing, vegetation removal, fence installation, demolition, and grading) shall occur outside the avian nesting season (prior to February 1 or after August 31). Active nesting is present if a bird is sitting in a nest, a nest has eggs or chicks in it, or adults are observed carrying food to the nest.

(b) If construction-related activities are scheduled to occur during the nesting season (February 1 through August 31), a qualified biologist shall conduct a habitat assessment and preconstruction nesting survey for nesting bird species no more than seven (7) days prior to initiation of work. The qualified biologist conducting the surveys shall be familiar with the breeding behaviors and nest structures of birds known to nest in the project site. Surveys shall be conducted at the appropriate times of day during periods of peak activity (i.e., early morning or dusk) and shall be of sufficient duration to observe movement patterns. Surveys shall be conducted within the project area and 250 feet of the construction limits for nesting non-raptors and 1,000 feet for nesting raptors. If the survey area is found to be absent of nesting birds, no further mitigation would be required. However, if project activities are delayed by more than seven days, an additional nesting bird survey shall be performed.

(c) If pre-construction nesting bird surveys result in the location of active nests, no site disturbance (including but not limited to equipment staging, fence installation, clearing, grubbing, vegetation removal, demolition, and grading) shall occur until a qualified biologist has established a temporary protective buffer around the nest(s). The buffer must be of sufficient size to protect the nesting site from construction-related disturbance and shall be established by a qualified ornithologist or biologist with extensive experience working with nesting birds near and on construction sites. Typically, adequate nesting buffers are up to

75 feet from the nest site or nest tree dripline for small birds and up to 1,000 feet for sensitive nesting birds that include several raptor species known from the region of the project site. The nest buffer, where it intersects the project site, shall be staked with orange construction fencing or orange lath staking. Monitoring by a qualified biologist shall be required to ensure compliance with the relevant California Fish and Game Code requirements. Monitoring dates and findings shall be documented. Active nests found inside the limits of the buffer zones or nests within the vicinity of the project site showing signs of distress from project activity, as determined by the qualified biologist, shall be monitored daily during the duration of the project for changes in breeding behavior. If changes in behavior are observed (e.g., distress, disruptions), the buffer shall be immediately adjusted by the qualified biologist until no further interruptions to breeding behavior are detected. The nest protection buffers may be reduced if the qualified biologist determines in coordination with CDFW that construction activities would not be likely to adversely affect the nest. If buffers are reduced, twice weekly monitoring shall be conducted to confirm that construction activity is not resulting in detectable adverse effects on nesting birds or their young. The qualified biologist and CDFW may agree upon an alternative monitoring schedule depending on the construction activity, season, and species potentially subject to impact. Construction shall not commence within the prescribed buffer areas until a qualified biologist has determined that the young have fledged, or the nest site is otherwise no longer in use.

(d) A report of the findings shall be prepared by a qualified biologist and submitted to the County prior to the initiation of construction-related activities that have the potential to disturb any active nests during the nesting season. The report shall include recommendations required for establishment of protective buffers as necessary to protect nesting birds. A copy of the report shall be submitted to the County and applicable regulatory agencies prior to the issuance of a grading permit.

Mitigation Monitoring:

Mitigation Monitoring BIO-1: The County shall not issue permit(s) for ground disturbing activities during the nesting bird season (February 1 through August 31) until after the site has been surveyed by a qualified biologist to ensure that no active bird nest disturbance or destruction would occur as a result of the project.

b) Have a substantial adverse effect on any riparian habitat or other sensitive natural community identified in local or regional plans, policies, regulations or by the California Department of Fish and Wildlife or U.S. Fish and Wildlife Service?

Comment:

Riparian habitat typically includes woody vegetation that grows along the margins of water features. Riparian habitat primarily exists along the unnamed ephemeral tributary to the north of the project site and extends onto the project site. Project cultivation areas (indoor and outdoor) would be outside of the County-mandated minimum 50-foot buffers for the riparian corridor. However, the proposed project sewer pipeline connecting to the adjacent parcel would cross the unnamed ephemeral tributary. In addition to standard Sonoma Count permit requirements for utility lines, the sewer pipeline could require a Lake and Streambed Alteration Agreement with the California Department of Fish and Wildlife to ensure that impacts on the tributary and related riparian habitat are minimized.

Significance Level: Less than Significant with Mitigation Incorporated

Mitigation:

Mitigation Measure BIO-2: Lake and Streambed Alteration Agreement

Prior to issuance of any grading or building permit for the sewer pipeline extension across the unnamed ephemeral tributary (to the north of the project site), the applicant shall submit the pipeline stream crossing plans to CDFW for review and shall either (1) execute a Lake and Streambed Alteration Agreement (LSAA) with CDFW, or (2) if CDFW determines appropriate, obtain from CDFW a waiver for the proposed work. In addition, the applicant shall file an application with the Water Board for any related actions that could result in the discharge of dredged or fill material to waters of the state. In addition to any Best Management Practices (BMPs) identified by CDFW or the Water Board, the applicant shall implement the following BMPs for any work in or near the stream, including, but not limited to:

1. Proper erosion control and other water quality BMPs shall be implemented to avoid sedimentation and disturbance in the streambed and downstream, where storm water may run off into the riparian corridor. All staging, maintenance, fueling, and storage of construction equipment shall be conducted in a location and in a manner that will prevent potential runoff of petroleum products into the adjacent streambed. During construction, oil-absorbent and spill containment materials shall be on site at all time. All construction workers shall be properly trained and informed of how to use and where to find on site the oil-absorbent and spill-containment materials.

2. No trees or riparian vegetation shall be removed for any construction activities.

Mitigation Monitoring:

Mitigation Monitoring BIO-2: Permit Sonoma shall not issue any grading or building permits until the applicant has provided copies of all required permits (or waivers) from the State Department of Fish and Wildlife and the San Francisco Regional Water Quality Control Board, and any documentation deemed necessary by the Grading & Storm Water Section of the Permit and Resource Management Department.

c) Have a substantial adverse effect on state or federally protected wetlands (including, but not limited to, marsh, vernal pool, coastal, etc.) through direct removal, filling, hydrological interruption, or other means?

Comment:
The Biological Assessment assessed four seasonal wetland areas on the project site: near the northeast property boundary; between the existing residential structures and the east property boundary; and two near the west property boundary by Highway 12. In addition, two small seasonal wetland depressions are near the southwest corner of the site along Trinity Road. The project proposes no cannabis cultivation within 100 feet of these seasonal wetland areas, in compliance with setback requirements for cannabis projects in County Code section 26-88-254(f)(13). The eastern project access road, which the project indicates would be used as the sole road for project activities, is over 50 feet from the wetland, which would allow room for any road improvements determined necessary by the County to be in compliance with the setback requirements in County Code section 11-14-110. Therefore, proposed project impacts on wetland features on the site would be expected to be less than significant.

Significance Level: Less than Significant Impact

d) Interfere substantially with the movement of any native resident or migratory fish or wildlife species or with established native resident or migratory wildlife corridors, or impede the use of native wildlife nursery sites?

Comment:
Many common bird species (including their eggs and young) are given special protection under the Migratory Bird Treaty Act of 1918 (Migratory Bird Act). Although the project does not propose to remove any trees, as discussed in section 4.a, the potential exists for inadvertent destruction or disturbance of nesting birds on and near the project site to occur as a result of construction activities. According to the Biological Assessment (p. 19), habitat connectivity improves at the property edges, in the ephemeral tributary, and along its riparian corridor. Because project activities would comply with stream and riparian setback requirements, the project would not infringe on potential habitat connectivity areas and therefore would not substantially interfere with wildlife movement in these corridors.

Significance Level: Less than Significant with Mitigation Incorporated

Mitigation:
Mitigation Measures BIO-1 and BIO-2

Mitigation Monitoring:
Mitigation Monitoring BIO-1 and BIO-2

e) Conflict with any local policies or ordinances protecting biological resources, such as tree preservation policy or ordinance?

Comment:
Sonoma County General Plan
The *Sonoma County General Plan 2020* (Sonoma County 2008) Land Use Element and Open Space & Resource Conservation Element both contain policies to protect natural resource lands including, but not limited to watershed, fish and wildlife habitat, biotic areas, and habitat connectivity corridors. Policy OSRC-8b establishes streamside conservation areas along designated riparian corridors.

Riparian Corridor Combining District
The RC combining zone is established to protect biotic resource communities, including critical habitat areas within and along riparian corridors, for their habitat and environmental value, and to implement the provisions of the General Plan Open Space and Resource Conservation and Water Resources Elements. These provisions are intended to protect and enhance riparian corridors and functions along designated streams, balancing the need for agricultural production, urban development, timber and mining operations, and other land uses with the preservation of riparian vegetation, protection of water resources, floodplain management, wildlife habitat and movement, stream shade, fisheries, water quality, channel stability, groundwater recharge, opportunities for recreation, education and aesthetic appreciation and other riparian functions and values.

Tree Protection Ordinance
Chapter 26D of the Sonoma County Code contains a tree protection ordinance (Section 26-88-010(m)). The ordinance designates 'protected' trees as well as provides mitigation standards for impacts to protected trees. This ordinance is used as a guide for determining impacts and appropriate mitigation measures.

Sonoma County Code, Chapter 11, Grading Ordinance
Section 11.14.070 – Removal of trees and other vegetation:

Construction grading and drainage shall not remove or disturb trees and other vegetation except in compliance with the department's best management practices for construction grading and drainage and the approved plans and specifications. Construction grading and drainage shall be conducted in compliance with the following requirements.

A. The limits of work-related ground disturbance shall be clearly identified and delineated on the approved plans and specifications and defined and marked on the site to prevent damage to surrounding trees and other vegetation.

B. Trees and other vegetation within the limits of work-related ground disturbance that are to be retained shall be identified and protected from damage by marking, fencing, or other measures.

As discussed in sections 4.a and 4.b, project cultivation activities do not involve areas containing sensitive habitat or biological resources, nor does the project propose to remove any trees. However, the possibility exists that project construction activities (including possible access driveway and road improvements, as determined necessary by the County) could destroy or disturb nesting birds on and near the project site.

Significance Level: Less than Significant with Mitigation Incorporated

Mitigation:
Mitigation Measures BIO-1 and BIO-2

Mitigation Monitoring:
Mitigation Monitoring BIO-1 and BIO-2

f) Conflict with the provisions of an adopted Habitat Conservation Plan, Natural Community Conservation Plan, or other approved local, regional, or state habitat conservation plan?

Comment:
Habitat Conservation Plans and natural community conservation plans are site-specific plans to address effects on sensitive species of plants and animals. The project site is not located in an area subject to a habitat conservation plan or natural community conservation plan. In addition, the project is not located in the Santa Rosa Plain Conservation Strategy area.

Significance Level: No Impact

5. CULTURAL RESOURCES

Would the project:

a) Cause a substantial adverse change in the significance of a historical resource pursuant to §15064.5?

Comment:
On May 3, 2019, Permit Sonoma staff referred the project application to the Northwest Information Center-Sonoma State University (NWIC) for review and recommendations. The NWIC noted (May 14, 2019) that the State Office of Historic Preservation recommends review of any buildings or structures older than 45 years to determine whether or not they are historic resources.

A June 6, 2019 Cultural Resources Study prepared for the project by Evans & De Shazo included a record search at the NWIC on May 7, 2019; review of other relevant resources (California Inventory of Historic Resources, Office of Historic Preservation, California Historical Landmarks, California Points of Historical Interest, California Register of Historical Resources, and the Directory of Properties in the Historic Property Data File for Sonoma County) and historic maps; and a field survey of the project site, which was conducted on May 15, 2019. The results of the research and field survey identified no historic buildings or structures 45 years of age or older on the project site.[14]

Significance Level: Less than Significant Impact

b) Cause a substantial adverse change in the significance of an archaeological resource pursuant to §15064.5?

Comment:
As described by the NWIC, the proposed project is in an area with the possibility of containing unrecorded archaeological site(s) and recommended a study prior to commencement of project activities. Because no cultural resource studies had been previously conducted for the project site, the NWIC also recommended contact with local Native American tribes for information on cultural resources.

As part of the Cultural Resources Study, Evans & De Shazo performed a field survey (May 15, 2019) to assess the project site for potential archaeological and cultural resources. The Cultural Resources Study (p. 24) concluded: *"No prehistoric or historic-era artifacts, archaeological deposits, or other cultural resource types were identified during the field survey of the Project Area."* Evans & De Shazo contacted seven local Native American tribes. Only one response was received, a May 21, 2019 email via from the Middletown Rancheria, which stated that the Tribe had no specific comments at the time but requested to be contacted if any new information or evidence of Native American activity was identified. In addition, Evans & De Shazo requested a Sacred Lands File search from the

[14]Evans & De Shazo, "Results of A Cultural Resources Study for the Proposed Cannabis Cultivation Project at 101 Trinity Road, Glen Ellen, Sonoma County, California," prepared for Andrew Dobbs-Kramer, Compliance Manager, Sparc, June 6, 2019.

Native American Heritage Commission (NAHC) on May 2, 2019. The NAHC search did not indicate the presence of Native American Sacred Sites within or near the project site.

In addition, Permit Sonoma contacted local tribes who requested AB 52 project notification and received responses from:

- Middletown Rancheria of Pomo Indians of California -- declined comment on the project because project not within their aboriginal territories;
- Stewarts Point Rancheria Band of Kashia Pomo Indians – no concerns or comments at this time because project not within their aboriginal territories; and
- Lytton Rancheria -- not requesting further consultation.

Sonoma County Code Section 11-14-050 requires projects to halt all work in the vicinity of where human remains or archaeological resources are discovered during construction grading and drainage and to perform the following prior to resumption of work:

"A. Human remains. If human remains or suspected human remains are discovered, the permittee shall notify the county coroner and comply with all state law requirements, including Health and Safety Code section 7050.5 and Public Resources Code section 5097.98, to ensure proper disposition of the human remains or suspected human remains, including those identified to be Native American remains."

"B. Archaeological resources. If archaeological resources or suspected archaeologic.al resources are discovered, the director shall notify the State Historic Preservation Officer and the Northwest Information Center at Sonoma State University, and the permittee shall retain a qualified archeologist to evaluate the find to ensure proper disposition of the archaeological resources or suspected archaeological resources. All costs associated with the evaluation and mitigation of the find shall be the responsibility of the permittee. The director shall provide notice of the find to any tribes that have been identified as having cultural ties and affiliation with the geographic area in which the archaeological resources or suspected archaeological resources were discovered, if the tribe or tribes have requested notice and provided a contact person and current address to which the notice is to be sent. The director may consult with and solicit comments from notified tribes to aid in the evaluation, protection, and proper disposition of the archaeological resources or suspected archaeological resources. The need for confidentiality of information concerning the archaeological resources or suspected archaeological resources shall be recognized by all parties. For the purposes of this section, archaeological resources include historic or prehistoric ruins, burial grounds, pottery, arrowheads, midden, or culturally modified soil deposits. Artifacts associated with prehistoric ruins include humanly modified stone, shell, bone, or other cultural materials such as charcoal, ash, and burned rock indicative of food procurement or processing

activities. Prehistoric domestic features include hearths, fire pits, or floor depressions; mortuary features are typically represented by human skeletal remains."

In addition, County Code Section 26-88-254(f)(14) also requires the following for commercial cannabis cultivation projects:

"Cultivation sites shall avoid impacts to significant cultural and historic resources by complying with the following standards. Sites located within a historic district shall be subject to review by the landmarks commission, unless otherwise exempt, consistent with Section 26-68-020 and shall be required to obtain a use permit. Cultivation operations involving ground disturbing activities, including but not limited to, new structures, roads, water storage, trenching for utilities, water, waste water, or drainage systems shall be subject to design standards and referral to the Northwest Information Center and local tribes. A use permit will be required if mitigation is recommended by the cultural resource survey or local tribe.

"The following minimum standards shall apply to cultivation permits involving ground disturbance. All grading and building permits shall include the following notes on the plans:

"If paleontological resources or prehistoric, historic-period or tribal cultural resources are encountered during ground-disturbing work at the project location, all work in the immediate vicinity shall be halted and the operator must immediately notify the agency having jurisdiction of the find. The operator shall be responsible for the cost to have a qualified paleontologist, archaeologist and tribal cultural resource specialist under contract to evaluate the find and make recommendations in a report to the agency having jurisdiction.

"Paleontological resources include fossils of animals, plants or other organisms. Historic-period resources include backfilled privies, wells, and refuse pits; concrete, stone, or wood structural elements or foundations; and concentrations of metal, glass, and ceramic refuse. Prehistoric and tribal cultural resources include obsidian and chert flaked-stone tools (e.g., projectile points, knives, choppers), midden (culturally darkened soil containing heat-affected rock, artifacts, animal bone, or shellfish remains), stone milling equipment, such as mortars and pestles, and certain sites features, places, cultural landscapes, sacred places and objects with cultural value to a California Native American tribe.

"If human remains are encountered, work in the immediate vicinity will stop and the operator shall notify the agency having jurisdiction and the Sonoma County Coroner immediately. At the same time, the operator shall be responsible for the cost to have a qualified archaeologist under contract to evaluate the discovery. If the human remains are determined to be of Native American origin, the Coroner must notify the Native American Heritage Commission within twenty-four (24) hours of this identification."

Project compliance with these County Code standards would protect archaeological and cultural resources during grading and construction activities, and therefore the impact related to uncovering cultural resources during construction would be less than significant.

Significance Level: Less than Significant Impact

c) Disturb any human remains, including those interred outside of dedicated cemeteries?

Comment:
The project site would require grading and construction activities, which could uncover undocumented materials, including human remains. The Sonoma County Code provides procedures for protection of human remains, including notifying the county coroner and complying with the requirements provided by State law (Health and Safety Code section 7050.5 and Public Resources Code section 5097.98) to ensure proper disposition of human remains or suspected human remains, including those identified to be Native American remains.

As required by State law and County Code Sections 11-14-050 and 26-254-88(f)(14), if human remains are encountered, work in the immediate vicinity shall be halted and the operator shall notify Permit Sonoma and the Sonoma County Coroner immediately. At the same time, the operator shall be responsible for the cost to have a qualified archaeologist under contract to evaluate the discovery. If the human remains are determined to be of Native American origin, the Coroner must notify the Native American Heritage Commission within 24 hours of this identification so that a Most Likely Descendant can be designated, and the appropriate measures implemented in compliance with the California Government Code and Public Resources Code. Implementation of State law and County Code policy would ensure that this impact would be less than significant.

Significance Level: Less than Significant Impact

6. ENERGY

Would the project:

a) Result in potentially significant environmental impact due to wasteful, inefficient, or unnecessary consumption of energy resources, during project construction or operation?

Comment:
Project construction would include temporary use of equipment such as bulldozers, excavators, skid steers, compactors, and boom lifts for limited periods ranging from an estimated 16 days for demolition activities to up to approximately 60 days for building

construction. Long-term energy demand would result from employees working on the project site and from employee vehicle trips (as discussed in section 17, Transportation, the proposed project could be expected to generate up to 52 daily trips). The proposed cannabis operation would also result in energy usage from electricity for lighting, odor-reducing fans, the security system (e.g., alarm, lights, cameras), and water and wastewater pumps.

Operation of the proposed project would increase energy usage relative to existing conditions in Sonoma County. However, this increase in energy use would not represent a substantial increase, nor would it be wasteful or inefficient because the applicant proposes to purchase 100 percent renewable power from the Sonoma Clean Power EverGreen program. In addition, lighting for the greenhouses would be high-efficiency LEDs lights; security lighting would be solar-powered.

Commercial cannabis cultivation projects are required to comply with County Code Section 26-88-254(g)(3), which requires that *"Electrical power for indoor cultivation, mixed light operations, and processing including but not limited to illumination, heating, cooling, and ventilation, shall be provided by any combination of the following: (i) on-grid power with one hundred percent (100%) renewable source; (ii) on-site zero net energy renewable source; or (iii) purchase of carbon offsets of any portion of power not from renewable sources. The use of generators for indoor and mixed light cultivation is prohibited, except for portable temporary use in emergencies only."*

Because of the use of renewable power and high-efficiency and solar-power lighting, project impacts related to wasteful, inefficient, or unnecessary energy resources would be less than significant.

<u>Significance Level</u>: Less than Significant Impact

b) Conflict with or obstruct a state or local plan for renewable energy or energy efficiency?

<u>Comment</u>:
The proposed project would be required to comply with local energy efficiency standards as defined in County Code Chapter 7 (Building Regulations), which specifies Title 24, Part 6 of the California Code of Regulations, California Energy Code (Building Energy Efficiency Standards), as the County standard for buildings.

<u>Significance Level</u>: Less than Significant Impact

7. GEOLOGY AND SOILS

Would the project:

a) Directly or indirectly cause potential substantial adverse effects, including the risk of loss, injury, or death involving:

i. Rupture of a known earthquake fault, as delineated on the most recent Alquist-Priolo Earthquake Fault Zoning Map issued by the State Geologist for the area or based on other substantial evidence of a known fault? Refer to Division of Mines and Geology Special Publication 42.

Comment:
The project itself is not within a fault hazard zone, as defined by the Alquist-Priolo fault maps.[15] The closest known fault in an Alquist-Priolo Earthquake Fault Zone is the Rodgers Creek fault located a little over six miles west of the project site.

Significance Level: Less than Significant Impact

ii. Strong seismic ground shaking?

Comment:
All of Sonoma County is subject to seismic shaking that would result from earthquakes along the San Andreas, Healdsburg, Rodgers Creek, and other faults. The nearest fault is the Bennett Valley fault, a little less than four miles to the west, although several unnamed, smaller faults are also in proximity. The expected relative intensity of ground shaking and damage from anticipated future earthquakes in the project area is categorized as 'Very Strong' according to Figure PS-1a (Earthquake Ground Shaking Hazard Areas) in the General Plan Public Safety Element.[16] However, by applying geotechnical evaluation techniques and appropriate engineering practices, potential injury and damage from seismic activity can be diminished, thereby exposing fewer people and less property to the effects of a major damaging earthquake. The design and construction of new structures are subject to engineering standards of the California Building Code (CBC), which account for soil properties, seismic shaking and foundation type. Project conditions of approval require that building permits be obtained for all construction and that the project meet all standard seismic and soil test/compaction requirements. In addition, planned improvements to the existing barn to convert it into a cannabis processing facility could require modifications or alterations to bring the barn into compliance with County building code standards. Therefore, with these standards applied to project structures, the project would not expose people to substantial risk of injury from seismic shaking.

[15] California Department of Conservation, Earthquake Zones of Required Investigation, https://maps.conservation.ca.gov/cgs/EQZApp/app/, accessed 9/8/20.
[16] Sonoma County General Plan 2020, Public Safety Element, Figure PS-1a, Earthquake Ground Shaking Hazard Areas, http://sonomacounty.ca.gov/PRMD/Long-Range-Plans/General-Plan/Public-Safety-Earthquake-Ground-Shaking-Hazard-Areas/, accessed 9/14/20.

Significance Level: Less than Significant Impact

iii. Seismic-related ground failure, including liquefaction?

Comment:
Strong ground shaking can result in liquefaction, the sudden loss of shear strength in saturated sandy material, resulting in ground failure. Areas of Sonoma County most at risk of liquefaction are along San Pablo Bay and in alluvial valleys. The project site is not located within a liquefaction hazard area according to the Sonoma County General Plan 2020 Public Safety Element.[17] According to the Sonoma County GIS tool, the parcel is located within a "Very Low Susceptibility" liquefaction hazard area.

Significance Level: Less than Significant Impact

iv. Landslides?

Comment:
Steep slopes characterize much of Sonoma County, particularly in the northern and eastern portions of the County. Where these areas are underlain by weak or unconsolidated earth materials, landslides are a hazard. The project is located in the eastern part of the county, in an area near the Mayacamas Mountains, which has rugged terrain, steep slopes, and deep canyons. However, the project site is not in an area highly susceptible to landslides, according to the General Plan Public Safety Element, Figure PS-1d.[18] The project site slopes gently to the east (approximately six percent) toward the hills. Proposed on-site grading would be minimal (a net fill of 104 cubic yards) and would be unlikely to destabilize slopes or result in slope failure. New structures proposed would be constructed where former ranch structures are or were located, some of which were destroyed or partially destroyed in the 2017 Nuns fire. The design and construction of all new structures, and planned improvements to the existing barn to convert it into a cannabis processing facility, would be subject to engineering standards of the California Building Code (CBC) and County building standards, which would ensure that potential landslide impacts are less than significant.

Significance Level: Less than Significant Impact

[17] Sonoma County General Plan 2020, Public Safety Element, Figure PS-1c, Liquefaction Hazard Areas, http://sonomacounty.ca.gov/PRMD/Long-Range-Plans/General-Plan/Public-Safety-Liquefaction-Hazard-Areas/, accessed 9/14/20.
[18] Sonoma County General Plan 2020, Public Safety Element, Figure PS-1d, Deep-Seated Landslide Hazard Areas, http://sonomacounty.ca.gov/WorkArea/DownloadAsset.aspx?id=2147542632, accessed 9/9/20.

b) Result in substantial soil erosion or the loss of topsoil?

Comment:
Though the project is proposing to use an existing barn for the central processing facility, ground-disturbing construction activities would include construction of a new greenhouse/nursery/ propagation/head house facility, a septic holding tank, one hammerhead turnaround, one roadway turnout, driveway and interior access road modifications (as determined necessary by the County), a fire hydrant and dedicated water pipeline connecting the hydrant to the water storage tank, and demolition of remaining structures (or portions of structures). As discussed in section 10, Hydrology and Water quality, the project would be required to comply with County erosion and sediment control provisions (County Code Chapter 7 and Chapter 11) that require an erosion prevention/sediment control plan plus implementation of best management practices to reduce runoff. Required inspections by Permit Sonoma staff would ensure that all grading and erosion control measures would be constructed according to the approved plans. Compliance with these County Code standards would ensure that soil erosion and topsoil loss impacts are less than significant.

Significance Level: Less than Significant Impact

c) Be located on a geologic unit or soil that is unstable, or that would become unstable as a result of the project, and potentially result in on- or off-site landslide, lateral spreading, subsidence, liquefaction or collapse?

Comment:
The project site is located in an area with alluvial fan deposits overlying Sonoma Volcanics, and a basement structure comprised of Franciscan Complex. Although the site would be subject to seismic shaking and other geologic hazards as described in section 7.a.ii, iii, and iv, the project site is not located in an area highly susceptible to landslides, nor is the project site located in an area with a high potential for liquefaction. The design and construction of all new structures (e.g., the greenhouse/nursery/ propagation/head house facility) and the planned improvements to the existing barn (to convert to a cannabis processing facility), plus any modifications or alterations necessary to bring the barn into compliance with County code, would be subject to engineering standards of the California Building Code (CBC), which take into account soil properties, seismic shaking, and foundation type. Project conditions of approval require that building permits be obtained for all construction, that the project meet all standard seismic and soil test/compaction requirements, and that all existing structures proposed for use by the project be in compliance with County and State building standards. Therefore, the project would not expose people to substantial risk of injury from seismic shaking.

Significance Level: Less than Significant Impact

d) Be located on expansive soil, as defined in Table 18-1-B of the Uniform Building Code (1994), creating substantial direct or indirect risks to life or property?

Comment:
Table 18-1-B of the Uniform Building Code is an index of the relative expansive characteristics of soil as determined through laboratory testing. Project site soils are mapped as predominantly Tuscan cobbly clay loam with some Red Hill clay loam. These soils have low to moderate shrink-swell potential; however, soils at the project site have not been tested for their expansive characteristics. The project would be required to comply with standard Building Code requirements, which would ensure that potential soil expansion at the proposed project, if expansive soils are found on-site, would be mediated through professional engineering design and practice. Therefore, risks from expansive soils would be less than significant.

Significance Level: Less than Significant Impact

e) Have soils incapable of adequately supporting the use of septic tanks or alternative wastewater disposal systems where sewers are not available for the disposal of wastewater?

Comment:
The project site is not in an area served by public sewer. Two existing septic systems serve the property (for the residence and the accessory dwelling unit, respectively). However, these existing systems would not provide wastewater disposal for the project. As discussed in section 19, Utilities and Service Systems, project wastewater would be disposed of by piping off-site to an existing, permitted leachfield on an adjacent parcel.

Significance Level: Less than Significant Impact

f) Directly or indirectly destroy a unique paleontological resource or site or unique geologic feature?

Comment:
Results of the on-line paleontological resources record search through the University of California Museum of Paleontology (UCMP) database indicate that there are no known vertebrate fossil localities or unique geological features that have been previously identified on the project parcel or nearby, although there are listings associated with the nearby area (i.e., Bennett Valley, Matanzas Creek).[19] An examination of the Geological Map of California

[19] UCMP Specimen Search, University of California Museum of Paleontology, https://ucmpdb.berkeley.edu/, accessed 9/16/20.

indicates that the area around the project consists of surface sediments composed of quaternary nonmarine terrace deposits and Pliocene volcanic rocks of the Sonoma Group.[20]

As discussed in section 5.b, Cultural Resources, Sonoma County Code Section 26-88-254(f)(14) provides standard procedures for protection of paleontological resources encountered during ground-disturbing work at the project location:

> *"The following minimum standards shall apply to cultivation permits involving ground disturbance. All grading and building permits shall include the following notes on the plans:*
>
> *"If paleontological resources or prehistoric, historic-period or tribal cultural resources are encountered during ground-disturbing work at the project location, all work in the immediate vicinity shall be halted and the operator must immediately notify the agency having jurisdiction of the find. The operator shall be responsible for the cost to have a qualified paleontologist, archaeologist and tribal cultural resource specialist under contract to evaluate the find and make recommendations in a report to the agency having jurisdiction.*
>
> *"Paleontological resources include fossils of animals, plants or other organisms. Historic-period resources include backfilled privies, wells, and refuse pits; concrete, stone, or wood structural elements or foundations; and concentrations of metal, glass, and ceramic refuse. Prehistoric and tribal cultural resources include obsidian and chert flaked-stone tools (e.g., projectile points, knives, choppers), midden (culturally darkened soil containing heat-affected rock, artifacts, animal bone, or shellfish remains), stone milling equipment, such as mortars and pestles, and certain sites features, places, cultural landscapes, sacred places and objects with cultural value to a California Native American tribe."*

Implementation of this standard County policy would ensure that this impact would be less than significant.

Significance Level: Less than Significant Impact

[20] State of California, Department of Conservation, Geological Map of California, Olaf P. Jenkins Edition, Santa Rosa Sheet, Compilation by James B. Koenig, 1963, https://www.conservation.ca.gov/cgs/Documents/Publications/Geologic-Atlas-Maps/GAM_022-Map-1963.pdf, accessed 9/15/20.

8. GREENHOUSE GAS EMISSIONS

Would the project:

a) Generate greenhouse gas emissions, either directly or indirectly, that may have a significant impact on the environment?

Comment:
Global greenhouse gas emissions contribute to climate change; individual projects do not generate enough GHG emissions to influence global climate change. Thus, the analysis of GHG emissions is by nature a cumulative analysis focused on whether an individual project's contribution to global climate change is cumulatively considerable.

The California Air Resources Board (CARB) is the lead agency for implementing Assembly Bill (AB) 32, the California Global Warming Solutions Act adopted by the Legislature in 2006. The Legislature amended AB 32 in 2016 with Senate Bill (SB) 32. AB 32 and SB 32 require the CARB to prepare a Scoping Plan containing the main strategies that would be used to achieve the State's GHG emissions reductions targets, which in general are:

- Reduce statewide GHG emissions to 1990 levels by 2020;
- Reduce GHG emissions to 40 percent below 1990 levels by 2030; and
- Reduce GHG emissions to 80 percent below 1990 levels by 2050

CARB prepares an annual Statewide GHG emissions inventory using Regional, State, and Federal data sources, including facility-specific emissions reports prepared pursuant to the State's Mandatory GHG Reporting Program. The Statewide GHG emissions inventory helps CARB track progress towards meeting the State's AB 32 GHG emissions target of 431 million metric tons of Carbon Dioxide (CO_2) equivalents ($MTCO_2e$), as well as to establish and understand trends in GHG emissions. According to CARB's most recent GHG emissions inventory (2017 edition), GHG emissions have generally decreased over the last decade, with 2015 levels (440 million $MTCO_2e$) approximately 10 percent less than 2004 levels (488 million $MTCO_2e$). The transportation sector (165 million $MTCO_2e$) accounted for more than one-third (approximately 37.5 percent) of the State's total GHG emissions inventory (440 million $MTCO_2e$) in 2015, while electric power generation accounted for approximately one-fifth (19 percent) of the State's total GHG emissions inventory.

The County concurs with and utilizes as County thresholds the Bay Area Air Quality Management District (BAAQMD)-recommended GHG significance thresholds. The County also concurs that these thresholds are supported by substantial evidence for the reasons stated by BAAQMD staff. For projects other than stationary sources, the GHG significance threshold is 1,100 $MTCO_2e$ or 4.6 metric tons of CO_2e per service population (residents and employees) per year.

The proposed project would generate GHG emissions from the same sources described in section 3, Air Quality, as well as from the following additional sources that are specific to GHG emissions:

- Energy use and consumption includes GHG emissions generated from purchased electricity and natural gas.
- Solid waste disposal includes GHG emissions generated from the transport and disposal of landfilled waste.
- Water/wastewater includes emissions from electricity used to supply water to land uses, and treat the resulting wastewater generated.

As summarized above, the transportation sector accounts for more than one-third of GHG emissions in the State and is typically one of the largest GHG emissions sources associated with a development project; however, as described in section 3, Air Quality, the proposed project would not generate a large amount of vehicle trips that would generate significant emissions. The electric power sector accounts for approximately one-fifth of GHG emissions in the State. Commercial cannabis facilities, such as the proposed project, can involve the use of lights, fans, and other equipment for 24 hours per day to control environmental conditions and provide ideal growing conditions. Also, the water required for cannabis cultivation requires energy to transport.

Although cannabis facilities can consume energy and water in quantities that may be higher (on a square-footage basis) than other general light industrial land uses, the proposed project would not generate significant GHG emissions from these sources because, as described in section 3, the project would provide electrical power through a combination of on-grid 100 percent renewable energy, an on-site zero net energy renewable energy system, or purchase of carbon offsets for power obtained from non-renewable resources, as required pursuant to County Code Section 26-88-254(g)(3). This requirement would reduce GHG emissions from the project's energy and water sources, consistent with State reduction goals.

As discussed in section 3, Air Quality, the BAAQMD *CEQA Air Quality Guidelines* contain screening criteria to provide lead agencies with a conservative indication of whether a proposed project could result in potentially significant air quality or GHG impact. Consistent with BAAQMD's guidance, if a project meets all the screening criteria, then the project would result in a less than significant GHG impact and a detailed GHG assessment is not required for the project. As shown in Table 4, the proposed project is below all applicable BAAQMD operational screening size criteria operational screening size criteria (construction less than 11 acres or 259,000 square feet of building space, and fewer than 540 employees; operations less than 72 acres or 541,000 square feet of building space and fewer than 1,249 employees). Therefore, the proposed project would be consistent with BAAQMD operational screening criteria and would result in less than significant GHG emissions.

The BAAQMD does not maintain GHG screening criteria for construction emissions; however, construction GHG emissions are usually amortized over the lifetime of a project (typically assumed to be 30 years) and included in the estimate of annual project operational GHG emissions. As discussed in section 3, Air Quality, the County is including BAAQMD-recommended basic construction measures into the project as Mitigation Measure AIR-1, which would reduce fuel combustion and GHG emissions by requiring equipment to be properly maintained and limiting idling emissions. GHG emissions associated with construction activities are not anticipated to be substantial and would not change the significance conclusion pertaining to GHG emissions. As a standard condition of approval, the County requires that projects submit a greenhouse gas reduction plan to reduce GHGs beyond statutory requirements to achieve compliance with General Plan GHG reduction goals.

Significance Level: Less than Significant Impact

b) Conflict with an applicable plan, policy or regulation adopted for the purpose of reducing the emissions of greenhouse gases?

Comment:
The proposed project would not conflict with an applicable plan, policy, or regulation adopted for the purpose of reducing the emissions of Greenhouse Gases (GHG). The County currently does not have an applicable countywide Climate Action Plan but has adopted a Climate Change Action Resolution in May 2018 to support reducing GHG emissions. The resolution establishes goals to establish a consistent framework throughout the County.

As described in section 8.a above, the proposed project would be consistent with the BAAQMD Clean Air Plan, would be required to reduce GHG emissions from energy consumption, and would, therefore, not generate GHG emissions that conflict with an applicable plan, policy, or regulation adopted for the purpose of reducing GHG emissions.

Significance Level: Less than Significant Impact

9. HAZARDS AND HAZARDOUS MATERIALS

Would the project:

a) Create a significant hazard to the public or the environment through the routine transport, use, or disposal of hazardous materials?

Comment:
Operation of the project, as well as ongoing maintenance activities over time, may involve the intermittent transport, storage, use, and disposal of potentially hazardous materials, including fuels such as propane and other materials commonly used for maintenance. In addition, plant nutrients, fertilizers, and approved pesticides and/or chemicals would be used during the cultivation and processing operation. Project use of any and all hazardous materials that may be generated, stored, transported, used, or disposed of would be subject to applicable local, State, and federal regulations. The project would include a backup power generator (approximately 600 kVA, for emergency purposes only), which would require fuel to be stored on the property. The applicant would be required to obtain a generator permit from Sonoma County. (Bay Area Air Quality Management District permit requirements for backup power generators are discussed in section 3, Air Quality.)

In addition, the project would be required to comply with the hazardous materials operating standards for cannabis cultivation set forth in Section 26-88-254(g)(4) of the County Code and would also need to maintain any applicable permits required by Sonoma County Fire and the Emergency Services Department of the Agriculture Commissioner.

Project construction activities (greenhouse/nursery/ propagation/head house facility, fencing, hammerhead turnaround, roadway turnout, driveway and interior access road modifications as determined necessary by the County, and associated infrastructure needed by the project) and conversion of the existing barn into a processing center may involve short-term transport, storage, and use of hazardous materials, but would not require routine or ongoing transport, use, or disposal of hazardous materials beyond periodic maintenance needs. These normal activities would also be subject to applicable local, State, and federal regulations.

With existing General Plan policies and federal, State, and local regulations and oversight of hazardous materials, and project compliance with County Code standards, the potential threat to public health and safety or the environment from hazardous materials transport, use or disposal would represent a less than significant impact.

Significance Level: Less than Significant Impact

b) Create a significant hazard to the public or the environment through reasonably foreseeable upset and accident conditions involving the release of hazardous materials into the environment?

Comment:
The project proposes to use organic pesticides, herbicides, and/or fungicides and would maintain a plan for appropriate use and disposal of these materials, subject to review by

County Fire. In addition, because the proposed project would include demolition of structures and/or partial structures remaining from the 2017 Nuns Fire, the project would be required to obtain a demolition permit from Permit Sonoma and would also be required to notify the Bay Area Air Quality Management District at least 10 business days before any demolition activities (regardless of potential building asbestos content). As discussed in section 9.a, with existing General Plan policies and federal, State, and local regulations, oversight of hazardous materials, and project compliance with County Code standards, the potential threat to public health and safety or the environment from accidental release of hazardous materials into the environment would be less than significant.

Significance Level: Less than Significant Impact

c) Emit hazardous emissions or handle hazardous or acutely hazardous materials, substances, or waste within one-quarter mile of an existing or proposed school?

Comment:
The nearest school is Dunbar Elementary School, located at 11700 Dunbar Road, Glen Ellen, about one-half mile northwest of the project site. Also, the project is not located in a 1,000-foot school buffer zone as defined by the cannabis ordinance. Therefore, there would be no impact.

Significance Level: No Impact

d) Be located on a site which is included on a list of hazardous materials sites compiled pursuant to Government Code Section 65962.5 and, as a result, would it create a significant hazard to the public or the environment?

Comment:
There is one site identified in State Water Resources Control Board GeoTracker database that is on a parcel near the project site: the Gordenker Turkey Farm - Sylvia Drive Vineyard at 12201 Sonoma Highway (an adjacent parcel). This vineyard site is registered in the Water Board's "Irrigated Lands Regulatory Program," which is part of the Water Board's General Waste Discharge Requirements for Vineyard Properties. There are no other known hazardous material sites within or adjacent to the project limits, based on review of the following databases on September 10, 2020.

1. The State Water Resources Control Board GeoTracker database,[21]

[21] State Water Resources Control Board GeoTracker Database, http://geotracker.waterboards.ca.gov/, accessed on 9/10/20.

2. The Department of Toxic Substances Control EnviroStor database (formerly known as Calsites),[22] and
3. The California Integrated Waste Management Board Solid Waste Information System (SWIS).[23]

Further, the project site is not included on the list of hazardous materials sites compiled pursuant to Government Code Section 65962.5.[24]

Significance Level: Less than Significant Impact

e) For a project located within an airport land use plan or, where such a plan has not been adopted, within two miles of a public airport or public use airport, would the project result in a safety hazard or excessive noise for people residing or working in the project area?

Comment:
The site is not within the Airport Referral Area as designated by the Sonoma County Comprehensive Airport Land Use Plan. The Charles M. Schulz Sonoma County Airport is located approximately 18 miles northwest of the project site. The nearest airport is Sonoma Skypark Airport, a public use airport located about 9.25 miles southeast of the project site. Petaluma Municipal airport is about 9.75 miles southwest of the project site.

Significance Level: No Impact

f) Impair implementation of or physically interfere with an adopted emergency response plan or emergency evacuation plan?

Comment:
The project would not impair implementation of, or physically interfere with, the County's adopted emergency operations plan (Sonoma County/Operational Area Emergency Operations Plan, December 2014). There is no separate emergency evacuation plan for the County. Given the minimal traffic associated with the project (an estimated 17 employees maximum, with an approximate trip generation of 52 average daily trips), the project would not result in a significant change in existing circulation patterns and would have no measurable effect on emergency response routes.

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[22] The Department of Toxic Substances Control EnviroStor Database, http://www.envirostor.dtsc.ca.gov/public/, accessed on 9/10/20.
[23] The California Integrated Waste Management Board of Solid Waste Information System (SWIS), https://www2.calrecycle.ca.gov/SolidWaste/Site/Search, accessed on 9/10/20.
[24] California Environmental Protection Agency, Cortese List Data Resources, http://www.calepa.ca.gov/SiteCleanup/CorteseList/default.htm, accessed on 9/10/20.

Significance Level: No Impact

g) Expose people or structures, either directly or indirectly, to a significant risk of loss, injury or death involving wildland fires?

Comment:
According to the Wildland Fire Hazard Areas mapping (Figure PS-1g) of the Sonoma County General Plan 2020,[25] the project site is located in a moderate fire hazard zone; however, it is near an area designated as a very high fire hazard zone. The 2020 Glass Fire perimeter was within four miles of the project site. In addition, several structures on the project site were destroyed during the 2017 Nuns Fire, which burned an area of approximately 56,600 acres.

The project site is in an area designated for agriculture east of Highway 12 and south of Trinity Road. West of Highway 12, the area is characterized by more rural residential properties intermixed with fields and wooded areas. Slopes on the project site are gentle (about six percent), rising to the east and into the Mayacamas Mountains where slopes become steeper toward mountain tops and ridges (Mt. Veeder, about three and a half miles from the project site, is approximately 2,700 feet in elevation). The mountain area is heavily forested with underlying chapparal, and the area has several canyons (e.g., Adobe Canyon, Nuns Canyon, Stuart Canyon).

The project site is not in a Wildland Urban Interface Area, but it would be required to comply with the California Building Code and the California Fire Code, which would reduce fire risks on people and structures.

In addition, as part of the County's planning referral process, the Fire Department responded with a comment letter to Permit Sonoma on May 24, 2019. The comment letter included several conditions of approval that the applicant would need to comply with, addressing the following areas:

- Compliance with pertinent codes, regulations, and ordinances related to building design and fire prevention
- Fire protection planning
- Emergency access
- Water supply
- Vegetation management

[25] Sonoma County General Plan 2020, Public Safety Element, Wildland Fire Hazard Areas, Figure PS-1g, https://sonomacounty.ca.gov/PRMD/Long-Range-Plans/General-Plan/Public-Safety-Wildland-Fire-Hazard-Areas/, accessed 9/16/20.

As a standard condition of approval, construction on the project site would be required to comply with Sonoma County Code Chapter 13 ("Sonoma County Fire Safety Ordinance," Ordinance No. 6184), including but not limited to fire sprinklers, emergency vehicle access, and water supply making the impact from risk of wildfire less than significant.

County Code Section 26-88-254(f)(16) also requires that the applicant prepare and implement a fire prevention plan for construction and ongoing operations, including provision for emergency vehicle access and turnouts, vegetation management, and fire break maintenance around all structures.

Project compliance with these standard County and State requirements would ensure that risks from wildland fires on people and structures would be less than significant.

Significance Level: Less than Significant Impact

10. HYDROLOGY AND WATER QUALITY

Would the project:

a) Violate any water quality standards or waste discharge requirements or otherwise substantially degrade surface or groundwater quality?

Comment:
The project would include grading of approximately 4,004 cubic yards (CY) of cut and 4,108 CY of fill, for a net fill of 104 CY. In addition, approximately 173,700 square feet of ground disturbance would result from the project greenhouse/nursery/ propagation/head house facility, the hammerhead turnaround and emergency turnout, modifications to the driveway and access roads as determined necessary by the County, associated infrastructure needed by the project, and the new cultivation areas. These improvements and project operations could affect the quantity and/or quality of storm water runoff.

The proposed cultivation areas have been previously disturbed (formerly occupied by buildings), and limited ground-disturbing activities would be anticipated to prepare the areas for cultivation (demolition of remaining structures from the 2017 Nuns Fire). The cannabis plants would be cultivated in grow bags placed on top of the ground, with gravel for the aisles or possibly wood chips in some areas.

Watershed. The project site is located in the Upper Sonoma Creek subwatershed of the Sonoma Creek-Frontal San Pablo Bay Estuaries watershed, which is part of the larger San Pablo Hydrologic Unit. The project site is in a Class 3 groundwater basin (Marginal Groundwater Availability), as classified in the County's Groundwater Availability map. There is an intermittent blue line stream outside the northern property line that runs close to Weise Road and connects with Calabazas Creek west of Highway 12, between Dunbar Road and Henno Road (referred to as an “unnamed ephemeral tributary” in section 4, Biological Resources). Calabazas Creek flows south and joins Sonoma Creek in Glen Ellen. From there, Sonoma Creek continues its southward flow before emptying in San Pablo Bay, about 16 miles away.

Sonoma Creek has been remapped (divided) into two parts for more consistent section 303 impairment analysis and implementation actions: (1) the southern “tidal” part of the creek connecting to San Pablo Bay (approximately seven miles long and tidally influenced), and (2) the northern “non-tidal” part (approximately 23 miles long and flowing through the Glen Ellen area). The “non-tidal” part of Sonoma Creek is listed by the State Water Resources Control Board (SWRCB) and San Francisco Bay Regional Water Quality Control Bord (SFRWQCB) under section 303 of the Clean Water Act as impaired for sedimentation/ siltation, nutrients, and pathogens. A total maximum daily limit (TMDL) action plan is currently in place for sedimentation/siltation and pathogens; a TMDL is required for nutrients. The southern “tidal” part of Sonoma Creek has been delisted for sedimentation/ siltation due to this mapping change; however, the southern “tidal” part is listed as impaired for nutrients and pathogens. A TMDL is currently in place for pathogens; a TMDL is required for nutrients. San Pablo Bay is listed under section 303 as impaired for metals, pesticides, and invasive species. A TMDL is currently in place for metals; a TMDL is required for pesticides and invasive species. In addition, Calabazas Creek, a tributary to Sonoma Creek, has been delisted due to incorrect assignment of data (which has been correctly assigned to a similarly named waterbody in Santa Clara County).[26]

Waste Discharge. The SWRCB Cannabis General Order WQ 2019-0001-DWQ (Cannabis General Order) for General Waste Discharge Requirements and Waiver of Waste Discharge Requirements for Discharges of Waste Associated with Cannabis Cultivation Activities, effective as of April 16, 2019, requires submittal of a Site Management Plan describing best management practices (BMPs) to protect water quality and may also require a site erosion and sediment control plan, disturbed area stabilization plan, and/or nitrogen management plan, depending on size and site characteristics of the operation. All outdoor commercial cultivation operations that disturb an area equal to or greater than 2,000 square feet of soil are required to enroll or to apply for a waiver of waste discharge (if applicable). Compliance with the Cannabis General Order is a standard condition of approval for all cannabis permits. County conditions of approval require a copy of the Waste Discharge Permit to be submitted prior to issuance of a Certificate of Occupancy or project operation and vesting the Use Permit.

[26] State Water Resources Control Board, Impaired Water Bodies, Final 2014/2016 California Integrated Report (Clean Water Act Section 303(d) List / 305(b) Report), https://www.waterboards.ca.gov/water_issues/programs/tmdl/integrated2014_2016.shtml, accessed 9/10/20.

The project would require coverage under the SWRCB General Construction Permit because project construction activities would disturb one or more acres of soil.

In addition, Section 26-88-254(g)(9) of the County Code requires that the applicant submit a wastewater management plan, as follows:

> *"A waste water management plan shall be submitted identifying the amount of waste water, excess irrigation and domestic waste water anticipated, as well as disposal. All cultivation operations shall comply with the best management practices issued by the agricultural commissioner and shall submit verification of compliance with the waste discharge requirements of the state water resource control board, or waiver thereof. Excess irrigation water or effluent from cultivation activities shall be directed to a sanitary sewer, septic, irrigation, graywater or bio-retention treatment systems. If discharging to a septic system, a system capacity evaluation by a qualified sanitary engineer shall be included in the management plan. All domestic waste for employees shall be disposed of in a permanent sanitary sewer or on-site septic system demonstrated to have adequate capacity."*

Runoff and storm water control for cannabis cultivation, as addressed in County Code Section 26-88-254(f)(20), requires:

> *"Runoff containing sediment or other waste or by-products shall not be allowed to drain to the storm drain system, waterways, or adjacent lands. Prior to beginning grading or construction, the operator shall prepare and implement a storm water management plan and an erosion and sediment control plan, approved by the agency having jurisdiction. The plan must include best management practices for erosion control during and after construction and permanent drainage and erosion control measures pursuant to Chapter 11 of the county code. All cultivation operators shall comply with the best management practices for cannabis cultivation issued by the agricultural commissioner for management of wastes, water, erosion control and management of fertilizers and pesticides."*

Drainage and Runoff. The cannabis cultivation best management practices prescribed by the County Agriculture Commissioner include measures related to pesticide and fertilizer storage and use, riparian protection, water storage and use, waste management, erosion control/grading and drainage for outdoor cultivation, and pesticide use, waste management, and water use for indoor cultivation.

In addition, project construction would need to meet all applicable County grading and drainage requirements (County Code Chapter 11--Construction Grading and Drainage Ordinance). Required inspections by Permit Sonoma staff would ensure that water quality standards and erosion control measures would be maintained according to the approved project plans and applicable policy regulations.

Application of these standard County and State storm water requirements and County conditions of approval would reduce project storm water runoff impacts to a less than significant level.

Significance Level: Less than Significant Impact

b) Substantially decrease groundwater supplies or interfere substantially with groundwater recharge such that the project may impede sustainable groundwater management of the basin?

Comment:
The project is not located in a Priority Groundwater Basin as indicated by the Department of Water Resources Sustainable Groundwater Management Act Basin Prioritization Dashboard. The project site is located near the Napa-Sonoma Valley - Sonoma Valley groundwater basin, which is a high priority groundwater basin. The project is located in Groundwater Availability Class 3 (Marginal Groundwater Area), and pursuant to Sonoma County General Plan Policy WR-2e and County Policy 8-1-14, would be required to complete and submit a hydrogeologic assessment to Permit Sonoma.

A hydrogeologic assessment was prepared by PJC & Associates, Inc. ("PJC"; "PJC Report") to describe the project recharge area (i.e., cumulative impact area), including estimates of groundwater storage in the aquifer, groundwater recharge rates, and proposed groundwater use; review well completion reports (drillers' logs) from the area and provide a characterization of local hydrogeologic conditions; and assess the potential for well interference between the project well and neighboring wells.[27] In addition, the PJC report considered the cumulative effects on groundwater demand of the proposed project in conjunction with two other cannabis projects on adjoining parcels: the Terra Luna Farms project to the north, and the Gordenker Ranch Cannabis Cultivation project to the east.

Recharge Area/Cumulative Impact Area/Groundwater Storage (PJC Report, pp. 6-8). PJC described the cumulative impact area (CIA) as parcels within 1,500 feet of the project parcel plus the two adjoining parcels (Terra Luna Farms and Gordenker Ranch). Based on this CIA, PJC estimated groundwater storage in the CIA at 800 acres, with the volume of the saturated aquifer estimated at 108,000 acre-feet. Due to the variability of actual water yield (based on the underlying rock structure), PJC conservatively estimated the aquifer groundwater storage capacity at 3,240 acre-feet.

[27] PJC & Associates, Inc., "Groundwater Availability Evaluation, Proposed 3-Lot Cannabis Development, Trinity Road & Sonoma Highway, APN: 053-110-076, 053-110-001 & 053-130-009, Glen Ellen, California," October 27, 2018.

Groundwater Recharge (PJC Report, pp. 8-12). Groundwater recharge was estimated based on mean annual precipitation in the area, minus losses due to evapotranspiration and surface runoff, and totaled approximately 233 acre-feet per year. Groundwater demand in the CIA was estimated based on the number of "cultivatable parcels," which assumed for calculation purposes that one-acre cannabis cultivation uses would occur on each of the parcels, for a total of 21 cultivatable parcels. Using that demand assumption, groundwater demand in the CIA, not including the project parcel, was estimated at 31.5 acre-feet per year.

Groundwater Use (PJC Report, pp. 9-12). PJC calculated domestic water use based on the number of dwelling units that the parcels in the CIA could be created under existing zoning and was estimated at 31.5 acre-feet per year. Vineyard water use and water for livestock were also calculated and added to the total groundwater demand in the CIA, as was water use for the existing vegetable garden on the project site.

PJC estimated total groundwater use for cannabis operations in the CIA, including the proposed project and the two adjoining parcels, at 35.0 acre-feet per year, and total domestic groundwater use in the CIA, including the proposed project and two adjoining parcels, at 36.0 acre-feet per year. Total livestock groundwater use in the CIA was estimated at 0.25 acre-feet per year.

Based on these individual estimates, PJC estimated total groundwater demand in the CIA at 112.75 acre-feet per year. The groundwater recharge rate is 233.0 acre-feet per year. And the total groundwater storage capacity is 3,240 acre-feet. Therefore, maximum potential groundwater demand in the CIA would be approximately 48 percent of groundwater recharge and approximately four percent of groundwater storage in the aquifer.

Groundwater Drawdown/Well Interference (PJC Report, pp. 12-13). PJC considered groundwater drawdown a function of distance, with wells at least 1,000 feet away not likely to be affected by project groundwater drawdown. Two of the nearest off-site wells were identified about 1,000 feet away, and a third well, 800 feet away, was no longer in use. PJC determined that this situation would be within tolerable limits and groundwater drawdown/well interference would not be substantial.

Groundwater Quality (PJC Report, pp. 13-14). Groundwater was tested for boron, iron, magnesium, total dissolved solids, pH, alkalinity, and specific conductance (which is an indirect measure of the presence of dissolved solids and can be used as an indicator of water pollution). Based on the testing, water quality was determined to be acceptable, however, PJC recommended the use of a filter to lower the iron content and noted that it may be necessary to consider using some method to increase pH levels. In addition, PJC recommended that water quality testing be performed for any new well drilled.

Potential Impacts to Surface Waters and Aquatic Habitats (PJC Report, pp. 13-14). There are several unnamed tributaries to Calabazas Creek in the CIA, but PJC determined that it would be highly unlikely that groundwater use would have an impact on aquatic or riparian habitat or critical flow of nearby streams based on the characteristics and depth of the aquifer system and the distance to major creeks and streams. At County request, PJC prepared a supplement to the PJC Report ("Supplemental Report") incorporating new flow rate information for Calabazas Creek provided by the Sonoma Ecology Center (two-year sample data from monitoring gauges on Highway 12 and Dunbar Road) to re-evaluate potential impacts to surface waters using the new data.[28] In the Supplemental Report, PJC also incorporated revised streamflow depletion rates in the computer model to reflect updated aquifer storativity estimates (storativity is the specific storage of an aquifer in relation to the thickness of the aquifer) and more accurately calculate stream depletion for Calabazas Creek. The PJC analysis (Supplemental Report, p. 4) concluded that using the most conservative dry season stream flow data, *"potential stream depletion on Calabazas Creek after 180 days would represent a less than 10 percent reduction of streamflow,"* and PJC determined that this would be *"a negligible amount."* PJC based this determination on: (1) the conservative dry season streamflow data used in the model; (2) the year-round flow conditions of Calabazas Creek, which are indicative of an area with abundant water; (3) the conservative stream depletion rates used in the computer model; (4) the distance of the well from Calabazas Creek (approximately 1,000 feet) and from the upland watershed of the creek; and (5) the depth at which the well obtains water from the aquifer (approximately 200 feet).[29] The Permit Sonoma Natural Resources Geologist (November 27, 2019) indicated that the PJC Supplemental Report was *"well documented and of appropriate detail and effort to support the findings."*

In addition, new project landscaping would be subject to the County's Water Efficient Landscape Ordinance (Chapter 7D3 of the Sonoma County Building Code).

Therefore, the proposed project would not result in a substantial decrease in groundwater supplies or substantial interference with groundwater recharge.

Significance Level: Less than Significant Impact

[28]PJC & Associates, Inc., "Supplemental Groundwater Availability Evaluation, Proposed 3-Lot Cannabis Development, Trinity Road & Sonoma Highway, APN: 053-110-076, 053-110-001 & 053-130-009, Glen Ellen, California," October 17, 2019.

[29]As noted in the Supplemental Report, the Calabazas Creek Open Space Preserve Resource Management Plan described the hydrologic conditions of the Calabazas Creek subwatershed as follows: *"The fact that the majority of the main channel* [of Calabazas Creek] *conducts water throughout the year, and supports a large number of deep pools (from a few inches to several feet) along most of its length, is evidence of the considerable amount of water conducted within the sub-watershed."* (Sonoma County Agricultural Preservation & Open Space District, Calabazas Creek Open Space Preserve Resource Management Plan, May 2016, p. 9.)

c) Substantially alter the existing drainage pattern of the site or area, including through the alteration of the course of a stream or river or through the addition of impervious surfaces, in a manner which

i. would result in substantial erosion or siltation on- or off-site?

Comment:
There are no blue line streams on the project site; however, as discussed in section 10.a, an unnamed intermittent blue-line stream runs roughly along Weise Road outside the northern project parcel border, which connects to Calabazas Creek, which is tributary to Sonoma Creek, which ultimately drains into San Pablo Bay.

The project would create approximately 79,140 square feet of impervious surfaces for the project greenhouse/nursery/ propagation/head house facility, roadway/driveway surfaces (including the new hammerhead turnaround, emergency turnout, and modifications to the driveway and access roads as determined necessary by the County), and the ADA restroom.

All construction activities associated with the proposed project would be required to adhere to Sonoma County Code Chapter 11 (Construction Grading and Drainage) requiring incorporation of best management practices (BMPs) to further control surface water runoff, and as a result would not be anticipated to alter the existing drainage pattern of the site or area in a way that would result in downstream erosion and/or sedimentation. Chapter 11 requires that drainage facilities and systems be designed to prevent or minimize soil loss through the use of storm drain culverts (pipes), storm drain inlets and outlets, storm drain outfalls, energy dissipators, flow dispersion, check dams, rolling dips, critical dips, proper location and sizing of culverts, revegetation of exposed or disturbed slopes, minimizing cross drains through road outsloping, minimizing the use of artificial slopes, and other BMPs referenced or detailed in the County's BMPs for construction grading and drainage.

In addition, Sonoma County Code Section 26-88-254(f)(20) includes runoff and stormwater control requirements for cannabis cultivation projects and prohibits draining of runoff to the storm drain system, waterways, or adjacent lands. Prior to commencement of grading or construction, the operator is required to prepare for County review and approval a storm water management plan and an erosion and sediment control plan, including BMPs pursuant to Chapter 11 of the County Code. All cultivation operators are required to comply with the BMPs for cannabis cultivation issued by the Agricultural Commissioner for water, erosion control, and management of wastes, fertilizers, and pesticides.

Therefore, based on application of these standard County Code requirements, the proposed project would not result in substantial erosion or siltation either on-site or off-site.

Significance Level: Less than Significant Impact

ii. substantially increase the rate or amount of surface runoff in a manner which would result in flooding on- or off-site;

Comment:
As discussed in section 10.c.i, the proposed project would increase impervious surface area; however, project compliance with County Code requirements related to storm water runoff and drainage would ensure that the project would not increase the rate or amount of surface runoff.

Significance Level: Less than Significant Impact.

iii. create or contribute runoff water which would exceed the capacity of existing or planned stormwater drainage systems or provide substantial additional sources of polluted runoff; or

Comment:
As discussed in section 10.c.i, the proposed project would increase impervious surface area; however, Permit Sonoma Grading and Stormwater Section staff reviewed the project referral and provided conditions of approval to ensure project compliance with the County Construction Grading and Drainage Ordinance (Zoning Code Chapter 11). The project would require a grading permit, which would not be issued until all recommended feasible storm water treatment options have been incorporated into project design in compliance with all applicable standards of the County Code. Project compliance with these standard conditions of approval and County Code requirements related to storm water runoff and drainage would ensure that the project storm water runoff would be reduced sufficiently to ensure that the capacity of existing or planned drainage systems are not exceeded by project storm water runoff or that project storm water runoff would not increase the rate or amount of surface runoff or polluted runoff.

Significance Level: Less than Significant Impact

iv. impede or redirect flood flows?

Comment:
There are no blue line streams on the project site; however, an intermittent blue-line stream runs roughly along Weise Road outside the northern project parcel border.

According to Figure PS-1e [30] of the General Plan, the project site is not located in a flood hazard area; the project site is in an "area of minimal flood hazard" as designated by FEMA (Zone X). [31]

Significance Level: Less than Significant Impact

d) In flood hazard, tsunami, or seiche zones, risk release of pollutants due to project inundation?

Comment:
As discussed in section 10.c.iv, the project site is not located in a flood hazard area. The project is not subject to seiche or tsunami because the project site is not located in an area subject to tsunami (about 26 miles from the coast). Seiche is a wave in a lake caused by strong winds or rapid changes in atmospheric pressure, or seismic or other processes, that push water from one end of a body of water to the other. The closest lake or similar water body is a man-made pond (about one acre in surface area) approximately 1,000 feet to the east.

Significance Level: No Impact

e) Conflict with or obstruct implementation of a water quality control plan or sustainable groundwater management plan?

Comment:
The County would require any construction activities to be designed and conducted to prevent or minimize the discharge of pollutants or waste from the project site. Best Management Practices (BMPs) to be used to accomplish this goal could include measures such as silt fencing, straw wattles, and soils discharge controls at construction site entrance(s). Storm Water Best Management Practices may also include primary and secondary containment for petroleum products, paints, lime and other hazardous materials of concern. Because no discharges from the project site to waters of the state are proposed, the project would not conflict with or obstruct the implementation of a water quality control plan. In addition, the project site is not presently located in a medium or high priority sustainable groundwater management plan (SGMA) basin for which there is an approved Groundwater Sustainability Plan. The nearest SGMA basin is the Napa-Sonoma Valley – Sonoma Valley Groundwater Basin, about 620 feet west of the project.

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[30] General Plan Safety Element Update, Figure PS-1E Flood Hazard Areas, http://sonomacounty.ca.gov/PRMD/Long-Range-Plans/General-Plan/Public-Safety-Flood-Hazard-Areas/, accessed 9/24/20.

[31] Federal Emergency Management Agency, Flood Map Service Center, National Flood Hazard Layer FIRMette, https://msc.fema.gov/portal/search?AddressQuery=101%20trinity%20road%2C%20glen%20ellen%2C%20cA#searchresultsanchor, accessed 9/17/20.

Significance Level: Less than Significant Impact

11. LAND USE AND PLANNING

Would the project:

a) Physically divide an established community?

Comment:
The project would not physically divide a community. The project is surrounded by rural residential lands, agricultural lands, and forest canopy. The project does not involve construction of a physical structure or removal of a road or other access route that would impair mobility, including changes to the existing roadway layout, within an established community or between a community and outlying areas.

Significance Level: No Impact

b) Cause a significant environmental impact due to a conflict with any land use plan, policy, or regulation adopted for the purpose of avoiding or mitigating an environmental effect?

Comment:
The project would not conflict with any applicable land use plan adopted for the purpose of avoiding or mitigating environmental effect, including the Sonoma County General Plan and Zoning Ordinance.

The General Plan Land Use designation for the parcel is Land Intensive Agriculture. As stated in the General Plan Land Use Element (p. LU-63), this land use designation is intended to *"enhance and protect lands capable of and generally used for animal husbandry and the production of food, fiber, and plant materials."*

The proposed project would be substantially consistent with goals, policies, and objectives in the Sonoma County General Plan 2020 related to avoiding or mitigating an environmental effect, including:

- The project would be designed to be in harmony with the natural and scenic qualities of the local area (Policy LU-12g), as the project would be effectively screened from public views from roads and other properties by existing trees.
- Preservation of biotic and scenic resources (General Plan Goal LU-10, Objective LU-10.1, Goal OSRC-2, Objective OSRC-2.1, Objective OSRC-2.2, Objective OSRC-2.3,

Policy OSC-2d, Goal OSCR-3, Policy OSRC-3a, Policy OSRC-3b, Policy OSRC-3c, Goal OSRC-6, Objective OSRC-6.1, and Policy OSRC-6a): The project would be consistent with regulations pertaining to avoiding biotic resources and would also be consistent with regulations designed to maintain the scenic qualities of the area. (See Section 1, Aesthetics, for further discussion).

- Maintaining very low residential densities (General Plan Objective LU-12.6): The project does not propose to increase residential density or construct new residences.
- Nighttime lighting and preservation of night time skies and visual character of rural areas (General Plan Goal OSRC-4, Objective OSRC-4.1, Objective OSRC-4.2, Policy OSRC-4a, Policy OSRC-4b, and Policy OSRC-4c): The project would use minimal, motion activated exterior lights which would comply with County requirements related to location, shielding, and light levels.
- Renewable Energy (General Plan Policy LU-11b, Goal OSRC-14, and Objective OSRC-14.2): The project would use 100 percent renewable energy as required for cannabis operations. This is consistent with County goals of increasing energy conservation and improving efficiency.
- Protection of Water Resources (General Plan Goal LU-8, Objective LU-8.1, Goal, Policy LU-8a): The project would be consistent with regulations pertaining to protecting Sonoma County's water resources and would also be consistent with regulations designed to avoid long term declines in available groundwater resources or water quality.
- Noise (General Plan Goal NE-1): Project construction and operations, including cannabis cultivation and processing, would not exceed the general plan noise standards Table NE-2 (See Section 12, Noise, for further discussion).

Within the Land Intensive Agriculture District zoning designation, commercial cannabis cultivation (up to one acre of cultivation area), including ancillary processing operations, is an allowed land use with a use permit (Sec. 26-04-010(p)). The proposed project would be consistent with the County Code for the Land Intensive Agriculture District zoning designation as well as the Development Criteria and Operating Standards from the Code intended to avoid and minimize potential environmental impacts (Sections 26-88-250 through 254).

No conflicts with other General Plan policies related to scenic, cultural, or biotic resource protection, noise, or transportation have been identified. No conflicts with the Development Criteria or Operating Standards have been identified and no exceptions or reductions to standards would be necessary. Therefore, the project would not conflict with any applicable land use plan, policy, or regulation adopted for the purpose of avoiding or mitigating an environmental effect.

Significance Level: Less than Significant Impact

12. MINERAL RESOURCES

Would the project:

a) Result in the loss of availability of a known mineral resource that would be of value to the region and the residents of the state?

Comment:
The project site is not located within a known mineral resource deposit area. [32] Sonoma County has adopted the Aggregate Resources Management Plan that identifies aggregate resources of statewide or regional significance (areas classified as MRZ-2 by the State Geologist).

The project site does not contain any active mines or known mineral resources that would require preservation and/or be impacted by the project.

Significance Level: No Impact

b) Result in the loss of availability of a locally important mineral resource recovery site delineated on a local general plan, specific plan or other land use plan?

Comment:
As discussed in section 12.a, the project site is not located within an area of locally-important mineral resource recovery site. The site is not zoned MR (Mineral Resources), and no locally-important mineral resources are known to occur at the site. [33]

Significance Level: No Impact

[32] California Geologic Survey Special Report 205, Update of Mineral Land Classification: Aggregate Materials in the North San Francisco Bay Production-consumption region, Sonoma, Napa, Marin, and Southwestern Solano Counties, California (California Geological Survey, 2013). Plate 1A, Plate 1B, and Plate 1C indicate the project site is classified as MRZ-3.

[33] Sonoma County. Aggregate Resources Management Plan, https://sonomacounty.ca.gov/PRMD/Long-Range-Plans/Aggregate-Resource-Management/Maps-and-Diagrams/, accessed September 1, 2020.

13. NOISE

Would the project result in:

a) Generation of a substantial temporary or permanent increase in ambient noise levels in the vicinity of the project in excess of standards established in the local general plan or noise ordinance, or applicable standards of other agencies?

Comment:
Noise may be defined as loud, unpleasant, or unwanted sound. The frequency (pitch), amplitude (intensity or loudness), and duration of noise all contribute to the effect on a listener, or receptor, and whether the receptor perceives the noise as objectionable, disturbing, or annoying. The decibel scale (dB) is a unit of measurement that indicates the relative amplitude of a sound. Sound levels in dB are calculated on a logarithmic basis. An increase of 10 dB represents a tenfold increase in acoustic energy, while 20dB is 100 times more intense, 30 dB is 1,000 more intense, and so on. In general, there is a relationship between the subjective noisiness, or loudness, of a sound and its amplitude, or intensity, with each 10 dB increase in sound level perceived as approximately a doubling of loudness.

There are several methods of characterizing sound. The most common method is the "A-weighted sound level," or dBA. This scale gives greater weight to the frequencies of sound to which the human ear is typically most sensitive. Thus, most environmental measurements are reported in dBA, which means "decibels on the A-scale." The energy contained in a sound pressure wave dissipates and is absorbed by the surrounding environment as the sound wave spreads out and travels away from the noise generating source. Theoretically, the sound level of a point source attenuates, or decreases, by 6dB with each doubling of distance from a point source of sound (i.e., stationary source of sound), and 3 dB for each doubling of distance from a mobile source of sound.

Sound levels are also affected by certain environmental factors, such as ground cover (asphalt versus grass or trees), atmospheric absorption, and attenuation by barriers. When more than one-point source contributes to the sound pressure level at a receiver point, the overall sound level is determined by combining the contributions of each source. Decibels, however, are logarithmic units and cannot be directly added or subtracted together. Under the dB scale, a doubling of sound energy corresponds to a 3 dB increase in noise levels. For example, if one noise source produces a sound power level of 70 dB, two of the same sources would not produce 140 dB – rather, they would combine to produce 73 dB. That means that for traffic noise to increase by 3 dB, which is at the lower end of the human range of perceptible sound, a doubling of traffic would be necessary.

Table 5 shows County noise standards (Table NE-2 of the General Plan), which establish a maximum allowable exterior noise exposure of 50 dBA in the daytime (7:00 AM to 10:00

PM) and 45 dBA in the nighttime (10:00 PM to 7:00 AM), as measured using the L50 value (the value exceeded 50 percent of the time, or 30 minutes in any hour – i.e., the median noise level).

Table 5. Maximum Allowable Exterior Noise Exposures for Non-transportation Noise Sources(A)

Hourly Noise Metric, dBA(B)	Daytime (7 AM - 10 PM)	Nighttime (10 PM - 7 AM)
L50 (30 minutes in any hour)	50	45
L25 (15 minutes in any hour)	55	50
L08 (4 minutes 48 seconds in any hour)	60	55
L02 (72 seconds in any hour)	65	60

Source: Sonoma County General Plan Noise Element Table NE-2

(A) Pursuant to General Plan Policy NE-1C, the noise standards apply at the exterior property line of any adjacent noise sensitive land use.

(B) The sound level exceeded n% of the time in any hour. For example, L50 is the value exceeded 50% of the time or 30 minutes in any hour; this is the median noise level.

As discussed in the 2016 Cannabis Ordinance ND (p. 39), *"Cannabis operations could cause potential noise impacts through preparation of land for outdoor cultivation, construction activities for associated structures, noise from on-site power generators, and road noise from related traffic."* Other potential sources of noise associated with cannabis operations can include fans (circulation, ventilation, exhaust, etc.), blowers (heaters, etc.), and alarms (on equipment such as forklifts).

Section 26-88-254(g)(6) of the County Code includes the following standard pertaining to cannabis: *"Cultivation operations shall not exceed the General Plan Noise Standards table NE-2, measured in accordance with the Sonoma County Noise Guidelines."* In addition, the Cannabis Ordinance also includes a provision that *"the use of generators as a primary source of power shall be prohibited."*

Due to the low trip generation associated with the project and the distance of project roads (driveways) from nearby residences, road noise from related project activities would also be minimal. Project traffic would have a minimal contribution to Highway 12 traffic noise.

Additionally, based on review of the project plans and distance information obtained via Google Earth, the outdoor cultivation area would be located over 600 feet from the nearest off-site residence. Because several of the neighboring residences were destroyed in the 2017 Nuns Fire and have not been replaced, the proposed greenhouse/nursery/ propagation/head house facility and the central processing building would be located approximately from 800 to over 1,000 feet from the nearest existing residences. These distances would allow for attenuation of most noise associated with project operations (mobile equipment activities) and project equipment (exhaust fans, blowers, etc.). In addition, because cultivation would occur in grow bags, there would be no noise associated with soil-tilling activities, only transport of the bags. Therefore, potential noise effects of the project would be expected to be less than the County's noise criteria at the adjacent properties.

However, the potential exists for project-generated noise levels to exceed County standards during construction and for the proposed back-up power generator. Therefore, incorporation of standard noise Best Management Practices (BMPs) (see Mitigation Measure NOISE-1) would ensure that temporary construction noise impacts would be less than significant. In addition, the project would be required to incorporate Mitigation Measure NOISE-2 to reduce backup generator noise impacts.

Significance Level: Less than Significant with Mitigation Incorporated

Mitigation Measures:

Mitigation Measure NOISE-1: The following construction noise control best management practices (BMPs) shall be incorporated into the project:

- Limit construction to between the hours of 8:00 AM and 6:00 PM, Monday through Friday. No construction activities shall occur on weekends or holidays.
- Locate construction staging areas as far as possible from nearby sensitive receptors.
- Locate stationary noise-generating equipment, such as air compressors or portable power generators, as far as possible from nearby sensitive receptors.
- Equip all internal combustion engine-driven equipment with intake and exhaust mufflers that are in good condition and appropriate for the equipment.
- Unnecessary idling of internal combustion engines shall be strictly prohibited.
- Utilize "quiet" air compressors and other "quiet" equipment where such technology exists.

Mitigation Measure NOISE-2: To reduce generator noise impacts, install the generator in an acoustical enclosure and position the generator to face away from the nearest residence. Conduct generator testing only during daytime hours (7:00 AM to 10:00 PM), with a preferred testing schedule between 10:00 AM and 4:00 PM to avoid noise-sensitive nighttime, morning, and evening hours. Notify adjacent landowners/residences of the testing schedule prior to testing.

Mitigation Monitoring:
Mitigation Monitoring NOISE-1 and NOISE-2: For Mitigation Measure NOISE-1, Permit Sonoma staff shall ensure that the above construction BMPs are listed on all necessary site alteration, grading, building or improvement plans, prior to issuance of grading or building permits. For Mitigation Measure NOISE-2, the final location of the generator and enclosure shall be submitted to the County for approval prior to the issuance of building permits. For both Mitigation Measure NOISE-1 and NOISE-2, any noise complaints shall be investigated by County staff and, if violations are found, the County shall require a noise consultant to evaluate the problem and recommend corrective actions.

b) Generation of excessive ground-borne vibration or ground-borne noise levels?

Comment:
According to the 2016 Cannabis Negative Declaration (p. 20), *"The nature of cannabis cultivation uses does not involve vibration or ground borne noises, except for potential impacts related to construction of related structures. These impacts would be from conventional construction equipment and would be short-term and temporary, limited to daytime hours. Some cannabis operations located in remote areas utilize power generators as the primary source of power, which can create noise impacts and expose people to excessive vibration and noise levels. The proposed Ordinance prohibits the use of generators as a primary source of power thus the potential for impacts is substantially reduced to less than significant."*

The proposed project would include construction activities for the greenhouse/nursery/ propagation/head house facility, fencing, wastewater pipeline, hammerhead turnaround, roadway turnout, driveway and interior access road modifications as determined necessary by the County, and associated infrastructure as needed by the project. These construction activities could generate ground borne vibration and noise levels due to vibration-inducing activities. The setback requirements in Section 26-88-254 of the County Code require cultivation areas and their associated structures to be located at least 100 feet from property lines, 300 feet from occupied residences and businesses, and 1,000 feet from schools, public parks, childcare centers, and alcohol and drug treatment facilities. These setbacks would ensure that any ground-borne vibration levels dissipate before reaching any sensitive receptor locations. The nearest residences to proposed construction activities would be south of the project driveway, across Trinity Road, and over 300 feet away.

Significance Level: Less than Significant Impact

c) For a project located within the vicinity of a private airstrip or an airport land use plan or, where such a plan has not been adopted, within two miles of a public airport or public use airport, would the project expose people residing or working in the project area to excessive noise levels?

Comment:
The site is not within the Airport Referral Area as designated by the Sonoma County Comprehensive Airport Land Use Plan.[34] The Charles M. Schulz Sonoma County Airport is located approximately 18 miles northwest of the project site. The nearest public airport is Sonoma Skypark Airport, a public use airport located about 9.25 miles southeast of the project site. Petaluma Municipal airport is about 9.75 miles southwest of the project site. The nearest private airport is Belos Cavalos Airport, about 4.5 miles northwest of the project site, near Kenwood. The Queen of the Valley Hospital (hospital heliport) is about 13 miles southeast of the project site. Because the project site is not within the vicinity of a private airstrip or within two miles of a public airport or public use airport, the project would not expose people working in the project area to excessive airport noise levels.

Significance Level: No Impact

14. POPULATION AND HOUSING

Would the project:

a) Induce substantial unplanned population growth in an area, either directly (for example, by proposing new homes and businesses) or indirectly (for example, through extension of roads or other infrastructure)?

Comment:
The project site contains an existing single-family residence and an accessory dwelling unit. Both of these would remain on-site and are not part of the proposed project. The project proposes cannabis cultivation operations that would employ a maximum of 17 employees, including 12 year-round and 5 seasonal (for the harvest). The proposed project therefore would not induce substantial population growth in the area, either directly or indirectly.

Significance Level: Less than Significant Impact

b) Displace substantial numbers of existing people or housing, necessitating the construction of replacement housing elsewhere?

Comment:
As discussed in section 14.a, the project site contains an existing single-family residence and an accessory dwelling unit. Both of these would remain on-site and are not part of the

[34] Sonoma County. "Sonoma County Airport Referral Area," https://sonomacounty.ca.gov/PRMD/Long-Range-Plans/Comprehensive-Airport-Land-Use/Sonoma-County-Airport/, accessed September 18, 2020.

current use permit application. The proposed project would not displace existing housing, and therefore would not necessitate the construction of replacement housing elsewhere.

Significance Level: No Impact

15. PUBLIC SERVICES

Would the project:

a) **Would the project result in substantial adverse physical impacts associated with the provision of new or physically altered governmental facilities, need for new or physically altered governmental facilities, the construction of which could cause significant environmental impacts, in order to maintain acceptable service ratios, response times or other performance objectives for any of the public services:**

Comment:
Construction of the project would not involve substantial adverse physical impacts associated with provision of public facilities or services, and the impact would be less than significant. No new housing is included in the project proposal. The project would employ 12 to 17 employees (depending on the season) and would not necessitate or facilitate construction of new public facilities because of the small scale of the project.

Significance Level: Less than Significant Impact

i. **Fire protection?**

Comment:
The project is located within the State Responsibility Area (SRA), under CalFire jurisdiction. The parcel is located in the Sonoma Valley Fire District. The Sonoma County Code requires that all new development meet County Fire Safe Standards. The County Fire Inspector reviewed the project description and plans on May 24, 2019, and required that the project comply with Fire Safe Standards (Sonoma County Code Ch. 13), including fire protection methods such as sprinklers in buildings, alarm systems, extinguishers, and emergency water supply, and would also have to comply with Hazardous Materials Regulations (Sonoma County Code Ch. 29), including hazardous materials management and management of flammable or combustible liquids and gases.

In addition, the project would be required by Sonoma County Code Section 26-88-254(f)(16) to: *"…prepare and implement a fire prevention plan for construction and ongoing operations and obtain any permits required from the fire and emergency services department. The fire prevention plan shall include, but not be limited to: emergency vehicle* *access and turn-around at the facility site(s), vegetation management and fire break maintenance around all structures."* Because none of these standard County Code requirements would result in the need to construct new or expanded fire protection/EMS facilities, project impacts on fire protection/EMS would be less than significant.

Significance Level: Less than Significant Impact

ii. Police?

Comment:
The Sonoma County Sheriff would continue to serve this area. There would be no increased need for police protection resulting from the project.

The project would not include construction of any new homes or a substantial amount of businesses or infrastructure, and therefore would not induce substantial population growth. The project would generate 12 to 17 jobs. Existing police protection facilities would be adequate to serve the proposed project.

Significance Level: Less than Significant Impact

iii. Schools, parks, or other public facilities?

Comment:
Development fees to offset potential impacts to public services, including school impact mitigation fees, are required by Sonoma County Code and state law for new subdivisions and residential developments. The project would not include new residential development, and no new schools are reasonably foreseeable as a result of the project. The project would not contribute to an increase in the need for expanded or additional schools, parks, or other public facilities, and therefore would not result in a significant impact.

Significance Level: No Impact

iv. Parks?

Comment:
The proposed project would not include the development of new residential uses and thus would not result in the need for new or expanded park facilities.

Significance Level: No Impact

v. Other public facilities?

Comment:
The project is less than 6.5 miles from the Sonoma Valley Regional library. The project would not create any new residential uses, and therefore increases in County library service demand resulting from the project would be less than significant. In addition, because the project would not be served by public sewer or water facilities, no expansion or construction of additional types of public facilities is anticipated as a result of this project.

Significance Level: No Impact

16. RECREATION

Would the project:

a) Would the project increase the use of existing neighborhood and regional parks or other recreational facilities such that substantial physical deterioration of the facility would occur or be accelerated?

Comment:
The proposed cannabis cultivation project would employ up to 17 employees (12 full-time employees with up to an additional five seasonal employees during harvest), which would not cause or accelerate substantial physical deterioration of parks or recreational facilities. The proposed project does not include any residential use and therefore would not lead to an increase in the use of existing neighborhood or regional parks or other recreational facilities.

Significance Level: No Impact

b) Does the project include recreational facilities or require the construction or expansion of recreational facilities which might have an adverse physical effect on the environment?

Comment:
The proposed project does not involve construction of recreational facilities. See section 16.a. above.

Significance Level: No Impact

17. TRANSPORTATION

Would the project:

a) Conflict with a program, plan, ordinance or policy addressing the circulation system, including transit, roadways, bicycle and pedestrian facilities?

Comment:
The Sonoma County General Plan Circulation and Transit Element includes adopted objectives for roadway system operations. As discussed in the 2016 Cannabis Ordinance Negative Declaration (ND), any increase in traffic generated as a result of cannabis operations were considered to be consistent with the General Plan 2020 and associated EIR, and therefore adoption of the Cannabis Ordinance (Ordinance No. 6198) was determined not to conflict with an applicable transportation/circulation plan. The 2016 ND (p. 44) also noted that while traffic impacts would vary with the type and size of individual cannabis operations (and number of employees), the greatest traffic generation anticipated would be for employee trips during the planting and harvest operations.

A Traffic Study and subsequent vehicle miles traveled analysis (VMT Analysis) were prepared for the project by W-Trans to address potential changes in traffic resulting from the project and evaluate the proposed project's traffic with those adopted objectives.[35] The Traffic Study also considered the cumulative effects on traffic of the proposed project in conjunction with two other cannabis projects on adjoining parcels: the Terra Luna Farms project to the north, and the Gordenker Ranch Cannabis Cultivation project to the east. In addition to traffic analysis, this traffic evaluation also helps the County determine each project's Traffic Mitigation Fee, per Chapter 26, Article 98 of the County Code.

The following analysis summarizes the key results, findings, and recommendations of the Traffic Study and VMT Analysis relevant to CEQA requirements. The results of the Traffic Study and VMT Analysis indicated that the proposed project could be expected to generate up to 52 daily trips (with a maximum of 9 trips during the AM peak hour and 8 trips during the PM peak hour). The total trip generation of the three projects cumulatively was estimated at up to 140 daily trips (with a maximum of 25 trips during the AM peak hour and 22 trips during the PM peak hour). However, these project trip generation numbers for the three projects combined included the 10 full-time employees engaged in a quarry that was being reclaimed on eastern parcel at the time of the traffic study. Therefore, after trips associated with that quarry use (31 trips) were deducted from the cumulative totals (because the quarry is ceasing operations), the adjusted cumulative trip totals would be up

[35]W-Trans, "Traffic Impact Study for the Gordenker Ranch Cannabis Cultivation Project," prepared for the County of Sonoma, March 20, 2020; W-Trans, "Addendum to the Traffic Impact Study for the Gordenker Ranch Cannabis Cultivation Project – Vehicle Miles Traveled (VMT) Analysis," prepared for Andrew Dobbs-Kramer, PARC Ventures, September 18, 2020.

to 109 new daily trips per day, including 20 trips during the AM peak hour and 17 trips during the PM peak hour.

The Traffic Study collected data to determine the existing traffic conditions for the project site and its vicinity at one intersection: Highway 12 and Trinity Road. Highway 12 (State Route 12) is a Caltrans facility; Trinity Road is a minor collector, according to the County.[36]

Collision History. The Traffic Study (p. 4) reviewed collision data from the California Highway Patrol for the most currently available five-year period (December 1, 2013 through November 30, 2018), during which time collisions at the study intersection were reported. Collision rates at this intersection were compared with statewide data (averages) for similar intersections. Collision rates for this intersection were calculated based on collisions per million vehicles entering (c/mve). The collision rate at the Highway 12/Trinity Road intersection during this time period was 0.04 c/mve, which is lower than the comparison statewide average of 0.23 c/mve. This would indicate that with respect to safety, compared with statewide data (averages) for similar intersections, the intersection is operating acceptably. Because the project is not proposing a substantial increase in traffic, the project is not expected to increase the risk of traffic collisions.

Bicycle Facilities. The Traffic Study (p. 5) noted that there are no existing bicycle facilities within the project vicinity. However, a Class I bicycle lane along the Central Sonoma Valley Trail is planned between Melita Road and Agua Caliente Road, which would parallel Highway 12 along the eastern side as part of a planned trail system. A Class II bike lane is planned for Highway 12 between Kunde Winery Road and Arnold Drive. A Class III bike lane is proposed for Trinity Road, between Highway 12 and the eastern County limits. All three of these planned bike lanes would pass through the project vicinity. The Traffic Study (p. 17) determined that bicycle facilities "are expected to be adequate" when completed; however, the current public right-of-way width for the Class I trail might be insufficient along the east side of Highway 12. The Traffic Study recommended that additional right-of-way to accommodate the bike trail should be dedicated. Sonoma County Regional Parks reviewed the application materials and Traffic Study, and requested an irrevocable offer to dedicate a public trail easement to the County along the entire project frontage of Highway 12 for the Sonoma Valley Trail's future installation of a Class I bike path per Caltrans design standards. Any dedication of additional ROW would not affect the proposed project.

Pedestrian Facilities. The Traffic Study (p. 5) identified no pedestrian facilities in the project vicinity, which is typical for the project's rural location, and determined (p. 17) that because employees would be unlikely to walk to the project site, *"[t]he lack of pedestrian facilities*

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[36] Sonoma County Department of Transportation & Public Works, County Roads Functional Classification Map, https://sonomacounty.maps.arcgis.com/apps/webappviewer/index.html?id=82e364c2c425408e8bedb308afe5da22, accessed 9/18/20.

serving the project site is consistent with the type of land use and surrounding area and is therefore considered acceptable." In addition, because pedestrians using transit would need to cross Highway 12, the Traffic Study (p. 17) evaluated whether a crosswalk would be necessary at the intersection of Highway 12 and Trinity Road. The Traffic Study (p. 17) determined that *"installation of a crosswalk at Trinity Road is not advised as it would generally result in less safe conditions for pedestrians due to the false sense of security associated with crosswalks."*

Transit Stops. According to the Traffic Study (p. 5), the project site is served by Sonoma County Transit (SCT), with a southbound stop on Highway 12 close to Trinity Road (on the south) and a northbound stop on Highway 12 close to Weise Road (on the south). The Traffic Study (p. 17) determined that *"Transit facilities serving the project site are adequate given the rural location of the project site and anticipated demand."*

Traffic Conclusions. The project is not proposing a substantial increase in traffic, and traffic resulting from the project would not be expected to substantially affect existing traffic operations. In addition, project operations would not interfere with bicycle, pedestrian, or transit facilities. Therefore, the proposed project would not be expected to conflict with any program, plan, ordinance, or policy addressing the circulation system, including transit, roadways, bicycle, and pedestrian facilities. In addition, the County would require the project, as a condition of approval, to pay a development fee (Traffic Mitigation Fee) based on project Average Daily Traffic (ADT) and the commercial fee in effect at the time of permit issuance, per Chapter 26, Article 98 of the County Code.

Significance Level: Less than Significant Impact

b) Conflict or be inconsistent with CEQA Guidelines Section 15064.3, subdivision (b)?

Comment:
Sonoma County has not adopted a significance threshold for evaluating VMT; therefore, W-Trans based its analysis on the Governor's Office of Planning and Research (OPR) "Transportation Impacts (SB 743) CEQA Guidelines Update and Technical Advisory, 2018," which identifies criteria for determining VMT impacts. For small projects, OPR determined that projects generating fewer than 110 vehicle trips per day would result in a less-than-significant VMT impact. As discussed in section 17.a, the trip totals of the proposed project would be approximately 52 new trips per day. Therefore, because the project is estimated to generate fewer than 110 trips per day, the project would have a less-than-significant impact on VMT.

Significance Level: Less than Significant Impact

c) Substantially increase hazards due to geometric design feature (e.g., sharp curves or dangerous intersections) or incompatible uses (e.g., farm equipment)?

Comment:
The project would not change the existing alignment of any roadway. Additionally, there are no sharp curves near the project site, and as determined by the Traffic Study (p. 21), the intersection of Highway 12 and Trinity Road is operating acceptably in terms of safety, based on a collision rate that is lower than the statewide average for similar facilities. The proposed cannabis cultivation use is consistent with allowable uses for the property and the size of the parcel, which would be compatible with the rural character of the area. Therefore, because the project does not propose any changes to roadways and proposed uses are compatible for the area, the project would not increase hazards due to geometric design features or incompatible uses.

In addition, the Traffic Study (p. 1) determined that the project's lack of pedestrian and bicycle facilities was typical for the rural setting and considered acceptable given the anticipated lack of demand. Therefore, construction-related hazards to pedestrians and bicyclists would not be considered significant. Because of the limited amount of construction anticipated for the project, construction-related hazards to drivers would also be considered less than significant.

Significance Level: Less than Significant Impact

d) Result in inadequate emergency access?

Comment:
County Fire reviewed the project description and plans on May 24, 2019 and determined that the project needs to comply with Fire Safe Standards (Sonoma County Code Ch. 13) and the California Fire Code related to fire apparatus access roads to the project site. Project plans would require review by a Permit Sonoma Fire Inspector during the building permit process to ensure compliance with emergency access issues. County Fire conditions of approval for driveway and access require road compliance with County standards. These conditions, and other standard County Code requirements and County review, would ensure that project impacts on emergency access would be less than significant.

Significance Level: Less than Significant Impact

e) Result in inadequate parking capacity?

Comment:
Sonoma County Code Section 26-86 does not include any specific parking requirements for cannabis cultivation land uses. The project would not be open to the public, and adequate parking would be provided on-site for employees. The project proposes 24 regular parking spaces and one ADA-compliant parking space between the processing building and the greenhouse/nursery buildings.

Significance Level: Less than Significant Impact

18. TRIBAL CULTURAL RESOURCES

Would the project cause a substantial adverse change in the significance of a tribal cultural resource, defined in Public Resources Code Section 21074 as either a site, feature, place, cultural landscape that is geographically defined in terms of the size and scope of the landscape, sacred place, or object with cultural value to a California Native American tribe, and that is:

a) Listed or eligible for listing in the California Register of Historical Resources, or in a local register of historical resources as defined in Public Resources Code Section 5030.1(k), or

b) A resource determined by the lead agency, in its discretion and supported by substantial evidence, to be significant pursuant to criteria set forth in subdivision (c) of Public Resources Code § 5024.1. In applying the criteria set forth in subdivision (c) of Public Resource Code § 5024.1, the lead agency shall consider the significance of the resource to a California Native American tribe.

Comment:
As discussed in section 5, Cultural Resources, Evans & De Shazo conducted research and a field survey to prepare a Cultural Resources Study for the project, which evaluated historical, archaeological, and cultural resources on the project site. The Cultural Resources Study determined: *"There are no California Inventory of Historic Resources (OHP 1976), California Historical Landmarks (1990), California Points of Historical Interest (1992), or California Register of Historical Resources (1998) within or adjacent to the Study Area."* [37] The results of a Northwest Information Center (NWIC) records search conducted by Evans & De Shazo, along with research of other related literature and historic maps, indicated: *"No*

[37] Evans & De Shazo, "Results of A Cultural Resources Study for the Proposed Cannabis Cultivation Project at 101 Trinity Road, Glen Ellen, Sonoma County, California," prepared for Andrew Dobbs-Kramer, Compliance Manager, Sparc, June 6, 2019, p. 16.

prehistoric or historic-era artifacts, archaeological deposits, or other cultural resource types were identified during the field survey of the Project Area." [38] Evans & De Shazo also contacted local Native American tribes. No known Traditional Cultural Resources (TCR) or unique archaeological resources associated with TCRs located within the project boundaries was indicated in the research and tribal communications. In addition, a Sacred Lands File search conducted by the Native American Heritage Commission (NAHC) on May 2, 2019 did not indicate the presence of Native American Sacred Sites within or near the project site.

Permit Sonoma sent out AB 52 project notifications to local Native American tribes. Tribal response to the Sonoma County notification also did not identify known TCRs or unique archaeological resources associated with TCRs within project boundaries, nor did any tribe request consultation.

The proposed project would result in no substantial adverse change in the significant of an archaeological resource as defined in CEQA Guidelines Section 15064.5. As further discussed in section 5, the project would be required to comply with the County grading ordinance (County Code Section 11-14-050), which includes provisions for the protection of human remains and archaeological resources during grading activities. The project would also be required to comply with County Code Section 26-88-254(f)(14), which requires that cannabis *"cultivation sites shall avoid impacts to significant cultural and historic resources…"* These standard County requirements would reduce potential project impacts on previously undiscovered TCRs or unique archaeological resources accidentally encountered during project implementation to a less than significant level.

Significance Level: Less than Significant Impact

19. UTILITIES AND SERVICE SYSTEMS

Would the project:

a) Require or result in the relocation or construction of new or expanded water, wastewater treatment or storm water drainage, electric power, natural gas, or telecommunications facilities, the construction or relocation of which could cause significant environmental effects?

Comment:
Project water would be supplied via an existing well located on the adjoining property and an existing pipeline; the project site also has an existing 150,000 gallon storage tank for irrigation and firefighting needs (which would support a new fire hydrant located near the greenhouse/nursery/propagation/head house facility). Existing septic systems serve the

[38] Evans & De Shazo, June 6, 2019, p. 24.

two on-site residences; however, the project proposes to collect wastewater in a new on-site septic tank and then convey it via a new pipeline to the adjacent northern parcel (APN 053-100-015), where the project wastewater would be disposed of in an existing, permitted leachfield (permit: SEL18-0544). County Code requirements and Best Management Practices (BMPs) necessary for project management of stormwater have been described in section 10, Hydrology and Water Quality. The project proposes installation of a new electrical transformer, to be located west of the processing building and north of the water tank, which would be required to comply with building, electrical, and fire standards. Construction-period impacts have been discussed elsewhere in this Initial Study (e.g., section 3, Air Quality; section 4, Biological Resources; section 5, Cultural Resources; section 8, Greenhouse Gas Emissions).

Significance Level: Less than Significant Impact

b) Have sufficient water supplies available to serve the project and reasonably foreseeable future development during normal, dry and multiple dry years?

Comment:
As discussed in section 10.b, Hydrology and Water Quality, a hydrogeological report was prepared for the applicant by PJC Associates, Inc., and submitted to the County. The County-required hydrogeologic report determined that the aquifer would have sufficient groundwater resources to supply the project water demands and that the project would be unlikely to cause a decline in groundwater elevations or deplete groundwater resources over time. The hydrogeological report was reviewed and approved by the Permit Sonoma Natural Resources Geologist.

Significance Level: Less than Significant Impact

c) Result in a determination by the wastewater treatment provider which serves or may serve the project that it has adequate capacity to serve the project's projected demand in addition to the provider's existing commitments?

Comment:
The proposed project would not be served by public wastewater and would not impact the capacity of public facilities. As discussed in section 19.a, the project proposes to collect wastewater in a new septic tank and then convey it via a new pipeline to the adjacent northern parcel (APN 053-100-015), where the project wastewater would be disposed in an existing permitted leachfield (permit: SEL18-0544). The project wastewater disposal system would be required to meet County standards.

Significance Level: Less than Significant Impact

d) Generate solid waste in excess of State or local standards, or in excess of the capacity of local infrastructure, or otherwise impair the attainment of solid waste reduction goals?

Comment:
Sonoma County has an existing solid waste management program that provides solid waste collection and disposal services for the entire County. The program can accommodate the permitted collection and disposal of the waste that would result from the proposed project. The project proposes two compost areas near the greenhouse/nursery building and the centralized processing facility.

In addition, Section 26-88-254(g)(8) of the County Code requires cannabis projects to prepare:

> *"A Waste Management Plan addressing the storing, handling and disposing of all waste by-products of the cultivation and processing activities in compliance with the Best Management Practices issued by the Agricultural Commissioner* [which] *shall be submitted for review and approval by the agency having jurisdiction. This plan shall characterize the volumes and types of waste generated, and the operational measures that are proposed to manage and dispose or reuse the wastes in compliance with Best Management Practices and County standards. All garbage and refuse on this site shall be accumulated or stored in non-absorbent, water-tight, vector resistant, durable, easily cleanable, galvanized metal or heavy plastic containers with tight fitting lids. No refuse container shall be filled beyond the capacity to completely close the lid. All garbage and refuse on this site shall not be accumulated or stored for more than seven calendar days, and shall be properly disposed of before the end of the seventh day in a manner prescribed by the Solid Waste Local Enforcement Agency. All waste, including but not limited to refuse, garbage, green waste and recyclables, must be disposed of in accordance with local and state codes, laws and regulations. All waste generated from cannabis operations must be properly stored and secured to prevent access from the public."*

As a standard County condition of approval and prior to building permit issuance and project operation, the project would be required to submit a design for trash enclosures, recycling areas, and a secured cannabis green waste area for review and approval by Permit Sonoma/Project Review-Health, with the following provisions: (1) no visually recognizable cannabis, nor materials that smell like cannabis shall be disposed of as ordinary refuse; and (2) all cannabis waste shall be ground, chipped or shredded as necessary and mixed with suitable materials and composted until it is no longer recognizable as cannabis by sight or smell. In addition, garbage and refuse on the project site shall not accumulate or be stored for more than seven calendar days and shall be properly disposed of at a County Transfer Station or County Landfill before the end of the seventh day. Also, as determined by the Sonoma Department of Health Services, the proposed composting site would need review by the Sonoma County Local Enforcement Agency for Solid Waste to determine if a solid waste permit is required.

Project compliance with these County Code requirements and conditions of approval would ensure that project impacts on solid waste disposal would be less than significant.

Significance Level: Less than Significant Impact

e) Comply with federal, state, and local management and reduction statutes and regulations related to solid waste?

Comment:
The proposed project would comply with federal, state, and local management and reducing statutes and regulations related to solid waste. See section 19.d for more information on Sonoma County waste management regulations.

Significance Level: No Impact

20. WILDFIRE

As discussed in section 9.g, Hazards and Hazardous Materials, the proposed project is located in a State Responsibility Area, with a Fire Hazard Severity Zone (FHSZ) designation of "Moderate." Moderate FHSZs include a) wildland areas of low fire frequency supporting modest fire behavior; and b) developed/urbanized areas with a very high density of non-burnable surfaces and low vegetation cover that is highly fragmented and low in flammability. However, the project site is approximately 570 feet from an area designated as a Very High fire hazard zone.[39]

If located in or near state responsibility areas or lands classified as very high fire severity zones, would the project:

a) Substantially impair an adopted emergency response plan or emergency evacuation plan?

Comment:
According to the Sonoma GIS tool the proposed project is located in a State Responsibility Area, with a Fire Hazard Severity Zone (FHSZ) designated as Moderate. As discussed in section 9.f, Hazards and Hazardous Materials, the project would not impair implementation

[39] Sonoma County. Permit Sonoma GIS, "Cannabis Site Evaluation," https://sonomacounty.maps.arcgis.com/apps/webappviewer/index.html?id=0b784d90045941798d780f288b6f7003, accessed 9/21/20.

of, or physically interfere with, the County's adopted emergency operations plan because traffic associated with the project would be minimal (an estimated 17 employees maximum, during harvest, with a trip generation of 52 average daily trips), the project would not result in a significant change in existing circulation patterns, and project traffic would have no measurable effect on emergency response routes (primarily Highway 12). In addition, although the project site has one access point (off of Trinity Road), emergency access is available off of Weise Road at the northern part of the site.

The project would be required to comply with the Sonoma County Fire Safe Standards (Ord. No. 5905), which would require providing the Fire Department with a map of the property (with the location of all fire-retardant supplies, entrances and exits, emergency vehicle turnouts, gas and electrical shutoffs) and any additional information required by the Fire Department. In accordance with Section 26-88-254(f)(16) of the County Code, the applicant is required to submit to the County, for County review and approval, a Fire Prevention Plan that would apply both to construction and ongoing operations, and would include provisions for emergency vehicle access and turn-around(s), vegetation management, and fire break maintenance for all structures. For State Responsibility Areas, State codes provide vegetation management standards related to maintaining defensible space from structures and fuel modification, which includes *"any combustible material, including petroleum-based products and wildland fuels."*[40] The applicant has submitted a Fire Prevention Plan for County review and approval. The applicant's plan discusses, among other items, current and proposed project site fuel modification activities and project water supply provisions (the existing 150,000-gallon water tank). In addition, project site plans show proposed installation of a fire hydrant approximately 70 feet northeast of the existing barn structure (proposed to be converted into a cannabis processing center), a dedicated water pipeline that would connect the hydrant to the water tank, a fire-safe ("hammerhead") turnaround near the northeastern project boundary and between the processing building and the greenhouse, and a fire-safe turnout along the access road (about halfway between the project entrance and the "hammerhead" turnaround). Compliance with these County Code and State requirements and standards would ensure that the proposed project would not conflict with or impair an adopted emergency response plan or emergency evacuation plan.

Significance Level: Less than Significant Impact

[40] California Public Resources Code section 4291(a)(1).

b) Due to slope, prevailing winds, and other factors, exacerbate wildfire risks, and thereby expose project occupants to, pollutant concentrations from a wildfire or the uncontrolled spread of a wildfire?

Comment:
According to the Sonoma GIS tool the proposed project is located in a State Responsibility Area, with a Fire Hazard Severity Zone (FHSZ) designated as Moderate.[41] The Moderate FHSZ designation includes: a) wildland areas of low fire frequency supporting modest fire behavior; and b) developed/urbanized areas with a very high density of non-burnable surfaces and low vegetation cover that is highly fragmented and low in flammability. However, several structures on the project site were destroyed during the 2017 Nuns Fire, which burned an area of approximately 56,600 acres. In addition, the project site is approximately 570 feet from an area designated as a very high fire hazard zone (which extends into the hills). The 2020 Glass Fire perimeter was within four miles of the project site.

The average slope on the project parcel is about six percent, rising to the east and into the Mayacamas Mountains where slopes become steeper toward mountain tops and ridges. This mountain area is heavily forested with underlying chapparal, and has several canyons (e.g., Adobe Canyon, Nuns Canyon, Stuart Canyon). Strong north-east "Santa Ana" winds can increase the severity of wildland fire in the fall months. During fire season, gradient winds are generally out of the south/southwest at 5-10 miles per hour (mph), strengthening to 10-15 mph in the late afternoon.[42] The proposed project would include 12 full-time employees (with up to five additional seasonal employees during harvest); there are currently one occupied residence and one accessory dwelling unit on the project site. The project would not result in an increase in on-site residents.

As discussed in section 20.a, the project would be required to comply with Sonoma County Code Chapter 13, which includes fuel modification and defensible space standards. The project would also be required to comply with County Code Section 26-88-254 (f)(16), which requires preparation of a fire prevention plan. The project currently has a 150,000 gallon water tank located approximately 40 feet from the existing barn structure (proposed to be converted into a cannabis processing center) and the proposed greenhouse/nursery/ propagation/head house facility. As a condition of approval by the Fire Department, the project would be required to provide an emergency water supply for fire protection, accessible in locations, quantities and delivery rates specified in the California Fire Code (as adopted and amended by Sonoma County Code), which would be calculated based on

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[41] Sonoma County. Permit Sonoma GIS, "Cannabis Site Evaluation," https://sonomacounty.maps.arcgis.com/apps/webappviewer/index.html?id=0b784d90045941798d780f288b6f7003, accessed 9/21/20.

[42] "Sonoma County Community Wildfire Protection Plan", p. 13.

finalized project details (e.g., construction type/materials, flammability/fire retardance, building area). As discussed above and in addition to the 150,000 gallon water tank, a fire hydrant is proposed to be installed approximately 70 feet northeast of the processing building with a dedicated pipeline that would connect the hydrant to the water tank. Project compliance with these County Fire Safe Standards and County review would ensure that project wildfire and wildfire pollutant concentration effects on project occupants would be less than significant.

Significance Level: Less than Significant Impact

c) **Require the installation or maintenance of associated infrastructure (such as roads, fuel breaks, emergency water sources, power lines or other utilities) that may exacerbate fire risk of that may result in temporary or ongoing impacts to the environment?**

Comment:
The proposed project is located on a site that has an existing structures. As discussed in section 20.a, the project would be required to comply with County Code Chapter 13 and County Code Section 26-88-254 (f)(16), which establish County standards for emergency access, minimum emergency water supply (on-site), fuel modification and defensible space, and sprinkler installation.

The project would include construction of one hammerhead road turnaround, one road turnout, and other modifications to the driveway and access roads as determined necessary by the County. However, these improvements would not exacerbate fire risk or result in significant impacts to the environment. In addition, the project would include installation of a new electrical transformer and a fuel storage area for the proposed backup generator (both near the proposed processing building). These improvements would be required to comply with California Fire Code, California Building Code, and related electrical and fire standards (California Electrical Code, IECC, NFPA, etc.).

For construction, pursuant to Public Resource Code 4442, the applicant would be required to include a note on all construction plans that internal combustion engines be equipped with an operational spark arrester, or the engine must be equipped for the prevention of fire.

Therefore, based on required project compliance with these County, State, and professional standards, the project would not result in exacerbated fire risk due to installation or maintenance of infrastructure.

Significance Level: Less than Significant Impact

d) Expose people or structures to significant risks, including downslope or downstream flooding or landslides, as a result of runoff, post-fire slope instability, or drainage changes?

Comment:
According to the County Post-Fire Hazard Assessment GIS map, the project site is located in a drainage basin with a moderate risk for debris flow during a design storm with a peak 15-minute rainfall intensity of 24 millimeters per hour.[43] However, as discussed in section 7.a.iv, the project site is not located in an area highly susceptible to landslides. The proposed project construction and grading would be unlikely to destabilize slopes or result in slope failure because proposed grading on-site would be minimal (a net fill of 104 cubic yards) and the project site slopes gently to the east (approximately six percent), toward the hills where the greater risk of landslide would be more likely to occur. Drainage on the site generally occurs as sheet flow; however, the unnamed tributary along Weise Road adjacent to the northern part of the site would direct flows toward the southwest to an existing drainage course along Highway 12. Other streams in the area would be anticipated to function similarly. The proposed new buildings and outdoor cultivation areas would be located in areas formerly occupied by agricultural buildings, so project changes to drainage patterns would be minimal. Therefore, the project would not expose people or structures to significant risks as a result of runoff, post-fire slope instability, or drainage changes.

Significance Level: Less than Significant Impact

21. MANDATORY FINDINGS OF SIGNIFICANCE

a) Does the project have the potential to substantially degrade the quality of the environment, substantially reduce the habitat of a fish or wildlife species, cause a fish or wildlife population to drop below self-sustaining levels, threaten to eliminate a plant or animal community, substantially reduce the number or restrict the range of a rare or endangered plant or animal or eliminate important examples of the major periods of California history or prehistory?

Comment:
Answer: no. Potential project impacts on special-status plant and fish/wildlife species and habitat are addressed in section 4. Implementation of the required Mitigation Measures (Mitigation Measures BIO-1 and BIO-2) would reduce these potential impacts to a less than significant level. Potential adverse project impacts on cultural resources are addressed in

[43] Sonoma County. Permit Sonoma GIS, "Post-Fire Hazard Assessment," https://sonomacounty.maps.arcgis.com/apps/webappviewer/index.html?id=5af1dd01cb9b446db928abe51a259763, accessed 9/22/20.

section 5; however, mitigation measures are not required. Potential adverse project impacts on Tribal Cultural Resources are addressed in section 18; however, mitigation measures are not required.

Significance Level: Less than Significant with Mitigation Incorporated

b) Does the project have impacts that are individually limited, but cumulatively considerable? ("Cumulatively considerable" means that the incremental effects of a project are considerable when viewed in connection with the effects of past projects, the effects of other current projects, and the effects of probable future projects)?

Comment:
Answer: no. Cumulative impacts were considered in each of the environmental topics evaluated in this Initial Study. No project impacts have been identified in this Initial Study that are individually limited but cumulatively considerable. The project would contribute to cumulative impacts related to air quality, biological resources, cultural and tribal cultural resources, and greenhouse gases, but mitigations, when deemed necessary, would ensure that the project's cumulative contributions would not be considerable.

See Section VIII of the Initial Study, Other Related Projects, for an outline of projects in the area.

Significance Level: Less than Significant with Mitigation Incorporated

c) Does the project have environmental effects which will cause substantial adverse effects on human beings, either directly or indirectly?

Comment:
Answer: no. Cannabis operations have the potential to cause substantial adverse impacts on human beings, both directly and indirectly. However, all potential impact and adverse effects on human beings (e.g., resulting from air quality/odors, hazards, noise) were analyzed, and would be less than significant with implementation of identified mitigation measures, when deemed necessary.

Significance Level: Less than Significant with Mitigation Incorporated

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EXHIBIT 53

Estimating Adequate Licensed Square Footage for Production

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Introduction

This document and associated spreadsheet provide a guide for estimating the cultivation area needed to support a given level of cannabis production. The data is drawn from a review of the relevant literature and from interviews conducted with 16 growers. This report finds that indoor and outdoor yields average about 40 grams per square foot per harvest, but with a considerable range. Yields per square foot per year can be much higher of course, because there can be multiple harvests per year, particularly for indoor production.

If the goal is to limit a licensee's production, restricting growing area may be a useful supplemental constraint. Setting a limit that is relatively generous (say double what one might expect is required) might discourage willful gross violations of production limits, without greatly inconveniencing a responsible grower. However, trying to make growing area the binding constraint invites a range of adaptations to increase yield per square foot that would also drive up cost and might even somewhat restrict the range of varieties brought to market.

Factors Complicating Cultivation Area Estimation

Estimating cultivation area seems straightforward. For example, if each of four harvests per year yields 50 grams per square foot, then to produce 120 metric tons of marijuana annually, one needs to license 120,000,000 / (4 * 50) = 600,000 square feet.

Five factors complicate the analysis:

1) Yield figures are not standardized.

2) Yield is normally expressed per square foot harvested, and indoor marijuana grows customarily produce multiple harvests per year.

3) Yields can vary by modality (e.g., greenhouse vs. artificial lights), variety of strain, and intensity (e.g., wattage of artificial lights or type and amount of fertilizer). We use averages that account for these variables.

4) Yields are conventionally described in terms of grams per square foot harvested, but production facilities also have ancillary spaces for seedlings, walkways, etc. A major decision point for the WSLCB, therefore, relates to whether the area-restriction applies to the entire building, all areas occupied by plants, or solely to areas occupied by mature plants that can be harvested.

5) The future mix of production strategies and associated yields is unknown and partially endogenous to WSLCB policy. For instance, if growing area is restricted, growers may have an incentive to employ higher yielding but more expensive production methods.

The Effect of Legalization on Average Yield

Growing in the U.S. has tended toward high yields per square foot because the need to avoid detection by law enforcement incentivizes a small operational footprint. However, there are some exceptions. Growers concerned about the 100-plant threshold, (qualifying the owner for a 5-year federal mandatory minimum sentence) and who have access to a large warehouse might grow 99 very large plants and spread them out to maximize each plant's yield. A more common approach is densely packing many small plants under artificial lights to mature them quickly enough to produce multiple harvests per year.

These may not represent best practices post legalization. Densely packed plants are more vulnerable to pests and disease. Furthermore, greenhouses are more economical (with cheaper structures and lower electricity costs), attested by the fact that few legal crops are grown entirely with artificial light. However, greenhouses' economic advantages disappear in winter due to heating costs. Greenhouse R-values are very low, meaning they are poorly insulated for heat, so greenhouses might not produce as many crops per year.

Hence, there is a trade-off between yield and production cost. If there is no limit on production area, one might expect greenhouse production to gain popularity due to cost considerations. However, if production area is constrained to the point that greenhouse production would leave some demand unsatisfied, growers might use their scarce growing area for production under artificial lights—unless production limits keep prices high.

There can be a similar trade-off across different modes of production under artificial lights. Some strains or varieties of cannabis yield more per square foot than others. Likewise, some mature faster, resulting in more crops per year. Similarly, increasing lighting or fertilizer intensity can increase yield. Therefore, if production area is constrained, growers might focus on the highest yielding varieties or use more lamps per square foot to boost yields—even if that constrains the range of varieties available for sale or increased electricity consumption and production cost per kilogram.

This complicates the establishment of suitable production quotas. For example, even if the WSLCB licensed the correct acreage to produce for the entire WA market at greenhouse-level yields, producers might still use all licensed and allocated space for high yield methods, if the excess production could still be sold (e.g., because "smurf and aggregate" operations carried the additional product to other states).

Using the Attached Spreadsheet as a Tool for Estimating Yield

The spreadsheet associated with this report accounts for multiple production forms and intensities. Users may enter not only the total production target (e.g., 120 metric tons), but also a description of the mix of production forms the industry is anticipated to employ. Those cells (indicated in blue in the spreadsheet) are now set to default values that represent our best guess at present, but should be updated by the WSLCB as better information on industry structure becomes available.

The spreadsheet is "preloaded" with five scenarios: (i) base case, (ii) high yield modalities, (iii) a low cost scenario, (iv) all indoor production (balanced mix), and (v) all greenhouse production.[1] Average yield varies by a factor of about 2 across the scenarios. For instance, the area needed for a target production of 120 metric tons varies from about 0.8 to 1.5 million square feet (19 – 34 acres). Of course, we would encourage the LCB to define its own scenarios as more and better information becomes available on grower behavior.[2]

Note: We set "no roof" (full sun) at 2% as a place holder, in the belief that it will account for a negligible share of production in Washington. If that proves false, then of course that parameter should be changed.

If the WSLCB tries to restrict production substantially by tightly constraining area cultivated, it should expect the industry to adapt in various ways and so achieve yields per unit area that are at the higher end of the ranges described. As a result, the WSLCB may prefer to utilize the "skewed toward high yield" in order to determine total allowable production area. Conversely, if production area were not meaningfully constrained, then the mix of production methods might trend toward modalities that produce less per square foot per year, and the "all greenhouse" scenario might be more informative.

Variables Pertinent to Yield-per-unit-area-harvested

Yield varies for three distinct types of reasons: (1) controlled variables, (2) the possibility of a partial or complete crop failure, and (3) random variation.

Besides venue (artificial lights vs. greenhouse vs. open air), controlled variables include factors such as variety, fertilizer, hydration, soil quality, pruning method,

[1] Scenarios can be accessed by choosing from the Excel (2010 or later) menu: Data, What-If Analysis, and Scenario Manager, then highlighting the desired scenario and clicking the "Show" button.

[2] Defining additional scenarios is easy in Excel. We would be happy to teach how if necessary.

harvest time, and lighting intensity. There are some predictable relationships, such as causation between more intense lighting and yield per unit area. Indeed, it is not uncommon to see the literature measure yield per watt rather than per square foot (e.g., Rosenthal). Other relationships are still being investigated. For example, Vanhove (2013) finds that matching the proper fertilizer to the strain type can have a substantial effect on yield. There are also factors that can affect yield post-harvest, in the drying, curing and processing phases.

Surprisingly, the grade of flower or THC potency does not necessarily play a factor in yield. A very high quality crop can have a very low yield, and a very low quality crop can have a high yield. However, since different strains have different lengths of growth cycles, limiting licensed growth square footage may encourage producers to grow those strains that have shorter growth cycles.

Crop failures can occur for a variety of reasons, including pests (mites), fungal contamination, and other miscellaneous causes. Even when the crop does not fail and the familiar control variables are held constant, there can still be variation from crop to crop. Even expert growers can have seemingly identical crops next to one another that vary in yield by 10-20%. Indeed, Vanhove et al. (2011) demonstrate that the average coefficient of variation in yield *within* a growth condition is 0.53. This is not a mystery or in any way unique to marijuana; yields in all forms of agriculture are more variable than in assembly line production.

Production potential per square foot harvested

The tables below summarize the evidence gathered for this task from the literature and 16 interviews with growers.[3] Indoor and outdoor yields average about 40 and 47 grams per square foot, respectively, regardless of whether ranges are reduced to point estimates via arithmetic or geometric averaging.[4]

The higher value for outdoor production is due to two very high estimates. It is the interviewer's judgment that one respondent was thinking of an extreme best case scenario, and that the second may have provided an anecdotal response not supported by reliable data. Due to outlier data points, a trimmed mean may be a more reliable central measure than the usual mean. The trimmed means, omitting the two lowest and two highest estimates, are very close to 40 grams per square foot indoor or out.[5]

---

[3] The Appendix provides further information on the estimates drawn from the literature beyond that reviewed by Leggett (2006).
[4] Geometric averages – meaning the n^{th} root of the product of n numbers – have some advantages over the traditional arithmetic mean when reducing ranges to point estimates, but in this case gave essentially the same overall answer.
[5] Indeed, the trimmed mean for indoor production (40.9) is slightly larger than for the outdoor estimates (39.6), indicating just how heavily the simple average of 47 grams per sq. ft. was influenced by the two very high reports.

Source	Item/Respondent	Details of Mode	Min	Max	Arithmetic Average	Geometric Average
Indoor						
Interviewer #1	#1		20	70	45	37.4
	#2		28.375	78.03	53.2025	47.1
	#3		20	70	45	37.4
	#4		20	70	45	37.4
	#5		20	70	45	37.4
	#6		15	60	37.5	30.0
	#7		28	56	42	39.6
	#8		30	60	45	42.4
Interviewer #2	#1		30	50	40	38.7
	#2		28	42	35	34.3
	#3		41	46	43.5	43.4
	#4		20	40	30	28.3
	#5		28	36	32	31.7
	#6		23	46	34.5	32.5
Leggett (2006) review	#1	Indoor scientific	37	56	46.5	45.5
	#2	Indoor scientific	17	65	40.9	33.0
	#3	Indica/sativa 1 m indoor	37	37	37.2	37.2
	#4	Indoor ("Skunk #1")	14	28	20.9	19.7
	#5	Indoor Sea of Green	30	47	38.5	37.5
	#6	Indoor Screen of Green	70	70	70.2	70.2
	#7	Indoor Screen of Green	47	47	46.8	46.8
	#8	Unspecified indoor	63	63	63.2	63.2
	#9	Indoor hydroponics	Dropped as an outlier			
	#10	Indoors	28	56	41.8	39.4
Toonen et al. (2006)			46.9	46.9	46.9	46.9
vanHove et al. (2011)		400 Watts / sq. meter	11.6	31.45	21.5	19.1
		600 Watts / sq. meter	21.44	44.9	33.2	31.0
Knight et al. (2010)		ScrOG, successful grow	32.7	32.7	32.7	32.7
Cervantes (2006)			29.6	53	41.3	39.6
Rosenthal			25.43	62.5	44.0	39.9
		Avg across respondents			**41.3**	**38.6**
Outdoor						
Interviewer #1	#9		27.24	27.24	27.24	27.2
Interviewer #2	#1		40	70	55	52.9
	#3		93	93	93	93.0
	#4		25	50	37.5	35.4
	#5		112	112	112	112.0
Leggett (2006) review	#1	Outdoor rain-fed	14	14	14.1	14.1
	#2	Outdoor irrigated	24	24	23.6	23.6
	#3	Unspecified outdoor	14	28	21.2	20.0
	#4	Outdoor	46	46	46.5	46.5
		Avg across respondents			**47.8**	**47.2**

Production potential per square foot *licensed*

It is crucial to understand that the figures cited above are per harvest and per area harvested.

Indoor production allows 4-6 harvests per year (5 being typical), whereas outdoor production allows only 1-3 harvests per year. Thus, production per square foot per year is much higher with indoor growing.

There were no complete estimates of yields in greenhouses. One might expect the production to be comparable per harvest per square foot, but that the number of harvests per year would be somewhat lower, since greenhouse heating can be so expensive in winter months. On the other hand, air conditioning costs in the summer when growing with artificial lights can also be very high.

There is also the complicated question of ancillary space that is essential to production, but which is not itself harvested. There are three types of ancillary space:

1) Space for growing plants that are not at the harvestable stage (mother plants, seedlings, etc.).

2) Dead space that is intertwined with area to be harvested (e.g., walkways).

3) Other areas not directly involved in growing (space used for drying, storing tools, record keeping, bathrooms, etc.).

Ancillary space can easily be half as large as the canopy area that is harvested, meaning that 2/3 of a facility may be devoted to canopy.

Administratively, the simplest approach might be to license the total size of the building, which would encompass all of these types of ancillary space. However, if the license limits the sum of all these types of space, then growers will have an incentive to go to great lengths and expenses to minimize the ancillary space. For example, a grower might employ crawl space under grow tables for storing supplies and moving about. Given the high potential value of cannabis yield per unit area, such limits could justify rather extraordinary measures.

An alternative would be to license just the area devoted to mature plants. This approach would allow officials to apply the yield figures above without adjustment. However, that would require some perhaps considerable extra effort for growers and inspectors to subtract out the area of walkways when computing area under canopy. Furthermore, there is also the question of how to write a clear and consistent rule that differentiates mature plants from seedlings.[6]

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[6] The mother plants do not require that much space in total, so folding them in with mature plants would require a relatively minor adjustment to the yield estimates above.

A third alternative would be to license total area devoted to plants, including mature plants, seedlings, and mother plants. That leaves out the third type of ancillary space, but includes the first two. In that case, the licensed area would be somewhat greater than what is occupied by mature plants, and the yield figures above would be reduced correspondingly.

Appendix A: Literature Review

From the published literature

Summary of Leggett (2006)

Leggett (2006, Table 3, pp.27-29) reviewed 35 yield estimates from a wide range of sources. Key elements of indoor estimates are reproduced below. Leggett (p.30) summarizes them as ranging from just over 300 to just under 800 grams per square meter per harvest, with an overall average of about 500 grams per square meter, with four-stage cultivation systems allowing 3-6 harvests per year.

Row	Source	Cultivation Style	Output per plant (grams)	Plants per square meter	Weight per Square Meter (grams)	Seasons per year	Output per square meter per year (grams)
#1	W. Scholten	Indoor scientific	100	4-6	400-600	4	1600-2400
#2	Br Columbia Compassion Club Soc	Indoor scientific			180-700		
#3	R. Clarke (2002, p.9)	Indica/sativa 1 m indoor	100	Assume 4	400	3-4	1200-1600
#4	R. Clarke (19998, p.189)	Indoor ("Skunk #1")			150-300 (flowers only)	3	
#5	M. Thomas (2002)	Indoor Sea of Green	9-14 (0.5 oz.)	36 (2 per sq. ft.)	324-504	4	1296-2016
#6	M. Thomas (2002)	Indoor Screen of Green	84 (3 oz.)	9	756	3	2268
#7	G. Green (2003)	Indoor Screen of Green	56 (2 oz.)	9	504	3	1512
#8	Onlinepot.org website	Unspecified indoor	170	Assume 4	680	4-52 (with CO2)	720-3400
#9	J. Cervantes (1993)	Indoor hydroponics	7	4	28	4	112
#10	Cannabis-seedbank.nl website	Indoors			300-600	3-6	

For outdoor yields, Leggett quotes Conrad in suggesting that yields of 200 grams per square meter are consistent with figures gathered from court cases in the U.S., but nonetheless uses 100 grams per square meter (one MT per hectare). Those figures would translate to 18.6 and 9.3 grams per square foot. Nonetheless, Leggett's Table 3 records some substantially greater yields, which are given here (exclusive of two described as "feral"). The sole greenhouse estimate is also included.

Row	Source	Cultivation Style	Output per plant (grams)	Plants per square meter	Weight per Square Meter (grams)	Seasons per year	Output per square meter per year (grams)
#1	UNODC Morocco	Outdoor rain-fed	76	1	76	2	152
#2	UNODC Morocco	Outdoor irrigated	4	30	127	2	254
#3	M. Starks (1990)	Unspecified outdoor	227-454	0.66	152-304	1	152-304
#4	M. Thomas (2002)	Outdoor	About 500	1	500	1	500
#5	Cannabis-seedbank.nl website	Outdoor	10-200	40 X 10 g	300-600		
#6	Cannabis-seedbank.nl website	Greenhouse		1-10	50-250	3-6	

Subsequent and Additional Citable Sources on Indoor Yield

Toonen et al. (2006) build a regression model based on 86 samples obtained from law enforcement raids in the Netherlands. Point estimate was 505 grams per square meter of dried female flower buds, which is equivalent to 46.9 grams per square foot.

Toonen et al. (2006, p.1053) also report that, "in popular cannabis cultivation literature, average yields of 366–610 g/m2 are described (11)" with the citation being to Green G. The cannabis grow bible. USA: Green Candy Press, 2001. That range is equivalent to 34.0 to 56.7 grams per square foot.

Vanhove et al. (2011) seek to improve on Toonen et al. via a growing experiment with a full factorial Latin square design, varying light intensity (400 or 600 W per sq. meter), plant density (16 and 20 plants per square meter), and plant variety (four varieties). Plants were harvested after 11 weeks. Yields were 11.6 – 44.9 grams per square foot, although the discussion states, "According to the Belgian Police, the yield figures presented in this study are below the average yield found in common illicit cannabis indoor plantations." Yields were substantially higher under the 600W condition, even slightly more than 1.5 times higher. Yields per unit area were not affected by plant density over this range. Yields did very considerably by variety. If we focus on the two higher-yielding varieties (Big Bug and Super Skunk) under the 600W condition, the average yield was 40.7 grams per square foot.

Vanhove et al. (2012) summarized more such experiments, stating: "the lower-bound of the one-sided 95% confidence interval of the yield of an indoor cannabis plantation can be set at 575 g/m^2."

Vanhove (2013, personal communications) performed a subsequent, unpublished, study interacting fertilizer type (complete scheme described in earlier papers vs. just NPK-fertilizers) crossed with variety. There was a (negative) main effect for the just NPK-fertilizer, but also a very strong interaction effect (e.g., Big Bud did better with basic fertilizer). The conclusion is that mismatching fertilizer with type can reduce yield below the 575 gram per square meter potential obtained earlier.

Knight et al. (2010) did three cycles of hydroponic growing ("Screen of Green" or ScrOG method). Each crop had six plants grown in 4.32m X 3.48 m. Production ranged from 94.2 to 186.4 ounces, which is 16.5 – 32.7 grams per square foot. Authors report problems with all three grows, due to their inexperience, particularly the two grows with lower yields. So the 32.7 gram per square foot figure would appear to the best most relevant from this study.

As an aside, the yields per plant were considerable. The authors conclude that they have demonstrated one can obtain 42 ounce per plant with THC of 30%.

Cervantes (2006, pp.148-152) describes a case study of three crops with yields of 29.6 – 53.0 grams per square foot in 10, 9, and 9 weeks, respectively.

	Crop #1	Crop #2	Crop #3
Space	16' 5" x 7' 10"	33' x 7' 10"	33' x 7' 10"
Sq. Feet	128.6	258.5	258.5
Yield (pounds)	8.4	27.6	30.2
Grams per sq ft.	**29.6**	**48.4**	**53.0**

This is consistent with his rule of thumb of “0.5g-1g/watt”, which at typical light densities, equates to 31.25g-62.5g/sq. ft.

Rosenthal (Marijuana Grower’s Handbook) states that “A 1000w lamp produces a yield of about 375-1000 grams.” Typically a 1000w flowering lamp is used every 16 sq. ft. (4’x4’), so this translates to 23.43g-62.5g per sq. ft.

Other studies read, but not deemed relevant

McNeill (1992, p.391, “Kif in the Rif”) reports outdoor production in Morocco as 2,000 kilograms per hectare, which is equivalent to 18.6 grams per square foot.

Chris Conrad (2007) Safe Access Now Online Handbook, Cannabis Yields and Dosage (Part 1-b), downloaded April 29, 2013 from http://www.safeaccessnow.net/adversitycanopy.htm.

“The typical indoor yield is 0.25 to 0.5 ounces per square foot” which would be 7.1 – 14.2 grams per square foot, but the gestalt of the overall document was an argument for liberal growing areas limits, so the author may have had an incentive to lowball yield per square foot. He relates, “About half of the area is used for flowering females … The other half is for mothers, seedlings, clones and young plants”

Amaducci et al. (2008) describe a careful agricultural experimental on yields using a completely randomized block design over two genotypes, three densities, and two harvest times, but is not really relevant since it pertained to outdoor production of cannabis for hemp. Yield in the better of the two growing seasons was close to 12 metric tons per hectare of dried stem matter, which corresponds to 111 grams per square foot. But, that is stem, so the study is worth mentioning only because it represents a true agricultural experiment.

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EXHIBIT 54

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How additional is the Clean Development Mechanism?

Analysis of the application of current tools and proposed alternatives

Berlin,
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Study prepared for DG CLIMA

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Abbreviations

CAR	Climate Action Reserve
CDM	Clean Development Mechanism
CER	Certified Emission Reduction
CFL	Compact Fluorescent Lamp
CO_2	Carbon Dioxide
CORSIA	Carbon Offset and Reduction Scheme for International Aviation
CP	Crediting Period
CPA	Component Project Activity of a PoA
DOE	Designated Operational Entity
EB	Executive Board of the CDM
ETS	Emissions Trading Scheme/System
f_{NRB}	Fraction of non-renewable biomass
GHG	Greenhouse Gas
GS	Gold Standard
JCM	Joint Crediting Mechanism
LED	Light Emitting Diode
MP	Methodologies Panel under the CDM EB
MRV	Monitoring, Reporting & Verification
NDC	Nationally Determined Contribution
NRB	Non-renewable Biomass
OECD	Organisation for Economic Co-operation and Development
PDD	Project Design Document
PMR	Partnership for Market Readiness (Initiative of the World Bank)
PoA	Programme of Activities
UNFCCC	United Nations Framework Convention on Climate Change
USD	United States Dollar
VCS	Verified Carbon Standard

Executive summary

With the adoption of the Paris Agreement, which establishes a mechanism to contribute to the mitigation of greenhouse gas emissions and support sustainable development (Article 6.4), it is clear that the Clean Development Mechanism (CDM) as a mechanism of the Kyoto Protocol will end. However, in terms of its standards, procedures and institutional arrangements, the CDM certainly forms an important basis for the elaboration and design of future international crediting mechanisms.

While this study provides important insights to **improve the CDM up to 2020**, the approach taken in this study could **also be applied more generally both to assess the environmental integrity of other compliance offset mechanisms**, as well as to avoid flaws in the design of new mechanisms being used or established for compliance. Many of the shortcomings identified in this study are inherent to crediting mechanisms in general, not least the considerable uncertainty involved in the assessment of additionality and the information asymmetry between project developers and regulators.

A fundamental feature of both the CDM and the mechanism under Article 6.4 is that they aim to achieve environmental integrity by ensuring that only real, measurable and additional emission reductions are generated. This study analyzes the opportunities and limits of the current CDM framework for ensuring environmental integrity, i.e. that projects are additional and that emission reductions are not overestimated. It looks at the way in which the CDM framework has evolved over time, assesses the likelihood that emission reductions credited under the CDM ensure environmental integrity and provides findings on the overall and project-type-specific environmental integrity of the CDM. In addition, it provides lessons learned and recommendations for improving additionality assessment that can be applied to crediting mechanisms generally, including to mechanisms to be used for compliance under the Carbon Offsetting and Reduction Scheme for International Aviation (CORSIA), and to mechanisms to be implemented under Article 6 of the Paris Agreement.

To ensure robust judgements, we have systematically analyzed the determination of additionality, the determination of baseline emissions and other issues that are key for environmental integrity. Towards this goal, we have evaluated those general CDM rules that are particularly relevant for environmental integrity and assessed in the case of specific project types the likelihood that they deliver real, measurable and additional emission reductions. Based on our analysis **key findings** include the following:

- Most **energy-related project types** (wind, hydro, waste heat recovery, fossil fuel switch and efficient lighting) are **unlikely to be additional**, irrespective of whether they involve the increase of renewable energy, energy efficiency improvements or fossil fuel switch.
- **Industrial gas projects** (HFC-23, adipic acid, nitric acid) are **likely to be additional** as long as the mitigation is not otherwise promoted or mandated through policies.
- **Methane projects** (landfill gas, coal mine methane) have a **high likelihood of being additional**.
- **Biomass power projects** have a **medium likelihood of being additional** overall because the assessment of additionality very much depends on the local conditions of individual projects.
- The additionality of the current pipeline of **efficient lighting projects** using small-scale methodologies is **highly unlikely** because in many host countries the move away from incandescent bulbs is well underway.

- In the case of **cook stove projects**, CDM revenues are often insufficient to cover the project costs and to make the project economically viable. Cook stove projects are also likely to considerably **over-estimate the emission reductions** due to a number of unrealistic assumptions and default values.

Overall, our results suggest that 85% of the projects covered in this analysis and 73% of the potential 2013-2020 Certified Emissions Reduction (CER) supply have a low likelihood that emission reductions are additional and are not over-estimated. Only 2% of the projects and 7% of potential CER supply have a high likelihood of ensuring that emission reductions are additional and are not over-estimated.

Our analysis suggests that the **CDM still has fundamental flaws in terms of overall environmental integrity**. It is likely that the large majority of the projects registered and CERs issued under the CDM are not providing real, measurable and additional emission reductions.

When considering the Paris Framework, the most important change from the Kyoto architecture is that all countries have made mitigation pledges in the form of Nationally Determined Contributions (NDC). An important implication is that host countries with ambitious and economy-wide mitigation pledges have **incentives to limit international transfers of credits** to activities with a **high likelihood of delivering additional emission reductions**, so that transferred credits do not compromise the host country's ability to reach their own mitigation targets. A second important implication is that countries should **only transfer emission reductions where this is consistent with their NDC**, implying that baselines may have to be determined in relation to the host country's mitigation pledges rather than using a 'counterfactual' business as usual scenario as a default.

Taking into account this context and the findings of our analysis, we recommend that the role of crediting in future climate policy should be revisited:

- We recommend potential buyers of CERs to limit any **purchase of CERs** to either **existing projects which risk discontinuing GHG abatement** when the incentive from the CDM ceases, such as landfill gas flaring or to new **projects among** the few project types identified t**hat have a high likelihood of ensuring environmental integrity**.

- Buyers should **accompany purchase of CERs with support for a transition of host countries to broader and more effective climate policies**. In the short–term, where offsetting is used, it should only be on the basis that purchase of CERs does not undermine the ability of host countries to achieve their mitigation pledges.

- Given the inherent shortcomings of crediting mechanisms, we recommend focusing **climate mitigation efforts** on forms of carbon pricing **that do not rely extensively on credits** and on measures such as results-based climate finance that does not result in the transfer of credits or offsetting the purchasing country's emissions. International crediting mechanisms should play a limited role after 2020, to address specific emission sources in countries that do not have the capacity to implement alternative climate policies.

- To enhance the environmental integrity of international crediting mechanisms such as the CDM and to make them more attractive to both buyers and host countries with ambitious NDCs, we recommend limiting such mechanisms to **project types** that have a **high likelihood of delivering additional emission reductions**. We also recommend reviewing methodologies systematically to address risks of over-crediting, as identified in this report.

- We also recommend provisions that provide strong incentives to the Parties involved to ensure the integrity of international unit transfers. This includes robust accounting provisions to **avoid double counting** of emission reductions, but could also extend to other elements, such as implementation of **ambitious mitigation pledges** as a prerequisite to participating in international mechanisms.

With the adoption of the Paris Agreement, implementing more effective climate policies becomes key to bringing down emissions quickly on a pathway consistent with well below 2°C. Our findings suggest that **crediting approaches** should play a **time-limited and niche role** focusing on those project types for which additionality can be relatively assured. Crediting should serve as a stepping-stone to other, more effective policies to achieve cost-effective mitigation. Continued support to developing countries will be key. We recommend using new innovative sources of climate finance, such as revenues from auctioning of emission trading scheme allowances, rather than crediting for compliance, to support developing countries in implementing their NDCs.

Summary

Aim of the study

With the adoption of the Paris Agreement, which establishes a mechanism to contribute to the mitigation of greenhouse gas emissions and support sustainable development (Article 6.4), it is clear that the role of the CDM as a mechanism of the Kyoto Protocol will end. However, in terms of its standards, procedures and institutional arrangements, the **CDM** certainly forms an **important basis** for the elaboration and design of future mechanisms for international carbon markets. One key feature of both the CDM and the mechanism under Article 6.4 is that they should generate **real and additional** emission reductions. In other words, emission reductions that are credited and transferred should not have occurred in the absence of the mechanism and should not be overestimated. This study analyzes the opportunities and limits of the current CDM framework and the way in which it has evolved over time and been applied to concrete projects. It provides findings on the **overall and project-type-specific environmental performance of the CDM** in the form of estimates of the **likelihood that the CDM results in real and additional emission reductions**. In addition, it provides lessons and recommendations for improving additionality assessment that can be applied to future crediting mechanisms.

Methodological approach

The main focus of this study is to assess the extent to which the CDM meets its objective to deliver "real, measurable and additional" emission reductions. In order make well-founded judgements about the overall and project-type-specific likelihood of additionality of CDM projects, we systematically analyze CDM rules and how they have been applied to real projects in practice. We examined the rules for 1) **additionality assessment**, for 2) the **determination of baseline emissions** and 3) a number of **other issues** including the length of crediting period, leakage effects, perverse incentives, double counting, non-permanence, monitoring provisions and third party validation and verification. We approach these aspects from two different perspectives: we evaluate 1) **general CDM rules** that are particularly relevant for the delivery of real, measurable and additional emission reductions and we evaluate 2) **specific project types** with a view to assessing how likely these project types deliver additional emission reductions. To assess the impacts of our analysis, we further estimate the **potential 2013-2020 CER supply** from different project types.

Project-types-specific results

Table 1-1 (p. 13) below provides an overview of the findings on environmental integrity based on the detailed analysis of individual project types. **Most energy-related project types** (wind, hydro, waste heat recovery, fossil fuel switch and efficient lighting) are **unlikely to be additional**, irrespectively of whether they involve the increase of renewable energy, efficiency improvements or fossil fuel switch. An important reason why these projects types are unlikely to be additional is that the revenue from the CDM for these project types is small compared to the investment costs and other cost or revenue streams, even if the CER prices would be much higher than today. Moreover, many projects are economically attractive, partially due to cost savings from project implementation (e.g. fossil fuel switch, waste heat recovery) or domestic support schemes (renewable power generation).

Table 1-1: How additional is the CDM?

	CDM projects			Potential CER supply 2013 to 2020		
	Low	Medium	High	Low	Medium	High
	… likelihood of emission reductions being real, measurable, additional					
	No. of projects			Mt CO_2e		
HFC-23 abatement from HCFC-22 production						
Version <6		5			191	
Verson >5			14			184
Adipic acid		4			257	
Nitric acid			97			175
Wind power	2.362			1.397		
Hydro power	2.010			1.669		
Biomass power		342			162	
Landfill gas		284			163	
Coal mine methane		83			170	
Waste heat recovery	277			222		
Fossil fuel switch	96			232		
Cook stoves	38			2		
Efficient lighting						
AMS II.C, AMS II.J	43			4		
AM0046, AM0113			0			0
Total	**4.826**	**718**	**111**	**3.527**	**943**	**359**

Sources: Authors' own calculations

Industrial gas projects (HFC-23, adipic acid, nitric acid) can generally be considered **likely to be additional** as long as they are not promoted or mandated through policies. They use end-of-pipe-technology to abate emissions and do not generate significant revenues other than CERs. HFC-23 and adipic acid projects triggered strong criticism because of their relatively low abatement costs, which provided perverse incentives and generated huge profits for plant operators. In the case of HFC-23 and nitric acid projects, perverse incentives have been adequately addressed. With regard to **adipic acid** projects, the risks for **carbon leakage have not yet been addressed**.

Methane projects (landfill gas, coal mine methane) also have a **high likelihood of being additional**. This is mainly because carbon revenues have, due to the GWP of methane, a relatively large impact on the profitability of these project types. However, both project types face **issues with regard to baseline emissions and perverse incentives** and may thus lead to overcrediting.

Biomass power projects have a **medium likelihood of being additional** since their additionality very much depends on the local conditions of individual projects. In some cases, biomass power can already be competitive with fossil generation while in other cases domestic support schemes provide incentives for increased use of biomass in electricity generation. However, where these conditions are not prevalent, projects **can be additional**, particularly if CER revenues for **methane avoidance can be claimed**. Biomass projects also face other issues, in particular with regard to demonstrating that the **biomass used is renewable**.

The additionality of **efficient lighting** projects using small-scale methodologies is **highly problematic** because there were large PoAs in countries in which the move away from incandescent bulbs was well underway. The **new methodologies** address these problems but they are **not mandatory** and the small-scale methodologies are, while the remaining small-scale methodology could still allow for automatic additionality for CFL programmes.

For **cook stove** projects, CDM revenues are often insufficient to cover the project costs and to make the project economically viable. Particularly in urban areas, the additionality of these project types is questionable. Cook stove projects are also likely to considerably over-estimate the emission reductions due to a number of unrealistic assumptions and default values.

Overall environmental assessment

Based on these considerations, we estimate that **85% of the covered projects and 73% of the potential 2013-2020 CER supply have a low likelihood** of ensuring environmental integrity (i.e. ensuring that emission reductions are additional and not over-estimated). Only **2% of the projects and 7% of potential CER supply have a high likelihood** of ensuring environmental integrity. The remainder, 13% of the projects and 20% of the potential CER supply, involve a medium likelihood of ensuring environmental integrity (Table 1-1, p. 13).

Compared to earlier assessments of the environmental integrity of the CDM, our analysis suggests that the CDM's **performance as a whole has anything but improved**, despite improvements of a number of CDM standards. The main reason for this is a **shift in the project portfolio towards projects with more questionable additionality**. In 2007, CERs from projects that do not have revenues other than CERs made up about two third of the project portfolio, whereas the 2013-2020 CER supply potential of these project types is only less than a quarter. A second reason is that the **CDM Executive Board (EB)** has not only improved rules but also **made simplifications** that undermined the integrity. For example, positive lists have been introduced for many technologies, for some of which the additionality is questionable and some of which are promoted or required by policies and regulations in some regions (e.g. efficient lighting). A third reason is that the **CDM EB** did not take effective means to **exclude project types** with a low likelihood of additionality. While positive lists have been introduced, project types with more questionable additionality have not been excluded from the CDM. Standardized baselines provide a further avenue to demonstrating additionality but do not reduce the number of projects wrongly claiming additionality. The improvements to the CDM mainly aimed at **simplifying requirements and reducing the number of false negatives** but did not address the false positives.

The result of our analysis therefore suggests that the **CDM has still fundamental flaws in terms of environmental integrity**. It is likely that the large majority of the projects registered and CER issued under the CDM are not providing real, measureable and additional emission reductions. Therefore, the experiences gathered so far with the CDM should be used to improve both the CDM rules for the remaining years and to avoid flaws in the design of new market mechanisms being established under the UNFCCC.

Recommendations for improving general additionality rules

For an additionality test to function effectively, it must be able to assess, with high confidence, whether the CDM was the deciding factor for the project investment. However, additionality tests can never fully avoid wrong conclusions. **Information asymmetry** between project developers and regulators, combined with the economic incentives for project developers to have their project recognised as additional, are a major challenge. We carefully scrutinised the **four main approaches** used to determine additionality. Our analysis shows that **prior consideration** is a necessary and important but not sufficient step for ensuring additionality of CDM projects and that this step largely works as intended. The subjective nature of the **investment analysis** limits its ability to assess with high confidence whether a project is additional. Especially for project types in which the financial impact of CERs is relatively small compared to variations in other parameters, such as large power projects, doubts remain as to whether investment analysis can provide a strong 'signal to noise' ratio. The **barrier analysis** has lost importance as a stand-alone approach of demonstrating additionality. Non-monetized barriers remain subjective and are often difficult to verify by the DOEs. In general, the **common practice analysis** can be considered a more objective approach than the barriers or investment analysis due to the fact that information on the sector as a whole is considered rather than specific information of a project only. However, the way in which common practice is currently assessed needs to be substantially reformed to provide a reasonable means of demonstrating additionality; it is important to reflect that market penetration is not for all project types a good proxy for the likelihood of additionality.

Against this background, we recommend that the **common practice analysis** is given a **more prominent role in additionality determination** though only after a significant reform:

- The 'one-size-fits-all' approach of determining common practice should be replaced by **sector- or project-type-specific guidance**, particularly with regard to distinguishing between different and similar technologies and with regard to the threshold for market penetration.
- The **technological potential** of a certain technology should also be taken into account in order to avoid that a project is deemed additional although the technological potential is already largely exploited in the respective country.
- The common practice analysis should at least cover the **entire country**. However, if the absolute number of activities in the host country does not ensure statistical confidence, the scope needs to be extended to other countries.
- As a default, all CDM projects should be included in the common practice analysis, unless a methodology includes different requirements.

We further recommend that the **investment analysis** is excluded as an approach for demonstrating additionality for projects types in which the 'signal to noise' ratio is insufficient to determine additionality with the required confidence. For those project types in which the investment analysis would still be eligible, the project participant must confirm the all information is true and accurate and that the investment analysis is consistent with the one presented to debt or equity funders. The **barrier analysis** should be abolished entirely as a separate approach in the determination of additionality at project level (though it may be used for determining additionality of project types). Barriers that can be monetized should be addressed in the investment analysis while all other barriers should be addressed in the context of the reformed common practice analysis.

In addition, we recommend improvements to key general CDM rules:

- **Renewal and length of crediting periods:** At the renewal of the crediting period the validity of the baseline scenario should be assessed for CDM project types for which the baseline is the 'continuation of the current practice' or if changes such as retrofits could also be implemented in the baseline scenario at a later stage. Crediting periods of project types or sectors that are highly dynamic or complex should be limited to one single crediting period. Moreover, generally abolishing the renewal of crediting periods while allowing a somewhat longer single crediting period for project types that require a continuous stream of CER revenues to continue operation may be considered.
- **Positive Lists:** The review of validity should also be extended to project types covered by the microscale additionality tool. In addition, positive lists must address the impact of na-

tional policies and measures to support low emission technologies (so-called E- policies). To maintain environmental integrity of the CDM overall, positive lists should be accompanied by negative lists.

- **Standardized baselines:** Once established in a country, their use should be made mandatory and all CDM facilities should be included in the peer group used for the establishment of standardized baselines.
- **Consideration of domestic policies (E+/E-):** The risk of undermining environmental integrity by over-crediting emission reductions is likely to be larger than the creation of perverse incentives for not establishing E- policies. Therefore, adopted policies and regulations reducing GHG emissions (E-) should be included when setting or reviewing crediting baselines while policies that increase GHG emissions (E+) should be discouraged by being excluded from the crediting baseline where possible.
- **Suppressed demand:** An expert process should be established to balance the risks of over-crediting with the potential increased development benefits. In addition, the application of suppressed demand could be restricted to countries where development needs are highest and the potential for over-crediting is the smallest.

Recommendations to improve project type specific rules

Industrial gas projects: Adipic acid production is a highly globalised industry and all plants are very similar in structure and technology. Therefore, a global benchmark of 30 kg/t applied to all plants would prevent carbon leakage, considerably reduce rents for plant operators, and allow the methodology to be simplified by eliminating the calculation of the N_2O formation rate. After issues related to perverse incentives have been successfully addressed through ambitious benchmarks, **HFC-23** and **nitric acid** projects would provide for a high degree of environmental integrity. However, industrial gas projects provide for low-cost mitigation options. These emission sources could therefore also be addressed through domestic policies, such as regulations, or by including the emission sources in domestic or regional ETS, and help countries achieve their Nationally Determined Contributions (NDCs) under the Paris Agreement. Parties to the Montreal Protocol are also considering regulating HFC emissions. We therefore recommend that HFC-23 projects are not eligible under the CDM.

Energy-related project types: We recommend **that these project types should, in principle, no longer be eligible** under the CDM. However, in least developed countries, some project types, particularly wind and small-scale hydropower plants, may still face considerable technological and/or cost barriers. These project types may thus remain **eligible in least developed countries**. In cases in which **biomass power generation** is not competitive with fossil generation technologies, CER revenues can have a significant impact on the profitability of a project, particularly if credits for methane avoidance are claimed as well. We therefore recommend that only biomass power projects avoiding methane emissions remain eligible under the CDM, provided that the corresponding provisions in the applicable methodologies are revised appropriately.

With regard to **demand-side energy efficiency** project types with distributed sources – **cook stoves** and **efficient lighting** – we have identified concerns which question their overall environmental integrity. However, if cook stove methodologies were revised considerably, including more appropriate values for the fraction of non-renewable biomass and if approaches for determining the penetration rate of efficient lighting technologies were made mandatory for all new projects and CPAs while the older methodologies are withdrawn, we recommend that these project types should remain eligible.

Methane projects: Landfill gas and **coal mine methane** projects are likely to be additional. However, there are concerns in terms of over-crediting, which should be addressed through improvements of the respective methodologies, particularly by introducing region-specific soil oxidations factors and requesting DOEs to verify that landfilling practices are not changed. With regard to landfill gas, we recommend that this project type only be eligible in countries that have policies in place to transition to more sustainable waste management practices.

Implication for the future use of international carbon markets

The **CDM has provided many benefits**. It has brought innovative technologies and financial transfers to developing countries, helped identify untapped mitigation opportunities, contributed to technology transfer, may have facilitated leapfrogging the establishment of extensive fossil energy infrastructures and created knowledge, institutions, and infrastructure that can facilitate further action on climate change. Some projects provided significant sustainable development co-benefits. Despite these benefits, after well over a decade of gathering considerable experience, the **enduring limitations** of GHG crediting mechanisms are apparent.

Firstly and most notably, the **elusiveness of additionality** for all but a limited set of project types is very difficult, if not impossible, to address. Information asymmetry between project participants and regulators remains a considerable challenge. This challenge is **difficult to address through improvements of rules**. Secondly, international crediting mechanisms involve an **inherent and unsolvable dilemma**: either they might create **perverse incentives for policy makers** in host countries not to implement policies or regulations to address GHG emissions – since this would reduce the potential for international crediting – or they **credit activities that are not additional** because they are implemented due to policies or regulations. Thirdly, for many project types, the **uncertainty of emission reductions** is considerable. Our analysis shows that risks for over-crediting or perverse incentives for project owners to inflate emission reductions have only partially been addressed. It is also highly uncertain for how long projects will reduce emissions, as they might anyhow be implemented at a later stage without incentives from a crediting mechanism – an issue that is not addressed at all under current CDM rules. A further overarching shortcoming of crediting mechanisms is that they do **not make all polluters pay but rather they make them subsidize the reduction of emissions**. Most of these shortcomings are inherent to using crediting mechanisms, which **questions the effectiveness of international crediting mechanisms as a key policy tool** for climate mitigation.

The future role of crediting mechanisms should therefore be revisited in the light of the Paris Agreement. Several **elements of the CDM could be used** when implementing the mechanism established under Article 6.4 of the Paris Agreement or when implementing (bilateral) crediting mechanisms under Article 6.2. However, the context for using crediting mechanisms has fundamentally changed. The most important change to the Kyoto architecture is that all countries have to submit NDCs that include mitigation pledges or actions. The Paris Agreement therefore requires countries to **adjust their reported GHG emissions** for international transfers of mitigation outcomes, in order to **avoid double counting** of emission reductions. This implies that the baseline, and therefore additionality, may be determined in relation to the mitigation pledges rather than using a ‘counterfactual’ scenario as under the CDM, and that countries could only transfer emission reductions that were beyond what they had pledged under their NDC. A second important implication relates to the incentives for host countries to ensure integrity. Host countries with ambitious and economy-wide mitigation pledges would have incentives to ensure that international transfers of credits are limited to activities with a high likelihood of delivering additional emission reductions. However, our analysis showed that only a few project types in the current CDM project portfolio have a high likelihood of providing additional emission reductions, whereas the environmental integrity is questionable and uncertain for most project types. In combination, this suggests that the future supply of credits may mainly come either from emission sources not covered by mitigation pledges or from countries with weak mitigation pledges. In both cases, host countries would not have incentives to ensure integrity and credits lacking environmental integrity could increase global GHG emissions.

At the same time, demand for international credits is also uncertain. Only a few countries have indicated that they intend to use international credits to achieve their mitigation pledges. An important source of demand could come from the market-based approach pursued under the International Civil Aviation Organization (ICAO), and possibly from an approach pursued under the International Maritime Organization (IMO). For these demand sources, avoiding double counting with emission reductions under NDCs will be a challenge that is similar to that of avoiding double counting between countries. A number of institutions are exploring the use of crediting mechanisms as a vehicle to disburse results-based climate finance without actually transferring any emission reduction units. This way of using crediting mechanisms could be more attractive to developing countries; they would not need to add exported credits to their reported GHG emissions, as long as the credits are not used by donors towards achieving mitigation pledges. The implications of non-additional credits are also different: they would not directly affect global GHG emissions, but could lead to a less effective use of climate finance. However, donors of climate finance aim to ensure that their funds be used for actions that would not go ahead without their support. Given the considerable shortcomings with the approaches for assessing additionality, we recommend that donors should not rely on current CDM rules in assessing the additionality of projects considered for funding.

Taking into account this context and the findings of our analysis, we recommend that the role of crediting in future climate policy should be revisited:

- We recommend potential buyers of CERs to limit any **purchase of CERs** to either existing **projects that are at risk of stopping GHG abatement** or the few project types that have a **high likelihood of ensuring environmental integrity**. Continued purchase of CERs should be accompanied with a plan and support to host countries to **transition to broader and more effective climate policies**. We further recommend to pursue the purchase and cancellation of CERs as a form of **results-based climate finance** rather than using CERs for compliance towards meeting mitigation targets.

- Given the inherent shortcomings of crediting mechanisms, we recommend **focusing climate mitigation efforts on** forms of carbon pricing that do **not rely extensively on credits**, and on measures such as results-based climate finance that do not necessarily serve to offset other emissions. International crediting mechanisms should play a limited role after 2020, to address specific emission sources in countries that do not have the capacity to implement broader climate policies.

- To enhance the integrity of international crediting mechanisms such as the CDM and to make them more attractive to both buyers and host countries with ambitious NDCs, we recommend **limiting** such mechanisms to **project types** that have a **high likelihood of delivering additional emission reductions**. We recommend reviewing methodologies systematically to address risks of over-crediting, as identified in this report. We further recommend revisiting the current approaches for additionality, with a view to abandoning subjective approaches and adopting more standardized approaches. We also recommend curtailing the length of the crediting periods with no renewal.

- Given the high integrity risks of crediting mechanisms, we recommend provisions that provide strong incentives to the Parties involved to ensure integrity of international unit transfers. This includes robust accounting provisions to **avoid double counting** of emission reductions, but could also extend to other elements, such as **ambitious mitigation pledges** as a prerequisite to participating in international mechanisms.

In conclusion, we believe that the CDM has had a very important role to play, in particular in countries that were not yet in a position to implement domestic climate policies. However, our assessment confirms, alongside other evaluations, the strong shortcomings inherent to crediting mechanisms. With the adoption of the Paris Agreement, implementing more effective climate policies becomes key to bringing down emissions quickly on a pathway consistent with well below 2°C. Our findings suggest that **crediting approaches** should play a **time-limited and niche-specific role** in which additionality can be relatively assured, and the mechanism can serve as stepping-stone to other, more effective policies to achieve cost-effective mitigation. In doing so, continued support to developing countries will be key. We recommend using new innovative sources of finance, such as revenues from auctioning of ETS allowances, rather than international crediting mechanisms, to support developing countries in implementing their NDCs.

1. Introduction

With almost 7,700 Clean Development Mechanism (CDM) projects and almost 300 programmes of activities (PoAs) registered and more than 1.6 billion Certified Emissions Reductions (CER) issued, the CDM has developed into an important component of the global carbon market. However, its role in the future remains uncertain. With the adoption of the Paris Agreement, which establishes a mechanism to contribute to the mitigation of greenhouse gas emissions and support sustainable development (Article 6.4), it is clear that the role of the CDM as a mechanism of the Kyoto Protocol will end, most likely soon after 2020.

However, in terms of its standards, procedures and institutional arrangements, the CDM forms certainly an important base for the elaboration and design of future mechanisms for international carbon markets. The mechanism established under Article 6.4 of the Paris Agreement includes several provisions that are similar to the CDM. Parties also decided that the rules, modalities and procedures of the new mechanism should be adopted on the basis of the “experience gained with and lessons learned from existing mechanisms”. Moreover, experiences gained from the CDM can also be used for the development of domestic baseline and credit policies both in developed and developing countries.

One key feature of both the mechanism under the Paris Agreement (Article 6.4) and domestic baseline and credit policies is that they should generate real and additional emission reductions, in other words: the credited and transferred emission reductions should not have occurred in the absence of the mechanism and or policy. The ability to deliver such a result depends heavily on having a reasonably effective way to assess additionality both for specific project types and on an aggregate basis, and to set a baseline such that the number of credits issued does, in total, not exceed actual reductions.

Demonstrating additionality and setting baselines are the areas in which the most concerns have been raised with the CDM, in particular regarding the investment, barrier and common practice analysis and the assessment of prior consideration. Given its counterfactual nature, asymmetries of information regarding costs, financing, barriers and local project conditions, and signal-to-noise issue, it has been difficult to implement a reliable method for assessing additionality and setting baselines. Other factors that also affect the overall mitigation outcome are the length of the crediting period used, how leakage concerns are dealt with and whether any perverse incentives are addressed, among others.

The difficulties with these traditional approaches have resulted in further refinement and revision of these approaches as well as the introduction of several alternative approaches to setting of baselines and testing additionality. Examples include the use of default values, performance benchmarks or penetration rates and discounting approaches. More fundamental changes include the use of highly standardized baselines and additionality tests at the sectoral level. It remains to be seen whether the methodological difficulties with highly standardized approaches can be solved to make them operational, and whether they will result in a lower likelihood of non-additional credits being issued.

The additionality of CDM projects has been assessed in the past in several general and project-specific studies. Much of the research was conducted before the improvement of rules and the introduction of new approaches, such as standardized baselines. This study aims to assess whether and how these changes have affected the quality of CDM projects, focusing on the project portfolio available in the second commitment period of the Kyoto Protocol and taking due account of the improvements implemented over time.

In order to make well-founded judgements about the overall and project-type-specific likelihood of additionality of CDM projects, a systematic assessment is required of the CDM rules and how they have been applied to real projects in practice. A similar exercise should be carried out for the different reforms suggested to the existing rules. This study therefore analyzes the opportunities and limits of the current CDM framework and the way in which it has evolved over time and been applied to concrete projects. It provides robust and quantified conclusions on the overall and project-type-specific environmental performance of the CDM in the form of estimates of the likelihood that the CDM results in real and additional emission reductions.

2. Methodological approach

2.1. General research approach

The main focus of this study is to assess the extent to which the CDM meets its objective stipulated in Article 12.5(c) of the Kyoto Protocol to deliver "real, measurable and additional" emission reductions. Based on the findings, concrete recommendations are made for further reform of the CDM and implications for the future role of the CDM are discussed.

There are two principal challenges to evaluating of the ability of the CDM to deliver additional emission reductions: the inherent uncertainty of a counter-factual baseline and the uncertainty and bias associated with project and baseline data. Therefore, any assessment of the extent of non-additional or otherwise under- or over-credited CDM activity can therefore only provide rough and directional estimates. Project design documents (PDDs) and monitoring reports provide substantial data and assumptions. However, these data and assumptions are often limited (they may not cover all relevant activity, especially non-CDM activity) and can involve considerable judgment by parties that have an interest in the outcome (e.g. selecting among alternative projections of future fuel prices) made for the purpose of meeting CDM requirements.

We examine the three main aspects as regards whether the CDM delivers additional emission reductions:

1. **Additionality assessment:** The assessment of additionality refers to the question of whether a project was implemented due to the CDM. Additionality is the most important prerequisite to providing an emissions benefit. If a project would have been implemented in the absence of the CDM incentives, the emission reductions would have occurred anyway. If a Party uses non-additional CERs rather than reducing its own emissions to meet its emission reduction commitments, global GHG emissions would be higher than they would have otherwise been. Because errors in additionally determination affect the validity of an entire project's CERs, additionality assessment forms the main focus of this study.

2. **Determination of baseline emissions:** A second important aspect is how the baseline emissions are determined. Determining baseline emissions is associated with considerable uncertainty. A crediting baseline that is above the emissions that would most likely occur in the absence of the project can lead to significant over-crediting. Vice versa, ambitious baselines that are below the emissions that would most likely occur in the absence of the project, can result in under-crediting.

3. **Other issues:** A number of other issues are important to deliver additional emission reductions, including:

   - the length of crediting period,
   - criteria for the renewal of the crediting period,

- approaches for determining indirect emission effects, such as leakage effects,
- the way in which perverse incentives for both project developers and policy makers are addressed,
- the extent to which double counting of emission reductions within the mechanism and with other mechanisms and pledges is avoided,
- whether potential non-permanence of emission reductions is sufficiently addressed,
- whether monitoring provisions are appropriate, and
- the effectiveness of the regulatory framework for third party validation and verification.

We also touch upon these issues, in particular when they raise concerns with regard to the integrity of the CDM. They do not, however, form the focus of this study.

In our examination, we approach these aspects from two different perspectives:

- **General CDM rules:** In Chapter 3, we evaluate approaches for determining general CDM additionality rules that are particularly relevant for the delivery of real, measurable and additional emission reductions. This includes an assessment of innovative and potentially more objective approaches for setting baselines and determining additionality and an analysis of whether and how these approaches could improve the determination of additionality under the CDM.

- **Specific project types:** In Chapter 4, we evaluate specific project types with a view to assessing how likely these project types deliver additional emission reductions. A separate evaluation by project type is important as the likelihood of additional emission reductions can differ significantly among project types. This evaluation covers the major project types contributing to a large share of the emission reductions in the CDM portfolio.

Drawing on findings from Chapters 3 and 4, we provide an overall assessment of the additionality of the CDM project portfolio in Chapter 5. In Chapter 6, we provide a summary of key recommendations for further reform of the CDM. Finally, we discuss the implications for the future use of the CDM in Chapter 7.

The study employs several analytical methodologies and approaches:

- **Literature analysis** forms the basis for our evaluation of general CDM rules, specific project types, and innovative approaches towards baseline setting and additionality assessment.

- **Qualitative assessment of relevant CDM rules** with a view to their ability for ensuring additional emission reductions. We identify potential shortcomings in the current rules and propose options for addressing them.

- **Empirical, quantitative evaluation of how the CDM rules are applied** through analysis of a representative random sample of projects. The analysis will be based on information in PDDs and validation reports and, where necessary, also monitoring and verification reports. The projects will be identified through stratified random sampling, aiming to ensure representativeness of host countries and project types. This empirical analysis aims to identify possible shortcomings in the application of general CDM rules. The information and data to be evaluated is specific for each of the identified general CDM rules and the questions identified. The methodological approach of the empirical evaluation is further specified in Section 2.2 below.

- **Economic assessment** of the feasibility of different project types is another important building block of the study. The economic assessment is conducted for the evaluation of specific project types in Chapter 4. The methodological approach of the empirical evaluation is further specified in Section 2.3 below.

- **Sectoral analysis** of the market situation for specific project types to assess whether the technology has often already been implemented without the CDM and whether an observed market uptake occurs due to the CDM. The sectoral analysis is conducted for the evaluation of specific project types in Chapter 4. The methodological approaches are further specified in the corresponding sections.

We use the CDM rules and the CDM project portfolio as of 1 January 2014 as the basis for the assessment.

To assess the impacts of our analysis, we further estimate the potential 2013-2020 CER supply for different project types. The method used to estimate the potential CER volume is described in Section 2.3.

2.2. Empirical evaluation of CDM projects

The assessment of key CDM rules for additionality demonstration in Chapter 3 is based on an in-depth evaluation of PDDs, validation reports, etc. of randomly selected CDM projects. The project samples were randomly drawn from the so-called CDM project pipeline as of 1 January 2014 (UNEP DTU 2014). This pipeline is a compilation of certain information and data provided in the project design document (PDD) of each CDM project. For this assessment, only registered CDM projects were taken into account as the PDDs usually undergo significant changes during the validation period. To ensure representativeness, the samples were stratified by the following characteristics and strata:

- Location (host country/region)
  - China
  - India
  - Asia & Pacific
  - Brazil
  - Latin America
  - Rest of the World
- Technology
  - Industry (HFC-23, N_2O, cement, energy efficiency, energy distribution, etc.)
  - Electricity generation from hydro
  - Electricity generation from wind
  - Electricity generation from renewable energy (solar, tidal, etc.)
  - Other renewable energy (biomass, geothermal, mixed renewable energy, etc.)
  - Waste sector (landfill gas, methane avoidance, etc.)
  - Other (afforestation, reforestation, agriculture, transport, etc.)
- Scale
  - Large-scale projects
  - Small-scale projects
- Time (registration year)
  - Pre 2010
  - In 2010 or 2011
  - Post 2011.

The in-depth assessment of project samples was conducted for the key additionality determination rules: investment analysis (Section 3.2), barrier analysis (Section 3.3) and common practice analysis (Section 3.3). For each of these rules a separate sample of 30 randomly selected CDM projects was drawn.

Since the CDM project pipeline did not include information about which option of additionality determination was applied in the PDD, we had to conduct a two-step sampling: In the first step, we drew a representative sample of 300 projects. For each of the projects of this sample we identified which additionality determination rules were applied so that we could use this sample as population for the second sampling step in which we drew the samples for each of the additionality determination rules.[1]

2.3. Estimation of the potential CER supply

We estimate the potential CER supply[2] for the purpose of assessing the overall integrity of the CDM based on our findings for specific project types or specific additionality tests. The potential CER supply is estimated mainly on the basis of the CDM pipeline as of 1 January 2014 (UNEP DTU 2014). Moreover, we included additional information from a similar pipeline which is provided by IGES (2014). All CDM projects which were registered by 1 January 2014 are taken into account (7,418). In the case of industrial gas projects (HFC-23, adipic acid, nitric acid), some baseline and monitoring methodologies were significantly revised, which has a major impact on the potential CER supply in the second and third crediting periods. For these projects, we use specific bottom-up estimates derived from project-specific information (Schneider & Cames 2014).

We distinguish the CER supply potential considering the duration of the commitment periods under the Kyoto Protocol:

- from credit start to the end of 2012,
- from the beginning of 2013 to the end of 2020 and
- from the beginning of 2021 to the end of the crediting periods (CP).

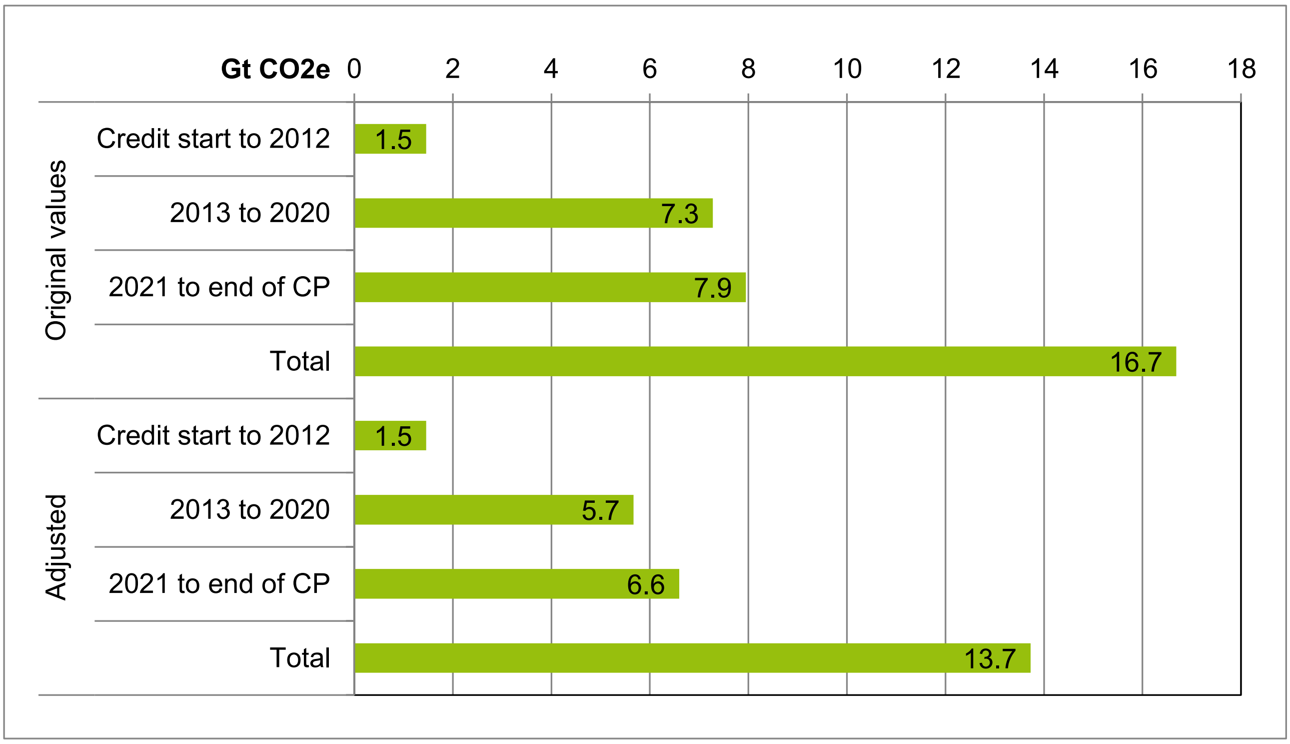
Our study is focused on the period of 2013 to 2020.

Figures for the period from credit start to the end of 2012 reflect the actual CER issuance rather than the potential supply (UNFCCC 2015a). For the latter two periods, we take into account the issuance success rate provided in the CDM pipeline and adjust the expected CER supply accordingly. For some projects, more CERs were issued than projected while for most of the CDM projects less CERs were issued. Several projects had not issued any CERs (4,913). For those projects we assume either the average issuance rate for the respective project type or – if no CERs have been issued for that project type so far – the overall average of the issuance success rate. Figure 2-1 provides an overview of the potential CER supply.

1 A more detailed description of the sampling approach, the code used for drawing the samples and the reference numbers of the projects drawn into each of the samples can be found in Section 8.1 of the Annex.

2 The actual CER supply depends on various conditions of the global carbon market and particularly on price expectations. However, also under normal market conditions, price forecasts are very uncertain. Under post-2012 market conditions, prices are even more uncertain. We therefore only estimate the potential CER supply which is derived from information in PDDs and other project specific or general documents but ignore any interaction with the global carbon market. At price levels of less than $1/CER, the estimated volumes will not be achieved in practice.

Figure 2-1: Potential CER supply, original and adjusted values

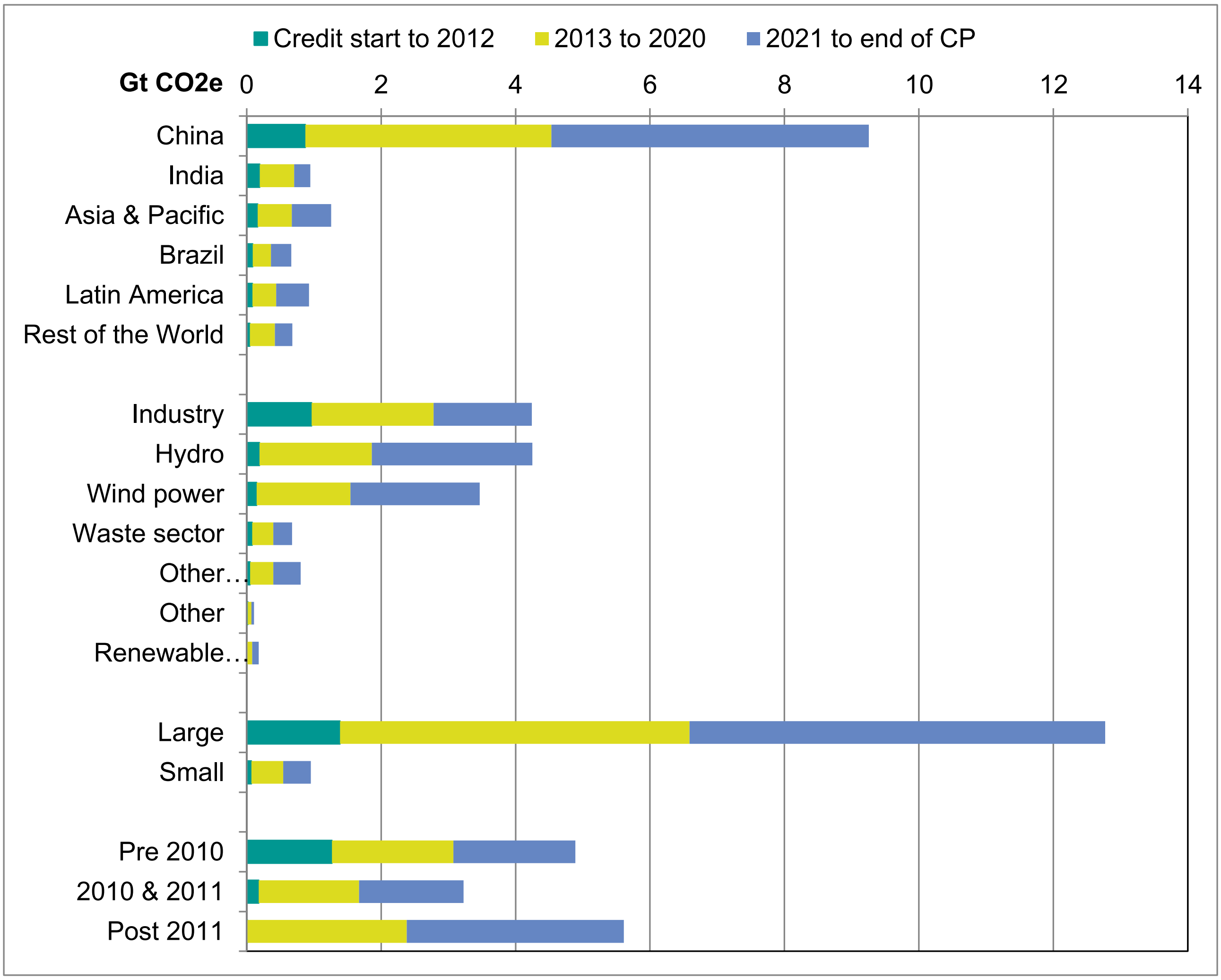


Sources: UNEP DTU 2014, IGES 2014, UNFCCC 2015a, Schneider & Cames 2014, authors' own calculations

The average adjustment factor is -22% though it ranges from -4% for N_2O projects to some -67% for transport projects. The adjusted CER supply for the period of 2013 to 2020 amounts to almost 5.7 billion CERs, almost 4 times the volume issued for the first crediting period.

Figure 2-2 illustrates where the potential CER supply stems from. Obviously China was and will remain the largest potential supplier of CERs. Almost two thirds (64.5%) of the potential CER supply in 2013 to 2020 are expected to be provided by Chinese CDM projects. In terms of project types, the large majority of supply stems from industry (32.0%), hydro (29.4%) and wind (24.6%) projects. Not surprisingly, the large majority (91.3%) of CERs stems from large scale projects while the breakdown in terms of registration period is more even: 31.8% stems from projects registered before 2010, 26.3% from projects registered in 2010 and 2011 while 41.8% of the potential CER supply in the period of 2013 to 2020 can be generated from CDM projects registered after 2011.

Figure 2-2: Potential CER supply by stratification categories



Sources: UNEP DTU 2014, IGES 2014, UNFCCC 2015a, Schneider & Cames 2014, authors' own calculations

In Chapter 4 we analyze the extent to which the likelihood of projects and CERs being additional depends on the project type. We look at 12 different project types, which together cover a broad range of activities and technologies. In terms of CER supply, these 12 project types amount to 85% of the potential supply in the period of 2013 to 2020 (Table 2-1). The largest supply potential is provided by hydro and wind power projects (29.4% and 24.6%, respectively). Industrial gas projects amount to almost 15% of the supply potential while biomass power, landfill gas, waste heat recovery and fossil fuel switch projects could each generate some 3-4% of the supply potential. Compared to these projects types the supply potential of cook stoves (0.04%) and efficient lighting (0.07%) are almost negligible. However, since these project types are often included in government purchase programs or voluntary offset schemes and since their share among projects registered after 2012 is significant, we consider it worthwhile to examine these two project types in greater depth and to assess their likelihood of being additional and of generating additional CERs.

Table 2-1: Potential CER supply by project type

	No. of projects	Credit start to 2012	2013 to 2020	2021 to end of CP	Total
			Adjusted		
		Mt CO_2e			
HFC-23 abatement from HCFC-22 production	19	507	375	547	1,429
Adipic acid	4	201	257	269	727
Nitric acid	97	57	175	172	404
Hydro power	2,010	191	1,669	2,388	4,249
Wind power	2,362	148	1,397	1,929	3,475
Biomass power	342	25	162	169	355
Landfill gas	284	57	163	159	380
Coal mine methane	83	34	170	123	327
Waste heat recovery	277	63	222	62	346
Fossil fuel switch	96	51	232	175	458
Cook stoves	38	0.1	2.3	0.4	2.7
Efficient lighting	43	0.4	3.8	0.2	4.5
Not covered	1,763	124	842	603	1,569
Total	7,418	1,459	5,671	6,596	13,726

Sources: UNEP DTU 2014, IGES 2014, UNFCCC 2015a, Schneider & Cames 2014, authors' own calculations

The first Programme of Activities (PoA) was registered in July 2009. From then until the end of 2013, 243 PoAs were registered in total, the large majority of them in 2012 (193). While cook stoves and efficient lighting account for only a small share in the CDM project pipeline, they are quite relevant in the context of PoAs. By the end of 2013, they account together for a quarter of the registered PoAs. Table 2-2 provides a breakdown of the potential CER supply from PoAs by project types.

Table 2-2: Potential CER supply from PoAs

	No. of programs	Credit start to 2012	2013 to 2020	2021 to end of CP	Total
		Mt CO_2e			
Hydro power	26		5	13	17
Wind power	24		18	45	63
Landfill gas	4	0	12	27	40
Coal mine methane	2		5	10	15
Fossil fuel switch	2		0	0	0
Cook stoves	31	0	33	82	115
Efficient lighting	30	2	17	63	82
Not covered	124	0	70	144	214
Total	243	2	161	385	547

Sources: UNEP DTU 2014, UNFCCC 2015b, authors' own calculations

The main difference of PoAs compared to projects bundles is that PoAs can – once registered – be extended over time by an unlimited number of so-called component project activities (CPA). An estimate of the CER supply potential is thus less reliable than the estimate for the project pipeline.

However, taking into account all CPAs included in PoAs by the end of 2013, the potential CER supply can roughly be estimated, though it is obvious that the actual supply could be much higher. PoA volumes are much more difficult to estimate, because a PoA might be registered with only one CPA that has 1,000 tCO_2 per year emissions reductions but which may ultimately include CPAs that reduce hundreds of thousands of tCO_2 per year.

Noting these limitations, all PoAs could supply some 0.16 billion CERs in total in the period of 2013 to 2020. The final volume of these PoAs could be many times this amount. Almost a third (31.4%) of this supply would be provided by cook stove or efficient lighting PoAs. CERs from renewable power generation programmes amount to 14% of the supply potential of PoAs. Interestingly, almost half of the PoAs do not fall into the project type categories which together account for 85% of the potential CER supply from CDM projects. This supports the hypothesis that PoAs address project categories or technologies that cannot be adequately addressed by individual CDM projects.

2.4. Economic assessment of CER impact

The demonstration of additionality has been a key issue in the CDM since the beginning of the Kyoto mechanisms (Chapter 3). While most researchers agree that there is no simple and objective approach to determining additionality, several authors argue that the impact of CER revenues on the economic feasibility of projects is an important indicator for the likelihood for projects to be additional (for example Sutter 2003, Schneider 2007, Spalding-Fecher et al. 2012). This builds on the assumption that project proponents are more likely to implement a project due to the CDM if CER revenues have a significant impact on the economic performance of the project. While other benefits from the CDM (e.g. the public relation aspect of registering a project under the UNFCCC) may in some cases help projects to go ahead that would not be implemented in the absence of the CDM, the economic benefit of CER revenues may be considered the main driver to implement CDM projects on a larger scale.

A high economic benefit resulting from CER revenues does not guarantee additionality, because some projects may already be economically viable without CER revenues and may only become more profitable with the CDM. However, low CER revenues are an indicator of a lower likelihood that the project is additional, because with low CER revenues it also becomes more likely that the project would be implemented in the absence of the CER revenues.

In 2005, the CDM Executive Board (EB) decided that, in order to be additional, projects have to demonstrate that they are economically unattractive; however, they are not required to demonstrate that with CER revenues they would become economically viable. Schneider (2007) highlighted that this leads to the situation in which projects with very low CER revenues can prove additionality even though the CER revenues contribute only marginally to closing the profitability gap.

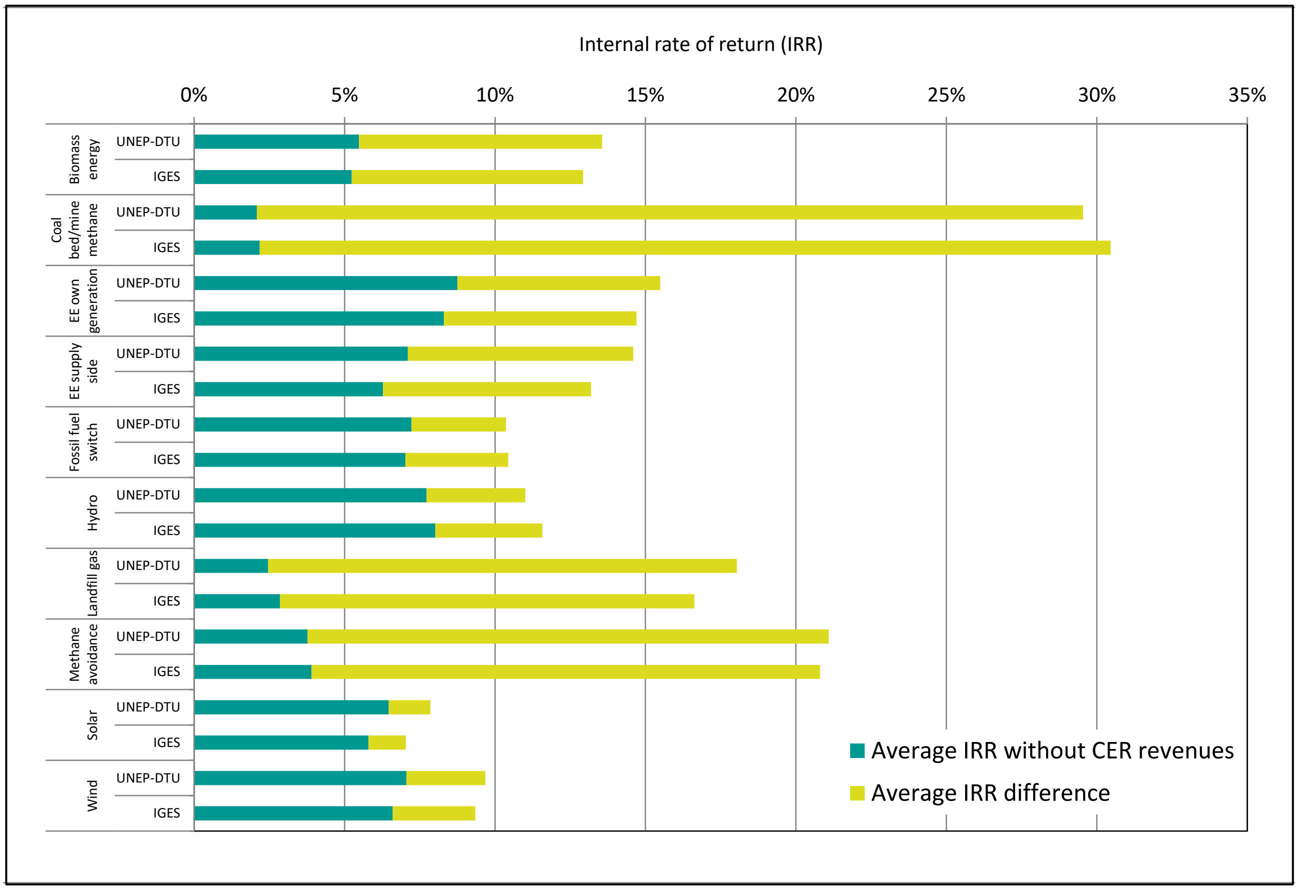
It is difficult to define a minimum required level of contribution from CER revenues that is needed to trigger an investment decision. An important concept in this context is the *signal-to-noise ratio* issue for investment analysis, as mentioned by, for example, Spalding-Fecher et al. (2012): The generally high variability and uncertainty of key parameters that determine the profitability of a mitigation project is often considerably higher than the expected economic benefit of CERs. If the economic impact of the CERs is lower than key uncertainties in the investment analysis, it is rather unlikely that the registration under the CER was the conclusive trigger for the investment and, hence, it is likely that the project is non-additional.

Table 2-3: Impact of CER revenues on the profitability of different project types

Type	Source	Projects with available IRR information	Average IRR without CER revenues	Average IRR with CER revenues	Average IRR difference
Biomass energy	UNEP-DTU	271	5.5%	13.6%	8.1%
	IGES	216	5.2%	12.9%	7.7%
Coal bed/mine methane	UNEP-DTU	70	2.1%	29.5%	27.5%
	IGES	75	2.2%	30.5%	28.3%
EE own generation	UNEP-DTU	205	8.8%	15.5%	6.7%
	IGES	202	8.3%	14.7%	6.4%
EE supply side	UNEP-DTU	36	7.1%	14.6%	7.5%
	IGES	23	6.3%	13.2%	6.9%
Fossil fuel switch	UNEP-DTU	47	7.2%	10.4%	3.1%
	IGES	39	7.0%	10.4%	3.4%
Hydro	UNEP-DTU	1,753	7.7%	11.0%	3.3%
	IGES	1,635	8.0%	11.6%	3.6%
Landfill gas	UNEP-DTU	183	2.5%	18.0%	15.6%
	IGES	165	2.8%	16.6%	13.8%
Methane avoidance	UNEP-DTU	203	3.8%	21.1%	17.3%
	IGES	204	3.9%	20.8%	16.9%
Solar	UNEP-DTU	154	6.5%	7.9%	1.4%
	IGES	122	5.8%	7.0%	1.2%
Wind	UNEP-DTU	2,162	7.1%	9.7%	2.6%
	IGES	1,804	6.6%	9.4%	2.8%

Sources: UNEP DTU 2014, IGES 2014, authors' own calculations

Figure 2-3: Impact of CER revenues on the profitability of different project types



Sources: UNEP DTU 2014, IGES 2014, authors' own calculations

Information on the impact of CER revenues on economic profitability is available from different sources. Table 2-3 and Figure 2-3 show the impact based on data included in project design documents and as documented in the databases by UNEP DTU (2014) and IGES (2014). In addition, Lütken (2012) has analyzed the annual CER revenues in relation to the capital investment and observed for some project types a (very) limited impact stemming from CER revenues. Spalding-Fecher et al. (2012) analyze the impact of CER revenues on the project IRR for different project types in the IGES database. They conclude that the CER impact on the project IRR is the lowest for renewables including hydro and wind (increase of IRR by 2-3%), fuel switch (4%), and supply-side efficiency (5%). They also provide an overview of more studies analysing the impact of CER revenues for different project types. The relatively low impact of CER revenues compared to other cash flows that are relevant for investment decisions is shown for energy efficiency projects below (Box 2-1).

Overall, the available information shows that the impact of CER revenues on the economic performance of projects varies considerably between project types:

- **Non-CO_2 projects**, such as industrial gas abatement, manure management, waste water treatment, landfill gas utilisation and coal mine methane capture, are characterised by a medium to high impact of CER revenues. For several of these project types, CER revenues increase the IRR by more than 10 percentage points, and for coal mine methane projects even by more than 25 percentage points. For these project types, the CER revenues clearly make a difference, which indicates a higher likelihood of additionality.

- **CO_2 projects in renewable energy** such as wind and hydro projects are characterised by a relatively low impact of CER revenues: for wind power, the IRR increases by about 2.5% to 3%, for hydropower by about 3% to 4%, and for solar by about 1% to 1.5%. According to Lütken (2012), the annual CER revenues in relation to investment costs (median) amounted to 1.84% for wind and 3.5% for hydro. Given the typical uncertainties surrounding costs and load factor in renewable projects, this level of CER contributions seems relatively low to justify that the project would not have been implemented in the absence of the CDM. Therefore, in many cases, the additionality of projects within these types may seem rather unlikely (though in some cases it may not be ruled out that additional CER revenues of +3.5% may be the decisive factor rendering a project attractive – though it may not be possible to prove this in an objective way). In addition, many renewable energy projects – in particular hydropower – show a relatively high economic performance without CER revenues (e.g. an IRR of nearly 8% for hydropower without CER revenues), compared to non-CO_2 projects (e.g. landfill gas, coal mine methane and methane avoidance with an IRR of about 2% to 4% without CER revenues).

- **CO_2 projects in fuel switch, energy efficiency, and waste heat utilisation** are typically characterised by relatively low investment costs. Thus, CER revenues are higher compared to investment costs (5% for waste heat and 20% for fuel switch – median value). The impact of CER revenues on the internal rate of return is about 3 to 8 percentage points. However, in this project type, fuel prices are the decisive element determining its profitability. Box 2-1 compares the impact of typical fuel costs and CER revenues for energy efficiency projects. Our analysis indicates that CER revenues tend to have a low impact on project profitability. In addition, these project types show a relatively good economic performance without CER revenues, compared to non-CO_2 projects.

Lütken's analysis was based on a CER price of €12. Our analysis in Table 2-3 and Spalding-Fetcher's build on PDD data with similar CER price assumptions. With today's much lower CER prices, the low impact of CER revenues on CO_2 projects and therefore their high risk of non-additionality is further aggravated.

In conclusion, non-CO_2 projects are characterised by a medium-to-high impact of CER revenues and a relatively low economic performance without CER revenues, while for most CO_2 project types the impact of CER revenues is much smaller and the performance without CER revenues higher. Overall, this indicates that on average non-CO_2 projects have a higher likelihood of additionality.

Box 2-1: An analysis of the impact of CER revenues for energy efficiency projects

Another way of assessing the relevance of CER revenues in investment decisions is to compare them to other important revenues or savings in the investment analysis. For instance, for energy efficiency projects to become profitable, they have to (i) save sufficient costs for fossil fuels and (ii) earn sufficient CERs to pay back the investment costs for new equipment improving the energy efficiency. Figure 2-1, Figure 2-2 and Figure 2-4 illustrate the order of magnitude of fuel cost savings in relation to one tonne of CO_2 reduced or CERs generated in the case of projects saving natural gas, light fuel oil and steam coal. For instance, if an installation implements new equipment that reduces the specific consumption of natural gas and the related GHG emissions by one tonne of CO_2, then the related reduction in fuel costs in 2010 would amount to approx. 150 USD/tCO_2 (at OECD average prices in 2010). For light fuel oil, the fuel cost reduction amounts to over 250 USD/tCO_2 and for steam coal, the savings still amount to 37 USD/tCO_2 (in 2010). With this, it becomes obvious that the impact of fuel cost savings on the project cash flow is much higher than contribution from CER revenues.

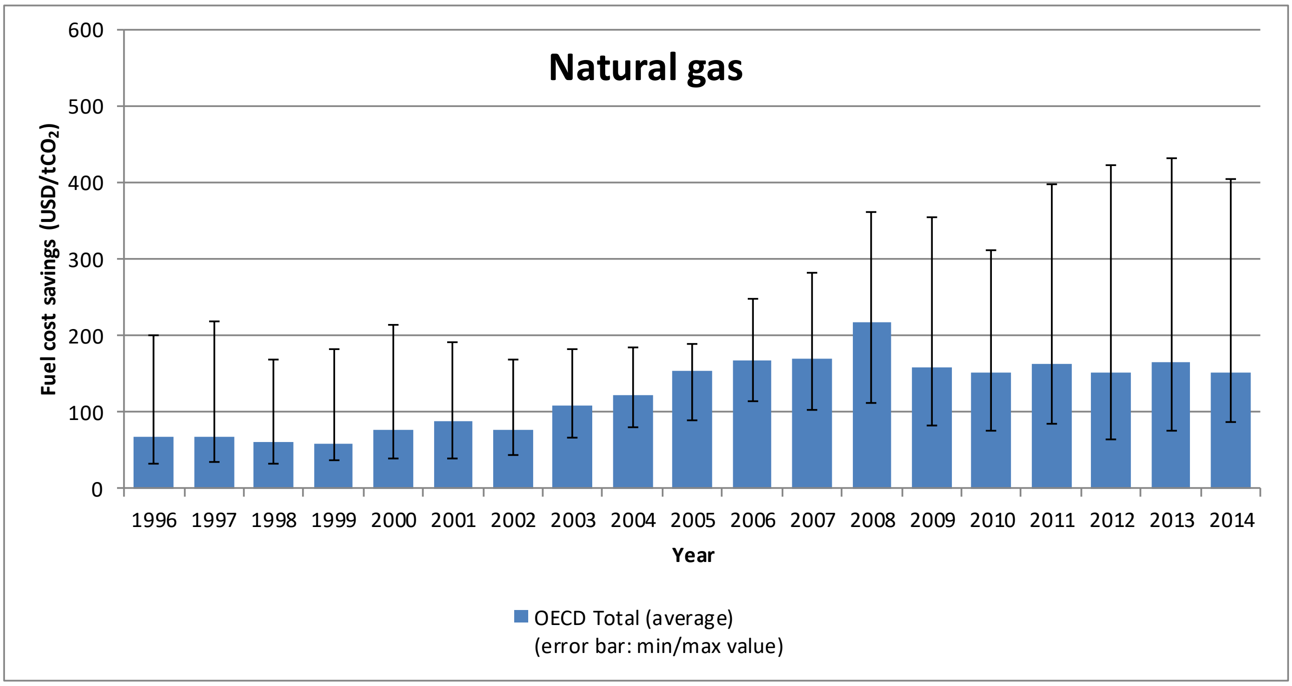
Figure 2-1, Figure 2-2 and Figure 2-4 also show the development of average (and min. and max.) OECD prices over time, which illustrates the high variability of energy prices since 1996. Average specific energy prices have fluctuated in the order of 20 USD/tCO_2 (steam coal) to 200 USD/tCO_2 (light fuel oil). Also compared to the historic fuel price variability, typical CER revenues are low to negligible compared to fuel cost savings.

Please note that because of limitations in data availability, the figures are based on fuel prices in OECD countries, which in many cases also include taxes and may not be representative for all developing countries. In particular, in some developed and developing countries fossil fuel subsidies are very high. In these cases, because of the low prices, the fuel cost savings are low and may be on a similarly low level as the contribution from CER revenues to the positive project cash flow. However, in such a low price situation, the total positive cash flow may in any case be far too small to justify investments in energy efficiency equipment and the scope for CDM may become rather limited.

Overall, it may be argued that for projects to have a high likelihood of additionality the impact of CER revenues should at least be comparable to the main contributor to a positive cash flow, the related fuel savings. This would indicate that in such project types CER prices for energy efficiency projects would need to reach a level of at least 10-20 USD/tCO_2 for steam coal, 30-50 USD/tCO_2 for natural gas and 100-200 USD/tCO_2 for light fuel oil based systems (if prices on the level of OECD countries are assumed). With such CER prices, the economic contribution from CER revenues to positive cash flow reaches a level that may be considered significant (i.e. in the order of ¼ to ½ of fuel cost savings).

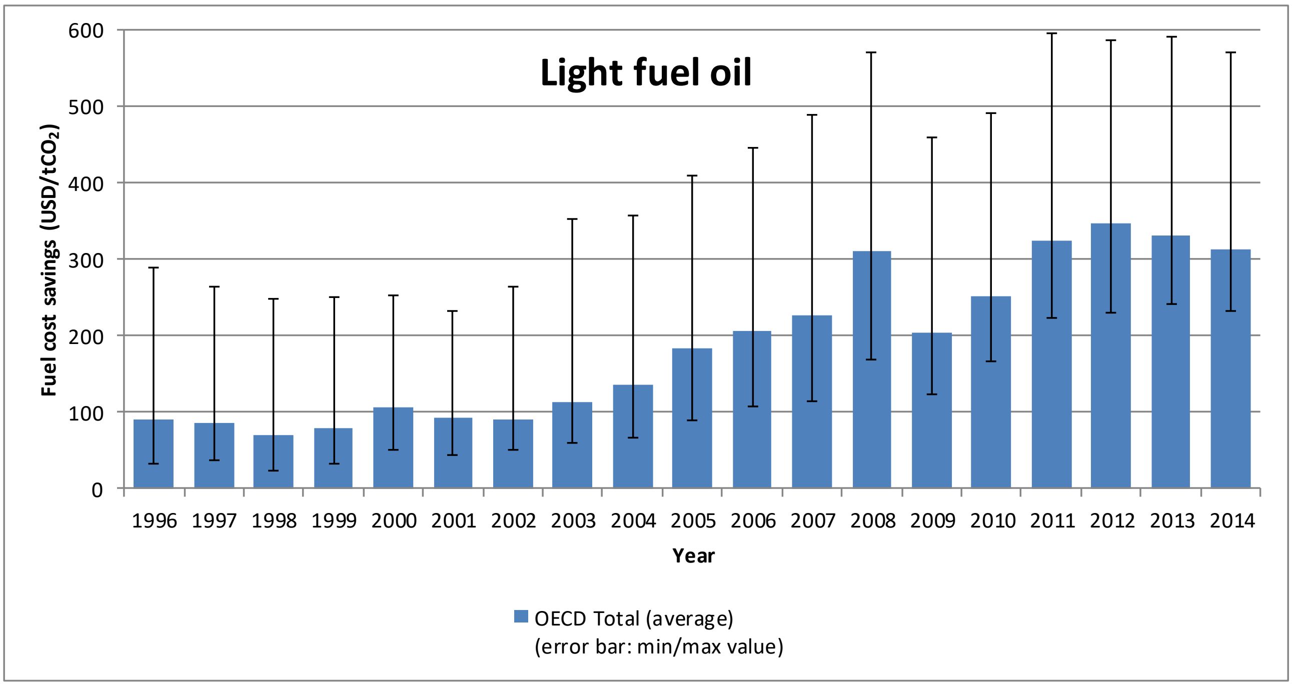
At prices significantly below this level, the economic impact of CERs is insignificant and the risk of non-additionality is very high.

Figure 2-4: Natural gas cost savings per tonne of CO_2 reduced in energy efficiency projects



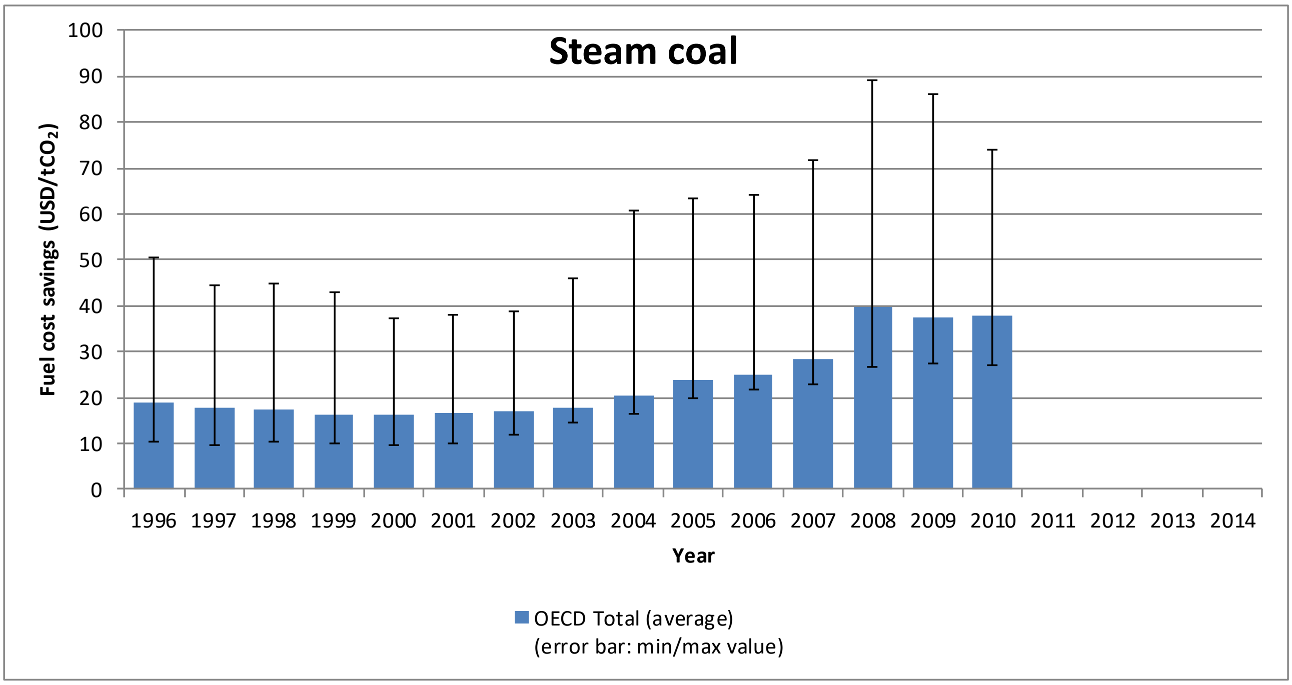
Notes: Average fuel prices of OECD countries (in USD/TJ).
Sources: IEA 2015, IPCC 2006, authors' own calculations

Figure 2-5: Light fuel oil cost savings per tonne of CO_2 reduced in energy efficiency projects



Notes: Average fuel prices of OECD countries (in USD/TJ).
Sources: IEA 2015, IPCC 2006, authors' own calculations

Figure 2-6: Steam coal cost savings per tonne of CO_2 reduced in energy efficiency projects



Notes: Average fuel prices of OECD countries (in USD/TJ).
Sources: IEA 2015, IPCC 2006, authors' own calculations

3. Assessment of approaches for determining additionality and rules relevant towards additionality

3.1. Prior consideration

3.1.1. Overview

Prior consideration is a key requirement in the CDM. It aims to ensure that only projects are registered in which the CDM was seriously considered when the decision to proceed with the investment was made.

In the first version of the additionality tool prepared in 2004[3], a provision was introduced for projects with a crediting period starting prior to registration, which stipulated that evidence has to be provided "that the incentive from the CDM was seriously considered in the decision to proceed with the project activity" and that the "evidence shall be based on (preferably official, legal and/or other corporate) documentation that was available to third parties at, or prior to, the start of the project activity." The provision remained almost unchanged in the second version of the additionality tool in 2005.

In the third version of the additionality tool in 2007, the provision was removed and then included in the Guidelines for completing the PDD, which are applicable to all projects and not only those applying the additionality tool. These guidelines stipulated that "project proponents shall provide an implementation timeline of the proposed CDM project activity" and that "the timeline should include, where applicable, the date when the investment decision was made, the date when construction

[3] EB 16, Annex 1: Tool for the demonstration and assessment of additionality.

works started, the date when commissioning started and the date of start-up (e.g. the date when commercial production started)". Also, according to the guidelines, "project participants shall provide a timeline of events and actions, which have been taken to achieve CDM registration, with description of the evidence used to support these actions"[4].

In 2008, the CDM EB introduced general guidance on the demonstration and assessment of prior consideration[5]. The guidance was subsequently revised twice[6], including further guidance for DOEs on how to validate real and continuing actions; in 2011 it was incorporated in the project standard (PS)[7]. According to the latest version of the project standard[8], "if the start date of a proposed CDM project activity … is prior to the date of publication of the PDD for the global stakeholder consultation, project participants shall demonstrate that the CDM benefits were considered necessary in the decision to undertake the project as a proposed CDM project activity". More specifically, project participants of project activities with a starting date on or after 2 August 2008 *"shall inform the host Party's designated national authority (DNA) and the secretariat of their intention to seek CDM status in accordance with the Project cycle procedure"*, while "for a proposed CDM project activity with a start date before 2 August 2008 and prior to the date of publication of the PDD for global stakeholder consultation, project participants shall demonstrate that the CDM was seriously considered in the decision to implement the proposed project activity". For this purpose, "project participants shall provide evidence of their awareness of the CDM prior to the start date of the proposed project activity, and that the benefits of the CDM were a decisive factor in the decision to proceed with the project"[9], *"provide evidence that continuing and real actions were taken to secure CDM status for the proposed project activity in parallel with its implementation"*[10] and "provide an implementation timeline of the proposed CDM project activity. The timeline should include, where applicable, the date when the investment decision was made, the date when construction works started, the date when commissioning started and the date of start-up (e.g. the date when commercial production started). Project participants shall provide a timeline of events and actions, which have been taken to achieve CDM registration, with description of the evidence used to support these actions".

The CDM project cycle procedure[11] includes details about the notification process related to prior consideration (i.e. forms to be used, etc.). According to this procedure, for project activities with a start date on or after 2 August 2008, notification to the DNA of the host country and to the Secretariat must be made "within 180 days of the start date of the project activity". A list of notifications received by the Secretariat is available on the UNFCCC website.[12]

The requirements for demonstrating prior consideration set out in the project standard are generally applicable with the exception of programmes of activities (PoAs).

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4 EB 41, Annex 12: Guidelines for Completing the Project Design Document (CDM-PDD) and the Proposed New Baseline and Monitoring Methodologies (CDM-NM) (Version 07).

5 EB 41, Annex 46: Guidance on the Demonstration and Assessment of Prior Consideration of the CDM.

6 EB 48, Annex 61 and EB 49, Annex 22.

7 EB 65, Annex 5.

8 CDM project standard, Version 07.0, EB 79, Annex 3.

9 Relevant evidence could, for instance, relate to "minutes and/or notes related to the consideration of the decision by the EB of Directors, or equivalent, of the project participants, to undertake the project as a CDM project activity".

10 Relevant evidences "should include one or more of the following: contracts with consultants for CDM / PDD / methodology / standardized baseline services; draft versions of PDDs and underlying documents such as letters of authorization, and if available, letters of intent; emission reduction purchase agreement (ERPA) term sheets, ERPAs, or other documentation related to the sale of the potential CERs (including correspondence with multilateral financial institutions or carbon funds); evidence of agreements or negotiations with a DOE for validation services; submission of a new methodology or standardized baseline, or requests for clarification or revision of existing methodologies or standardized baselines to the EB; publication in a newspaper; interviews with DNA; earlier correspondence on the project with the DNA or the secretariat".

11 Current version 07.0, EB 65, Annex 32.

12 https://cdm.unfccc.int/Projects/PriorCDM/notifications/index_html.

With regard to PoAs, the project cycle procedure includes the non-binding provision that "*the coordinating/managing entity may notify to the DNA(s) of the host Party(ies) of the PoA and the secretariat in writing of the intention to seek the CDM status for the PoA, using the [corresponding form] for the purpose of determining the start date of the PoA*". According to the CDM project standard, the start date of a PoA is either "*the date of notification of the intention to seek the CDM status by the coordinating/managing entity to the secretariat and the DNA*" or "*the date of publication of the PoA-DD for global stakeholder consultation*". With regard to CPAs, "*the start date of a CPA is the earliest date at which either the implementation or construction or real action of the CPA begins*" and it shall be confirmed that "*the start date of any proposed CPA is on or after the start date of the PoA*". The only exception to this rule relates to afforestation and reforestation (A/R) PoAs, which allows *"the inclusion of any A/R project activity that started after 1 January 2000 but has not been registered as a CDM project activity as a CPA in an A/R PoA".*[13]

3.1.2. Assessment

The issue of projects obtaining registration as CDM projects without serious consideration of the CDM benefits at the time of the investment decision was especially a concern during the first years of the CDM. The requirement to demonstrate prior consideration was only gradually introduced over time and became generally applicable only in 2007. Also, as pointed out by Schneider (2007), the requirement was also not always followed: only 36% of the projects seeking retroactive crediting provided evidence that the CDM was considered in the decision to proceed with the project and it is reported that relevant documentation has been backdated. It can, therefore, be concluded that for early CDM projects, the demonstration of prior consideration was questionable.

The approach applied as of August 2008 (i.e. for the bulk of projects and generated CERs) requires notification of the prior consideration of the CDM as well as, in situations of delay, evidence of continued interest in the CDM using a form designed for this purpose. This requirement addresses the issue of prior consideration in a more objective and appropriate manner, avoiding the risk of back-dating of company-internal information or subjective claims of prior consideration. In this regard, the rules have improved over time and there is no evident flaw in the current rules and therefore no need for the current practice to be changed.

However, it should be noted that the notification of prior consideration ensures that projects cannot claim CDM registration retroactively, but does not demonstrate whether or not a project is additional. In this regard, this rule does not provide any information on the additionality of projects since both truly additional projects and free riders may apply for the CDM status. This rule is therefore important to exclude projects which did not consider the CDM at all and are therefore clearly not additional, but it is not sufficient for assessing whether a project can be considered additional or not.

With regard to the practical implementation, a period of 180 days for notification of prior consideration can be considered quite generous. While a certain grace period is certainly reasonable due to the administrative process of making the PDDs available for global stakeholder consultation, a period of six months could mean that the project is already quite advanced, which would then call into question whether CDM benefits were actually necessary for the project to proceed. A long grace period could therefore be regarded as allowing retroactive crediting.

The requirements regarding the start date of PoAs and CPAs are sufficiently strict to avoid any project activity that has already started being registered as CPAs under a PoA. The only rule that cannot be considered adequate relates to the inclusion of old A/R activities in a newly registered

[13] Clarification "Start date and crediting period of component project activities under an afforestation and reforestation programme of activities", EB 73, Annex 16.

A/R PoA (see above). For these A/R activities, CDM rules do not require demonstrating prior consideration of the CDM.

3.1.3. Summary of findings

There is no evident flaw in the general design of this rule with the exception of the inclusion of old A/R activities in a newly registered A/R PoA. Also, as outlined above, the time frame for notification of prior consideration appears to be quite generous.

3.1.4. Recommendations for reform of CDM rules

The only rule that needs to be changed relates to the inclusion of old A/R activities in a newly registered A/R PoA (see above). It is therefore recommended that the corresponding rule be withdrawn.

Furthermore, it is recommended that the time frame for notification of prior consideration be shortened in order to reduce the risk that projects apply for the CDM having only learned of the possibility after the project has started. The grace period for notification to the secretariat should therefore be reduced in general, e.g. to a maximum of 30 days after the project start.

3.2. Investment analysis

3.2.1. Overview

The CDM's *additionality tool* requires demonstration that a prospective project is either not financially viable without the CDM (using investment analysis) or that there is at least one barrier preventing the proposed project without the CDM (using barrier analysis). Though both methods are common (and some projects use both), investment analysis is the most widely used, by over three-quarters of all projects and over 90% of the renewable energy (especially hydro and wind) projects that are expected to dominate future CER supplies (Spalding-Fecher & Michaelowa 2013). Investment analysis (or a variation of it) is also used in the *combined tool* and in some CDM baseline and monitoring methodologies that refer neither to the *additionality tool* nor to the *combined tool* for demonstrating additionality.

The additionality tool provides three alternative options for conducting investment analysis:

- For projects with costs but no revenues (other than CERs), a **simple cost analysis** can be used to demonstrate that at least one scenario (other than the project) is less costly. This approach is quite common for a few project types (e.g. projects that capture N_2O from adipic acid plants, or methane from landfills), but it is not common overall.
- The **investment comparison analysis** compares the economic attractiveness of the project without revenues from CERs to other investment alternatives that provide similar outputs or services; this approach is common for just a few project types (e.g. higher-efficiency fossil power), and is not common overall.
- The **benchmark analysis** is used to demonstrate that a proposed project is, without revenues from CERs, economically not attractive (i.e. it does not meet a stated financial benchmark); this approach is, by far, the most common form of investment analysis.

In all cases, investment analysis relies on the premise that, if a project is not a better investment (or less costly) than an alternative or a financial benchmark, then it would not have proceeded but for the existence of the CDM. Exactly how the CDM causes it to proceed, whether through CER revenue or otherwise, does not need to be specified.

The approach to investment analysis has also been refined over time. In particular, in 2008 the CDM EB adopted “Guidelines on the assessment of investment analysis”, which aimed to provide further clarity and reduce ambiguity by, for example, clarifying how to calculate the common financial benchmarks net present value (NPV) and internal rate of return (IRR) and suggested ranges for conducting sensitivity analysis in these parameters. In 2011, this guidance was further revised to introduce default values for the expected return on equity for different project types and host countries, which can (but are not required to) be used by project developers as benchmarks for the benchmark analysis.

3.2.2. Assessment

The expected financial performance of a project is clearly one important factor in determining whether or not it will proceed (see further discussion of this in Section 2.3). For example, unless mandated by an (enforced) government policy, there is little reason for projects with no revenue (other than CER values) to proceed, simplifying the assessment of additionality.

For projects that do collect revenue other than CER values, such as by selling electricity, the CDM rules seek to determine whether the project would not have been financially attractive (and therefore not have proceeded) without the CDM. Researchers have raised several critiques of this approach, which we address in this report under two broad themes.

The first is perhaps the most fundamental, and is whether investment analysis is appropriate for investments that may be driven largely by other (non-economic) factors. This critique asserts that many investments in common CDM activities – e.g. power generation – are undertaken for a host of political, social, and strategic reasons that extend beyond simple project-level economics and may not be designed to maximise economic return. Such critics argue that a market-based test such as investment analysis is not applicable in what is largely a non-market environment, perhaps especially so in centrally planned countries such as China (He & Morse 2010). For example, Bogner & Schneider (2011) and Haya & Parekh (2011) have argued that governments have already subsidized and developed large hydroelectricity projects in developing countries well before the CDM, making them financially viable and therefore raising questions about the extent to which investment analysis can credibly determine that they would not proceed but for the incentive provided by the CDM. For investment analysis to function properly – indeed, for any additionality test to function properly – it must be able to demonstrate, with high confidence, that the CDM was the deciding factor for the project investment. For project types that are routinely constructed outside the CDM, including (but not exclusively) for broader economic, energy security, or political reasons, it remains highly difficult to determine with confidence that, in any particular case, a project’s financial returns are the reason it is not proceeding and that the financial incentive provided by the CDM is the reason for it proceeding (Dechezleprêtre et al. 2014).

Table 4-5 provides an example of how the decision of selecting a certain fuel (coal, fuel oil or natural gas) may depend on many factors that are not are only insufficiently covered in an investment analysis, such as level of initial investment or flexibility in operation that may lead, for example, in investment in a natural–gas-fired boiler rather than a coal–based one, even though natural gas may be more costly than coal in terms of direct costs.

The second critique is concerned with transparency, subjectivity, and information asymmetry, such as whether project developers provide sufficient and credible information to allow replication of their calculations and justification of their conclusions, as well as the inherent information asymmetry between project developers and those, especially the CDM EB, tasked with reviewing the information. For example, early research found that project developers regularly provided investment analyzes that were opaque, relied on proprietary company information, or were incomplete (Schneider 2009).

This analysis takes a new look at several aspects of this second critique, including:

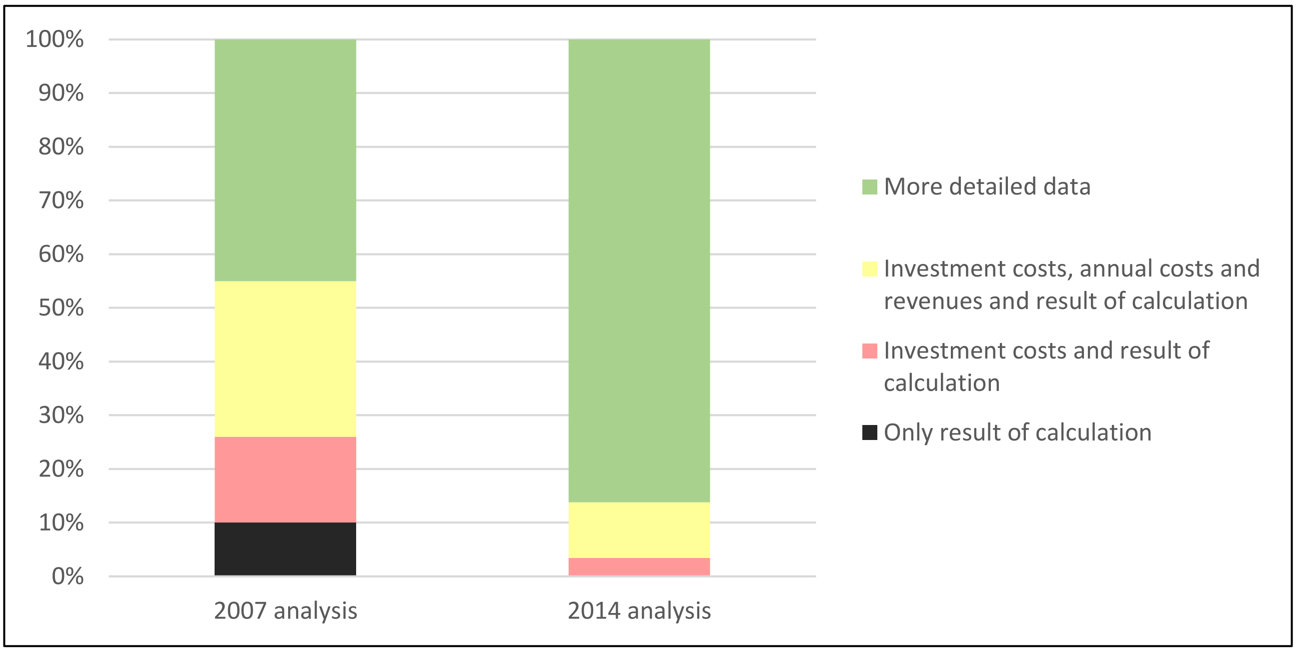
- Transparency, by re-visiting the prior work of Schneider (2009) to gauge how transparently developers conduct the investment analysis.
- Subjectivity and asymmetry, with a new exploration of benchmark rates and CER prices.

These two broad topics are addressed in turn below.

Transparency

To explore transparency in investment analyzes, Figure 3-1 updates the analysis of Schneider (2009) who reviewed a randomly selected group of PDDs for the level of information provided. In our updated analysis, 29 registered projects using the investment analysis were selected at random.[14] Over 90% of the projects selected were registered after 2007, the year of Schneider's prior analysis, so this sample can indicate how practices have changed. In particular, over 80% of the 29 projects in this new analysis provided detailed input data to support their calculations of capital and operating costs and revenues, compared to 2007, when fewer than half did. Furthermore, no projects provided only the result of their calculation in this analysis, with no input data to support their findings. These findings suggest that investment analysis has become more transparent.

Figure 3-1: Level of information provided in PDDs on the investment analysis



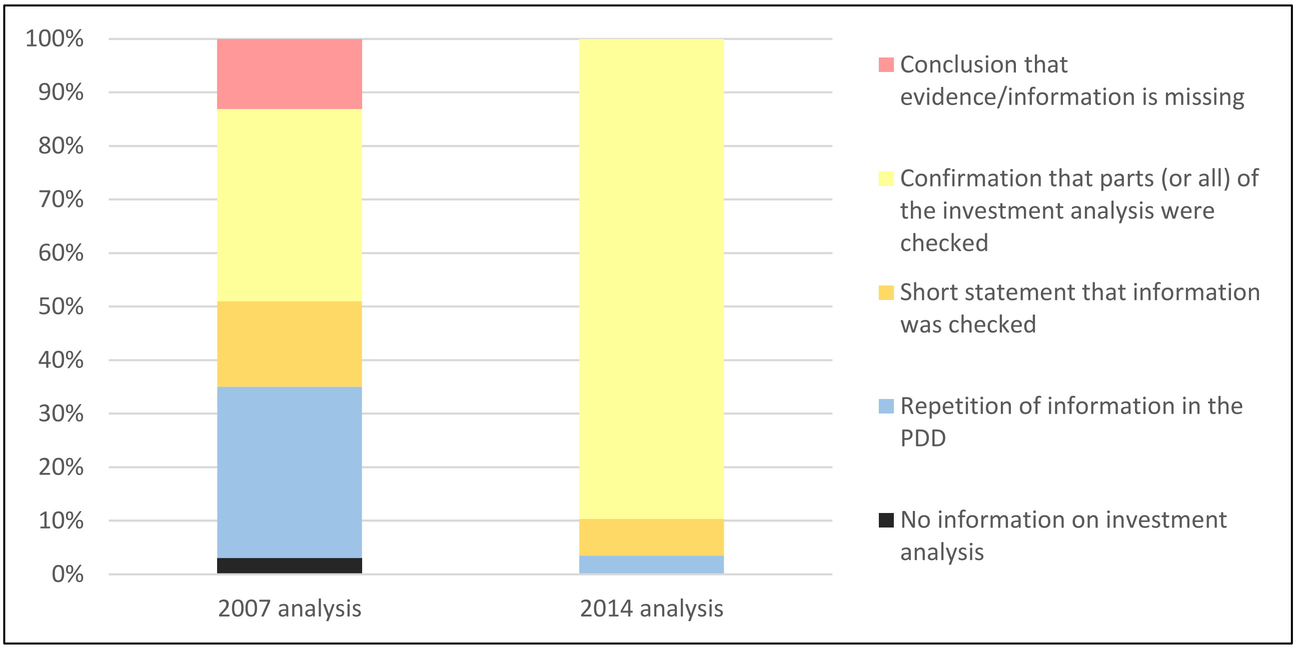
Notes: 2007: n=31, 2014: n=29.
Sources: Schneider (2009), authors' own calculations

Validation reports that review the investment analyzes also appear to have become more thorough. Figure 3-2 also returns to Schneider's prior analysis to update it based on the same randomly selected group of projects as in Figure 3-1. As seen in Figure 3-2, more than 80% of the validation reports confirm that validators checked some or all of the key assumptions of the investment analyzes. The validation reports often review each of several of the most critical investment analy-

[14] According to the sampling design, 30 projects using investment analysis were to be selected. Upon further examination, one of the thirty projects selected, a small-scale, run-of-river hydropower plant, had demonstrated additionality using other methods, as outlined in the "Guidelines for Demonstration Additionality of microscale project activities" and so was not considered in this analysis.

sis inputs and describe that the inputs are reasonable, in many cases citing contract or other documents reviewed to support the choice of inputs.

Figure 3-2: Information in validation reports on the investment analysis



Notes: 2007: n=31, 2014: n=29.
Sources: Schneider (2009), authors' own calculations

Subjectivity and information asymmetry

Despite the findings above, transparency and validator review of the input parameters do not remove subjectivity or choice of alternate input parameters in different contexts. For example, in some cases, project proponents have used different values for key input parameters when submitting applications to financial institutions (Haya 2009), suggesting that the metrics used (and choice of inputs therein) and reliability of such may vary. Indeed, project developers will always have much more information on the project's local conditions – including costs and technical parameters – than will outside parties, whether validators or CDM administrators, and therefore have an incentive to provide biased or inaccurate information to increase the chance of a successful additionality determination and, therefore, the eventual awarding of credits to their project (Gillenwater 2011). This phenomenon is widely referred to as '*information asymmetry*'. As shown above, validators do have more information at their disposal now than in the past, but still lack an objective basis for determining that the investment would not have been undertaken and that inputs provided are the same as they would have been had CDM credits not been sought. Small changes in a number of input parameters – even if individually well within the range of other similar projects (CDM or not), could lead to significant changes in the overall stated financial return of the project. Interestingly, under the CDM, project participants do not need to provide any confirmation that they are submitting truthful information. Some project developers reported that different versions of investment analysis were used for CDM purposes and for the purpose of securing other funding for a project (e.g. loans). Other crediting mechanisms, such as the VCS and CAR, require declaration or attestations from project developers that all information is accurate and presents the truth. To explore further the issue of subjectivity and information asymmetry in input parameters, we take a deeper look at two particular inputs: benchmark rates and CER prices.

Closer examination of benchmark rates

This critique concerns appropriate levels for financial benchmarks (e.g., IRR) (Michaelowa 2009). To explore this question, we reviewed data on IRR benchmarks used by wind, hydro, biomass, and waste gas or heat projects in China, wind and hydro projects in India, and hydropower projects in Vietnam.[15]

Nearly all projects in China use standard, government-issued IRR benchmarks. By far the most common benchmark used is 8%, which is applied for most power projects, and derives from a 2002/2003 Chinese government source, *Interim Rules on Economic Assessment of Electric Engineering Retrofit Projects*. Other common benchmarks based on government rules include 10% for small hydro projects, and 12-13% for waste gas/heat projects.

Table 3-1: Summary of most common benchmark rates used in IRR analysis in Chinese CDM projects

Project type	Common IRR benchmark	Fraction of projects using this benchmark	Source of this benchmark
Wind	8.0%	99%	Government's *Interim Rules on Economic Assessment of Electric Engineering Retrofit Projects* (2002/2003)
Hydro	10.0%	71%	Government's *Economic Evaluation Code for Small Hydropower Projects* (1995)
	8.0%	29%	Government's *Interim Rules on Economic Assessment of Electric Engineering Retrofit Projects* (2002/2003)
Biomass	8.0%	98%	Government's *Interim Rules on Economic Assessment of Electric Engineering Retrofit Projects* (2002/2003)
Waste gas / heat	12.0%	30%	Government's *Economical Assessment and Parameters for Construction Project, 3rd edition* (2006)
	13.0%	17%	Government's *Economical Assessment and Parameters for Construction Project, 3rd edition* (2006)
	18.0%	16%	Conch Cement Company internal WACC

Notes: In this table, and throughout this section, we report IRR benchmarks and values based on analysis of IGES's investment analysis database. We believe that most of the benchmarks, and values reported in the database, are in real terms, based on a review of a small number of PDDs and the assumption in the CDM's Guidelines on the Assessment of Investment Analysis that is conducted in real terms. We make no attempt to identify or convert values in the database that may be in nominal terms.

Sources: IGES 2014, authors' own calculations

Despite the ubiquity of the 8% government-set threshold in China, it is not clear how or why it matches the internal thresholds used by actual project inventors, who may themselves demand returns either higher or lower. (For example, benchmarks for wind power projects in India, where they are determined to a greater extent by investor hurdle rates, are more variable and, on average, higher). For this reason, it is not clear why 8% is the 'correct' benchmark for a test intended to gauge the attractiveness of an investment. Furthermore, it is not clear why common benchmarks used for hydro or waste gas are higher (10% or at least 12%, respectively), and whether these

[15] These project type / country combinations were selected because each of them represents at least 1% of the registered projects in the CDM that use investment analysis (IGES 2012). Though this 1% threshold is arbitrary, it provided us with a basis for focusing the analysis.

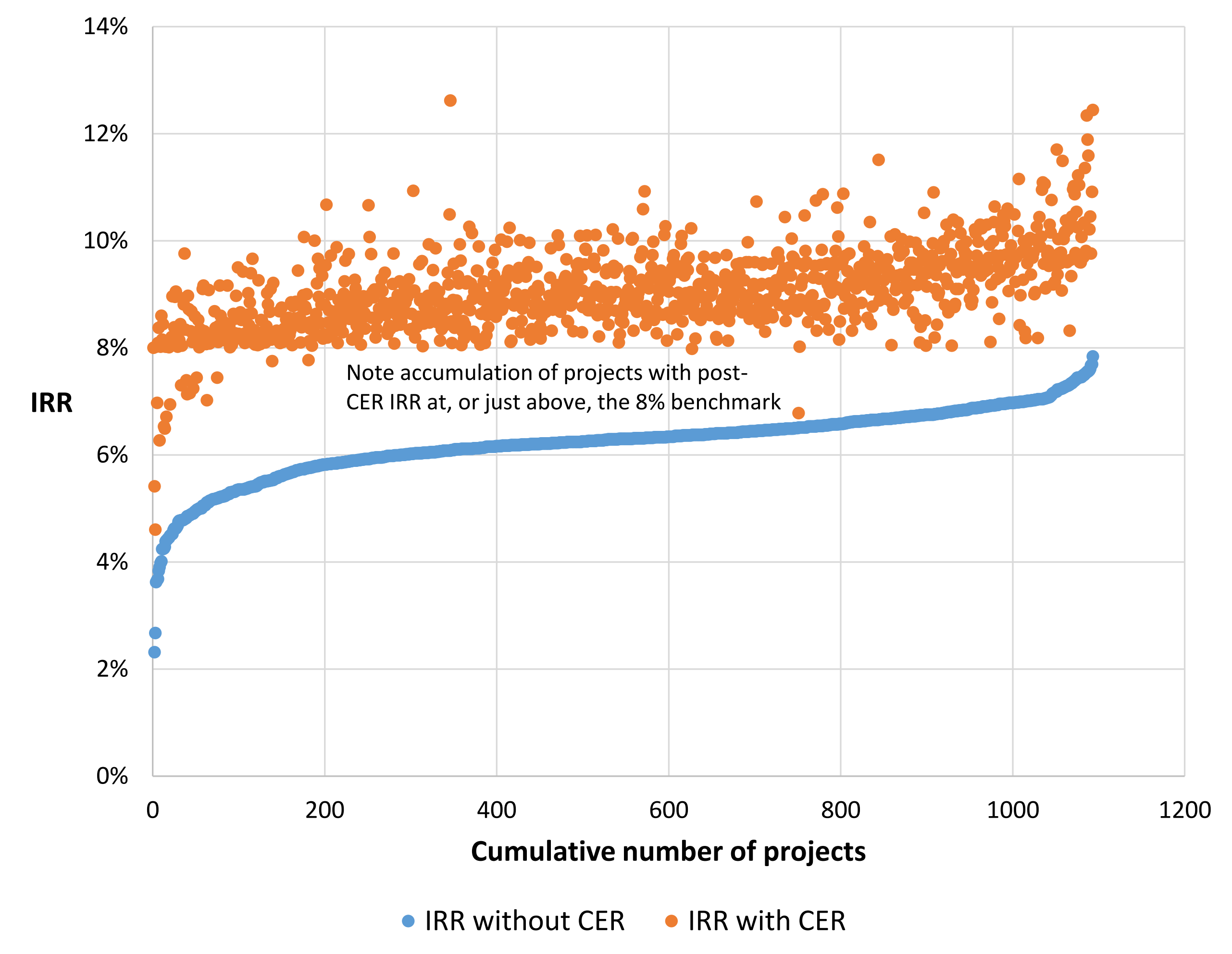
rates accurately capture the risk and expected financial returns in these types of projects. Further analysis of this issue may be warranted, e.g. by comparing it with other sources of equity rates for different investments in China or for similar projects in other countries. A source of such data for projects within China was not immediately known, however.

In principal, the logic of investment analysis is that the project would not have proceeded but for the financial incentive provided by the CDM. That financial incentive is the value of CERs. Many project developers conduct an analysis to show that, at assumed CER prices, the financial return of the project is expected to clear the financial benchmark used. However, this is not actually required by the additionality tool. (In the first versions of additionality, a step 5 ‘impact of the CDM’ was included, which was interpreted by many project developers as an obligation to show that the project is made economically attractive through the CDM. This was later removed).

The above discussion investigated benchmarks used in China, with special attention paid to the widely used 8% benchmark. Because of its ubiquity, this 8% benchmark provides an opportunity to investigate the extent to which CER values indeed bring about expected project returns above this value and therefore, in the logic of the investment analysis, enable the project to proceed. As stated above, though projects are not required to actually show that CER values would push the project above its stated threshold, most do report results of expected return.

The following chart (Figure 3-3) shows the stated IRRs before and after CERs for all wind projects in China that use a benchmark of 8%. As seen in the figure, most of these projects state an IRR without CERs of between 6% and 7%, and an IRR after CER value of 8% to 10%. Note in particular the sharp line at 8%, at which very few projects claim an after-CER IRR of just under 8%, but a large number of projects find a post-CER IRR of just barely more than 8%.

Figure 3-3: Stated IRRs of Chinese wind projects using a benchmark of 8% before and after assumed CER value



Sources: IGES 2014, authors' own calculations

In principle, one explanation for this distribution is that projects in which the 8% threshold is not reached with CER revenues are not implemented, do not apply for CDM registration, and are therefore not represented in this graph. The fact that so many projects just barely meet the 8% threshold (even though they are not required to do so), and so few do not meet it, may instead indicate, however, that project developers are eager to claim that the CER value has allowed the project to clear the benchmark rate.

In contrast to the situation in China where standard government benchmarks are provided, most projects in India use internal, company-specific required rates of return as their IRR benchmarks. However, as in China, the CER value tends to provide a similar increase in expected return (e.g., an increase in IRR of two to three percentage points), just clearing the stated benchmark.

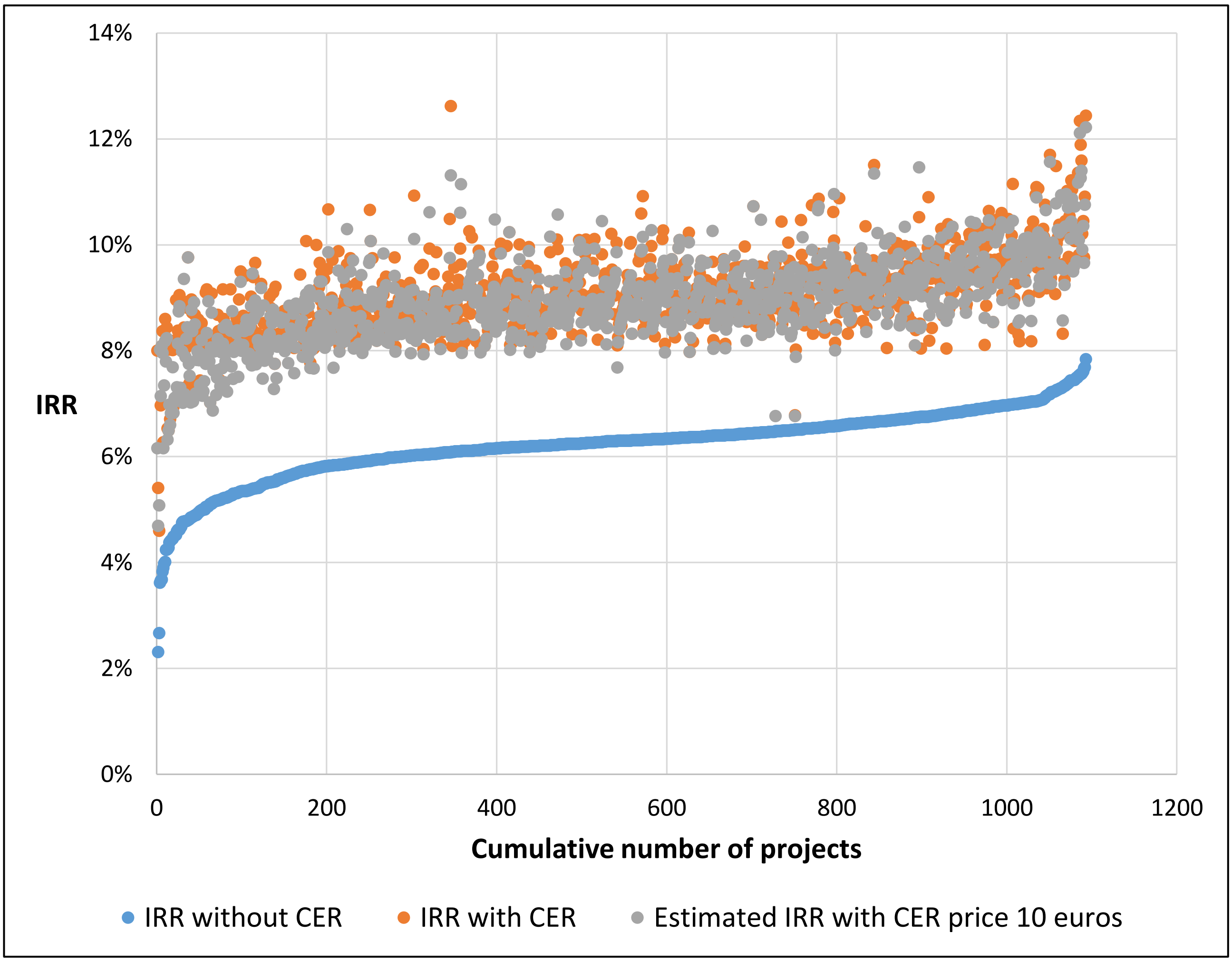
To demonstrate that projects just clear the benchmarks, project developers could select project input parameters so that the benchmark is achieved. These parameters could include CER price, load factor, electricity tariff, or a number of other inputs required in calculating an IRR.

One such parameter that could be adjusted is the expected CER price, which rose consistently through mid-2008, then fell precipitously, and for which forecasts have varied widely since, providing a potentially broad scope for selecting possible future CER prices.

Closer examination of selection of the CER price

To explore the potential effect of the CER price in more detail, Figure 3-4 adjusts the post-CER values stated in the PDDs (as displayed in Figure 3-3) to use a common CER value of €10 for all projects. (€10 is the median value used across all registered projects.) In this example, a large number of projects no longer meet the 8% benchmark. In particular, about 70 projects with pre-CER IRRs of 4% to 6% used CER prices as high as €17 in order to claim they would meet the 8% benchmark. Though this represents just a small share (about 1%) of wind power projects in China, it strongly suggests that input parameters (CER values) have been chosen to achieve the desired result of the 8% government-set IRR benchmark.

Figure 3-4: Estimated IRRs of Chinese wind projects using a benchmark of 8% before and after CER value of €10



Sources: IGES 2014, authors' own calculations

Similar to the situation for Chinese wind power projects discussed above, a number of Indian wind projects that claimed that CER values (median price assumed: €14) would lead them to exceed their benchmark would not have been able to claim that their benchmarks are met if they had used a lower, and more common, CER price of €10. This suggests that, as found in the case of wind power projects in China, project developers in some instances may select CER values that depart from values used by their peers in order to claim that CDM revenues will make the projects financially attractive.

A similar pattern emerges for hydropower projects in Vietnam, where benchmarks (averaging 13.1%) were derived either as the weighted average cost of capital (WACC) or a stated commercial lending rate.[16] Of the projects analyzed[17], over half of the hydro projects would not have met their benchmarks if they had used a CER price of €10 instead of higher prices (median price assumed: €15.5, and as high as €30, in contrast to the remainder of Vietnamese hydro projects with median price assumed of €10). As above, while this is not definitive evidence of gaming, it suggests that project developers tend to invoke higher CER prices than their peers when needed to claim that their projects become economically viable under the CDM.

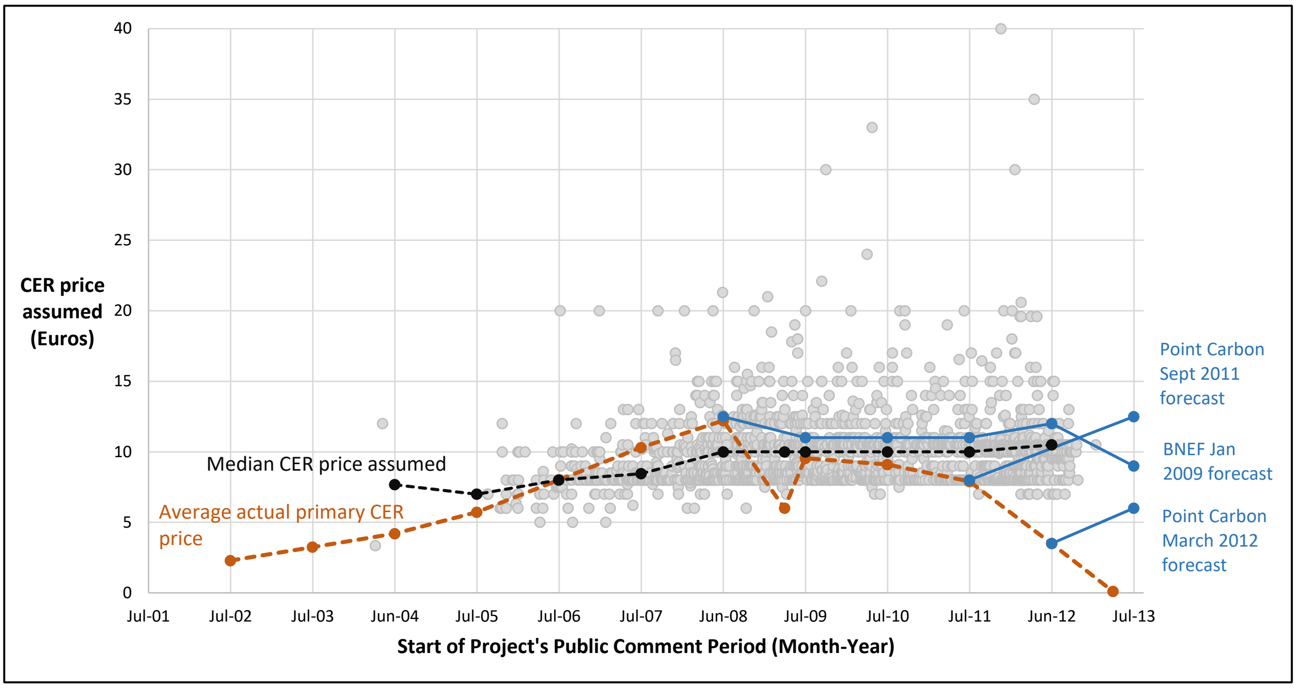
This raises the question of the plausibility of CER prices used by project developers. Looking at all registered projects (Figure 3-5), it appears that the CER prices used by project developers, though highly variable, tended to track then-current primary CER prices, through 2010, when CER prices began a steady decline. Project developers did not then use lower prices, but neither did industry analysts, who forecasted that higher prices would return.

These trends therefore display little evidence that project developers have systematically over- or under-estimated expected CER prices, at least as judged by the median (black line) values. However, the distribution of prices around that median displays a skew wherein a small fraction of projects use very high prices, perhaps because, as shown above, such high prices may be needed to demonstrate that these projects have met benchmarks.

[16] In Vietnam, the median IRR benchmark used by projects in Vietnam was 13.1%, and most benchmarks were derived either as the weighted average cost of capital (WACC) or a stated commercial lending rate. The default expected return on equity for power projects in Vietnam, per the CDM's *Guidelines on the Assessment of Investment Analysis*, is 12.75%; 60% of power projects in Vietnam use an IRR benchmark higher than this rate; 5% have an IRR without a CER value exceeding this.

[17] From the IGES investment analysis database, all hydro projects in Vietnam were selected that reported CER price assumptions in € as well as pre- and post-CER IRR values.

Figure 3-5: CER prices – assumed and estimated



Notes: CER prices assumed by project developers (grey dots) have been relatively consistent with industry forecasts made at the time (blue lines), even though they have been higher than market prices (orange line) since 2008.
Sources: IGES 2014, Point Carbon 2011, Point Carbon 2012

Sensitivity analysis: can it help address subjectivity?

The CDM addresses the subjectivity of input parameters, in part, through the use of sensitivity analysis required in investment analysis. As specified in the *Guidelines on the assessment of investment analysis,* "variables…that constitute more than 20% of either total project costs or total project revenues should be subjected to reasonable variation … and the results of this variation should be presented." However, the guidelines do not require that parameters be varied simultaneously, and few project developers do so. For example, in calculating project IRRs (in the PDDs), no project developer of the 30 randomly selected projects assessed the possibility that more than one of the key input variables could vary simultaneously. Furthermore, nearly all claim that even the standard variations of as much as 10% in the individual parameters are implausible, despite evidence (as presented here) that variation in the input values used is quite common. Accordingly, because the possibility that individual parameters could vary widely is discounted, and the possibility that multiple inputs could vary is not considered, the sensitivity analysis as currently applied is not sufficient to address the subjectivity in these parameters.

3.2.3. Summary of findings

Investment analysis is designed to determine whether a project would be uneconomical or less attractive than an alternative in the absence of the CDM. The premise is that if the project is not economical (most often as compared to a particular investment threshold), it would not have proceeded. From a strictly financial perspective, this may well be the case. However, researchers have pointed out that several types of projects in the CDM – especially large power projects that dominate the CDM pipeline – are pursued for reasons that extend beyond simple financial return, particularly in the largely non-market regulatory environments that are found in some of the largest CDM countries. This may be the most fundamental critique of investment analysis, and yet it is also the most analytically challenging to prove or disprove. Projects may proceed for a variety of factors – economic, strategic, and social – that defy attempts to attribute the viability, or failure, to any one factor. Complicated statistical tests have been proposed – and some statistical research has been attempted – but few compelling approaches have yet emerged.

This research has further explored the issues of information asymmetry, transparency, and subjectivity of input assumptions. Regarding information asymmetry, project developers have considerably more information about their own project than do those – likely including validators – that are charged with reviewing and assessing their additionality. Regarding transparency, this research finds that, since 2007, the transparency of both project design documents and validator assessments has increased markedly, such that the strong majority of projects now include detailed information on input assumptions that their investment analysis could be replicated.

In some cases, there is little reason to question the validity of these input assumptions, as they are based on contract documents (e.g. with equipment providers that would seem to reflect actual prices paid). In other cases, the input assumptions are highly subjective, as in estimates of future fuel prices (e.g. for biomass), electricity tariffs that may be adjusted, or CER prices. In particular, this research has identified dozens of cases in China, India, and Vietnam in which it appears that project developers have used CER prices higher (in some cases, much higher) than their peers in order to claim that the CDM would make their project exceed the chosen financial benchmark. This demonstrates how eager some project developers may be to select input values to give results that would give the appearance of additionality.

3.2.4. Recommendations for reform of CDM rules

As stated above, for an additionality test to function properly, it must be able to demonstrate with high confidence that the CDM was the deciding factor in project implementation. This analysis has demonstrated that the subjective nature of the investment analysis limits its ability to provide that confidence. It is possible that improvements could decrease this subjectivity, such as by applying more complicated tests to assess the true motivations and financial performance of the project. Still, doubts may remain, especially for project types for which the financial impact of CERs is insufficiently large relative to variations in other potential inputs to provide a strong 'signal-to-noise' ratio, such as for large power projects. CDM administrators may therefore want to consider whether certain project types, if they cannot be confidently deemed additional by other tests (e.g. barrier analysis, common practice analysis, as in the next sections of this report), might be phased out of the CDM. If the investment analysis continues to be applied, we recommend further improving the guidance to reduce subjectivity. CDM rules could also require formal declarations by the project participants that information is true and accurate. Such declarations may discourage project participants from providing false information, as a violation of such a declaration may have consequences under national legislation. An even stronger form could be a declaration in lieu of an oath.

3.3. First of its kind and common practice analysis

3.3.1. Overview

The CDM uses two approaches to assess additionality based on the market penetration of technologies: the first-of-its-kind approach and the common practice analysis. Under the first-of-its-kind approach, a project is deemed automatically additional if certain conditions apply. The common practice analysis often complements the investment or barrier analysis. It requires an assessment of the extent to which the proposed project type (e.g. technology or practice) has already diffused in the relevant sector and region. It is a credibility check to demonstrate that a project is not common practice in the region or country in which it is implemented. The common practice analysis can also be used to demonstrate that the baseline technology or practice is frequently implemented and is hence a realistic scenario. The common practice analysis is only relevant for large-scale projects. Small-scale projects are entitled to use simplified modalities and procedures for small-scale CDM project activities, which do not require common practice analysis.

The first-of-its-kind approach was initially applied as part of the barrier analysis; it was sometimes also referred to as the barrier of lack of 'prevailing practice'. In 2011, the EB adopted guidelines specifying how first-of-its-kind should be demonstrated. The guidelines were further revised in 2012 and reclassified as a tool in 2015.[18] Showing that a project is the first-of-its-kind is the first step in the additionality tool and combined tool, which stipulate that if a project is the first-of-its-kind, it is considered additional. The steps to be followed for demonstrating first-of-its-kind are further specified in the corresponding guidelines and, since 2015, the methodological tool. According to version 03.0 of the tool, a project activity is "first of its kind in the applicable geographical area" if

- "the project is the first in the applicable geographical area that applies a technology that is different from technologies that are implemented by any other project" with the same output and that "have started commercial operation in the applicable geographical area before" the PDD "is published for global stakeholder consultation or before the start date of the proposed project activity, whichever is earlier", if
- "the project implements one or more of the measures" and
- "the project participants selected a crediting period for the project activity that is "a maximum of 10 years with no option of renewal".

The common practice test was first introduced in the additionality tool in 2004 to complement the investment and barrier analyzes, as a safeguard to ensure the environmental integrity of the CDM. In a first step, other previous or current projects which are similar to the project activity were analyzed. Projects were considered similar "if they are in the same country/region and/or rely on a broadly similar technology, are of a similar scale, and take place in a comparable environment with respect to regulatory framework, investment climate, access to technology, access to financing, etc." Other CDM projects were excluded from this analysis. In case similar activities were identified, it was necessary to justify why these exist, while the project activity is considered to be financially unattractive or as facing barriers. 'Essential distinctions' had to be identified which may for instance be due to the fact that new barriers have arisen or promotional policies have ended.

For both the first-of-its-kind approach and the common practice analysis, the key issues are defining what is regarded as a comparable technology, what the appropriate geographical scale is and what threshold should be used for a technology to be regarded as first-of-its-kind or common practice. Critics pointed out that no clear definitions of when a project activity should be regarded as common practice were given in the early versions of the additionality tool (Schneider 2009). Another criticism was that the common practice test allows project developers to claim that a frequently implemented project type is not deemed common practice if they can justify 'essential distinctions' from other projects. Yet the key terms 'similar' and 'essentially distinct' were defined so vaguely that any project could be argued to be not common practice, simply by defining 'similar' very narrowly or 'distinct' very broadly (Schneider 2009; Spalding-Fecher et al. 2012).

The requirements for the common practice analysis in the additionality tool remained largely unchanged until September 2011 when the "Guidelines on Common Practice" were introduced, incorporating elements from the additionality tool and providing additional guidance[19]. In parallel to the revision of the "Guidelines on first-of-its-kind", the "Guidelines on Common Practice" were further revised in 2012 and reclassified as a tool in 2015.

[18] Methodological tool. Additionality of first-of-its-kind project activities (version 03.0).
[19] The new requirements of the Guidelines on Common Practice were then also incorporated in the additionality tool in the same year.

Both guidelines or tools are applicable to four GHG reduction activities, namely, "fuel and feedstock switch, switch of technology with or without change of energy source (including energy efficiency improvement), methane destruction" and "methane formation avoidance"[20]. Both also use similar approaches for defining similar or different technologies and the appropriate geographical area.

In the 2011 version of the common practice guidelines, the first step was to calculate the applicable output range as +/-50% of the capacity of the project activity. In the next step, all existing plants in the geographical area within this capacity range needed to be identified (with the exception of registered CDM projects). The default applicable geographical area was the entire host country. If the technology was not country-specific, the geographical area should be extended to other countries. If projects differ significantly between locations, the geographical area could also be smaller than the host country. In the next step, among the identified projects, those with different technologies from the project activity were identified. A technology was considered different if it has a different energy source/fuel, feedstock, installation size (micro, small, large), investment climate at the time of the investment decision[21] or other features.[22] Eventually, if the share of plants using similar technology as in the project activity in all plants with the same capacity as the project activity is greater than 20% and if the absolute number of projects using a similar technology is larger than three, then the project activity is considered common practice.

In revising the Guidelines on Common Practice in September 2012, the rules and definitions were further clarified. It is now mandatory to provide a justification for using a geographical area smaller than the entire host country (e.g. province, region). The reference to extending the geographical area was removed from the guidelines. The exclusion of CDM activities was broadened to include registered projects, those requesting registration and those at validation. Furthermore, several definitions and the step-wise approach were better explained (without change in substance). Minor changes to the common practice analysis were made in subsequent versions of the additionality tool.

The definition of different technologies in the first-of-its-kind approach corresponds to the common practice analysis, with the exception that investment climate at the time of the investment decision and other features are not included.

3.3.2. Assessment

The general strength of using market penetration approaches for assessing additionality is that they do not assess the motivation or intent of project developers, but provide a more objective approach to evaluating additionality, based on the extent to which the project activity is already being implemented in the host country or region (Schneider 2009).

The initial criticism of the lack of clear definitions of similar projects and essential distinctions for common practice was addressed by the introduction and further refinement of the common practice guidelines, which clearly outline steps to follow and provide a definition of terms for a common understanding between project developers. Especially, the introduction of a threshold for common practice (20% and at least three similar projects) constitutes a significant improvement since it requires a quantitative assessment against a clear threshold. Clarity about the rules related to common practice analysis has therefore improved considerably over time. Also, from the sampled projects, it can be concluded that the introduction of the common practice guidelines has generally led to more detailed and better structured PDDs.

[20] For other types of GHG reduction activities, the more general rules of the additionality tool continue to apply.
[21] "Inter alia, access to technology, subsidies or other financial flows, promotional policies, legal regulations."
[22] Such as a difference in unit cost of output by at least 20%.

However, several unresolved issues still exist. In the following, different aspects of the common practice analysis and the first-of-its-kind approach are discussed and assessed. The assessment is based on an analysis of the common practice provisions and on the findings of an empirical evaluation of 30 representatively selected projects (i.e. the review of PDDs and validation reports) (Section 2.2).[23]

When defining similar projects in the common practice tool, the applicable output range is defined as “+/-50% of the design output or capacity of the proposed project activity”. This definition does not always reflect the scales of a technology, between which meaningful technological differences occur. For instance, in the case of a power plant with a size of 400 MW, power plants between 200 MW and 600 MW would need to be considered in the analysis. However, there may be smaller (e.g. 100 MW) or larger (e.g. 800 MW) power plants which still feature similar technical, economic characteristics (e.g. efficiency), a similar regulatory environment, or which are used in a similar manner (e.g. provision of electricity to the public grid). At the same time, a small power plant (e.g. 5 MW), may be significantly different in terms of technology or use. Also, when several plants are grouped to form a project (e.g. wind farm consisting of several wind generators), an output of +/-50% may be misleading. For instance, for a wind farm with 20 wind generators of 1 MW capacity, the output range would be 10 to 30 MW. However, a smaller wind farm with only 10 wind generators of 1 MW capacity has similar characteristics since the wind generator is identical. For wind power, the test may provide more meaningful results if there was no scale at all since wind parks are usually composed of different wind generators of the same size. However, small internal combustion engines may well differ, from a technological perspective, from a large combined cycle power plant. In conclusion, the definition in the common practice guidelines (+/- 50%) does not allow for a meaningful classification of scale for different technology types. This definition can therefore be considered arbitrary and may lead to the erroneous exclusion of similar plants from the analysis. In contrast to the common practice tool, the first-of-its-kind tool does not use an output range to define similar technologies. This approach seems more appropriate.

When identifying similar projects, the common practice tool excludes CDM projects (registered, submitted for registration or undergoing validation) from the analysis. In the empirical analysis, of the 30 sampled projects, only three identified similar non-CDM projects. All other projects only identified projects under the CDM. A commonly used rationale (i.e. used by 9 of the 30 projects) is that, because all other comparable facilities are either CDM projects or are awaiting registration as CDM projects, the proposed project would also be non-viable without the CDM (i.e. not common practice). However, it could be argued that the general viability of projects is assessed as part of the barriers and/or investment analyzes and should therefore not be used as a pre-emptive argument for excluding CDM projects from the common practice analysis. The exclusion of CDM projects from the common practice analysis is particularly problematic if most or all new facilities in a sector use the CDM. For example, if all new wind power plants in a country register under the CDM, wind power could never become common practice, even if it reached a market share of more than 50% and was highly economically attractive. In contrast to the common practice tool, the first-of-its-kind tool does not have provisions to exclude CDM projects, which suggests that all existing projects, including CDM projects, are considered.

[23] Of the 30 projects sampled for the evaluation of the common practice analysis, the majority stem from China (20 projects), followed by India (3), Egypt (2), Pakistan (2), Brazil (1), Nicaragua (1) and Israel (1). Ten projects were registered before 2010, eight in the 2010-2011 period and twelve after 2011. Technology types in the sample are wind power (17 projects), hydropower (5), industrial projects such as coal mine methane utilisation or waste heat recovery (3), waste projects such as landfill gas capture (4) and other renewable energies such as biomass (1). Most projects (28 of 30) are classified as large-scale. Although the sampled two small-scale projects are not required to conduct a common practice analysis, some information on common practice was given in the corresponding PDDs.

The common practice tool and the first-of-its-kind tool use the same definition of the geographical area, which should be the entire host country, unless justification can be provided for a smaller geographical area. In the common practice analysis sample, 24 of 30 projects limited the applicable geographical area to a specific area smaller than the host country (such as province, region, state, municipality, etc.). All sampled wind projects from China (11)[24] and from India (3) selected an area smaller than the host country as the applicable geographical area. The most commonly used justification in the corresponding PDDs for limiting the geographical area is that investment conditions, especially in terms of electricity tariffs, available resources and labour costs, differ from province to province, making provincial/state level comparison necessary.

At first sight, this appears to be plausible since China and India are large countries with regions/states being important players in infrastructure development. Notwithstanding this, the size of the country and the political structure may not be sufficient to justify the choice of the regional/state level. In China, a nationwide feed-in tariff for wind power generation was introduced in 2009, establishing four different tariff categories, ranging from 0.51 CNY/kWh (0.08 USD/kWh) to 0.61 CNY/kWh (0.10 USD/kWh), depending on the region's wind resources (International Renewable Energy Agency 2012). For projects in India, the Electricity Act of 2003 and the resulting new tariff regulations were cited as the cause of different investment climates in various states. In fact, for wind power, the tariff varies based on local wind resources. Four bands of wind power density in W/m^2 determine the level of the feed-in tariff (International Energy Agency 2012). This means that the feed-in tariff may differ even between project locations in the same province if these feature different wind conditions. Therefore, the fact that there are different feed-in tariffs between provinces alone does not explain fundamentally different investment conditions in the different regions, as claimed in many PDDs, but rather only accounts for locally different wind resources, while the general support scheme is national[25]. Based on these considerations, the rationale used by many projects for limiting the geographical area to a level below the entire country seems questionable. It can also be problematic to consider only the host country as the geographical area. If no or only a very few plants providing the same service exist in the host country, market penetration approaches do not give reasonable results. For example, the first aluminium plant in a country would always automatically be deemed additional, even if it used a technology that is clearly business-as-usual.

While the introduction of the common practice guidelines aimed to address the criticism of a vague definition of what constitutes 'different' technologies, several concerns remain. The possibility of defining a technology "as being different if there is a difference with regard to energy source/fuel, feed stock, installation size (micro, small, large), investment climate at the time of the investment decision (including, "inter alia, access to technology, subsidies or other financial flows, promotional policies, legal regulations") or other features (such as difference in unit cost of output by at least 20%)" still allows for significant possibilities to claim that rather similar projects are very different. This allows for the project to be defined rather narrowly and other plants very broadly, so that the threshold of 20% is not reached. With regard to the installation size, the same issue as for the output range (above) applies. Also, the criterion 'energy source/fuel' may be misleading. For instance, if a country has been using light fuel oil as a basis for its power plants, a switch to natural gas constitutes a different fuel, but does not explain a significant difference since the same generation technology can be used for both fuels. The same holds true for different solid fuels. Finally, 'other features' is a very broad term allowing for arbitrary interpretations. For example, a difference in unit cost of output does not constitute a plausible difference per se[26]. For instance, higher unit costs

[24] Also all other Chinese (non-wind) projects included in the sample use a sub-national geographical area with a similar rationale as that for wind projects.
[25] A differentiation of the feed-in tariff depending on local wind resources is common practice in other countries as well.
[26] Two sampled hydro projects used this rationale.

may be required for technical or other reasons and may be compensated for by higher yields[27]. Also, according to this interpretation, a proposed CDM project with *lower* unit costs would be considered different from projects already implemented without CDM, even though it is more profitable than other projects. Although in some cases, 'differences' may be well justified (e.g. by explaining that the investment climate was significantly different due to a change from a state-controlled to a more private investment-oriented power market), overall, the review of arguments presented in the sampled PDDs indicate that the term 'different' allows for significant room for interpretation.

The threshold of 20% market diffusion in the common practice tool cannot be considered robust if applied to all technologies and sectors. The stringency of the 20% is highly dependent on the number of technologies in a sector. In a sector with only two technologies, both available technologies could easily exceed the threshold, whereas none of the technologies may ever reach the 20% threshold in sectors with many different technologies. For instance, in a country with several fuels and technologies available for power generation (e.g. natural gas, coal, wind, hydro, biomass, PV), a low market diffusion may still constitute common practice due to the abundance of options and due to the (potentially) limited potential of some technologies. For instance, hydro electricity generation may constitute only 5% of overall electricity generation. Nevertheless, hydropower could still be considered common practice due to the fact that hydro resources are limited and most of the resources have already been exploited. In contrast, in a sector in which there are only a few technologies (e.g. for a certain industrial process) a market diffusion of 20% may constitute a reasonable value for determining common practice. Also, even though a technology may not be considered common practice considering all existing plants in a sector (i.e. considering the market saturation), it may be common practice considering the recent trend (i.e. considering the market share in a certain year)[28]. For instance, electricity generation from wind may constitute only a small share of the overall electricity generation in a country (e.g. 1%). However, capacity additions in recent years may constitute a significant share of overall new capacity built. In the former case, wind power would not be considered common practice, whereas in the latter, trend-oriented, perspective wind power would constitute common practice. This issue is especially relevant in the case of long-lived capital stock such as in the power sector (Kartha et al. 2005). Similarly, the provision that at least three plants with a similar technology must have been constructed to consider a project common practice may not be appropriate in all situations. For example, if only four plants exist in a country and three use the same technology, thus constituting a market share of 75%, the construction of a fifth plant with the same technology would still not be regarded as common practice. In conclusion, a one-fits-all value as threshold for market diffusion cannot be considered appropriate.

With regard to the quality of evidence used for the demonstration that a project is not common practice, almost all PDDs provided anecdotal evidence to support their claims. Commonly made statements are that there is no evidence to suggest that a similar project has been, is being or will be implemented in this area and that all other projects use CDM financing as well. To support these claims, publicly available external documents such as energy statistics were used in the majority of projects (20 of 30 projects). Yet, these public documents do not provide information about different investment climates in terms of labour costs, available resources and feed-in tariffs.

As regards the validation of common practice, in 21 of 30 sampled projects, the DOE reviewed documents such as the World Bank website or energy statistics. Other means of validation were conducting interviews with stakeholders such as personnel with knowledge of the project design and implementation, local residents and officials.[29] However, the DOEs did not evaluate claims

[27] E.g. higher units costs may be required for certain equipment for small hydro in a mountainous area, which may be compensated for by higher yields due to a higher head of water.

[28] See Kartha/Lazarus/LeFranc (2005) for a definition of market saturation vs. market share.

[29] There is no further information available in the PDDs on the content of the interviews with the stakeholders.

made in the PDDs about different investment climates. In nine cases, the DOE in its validation report just repeated the claims made by the PDD.

3.3.3. Summary of findings

Overall, clarity about the rules related to first-of-its-kind and common practice analysis have improved considerably over time. In addition, from the sampled projects it can be concluded that the introduction of the common practice guidelines has generally led to more detailed and better structured PDDs. However, several flaws remain:

- The definition of the output range in the common practice tool is arbitrary and not linked to actual differences in scale of technologies or use.
- The exclusion of CDM projects from the analysis is questionable in a market situation in which most projects are implemented as CDM projects and significant technological changes and cost reductions occur.
- The rationale for limiting the geographical area to a level below the entire country is questionable. In some instances, limiting the geographical area to the host country can be problematic.
- The definition of a project as ‘different’ in the current common practice guidelines is still too vague and corresponding rules still leave significant room for interpretation.
- The share of 20% market diffusion and absolute number of three similar projects, across all sectors, cannot be considered robust since the appropriateness of these values depends on the number of available technologies in the sector. Additionally, the result of the common practice analysis is highly sensitive to whether all plants of a sector are considered or whether the recent trend (new plants built) is considered. This is especially relevant for sectors with long-lived capital stock.
- Generally, evidence used for the common practice analysis was not adequate in the sampled projects since relevant information for the determination of common practice (e.g. on different investment climates, available resources or feed-in tariffs) was not provided in the PDDs. Also, the validation by DOEs was not adequate in the sampled projects since claims on investment climates were not evaluated and since in several cases the DOE only repeated the claims made by the project participants.

3.3.4. Recommendations for reform of CDM rules

In general, the first-of-its-kind approach and the common practice analysis can be considered more objective approaches than the barrier or investment analysis due to the fact that information on the sector as a whole is taken into account rather than specific information of a project only. It reduces the information asymmetry inherent in the investment and barrier analysis. In this regard, expanding the use of market penetration approaches could be a reasonable approach to assessing additionality more objectively. However, the presented analysis shows that the way in which first-of-its-kind and common practice are currently assessed needs to be reformed in order to provide a reasonable means of demonstrating additionality. In the following, several recommendations are made for the reform of the current rules.

We identified several issues with the approach of using the same generic approach in the context of rather different sectors or project types. We therefore recommend abandoning this ‘one-size-fits-all’ approach and introducing specific approaches for specific project types, which adequately reflect the circumstances of the sector, in particular with regard to the definition of what is considered a different technology and the threshold used to define common practice. A practical means of implementing this is including specific guidance in each methodology.

- Due to the inherently vague concept of ‘different’ technologies, it is recommended that the common practice rules are revised in such a way that methodologies or overarching guidance provide clearer guidance on how to support the claim of a ‘different’ technology including the evidence required (including evidence to demonstrate credible differences in the investment climate). Corresponding provisions in the VVS should also be amended in such a way to provide more specific guidance on how DOEs should assess the claim of ‘essential distinctions’ for different projects types. With regard to the above-mentioned arbitrary definition of the applicable output range, it is recommended that the common practice guidelines are revised in such a way to provide general guidance on how meaningful differences according to scale can be identified for different technologies. More specific guidance on how to define a range of capacity/output should then be defined in the corresponding methodology. In the absence of any definition of capacity/output range in the methodologies, the whole spectrum of plants or activities (from very small to very large) should be covered by the analysis.

- With regard to the exclusion of CDM projects from the common practice analysis, the rules should be amended in such a way that all CDM projects are to be included in the analysis as a general rule, unless specified otherwise by the methodology. Methodologies could specify that CDM projects are excluded to a certain extent and then gradually introduce them in the analysis. This is especially relevant if all projects of a certain technology use the CDM. As Schneider (2009) points out “other CDM projects could be included in the common practice analysis after a certain period or after a specific number of CDM projects have been implemented”. Another criterion for inclusion of CDM could be their market penetration. (International Rivers 2011) suggest that “after 3 years of full operation, a CDM project should be included in the common practice analysis”. Furthermore, a “list of project types that are not eligible for the CDM because they are common practice” (ibid.) (negative list) could also be helpful in this regard.

- Due to our finding that the selection of an area below the host country level as the applicable geographical area is a questionable assumption, it is recommended that the rules be revised to define the appropriate geographical area in the context of the specific circumstances, such as the number of projects or installations in the host country. A level below the host country level should not be used.

- The threshold for common practice should be defined depending on the type of technology and sector. Corresponding guidance should be provided in the methodologies. In sectors with long-lived capital stock (e.g. power sector), the common practice analysis could consider two different perspectives: a) common practice in the sector (e.g. power sector) as a whole (market saturation) and b) common practice in more recent investments (market share) (i.e. similar to the operating and build margin approach for projects displacing electricity). If common practice is established according to at least one of these perspectives, the project should be considered common practice. Since data availability for determining market diffusion may not be sufficient in each country and in order to ensure consistency in determining market diffusion, efforts (e.g. multilateral) for collecting this data and for providing this information to project developers could be helpful. Several global datasets already exist (e.g. UNEP DTU 2014, statistics by the World Bank, sectoral statistics, Platts database on power plants or cement statistics by Cembureau), which could be used to estimate market diffusion in different countries in a consistent manner. An extensive discussion of the usefulness of market penetration for establishing common practice for certain projects types is included in (Kartha et al. 2005).

Due to the fact that several DOEs repeated the claims made by the project participants without documenting the way in which they actually assessed the appropriateness of the claims, we recommend strengthening efforts to ensure that all DOEs effectively comply with the reporting requirements related to the common practice analysis outlined in the VVS. For this purpose, no change in rules has to be applied, but the accreditation system may need to be strengthened to ensure compliance of all DOEs with applicable CDM requirements.

Another option for improving the analysis of common practice is to consider the overall potential available in a country. For instance, a small share of hydro in overall electricity generation may, on the one hand, be due to barriers, risks or economic unfeasibility of hydro construction (hydro electricity generation would therefore not be common practice). On the other hand, the small share of electricity generation from hydro may be due to the very limited hydro potential in the country. Most of the (small) potential may already have been exploited. Any additional hydro capacity could then be considered common practice since it has been exploited before. However, this approach would bring about the problem of defining ways to establish the potential (e.g. technical vs. economic potential, etc.), and the practicalities and transaction costs of evaluating this for many different technologies.

Furthermore, the common practice analysis could "be the first step in the additionality tool rather than the last" (International Rivers 2011). This way, instead of using often vague arguments for establishing common practice *after* the investment analysis, project developers would need to discuss common practice explicitly at the beginning of the analysis.

3.4. Barrier analysis

3.4.1. Overview

Historically, barrier analysis has been used as an important alternative or complement to the investment analysis analyzed above in Section 3.2. The barrier analysis is used to demonstrate that a project faces barriers that impede the project's implementation in the absence of the incentives from the CDM. It is applicable to both small- and large-scale CDM projects:

Small-scale projects

According to Attachment A to Appendix B to Annex II of 4/CMP.1 the following barriers may be considered for small-scale projects:

- **Investment barrier**: a financially more viable alternative to the project activity would have led to higher emissions; this includes "the application of investment comparison analysis using a relevant financial indicator, application of a benchmark analysis or a simple cost analysis".[30] In essence, this barrier allows an investment analysis to be conducted, as described in Section 3.2, but without providing any guidance on how the investment analysis should be conducted. In practice, however, it appears that guidance for investment analysis for large-scale projects (e.g. justification of benchmark IRR or sensitivity analysis) is, in most cases, also applied to small-scale projects.
- **Access-to-finance barrier**: the project activity could not access appropriate capital without consideration of the CDM revenues;

[30] See "Non-binding best practice examples to demonstrate additionality for small-scale projects" (EB 35, Annex 34).

- **Technological barrier**: a less technologically advanced alternative to the project activity involves lower risks due to the performance uncertainty or low market share of the new technology adopted for the project activity and so would have led to higher emissions;
- Barrier due to **prevailing practice**: prevailing practice or existing regulatory or policy requirements would have led to implementation of a technology with higher emissions;
- **Other barriers** such as institutional barriers or limited information, managerial resources, organisational capacity, or capacity to absorb new technologies.

Large-scale projects

In large-scale projects, the barrier analysis is part of the additionality tool and the combined tool. It is applied in two steps:

1. Identify barriers that would prevent the implementation of the proposed CDM project activity. Here, the eligible barriers are similar to the barriers relevant for small-scale projects, with the following differences:
   - The ‘investment barrier’ of the small-scale guidance is, in the large-scale guidance, referred to as ‘investment analysis’ (Section 3.2); a separate option for demonstrating additionality besides ‘barrier analysis’;
   - The ‘access-to-finance barriers’ of the small-scale guidance is called ‘investment barriers’ in the large-scale guidance; and
   - ‘prevailing practice’ of the small-scale guidance is, in the large-scale guidance, usually a mandatory additional step termed ‘common practice analysis’ that is required but is not sufficient in itself to prove additionality.
2. Show that the identified barriers would not prevent the implementation of at least one of the alternatives (except the proposed project activity).

Another important requirement of the two tools is the following: “If the CDM does not alleviate the identified barriers that prevent the proposed project activity from occurring, then the project activity is not additional.”

If these steps are satisfied, the project is potentially additional (pending passing of the common practice analysis).

In late 2009 (EB50), the CDM EB adopted the “Guidelines for objective demonstration and assessment of barriers” with a view to improving the objectivity of the barrier analysis. The document provides guidance on the objective demonstration of different types of barriers. For instance, it requires that “barriers that can be mitigated by additional financial means can be quantified and represented as costs and should not be identified as a barrier for implementation of project while conducting the barrier analysis, but rather should be considered in the framework of investment analysis” (Guideline 4 in EB50 A13).

In addition, methodologies may – instead of using one of the tools – provide their own combination of steps from the tools.

3.4.2. Assessment

The concept of barriers preventing investments and mitigation activities is an important element of the research and discussion on technology diffusion and low carbon pathways. From this, it seems reasonable that the additionality test could also take barriers into account and not only be based on investment analysis. However, the barrier analysis faces multiple challenges in practice that strongly limit its usefulness in the context of the CDM.

Objectivity in barrier analysis

In earlier phases of the CDM, the claim for barriers preventing the implementation of projects was often based on anecdotal evidence, and it was very difficult to provide objective proof of why a barrier is sufficient to "prevent the implementation" (Schneider 2009). In practice, the concept of barriers per se as proof for additionality is problematic, as all investment projects in all countries faces some sort of barriers to its implementation, be they financial, technical or other. In earlier CDM projects, it was sufficient for PDD consultants to state barriers without providing objective and verifiable evidence that they actually *prevent* the implementation of the project. This led to some market participants claiming that with good PDD consultants you could have any project registered based on barriers.

Guidance on objective barriers

In late 2009 (EB50), these problems with barrier analysis led to the adoption of the "Guidelines for objective demonstration and assessment of barriers" by the CDM EB (Section 3.4.1). With their requirement to monetize barriers, the guidelines aim to assess the role of barriers in preventing the implementation of projects in a more transparent way. The monetization of barriers and their inclusion in the investment analysis provide a framework that allows an objective balancing of higher barriers and associated costs with the need for higher revenues. This may be one of the reasons why investment analysis (with or without monetized barriers) has largely replaced the use of the barrier analysis without application of investment analysis in demonstrating additionality (see below).

How much alleviation is necessary to overcome a barrier?

Another weakness of the barrier analysis lies in the application of the requirement to demonstrate that the CDM "alleviates the identified barriers that prevent the proposed project activity from occurring". The fulfilment of this requirement was not often (explicitly) provided in PDDs nor checked by DOEs. Moreover, the tools do not require that the degree of 'alleviation' should be at least comparable to the strengths of the barrier under consideration. To demonstrate the viability of the project with the CDM, one would need to make the case as to why, for example, €x of CER revenues are sufficient to alleviate the risk of damage to a wind farm due to severe sand storms.

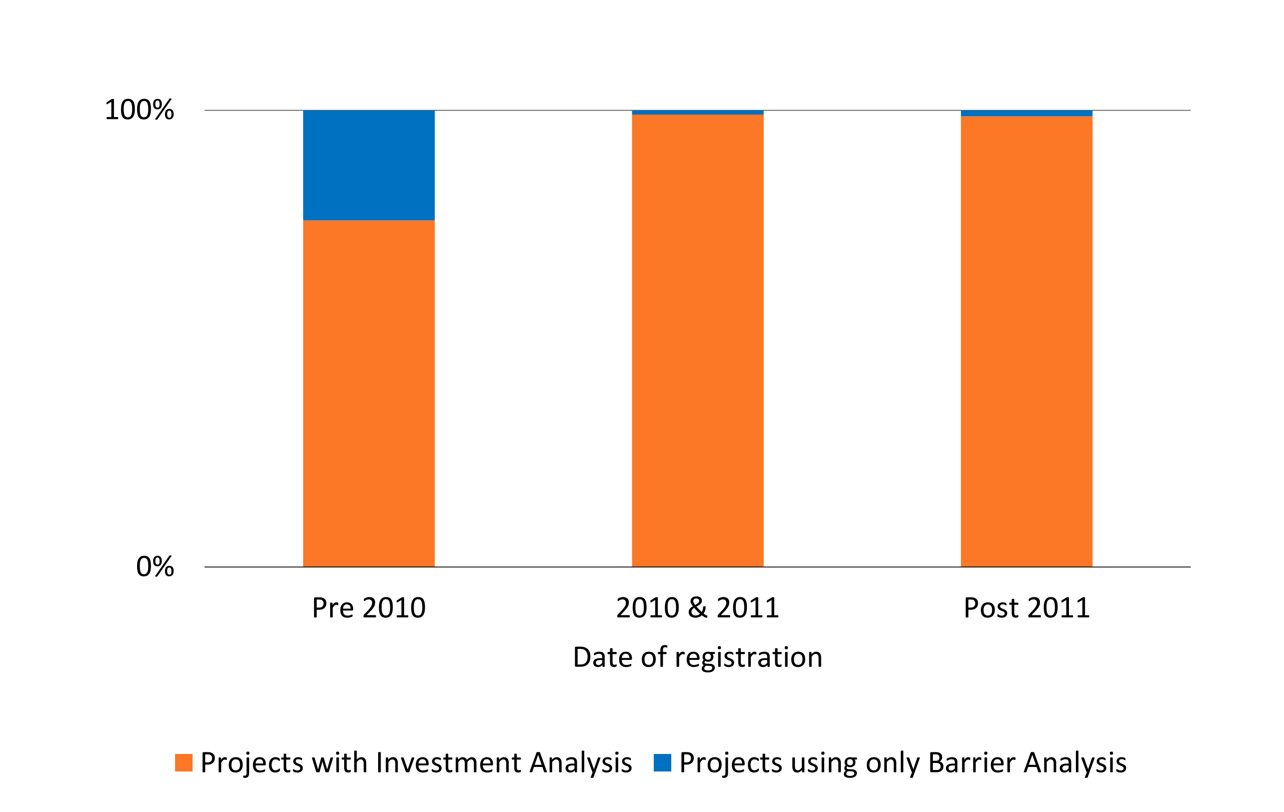
Also with regard to this requirement, the Guidelines provide greater specificity: "Demonstrate in an objective way how the CDM alleviates each of the identified barriers to a level that the project is not prevented anymore from occurring by any of the barriers" (Guideline 2 in EB50 A13).

The vanishing role of barrier analysis in the CDM

The role of barrier analysis in demonstrating additionality in the CDM has been dramatically reduced from 2010 onwards (Figure 3-6). While in the period before 2010 approx. 24% of registered projects used the barrier analysis *without applying an investment analysis in parallel*, this share was reduced to approx. 1-2% of registered projects from 2010 onwards. Since then, the barrier analysis plays a certain role in reinforcing the additionality argument made in the investment analysis, but has largely lost its role as the main approach for demonstrating additionality.

This development might be explained by the introduction of the guidelines for objective demonstration and assessment of barriers.

Figure 3-6: Share of projects using the barrier analysis without applying the investment analysis in total projects



Notes: Own research based on a representative sample of PDDs from 30 stratified and randomly sampled projects that were labelled Investment Analysis option 'none' by the IGES (2014) database revealed that a certain percentage of these PDDs used an approach that in essence follows the Investment Analysis approach of the additionality tool, but was labelled 'Barrier Analysis'. The confusion in terminology was most prominent in small-scale project PDDs, which have the option to demonstrate 'financial barriers' which includes and is often an Investment Analysis. In the representative sample, the fraction of PDDs using actually an Investment Analysis while being labelled Investment Analysis option 'none' by IGES was 36.4% pre 2010 and 90% afterwards. The share of projects using Investment Analysis from the IGES database has, therefore, been increased by these shares from the sample analysis. Without this correction, the share of projects without investment analysis in the IGES database are 38%, 10% and 14%, respectively, for the three considered time periods of registration.

Sources: IGES 2014, authors' own PDD research

With the adoption of the guidelines, the barrier analysis has largely lost its role as the main argument for demonstrating additionality. After 2010, non-financial barriers are quoted in some projects, but merely as additional information to reinforce the main case for additionality, which tends to be based almost uniformly on investment analysis. Potentially, this development may have been supported by an improved performance of DOEs in validating barrier analysis in PDDs, due to an improved accreditation system.

3.4.3. Summary of findings

In early CDM projects, the routine use of anecdotal and often subjective evidence for claiming barriers has led to the registration of projects with questionable claims for additionality, which cannot be objectively assessed by DOEs. With the adoption of the Guidelines and possibly the improved performance of DOEs, the barrier analysis has largely lost its role as the main line of argument for demonstrating additionality. Rather, barriers are monetized and reflected in the investment analysis.

In the CDM, barrier analysis has lost importance as a stand-alone approach to demonstrating additionality because of the subjectivity of the approach. With the guideline, if barriers are claimed, they are monetized and integrated as costs in the investment analysis.

3.4.4. Recommendations for reform of CDM rules

Non-financial barriers can be important factors preventing the implementation of projects even though they may be profitable. Therefore, considering barriers in approaches for additionality determination is a valid approach.

However, the objective demonstration of barriers (as required in the Guidance) has turned out to be very difficult to operationalise without the reflection and monetization in an investment analysis.

Given the de facto non-application of the barrier analysis without investment analysis approaches in the current CDM practice, we recommend removing the barrier analysis from the additionality and combined tools. In return, key aspects of the Guideline related to the monetization of barriers[31] may be included in the investment analysis step in the additionality and combined tools.

In order to demonstrate additionality of projects with high (non-financial) barriers that may not be monetized, a comprehensive 'common practice' analysis or in small-scale projects 'prevailing practice' analysis shall be carried out (Section 3.3). Here, objective data on market shares of technologies/project types may be collected that may serve as objective proxy information for the extent to which barriers actually prevent the implementation of projects.

On another note, the approval of "Guideline on objective demonstration and assessment of barriers" by the CDM EB may be seen as a positive example of how the CDM regulator, under the right conditions, can react to an obvious flaw in the rules and practice, and rectify the system.

3.5. Crediting period and their renewal

3.5.1. Overview

Project participants can choose between one crediting period of 10 years without renewal or a crediting period of seven years for their project, which is due for renewal every 7 years for a maximum of two renewals (a total of 21 years for normal CDM projects). (For afforestation and reforestation projects, the choice is between one period of 30 years and three periods of 20 years). The Marrakesh Accords state that for each renewal, a designated operational entity shall determine that "the original project baseline is still valid or has been updated taking account of new data where applicable".

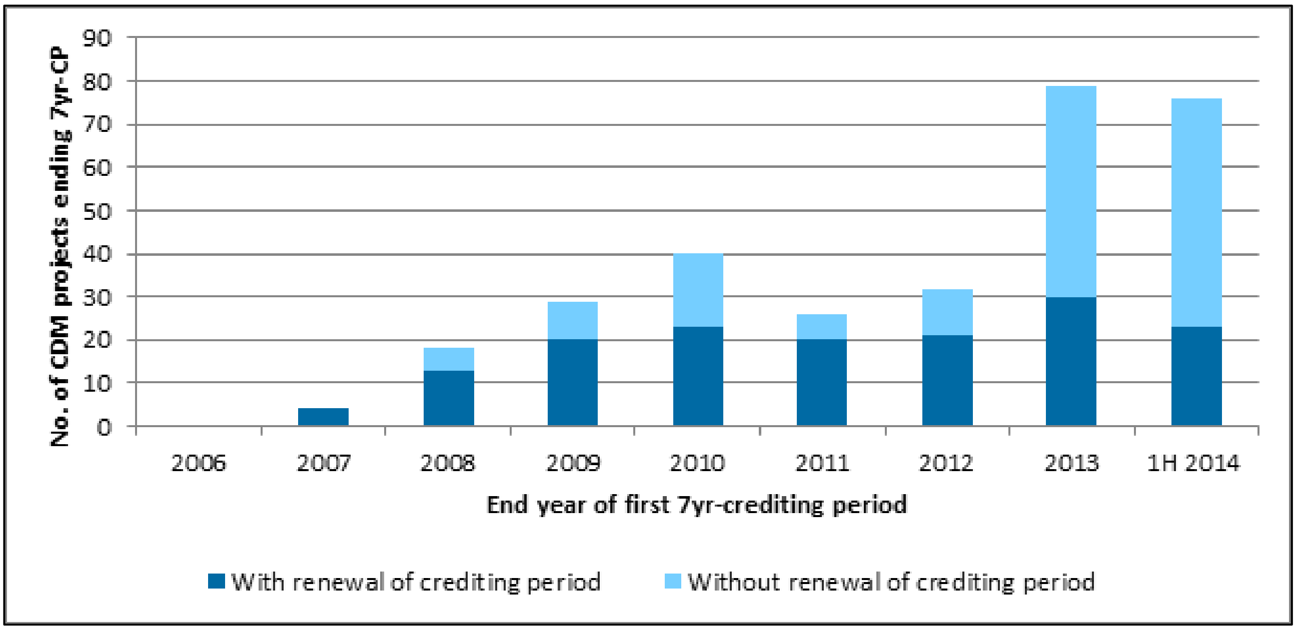
Requirements regarding the renewal of the crediting period were initially adopted in 2006 (EB28, Annex 40), subsequently revised several times (EB33, EB36, EB43, EB46, EB63, EB65, EB66), and partially incorporated in the project standard. At the renewal of crediting period, the latest valid version of a methodology must be used. If a methodology has been withdrawn or is no longer applicable, the project developers may use another methodology or request deviation from an applicable methodology. The CDM EB interpreted the 'validity test' in the Marrakech Accords in such a way that neither additionality nor the baseline scenario needs to be reassessed during the renewal of the crediting period. "The demonstration of the validity of the original baseline or its update does not require a reassessment of the baseline scenario, but rather an assessment of the emissions which would have resulted from that scenario" (Project Standard, Version 07.0, paragraph 289). The current rules mainly require an assessment of the regulatory framework, an assessment of

[31] This relates to Guidelines no. 4 and 5 of EB50 Annex 13 that may be integrated as cost items related to barriers/risks in the investment analysis of the additionality and combined tool. Guideline 2 may also be implemented in the context of the investment analysis in the tools, in that the CER revenues should be sufficient to overcome the financial gap in project finance that is due to the barrier.

circumstances, an assessment of the remaining lifetime of technical equipment to be used in the baseline, and an update of data and parameters, such as emission factors.

Figure 3-7 plots the number of projects that have chosen a 7-year crediting period and that end their first crediting period in a given year and are therefore potentially entering a process of crediting period renewal. The increase in project registrations with the maturing of the CDM market from 2005 is mirrored by a steep increase in candidate projects for renewal seven years later, after 2012. The graph also indicates that the fraction of these candidate projects that actually underwent renewal significantly declines after 2012: While before 2012 roughly two thirds of all candidate projects underwent renewal on average, the rate dropped to roughly one third after 2012. This may be explained by the collapse in pricing and the petering out of the classical CDM market in 2011-2012, whereby CER prices below marginal transaction costs make renewal of crediting economically non-viable for most projects that do not benefit from long-term futures contracts with higher prices.

Figure 3-7: Number of CDM projects ending first seven-year-crediting period – with and without renewals



Sources: UNFCCC 2014, authors' own analysis

3.5.2. Assessment

The requirements to use the latest approved version of a methodology is a very important rule to assure that changes in the methodological ruling are also implemented in CDM projects within a reasonable timeframe and therefore seem appropriate. At the same time, it provides some certainty for investors that rules regarding the calculation of emission reductions are not changed within their crediting period.

The CDM EB's decision to interpret the Marrakesh requirement of assessing that "the original project baseline is still valid" in such a way that that only baseline emissions must be updated but that neither additionality nor the baseline scenario needs to be re-assessed could constitute a major risk for the environmental integrity of some project types. In 2011, the Meth Panel highlighted certain issues with this approach in an Information note to the EB (MP51 Annex 21[32]), but the rules were not changed in response. In the following, we briefly analyze two main issues:

- The case of the baseline scenario changing over the course of the crediting period in a way that is not captured by the baseline methodology;
- The case of limited 'lifetime' of a baseline scenario.

Baseline scenario changing over of the course of crediting periods

In a number of instances, a baseline scenario could change over time during crediting periods and deviate from the assumptions in the underlying methodology. One example is a CDM project consisting of the conversion of an existing open cycle power plant to a closed cycle system. Assuming that after the first crediting period, new and lower cost technologies for the conversion would become available that would make the project economically viable, the implementation of the project activity after the first crediting period might be the most probable baseline scenario in the absence of the CDM. We are not referring here to the concept of dynamic baselines, e.g. the fact that baseline emissions are calculated based on the project output (e.g. in tons of steel or MWh per year). Rather, the scenario is changing, i.e. this refers to projects (or another low carbon activity) which, in the absence of the CDM project, would have been implemented at a later date due to changing circumstances.

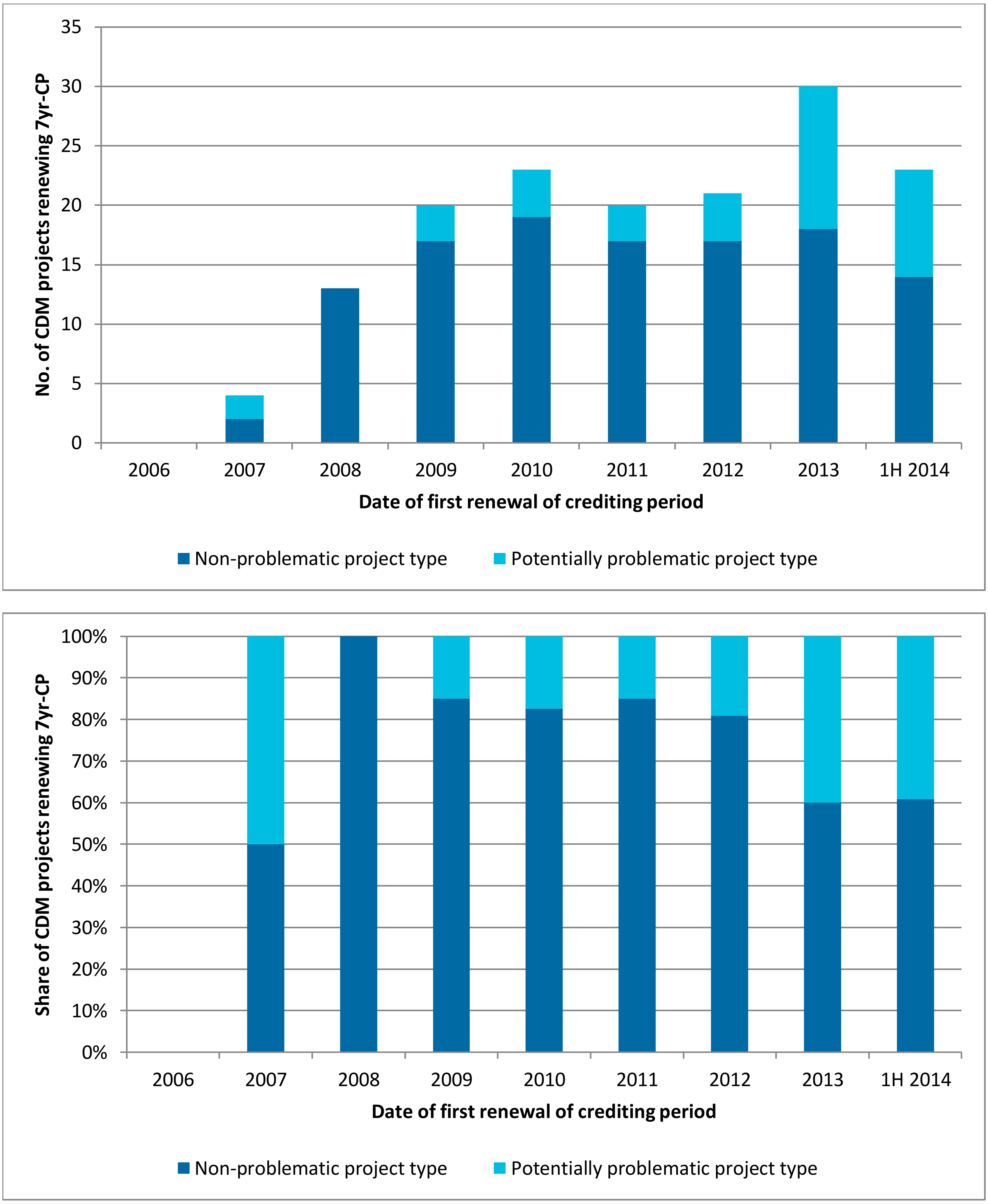
However, it is important to note that not all CDM project types are prone to changing baseline scenarios. Baseline scenarios typically change over time if they are the 'continuation of the current practice'. In such cases, changes such as retrofits could also be implemented at a later stage. In contrast, baseline scenarios do not change over time when they include a significant investment at project start in an alternative that provides similar services. This is the case if, for example, an industry can choose to fulfil their heat demand by either a new biomass boiler (project activity) or a new coal boiler (baseline). If one assumes that the project participant carries out a significant investment at the beginning of the baseline (e.g. to build the new coal boiler), it may be assumed that this investment is used until the end of its operational lifetime; replacing the coal boiler by a biomass boiler after seven years is economically not viable in general.

However, because CDM requirements explicitly rule out the re-assessment of the baseline scenario, cases with a change in baseline scenario cannot be taken into account, which leads to potential over-crediting in the second and third crediting periods in the case that the activity would have been implemented after the first crediting period due to changing circumstances.

Practical examples of such changing circumstances and related potential over-crediting can be found in Purdon (2014) for the co-generation sector. The paper provides an overview of how a change in external influence factors (e.g. sugar price) can influence the additionality and how a baseline scenario that is kept constant over several crediting periods can result in over-crediting.

[32] https://cdm.unfccc.int/Panels/meth/meeting/11/051/mp51_an21.pdf.

Figure 3-8: Share of CDM projects renewing their seven year crediting period that is deemed non-problematic



Notes: Potentially non-problematic project types have been selected according to the criteria of having a lower risk of changes in the baseline scenario over several crediting periods.

Sources: UNFCCC 2014, authors' own analysis

Assessment of the scale of the issue

In the following, we make a very rough assessment of the scale of this issue. As mentioned above, not all project types are in danger of undergoing changes in baseline scenarios that are not foreseen in the underlying methodology. In order to arrive at a preliminary estimate of the scale of the potential issue, a list of 'potentially problematic' project types was identified that have a higher risk of changes in the baseline scenario over several crediting periods than those categorised as 'unproblematic'.[33]

Please note that 'potentially problematic' does not mean that all projects in that project type have issues with the renewal of the crediting period, it simply means that the projects are in a sub-type that may contain potentially problematic projects. Figure 3-8 depicts the number of projects of a non-problematic project type in the total number of projects that actually underwent renewal of the 7-year crediting period in a given year.

The graph indicates that the number of projects renewing their crediting periods increased in 2007-2009. Until 2012, non-problematic projects made up the large majority of renewals. However, from 2013 the share of non-problematic projects dropped to approx. 60% of renewed projects. With such a low share, the issue may become more important in the future with a further increase in renewals (although the increase may be somewhat muted by the unfavourable market conditions).

In this context, it is important to note that CDM projects do not need to renewal immediately, but may wait until market conditions are more favourable. Given the high number of projects that may undergo renewal at a later point in time combined with the lowering in the share of non-problematic project types may lead to considerable over-crediting.

Lifetime of baseline scenario

Another, also related, issue is that in more complex and very dynamic systems, such as the transport sector, the determination of a counterfactual baseline scenario is exposed to fundamental limitations in the ability to predict future developments. These limitations can lead to very high uncertainties in the baseline determination. In some instances even after a very few years, the actual baseline emissions could be significantly higher (or lower) than the calculated baseline emissions. For example, while it may be relatively certain that a project proponent choosing in the baseline situation to build a coal-fired boiler will continue to operate this boiler over its lifetime to meet its heat demand, the development of a city's transport system in the absence of a specific urban rail project could be very difficult and uncertain to predict: over some years one may assume that an increase in transport demand is catered for by increased use of private cars; however, street capacities may be limited and the municipalities may have to find solutions to their transport problems anyway, also in the absence of a specific project activity.

It therefore might be considered that for some project types in complex and dynamic environments, such as transport systems, the baseline scenario cannot be reasonably extended over a period of

33 For a preliminary screening, the following projects sub-types (according to the classification of UNEP DTU) have been classified as "potentially problematic", i.e. it cannot be ruled out that the projects would be implemented later in time without the CDM under changing circumstances (please note that the sub-types may also contain projects which clearly do not have an issue): Adipic acid, Aerobic treatment of waste water, Agricultural residues: mustard crop, Air conditioning, Appliances , Biodiesel from waste oil, Biogas from MSW, Bus Rapid Transit, Cable cars, Caprolactam, Carbon black gas, EE industry – Cement, Cement heat, Charcoal production, EE industry - Chemicals, EE own generation - Chemicals heat, Clinker replacement, CMM & Ventilation Air Methane, CO_2 recycling, Coal Mine Methane, Coal to natural gas, Coke oven gas, Combustion of MSW, Composting, Domestic manure, EE public buildings, Existing dam, Food, Glass, Glass heat, HFC134a, HFC23, Industrial waste, Iron & steel, Landfill composting, Landfill aeration, Landfill flaring, Landfill power, Lighting, Machinery, Manure, Mode shift - road to rail, Natural gas pipelines, Nitric acid, EE industry - Non-ferrous metals, EE own generation - Non-ferrous metals heat, Non-hydrocarbon mining, Oil and gas processing flaring, Oil field flaring reduction, Oil to natural gas, EE industry – Paper, EE industry – Petrochemicals, PFCs, Power plant rehabilitation, Rail: regenerative braking, Solar water heating, Stoves, EE industry – Textiles, Ventilation Air Methane, Waste water. All other project types are deemed "non-problematic".

ten years and a renewal of crediting periods should not be allowed, given the risks of inadequate and very uncertain baseline scenarios for later time periods.

It was for this reason that the crediting period was initially limited to a single crediting period for some project types, including:

- PFC emissions from manufacturing in the semi-conductor industry (e.g. AM0092). This is an industry in which manufacturing technologies and composition of materials etc. change frequently compared to the duration of a 7-year crediting period
- Power saving from efficient management of data centers. Technologies and operating systems also typically have short lifespans compared to a 7-year crediting period.
- Complex transport systems such as the introduction of Bus Rapid Transport (BRT) systems in cities. In this context, the uncertainty in the baseline scenario and the resulting baseline emissions grows very rapidly, because development of transport systems over 5-10 years is difficult to predict with accuracy.

For these project types, the maximum crediting period has been set to 10 years in earlier versions of the methodology, because the uncertainty in the baseline scenario after 10 years did not allow for an objective determination of the emission reduction.

This limit in the crediting period to 10 years also allowed the methodology to be simplified, as the projection of baseline emissions over a limited period allows for simpler approaches and requires less monitoring provisions, thus reducing transaction costs.

Subsequently, however, the CDM EB took the decision (EB67, Para 107) that for each project type and methodology multiple crediting periods can be used (independent of any methodological limitations and uncertainty issues for the baseline setting as discussed above). This decision has been taken based on para 49 of the Modalities and Procedures for the CDM (decision 3/CMP.1, annex) that mentions alternative approaches. The paragraph was interpreted in such a way that both options shall be allowed in *each and every* methodology.

Since then, the relevant methodologies have been revised, allowing crediting for up to 21 years for all methodologies, without providing for further safeguards that would reduce the uncertainty in baseline scenario projection and potential over-crediting.

The issue of renewal of crediting period and more generally the updating of baseline scenarios is further discussed in Schneider et al. (2014).

3.5.3. Summary of findings

When the crediting period of a CDM project is to be renewed, the Marrakesh Accords require that the DOE check the validity of the original project baseline. A subsequent EB ruling (EB 43, Annex 13, paragraph 3) limited this check to an assessment of the regulatory framework, an assessment of the remaining lifetime of technical equipment that would be used in the baseline and an update of data and parameters, such as emission factors. The EB clarified that the validity of the baseline scenario should not be re-assessed.

With CDM project types for which the baseline scenario does not require a significant investment at the beginning of the crediting period (that would determine the baseline technology over the lifetime) this may lead to potential over-crediting. A preliminary analysis of projects that underwent renewal of the crediting period in recent years reveals that from 2013 onwards the share of potentially problematic project types (that might have issues of changing baseline scenarios leading to over-crediting) increases to approx. 40% of projects with renewal. It is therefore recommended that this issue is resolved.

A subsequent ruling by the EB to remove the limit in the crediting period that some project types had in their methodology in sectors especially prone to baseline uncertainty over one crediting period (e.g. semi-conductor manufacturing, information technology, transport) further exacerbated the issue.

3.5.4. Recommendations for reform of CDM rules

We recommend two reforms to the current rules:

- Reassessing the baseline scenario at the renewal of the crediting period: The issue of potential over-crediting arising from inadequate checking of the validity of the baseline at the renewal of the crediting period could be addressed by expanding the assessment to the validity of the baseline scenario for CDM projects that are potentially problematic in this regard. For this, clear criteria for problematic project types should be formulated and guidance should be provided on how to test the validity of baseline scenarios for specific CDM methodologies.

- Limitation of the overall length of crediting for specific project types: Project types in sectors or systems that are highly dynamic and complex, and in which the determination of baselines is notoriously difficult (e.g. urban transport systems) should be limited to a single 10 year CDM crediting period or should be supported by other (non-crediting) finance sources.

- A further step that may be considered is a general limitation of projects to one 7 years crediting period. This may also build on the observation that when discounting future streams of CER revenue beyond 7 (or 10) years at typical hurdle rates longer crediting periods do not really matter for the NPV calculation. Longer crediting periods would only be allowed for project types that require a continuous stream of CER revenues to continue operation such as landfill gas utilization/flaring etc.

3.6. Additionality of PoAs

The advent of CDM Programmes of Activities (PoA) in 2007, and the subsequent refinement of related additionality approaches, changed the nature of additionality testing for many project types. Additionality assessment for PoAs is simplified compared to the requirements for the registration of individual projects. Project developers can establish eligibility criteria to assess additionality, including eligibility criteria, which identify project types that may be automatically additional. More importantly, because the thresholds for identifying small-scale and microscale activities with simplified additionality procedures are set at the level of the Component Project Activity (CPA) and not the level of the PoA, the overall PoA could be far larger than these thresholds. For example, the registered PoA “Installation of Solar Home Systems in Bangladesh” (Ref. 2765) has so far installed 123 MW of solar power and has estimated emissions reductions of 569,000 tCO_2 per year, or almost ten times the small-scale CDM threshold.

In the period of 2013 to 2020, PoAs potentially could supply 0.16 billion CERs. However, as discussed in Section 2.3, the eventual volume for these PoAs could be many times this amount.

3.6.1. Assessment

There are three principle issues with the demonstration of additionality in PoAs: specific additionality concerns about the technology areas covered by PoAs, the robustness of eligibility criteria to check additionality, and the use of small and microscale thresholds for PoAs that are much larger in total than these thresholds. The first point is largely addressed in Chapter 4, because it is related to the mitigation technologies used in PoAs. As shown in Table 2-2, the majority of PoAs are in technology areas that are analyzed in this report (e.g. efficient cook stoves, efficient lighting, wind, hydropower, biomass), so these chapters should be consulted for an assessment of those technologies.

The second point concerns eligibility criteria, namely that the PoA rules require that the project participants develop a set of eligibility criteria that should guide the inclusion of CPAs. The criteria should be constructed so that, for each new CPA, simply confirming that the CPA meets the criteria is enough to ensure that the CPA is additional. These criteria should be based on approaches used in the relevant methodology or other additionality approach that is relevant for the PoA. In other words, there is not a detailed additionality assessment for each CPA in the way that project activities submitted for registration are evaluated. Instead, the eligibility criteria in the registered PoA design document (PoA-DD) should ensure that the CPA meets the relevant additionality test. For example, if part of demonstrating additionality in the relevant methodology is proving that the project is a particular scale or uses a particular technology, then the scale and technology specification would be listed as eligibility criteria against which each new CPA was checked. A possible concern could be that, if the project participants proposed eligibility criteria in the PoA-DD that did not fully capture the additionality requirements of the underlying methodology, there would be a risk that future CPAs could be included even if they were not additional. Although there was some confusion during the early days of PoAs on how to formulate eligibility criteria, this has not been the case since late 2011 when the EB published a standard for eligibility criteria. This was later replaced by the standard for “Demonstration of additionality, development of eligibility criteria and application of multiple methodologies for programme of activities” (CDM-EB65-A03-STAN, version 3.0). This standard provides not only the full list of issues that must be covered in the eligibility criteria, but also clear rules on how additionality may assessed for PoAs.

The third point is perhaps the most important – whether allowing PoAs that are, in total, much larger than the size thresholds for small and microscale projects could increase the risks of non-additionality among PoAs. The small-scale CDM thresholds are 15 MW for renewable energy, 60 GWh savings for energy efficiency, and 60,000 tCO_2 per year emissions reductions for other project types with approved small-scale methodologies. The scale limits for the microscale additionality rules are 5 MW for renewable energy, 20 GWh savings for energy efficiency projects, and 20,000 tCO_2 for other project types, and are then combined with other criteria (described in detail in Chapter 4, e.g. country type, size of individual units, or even designation by a national authority), to qualify as automatically additional. However, the EB decided at their 86th meeting that microscale technologies using unit size as the basis of automatic additionality (i.e. independent units of < 1500 kW for renewables, < 600 MWh for energy efficiency and < 600 tCO_2 for other projects, all serving households and communities) would have no limit of the total scale of the project or CPA. In other words, an efficient cook stove project activity or CPA could have total emission reductions of greater than 20, or even 60, $ktCO_2$ per year.

Projects (in this case, CPAs) that qualify as small-scale CDM (SSC) then have access to the technology-based ‘positive list’ in the tool for “Demonstration of additionality of small-scale project activities” (Tool21, version 10.0). CPAs below the micro-scale thresholds would all be automatically additional as long as they meet both the scale and other requirements (e.g. technology, location, etc.). For small-scale CDM, the list of technologies considered automatically additional includes the following:

- Certain technologies whether grid-connected or off-grid: solar (PV and thermal), off-shore wind, marine (wave and tidal), and building-integrated wind turbines or household rooftop wind turbines up to 100 kW;

- Additional off-grid technologies below the SSC thresholds: micro/pico-hydro (with power plant size up to 100 kW), micro/pico-wind turbine (up to 100 kW), PV-wind hybrid (up to 100 kW), geothermal (up to 200 kW), biomass gasification/biogas (up to 100 kW);
- Technologies with isolated units where the users of the technology/measure are households or communities or Small and Medium Enterprises (SMEs) and where the size of each unit is no larger than 5% of the small-scale CDM thresholds;
- Rural electrification projects using renewable energy in countries with rural electrification rates less than 20%.

Both microscale additionality and the small-scale CDM positive list approaches have been used extensively by PoAs. As shown in Table 3-2, 33% of the CPAs in registered PoAs, representing 27% of expected CERs, have applied the microscale or small-scale positive list approaches ('first of its kind' is discussed in Chapter 4). An analysis by the UNFCCC Secretariat[34] also shows that 142 of the 282 registered PoAs use microscale or small-scale rules for automatic additionality, with 65% of PoAs targeting households utilising one of these tools (Table 3-3). Many of these PoAs have already exceeded the microscale and small-scale thresholds at an aggregate level, as allowed in the CDM PoA rules. In contrast, the 120 CDM project activities that have used small-scale positive lists or microscale guidelines comprise only 0.8% of projects and 0.1% of expected emissions reductions (UNEP DTU 2015a).

Table 3-2: Use of automatic additionality approaches in CPAs within registered PoAs

Approach for automatic additionality	Annual CERs ($ktCO_2$/yr)	CPAs	CERs	CPAs
Microscale tool: country, unit size or DNA selection	3,520	188	11%	23%
Microscale tool: SUZ	60	9	0%	0%
SSC positive list	5,078	91	16%	10%
None	21,279	551	70%	65%
Total	29,936	839	100%	100%

Notes: A more recent version of the PoA pipeline was used here because of a revision of how the use of automatic additionality is classified.

Sources: UNEP DTU 2015b

[34] "Concept note: Thresholds for microscale activities under programmes of activities" (CDM-EB85-AA-A09)

Table 3-3: Technology and end-user types in registered PoAs that applied microscale and/or small-scale positive list criteria

Technology type	PoAs	Share of this type of PoA
End use type: Households	**92**	**65%**
Household biogas digesters	13	
Energy efficiency - household	2	
Energy-efficient lighting (LED and CFL)	28	
Improved cookstoves	36	
Solar water heaters	7	
Water purifiers	5	
Renewable-based rural electrification	1	
End use type: Others	**50**	**35%**
Energy efficiency – industrial	2	
Fuel switch	3	
Grid/off-grid connected renewable energy technologies (e.g. wind, solar PV, geothermal)	35	
Waste treatment (e.g. Wastewater, animal waste)	10	
Total	**142**	**100%**

Sources: Concept note: Thresholds for microscale activities under programmes of activities (CDM-EB85-AA-A09)

Whether granting automatic additionality to PoAs that are over the small and microscale thresholds poses a risk for additionality testing depends on the *reason* for the positive list designations. One of the main issues raised by the positive list is the *unit size* of the technology, with the argument being that the unit size on its own may be sufficient to identify a project type with a high likelihood of additionality (in combination with the other microscale criteria, where relevant). On this basis, the EB recently agreed that the size criterion for the microscale additionality tool should be *only* unit size, and not total project size.[35] This means that even a PoA using a large-scale methodology and have a total size beyond the SSC thresholds can still apply microscale additionality guidelines, as long as the unit size and other criteria are met.

The SCC positive list sets unit size limits for most categories of eligibility, although not for rural electrification or the grid-connected technologies (other than the 15 MW limit). The microscale guidelines also include the option of using a unit size less than 1% of the SSC threshold as a justification for applying these guidelines even if the projects are not located in Least Developed Countries (LDCs) or Special Underdeveloped Zone (SUZs).

The most important categories of PoAs (in terms of their contribution to expected CERs) utilising these tools are improved cook stoves, energy efficient lighting, biogas and small unit size solar power[36]. For the first three technologies, the unit size is inherently small, so the size of the total project or PoA should not, by itself, determine the viability of the technology (bearing in mind, however, that overhead programme costs are obviously lower per unit for larger programmes). The additionality issues with improved cook stoves and energy efficient lighting are reviewed in Sections 4.12 and 4.13, respectively. These sections raise important questions about the additionality

[35] The changes to the Tools for "Demonstration of additionality of small-scale activities" (version 22) and "Demonstration of additionality of microscale project activities" (version 07) were approved at EB86 (October 2015), as were changes in the Project Standard, Project Cycle Procedure, and standard on standard on "Demonstration of additionality, development of eligibility criteria and application of multiple methodologies for programmes of activities."

[36] Although the table from the UNFCCC Secretariat refers to "Grid/off-grid connected renewable energy technologies (e.g. wind, solar PV, geothermal)", our analysis has not identified any wind or geothermal PoAs using the small-scale positive list or the microscale guidelines.

of these project types, despite their small unit size, particularly because of the role of other support programmes in promoting these technologies and possible over-crediting for cook stoves, for example. On the other hand, the extensive literature on household energy access technologies and carbon markets also points to numerous well documented barriers, and the high unit transaction costs associated with small unit size technologies (e.g. Gatti & Bryan 2013; IFC 2012; Warnecke et al. 2015, 2013). In addition, the analysis from the UNFCCC Secretariat mentioned earlier also shows that the average unit size of PoAs using the small-scale and microscale positive lists is, in fact, far below even the microscale unit size of 1% of the SSC threshold (Table 3-4).

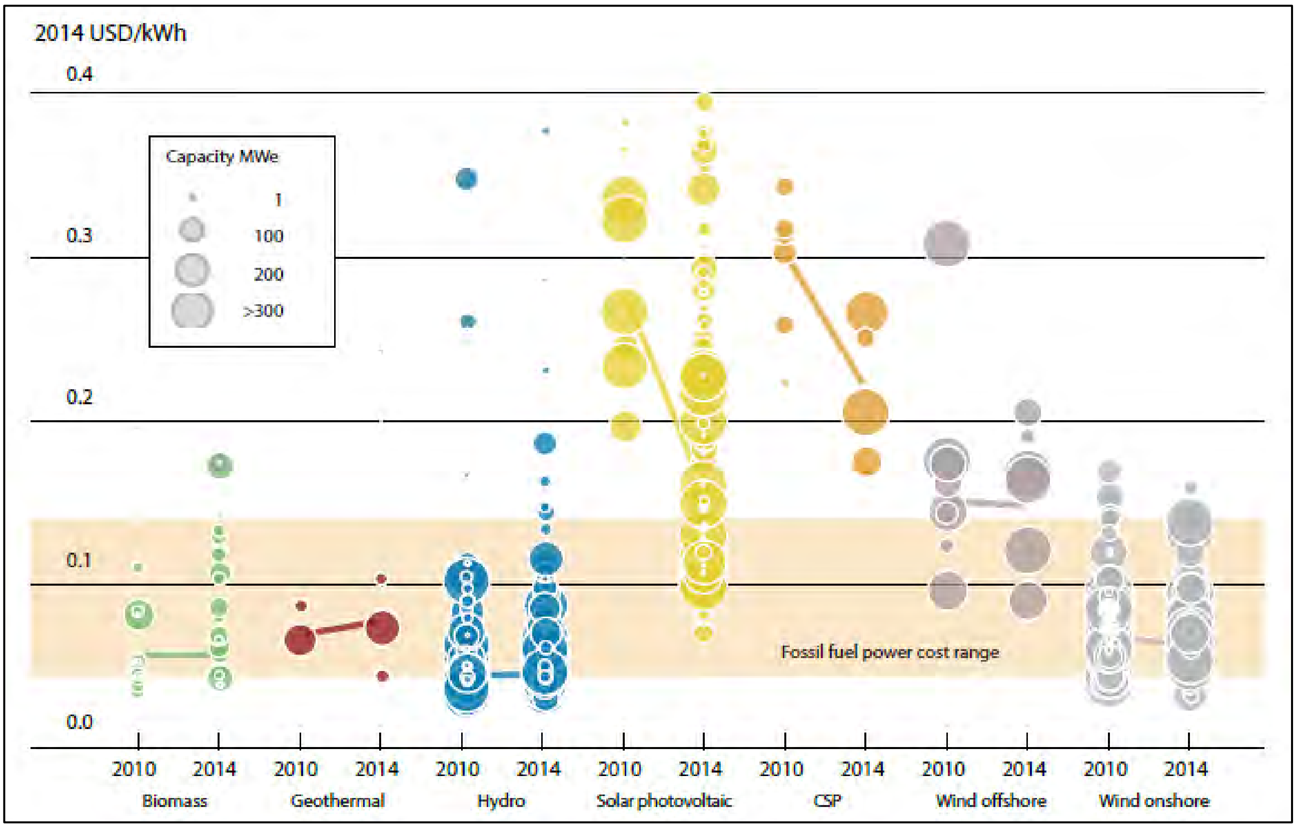
Table 3-4: Size of individual units in microscale and small-scale PoAs using positive lists

Unit size as % of SSC threshold	Type I (kW)	Type II (MWh)	Type III (tCO2)
1%	150	600	600
PoAs applying microscale criteria			
Average – 0.022%	3.3	13.3	13.2
Std deviation – 0.054%	8.1	32.4	32.4
PoAs applying small-scale criteria			
Average – 0.23%	34	136	137
Std deviation – 0.34%	51	204	204

Sources: Concept note: Thresholds for microscale activities under programmes of activities (CDM-EB85-AA-A09)

For renewable power technologies, even if the total capacity of a PoA was over 15 MW, the unit size could not be larger than 5 MW for most technologies (15 MW for solar PV or solar thermal) to qualify for automatic additionality. Given the economies of scale in renewable energy power generation (Prysma 2012), small unit sizes would be expected to have higher capital costs, and would therefore be more likely to face investment barriers than larger scale plants. Project-level analysis by the International Renewable Energy Agency (IRENA) also suggests that smaller renewable energy plants not only have higher costs (i.e. because the smaller dots, representing smaller scale projects, are generally higher up in the figure), but that for solar PV and solar thermal these costs are still considerably higher than for fossils fuels (Figure 3-9). Analysis by EPRI has also shown that solar power at the several MW scale is considerably more expensive than conventional alternatives (EPRI 2012). This suggests that a solar PV (grid connected or off-grid) programme of any total size would not be economically viable if the units were below the small-scale thresholds. However, the challenge with solar technologies is that they are so expensive that carbon revenue is unlikely to close the financial viability gap, so they may be more driven by national policies than carbon markets (Section 3.7).

Figure 3-9: Levelized cost of electricity from renewable technologies, 2010 and 2014



Notes: Size of the diameter of the circle represents the size of the project. The centre of each circle is the value for the cost of each project on the Y axis. The LCOE of a given technology is the ratio of lifetime costs to lifetime electricity generation, both of which are discounted back to a common year using a discount rate that reflects the average cost of capital.

Sources: IRENA (2015)

On the basis of the unit size analysis shown in Table 3-4, the Secretariat prepared a concept note with recommendations to the EB using on unit size, and not total project or CPA size, as the basis for determining microscale additionality (CDM-EB85-AA-A09). The EB agreed to begin to implement an approach of using only a unit size threshold to determine if the size of the project qualifies for microscale (EB85 report, paragraph 42). The other requirements for microscale (e.g. location in an LDC or SUZ, if the unit size is greater than 1% of the SSC threshold) would remain unchanged. This means that the CPAs comprised of technologies that were below the unit size threshold would not be limited in their total size. For example, a CFL PoA in an LDC could have a CPA with 100,000 MWh savings and still apply the microscale additionality guidelines.

3.6.2. Summary of findings

While the PoA rules do allow programmes with a total size greater than the small-scale and microscale thresholds to utilise the automatic additionality provisions for these scales of projects, there is no evidence that this increases the risk of non-additional projects on its own (i.e. the share of projects that could be non-additional). In other words, the PoA rules do not fundamentally change the additionality risks for a given category of project technologies. The PoA process could, of course, increase the overall *scale* of the risk because they were designed to facilitate the large scale dissemination of small, distributed technologies. For example, there are 40 registered 'improved stove' project activities with expected CERs of 1 million tCO_2 per year, but there are 46 registered 'improved stove' PoAs that already have expected CERs of 8.1 million tCO_2 per year.

3.6.3. Recommendations for reform of CDM rules

Reform of the CDM rules related to additionality for particular project types and positive lists will address any concerns about additionality of PoAs.

3.7. Positive lists

The concept of 'positive lists' means that specific project types are considered automatically additional. Positive lists are one option to reduce transaction costs and increase the certainty of the CDM system from the perspective of project developers. Similar to standardized baselines, creating a positive list requires an upfront evaluation of technologies and their economic and regulatory environment, independent of the assessment of a particular CDM project proposal, to establish certain objective criteria that, if met, will result in a high likelihood of additionality. Once a positive list is established, a specific CDM project only needs to show that the pre-defined criteria are met, and does not have to apply other tools to justify additionality.

3.7.1. Positive lists in the CDM and impact on CER supply

Positive lists were introduced in the CDM through various routes. As briefly mentioned in Section 3.6, the CDM EB adopted the "Guidelines for demonstrating additionality of micro-scale project activities" in 2010, which were subsequently converted to a methodological tool, which first established automatic additionality for certain project types regardless of the type of methodology used (i.e. small-scale or large scale). Table 3-5 shows the technologies covered under version 7 of that tool, and the criteria they must meet in order to be deemed automatically additional. In addition to total project size (or, in the case of PoAs, the size of an individual CPA), the technologies must meet a further criterion such as location, unit size and/or consumer group.

Table 3-5: Projects considered automatically additional under the tool "Demonstration of additionality of microscale project activities"

1	**Based on country (LDCs, SIDSs)** • Renewable energy up to 5 MW • Energy efficiency up to 20 GWh savings per year • Other small-scale CDM projects (Type III) up to 20 $ktCO_2$ emissions reductions per year
2	**Based on unit size and consumer (households, communities, SMEs) (i.e. any country)** • Renewable energy of any size as long as unit size is less than 1500 kW • Energy efficiency of any size as long as unit savings are less than 600 MWh per year • Other small-scale CDM projects (Type III) of any size as long as unit savings are less than 600 tCO_2 per year
3	**Based on host country designation of special underdeveloped zone (SUZ)** • Renewable energy up to 5 MW • Energy efficiency up to 20 GWh savings per year • Other small-scale CDM projects (Type III) up to 20 ktCO2 emissions reductions per year
4	**Based on designation of a technology by the host country** • Grid connected renewable energy specified by DNA, up to 5 MW, which comprises less than 3% of total grid connected capacity
5	**Based on other technical criteria** • Off-grid renewable energy up to 5 MW supplying households/communities (less than 12 hours grid availability per 24 hours is also considered 'off-grid')

Notes: LDCs = Least Developed Countries, SIDSs = Small Island Developing States, SME = Small and micro enterprises, DNA = Designated National Authority.

Sources: Tool for "Demonstration of additionality for microscale activities"

In 2011, the "Guidelines on the demonstration of additionality of small scale project activities", which later were similarly converted to a methodological tool, also included for the first time a list of technologies that would be considered automatically additional for any project meeting the small-scale CDM thresholds. This initially only included a list of grid and off-grid renewable energy technologies (i.e. the first two blocks in Table 3-6), but was expanded in 2012 to include small isolated units serving communities and renewable energy-based rural electrification.

Table 3-6: Technologies considered automatically additional under the tool "Demonstration of additionality of small-scale project activities"

6	**Renewable energy (up to 15 MW, grid or off-grid, all end users)** • Solar PV and solar-thermal electricity generation • Offshore wind • Marine technologies (e.g. wave and tidal) • Building integrated wind turbines or household roof top wind turbines (unit size =< 100 kW)
7	**Renewable energy (up to 15 MW, off-grid only)** • Micro/pico-hydro (unit size =< 100 kW) • Micro/pico-wind turbine (unit size =< 100 kW) • PV-wind hybrid (unit size =< 100 kW) • Geothermal (unit size =< 200 kW) • Biomass gasification/biogas (unit size =<100 kW)
8	**Distributed technologies for households/communities/SMEs (off-grid only)** • Aggregate size up to SSC threshold (15 MW, 60 GWh or 60 ktCO_2 emission reductions) with unit size =< 5 per cent of SSC thresholds (i.e. =< 750 kW, =< 3 GWh/y or 3 ktCO_2e/y)
9	**Rural electrification using renewable energy** • In countries with rural electrification rates less than 20%

Notes: Numbers in left hand column continue from previous table.
Sources: Tool for "Demonstration of additionality of small-scale activities" (version 10.0)

In addition to these tools, which apply across many methodologies, some individual methodologies have provided for automatic additionality for certain project types, often related to regulations. The most widely used is ACM0002 "Grid-connected electricity generation from renewable sources" (version 16.0), which was revised in November 2014 to include a two-part positive list for grid connected technologies. The first part is a list of technologies that are considered automatically additional: solar PV, solar thermal, offshore wind, marine wave and marine tidal (i.e. the technologies included in the first part of the small-scale CDM additionality tool, except at larger scale). The second part says that any technology with less than 2% of the total grid-connected capacity or less than 50 MW total capacity in the country is considered automatically additional. Since the revision of ACM0002, ten new project activities have requested and completed registration (no new PoAs have been registered). Of these, only one project has applied the new positive list provisions – a 141 MW solar PV facility in Chile. This is the largest solar facility to be granted automatic additionality.

Another important methodology with automatic additionality provisions includes ACM0001 "Consolidated baseline and monitoring methodology for landfill gas project activities" (version 15.0), which was revised in late 2013 to consider the following technologies automatically additional if, prior to the project activity, landfill gas was only vented and/or flared:

- electricity generation in one or several power plants with a total nameplate capacity that equals or is below 10 MW;
- heat generation for internal or external consumption;
- flaring (assuming no flaring prior to the project).

AM0113 “Distribution of compact fluorescent lamps (CFL) and light-emitting diode (LED) lamps to households” (version 01.0) provides for automatic additionality for any project distributing self-ballasted LED lamps to households. Projects distributing CFLs are only considered automatically additional if they are in a country with “no or only limited lighting efficiency regulations” reported by the UNEP en.lighten initiative’s Efficient Lighting Policy Status Map. AM0086 “Distribution of zero energy water purification systems for safe drinking water” (version 04.0) considers projects automatically additional if less than 60 percent of the population has access to improved drinking water sources or if the project proponents can demonstrate that more than half of the improved drinking water delivered does not actually meet the appropriate health standards. AMS-III.D “Methane recovery in animal manure management systems” (version 19.0) considers projects automatically additional when there is no regulation that requires the collection and destruction of methane from livestock manure. In addition to these, AM0001 “Decomposition of fluoroform (HFC-23) waste streams” (version 6.0), the first approved large-scale methodology, essentially uses a positive list approach based on regulation, because any project that does not face a regulatory requirement to abate HFC-23 emissions is considered additional. The same is true for ACM0019 “N_2O abatement from nitric acid production” (version 02.0).

While the positive lists presented above have not been used widely by CDM project activities (e.g. only 121 registered projects), PoAs have utilised the lists in the small-scale and microscale additionality tools (Table 3-2), with a third of CPAs in registered PoAs using these additionality approaches. Whether this growing group of PoAs presents concerns for the additionality depends on the strength of the justification for the original positive lists and for how long this justification is likely to be valid (i.e. how often the lists should be updated).

The criteria used to select the positive lists as well as the validity of these lists are presented in an information note prepared by the Small-scale Working Group in November 2014 called “Criteria for graduation and expansion of positive list of technologies under the small-scale CDM” (CDM-SSCWG46-A23). Table 3-7 summarises all of the positive list approaches, and shows the range of criteria used. The individual methodologies often refer to regulations to determine automatic additionality, or current penetration rates. The small-scale and microscale additionality tools use a mix of end-users, location, cost of service and penetration rates, depending on the specific technology group. This also highlights the similarity between positive lists discussed here and standardized baselines (Section 3.8), which also define a list of automatically additional technologies based on penetration rates and comparative costs.

Table 3-7: Criteria used for determining positive lists

		End-user	Regulation	Location	LCOS	Penetration	Capital cost
1	Microscale based on country (LDCs, SIDSs)						
	Renewable energy < 5 MW; Energy efficiency < 20 GWh; Other up to 20 $ktCO_2$			x			
2	Microscale based on unit size and consumer (households, communities, SMEs) (i.e. any country)						
	Renewable energy < 5 MW and unit size <1500 kW; Energy efficiency < 20 GWh and unit savings < 600 MWh; Other < 20 $ktCO_2$ with unit savings < 600 tCO_2	x					x
3	Microscale based on host country designation of special underdeveloped zone (SUZ)						
	Renewable energy < 5 MW; Energy efficiency < 20 GWh; Other < 20 $ktCO_2$			x			
4	Microscale based on designation of a technology by the host country						
	Grid connected renewable energy specified by DNA, up to 5 MW, < 3% of capacity					x	
5	Microscale based on other technical criteria						
	Off-grid renewables < 5 MW supplying households	x					
6	Small-scale renewable energy (up to 15 MW, grid or off-grid, all end users)						
	Solar PV and solar-thermal electricity generation; off-shore wind; marine (e.g. wave and tidal); building integrated wind turbines or household p wind =< 100 kW				x		
7	Small-scale renewable energy (up to 15 MW, off grid only)						
	Micro/pico-hydro (unit <= 100 kW); micro/pico-wind (unit <= 100 kW); PV-wind hybrid (unit <= 100 kW); geothermal (unit <= 200 kW); biomass gasification/biogas (unit <= 100 kW)						x
8	Small-scale off-grid distributed technologies for communities						
	Unit size =< 5 per cent of SSC thresholds	x					
9	Rural electrification using renewable energy						
	In countries with rural electrification rates less than 20%						
10	AM0086 water purification						
	<60% access to improved drinking water and <50% use of point-of-use zero energy water purification					x	
11	AM0113 energy efficient lighting						
	CFLs in countries with no or limited regulatory support All self-ballasted LED lamps		x			x	
12	ACM1 landfill gas utilisation						
	LFG for electricity or heat where vented or flared, or flaring where previously vented					x	x
13	AMS III.D methane and manure management						
	Biogas for power < 5 MW where no regulation requires collections and destruction of methane		x				
14	AMS III.C electric and hybrid vehicles						
	Market share of electric/hybrid vehicles < 5%					x	

Notes: LCOS = Levelized cost of service, LDCs = Least Developed Countries, SIDSs = Small Island Developing States, SMEs = Small and micro enterprises, DNA = Designated National Authority.

Sources: UNFCCC documents as cited in text

In terms of the duration of validity of the positive lists, the small-scale and microscale additionality tools did not originally include a time limit, although many of the methodologies specify a three-year duration of validity. The EB (EB81, paragraph 72) accepted a Small-Scale Working Group recommendation in late 2014 to set a three-year limit on validity for the small-scale CDM positive lists. In addition, the EB agreed on thresholds for 'levelized cost of service', 'penetration rate', and 'capital cost#, as shown in Table 3-8. Note that these new rules only apply to the positive lists under the tool for "Demonstration of additionality of small-scale project activities", and not to microscale activities or any other positive lists.

Table 3-8: Graduation criteria for technologies under the tool for "Demonstration of additionality of small-scale project activities"

	End-user	LCOS	Penetration	Capital cost
Grid connected renewable electricity generation				
All renewable energy technologies in the current positive list		>= 50% higher than all fossil fuels	Global average penetration <3%	
Off-grid renewable electricity generation				
All off-grid renewable technologies in the current positive list				>= 3 times the cost of all fossil fuels
Distributed technologies for households/communities/SMEs				
All distributed technologies eligible under Type I/II/III and providing services of households/communities/SMEs	Assess appropriateness of user groups		Global average penetration rate < 3%	>= 3 times cost of all plausible baseline technologies

Sources: Information note "Criteria for graduation and expansion of positive list of technologies under the small-scale CDM" (CDM-SSCWG46-A23)

3.7.2. Assessment of current positive lists

The positive lists developed under the CDM to date are based on specific criteria such as penetration rate, costs, regulatory environment, and location. While these lists have not been used widely for automatic additionality among CDM project activities, their use among PoAs is widespread and growing. Some of the positive lists are now reviewed regularly, and have a clear basis for determining whether a technology should still be included in the lists. **This review of validity should also be extended to other project types, in particular those covered by the microscale additionality tool or approaches used in relevant methodologies (e.g. ACM0002).**

An important challenge with the current positive lists, however, is that the basis upon which they are established varies widely, without a clear rationale for the choice or level of the indicator (e.g. why penetration might be used for some technologies but levelized cost of service for others). **A consistent approach to determining technology eligibility is needed** to ensure that existing and new positive lists do not pose risks of non-additionality. The criteria and indicators used should have clear justification for how they influence project implementation. For example, while low market penetration or high capital costs could be strong indicators of prohibitive barriers for some technologies, it is not clear how the concept of 'special underdeveloped zones' (SUZ), which may be defined differently by each DNA according to UNFCCC guidelines, is a reliable indicator of barriers.

As part of the justification of project types and technology choices, **positive lists must address the impact of national policies and measures to support low emissions technologies** (so-called, E- policies). As discussed in Section 3.9 and many of the sections within Chapter 4, national policies may be the primary driving factor for the implementation of certain technologies, rather than their underlying economics, market position or location. In fact, one of the criticisms of allowing renewable technologies to be considered automatically additional is that their costs are so high that carbon revenue alone cannot possibly make them financially viable, and so other incentives and policies are the real determining factor (Lazarus et al. 2012; Spalding-Fecher et al. 2012). This is even truer with smaller scale technologies. For example, in a study in Southern Africa, the levelized cost of roof-top solar PV was 20% more expensive than utility scale solar PV, while small hydropower was 70% more expensive than large scale (Miketa & Merven 2013). For positive lists to avoid the possibility of 'false positives' driven by national policies, some objective measure of renewable energy support may be needed as part of the evaluation process. An example of this would be the REN21 renewable energy global overview and interactive map,[37] which provides a comprehensive technology-specific database of the policies in place to support renewables. A positive list that included renewables could therefore be qualified by restricting its applicability to countries that did not have any support policies in place for that technology. Having support policies in place does *not*, on its own, mean that those technologies would not be additional, but only that there is a greater risk of this and so applying a positive list approach in that country would not be appropriate. Projects in those countries could still use the other tools available for demonstrating additionality for small- and large-scale projects – they would only not have access to automatic additionality based on the positive list. As an example, the positive list in the tool for "Demonstration of additionality of small-scale project activities" includes all solar PV and solar thermal technologies in all CDM-eligible countries. According to the REN21 policy database, however, the following countries have support policies[38] in place for solar PV: Algeria, Argentina, Brazil, Cape Verde, China, Côte d'Ivoire, Ecuador, Egypt, Gambia, Ghana, India, Jordan, Lebanon, Malaysia, Mauritius, Nepal, Nigeria, Republic of Korea, Senegal, Thailand, Uruguay, Uzbekistan, and Venezuela. For these countries, therefore, it might be more appropriate to require an analysis of barriers to solar PV rather than considering them automatically additional. This approach could be refined based on additional research into publicly available and up-to-date databases of renewable energy policies.

Finally, to maintain environmental integrity of the CDM overall, **positive lists should be accompanied by negative lists**. This is because the introduction of a positive list without any negative list could, by definition, only lower environmental integrity compared to the traditional approaches. Projects that do not fall within the positive list can still apply the traditional approaches. So, the positive list will lead to more 'false negatives' passing the test, but will not rule out any projects that are not additional. Overall, environmental integrity is thus lowered (albeit with the positive element of reducing transaction costs). An exception to this could be the few methodologies that deem projects as ineligible if they reach a market penetration threshold above a certain level, because they, in essence, include both a positive and negative list.

[37] The interactive map is shown at: http://www.ren21.net/status-of-renewables/ren21-interactive-map/ . The full database of policies is available at http://www.ren21.net/wp-content/uploads/2015/09/Downloadable-Consolidatedv1.2.1.xlsx.

[38] Support policies may include, for example, feed-in tariffs, electric utility quota obligation, capital subsidies, tax credits, and net metering, but exclude renewable energy targets not accompanied by other incentives.

3.8. Standardized baselines

Project developers have repeatedly complained about the expensive and time-consuming process for formally registering a project under the CDM. The setting of the baseline for the greenhouse gas emission reductions associated with a project has required project developers to apply project specific methodologies in order to calculate baseline emission levels. The project developers take on significant costs before the approval of their project when collecting the data necessary to set the baseline and demonstrate additionality. In some cases the risks associated with these upfront costs may be too high for developers of smaller projects in poorer countries (Spalding-Fecher & Michaelowa 2013) – impacting the regional distribution of projects under the CDM. Apart from high transaction costs, the project-specific determination of baselines and assessment of additionality has been criticised in the past for being subjective (Schneider 2009). Due to the information asymmetry between project developers and DOEs subjective assumptions may be difficult to verify, which could result in non-additional projects or over-crediting, which both undermine the environmental integrity of the CDM.

The Cancun Agreements in 2010 provided for the use of *standardized baselines* in the CDM to address these limitations with the aim *"to reduce transaction costs, enhance transparency, objectivity and predictability, facilitate access to the clean development mechanism, particularly with regard to under-represented project types and regions, and scale up the abatement of greenhouse gas emissions, while ensuring environmental integrity"* (UNFCCC 2011c). In contrast to the project-by-project approach to setting baselines and demonstrating additionality, standardized baselines are established for a project type or sector in one or several CDM host countries. Standardized baselines can address any or all of three areas for standardization: demonstrating additionality, determining the baseline scenario or determining baseline emissions. In the latter case, standardization can include emission factors or individual parameters needed to calculate emission reductions.

Standardized baselines require host country approval and are submitted through the DNA of the host Party. They can cover one or several Parties. Once approved, project developers can use a standardized baseline when submitting a project for registration. In 2014, the EB further decided that it is up to the host Parties to decide whether projects must use an approved standardized baseline or whether they may alternatively use a project-specific approach, but noted that the EB could reject standardized baselines if this poses a risk to environmental integrity (CDM-EB78, para 24). In practice, all approved standardized baselines have so far been voluntary, except for a multi-country grid emission factor in the Southern African region.

The CDM allows standardized baselines to be derived either from suitable methodologies, from tools such as the *'Tool to calculate the emission factor for an electricity system'*[39] or from a generic framework that is applicable to all project types and sectors such as the *'Guidelines for the establishment of sector specific standardized baselines'*[40] adopted by the EB in 2011. Further regulatory documents include a procedure for submission of standardized baselines, a standard on the coverage and vintage of data, and guidelines for quality assurance and quality control.

The *'Guidelines for the establishment of sector specific standardized baselines'* combine elements of market penetration, performance benchmarks, investment and barrier analysis. Under this framework, the standardized baseline results in a positive list of fuels, feedstocks and/or technologies for a given sector. The least emission-intensive fuel/feedstock/technology needed to produce

39 https://cdm.unfccc.int/methodologies/PAmethodologies/tools/am-tool-07-v2.pdf.
40 https://cdm.unfccc.int/filestorage/4/I/Y/4IY1RB7DMKLWPGF59XC3UE6JNH8Q2A/eb62_repan08.pdf?t=N2d8bnRoeHN3fDDSYyp3xU9Kx6IMk5Ho1yFw.

a certain percentage of the sector's output (i.e. defined by the CDM EB)[41] is selected as the baseline fuel/feedstock/technology. All fuels/feedstocks/technologies that are associated with lower emission intensities than the baseline technology are candidates for inclusion in a positive list of fuels/feedstocks/technologies that are automatically deemed additional. The DNA of the host country also needs to demonstrate for each of the candidates for the positive list that they are either less economically attractive than the non-candidates or face barriers to entry (Schneider et al. 2012). The baseline technology is also used to determine the baseline against which emission reductions are calculated (Hermwille et al. 2013).

Table 3-9: Approaches for deriving grid emission factors

DNAs could use either the standardized baseline guidelines or the grid emission factor tool to determine the grid emission factor and submit the value as a standardized baseline. The weaknesses of this opportunity to choose between two alternative approaches are explained below:

1) **Pick and choose issue:** The two approaches will provide two different values for the grid emission factor. Thus, the DNA could pick and choose between two completely different methodological approaches for determining the grid emission factor. Countries for which the guidelines result in higher values will use that approach, whereas countries for which the tool results in higher values will use that approach. Overall, having two parallel approaches could undermine the environmental integrity compared to the current situation in which only one approach is available.

2) **Vintage of data issue:** The standardized baseline guidelines consider all plants, whether they were recently constructed or decades ago. This could result in a situation in which coal power is determined as the baseline fuel, even if no coal power plant has been constructed or been under construction for a decade. In contrast, the grid emission factor tool aims to consider recent developments by observing which plant types were recently added to the system or are under construction or which plants actually operate at the margin.

3) ***'One size fits all'* issue:** The grid emission factor tool uses a methodologically approach that considers the particularities of the electricity system, considering different possible effects of displacing grid electricity (marginal plants not being dispatched/the construction of other power plants avoided or delayed). In contrast, the guidelines do not consider the characteristics of the sector and make generalised assumptions, which have little meaning in the power sector. The guidelines therefore result in less accurate grid emission factors than the grid emission factor tool.

Sources: Own compilation

The environmental impact of standardized baselines will be affected by how stringently the standardized baseline is set for a given project type. The stringency of standardized baselines needs to safeguard the environmental integrity of the CDM whilst also striking the right balance between accuracy and transactions costs in order to ensure that there is an incentive for developing new CDM projects.

The implications of standardized baselines on environmental integrity will also vary depending upon the sector that they are applied to, as the approach relies considerably upon the assumption that the penetration of a fuel/feedstock/technology is negatively correlated with its cost and/or with barriers that impede their deployment (Hermwille et al. 2013). For certain sectors there will undoubtedly be a strong correlation, i.e. energy efficient lighting and efficient electrical appliances.

[41] In its guidance, the EB has defined a preliminary additionality/crediting threshold of 80 % in priority sectors and 90% in other sectors.

However for other sectors, i.e. with multiple products or with strongly varying circumstances among installations, the correlation will be weaker or absent and alternative approaches for setting baselines and demonstrating additionality may be more suitable (Hermwille et al. 2013). Applying the current framework to sectors for which such a correlation is lacking could broaden the positive lists for technologies that are unlikely to be additional. In the power sector, for example, the guidelines do not reflect the particular features of an electricity system. The Methodologies Panel recommended that the EB limits the applicability of the SB standard to sectors other than the power sector (MP65, paragraph 38 and 39). In response, the EB requested the Methodologies Panel to assess the applicability of the proposed framework to different project types (EB81, paragraph 41). However, as of January 2016, the current guidelines are still applicable to all sectors. In 2015, a standardized baseline was finalized for consideration by the EB, which includes grid emission factors for different islands of Cape Verde and applies for some islands the "*Guidelines for the establishment of sector specific standardized baseline*" and for others the grid emission factor tool. The issues arising from the application of the guidelines to the power sector are highlighted in Table 3-9.

The following issues may pose further environmental risks through the implementation of standardized baselines in the future:

- **Mandatory versus voluntary use of standardized baselines:** The current CDM EB framework does not make the use of standardized baselines mandatory (CDM-EB74, para 24). It is the discretion of the DNA to decide whether project participants can select between project-specific or standardized baselines. In this regard, the DNA can make their use voluntary or mandatory. This may have two consequences:

  - Standardized baselines open an alternative route towards positive lists (Section 3.7), while keeping the approach of demonstrating additionality through the current means. By definition, this can only increase the number of false positives. Hence, the likelihood for additionality is lower, compared to a situation in which there would be no standardized baselines.

  - The voluntary use of standardized baselines could lead to project developers picking and choosing between baseline emission factors which could result in over-crediting (Table 3-9, bullet point 1). Indeed, Spalding-Fecher & Michaelowa (2013) argue that the CMP should make standardized baselines mandatory.

  The degree of these risks depends on how conservative the standardized baselines are set. The more conservatively that they are set, the lower the risk is. An example of how picking and choosing between project-specific and standardized baselines can undermine environmental integrity is the approved standardized baseline ASB0018 for cook stove projects in Burundi. The approved standardized baseline provides default values for the amount of non-renewable biomass consumed in the baseline (1.5 tonnes per person and year for households in urban areas and 1.1 tonnes per person and year for households in rural areas). However, at the same time, a PoA (9634) is registered in Burundi with project-specific baseline values based on data from a more recent survey. The project-specific baseline is more ambitious (1.21 tonnes per person and year for households in urban areas and 0.83 tonnes per person and year for households in rural areas). Had the standardized baseline been approved prior to the registration of the project, the project could have opted for the less ambitious standardized baseline. At the same time, projects with higher project-specific baseline values could opt for their project-specific baseline and not use the standardized baseline.

- **Quality assurance and quality control (QA/QC) of standardized baselines:** Version 04.0 of the procedure *'Development, revision, clarification and update of standardized baselines'*

(CDM-EB84-A10) sets out how a project developer can submit a proposal for a standardized baseline to the CDM EB following first the approval of the relevant DNA. It is necessary for the project developer to provide a list of documents when submitting a standardized baseline proposal, which includes the Form F-CDM-PSB, supporting documents and an Assessment Report of QA/QC. The CDM EB clarified only in 2015 that DOEs not only need to verify whether the required documents were submitted and that the data were collected according to guidelines for quality assurance and quality control but that they also need to check that the standardized baseline has been calculated in accordance with the relevant standards (CDM-EB85-A10). However, this decision still needs to be adequately reflected in the latest version of the *'CDM validation and verification standard'* (CDM-EB82-A14). Moreover, stakeholders expressed concerns that if the requirements for QA/QC are too stringent, it may prevent the approval of standardized baselines from LDCs (Hermwille et al. 2013). Therefore, the QA/QC Assessment Report is currently not compulsory for countries with 10 or fewer registered CDM projects as of 31 December 2010 for the first 3 submissions (CDM-EB84-A10, Para. 18), even though countries can request financial support from the UNFCCC for the development of Assessment Reports. These exemptions from applying the QA/QC guidelines could undermine the environmental integrity of the CDM.

- **Development of country-specific thresholds:** CMP9 requested the EB *"to prioritise the development of top-down thresholds for baseline and additionality for the underrepresented countries in CDM"'* (CDM-EB82-AA-A10, Para. 3). Many stakeholders regard the currently approved default thresholds for additionality and baseline as *'unattractive'* and *'not suitable'* for specific national/regional/sectoral circumstances (CDM-EB82-AA-A10). However, the adoption of country-specific thresholds could be a difficult process as such thresholds are a policy choice rather than a methodological choice. It is uncertain whether or not the development of country-specific thresholds would undermine the environmental integrity of the CDM. However, it would likely result in the incomparability of emission reductions from different standardized baselines within the same project type or technology.

- **Exclusion or inclusion of CDM facilities in the peer group to determine standardized baselines:** The development of certain standardized baselines relies upon the performance and actual output from the facilities of a sector of the host country. Some of these facilities may already have registered CDM projects (i.e. referred to as CDM facilities) that would have improved performance due to the incentives provided by the CDM. Given that it is difficult to determine the performance and outputs of these facilities in the absence of the CDM, it is necessary to take a decision on whether to include CDM facilities in the calculation of a standardized baseline or not. Exclusion of CDM facilities could undermine the environmental integrity of the CDM (CDM-EB78-AA-A05). As a default all CDM projects need to be included in the respective cohort unless the DNA can demonstrate that the cost of fuels/feedstocks/technologies exceed those of certain comparable projects (CDM-EB79, para 41).

- **Vintage of standardized baselines and static versus dynamic standardized baselines:** Standardized baselines are often constructed based on plants for which the investment decision was taken many years in the past. If a standardized baseline is static and not frequently updated, it can mean that additionality is established and baselines are determined based on a market situation that is ten or twenty years old (i.e. failing to take into account technological breakthroughs). This could result in significant crediting of BAU (Table 3-9, bullet point 2). The high-level CDM Policy Dialogue has therefore recommended that in order to drive technological change, the standardized baseline framework must ensure *"that the focus of incentives constantly shifts to the next generation of technologies"* (CDM Policy Dialogue 2012, p. 6). As a consequence, the current standardized baseline framework specified interim data vintages and update frequencies of 3 years respectively (CDM-EB77-A05). For example, sectors associated with slow dynamic developments in the past may allow for a relaxation in the frequency of updates without compromising the environmental integrity of the CDM.

- **Level of disaggregation:** The level of disaggregation is an important factor to consider in the development of a standardized baseline, which can enable a DNA with limited resources to prioritise which mitigation measures to incentivise within a sector. For example, Hermwille et al. (2013) refer to a case study of the rice mill sector in Cambodia where only a small number of large scale rice mills account for approximately 60% of the total output. Given that the remaining output is provided by thousands of small-scale rice mills with very varied use of technologies that are associated with different emission intensities, it was necessary to disaggregate the standardized baseline on the basis of plant size (i.e. focus standardisation on the large-scale mills). The importance of disaggregation of standardized baselines is further demonstrated in the power sector. If a standardized baseline is based upon the entire power sector of a country, it is likely that the use of renewables and possibly of the most efficient fossil fuel technologies would be encouraged. However, if the standardized baseline was disaggregated further to consider fossil fuel consumption only – different mitigation options such as fossil fuel switching would be encouraged instead (Hermwille et al. 2013). The appropriate level of disaggregation depends very much on the project type and the actual circumstances. With the current approach, DNAs can determine the level of disaggregation, though there is no EB guidance on how the appropriate level can be determined. In addition, such guidance would hardly be compatible with the 'one size fits all' approach pursued in the standardized baseline guidance.

In light of all of these challenges, the implementation of standardized baselines may not be suitable for all sectors, project types or countries. The development of a standardized baseline can achieve the objective of simplification in certain sectors associated with more homogenous products. However, standardized baselines will be more difficult to apply to sectors associated with a range of products and strongly varied circumstances amongst installations. Therefore, it should be carefully checked for which purposes, sectors, project types and baseline emission sources standardized baselines are appropriate. Applying one single approach to establish standardized baselines for different sectors, project types and locations, as currently pursued under the CDM, is likely to undermine the environmental integrity of the CDM. Standardized baselines should be developed from actual projects and reflect the particular circumstances of the sector, project type and location. Once approved within a country or region, standardized baselines need to be mandatory for all new CDM projects to prevent that more CERs are issued as if the standardized baseline was not established (Schneider et al. 2012).

To ensure that the concept of standardized baselines provides what it was established for, particularly *"to reduce transaction costs, … while ensuring environmental integrity"* (UNFCCC 2011c), the EB should review the standardized baseline framework. This review should ensure that

- stringent QA/QC procedures are applied to all standardized baselines,
- all CDM facilities without any exemptions are included in the peer group for the standardized baseline,
- DNAs can build their decision on the appropriate disaggregation level on a clear guidance document which aims to determine the level of disaggregation in a way that covers the mitigation activity of the standardized baseline as accurately as possible and includes as few external factors ('noise') as possible;
- the practice of using the same methodological approach to establish standardized baselines for all the different sectors, project types and locations is replaced by the development

of project-specific standards derived from actual projects and reflect the particular circumstances of the sector, project type and location, and last but not least,
- standardized baselines are mandatory for new projects once they are approved for a country.

If these improvements were introduced, standardized baselines could be a valuable tool to improve the environmental integrity of the CDM while lowering transaction costs.

3.9. Consideration of policies and regulations

The consideration of policies and regulations in demonstrating additionality and establishing emissions baseline has been a controversial issue for project-based mechanisms as the CDM. Policies and regulations adopted by the host country can have a significant impact upon future emission pathways. For example, the introduction of air quality regulations for power plants impacts their CO_2 emissions while fossil fuel subsidies reduce the viability of less emission-intensive technologies (Schneider et al. 2014). When setting the baseline and demonstrating additionality there have been concerns raised about both perverse incentives for policy makers (i.e. host countries not implementing policies and measures that reduce emissions so that they can secure greater carbon revenues) and about environmental integrity, by either over-crediting of emission reductions (i.e. inflating the baseline by excluding polices and measures that reduce emissions) or non-additional projects (i.e. registering projects that are economically viable and do not face barriers by allowing the exclusion of subsidies in the investment analysis).

The modalities and procedures for the CDM require that *"a baseline shall be established taking into account relevant national and/or sectoral policies and circumstances, such as sectoral reform initiatives, local fuel availability, power sector expansion plans, and the economic situation in the project sector"* (decision 3/CMP.1, para 45(e)). However, in order to avoid the creation of perverse incentives for policy makers, the CDM EB adopted, at its 22nd meeting, the following rules with regard to the consideration of policies in setting baselines:

- **E+ policies:** to not consider polices adopted after 1997 which *“give comparative advantages to more emissions intensive technologies or fuels over less emissions intensive technologies or fuels”* in setting the baseline;

- **E- policies:** to not consider policies adopted after 2001 which *“‘give comparative advantages to less emissions intensive technologies over more emissions intensive technologies”* in setting the baseline.[42]

These rules failed, however, to fully address perverse incentives for policy makers, as host countries would continue to have incentives to maintain existing E+ policies such as fossil fuel subsidies. Furthermore, although host countries will not be discouraged from implementing national policies and measures that reduce emissions (E- policies), the rules are likely to result in over-crediting of emission reductions.

Overall, in the case of E- policies it seems difficult to reconcile the two policy objectives: avoiding perverse incentives for policy makers and ensuring environmental integrity. If E- policies were excluded when demonstrating additionality or setting baselines, perverse incentives would be addressed but environmental integrity would be undermined, since projects that are financially viable could claim they are not, and emissions baselines would be inflated. If E- policies were included, environmental integrity would be ensured but perverse incentives not addressed.

[42] EB 22 report, Annex 3: Clarifications on the consideration of national and/or sectoral policies and circumstances in baseline Scenarios (Version 02), https://cdm.unfccc.int/EB/022/eb22_repan3.pdf.

In 2013, the EB reviewed its E- policy guidelines with a view to balancing these two conflicting policy objectives and *"agreed to pursue an approach by which, for the first seven years from the effective implementation date of the relevant E- policy, the benefit of that E- policy does not need to be considered by project participants in the additionality demonstration through investment analysis"* (CDM-EB73, para. 70). The approach would thus ignore new E- policies but for a limited time period. Initially allowing the exclusion of E- policies could be seen as addressing perverse incentives for policy makers, while ensuring environmental integrity in the longer term. It would also expand the approach of ignoring E- policies from baseline setting to demonstrating additionality. However, the EB has not yet been able to agree on a revision of its E+/- policy guidelines.

Based upon an econometric analysis, Lui (2014) raises questions about the decline of feed-in tariffs in China[43] that may imply a gaming to ensure wind projects are not economically attractive for the purpose of demonstrating additionality under the CDM. Schneider et al. (2014) argue that with regards to E- policies it is simply not feasible to achieve both a robust crediting baseline and avoid the creation of perverse incentives at the same time. Striking a balance between the two objectives is therefore required when setting the crediting baseline, which is likely to vary depending upon the sector, project type and type of policy.

Given the contrasting objectives, the decision on whether to include E- policies in the baseline or not and the determination of additionality of a project-based mitigation activity should depend upon the potential risk of either creating perverse incentives or over-crediting. Schneider et al. (2014) recommend that the following approach should be pursued when setting baselines and determining additionality:

- If the **risk of creating perverse incentives** is judged to be considerably larger than the risk of over-crediting, then E- policies should not be considered (for a certain period) in setting the baseline;
- If the **risk of over-crediting** is deemed to be considerably greater than the risk of creating perverse incentives, then E- policies should be considered in setting the baseline.

The extent to which the setting of baseline and determination of additionality for a project-based mitigation activity is more liable to either the risks of perverse incentives or over-crediting depends upon the wider co-benefits associated with a policy other than simply climate change mitigation. For example, the deployment of renewables is associated with multiple co-benefits such as employment opportunities, energy security and air quality improvements. Given the additional benefits associated with such E- policies, it is less likely that these policies would not be adopted as a consequence of changes to an international crediting mechanism. Schneider et al. (2014) and Spalding-Fecher (2013) therefore both argue that the risk of creating perverse incentives (i.e. delaying policies and regulations to secure more CER revenues) may be lower than the risks of setting a less robust baseline (i.e. by not including E- policies in the baseline) that leads to the over-crediting of emission reductions. Spalding-Fecher (2013) also points out that such co-benefits are likely to occur with electricity generation, energy efficiency and agriculture projects.

However, the risk of creating perverse incentives is likely to be greater from mitigation activities such as the capture of HFC-23, which reduce GHG emissions but do not lead to significant co-benefits. In such a case, preventing the creation of perverse incentives (i.e. host country delaying regulation on the capture of HFC-23) could be given priority over additionality and environmental integrity by not considering such E- policies when setting the baseline. Nevertheless, CERs resulting from such projects would be used to offset GHG emissions in other capped systems and, since

[43] Spalding-Fecher (2013) discusses the uncertainty within the CDM EB on how such a policy change should be classified under the E+/- policy guidance.

they are not truly additional, result in globally higher emissions. Therefore, it would be more appropriate to support such technologies by other means such as ODA or climate finance or by addressing these mitigation potentials as own contribution under the ADP negotiations.

From a more practical perspective, Spalding-Fecher (2013) emphasises the difficulty of accurately accounting for the effects of E- policies when setting either the baseline or demonstrating additionality. The level of difficulty depends upon the policy type. For example, the impact of direct financial incentives such as mandatory feed-in tariffs can be removed more easily from an emissions baseline than indirect sectoral incentives such as renewable energy portfolio standards or economy-wide policies such as domestic emissions trading schemes. Furthermore, defining the date of policy implementation and the effectiveness of enforcement may sometimes represent additional challenges (Spalding-Fecher 2013). If the guidance provided by the CDM EB – given the difficulty in isolating the impact of multiple (and sometimes conflicting) policies when setting emission baselines or demonstrating additionality – would only relate to direct financial incentives this could lead to the unequal treatment of host countries under the CDM based upon the types of policies implemented (Spalding-Fecher 2013). For example, it would be easier to determine the additionality of a renewable energy project in a host country with direct financial incentives such as feed-in tariffs compared to a host country that adopted a domestic emissions trading scheme. This practical problem could not only undermine the environmental integrity of the CDM but also mean that excluding E+ or E- policies may simply not be practical.

Taking into account the various challenges to strike the right balance between avoiding perverse incentives for policy makers and ensuring environmental integrity, Spalding-Fecher (2013) concludes that the risk of perverse incentives is not as high as previously assumed in many countries and sectors, while the risk of over-crediting is substantial. He therefore suggests that as a general rule all E- policies should be considered in both baseline-setting and additionality determination. Schneider et al. (2014) outline the following options in relation to E- policies:[44]

- No consideration of E- policies: No perverse incentives would be created if both existing and planned E- policies were not considered when setting the crediting baseline. In fact, host countries would be encouraged to introduce further E- policies to further reduce emissions below the baseline. However, the disadvantage of this option would be that the emission baseline would most likely be inflated above BAU.
- Consideration of existing E- policies, exclusion of future E- policies: A more balanced approach could involve the introduction of a cut-off date for excluding future E- policies from being considered in the setting of the crediting baseline. However the setting of a cut-off date is problematic. For example, if the cut-off point is set too early it may inflate the crediting baseline by considering E- policies that have already been adopted. Nevertheless, the option provides a positive incentive for host countries to adopt new E- policies (after the cut-off point) to reduce emissions.
- Consideration of existing and future E- policies: A robust crediting baseline would be established if both existing and future E- policies were considered (either ex-ante or ex-post), however this would most likely create disincentives to introduce E- policies as their introduction could lower the potential for credits. In addition, this option would provide greater uncertainty for investors as to when a crediting baseline would be updated.

In order to prevent the over-crediting of emission reductions, it would be a sensible approach to include current E- policies in the crediting baseline. However, accounting for future E- policies is

[44] These options are outlined in the context of a sector based crediting mechanism though they also apply to the CDM.

more problematic and warrants further research to ensure that a reasonable balance is achieved between limiting the over-crediting of emission reductions and preventing the creation of perverse incentives. Schneider et al. (2014) and Spalding-Fecher (2013) conclude that the balance should be more in favour of limiting over-crediting in the CDM or future mechanisms as they judge this risk to be greater to undermining environment integrity than from the creation of perverse incentives. Therefore, as a general rule Schneider et al. (2014) recommend that adopted policies and regulations reducing GHG emissions should be included when setting crediting baselines and policies that increase GHG emissions should be discouraged by their exclusion from the crediting baseline where possible.

3.10. Suppressed demand

One of the challenges of applying GHG accounting approaches in poor communities is that the current consumption of many household services (e.g. heating and cooking energy, lighting and potable water) may not reflect the real demand for those services. This could be a result of lack of infrastructure, lack of natural resources or poverty, particularly the high costs of these services relative to household incomes. The situation of 'suppressed demand' creates a problem for setting baselines, because the CDM rules say that the baseline scenario selected for a project should provide the same level of service and quality as the project scenario (Gavaldão et al. 2012; Michaelowa et al. 2014; Spalding-Fecher 2015; Winkler & Thorne 2002). This is clearly not the case if the project scenario provides a much higher service level, owing to low historical consumption. At the same time, the CDM rules state that "the baseline may include a scenario in which future anthropogenic emissions by sources are projected to rise above current levels, due to the specific circumstances of the host Party" (UNFCCC 2006a para. 46). This section analyzes how the concept of suppressed demand has been implemented in CDM methodologies and what the potential impacts on CER issuance as a result of the revised and new methodologies. For a more detailed conceptual explanation of suppressed demand, as well as background on previous EB decisions and guidance, see Chapter 9 of Spalding-Fecher et al. (2012).

3.10.1. Treatment of suppressed demand in approved methodologies

Table 3-10 below shows the methodologies in which suppressed demand has been explicitly considered, in three different categories. The first group is from a work plan agreed by the EB at their 67th meeting, when the EB requested that the Secretariat and relevant support panels explore how to incorporate suppressed demand. The second group is methodology revisions for which the proponent of the revision motivated the change based on the Suppressed Demand guidance. The final group is new methodologies that were developed after the approvals of the Suppressed Demand guidance and incorporated those ideas, as documented in the UNFCCC Methodology Guidebook. Of the original 10 methodologies in the EB work plan, 5 were revised or replaced, while an additional 8 methodologies fall into the second and third categories.

Note that a group of methodologies not listed here, but that implicitly recognise suppressed demand, are those addressing new large-scale power generation or industrial development. New renewable energy, natural gas or high-efficiency coal power plants are not required to show that they actually replace an existing power plant. Given that most developing countries have shortages in power supply, building a new natural-gas-fired power plant, for example, could potentially increase emissions compared to current levels. However, the accepted principle on baseline development across the CDM is that the baseline is not necessarily the same as historical emissions, but should reflect the most likely development scenario for the sector. Even in countries with chronic power shortages, it would be difficult to argue that there would be *no* capacity increases under the baseline scenario. This means that, even in these cases, CDM projects – if properly justified –

would potentially displace another alternative new plant. The determination of the alternative plant is then the subject of the methodology's baseline scenario analysis.

Table 3-10: Methodologies explicitly addressing suppressed demand or part of EB work plan on suppressed demand

Meth No.	Meth Name	Re-vised?	When	Pipeline[1)]	
				Pro-jects	PoAs
From EB67 work plan List of Methodologies					
AM0025	Alternative waste treatment processes	ACM22	EB69	127	5
AM0046	Distribution of efficient light bulbs to households	No		2	0
AM0086	Installation of zero energy water purifier for safe drinking water application	No	EB70	1	0
AM0094	Distribution of biomass based stove and/or heater for house-hold or institution	No	EB70	0	0
ACM0014	Treatment of wastewater	Yes	EB77	47	1
ACM0016	Mass Rapid Transit Projects	No		16	1
AMS I.A	Electricity generation by the user	Yes	EB69	50	17
AMS I.E	Switch from non-renewable biomass for thermal applications by the user	Not nec-essary	EB70	24	58
AMS II.E	Energy efficiency and fuel switching measures for buildings	No		44	5
AMS III.AR	Substituting fossil fuel based lighting with LED/CFL lighting systems	Yes	EB68	4	14
Additional revisions referring to Suppressed Demand					
AM0091	Energy efficiency technologies and fuel switching in new and existing buildings	Yes	EB77	0	0
AMS II.G	Energy efficiency measures in thermal applications of non-renewable biomass	Yes	EB70	45	62
AMS III.F	Avoidance of methane emissions through composting	Yes	EB67	103	20
New methodologies where EB noted Suppressed Demand					
ACM0022	Alternative waste treatment processes	New	EB69	10	0
AMS II.R	Energy efficiency space heating measures for residential buildings	New	EB73	0	0
AMS I.L	Electrification of rural communities using renewable energy	New	EB66	0	1
AMS III.BB	Electrification of communities through grid extension or new mini-grids	New	EB67	0	0
AMS III.AV	Low greenhouse gas emitting safe drinking water production systems	New	EB60/62	0	10
Total with revisions or new related to suppressed demand				**473**	**194**
Total pipeline				**11,990**	**446**[2)]

Notes: [1)] Pipeline is as of 1 January 2014. [2)] PoA DD's submitted, which may include multiple methodologies and include 23 PoAs replaced by new versions. Total number of methodology citations in all PoAs submitted is 874.

Sources: Authors' own compilation

While the proportion of project activities influenced by these methodologies is very small, a significant share of PoAs are utilising the revised or new methodologies. In terms of the quantitative impact of the revisions to methodologies to incorporate suppressed demand; however, this may only relate to projects or PoAs entering the pipeline after the revision. While project participants are allowed to update the version of the methodology that they use prior to the renewal of the crediting period, this should not make the emission reduction calculations less conservative. Given that the suppressed demand revisions could increase the baseline significantly, it is not entirely clear whether the EB would approve this revision for existing projects prior to the renewable of the crediting period (when the latest version of the methodology must be used). Because AM00025 was replaced by ACM0022 in order to address suppressed demand, none of the projects or PoAs under AM0025 (which was not used after October 2012) would be able to utilise the new suppressed demand approach embodied in ACM0022. Table 3-11 below shows the number of PoAs and Projects in the pipeline both before and after the revisions.

Table 3-11: CDM pipeline affected by suppressed demand methodologies

Meth No.	Meth Name	Total pipeline		New pipeline since revision	
		Projects	PoAs	Projects	PoAs
Revised methodologies					
ACM0014	Treatment of wastewater	47	1	0	0
AMS I.A	Electricity generation by the user	50	17	0	13
AMS III.AR	Substituting fossil fuel based lighting with LED/CFL lighting systems	4	14	3	1
AM0091	Energy efficiency technologies and fuel switching in new and existing buildings	0	0	0	0
AMS II.G	Energy efficiency measures in thermal applications of non-renewable biomass	45	62	2	18
AMS III.F	Avoidance of methane emissions through composting	103	20	7	8
New methodologies that incorporate suppressed demand					
AMS I.E	Switch from non-renewable biomass for thermal applications by the user	24	58	24	58
ACM0022	Alternative waste treatment processes	10	0	10	0
AMS II.R	Energy efficiency space heating measures for residential buildings	0	0	0	0
AMS I.L	Electrification of rural communities using renewable energy	0	1	0	1
AMS III.BB	Electrification of communities through grid extension or construction of new mini-grids	0	0	0	0
AMS III.AV	Low greenhouse gas emitting safe drinking water production systems	0	10	0	10
Total		**283**	**183**	**46**	**109**

Sources: Authors' own compilation

How the suppressed demand concepts and guidance are implemented varies significantly by methodology. With the exception of AMS III.AR, all of the methodologies use the project activity level as the baseline activity level. Only AMS III.AR defines a quantitative Minimum Service Level that is used to calculate baseline emissions. AMS I.L and AMS III.BB define an MSL, but it is only used to adjust the emissions factor for the baseline, rather than to directly calculate baseline activity levels or emissions. For AMS III.F and ACM0022, the minimum service level is qualitatively defined as having a solid waste disposal site (i.e. rather than considering the quantity of waste processed per household). What the methodologies all do, however, is to define a baseline technology that may have higher emissions than the actual current technology. For example, households may currently only use candles and kerosene hurricane lamps, and therefore have very low lighting services, but the methodologies use a kerosene pressure lamps for the baseline technology, because this can deliver the MSL for lighting services.

For the revised methodologies, the resulting baselines emissions could be substantially higher per household (Annex 8.2, Table 8-1). For example, under ACM0014, baseline methane emissions may still be considered even if the wastewater is currently not treated or stored in a way that would necessarily produce emissions (e.g. lagoons with depth less than 1 m). ACM0022 and AMS III.F have emissions factors that could be double the current practices, while for AMS I.L and AMS

III.BB, the emission factor for very small users (e.g. 50 kWh/yr) is almost 7 times the emissions factor originally used in AMS I.A for these projects.

3.10.2. Impact on CER supply

If current energy service demand is suppressed by lack of income, relatively high energy prices and/or lack of physical access, how quickly might this change without the CDM project? In other words, how long might it take for the current emissions to reach the suppressed baseline emissions? This depends on many factors, including income growth in the host communities and changes in access. Data from the World Bank's World Development Indicators (World Bank 2014), for example, shows that, at a highly aggregated level, per capita incomes in most developing regions have, indeed, increased substantially, but this is slower in low income countries. Electricity consumption per capita, however, has not shown such consistent growth in Africa, largely due to population growth outstripping energy supply growth and electrification programmes (World Bank 2014). This data cannot necessarily be applied to specific sub-regions or project areas, but does show that significant increases in energy consumption are possible in a relatively short time frame. In terms of electrification rates, these have increased relatively rapidly for key countries, rising from 25% or 30% to 60% to 80% in as little as 10 or as many as 30 years (Bazilian et al. 2011). Clearly, the level at which the minimum service level is set will also influence the risk of over-crediting, with lower service levels being more likely to reflect potential consumption in the shorter term without the CDM.

Even if the households were not to reach the minimum service levels in the near term and the emissions factors used in these methodologies is substantially higher than in traditional methodologies, the overall impact on CER generation is likely to be very small. The total CERs projected to 2020 for the methodologies in Table 3-11 after the revisions to those methodologies is approximately 17 million. Even if all of the CERs for those methodologies are considered (i.e. before and after revision), at approximately 112 million, this is still less than 1% of the entire CDM pipeline, and so does not represent a significant impact on emissions.

3.10.3. Additionality concerns

In summary, while the introduction of the concept of suppressed demand in CDM methodologies is expanding, and will have important development impacts, it is unlikely to have a major impact on the overall additionality of CDM projects. In many project areas, it is likely that the communities could reach the Minimum Service Levels during the course of the CDM project life, although this is uncertain and will depend on local circumstances. Creating an open and transparent process of setting minimum service levels, with expert input as well as input from other stakeholders, could also help to balance the risks of over-crediting with the potential increased development benefits. In addition, the application of suppressed demand principles in methodologies could be restricted to certain country groups (e.g. LDCs, under-represented countries), in which development needs are highest and the potential for over-crediting it the smallest. Even if the suppressed demand does lead to some over-crediting, the overall impact is very small, particularly if restricted geographically. More importantly, the increased contribution to sustainable development provides a strong justification for this approach to project types that address poverty and development issues.

4. Assessment of specific CDM project types

The relevant literature highlights that the likelihood of CERs representing real, measurable and additional emission reductions varies considerably among project types. Some project types do not generate revenues other than CERs. These projects have a high likelihood of being additional. Other project types are heavily promoted and/or subsidized by governments, generate significant other revenues, or their economic feasibility is hardly impacted by CER revenues. For these projects, additionality is more questionable.

Other aspects affecting the quality of CERs also vary among project types. Perverse incentives are particularly relevant for projects that generate large CER revenues compared to the cost structure of their main business (e.g. HFC-23 projects). Baselines are particularly challenging to determine in dynamic sectors with high rates of learning and innovation and penetration of new technologies over relatively short periods of time. The length of crediting is critical for project types which are implemented earlier due to the CDM incentives.

For these reasons, this chapter evaluates the ability to deliver real, measurable and additional emissions reductions for specific CDM project types. In the following, we select important project types in Section 4.1 and assess these project types in the subsequent sections.

4.1. Project types selected for evaluation

We select the project types for evaluation mostly based on their potential CER volume in the period of 2013 to 2020 according to the current CDM project portfolio. Focusing on the period of 2013 to 2020 and on the largest CDM project types in terms of potential CER volume allows the best estimation of the quality of the overall CDM project portfolio for future new demand for CERs. Moreover, the project types with the largest market share are most critical for the overall quality of the CDM.

The specific project types selected for evaluation are provided in Table 4-1. The table also shows that these project types cover a potential CER volume of 4.8 billion CERs, which corresponds to 85% of the overall CER supply potential for the period of 2013 to 2020 (Section 2.3). This ensures a large representativeness.

Table 4-1: Project types selected for evaluation

Project type	Potential CER supply 2013 to 2020 [million]	Focus areas analyzed
Wind power	1,397	Additionality, baselines
Hydropower	1,669	Additionality, baselines
Biomass power	162	Additionality, baselines, leakage
HFC-23	375	Perverse incentive, baselines
Adipic acid	257	Perverse incentives (leakage)
Nitric acid	175	Perverse incentives, baselines
Landfill gas	163	Additionality, baselines, perverse incentives
Coal mine methane	170	Additionality, baselines
Waste heat recovery	222	Additionality, baselines
Fossil fuel switch	232	Additionality, baselines
Efficient cook stoves	2.3	Additionality, baselines
Efficient lighting	3.8	Additionality
Total of all selected project types	**4,829**	
Total of all projects in the CDM portfolio	**5,671**	

Source: Authors' own compilation and calculations

4.2. HFC-23 abatement from HCFC-22 production

4.2.1. Overview

Hydrofluorocarbon-23 (HFC-23) is a waste gas from the production of hydrochlorofluorocarbon-22 (HCFC-22), which is a GHG and an ozone-depleting substance (ODS) regulated under the Montreal Protocol on Substances that Deplete the Ozone Layer. HCFCs were introduced as an alternative to the highly ozone-depleting chloro-fluorocarbons (CFCs) because of their lower ozone-depleting potential. HCFC-22 is mainly used for two purposes: as a refrigerant in refrigeration and air-conditioning appliances and as a feedstock in the production of polytetrafluoroethylene (PTFE). The production for the refrigeration and air-conditioning industry is regulated under the Montreal Protocol, whereas the production for feedstock purposes is not.

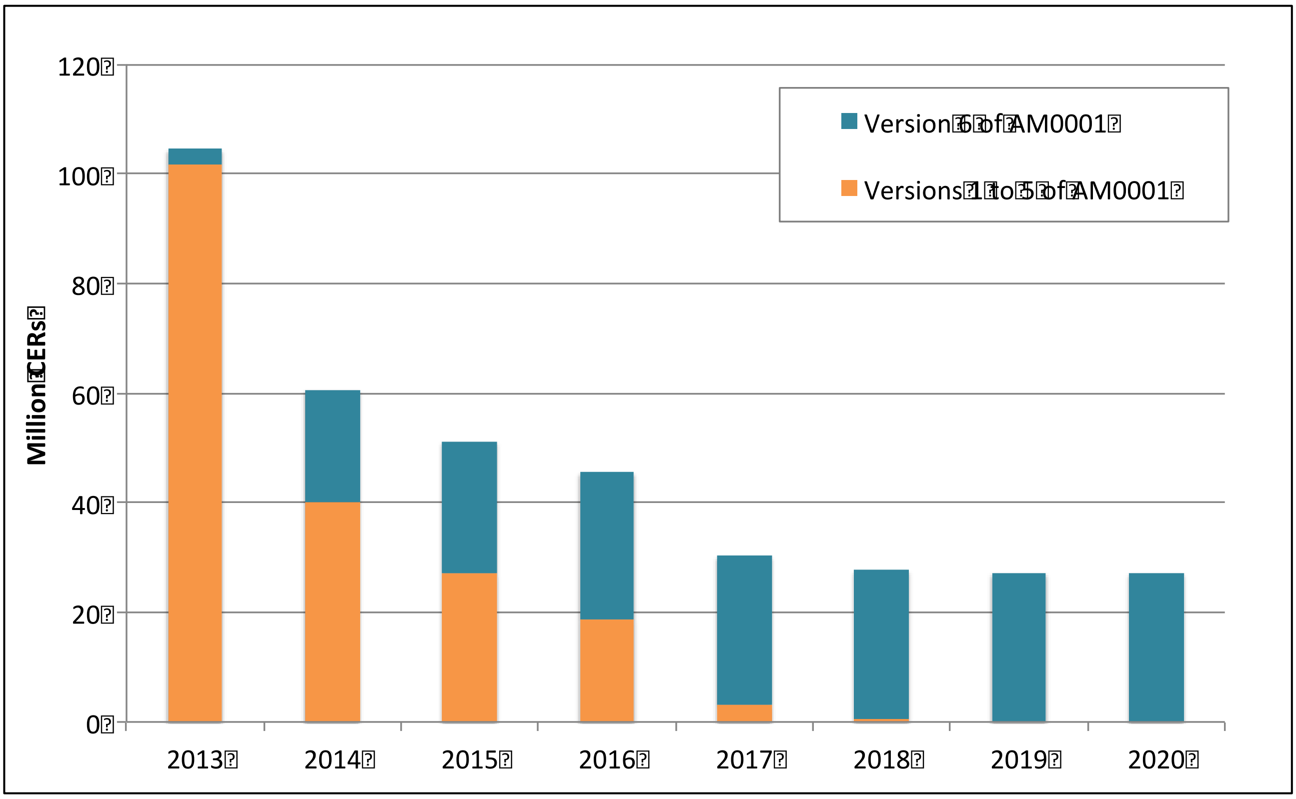
HFC-23 is a potent greenhouse gas; its global warming potential (GWP) is estimated at 14,800 for the second commitment period of the Kyoto Protocol. Emissions of HFC-23 from HCFC-22 production can be abated in two ways: a) by reducing the rate of waste gas generation (by-product rate) through process optimization and b) by capturing and destroying HFC-23 through installation and operation of high temperature incinerators. In the absence of regulations, incentives, or voluntary commitments by the industry, HFC-23 is usually vented to the atmosphere (Schneider & Cames 2014).

4.2.2. Potential CER volume

Under the CDM, 19 HFC-23 projects have been registered. Eleven projects are located in China, five in India; South Korea, Argentina and Mexico each host one project. All projects apply the baseline and monitoring methodology AM0001. In the first commitment period of the Kyoto Protocol, the abatement of HFC-23 has been the project type with the largest CER issuance: 516 million HFC-

23 CERs or 36% were issued of a total of 1.4 billion CERs by the end of 2013. The potential CER supply for the period of 2013 to 2020 is estimated using a bottom-up model based on a detailed evaluation of the information in PDDs and monitoring reports from all 19 projects (Schneider & Cames 2014). In estimating the potential CER supply we differentiate between CERs from the application of versions 1 to 5 and version 6 of the applicable baseline and monitoring methodology AM0001 due to the significant differences between these methodology versions. The potential CER supply for the period of 2013 to 2020 is illustrated in Figure 4-1; it amounts to approx. 375 million CERs for the entire period, with 191 million from the application of version 1 to 5 and 184 million from the application of version 6 of the methodology AM0001.

Figure 4-1: CER supply potential of HFC-23 projects



Sources: Authors' own compilation

4.2.3. Additionality

All versions of the applicable baseline and monitoring methodology AM0001 consider HFC-23 projects to be automatically additional, as long as no regulations to abate HFC-23 are in place in the host country. This rule seems appropriate. Prior to the CDM, none of the plants in developing countries had equipment to destruct destroy HFC-23; HFC-23 generated in the production process was vented to the atmosphere. The same holds for plants that are not eligible for crediting under the CDM because they started commercial operation after 31 December 2001. Plant operators do not have economic incentives to install HFC-23 destruction equipment, as the installation and operation does not reduce costs or generate any significant revenues other than from CERs.[45] Based on these considerations, we assess that this project type is very likely to be additional.

[45] Schneider & Cames (2014) report that plant operators could sell HF which is a by-product from flue gas treatment. However, these revenues are likely lower than the costs for HFC-23 destruction.

4.2.4. Baseline emissions

HFC-23 generation from HCFC-22 production depends on two factors: the amount of HCFC-22 production and the ratio between HFC-23 generation and HCFC-22 production, which is often referred to as 'waste generation rate'. The applicable methodology AM0001 determines baseline emissions of HFC-23 based on these two factors, by multiplying the baseline HCFC-22 production with the baseline waste generation rate.[46] How these two parameters are calculated, has evolved over time.

The approaches changed over time with a view to addressing perverse incentives which are a particular concern for the crediting of HFC-23, due to the low technical abatement costs[47] and significant profits which can accrue from CER revenues and could exceed the costs of HCFC-22 production (Schneider 2011, UNFCCC 2011b, TEAP 2005). Significant perverse incentives were observed in two JI projects in which plant operators increased the waste generation rate to unprecedented levels once methodological safeguards were abandoned (Schneider & Kollmuss 2015). Perverse incentives can arise from the CDM in the following ways:

- HCFC-22 plants could operate at a higher waste generation rate than they would in the absence of the CER revenues, leading to over-crediting;
- The amount of HCFC-22 produced at CDM plants could be higher than in the absence of the CER revenues. This could lead to over-crediting if
  - HCFC-22 production is displaced at non-CDM plants that have a lower waste generation rate than the baseline rate used at the CDM plants;
  - HCFC-22 production is displaced at plants located in Annex I countries that already are required to abate HFC-23 emissions;
  - HCFC-22 is not produced for use in applications but is vented to the atmosphere;
  - The use of HCFC-22 becomes economically more attractive due to the CDM and is increasingly used compared to other less GHG-intensive alternatives;
  - The base year emissions (2009-2010) under the accelerated phase-out under the 2007 amendment to the Montreal Protocol are higher due to the CDM;
  - The implementation of the accelerated phase-out of HCFC-22 is delayed due to the CDM.
- The HCFC-22 plants could operate longer than they would in the absence of CDM revenues. This could lead to over-crediting under the same circumstances as a higher HCFC-22 production at the plants.

Robustness and conservativeness of the methodology has significantly increased over time. Perverse incentives constitute a major challenge in versions 1 to 5, whereas the conservative approach in version 6 largely avoids and compensates for perverse incentives.

For CERs issued to projects under versions 1 to 5, the amount of over-crediting is uncertain, since it hinges strongly on assumptions on HCFC-22 production levels, HFC-23 waste generation rates and the indirect effects noted above. Munnings et al. (2016) suggest that under-crediting due to conservative baselines may have more than compensated for the potential over-crediting from perverse incentives that these baselines were intended to curb. However, Munnings et al. (2016) make several assumptions that seem rather implausible. For example, they assume that in the absence of the CDM, some plants would have produced more HCFC-22 than they did under the CDM. As a result, we do not find their arguments persuasive.

[46] Versions 1 to 5 of methodology AM0001 do not explicitly calculate baseline emissions but directly calculate the emission reductions.
[47] Schneider & Cames (2014), Appendix, provide an overview of technical abatement costs for HFC-23 destruction.

Under version 6, on the other hand, net under-crediting (or net emissions benefit) is very likely since the methodology uses an ambitious default value of 1.0% for the baseline waste generation rate and caps the amount of HCFC-22 production that is eligible for crediting in a more conservative manner (Erickson et al. 2014). However, as of 1 January 2016, no credits have been issued under version 6.

4.2.5. Other issues

Continued low CER prices could jeopardize continued abatement activities at CDM HFC-23 project sites, an unfortunate outcome given the very inexpensive abatement opportunities they provide. At the same time, the failure of the CDM market to ensure continued abatement creates the opportunity for other policies that could yield even greater net emission benefits, especially if no credits are generated that could be also used to increase emissions elsewhere. For example, China recently launched a results-based finance programme that supports HFC-23 abatement in CDM and non-CDM plants (NDRC 2015). This programme helps support HFC-23 abatement across the sector in China. However, continued abatement in other CDM-eligible countries is less certain.

There are also other means to ensure these important abatement opportunities are not lost. Emissions of HFC-23 from HCFC-22 production can be regulated through the Montreal Protocol and for new facilities that have not yet installed GHG abatement, the Protocol's Multilateral Fund (MLF) for GHG abatement can provide financial support (Schneider & Cames 2014).

Note also that continued crediting under the CDM could also create perverse incentives for policy makers not to pursue alternative policies such as these, which address emissions without yielding CERs.

4.2.6. Summary of findings

Past changes to methodologies have now improved the integrity of these projects. If they are operated they are likely to yield more emissions reductions than CERs – i.e. a net mitigation benefit. However, continued low CER prices jeopardize their continued operation in some countries.

Additionality	• Likely to be additional
Over-crediting	• Risk of perverse incentives largely addressed in most recent methodology (version 6). • Version 6 could lead to under-crediting (net mitigation benefit)
Other issues	• Low CER prices jeopardizes continued operation • Emissions could be addressed through Montreal Protocol • Perverse incentives to avoid domestic regulation

4.2.7. Recommendations for reform of CDM rules

The necessary changes in AM0001 have been implemented in recent years. No changes in CDM rules are needed.

4.3. Adipic acid

4.3.1. Overview

Adipic acid is an organic chemical that is used as a building block in a range of different products, most importantly polyamide, often referred to as 'nylon'. Other applications include the production of polyurethanes and plasticizers. Adipic acid is a globally traded commodity, with more than one-third of the production traded internationally. Nitrous oxide (N_2O) is an unwanted by-product of adipic acid production. The formation of N_2O cannot be avoided; it is the result of using nitric acid to oxidize cyclohexanone and/or cyclohexanol. Generally, the amount of N_2O generated varies very little over time and among plants.

N_2O in the waste gas stream can be abated in different ways: by catalytic destruction, by thermal decomposition, by using the N_2O for nitric acid production, or by recycling the N_2O as feedstock for adipic acid production (Schneider, L. et al. 2010). These methods typically reach an abatement level of about 90% (IPCC 2006, p. 3.30, Ecofys et al. 2009, p. 44). However, plants implemented under CDM and JI achieved significantly higher abatement levels of approx. 99% in the case of CDM and 92% to 99% in the case of JI, apparently through the strong economic incentives from the CDM and JI (Schneider, L. et al. 2010).

4.3.2. Potential CER volume

Under the CDM, four projects were registered. Two projects are located in China, one is in Brazil and one in South Korea. All four CDM plants had no abatement installed before project implementation and applied either thermal or catalytic abatement. The four implemented CDM plants cover only a part of the adipic acid production in developing countries because the applicable CDM methodology AM0021 is limited to plants that started commercial operation before 2005. Since then, five new plants are known to have started commercial operation in China; none of them abates N_2O emissions (Schneider & Cames 2014). Based on a bottom-up model used by Schneider & Cames (2014), the four CDM projects could generate about 257 million CERs in the period of 2013 to 2020.

4.3.3. Additionality

The applicable methodology AM0021 combines the approaches included in the different approaches to demonstrate additionality. Version 1 establishes three criteria for additionality demonstration: no regulations should require N_2O abatement, the project should not be common practice and it should not be economically viable. Versions 2 and 3 refer to the additionality tool and hence the investment analysis is not mandatory for additionality demonstration, as compared to version 1. Nevertheless, all four registered projects conduct an investment analysis and determine the net present value (NPV). Versions 2 and 3 also require reassessment of additionality during the crediting period if new NO_X regulations were introduced.

N_2O abatement from adipic acid production can be regarded as highly likely to be additional, for several reasons. Firstly, none of the non-Annex I countries in which adipic acid is produced have regulations in place to abate N_2O. Secondly, for thermal or catalytic destruction of N_2O, plant operators have no economic incentives to abate N_2O emissions. The abatement generates steam as a by-product; however, the cost savings or revenues are lower than the investment and operation and maintenance costs. Based on a review of PDDs and literature information, the technical abatement costs are estimated at €0.3/t CO_2e, with a range from €0.1/t CO_2e to €1.2/t CO_2e (Schneider & Cames 2014).

Thirdly, the abatement of N_2O from adipic acid production is not common practice in non-Annex I countries. In Western industrialized countries, N_2O has been abated voluntarily since the 1990s. In non-Annex I countries, only one plant in Singapore had abatement technology installed prior to the CDM (Schneider, L. et al. 2010). None of the plants commissioned after 2004, which are not eligible for crediting under the CDM, installed N_2O abatement technology.

4.3.4. Baseline emissions

Baseline emissions of N_2O are determined by multiplying the amount of adipic acid production eligible for crediting with a baseline emission factor. The methodology further estimates baseline emissions from steam generated during the catalytic or thermal destruction of N_2O. Baseline emissions from steam generation are very small compared to baseline emissions of N_2O.

The baseline emission factor is determined as the lower value between the actual rate of N_2O formation and a default value of 270 kg N_2O / t adipic acid, which corresponds to the lower end of the uncertainty range of the IPCC default value of 300 kg / t adipic acid (IPCC 2006). This approach is used in all three methodology versions and intends to exclude the possibility of manipulating the production process to increase the rate of N_2O formation. Versions 2 and 3 require the actual N_2O formation rate to be determined in two ways: 1) based on the consumption of nitric acid and the ratio of N_2O to N_2 in the off-gas, and 2) based on direct measurements of N_2O in the off-gas adjusted by a 5% discount factor to account for measurement uncertainty. As a conservative approach, the lower resulting value of the two ways is used to determine the baseline emission factor. Overall, the methodology ensures that the baseline emission factor is determined in a conservative manner. The rate of N_2O formation typically observed is higher than the default value of 270 kg / t adipic acid, which could potentially lead to under-crediting of few percentage points.

The amount of adipic acid production that is eligible for crediting is capped in all three methodology versions with a view to avoiding incentives to expand the production as a result of the CDM. Version 2 and 3 establish the cap as the highest annual production in the three years prior to the implementation of the project activity. Version 1 does not provide a procedure to determine a cap but specifies that the methodology is "only applicable for installed capacity (measured in tons of adipic acid per year) that exists by the end of the year 2004". There has been controversy about how this requirement is to be interpreted. Following a request for clarification (AM_CLA_0148), the Methodologies Panel recommended using production data from three historical years, similar to Versions 2 and 3. However, the CDM EB concluded that the panels' clarification "provides too extensive interpretation to an older version of methodology" and clarified instead that the cap should be determined as the "validated maximum daily production of adipic acid multiplied by 365 days multiplied by the operational rate".[48] This was further interpreted in a way that allowed plants to seek credits beyond their annual design capacity specified in PDDs. All four CDM projects were registered with Version 1 of the methodology. Two projects (0099 and 0116) recently renewed their crediting period, applying Version 3 of the methodology, which lead to caps that that are 14.8% and 13.9% lower than the caps applicable in their first crediting period.

While the methodology intended to avoid production shifts through caps on the amount of production that is eligible for crediting, data on adipic acid production, plant utilisation and international trade patterns suggest that carbon leakage, i.e. a shift of production from non-CDM plants to CDM plants, occurred during the economic downturn in 2008 and 2009 (Schneider, L. et al. 2010). Such production shifts do not only lead to distortions in the adipic acid market but can also lead to over-crediting if N_2O is abated in the non-CDM plants. Schneider, L. et al. (2010) estimate that carbon leakage leads to over-crediting of approx. 6.3 $MtCO_2e$ or about 17% of the CERs from adipic acid projects issued in 2008 and approx. 7.2 $MtCO_2e$ or about 21% of the CERs from adipic acid projects in 2009. These effects could thus outweigh the conservative determination of the baseline emission factor.

The lenient interpretation of historical production capacity in version 1 of the methodology considerably contributed to the carbon leakage. However, the more conservative approach for the establishment of the cap on adipic acid production in versions 2 and 3 of the methodology addresses this issue only partially. In a global economic recession, adipic acid production could fall well below historical rates of plant utilisation. Depending on the CER prices, CDM plants operators would then have significant competitive advantage over non-CDM plants, which could lead to similar produc-

[48] Report of the 48th meeting of the EB, paragraph 24.

tion shifts as observed in 2008 and 2009. As for HCFC-22 production, the underlying issue is that carbon market revenues can have a strong impact on adipic acid production costs. Carbon leakage is unlikely to occur at current market prices for CERs, but could become an issue again if CER prices increased.

4.3.5. Other issues

No other issues were identified.

4.3.6. Summary of findings

Adipic acid projects have a very high likelihood of additionality. The baseline emission factor is determined in a conservative manner that could lead to a few percentage points of under-crediting. The methodology does not include sufficient provisions to address carbon leakage. This could lead to significant over-crediting in times of higher CERs prices and when the adipic acid production capacity significantly exceeds demand.

Additio-nality	• Likely to be additional
Over-crediting	• Most recent methodology could lead to slight under-crediting • Leakage could lead to significant over-crediting in times of higher CER prices
Other issues	• None

4.3.7. Recommendations for reform of CDM rules

Based on the considerations above, we recommend revising the applicable CDM methodology as follows:

- The provisions for additionality demonstration could be simplified, as this project type can be considered to be very likely additional. We recommend considering this project type as automatically additional, as long as no regulations require N_2O abatement.
- The potential for carbon leakage should be addressed. We recommend introducing a standardized ambitious emission benchmark to determine baseline emissions. Carbon leakage would be avoided most effectively if a consistent emissions benchmark is used for all plants around the world, including plants under ETSs, and if it is set at or below the abatement level typically achieved in the industry. A standardized global emission benchmark for all adipic acid plants, regardless of policy approach or specific emission trading mechanism, could provide a level playing field for the adipic acid industry and eliminate potential economic distortions. Adipic acid production is particularly amenable to a standardized global benchmark because it is a highly globalized industry, and all plants are very similar in structure and technology (Schneider, L. et al. 2010). We recommend a level at or below 30 kg/t adipic acid, which reflects the abatement level achieved by the large majority of producers world-wide.
- If a standardized ambitious emissions benchmark is introduced, the methodology could be further simplified as measurements and calculations of the rate of N_2O formation would not be necessary.

4.4. Nitric acid

4.4.1. Overview

Nitric acid is mainly used for the production of synthetic fertilizers and explosives. In the industrial production of nitric acid, ammonia (NH_3) is oxidized over precious metal gauzes (primary catalyst) to produce nitrogen monoxide (NO), which then reacts with oxygen and water to form nitric acid. N_2O is an unwanted by-product generated at the primary catalyst. The better a primary catalyst functions, the lower the N_2O emissions. Nitric acid is produced during production campaigns of typically 3-12 months (Kollmuss & Lazarus 2010).

N_2O emissions from nitric acid production can be abated in three ways (Schneider & Cames 2014):

- **Primary abatement** prevents the formation of N_2O at the primary catalyst. According to gauze suppliers, improved gauzes could potentially lead to a 30-40% reduction of N_2O formation (Ecofys et al. 2009).
- **Secondary abatement** removes N_2O through the installation of a secondary N_2O destruction catalyst in the oxidation reactor. The abatement efficiency of the secondary catalyst is often estimated as ranging from 80% to 90%. However, in practice it varies in CDM plants from about 50% to more than 90%. Registered CDM projects achieved an average abatement efficiency of 70% (Kollmuss & Lazarus 2010, Debor et al. 2010).
- **Tertiary abatement** removes N_2O from the tail gas through either thermal or catalytic decomposition. Tertiary abatement can reduce N_2O emissions by more than 90% but involves larger investment and operating costs and more demanding technical requirements than secondary abatement. Registered CDM projects achieved an average abatement efficiency of 86% (Kollmuss & Lazarus 2010, Debor et al. 2010).

Four methodologies have been approved for N_2O abatement from nitric acid production:

- **AM0028** is applicable to tertiary abatement in plants that started commercial operation before 2006. 19 projects used the methodology. In 2013, the methodology was limited to caprolactam production in 2013, and replaced by amending the methodology ACM0019.
- **AM0034** is applicable to secondary abatement in plants that started commercial operation before 2006. 56 projects used the methodology. In 2013, the methodology was withdrawn and replaced by amending the methodology ACM0019.
- **AM0051** is also applicable to secondary abatement in plants that started commercial operation before 2006. The methodology was never used and was withdrawn in 2013. It is therefore not considered in detail in this study.
- **ACM0019** is applicable to both secondary and tertiary abatement and both existing and new plants. 26 projects used the methodology. Since 2013, this is the only valid methodology for nitric acid projects.

Table 4-2 provides an overview of the main features of and differences between the methodologies.

Table 4-2: Overview of methodologies for nitric acid projects

	AM0028	AM0034	AM0051	ACM0019
Projects	19	56	None	26
Technology	Tertiary	Secondary		Secondary and tertiary
Validity	Limited to caprolactam in 2013	Withdrawn in 2013		Valid
Applicability	Plants that started operation before 2006			Existing and new plants
Additionality demonstration	Additionality tool			Automatically additional
Baseline emission factor	Ex-post measurements	Ex-ante measurement campaign	Ex-post measurements	Emission benchmark
Cap on baseline production	Design capacity			No cap
Re-assessment of baseline scenario or additionality	In case of new NO_X regulations			Not applicable

Sources: Authors' own compilation

4.4.2. Potential CER volume

Under the CDM, 97 projects were registered and another four projects were submitted for validation as of January 2014. China is the most important host country with 44 projects. Other important countries are India (5 projects), Uzbekistan (6 projects), South Africa (5 projects), and Brazil, Egypt, Israel and South Korea which host each four projects. Among the 97 registered CDM projects, only 51 have issued CERs as of January 2014. In the current market situation, it is likely that most of the remaining 47 projects have not been implemented. Based on a bottom-up model developed by Schneider & Cames (2014), the 101 published CDM projects could generate approx. 175 million CERs in the period of 2013 to 2020. Potential new projects that have not yet been developed or published are estimated to have a potential of approx. 31 million CERs over the same period.

4.4.3. Additionality

Up to 2011, all three approved methodologies (AM0028, AM0034, AM0051) used the additionality tool to demonstrate additionality. In 2011, ACM0019 was adopted, which deems projects to be automatically additional and employs a dynamic emission benchmark to determine baseline emissions.

N_2O abatement from nitric acid production can be regarded as highly likely to be additional, for similar reasons as for HFC-23 abatement from HCFC-22 production and N_2O abatement from adipic acid production. Non-Annex I countries usually do not have regulations which address N_2O emissions from nitric acid production. Prior to the CDM, secondary or tertiary abatement is not known to have been used in non-Annex I countries and N_2O is usually released to the atmosphere. While plant operators have economic incentives to take primary abatement measures to reduce the rate of N_2O formation, they do not save any costs or generate any revenues – other than carbon market revenues – from the installation of secondary or tertiary abatement. Based on a review from PDDs and literature information, the average technical abatement costs are estimated at €0.9/t CO_2e for secondary abatement and at €3.2/t CO_2e for tertiary abatement (Schneider & Cames 2014). For these reasons, in our assessment, the approach in ACM0019 of assuming this project type automatically additional seems reasonable.

4.4.4. Baseline emissions

Baseline emissions are determined by multiplying the amount of nitric acid production with a baseline emission factor. The methodologies AM0028, AM0034 and AM0051 limit the amount of nitric acid production eligible for claiming emission reductions to the design capacity of the plant in 2005; ACM0019 has no such cap. The baseline emissions factor is determined in three different ways in CDM methodologies: through measurement campaigns conducted prior to the installation of the abatement technology (AM0034), through measurements during the crediting period (AM0028 and AM0051), and by using an emissions benchmark (ACM0019).

All three methodologies using measurements (AM0028, AM0034 and AM0051) aim to provide safeguards to avoid perverse incentives to artificially increase the rate of N_2O formation in order to increase CDM revenues (UNFCCC 2012b; UNFCCC 2013; Schneider & Cames 2014). In AM0028, the baseline emission factor is capped to the level of previous monitoring periods if project participants do not use a primary catalyst that is common practice in the region or has been used in the nitric acid plant during the last three years and if they cannot justify the use of a different catalyst. In addition, key operating conditions of the plants cannot be changed during project implementation. In AM0034, the methodology requires a new baseline measurement campaign to be conducted if the chemical composition of the primary catalyst is changed after project implementation. While these provisions aimed to avoid perverse incentives to increase the N_2O formation due to the CDM, they provide economic disincentives to plant operators to use primary catalysts that reduce the formation of N_2O, as this would lower their CER revenues and could involve additional costs for conducting a new baseline campaign (UNFCCC 2012b; UNFCCC 2013; Schneider & Cames 2014). However, advanced primary catalysts that increase the NO yield and lower the generation of the by-product N_2O are emerging in the industry. They have become widespread in Europe, are gaining market shares in other parts of the world, and have been used in a number of CDM projects prior to their start (UNFCCC 2012b). It is thus possible that some CDM projects applying the AM0034 or AM0028 methodology would, in the absence of the CDM incentives, employ more advanced primary catalysts, in particular over the time frame of three crediting periods, leading to over-crediting (UNFCCC 2012b).

The Methodologies Panel further identified that some plants using the AM0034 methodology had established baseline emission factors which are significantly above the uncertainty range of the IPCC default values and which would result in considerable economic losses for the plant operators (UNFCCC 2012b). The highest reported value from a baseline measurement campaign is 37.0 kg N_2O / t nitric acid, while the highest IPCC default value is 9.0 kg N_2O/t nitric acid, with an uncertainty range of ±40% (IPCC 2006). Such high emission factors indicate that these plants are operated at a high specific ammonia consumption. Plant operators could intentionally reduce the production efficiency during the baseline campaign in order to achieve a higher CDM baseline emission factor (UNFCCC 2012b). Moreover, while inefficient plant operation can be observed in Non-Annex I countries, it seems questionable whether the observed levels of nitrogen loss would continue over the course of three crediting periods. On the other hand, it is important to take into account that the IPCC default emission factors were estimated at times when much less information was available on N_2O formation from nitric acid plants. In particular, continuous measurements over the length of a production campaign, with increasing N_2O emissions towards the end of the campaign, were not available. The values and their assigned uncertainty should therefore not be overweighed.

To address these two issues, the CDM EB withdrew the AM0034 and AM0051 methodologies and limited the applicability of the AM0028 methodology to caprolactam plants in 2013. At the same time, the EB revised the methodology ACM0019, distinguishing the approach between plants that used AM0028 or AM0034 in their first crediting period and other (mostly newer) plants. For AM0028 and AM0034 plants up to their design capacity, the methodology uses the lower value between the historical baseline emissions during the first crediting period under AM0028 and AM0034 and a default value set at the upper end of the uncertainty range of the IPCC default value and declining by 0.2 kg N_2O/t nitric acid per year to reflect technological innovation in primary catalysts that may reduce emissions over time. This approach caps the baseline emissions particularly for those plants that have established baseline emission factors above the IPCC uncertainty range. It also reduces the maximum amount of baseline emissions that can be claimed over time to account for technological innovations in primary catalysts. For production above the design capacity and other (mostly newer) plants, the methodology uses a more ambitious emissions benchmark set at 3.7 kg N_2O/t nitric acid in 2013 and declining by 0.2 kg N_2O/t nitric acid per year, up to a level of 2.5 kg N_2O/t nitric acid in 2020 which is maintained in subsequent years.

The new approach has several advantages but also some shortcomings:

- Importantly, using default emission benchmarks – whatever the real baseline emissions from a specific plant are – fully avoids perverse incentives for plant operators not to use advanced primary catalysts that reduce the formation of N_2O. Plant operators have incentives to innovate, as this lowers their project emissions and increases the number of CERs issued;
- Using default emission benchmarks further fully avoids the risk that plant operators could intentionally increase the rate of N_2O formation during a baseline campaign in order to maximize CER revenues;
- Using default emission benchmarks can lead to over-crediting in plants that actually have lower N_2O formation rates and to under-crediting in plants that actually have higher N_2O formation rates. Both under- and over-crediting is likely to occur since the N_2O formation rate observed in CDM projects varies by a factor of 10 from 3.5 to 37.0 kg N_2O/t nitric acid, with an average value of 8.6 kg N_2O/t nitric acid (UNFCCC 2012b). Significant over- and under-crediting can have several unintended consequences (Schneider et al. 2014). Plants with a high N_2O formation rate may not be able to reduce their project emissions significantly below the emissions benchmark and may thus not be implemented – although their implementation would be possible with a project-specific baseline. Such 'lost opportunities' could increase the global cost of GHG abatement.

The overall impact on environmental integrity depends on the methodology and plant type (Table 4-3). For newer plants, the emission benchmark declining from 3.7 to 2.5 kg N_2O / t nitric acid is rather conservative and will likely lead to under-crediting for most – if not all – plants. For plants that used AM0028 or AM0034 in the first crediting period, the declining project-specific benchmark in ACM0019 is a reasonable baseline on average over all projects in our assessment; projects with higher baseline emission rates than the IPCC range will receive less CERs, while some over-crediting could occur for projects that adopt more advanced catalysts at a faster rate than the decrease of 0.2 kg N_2O / t nitric acid per year foreseen in the methodology. The use of AM0028 and AM0034 could lead to over-crediting in some instances, due to the issues identified above. Considering all plant types and methodology versions together, it seems likely that the approaches for baseline emissions overall reasonably provide for environmental integrity; the low or moderate levels of over-crediting that could occur under AM0028 and AM0034 could be compensated by significant under-crediting for newer plants applying ACM0019. Over time, the quality of CERs will increase due to the increased phase-in of ACM0019.

Table 4-3: Assessment of environmental integrity of nitric acid projects

Plant type	Metho-dology	Identified environmental integrity issues	2013-2020 CER potential	Potential for under- or over-crediting
Plants that started operation before 2006: 1st CP	AM0028 AM0034	• Perverse incentives not to adopt technologies that reduce the rate of N_2O formation • Risk of manipulation of the production process during the baseline campaign	73 million	Low or moderate over-crediting
Plants that started operation before 2006: 2nd and 3rd CP	ACM 0019	• Under-crediting for plants with higher N_2O formation rates than the IPCC range • Over-crediting for plants that adopt advanced primary catalyst technologies at faster rates	70 million	Neutral / Low over- or under-crediting
Newer plants or plants that did not use AM0028/ AM0034	ACM 0019	• None	32 million	Moderate to significant under-crediting

Sources: Authors' own compilation

4.4.5. Other issues

No other issues were identified.

4.4.6. Summary of findings

Nitric acid projects have a very high likelihood of additionality. Baseline emissions can be over- or under-credited; overall, they are likely to reasonably ensure environmental integrity for 2013-2020 CERs, with the average quality of CERs improving over time.

An important lesson learned from this project type is that the potential for technological innovation and perverse incentives was not sufficiently considered when approving the initial methodologies. For sectors that could undergo significant technological innovation, using historic data or measurement campaigns to establish a baseline for up to 21 years is debatable. The more recent ACM0019 methodology accounts for technological innovation by using an emission benchmark that declines over time.

Additio-nality	• Likely to be additional
Over-crediting	• Most recent methodologies lead to under-crediting • Overall, little risks of overall over-crediting
Other issues	• None

4.4.7. Recommendations for reform of CDM rules

No recommendations.

4.5. Wind power

4.5.1. Overview

CDM wind power projects mainly use four methodologies.[49] The vast majority of projects (more than 99% of all CDM wind projects) feed electricity into the grid.[50]

According to the UNEP DTU (2014), by the end of 2013, an overall wind power capacity of 111 GW had been installed by projects using the CDM. The main contributors to this overall capacity are China (83 GW), India (10 GW), Mexico and Brazil (both 4 GW). The other 36 countries with CDM wind power projects account for 10 GW of installed capacity in total.

Figure 4-2, Figure 4-3 and Figure 4-4 illustrate the development of wind power capacity and the use of the CDM in China, India and Brazil.[51] In China, installation of wind power capacity accelerated from 2005 onwards. A comparison of the total wind power capacity installed and the capacity installed by projects using the CDM[52] over the 2005 to 2012 period (Figure 4-2) shows that CDM projects accounted for about 90% of the total cumulated installed capacity as of 2012 (about 75 GW). In the case of India (Figure 4-3), installed capacity increased significantly between 2005 and 2012 from 1.4 GW in 2005 to more than 15 GW in 2012. CDM projects accounted for about half (51%) of the total cumulated capacity installed as of 2012. In the case of Brazil (Figure 4-4), the total cumulated installed capacity as of 2012 was much smaller (2.5 GW). The share of CDM projects in cumulative capacity was 43% as of 2012.

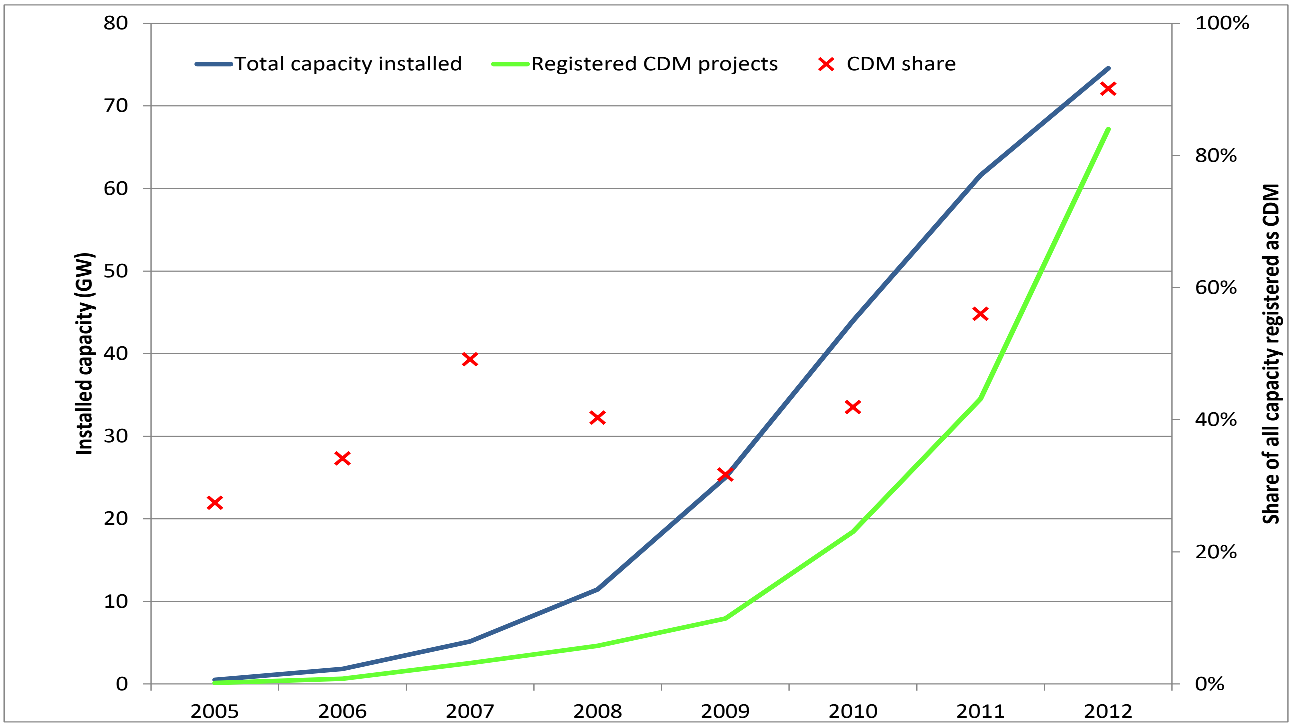
49 ACM0002, AMS-I.A, AMS-I.D, AMS-I.F.

50 ACM0002 (large scale), AMS-I.D (small scale).

51 China, India and Brazil are selected for the graphs in order to ensure comparability across chapters on renewable power generation since they are important CDM countries for hydropower and biomass power, too.

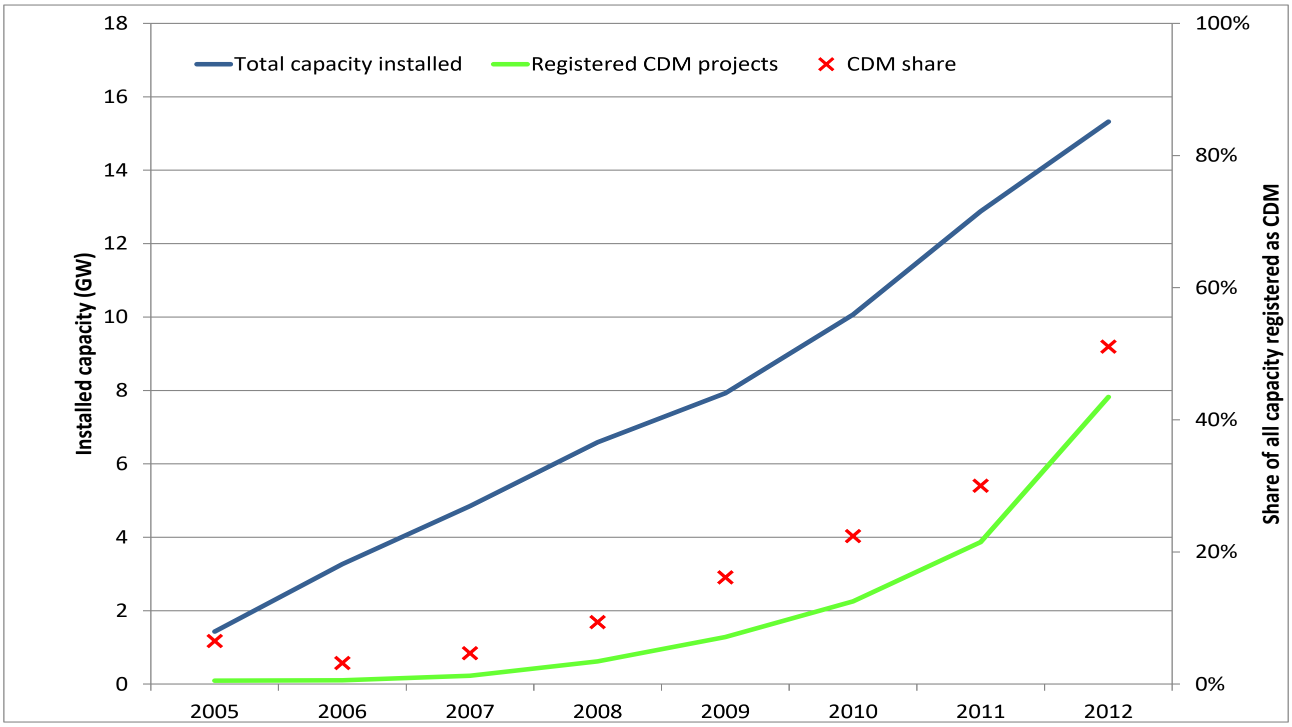
52 The total installed capacity between 2005 and 2012 is taken from the World Wind Energy Association statistics (WWEA 2015) and accumulated across the years. The installed capacity of projects using the CDM is taken from UNEP DTU (2014) and accumulated, too. The installation year is taken as the starting date of the crediting period. Cumulative values were used to illustrate the contribution of the CDM since annual values are misleading due to potential differences between the year of construction and the year in which the crediting period starts. Therefore, cumulative values provide a better picture of the general trend of the CDM share in total capacity installed.

Figure 4-2: Total cumulated wind power capacity installed in China between 2005 and 2012



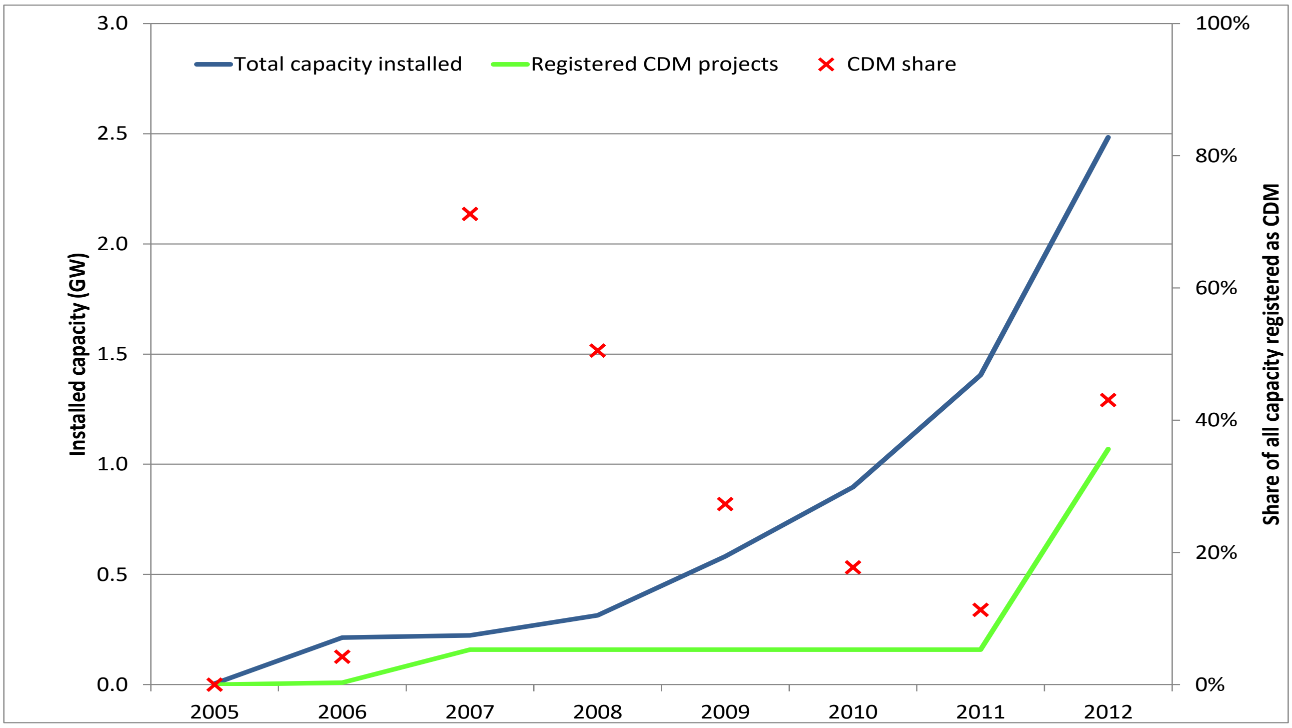
Sources: UNEP DTU 2014, WWEA 2015, authors' own calculations

Figure 4-3: Total cumulated wind power capacity installed in India between 2005 and 2012



Sources: UNEP DTU 2014, WWEA 2015, authors' own calculations

Figure 4-4: Total cumulated wind power capacity installed in Brazil between 2005 and 2012



Sources: UNEP DTU 2014, WWEA 2015, authors' own calculations

4.5.2. Potential CER volume

According to our own estimates, registered CDM wind power projects have the potential to issue 3.5 billion CERs by the end of their respective crediting periods, of which 1.4 billion CERs fall in the period from 2013 to 2020 (Table 2-1). CERs from wind power account for about one quarter of the total CER issuance potential.

4.5.3. Additionality

Large-scale wind power projects apply the methodology ACM0002 which requires using the "Tool for the demonstration and assessment of additionality" to demonstrate additionality.[53] In this tool, the investment analysis is one of the approaches for demonstrating additionality. Most CDM wind power projects use investment analysis. The tool for small-scale projects ("Methodological tool. Demonstration of additionality of small-scale project activities"[54]) requires "an explanation to show that the project activity would not have occurred anyway due [...] to barriers", among which one of the most important barriers is the so-called 'investment barrier', which generally features a similar rationale as for the investment analysis of large-scale projects.

Section 3.2 describes the general criticism associated with the investment analysis and Section 2.4 assesses for different project types the impact of CER revenues on their economic performance. According to these analyzes, for wind power projects, CER revenues lead to an increase in the internal rate of return (IRR) of two to three percentage points. An analysis by the World Bank finds that "the incremental IRR from future carbon revenues in renewable energy projects, taking the World Bank's projects as an example, is quite low" (Carbon Finance at the World Bank 2010). In

[53] Current version 07.0.0 (EB 70, Annex 8).
[54] Current version 10.0 (EB 83, Annex 14).

this analysis, the incremental IRR for renewable energy projects amounts to 1.7% for a purchase period of 10 years and an assumed CER price of $10/t. Another analysis finds that “wind, hydro and biomass projects experience only a small increase in profitability through CDM” and that “the change in profitability caused by regional variables is greater than the CDM’s impact for wind, hydro and biomass”[55] (Schneider, M. et al. 2010). From these analyzes, it can be concluded that the CDM impact in the profitability of wind power plants is generally relatively low and that the ‘signal’ provided by the CDM is usually much smaller than the ‘noise’ of national and regional variations in other parameters.

In addition, many countries have set up domestic support schemes in order to promote the increased use of renewables. Spalding-Fecher et al. (2012) provide an overview of several important support incentives for renewable energy generation in major CDM countries (such as China and India) and find “that national policies on electricity tariffs for renewable power could be a more important driver of the viability of wind, hydropower and biomass projects than the CDM is.” In the case of wind power plants in China, Bogner & Schneider (2011) point out that “the wind power boom in China is mainly driven by favourable policies and not by the CDM” and that “the majority of projects would most likely have been implemented without the CDM”. Liu (2014) elaborates on the links between the CDM and national policy in the case of wind power development in China. He finds that a decreasing national feed-in tariff can increase “CDM-supported installed capacity because more projects may comply with CDM requirements as their financial returns remain below the predefined additionality threshold”, which indicates that there is a clear interference between national policy development and the additionality requirements of the CDM. He also finds that “the reduction of technology costs combined with an increasing local manufacturing capacity has paved the way for a scaled-up deployment of wind capacity” (ibid.), which indicates that other factors than the CDM were important in the significant growth of wind power in China. However, he concludes that the CDM “effect on wind technology diffusion [...] is more than twice as high as that of technology cost and industrial policy” (ibid.). He also finds that “while domestic policies must be the engine for large-scale clean energy investments in developing countries, the international carbon offset policy can help that engine run faster, but only if the engine is running” (ibid.). For India, in comparing wind power projects registered under the CDM with those without such support, Dechezleprêtre et al. (2014) find that, “all other things being equal, CDM wind farms tend to be larger, to benefit from higher feed-in-tariffs, and to be located in windier areas, three factors which increase profitability.” According to this analysis, there is “serious evidence of non-additionality of the CDM” (ibid.). He & Morse (2013) find that “Chinese power prices are either tightly controlled by state regulators or are distorted by the presence of large state owned enterprises (SOEs)” and this leads to the conclusion that “IRR-based additionality tests are fundamentally incompatible with state-controlled power pricing regime”.

Furthermore, investment costs for wind power generators have decreased significantly in recent years, which results in wind power featuring (in many cases) competitive levelited costs of electricity in comparison to new fossil-fired power plants (IRENA 2015; ISE 2013). In addition, IRENA (2015) also shows that specific investments costs for onshore wind power plants are significantly lower in China and India than in OECD and ‘rest of the world’ countries. Similarly, Schmidt (2014) finds that the risk associated with low-carbon investment is higher in some parts of the world than in others. In an analysis for industrialised and low-income countries (using typical values for costs of capital in these countries), he finds that due to the higher cost of capital in low-income countries, levelized costs of electricity for onshore wind power plants could be as much as 46% higher than in low-risk countries. Altogether, the available information indicates that the profitability of wind power

55 In this analysis, regional factors are the electricity tariff, the load factor and the discount rate.

plants has generally improved. However, there is also a significant dependence of the profitability on regional circumstances.

Overall, due to the limited impact of CER revenues on the profitability of wind power plants, the widespread introduction of domestic support schemes and the significant decrease of wind power costs, we consider the additionality of wind power projects as generally questionable in the context of the CDM, at least for countries with support schemes, low investment costs for wind power and low investment risks.

4.5.4. Baseline emissions

Baseline emissions of CDM wind power projects feeding electricity into the grid include CO_2 emissions from fossil-fired power plants that are displaced due to the project activity. In most cases, the corresponding baseline CO_2 emission factor is estimated using the "Tool to calculate the emission factor of an electricity system"[56] (Box 4-1).

Box 4-1: The grid emission factor tool

The grid emission factor is calculated as the "combined margin (CM), consisting of the combination of operating margin (OM) and build margin (BM)".[57] According to the tool, "the operating margin is the emission factor that refers to the group of existing power plants whose current electricity generation would be affected by the proposed CDM project activity. The build margin is the emission factor that refers to the group of prospective power plants whose construction and future operation would be affected by the proposed CDM project activity."

In the tool, several approaches for estimating the combined margin are presented, depending on the specific conditions of the project and data available. In general, the approach of using a combination of OM and BM, depending on the type of project, is appropriate. It suitably reflects that CDM projects could have short-term impacts on the dispatch of power plants and long-term impacts on the power plants built, and different weights for the OM and the BM can be applied (depending on the crediting period and on whether it relates to a project using intermittent or non-intermittent sources), which also can be considered appropriate. A number of specific issues arise from the tool:

In many cases, so-called low-cost and must-run power plants are not considered in the calculation of the CO_2 grid emission factor, which may lead to higher baseline emissions per amount of electricity produced. Neglecting low-cost/must-run power plants, such as renewables or nuclear power, may generally be considered adequate for the estimation of the operating margin (since low-cost/must-run power plants can be expected to be running irrespective of any other power plant in the system). However, an increasing share of renewables (e.g. wind or solar) in the system may lead to a situation in which renewable power generation is at the margin in some hours, i.e. an additional kilowatt hour of renewable electricity does not displace fossil fuels in that hour. In some countries, for example, wind power plants are switched off when electricity supply exceeds demand in order to ensure a stable electricity system. Furthermore, 'low-cost' power plants are not clearly defined and some of them may be dispatchable (such as biomass). Overall, the provision of excluding low-cost/must-run power plants may lead to an overestimation of baseline emissions.[58]

[56] Current version 04.0 (EB 75, Annex 15).

[57] AMS-I.D, version 17 (EB 61, Annex 17).

[58] It has to be noted, however, that in the case the country has a large share of low-cost/must-run power plants (more than 50%), e.g. hydro, the simple adjusted operating margin has to be used. In that case, whenever hydro electricity provides sufficient electricity to cover the load demand in a certain hour, this hour is counted as not emitting. This leads to lower baseline emission factors overall than the simple operating margin. The implicit assumption is that water would be spilled in that hour if additional (i.e. CDM) power

Also, both the operating and the build margin approaches are based on historical production and installation data if the option of determining the grid emission factor at the validation stage (ex-ante) is chosen. The resulting baseline grid emission factor is then kept constant throughout the crediting period and only updated at the renewal of the crediting period. This approach does not reflect the general trend towards an increasing share of less-emitting power sources in the electricity mix of many countries. It is oriented to past power systems (backward-looking perspective) rather than to the actual power systems during the crediting period with a higher penetration of renewables (forward-looking perspective). This is especially problematic in countries with a rapidly changing or expanding electricity system. In countries with a growing share of renewable energy capacities, this approach may lead to an overestimation of baseline emissions. However, due to the long-lived capital stock in the electricity sector, changes of the grid emission factor are only gradual (i.e. take several years) in case the power system as a whole is not expanding fast. An advantage of using historical data is that it relies on observed and objective information, whereas scenarios for the future development of the power system may be prone to uncertainty and use of unrealistic assumptions.[59] Therefore, the determination of the grid emission factor based on historical data is not considered problematic per se but should be adjusted to account for trends in the sector.[60] Another option for determining the grid emission factor is the ex-post determination during monitoring. This approach is certainly adequate since it reflects the current state of the power sector.

With regard to the build margin, CDM projects are generally excluded from the estimation of the CO_2 emission factor. CDM projects only need to be gradually included if they comprise a significant share of power plants built in the last ten years. This approach can generally be considered adequate, especially in countries with an already significant share of renewable electricity generation or promotional policies for renewables in place, in which case a neglect of CDM projects in the build margin would not be a plausible representation of what would have happened in the absence of the project. This approach therefore addresses the risk of over-estimating baseline emissions in countries with a large share of CDM projects.

The quality of input data in calculating the grid emission factor is also important. In analysing grid emission factors provided by different DNAs, Michaelowa (2011) finds “that most of the documents provided by the DNAs do not allow an external observer to judge whether the data has been collected correctly” and that “there are clear indications that the grid emission factors, as well as the coal power plant benchmarks, have been overestimated both in China and India.” In some countries, the governments established grid emission factors, and DOEs apparently used the values without validating whether they comply with the methodological requirements under the CDM. In order to address this issue, Michaelowa (2011) recommends, inter alia, an “independent validation of grid EF”. Recently, few grid emission factors are submitted as standardized baselines which ensures independent validation by a DOE or the UNFCCC secretariat.

Furthermore, the tool provides several default values for parameters such as the electric efficiency of power plants. The values provided can be considered quite conservative, i.e. they assume rather high electric efficiencies. For those countries using the default values, this may lead to an under-estimation of baseline emissions.

generation is available. However, some countries do not only have run-of-river hydro power plants (for which case, the assumption of spilling water may be reasonable), but water may also be stored in large reservoirs and thus used at a later stage. In this regard, the estimation of baseline grid emissions for countries with a large share of low-cost/must-run power plants can be considered conservative, i.e. tending to under-estimate baseline emissions. However, it has to be noted that less than 5% of CDM projects used this approach for estimating the grid emission factor.

59 E.g. assuming that there would be a significant increase of coal-fired power generation without straightforward evidence.

60 For example, trends in a changing composition of the electricity grid or the grid emission factor observed in recent years could be considered and extrapolated for future years. Similar approaches are used in a number of other CDM methodologies.

The overall emissions impact of wind power plants also depends on other factors. Firstly, the upstream emissions from wind power, such as for construction, are relatively low (about 10 g CO_2e/kWh (IPCC 2014)); for most countries they are likely to be lower than upstream emissions from fossil fuel use displaced in grid power plants. Ignoring upstream emissions is therefore a conservative assumption. Secondly, an increasing uptake of wind power plants due to the CDM may lead to decreasing costs for wind power generation, which in turn could contribute to a higher uptake of wind power. This positive spillover effect is, however, difficult to estimate, in particular with regard to any emissions outcome. Thirdly, the length of the crediting period may lead to under-crediting if wind power plants are operated longer than the crediting periods.[61] However, many wind power plants are expected to operate for about 20 years and about three quarter of wind power projects have selected a renewable crediting period of up to 21 years. Further aspects of potential over- and underestimation of baseline emissions are described in (Erickson et al. 2014).

Overall, we conclude that the current approach for estimating emission reductions from CDM wind projects is largely suitable. Methodological assumptions lead to both over- and under-estimation of emission reductions but can be considered appropriate for estimating baseline emissions of CDM wind projects.

4.5.5. Other issues

No other issues were identified.

4.5.6. Summary of findings

Additio-nality	• **CER revenue** has only a **limited impact** on profitability of wind power plants • **Support schemes** often exist and are a main driver for wind power development • **Investment costs have decreased significantly in recent years,** making wind power in some cases **competitive with fossil generation (LCOE)** • Wind power is already **widely used** in large CDM countries (e.g. China, India)
Over-crediting	• Methodological assumptions may lead to both over- and under-crediting; no clear-cut conclusion on whether over- or under-crediting occurs overall
Other issues	• None

4.5.7. Recommendations for reform of CDM rules

Due to our finding of an overall questionable additionality of wind power projects, we recommend that this project type is generally no longer eligible for new projects under the CDM. As an exception to this rule, countries with significant technological and cost barriers[62] may be allowed to further use the CDM for implementing wind power plants.

With regard to the estimation of baseline emissions, we recommend the following:

- The CDM EB should ensure that grid emission factors are always verified by designated operational entities (DOEs);

[61] For a discussion of the effects of the crediting period, refer to Section 3.5.

[62] Such as transaction costs, e.g. due to the non-availability of technical knowledge in the country, or risk premiums in low-income countries. Least-developed countries could, for instance, be included in the list of eligible countries. Furthermore, the market share of wind power could be used to establish eligibility since it could be considered an indicator for barriers in the country.

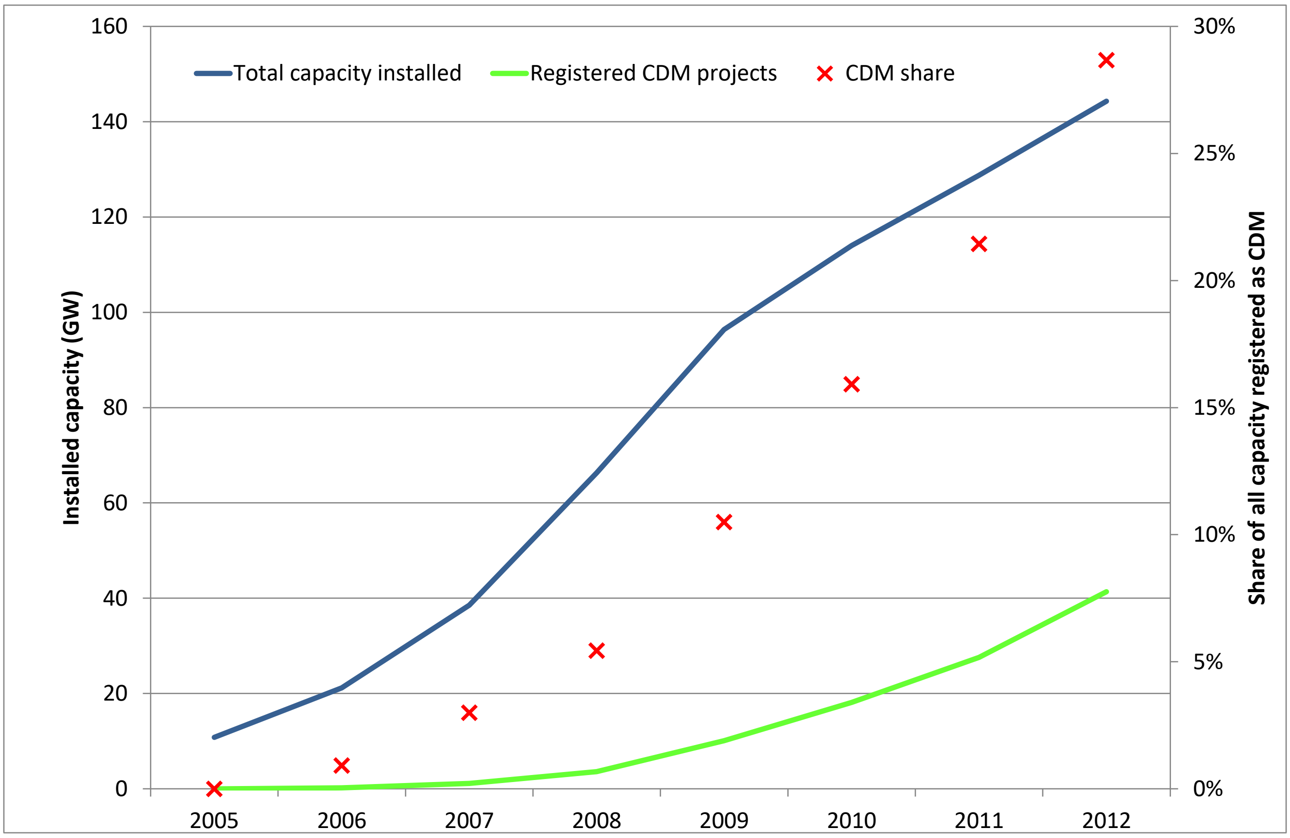
- The provisions for low-cost/must-run plants should be reviewed, including a clear definition of such plants and provisions which ensure that such plants are included in the operating margin if they are at the margin of the dispatch at any time;
- The grid emission factor tool should be revised to reflect trends in the composition of the power sector over time.

4.6. Hydropower

4.6.1. Overview

CDM hydropower projects mainly use two methodologies.[63] According to the UNEP DTU (2014), by the end of 2013, an overall hydropower capacity of 92 GW had been installed by projects using the CDM. The main contributors to this overall capacity are China (58 GW), Brazil (12 GW), followed by Vietnam and India (6 GW each). The other 44 countries with CDM hydropower projects account for 11 GW of installed capacity in total.

Figure 4-5: Total cumulated hydropower capacity installed in China between 2005 and 2012



Sources: UNEP DTU 2014, Platts 2014, authors' own calculations

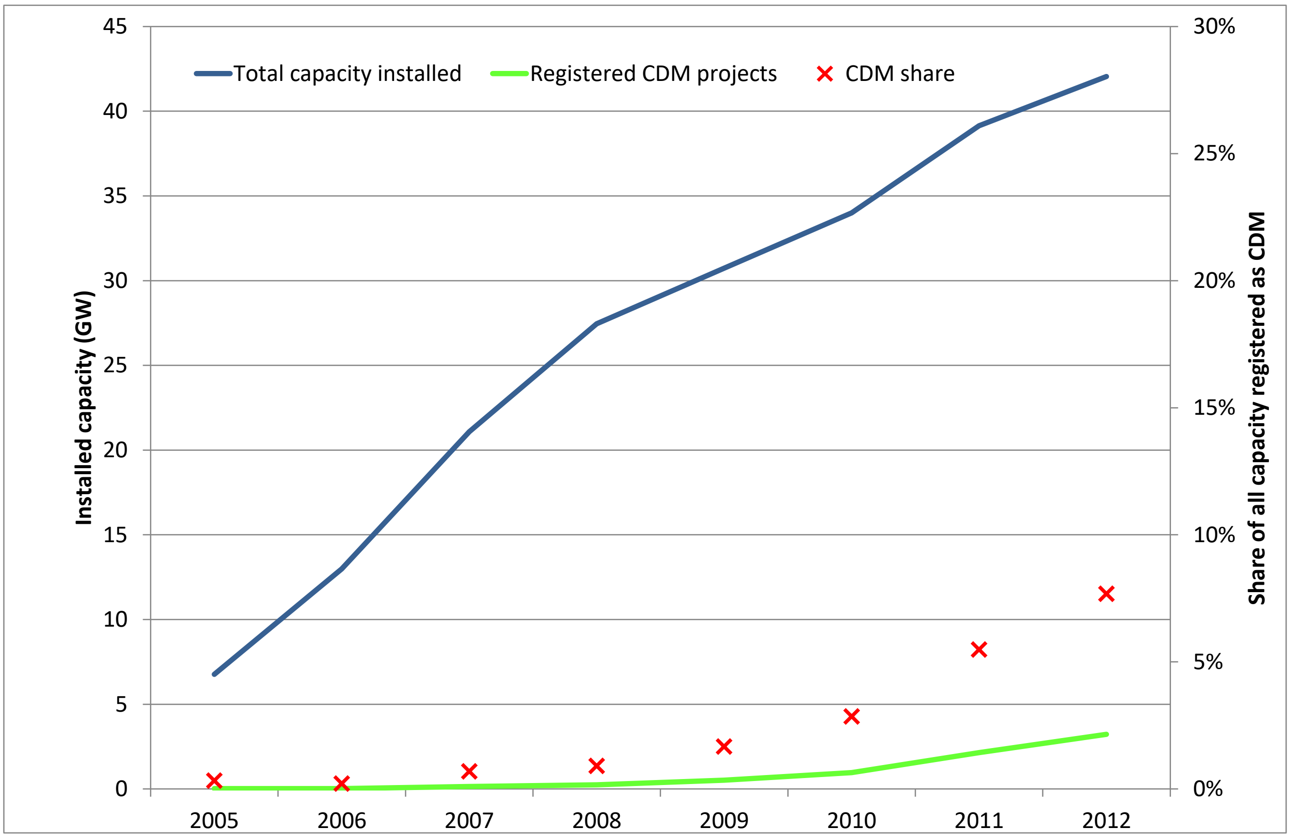
As for wind power, Figure 4-5, Figure 4-6 and Figure 4-7[64] illustrate the development of hydropower capacity and the use of the CDM in China, India and Brazil. In all three countries, hydropower has played an important role for many decades. Significant capacity has been installed without the CDM. Hydropower may therefore be considered common practice in all three countries.

[63] ACM0002, AMS-I.D.
[64] Cf. footnote 51.

In China, the cumulated installed capacity in 1990 amounted to approx. 25 GW. A comparison of total hydro capacity installed and the capacity installed by projects using the CDM[65] over the 2005-2012 period (Figure 4-5) shows that there were no CDM projects until 2005, even though capacity additions in that year amounted to 11 GW. As of 2012, the share of CDM projects was 29% of total installed capacity.

In the case of India (Figure 4-6), the cumulated installed capacity in 1990 amounted to approx. 19 GW. Almost 7 GW of capacity was added in 2005 alone, with the CDM covering only a negligible share. After the introduction of the CDM, only a small share of hydropower projects used the CDM, with the CDM accounting for about 8% of total cumulated installed capacity[66] as of 2012.

Figure 4-6: Total cumulated hydropower capacity installed in India between 2005 and 2012



Sources: UNEP DTU 2014, Platts 2014, authors' own calculations

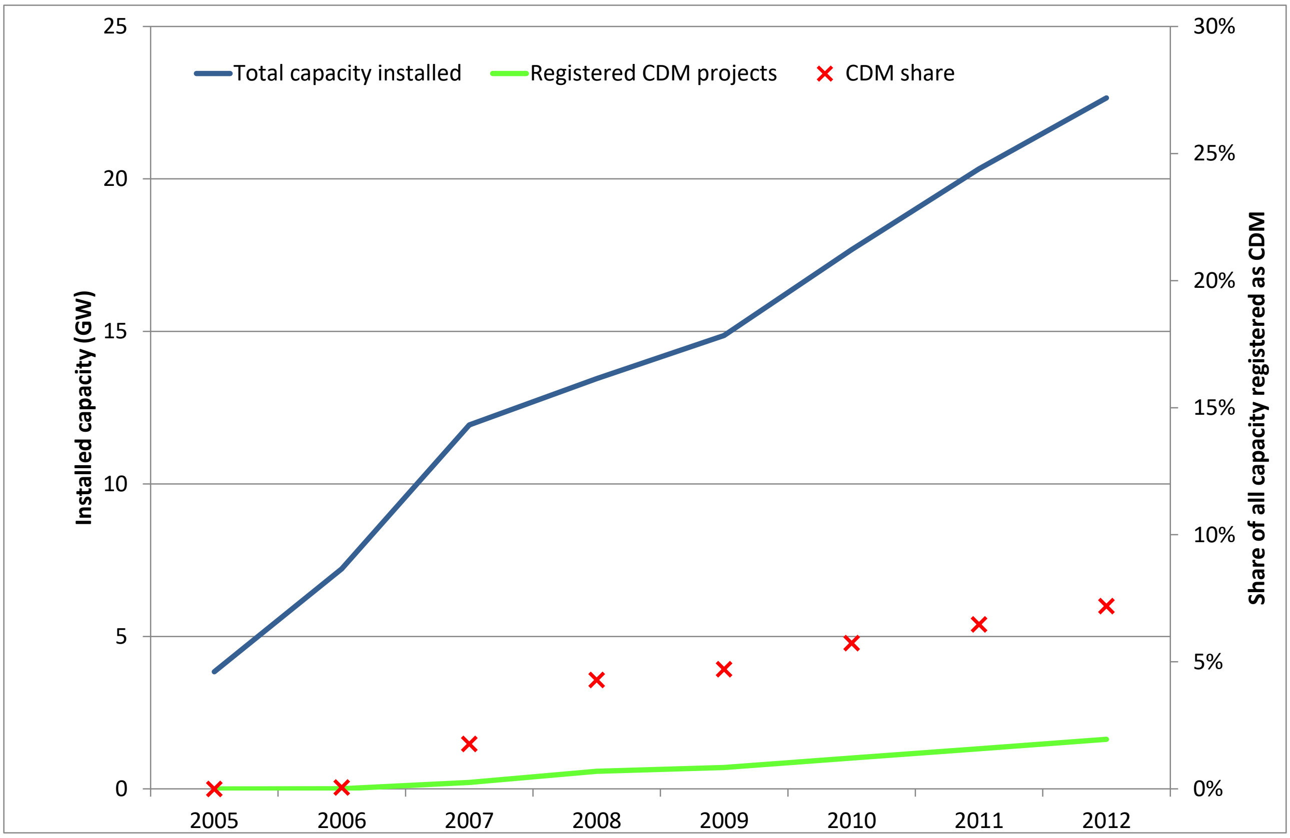
In the case of Brazil (Figure 4-7), the cumulated installed capacity in 1990 amounted to approx. 53 GW. Almost 4 GW of capacity was added in 2005, with no CDM projects being registered in that year. Even after the introduction of the CDM, only a small share of hydropower projects used the CDM (approx. 7% of total cumulated installed capacity[67] as of 2012).

65 The total installed capacity between 2005 and 2012 is taken from the Platts database and accumulated across the years. The installed capacity of projects using the CDM is taken from the UNEP DTU (2014) and accumulated, too. The installation year is taken as the starting date of the crediting period. See Section 4.5 for the rationale of using cumulative data.

66 Between 2005 and 2012.

67 Between 2005 and 2012.

Figure 4-7: Total cumulated hydropower capacity installed in Brazil between 2005 and 2012



Sources: UNEP DTU 2014, Platts 2014, authors' own calculations

4.6.2. Potential CER volume

According to our own estimates, registered CDM hydropower projects have the potential to issue 4.2 billion CERs by the end of their respective crediting periods, of which 1.7 billion CERs fall in the 2013-2020 period (Table 2-1). CERs from hydropower account for approx. 30% of the total CER issuance potential.

4.6.3. Additionality

Generally, the same methodologies and additionality rules apply as for wind power (Section 4.5.2). Hydropower CDM projects primarily use investment analysis to demonstrate additionality.

The analysis in Section 4.6.1 demonstrates that hydropower plants have been constructed for a long time in many countries, which suggests that the technology may be regarded as common practice in many countries. In many cases, especially large hydropower plants were established without subsidies, which is demonstrated by the uptake of hydropower many years ago (Section 4.6.1). In the case of small hydropower (SHP) plants in China, Bogner & Schneider (2011) find that "apparently, smaller SHP plants face stronger barriers despite the government's commitment to SHP development" and that "an especially remote location, an inappropriate feed-in tariff or banks that deny loans can be possible barriers". Therefore, they conclude that "the CDM may have played a certain role for some SHP project developments" (ibid.). However, they argue that "investment in SHP stations between 20 and 50 MW appear more feasible without the CDM" (ibid.). Moreover, according to their analysis "medium and large hydropower has witnessed considerable growth a long time before the CDM even existed, which makes it difficult to justify that new projects can only be implemented with the help of the CDM. In conclusion, our analysis suggests that the CDM is for most projects not an important factor for investment decisions in the medium and large hydropower plants. It appears likely that most projects would have been implemented in any case, i.e. without the CDM".

The impact of CER revenues on profitability is, at three to four percentage points, somewhat larger than for wind power (Section 2.4), mostly due to a higher plant utilization than for wind power. However, the increase in profitability due to CDM revenues is still relatively small compared to other project types[68]. Also, in many cases, hydropower generally features competitive levelized costs of electricity in comparison to new fossil-fired power plants (IRENA 2015; ISE 2013).

Overall, due to the fact that hydropower is common practice in many countries, the limited impact of CER revenues on the profitability of hydropower plants and the competitiveness of hydropower with fossil electricity generation in many cases, we consider additionality of hydropower projects as questionable in the context of the CDM, especially for large hydropower.

4.6.4. Baseline emissions

Hydropower projects largely use the same methodological approaches for baseline emissions as wind power plants, and hence the same conclusions apply with regard to different aspects of over- or under-crediting. Few differences should be noted with regard to the emission impacts: Hydropower projects have, on average, somewhat higher upstream emissions for their construction (approx. 20 g CO_2e/kWh related to the "infrastructure & supply chain emissions" according to (IPCC 2014)), which, however, are still lower than typical upstream emissions from fossil use in the baseline. Thus, ignoring upstream emissions is still conservative. More importantly, the lifetime of hydropower can be significantly longer than the maximum crediting period under the CDM (21 years), which adds to the conservatism of the estimation of emission reductions for hydropower plants. In this regard, over the plants' lifetime, overall emission reductions may be rather under-estimated than over-estimated.

4.6.5. Other issues

In addition to baseline emissions, project CH_4 emissions ensuing from hydro reservoirs are considered under the CDM. The ACM0002 methodology uses the power density, which is defined as the installed hydro capacity divided by the reservoir surface, as an indicator of whether CH_4 emissions from reservoirs need to be considered. CDM projects with a power density below 4 W / m^2 are not eligible and projects with a power density between 4 and 10 W / m^2 have to estimate methane emissions, using a default emission factor of 90 g CO_2e/kWh. According to (IPCC 2014), methane emissions from "currently commercially available technologies" amount to 88 g CO_2e/kWh, however, the bandwidth is quite large. However, according to (Fearnside 2015), the default emission factor of 90 g CO_2e/kWh refers "only to bubbling and diffusion from the reservoir surface and" is an underestimate "of hydropower impact because these values ignore the main sources of methane release: the turbines and spillways". Overall, he finds that "tropical hydroelectric dams themselves emit more greenhouse gases than are recognized in CDM procedures". It can therefore be concluded that the current methodological rules under the CDM may lead to a potential underestimation of methane emissions from hydropower.

[68] It has to be noted, however, that the range of operating hours and investment costs of hydro power plants depends quite strongly on plant-specific conditions, for which reason the contribution of the CDM to overall profitability may be higher in some cases and lower in others.

4.6.6. Summary of findings

Additio-nality	• **Common practice** in many countries • **CERs** have only a **moderate impact** on profitability • In many cases **competitive with fossil generation** (LCOE)
Over-crediting	• Methodological assumptions may lead to both over- and under-crediting; over the lifetime of the project, emission reductions are likely to be underestimated
Other issues	• Potentially significant **methane emissions** from reservoirs which may not be fully reflected by CDM methodologies

4.6.7. Recommendations for reform of CDM rules

We recommend excluding large scale hydropower projects from being eligible under the CDM, due to the overall questionable additionality. A similar recommendation is made by (Erickson et al. 2014), who, in an analysis of the net mitigation impact of the CDM conclude "that excluding large scale power supply projects from the CDM could help increase the net mitigation impact of the CDM, as well as steer investment towards projects that are truly dependent on CER revenues". We recommend that small-scale hydropower projects with significant technological or cost barriers[69] may be allowed under the CDM.

With regard to the estimation of baseline emissions, our recommendations for wind power plants (Section 4.5.7) also apply here. In addition, the provisions with regard to the estimation of methane emission from hydropower should be revised to address the potentially significant magnitude of these emissions.

4.7. Biomass power

4.7.1. Overview

CDM biomass power projects mainly use four methodologies.[70] According to the UNEP DTU (2014), by the end of 2013, an overall biomass energy[71] capacity of 8.5 GW was installed by projects using the CDM. The main contributors to this overall capacity are China (3.7 GW) and India (2.1 GW), followed by Brazil (0.9 GW). The other 36 countries with CDM biomass projects account for 1.8 GW of installed capacity in total.

Generally, data availability is not sufficient to judge the magnitude of biomass capacity installed prior to the introduction of the CDM. Moreover, due to inconsistencies in the data, no meaningful comparisons can be made between projects installed with and without the use of the CDM.

4.7.2. Potential CER volume

According to our own estimates, all registered CDM biomass power projects have the potential to issue 0.36 billion CERs by the end of their respective crediting periods, of which 0.16 billion CERs fall in the period from 2013 to 2020 (Table 2-1). CERs from biomass power account for about 3% of the total CER issuance potential.

[69] The criteria need to be further specified. See also footnote 62.
[70] ACM0006, AM0015, AMS-I.C, AMS-I.D. It has to be noted, however, that the AM0015 methodology was only used for CDM projects registered in the early phase of the CDM.
[71] Including different energy forms from biogenic sources.

4.7.3. Additionality

For large-scale projects (according to ACM0006), the identification of the baseline scenario and the demonstration of additionality are conducted in parallel.[72]

With regard to the investment analysis, due to the diversity of project types, no overall conclusions can be drawn. Also, analysis available in the literature is quite limited, in contrast to wind and hydropower. On average, the impact of CER revenues on the profitability of projects is with about eight percentage points considerably larger than for wind or hydropower plants, making additionality claims more plausible (Section 2.4). The profitability of projects without CER revenues is, with an average IRR of approx. 5%, also lower than for wind (approx. 7%) and hydro (approx. 8%). The higher impact of the CDM is mostly due to the claiming of avoided methane emissions in many projects, which significantly improves the profitability of CDM biomass projects.

The investment analysis, which is applied by many projects, involves considerable uncertainty due to the variability of the biomass price, which strongly affects the profitability of biomass plants. In addition, many countries have set up domestic support schemes in order to promote the increased use of renewables, including ones for biomass power generation. In addition, biomass power is not a completely new technology, but is rather based on the technology of thermal power plants in general and has been used extensively in some industries and countries before (e.g. in the sugar cane industry in Brazil), which indicates that the technology has been profitable in the past in some instances. This is underpinned by the fact that biomass power features competitive levelized costs of electricity in comparison to new fossil-fired power plants (IRENA 2015; ISE 2013).

Only a few scholars explicitly deal with the additionality of CDM biomass power projects. Stua (2013) finds that, in the case of China, the national feed-in tariff made "most of the biomass-fuelled power plants [cost-competitive] against [...] coal-fired plants".

Overall, based on the information presented above, we cannot clearly conclude on the likelihood of the additionality of biomass power plants.

4.7.4. Baseline emissions

As outlined in Section 4.7.2, the identification of the baseline scenario and the demonstration of additionality are conducted in parallel, considering a wealth of different options.

One key requirement in methodologies for using biomass residues is that the biomass residues would not be used in the absence of the project and would be left to decay (sometimes aerobically, sometimes anaerobically also claiming CH_4 baseline emissions). This requirement is appropriate and important due to potential competing uses for the biomass. If the biomass residues were used in the absence of the project for other purposes, there may be no emission reductions, since the diversion of biomass from one use to another due to the CDM may lead to increased emissions elsewhere. If CDM projects only divert the use of biomass residues but do not result in more biomass residues being collected which would otherwise decay, this may also lead to indirect land-use change, i.e. due to the increased use of biomass (residues), previous demand may be covered by drawing on biomass from other areas, thus leading to decreasing carbon stocks there.

Methodologies vary with regard to how they assess that the biomass residues are indeed 'available in abundance' and that decay is a likely scenario. In older versions, the abundance of biomass residues had to be monitored annually, while in newer versions this is only checked once at the project start and at the renewal of the crediting period.

[72] For small-scale biomass projects, the same additionality rules as for wind power apply (Section 4.5.2).

In general terms, there is an increasing demand of biomass for different uses (food, raw materials, energy) worldwide. This means that biomass residues (in many cases) either already have or will likely have a price in the future. As a consequence, the demonstration that biomass residues would otherwise be (completely) left to decay needs to take current market developments into account. For this reason, a regular checking of the abundance of biomass residues through monitoring may be more appropriate than a simple check once at the project start.

Furthermore, in many cases, anaerobic decay of biomass is claimed by project developers. However, this assumption may be contested depending on the circumstances. For instance, if biomass waste is spread on fields, biomass decay is rather aerobic than anaerobic, thus producing little or no methane emissions. In many instances, the amount of methane emissions claimed appears very large; it may be questionable whether truly anaerobic conditions prevail in the typical circumstances in which biomass residues are left to decay. We therefore conclude that the current approach of demonstrating the abundance of biomass residues may lead to a risk of over-crediting as no adequate monitoring of availability of biomass residues is in place. In addition, exaggerated claims of anaerobic decay of biomass may lead to further over-crediting.

With regard to the baseline emissions from displacing power plants in the grid, the same conclusions apply as discussed in Section 4.5.4.

4.7.5. Other issues

No other issues were identified.

4.7.6. Summary of findings

Additionality	• Significant impact of CER revenues on plant profitability due to claims of methane emission reductions • In many cases **competitive with fossil generation** (LCOE) • **Support schemes** exist
Over-crediting	• Demonstration that **biomass** is left to **decay or available in abundance** is only conducted once at the start of the project activity • Risk of **exaggerated claims of anaerobic decay**
Other issues	• None

4.7.7. Recommendations for reform of CDM rules

Due to our finding that the demonstration of abundance of biomass as well as of the claim that biomass is left to decay (under potentially anaerobic conditions) is key for avoiding any over-crediting of emissions, it is recommended that corresponding provisions in the applicable methodologies are reviewed, with a view to ensuring that this demonstration considers current trends of biomass use and disposal and that any claims for anaerobic conditions of biomass decay are realistic. In particular, the monitoring of biomass abundance should be carried out more frequently (e.g. annually).

4.8. Landfill gas

4.8.1. Overview

Decomposition of solid waste in landfills generates carbon dioxide (CO_2) and methane (CH_4). This landfill gas can be captured and flared or captured and utilised for electricity production or as a fuel. GHG emission reductions are achieved through the destruction of methane, and in the case of energy production, displacement of a more GHG-intensive energy source. Global estimates suggest that 50 Mt of methane are generated annually from landfills (IPCC 2014).

The composition of landfill gas is usually approx. 50% CO_2 and 50% CH_4 (Hoornweg & Bhada-Tata 2012; US EPA 2013). It varies by climate and waste composition. In general, methane generation increases in wetter versus arid climates and warmer versus cooler climates. Warmer climates increase the growth of methane-producing bacteria (US EPA 2013). Waste composition with a higher percentage of organic material generates more methane and degrades more quickly (US EPA 2013). Waste in lower income countries often includes a higher percentage of organic material than higher income countries (Hoornweg & Bhada-Tata 2012).

4.8.2. Potential CER volume

The potential to capture landfill gas varies by landfill management type. Gas collection rates can be as high as 75% for basic landfills in which waste is compacted and covered and up to 85 - 95% for engineered sanitary landfills whereby landfills are lined or capped to prevent leakage or contamination from the waste (US EPA 2013). Landfill management practices vary by region. While the majority of landfills in developed countries are engineered landfills, in developing countries mitigation opportunities are more limited because the majority of landfills are basic landfills or open dumps (US EPA 2013). In open dumpsites, decomposition is predominantly aerobic; as a result methane generation rates are relatively low and gas recovery rates are limited (~10%) (US EPA 2013). Because there is often a high concentration of food waste and wet condition in developing country sites, waste decays quickly and the methane gas is released quickly. As a result, mitigation activities to capture methane must be implemented on active open dumpsites, since after a lag of even 1-2 years most of the methane will have already been generated[73] (US EPA et al. 2012).

There are two primary landfill gas methodologies under the CDM. ACM0001 is the consolidated large-scale methodology and AMS-III.G is the small-scale methodology. As of 1 July 2015, there were 364 registered landfill gas projects. Predominantly these are large-scale projects located in Latin America and Asia/Pacific regions, though there are also projects in Africa, Europe/Central Asia and the Middle East. Of the 364, 149 projects have issued a total of 69 million CERs. As of 1 August 2015, the average issuance success rate amounted to 58% (UNEP DTU 2015a).

4.8.3. Additionality

Prior to 2013, large-scale landfill gas projects assessed additionality according to the CDM "Combined tool to identify the baseline scenario and demonstrate additionality". This tool, similar to the CDM 'additionality tool' requires that projects demonstrate that they are additional based on either an investment or a barrier analysis, complemented by a common practice analysis. Similarly, prior to 2014, small-scale projects applied the general guidelines or tool for small-scale activities. Most projects used investment analysis to demonstrate additionality, predominantly benchmark analysis or simple cost analysis (IGES 2014, similar to earlier results from Spalding-Fecher et al. 2012).

A standardized approach to additionality assessment was incorporated into Version 15 of ACM0001, eligible as of 8 November 2013, and version 9 of AMS-III.G, eligible as of 28 November 2014. This revision established a positive list for additionality of landfill gas projects. All landfill gas projects are automatically considered additional if prior to the implementation of the project they only vented or flared methane, and if under the project activity they either flare the methane, or use methane to generate heat, or use the methane to generate power with a capacity of less than 10 MW. As of 1 May 2014, only one landfill gas project had been registered using this methodology

[73] While not applicable for the landfill gas methodology (ACM0001), the rapid decay rates may have implications on the applicability of the first order decay model used in the CDM "Tool to determine methane emissions avoided from dumping waste at a solid waste disposal site" and included in the avoided landfilling via composting methodologies.

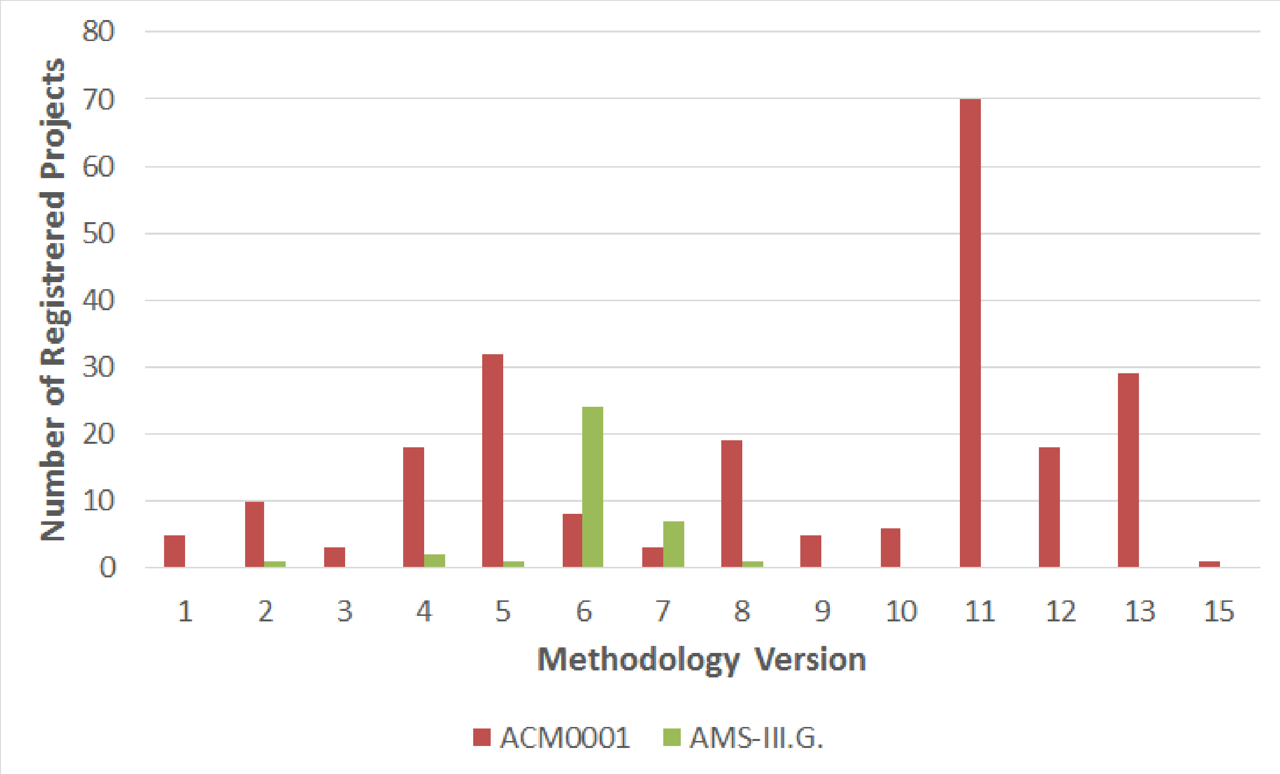
Version 15, as shown in Figure 4-8. The CDM EB will review the validity of these standardized procedures after a three-year time period.

CDM projects can only claim emission reductions for methane capture that exceeds any applicable regulations. In regions in which a regulation is in place but it can be demonstrated that it is not enforced, projects can still claim emission reductions for implementing the regulation. This has raised concerns that enforcement may be discouraged by constituencies receiving CER revenues. One such example is in the Philippines, where regulation has been established requiring gas capture and destruction, but it has not been enforced. Concerns have been raised that CER revenue has led to a pressure to discourage enforcement (Docena 2010).

Projects that capture and flare methane have no independent revenue source (US EPA et al. 2012). Flaring projects are therefore very likely to be additional. For projects using landfill gas for energy generation, additionality seems likely. As shown in Section 2.4, the available data from CDM projects indicates that the IRR is rather low without CER revenues (approx. 2.5-2.8% on average) but increase substantially with CER revenues (to approx. 16.6-18% on average). Indeed, collection and flaring of landfill gas is not common practice in developing countries without carbon finance, though it may be possible to implement projects economically where there are renewable portfolio standards (RPS) or feed-in tariffs, to allow energy production revenue to cover costs and provide capital investment for methane collection systems. For projects that supply heat, electricity, or methane to natural gas pipelines, the price and revenue from energy generation are a primary driver of the economics of the project. With economies of scale, the larger the landfill gas project, the more energy can be generated and the more likely the project is profitable.

Overall there are no substantial concerns with the approach to assess additionality for large- and small-scale landfill gas projects. The primary lingering concern is the potential for CDM projects to discourage the implementation of regulations that require capture and destruction of landfill gas.

Figure 4-8: Number of registered landfill gas projects by methodology



Source: IGES 2014

4.8.4. Baseline emissions

The baseline scenario for ACM0001 and AMS-III.G is assumed to be the atmospheric release of methane, unless capture and flaring is required by regulation or unless capture occurred to some extent prior to the implementation of the project. Baseline emissions are determined based on the amount of methane flared or used under the project activity (less any methane gas that was flared under the baseline). The overall volume of emission reductions generated is based on the baseline emissions minus any combustion efficiency losses and minus any methane that would have been destroyed under the baseline via soil oxidation. ACM0001 considers four different cases for how to account for regulation and existing landfill gas capture systems. These include no regulation/no existing capture system, no regulation with existing capture, regulation without existing capture, and regulation with existing capture. The small-scale methodology uses, in principle, the same approach but is less specific; the baseline emissions must take into account the volume of landfill gas required to be collected by regulation and the presence of pre-existing landfill gas collection and combustion systems. The overall approach of estimating the baseline emissions based on the amount of captured gas seems reasonable. However, there are concerns related to the default assumptions for pre-existing systems and regulations, and the accounting for soil oxidation.

If a regulation requires the collection of landfill gas or if a landfill gas collection system was pre-existing, but the regulation does not specify the amount to be collected or the historical amount collected is not known precisely, then both methodologies assume that 20% of the amount captured under the project scenario would be captured in the baseline. The methodology explains that this default value is based on assumptions that the capture efficiency of the project system is 50% and under the baseline 20%, and that in the baseline the methane was flared using an open flare with an efficiency of 50%. Despite the explanation, it remains unclear how the overall default value of 20% of project emissions is derived. While a 50% destruction efficiency for an open flare is conservative when considering project emissions, used in the context of baseline emissions it has the potential to actually overestimate the emission reductions. The methodologies implicitly assume that the CDM project captures five times the amount of methane than would be captured under a regulation. This assumption seems rather optimistic and likely leads to a significant over-estimation of emission reductions.

There are two types of soil oxidation that can occur at a landfill. Top-layer soil oxidation refers to soil oxidation under baseline conditions when methane oxidizes as it passes through the top layers of the landfill. The second type of oxidation can occur when additional air is introduced into the landfill due to suction from the LFG capture system under the project scenario.

Early versions of ACM0001 and AMS-III.G did not account for these two effects. This likely led to an overestimation of baseline emissions for projects that were registered up to version 11 of ACM0001 (valid until 25 July 2012) and up to version 7 of AMS-III.G (valid for registrations until 28 May 2013). This shortcoming was recognised and, in principle, addressed from version 12 of ACM0001 and version 8 of AMS-III.G onwards, by introducing a default factor for the amount of methane that would oxidize in the baseline, using 10% for “managed solid waste disposal sites that are covered with oxidizing material such as soil or compost” and 0 “for other types of solid waste disposal sites”.

Concerns have been raised about the default values applied for the soil oxidation factor. Methane oxidation in covered landfills occurs mainly through bacterial degradation, primarily by methanotroph bacteria, resulting in production of carbon dioxide, water, and biomass. The rate of oxidation is influenced by a variety of physical factors, including different soil cover types (Chanton et al. 2009). Methane oxidation generally increases with temperature up to around 40°C and is also influenced by moisture, where either too dry or too wet conditions can inhibit methane oxidation (Chanton et al. 2009; Spokas & Bogner 2011). Soil oxidation further depends on the type of soil cover and the thickness of soil cover. Higher soil oxidation rates occur in landfills that are well managed with a thick soil cover. In a study of landfills with similar operational characteristics in different climate zones of the United States, methane oxidation was lowest in humid subtropical regions and highest in arid regions (Chanton et al. 2011). This research suggests that for poorly managed landfills in humid sub-tropical and tropical regions the soil oxidation rates may be very low.

The IPCC sets default values for landfill cover methane oxidation are typically between 0% and 10% of generated CH_4 (IPCC 2006), possibly derived from one early study of a New Hampshire landfill. The 2006 IPCC Guidelines for National Greenhouse Gas Inventories indicate that:

“The use of the oxidation value of 10% is justified for covered, well-managed solid waste disposal sites to estimate both diffusion through the cap and escape by cracks/fissures. The use of an oxidation value higher than 10%, should be clearly documented, referenced and supported by data relevant to national circumstances.”

This highlights that the 2006 IPCC Guidelines consider a soil oxidation value of 10% as justified only for covered and well-managed sites. However, more recent literature surveys and experimental studies indicate that oxidation rates for covered landfills are higher, amounting on average to approx. 30% (Chanton et al. 2009; Chanton et al. 2011), although the 2009 paper indicates that the data may over-represent warmer conditions when oxidation rates would be higher.

Some stakeholders have raised concerns that the soil oxidation factor was not adjusted upwards in the CDM methodologies when more recent research indicated that an average value of 30% may be more representative (Chanton et al. 2009). However, the higher soil oxidation rates reported by

(Chanton et al. 2009) may not be fully appropriate for the context of developing countries, given that both an intermediate and final cap would have to be in place to a certain engineering standard. In most developing countries, landfills are rarely well managed with a thick soil cover required for this level of soil oxidation. This suggests that the higher soil oxidation rates may not be applicable to the conditions for some CDM projects. Nevertheless, having a default factor for both managed and unmanaged landfills avoids creating a disincentive for covering and managing landfills. The use of the soil oxidation rates as a standard default for all projects runs the risk of underestimating the volume of credits generated in some sub-tropical and tropical regions with unmanaged landfills for which soil oxidation rates under the baseline would have been very low or zero.

4.8.5. Other issues

Stakeholders have commented in public submissions to the UNFCCC with regard to revisions of ACM0001 that different types of perverse incentives can arise from landfill gas projects. Two main perverse incentives can be of concern, which both lead to an over-estimation of emission reductions.

Firstly, project developers can have an incentive to store the waste in a manner that generates more methane. For example, a 'flat' landfill with low methane generation potential could be changed to store waste at a greater height. Moreover, project proponents can have an incentive to maximise methane generation through other means, such as pulling water in the landfill to create anaerobic conditions. On a site visit to a landfill gas project in China in 2005, engineers proudly explained how they had found a way to generate more methane by stacking waste higher in one section of the landfill rather than spreading it evenly across the landfill site. While this is just one anecdotal example, there is reason to believe that some landfill projects may be altering management practices to do so. Based on these observations, in 2012 more recent versions of both the large- (version 13.0) and small-scale methodologies (version 8.0) included an applicability criterion that excludes projects in which the management is changed in order to increase methane generation. However, verifying this requirement may be difficult in practice and it has not been included as an explicit provision for DOEs to assess after the project implementation.

Secondly, there could be perverse incentives for policy makers and private actors not to engage in recycling or other ways of preventing waste generation, as this could lower the potential for CDM landfill gas projects. Similarly, there could also be perverse incentives to continue landfilling instead of introducing other waste treatment methods (incineration, composting).

Public comments received on behalf of waste picker organizations have raised concerns that development of a project limits access of waste pickers who, through the informal economy, contribute significantly to the recycling of materials (Global Alliance for Incenterator Alternatives, GAIA). Project developers who were interviewed acknowledged that sites need to be secured for project installation, to avoid having equipment tampered with or material stolen. For certain projects, including examples in Latin America and Thailand, agreements have been made for waste pickers to pick through waste before it is transferred into the secure site. However, in other cases there has not been any cooperation between the project developers and waste pickers, which has resulted in conflict and loss of livelihoods. There is evidence that the development of landfill gas projects is limiting the access of waste pickers and thereby reducing the reuse and recycling of waste through the informal economy. Given the success of collaborative agreements with waste pickers, this may be a model which new projects should be required to incorporate.

Pursuing landfilling instead of other waste treatment methods, such as recycling, incineration or composting, is likely to result in overall higher GHG emissions, even if the landfill gas is captured, because landfill gas collection systems are not able to capture all of the methane. The CDM may thus provide perverse incentives for policy makers or project owners to continue pursuing a waste treatment method that is more GHG-intensive. If in the absence of the CDM, other waste treatment methods would be pursued, it would lead to an over-estimation of emission reductions.

Early versions of CDM methodologies did not include any provisions to address this issue. Regarding the potential perverse incentive to reduce recycling, starting with version 12 of ACM0001, an applicability criterion requires that “the implementation of the project activity does not reduce the amount of organic waste that would be recycled in the absence of the project activity”. However, there is no reference to how this should be assessed. Moreover, this applicability condition does not address the broader concern that the CDM provides incentives to continue pursuing landfilling and not composting or waste incineration. In public comments submitted by non-governmental organisations, such as the GAIA, there have been calls for eligibility requirements that would allow projects only on closed landfills in order to prevent the potential for this perverse incentive of reducing recycling and composting. Project developers argued that in developing country contexts, with warmer climates and higher percentage of organics in the waste stream, the capture of methane must take place while the landfill is actively being used, otherwise the methane will have already been released once it is closed. This is in contrast to landfills in more temperate climates, where methane production happens more slowly and where it is more common to develop a project at a closed landfill.

Overall, there is reason to believe that landfill gas projects are contributing to perverse incentives to manage landfills in ways that generate more methane and to reduce reuse and recycling or avoid a shift towards compositing or waste incineration. In addition, it appears there are cases in which project participants increase methane production – an issue which may deserve particular attention in the validation and verification auditing processes.

4.8.6. Summary of findings

Additionality	• Likely to be additional
Over-crediting	• Default assumptions for the rate of methane captured under pre-existing collection systems or regulations are unjustified and have the potential to overestimate emission reductions • Default soil oxidation rates may underestimate emission reductions for uncovered landfills in humid sub-tropical and tropical regions with very low soil oxidation rates; nevertheless, requiring the use of a default soil oxidation rate for baseline emissions avoids creating a perverse incentive to avoid covering landfills • Potential for perverse incentives for policy makers not to regulate landfills or enforcing regulations in place • Perverse incentives for project developers to manage landfills in ways that increase methane generation
Other issues	• Perverse incentives for policy makers not to pursue less GHG-intensive waste treatment methods, such as composting or incineration • Some landfill gas projects exclude waste pickers and informal sector recycling, reducing overall rates of reuse and recycling

4.8.7. Recommendations for reform of CDM rules

We recommend several revisions to the CDM landfill gas methodologies to address the potential over-crediting, in particular the perverse incentives for both project owners and policy makers:

- Instead of applying one value for the soil oxidation factor to all projects, different values could be applied to different regions based on the climatic conditions and practices in that region.

- The approach of the default factors used for estimating methane capture from pre-existing collection system or landfills with regulations should be revisited. Assumptions in the default factor could be revised to be more conservative by assuming that more (rather than less) methane was captured and destroyed.
- Include specific requirements for DOEs to verify that the landfilling practice was not changed with a view to generating more methane.
- To avoid the reduction in recycling by excluding waste pickers access to the site, the methodology could be revised to be more specific about how projects should provide waste pickers with access to solid waste before it is deposited in the secure dumpsite.
- Given the long-term need to transition away from landfilling and increase composting and recycling, there could be a sunset clause considered for CDM landfill projects.

4.9. Coal mine methane

4.9.1. Overview

Methane is stored within coal as part of the coal formation process. During coal mining activities some of the methane is released. The build-up of methane in coal mines creates a potential explosive hazard and efforts before, during, and after mining are taken to reduce the safety risk by releasing methane into the atmosphere. Methane released from coal mines makes up approx. 8% of global anthropogenic methane emissions (Global Methane Initiative 2011). Methane originating in coal seams that is drained prior to mining is known as coal bed methane (CBM). Through a process of pre-mining drainage, this methane can be extracted to reduce the safety risk. During coal mining, methane can be vented from coal mines, which is known as ventilation air methane (VAM). After mining has ceased, methane can be extracted, which is known as post mining or post drainage coal mine methane (CMM). Coal mine methane projects involve installation of control technologies to collect and destroy and/or utilise methane from existing and abandoned mines, instead of releasing it to the atmosphere. Under the ACM0008 methodology of the CDM, capturing methane is eligible from pre-mining via underground boreholes and surface drainage of CBM, during mining from VAM that would normally be vented, as well as post mining from abandoned/decommissioned mines.

4.9.2. Potential CER volume

Of the 84 CMM projects that have been registered under the CDM, all are located in China, except for one project in Mexico. Projects from other countries, including India, Indonesia, Philippines and South Africa have been submitted to the UNFCCC but not registered.[74] As of 1 May 2014, 34 million CERs have been issued from 37 projects located in China. The total volume of credits expected from the credit start dates up to 2020 is 170 million CERs (Section 2.3).

The best conditions for CMM projects are deep coal mines with high methane concentrations. Under these conditions, methane is concentrated and easy to collect. For geographic and regulatory reasons, coal mines in China have been well suited for CMM projects to date. In India, for example, most coal mines are surface mines, where methane concentrations are lower and it is harder to collect the methane. Another barrier in India is national regulation that divides permits for using coal and gas. This means that coal mines do not have a permit to utilise the methane gas generated and would be unable to authorise a CMM project. A CMM project would require an additional permit process, an added administrative barrier.

[74] There are two projects under validation from India and one from the Philippines. Projects in Indonesia and South Africa have had their validation terminated or validation replaced.

4.9.3. Additionality

All of the registered CMM projects use the large-scale ACM0008 methodology. The most recent ACM0008 Version 8 requires use of the "Combined tool to identify the baseline scenario and demonstrate additionality" and provides further guidance on the application of the tool in the context of CMM projects. As of May 2014, no projects had been registered under version 8, which was approved in February 2014. The majority of projects are registered under versions 6 and 7. In these prior versions, the CDM additionality tool was applied, and a separate procedure was used to select the baseline scenario. Starting with version 6, the methodology was changed to allow for benchmark analysis as part of investment analysis for projects where no investment would occur in the baseline scenario.

Most CDM CMM projects apply a benchmark analysis to demonstrate additionality, as shown in Table 4-4. Benchmark analysis compares the financial performance of the project, often expressed as IRR, to a relevant benchmark or investment 'hurdle rate'. In contrast to some other project types, CER revenue for CMM projects does make up a large portion of the return on investment on capital expenditures for projects. According to information from PDDs, the IRR without CER revenue is approx. 2% on average and increases to approx. 28% with CER revenues, the largest increase among all project types (Section 2.4). When we derive a simple indicator that puts the capital investment in relation to the number of CERs generated over ten years, as referenced in Section 2.4 in this report, we find an average ratio of about USD 4 / CER for all CMM projects. These calculations show that CMM projects have a high likelihood of additionality. They support reports from technical experts and project developers that abatement costs for CMM co-generation plants are approximately USD 3 - 5 per tCO_2 during 10 years of operation. Other reports indicate that CMM projects are usually not economically viable; according to United Nations (2010) power generation from CMM only becomes economically viable for coal mines with very large methane sources exceeding 20 m^3/t (United Nations 2010).

Table 4-4: Additionality approaches used by CDM CMM project activities

Additionality approach	Number of project	Average Annual CERs (1,000)
Benchmark Analysis	76	33,465
Investment Comparison Analysis	4	1,557
Investment Comparison Analysis and Benchmark Analysis	1	266
Simple Cost Analysis	4	1,883

Sources: IGES 2014

A high likelihood of additionality is also supported by observation of common practice in the sector. Coal mines are very averse to having any combustion on-site. Combustion of any kind increases the potential risk of a methane gas explosion. Venting methane is the safest approach to avoid combustion, and miners and management are very familiar with this approach. Coal mine operators are generally averse to having a methane combustion system onsite as a result in order to avoid the risk of mine closures due to concerns around worker safety. Global Methane Initiative staff reported that in China, prior to the presence of the carbon market, efforts by the Global Methane Initiative were wholly unsuccessful in implementing CMM projects. No pilot projects or sponsored projects were able to get off the ground. Technical barriers were significant and persistent. The equipment used was unable to cope with the difficulties of the coal mine system, including the concentrations of volatile methane and the gas volumes. Only with the revenue from CERs were there sufficient incentives to develop technologies that worked well for these conditions. Now, in

China, it has become common practice for large coal mines to capture methane with revenue from a CDM project. As of 2014, there were still 2 projects in China at the validation stage; however since the technology for developing CMM projects in China is now proven, it can no longer be claimed to be first of its kind or a technology barrier. Although the CMM projects have become common practice, this has only been the case with CDM revenue. Overall, the risk for non-additionality is low for VAM projects.

4.9.4. Baseline emissions

Baseline emissions are calculated as the sum of CO_2 emissions from destruction of methane that would occur in the baseline scenario, emissions from the production of power, heat, or use of gas replaced by the project activity, and release of methane into the atmosphere that is avoided by the project activity. The baseline scenario is selected based on an examination of all the options that are technically feasible and comply with applicable regulations and elimination of all baseline scenario alternatives that face prohibitive investment, technological and/or prevailing practice barriers.

There is some concern that mines may take part in marginally more pre-mining drainage than they would have done without incentives from the CDM; however, the drained methane would likely have been emitted upon mining (and likely would have been emitted through ventilation later on). So these concerns seem limited, given that there are provisions in the methodology that emission reductions may only be credited once mining starts, ensuring that CERs are not issued in cases in which mining may not have occurred under the baseline. Our review has not identified any other concerns related to the determination of baseline emissions.

4.9.5. Other issues

The methodology includes a requirement that methane collection must exceed that which is required by applicable regulations, with the exception of cases in which it can be shown that the regulation is not enforced. A regulation was put in place in China requiring that methane captured from coal mines that exceeds 30% methane concentration must be captured and used. It has been suggested by project proponents that the Chinese government actually put this regulation in place as a result of the success of the CDM, to support the use of CDM financing to capture methane as best practice and to stimulate more CDM project development. However, interpretations vary and it has led to questions around the additionality of projects and whether or not they would have been required by regulation. As a consequence, project developers focused on projects where the methane concentration was below 30%. These projects would be avoided for safety reasons in North America or Europe, because this gets close to the explosive range of methane concentrations of 15-25%. It is better practice and safer to improve the capture rate and increase the concentration of methane, however this could run the risk of exceeding the 30% concentration regulatory requirement in China, and hence not meeting the CDM additionality requirements. This raises the risk of perverse incentives for project developers to diluting methane gas to reduce the concentration below 30% in order to be eligible for the CDM. However, no evidence is available whether this happened.

4.9.6. Summary of findings

Additio-nality	• Likely to be additional • CDM revenue makes up a large portion of return on capital investment • Technology for CMM in China is now well demonstrated, no longer technical barriers
Over-crediting	• Potential concerns regarding increased mining and/or pre drainage of coal mine methane but no evidence whether or not this occurs
Other issues	• Potential perverse incentives to dilute methane in order to avoid that abatement is required by regulations

4.9.7. Recommendations for reform of CDM rules

There are no recommendations regarding reforming the CDM rules for CMM projects. Further investigation of China's regulations for methane capture are warranted to ensure that perverse incentives are avoided.

4.10. Waste heat recovery

4.10.1. Overview

Waste heat utilization includes generally energy efficiency measures, where the thermal content of hot waste gases that would be vented in the absence of the CDM project activity is used for heating purposes, replacing fossil fuel use. For example, hot exhaust gases from cement kilns can be used to pre-heat the raw material before entering into the kiln.

A related category of projects is waste gas utilization where the calorific value of waste gases that contain a certain fraction of hydrocarbons or hydrogen that would be flared in the absence of the CDM project activity is used to replace regular fossil fuels. For example, waste gases with a high content of carbon monoxide and hydrogen can be used as fuel for steam production in industry. This second project category has similar features than the 'thermal' recovery of waste gases, but the present chapter focusses on the first category.

4.10.2. Potential CER volume

According to our own estimates, registered CDM projects have the potential to issue 0.35 billion CERs by the end of their respective crediting periods, of which 0.22 billion CERs fall in the period from 2013 to 2020 (Table 2-1). CERs from these projects account for about 2.5% of the total CER issuance potential.

4.10.3. Additionality

The methodologies for waste heat utilization (AM58, AM66, AM95, AM98, ACM12, AMS-II.I., AMS-III.P.AMS-III.Q., AMS-III.BI.) generally use standard CDM additionality tests based on barrier and/or investment analysis.

The general issue with this project type is that the use of waste heat is a standard practice in many integrated industrial facilities, in particular where energy costs represent a larger fraction of production costs such as in cement production, refineries, iron and steel and chemicals. However, the extent of the use of waste heat and energy efficiency may vary significantly even within a country, as energy costs, financial resources and engineering and management skills may differ between sectors and plants. While one steel plant may define its competitive edge in systematically using all waste heat and reducing heat loss along the steelmaking process because of competitive steel markets and relatively high fuel costs, a refinery plant may vent significant amounts of waste heat and experience severe heat losses all over the refinery because its cost of fuel is very low.

In the use of investment analysis for demonstrating additionality for waste heat recovery projects involves several uncertainties: the highest uncertainties are in the in the assumptions on future fuel prices which show high variability over time (Figure 2-4 to Figure 2-6). In addition, the considerable uncertainties in investment cost for equipment and construction and the often uncertain impact of the considered measure on efficiency makes it difficult to objectively determine the profitability of the measure and the relevant hurdle rate (Section 3.2).

For projects implemented in existing plants, the methodologies require demonstrating that the waste heat or gas has been flared/vented at least three years before the project implementation. This is an important safeguard to assure at least some degree of additionality.

Some methodologies, such as ACM0012, also allow waste heat recovery projects in greenfield plants. This is very problematic, as it is very difficult to demonstrate that the waste heat utilization would not have been implemented in the absence of the CDM (Section 3.2). The methodology ACM0012 (V.5) provides for two options for demonstration additionality in the case of greenfield plants. Option 1 requires to identify similar plants; the project is deemed as additional "if *more than 80 per cent of the analyzed facilities in the list do not use waste energy, it can be decided that the proposed Greenfield facility also would have wasted the energy in the absence of waste energy recovery CDM project"*. While the methodology tries to be descriptive on how to identify baseline waste energy use, there remain large uncertainties and most importantly, data on the degree of waste energy usage in plants from competitors may be very difficult to obtain. Under option 2, project participants can submit a (hypothetical) *alternative design* without or with a lower level of waste heat recovery and demonstrate using investment analysis that the alternative design would be the baseline scenario for the waste energy generated in the greenfield facility. Given the high uncertainties in price data and hypothetical level of waste heat utilization in the absence of the CDM, this leads to significant risks of non-additionality.

The economic impact of CERs on the profitability of the waste heat recovery project is usually rather small compared to related fuel cost saving. I.e. a change in fuel costs of a few percent may have the same impact as the CER revenues (Sections 2.4 and 3.2).

Overall, the risk for non-additionality of greenfield plants seems higher than for existing plants, where the requirement for a minimum of three years of generation of waste heat prior to the start of operation of the CDM project has to be demonstrated.

4.10.4. Baseline emissions

Baseline emissions are usually derived from the amount of waste heat used in the project case. It is assumed, that this heat would be generated by fossil fuels in the baseline scenario.

However, even though the methodologies for existing facilities require demonstrating that the waste heat or gas has been flared/vented at least three years before the project implementation, in practice it may be very difficult to rule out that waste heat has not been used in some form in existing facilities before project implementation, which may inflate baseline emissions.

Also, waste heat recovery may lead to a different operation of the plant than in the baseline scenario. For example, if waste heat is used for pre-heating of a product, the plant may be run in such a way that more waste heat is generated to assure a certain temperature level of the pre-heated product, which leads to a higher fuel consumption in the boiler generating the waste heat. Therefore the amount of heat wasted in the baseline may be overestimated. Moreover, baseline usually do not capture any other autonomous energy efficiency improvements that might be implemented in the absence of the project.

In greenfield projects, the emission reduction is based on the difference in emissions in modelling a baseline and project scenario. The models build on many assumptions that are difficult to validate objectively. The results are therefore prone to high uncertainty and may lead to over-crediting.

Lastly, the methodologies do not consider emission reductions from the reduction in upstream emissions (such as from the production of natural gas or coal) which leads to a slight under-crediting, if upstream emissions occur in a non-annex I country.

4.10.5. Other issues

None.

4.10.6. Summary of findings

Additio-nality	• CER revenues are very small compared to cost reduction from fuel savings • Ex-ante estimation of key parameters including investment costs and fuel savings has large uncertainties • Waste heat recovery is common practice in many countries and sectors (though not in all)
Over-crediting	• In existing facilities: It is very difficult to rule out that waste heat has not been used in some form before project implementation, which may inflate baseline emissions • In greenfield projects: Modelling of amount of waste heat lost in baseline is subject to very high uncertainties. • Waste heat recovery may lead to a different operation of the plant than in the baseline case, e.g. to assure a certain temperature level of the heat medium or to NCV level of waste gas, therefore the amount of gas wasted in the baseline may be overestimated
Other is-sues	• None

4.10.7. Recommendations for reform of CDM rules

Waste heat recovery is standard practice in many energy intensive industrial sectors, though there exist barriers to the implementation of waste to energy measures. The high uncertainty in additionality demonstration make it less suitable for the CDM, the project type may be taken out of the CDM or restricted to cases with clear additionality demonstration, e.g. of a very low uptake of waste heat recovery can be demonstrated in a specific industrial sector. We recommend that option 1 in Appendix 1 of ACM0012 be maintained as it provides a more objective way of assessing the practice in the sector and country and that option 2 not be used.

4.11. Fossil fuel switch

4.11.1. Overview

Fossil fuel switch includes the switching from a fuel with higher carbon intensity (such as coal or petroleum) to a fossil fuel with lower carbon intensity (such as natural gas) in the generation of heat for industrial processes or in power plants. In this section we do not consider switching from fossil fuels to biomass. Methodologies are for existing installations only (e.g. ACM0009, ACM0011, AMS-III.AH., AMS-III.AN) or for both existing and greenfield installations (AMS-III.B and AMS-III.AG – power only).

4.11.2. Potential CER volume

According to our own estimates, registered CDM wind power projects have the potential to issue 0.46 billion CERs by the end of their respective crediting periods, of which 0.23 billion CERs fall in the period from 2013 to 2020 (Table 2-1). CERs from wind power account for about 3.3% of the total CER issuance potential.

4.11.3. Additionality

Both fossil fuels with higher carbon intensity such as hard coal, lignite or fuel oil and fuels with lower carbon intensity such as natural gas are widely used in stationary installations in energy and manufacturing industries as well as in the buildings sector. In existing facilities, the choice of fuel is often determined by the existing fuel, because fuel changes may be costly, though there are also multi-fuel systems. In greenfield plants, the fuel choice usually depends on the economic viability of each fuel option.

Table 4-5: Examples of differences in characteristics between the use of coal and fuel oil compared to natural gas

Characteristics	Hard coal, lignite (fuel with high carbon intensity)	Natural gas (fuel with lower carbon intensity)	Considered in investment analysis
Initial investment for burner/ boilers etc.	Higher	Lower[1)]	Yes
Fuel cost per energy unit	Lower	Higher	Yes
Non-fuel operation costs	Higher	Lower	Yes
Flexibility in operation[2)]	Lower	Higher	No
Means of distribution to end-user	Vehicle-based: by trucks, train i.e. requires access roads or rails	Network based: by distribution lines[3)]	No
Price building mechanisms	In many countries based on world market price	In many countries price is based on local long term contracts, often taking into account a price index, e.g. based on oil price	No
Dependence on specific supplier	Lower	Higher	No
Compliance with local air quality standards (if any)	More difficult: Coal based furnaces may require expensive exhaust cleaning systems	Less difficult: Natural gas based furnaces have generally lower air pollutant emission levels[4)]	No
Need of space for local fuel storage	Yes	No[5)]	No

Notes: [1)] This is the case if the (higher) investment for distribution lines necessary to connect to the natural gas grid is borne by a different entity, e.g. the natural gas supplier. In case of LNG initial investment costs may be somewhat higher for LNG terminals, local storage facilities etc. [2)] E.g. shorter time lag to start-up operation of power plant if dispatching system in a grid requires more power. [3)] Or Vehicle based in case of LNG. [4)] Please note that this may hold true even though local air quality standards may be stricter for natural gas than for coal-based systems. [5)] Except for LNG.

Sources: Author's own research

The large-scale methodologies ACM0009 and ACM0011 require an investment analysis for demonstrating additionality, a barrier analysis (Section 3.2) is not deemed sufficient.[75] This makes sense as the economic viability may be seen as one of the key aspects when deciding on a specific fuel. Requiring investment analysis may reduce the risk of non-additionality, because using this

[75] Though e.g. ACM0009 allows for the additionality to be proven by claiming „prohibitive barriers“ for the project (natural gas) scenario applying step 3 of the additionality tool.

test may be more difficult in the case of very lucrative fuel switches (e.g. if cheap natural gas becomes newly available in a project site).

In general, fuel prices per energy unit are generally lower for coal than for natural gas. This is offset to a certain degree by higher initial investment and non-fuel operation costs for coal furnaces (Table 4-5). However, while the investment analysis takes these cost factors into account, there could be other factors that may lead to the choice of natural gas as a fuel, even though it may be economically somewhat less attractive than lignite or hard coal.

An issue that contributes to the high uncertainty in investment analysis are the assumptions made about future developments of fuel prices. In the investment analysis, the fossil fuel switch methodologies allow to choose between (i) keeping fuel prices at present levels for future years, or (ii) to use future prices that "*have to be substantiated by a public and official publication from a governmental body or an intergovernmental institution"* (ACM0009 V.5, Section 5.2.4).

For small-scale projects, however, the barrier analysis is deemed sufficient, which may considerably increase the risk of non-additionality (Section 3.3). This risk is only somewhat mitigated by some small-scale methodologies requiring that the CDM project involves at least some capital investments[76], ruling out projects where fuel switch can be carried out without any investment in additional fuel switching equipment, e.g. in natural gas burners. Still, small-scale fuel switching methodologies have the full set of issues that have been identified for barrier analysis (Section 3.3).

In addition, similar to other energy related project types, with fuel switch projects CER revenues are very small compared to typical fluctuations of price differences between fuels (dark-spark spread), which increases the risk of non-additionality.

4.11.4. Baseline emissions

The exploitation, transport, processing and distribution of fossil fuels results in upstream emissions, many of which may originate in non-Annex I countries. In most CDM project types, the amount of fossil fuel used is *reduced* with the project; therefore, it may be assumed that also upstream emissions are reduced. As a conservative simplification, the relevant methodologies usually do not consider upstream emissions. In the case of fossil fuel switch, however, upstream emissions from fossil fuels could either increase or decrease. In general, upstream emissions from natural gas tend to be higher than upstream emissions from lignite, hard coal or fuel oil (depending on source of fuel).

With fuel switch activities the amount of fuel used in terms of energy content remains more or less constant (or may slightly be reduced because of higher efficiency of natural gas burners). Because of the potentially higher upstream emissions of natural gas, switching from coal/oil to natural gas may result in an increase in upstream emissions, the so-called 'upstream leakage' emissions. For this reason, CDM methodologies for fossil fuel switch projects consider upstream emissions.

The procedures for estimating upstream emissions are included in the methodological Tool "Upstream leakage emissions associated with fossil fuel use" (V.1, EB69 Annex12). The tool allows project developers to use default values for upstream emissions or to come forward with their own values derived from relevant data. The default values have been substantially revised with the tool (e.g. from the values included in Table 3 of methodology ACM0009 V.4 (EB68 Annex 12)).

For instance, according to the latest version of the tool, default upstream emissions values from natural gas are 2.9 tCO_2/TJ, based on data from the US. This is comparable to the 2.6 tCO_2/TJ

[76] For example, as in the applicability requirements of small-scale methodology AMS-III.B (V.18): "The methodology is limited to fuel switching measures which require capital investments. Examples of capital investment include creating infrastructure required to use project fuel or retrofitting existing installations."

(105 tCH_4/PJ; total) default upstream emissions in Western Europe in ACM0009 V.4 (based on IPCC), but is much lower than in e.g. the former values for Eastern Europe and former Soviet Union (23 tCO_2/TJ) or Rest of the World (7.4 tCO_2/TJ).

Also, the revised aggregated default values for natural gas (Table 1 in the tool) of 2.9 appears much lower than the sum of the default values for the different elements in the upstream chain of natural gas (Table 3 in the tool), including exploration and production (3.4 tCO_2/TJ), processing (4 tCO_2/TJ), storage (1.6) and distribution (2.2). The latter are all based on the US Department of Energy's GREET model, which may not necessarily be representative for upstream emissions of natural gas in developing countries.

With this, the revised values become comparable to those from (underground) coal. It is unclear whether this is a reasonable assumption or an artefact because of the origin of the natural gas upstream emissions data. If the values in the upstream tool are not conservative, i.e. provide too low default values for natural gas upstream emissions, this would lead to an increased risk of overcrediting of fuel switch projects.

An additional issue is the assumptions for the default values on the share of upstream emissions that are covered by caps of Annex-I countries – and how effective these caps are in limiting upstream emissions.

Table 4-6: Default emission factors for upstream emissions for different types of fuels reproduced from upstream tool (Version 01.0.0)

Fossil fuel type x		Default emission factor (tCO_2e/TJ)
Natural Gas (NG)		2.9
Natural Gas Liquids (NGL)		2.2
Liquefied Natural Gas (LNG)		16.2
Compressed Natural Gas (CNG)		10
Light Fuel Oil (Diesel)		16.7
Heavy Fuel Oil (Bunker or Marine Type)		9.4
Gasoline		13.5
Kerosene (household and aviation)		8.5
LPG (including butane and propane)		8.7
Coal/lignite (unknown mine location(s) or coal/lignite not 100%	Lignite	2.9
	Surface mine, or any other situation	2.8
	Underground (100% source)	10.4
Coal/lignite (coal/lignite 100% sourced from within host country)	Lignite	6
	Surface mine, or any other situation	5.8
	Underground (100% source)	21.4

Notes: The detailed table 3 in tool does not seem to provide data for conventional NG upstream emissions.
Sources: EB69, Annex 12, https://cdm.unfccc.int/methodologies/PAmethodologies/tools/am-tool-15-v1.pdf

Table 4-7: Former default emission factors for upstream emissions for different types of fuels

Activity	Unit	Default emission factor	Reference for the underlying emission factor range in Volume 3 of the *1996 Revised IPCC Guidelines*
Coal			
Underground mining	t CH4 / kt coal	13.4	Equations 1 and 4, p. 1.105 and 1.110
Surface mining	t CH4 / kt coal	0.8	Equations 2 and 4, p.1.108 and 1.110
Oil			
Production	t CH4 / PJ	2.5	Tables 1-60 to 1-64, p. 1.129 - 1.131
Transport, refining and storage	t CH4 / PJ	1.6	Tables 1-60 to 1-64, p. 1.129 - 1.131
Total	t CH4 / PJ	4.1	
Natural gas			
USA and Canada			
Production	t CH4 / PJ	72	Table 1-60, p. 1.129
Processing, transport and distribution	t CH4 / PJ	88	Table 1-60, p. 1.129
Total	t CH4 / PJ	160	
Eastern Europe and former USSR			
Production	t CH4 / PJ	393	Table 1-61, p. 1.129
Processing, transport and distribution	t CH4 / PJ	528	Table 1-61, p. 1.129
Total	t CH4 / PJ	921	
Western Europe			
Production	t CH4 / PJ	21	Table 1-62, p. 1.130
Processing, transport and distribution	t CH4 / PJ	85	Table 1-62, p. 1.130
Total	t CH4 / PJ	105	
Other oil exporting countries / Rest of world			
Production	t CH4 / PJ	68	Table 1-63 and 1-64, p. 1.130 and 1.131
Processing, transport and distribution	t CH4 / PJ	228	Table 1-63 and 1-64, p. 1.130 and 1.131
Total	t CH4 / PJ	296	

Note: The emission factors in this table have been derived from IPCC default Tier 1 emission factors provided in Volume 3 of the 1996 Revised IPCC Guidelines, by calculating the average of the provided default emission factor range.

Sources: EB68 Annex 12, ACM0009, V.4, Table 3, http://cdm.unfccc.int/filestorage/r/t/4M2I7TA9GRCU5QDB0JLNHK6PY1ZOWE.pdf/eb68_repan12.pdf?t=Z0p8bzJ3YnExfDBVPWpbmgO_k-sMZsZIso1q

4.11.5. Other issues

None.

4.11.6. Summary of findings

Additio-nality	• Small-scale methodologies for fuel switching do not require investment analysis but may build only on barrier analysis, which provides a high risk for non-additionality • Even in large scale methodologies, modelling of fuel choice depends not only on prices, but also on availability/reliability, need for diversification, and operational needs (e.g. NG power plants for covering peak demand); this may imply that the investment analysis may not be sufficient to determining additionality • CER revenues are very small compared to typical fluctuations of the price difference be-tween fuels (dark-spark spread)
Over-crediting	• Upstream emissions need to be taken into account, but with the revised default values of the tool they may not be addressed in an adequate way anymore
Other is-sues	• None

4.11.7. Recommendations for reform of CDM rules

In sum, the revision of upstream default values as documented in the tool practically eliminates the consideration of upstream emission in a fuel switch e.g. from (underground) coal to natural gas. The assumptions behind the revisions (mostly data from the US may not be representative for the situation with natural gas used in developing countries and require urgent independent analysis and revision.

4.12. Efficient cook stoves

4.12.1. Overview

Under the CDM, there are two methodologies applicable to efficient cook stoves. AMS-II.G[77] applies to cases where inefficient existing cook stoves are replaced by improved-efficiency cook stoves to reduce the demand for non-renewable biomass. AMS-I.E[78] applies to cases where a renewable technology, such as biogas or solar cookers, is introduced to displace existing cook stoves using non-renewable biomass. The number of projects has increased quickly since the introduction of these methodologies in 2008/2009. Most notably the introduction of PoAs, enabling multiple project activities to be registered through a single approval process, has lowered the transaction costs and increased scalability for projects like efficient cook stoves.

4.12.2. Potential CER Volume

As of 1 July 2015, a total of 102 cook stove projects have been registered under the CDM, 37 as individual CDM project activities and 65 as PoAs (along with a total of 180 individual CDM Program Activities (CPAs)).

Table 4-8: Number of efficient cook stove single CDM project activities by country

Country	Number of CDM project activites	Annual CERs (1,000)	Avg. CERs per CDM project activity (1,000)
China	1	12	12
India	29	469	16
Lesotho	1	34	34
Malawi	2	71	35
Mozambique	1	192	192
Nepal	1	20	20
Nigeria	1	31	31
Zambia	1	130	130
Total	**37**	**960**	

Sources: UNEP DTU 2015a

Project activity under the CDM peaked in 2012 and dropped sharply in 2013. As of 1 July 2015, single CDM cook stove projects are mostly located in the Asia and Pacific regions (Table 4-8), while component project activities developed under PoAs are predominantly located in Africa, as shown in Table 4-9. The annual volume of CERs estimated by project developers from PoA projects is 9.2 million, nearly 10 times the annual volume of CERs projected from single CDM project

[77] AMS-II.G.: Energy efficiency measures in thermal applications of non-renewable biomass, https://cdm.unfccc.int/methodologies/DB/UFM2QB70KFMWLVO7LJN8XD1O2RKHEK.

[78] AMS-I.E.: Switch from non-renewable biomass for thermal applications by the user, https://cdm.unfccc.int/methodologies/DB/O799FU5XYGECUSN22G84U5SBXJVM6S.

activities of 0.96 million. Many of the registered PoAs have only 1 or a few CPAs associated with them (Table 4-9), so there is potential to scale up CPAs in these cases. In Bangladesh and Madagascar, many individual CPAs have already been developed under the one PoA registered in each of these countries (Table 4-9).

Table 4-9: Number of efficient cook stove PoAs and CERs by country and methodology

Country	Number of PoAs	Annual CERs (1,000)	CPAs per PoA	Annual CERs/ CPA (1,000)
Bangladesh	1	543	11	49
Burkina Faso	2	68	1	68
Burundi	2	452	4	113
China	1	10	1	10
Congo DR	3	124	1	124
Côte d'Ivoire	2	160	2	80
El Salvador	2	90	1	90
Ethiopia	3	201	2	121
Ghana	2	377	4	108
Guatemala	1	43	1	43
Haiti	2	68	1	68
Honduras	1	34	1	34
India	5	543	2	302
Kenya	4	319	2	159
Madagascar	1	4,198	59	71
Malawi	6	299	1	257
Mali	1	33	1	33
Mexico	1	40	1	40
Mozambique	1	28	1	28
Myanmar	1	43	1	43
Nepal	4	204	2	136
Nigeria	2	226	4	56
Rwanda	3	229	2	114
Senegal	3	209	1	209
South Africa	1	32	1	32
Tanzania	1	63	1	63
Togo	3	48		144
Uganda	3	265	2	132
Zambia	3	345	3	129
AMS-I.E	7	4,657	9	509
AMS-II.G	57	4,535	2	2,371
AMS-I.E + AMS II.G	1	100	1	100
Total	**65**	**9,292**		

Sources: UNEP DTU 2015a

4.12.3. Additionality

Improved cook stove methodologies under the CDM fall under one of two types: improved energy efficiency (AMS-II.G) or fuel switching to renewable energy (AMS-I.E). Under both methodologies projects must apply the CDM "Guidelines on the demonstrating of additionality of SSC project activities" (Methodological Tool: Demonstration of additionality of small-scale project activities. Version 10.0). Following these CDM guidelines, projects using either of these methodologies are on the positive list of project types and automatically considered additional so long as each unit is no larger than 5% of the small-scale CDM threshold (750 kW installed capacity or 3000MWh energy savings per year or 3,000 metric tons emission reductions per year), and end users are households/communities.

Lambe et al. (2015) reviewed PDDs for cook stove projects in Kenya and India. Although projects are considered automatically additional and were thus not required to document barriers, the study found that several did include a discussion of barriers in the PDDs. The most-cited barrier was household poverty, which makes improved stoves unaffordable. The study found that several PDDs for projects in Kenya include simple cost analysis to assess the ability of households to purchase an efficient cook stove based on their income and their costs for food and fuel; the calculations suggest that households would need to save 22–30% of their remaining income for a year to purchase a stove. This claim was supported in the pricing models the authors found used by projects in rural areas, which nearly exclusively distributed stoves for a free or subsidized price. In an urban setting, the study found that many projects were selling stoves at the retail price with microfinance options. The study noted that these PDDs suggest that since urban households are already purchasing charcoal, they have an incentive to buy an improved cook stove to reduce their fuel costs. The study authors also found that many projects also cited the lack of access to credit for working capital, low profit margins, high upfront capital costs, lack of sufficient consumer outreach and support for program operations, reduced consumer demand resulting from failure of past efforts, need for ongoing improvement and modifications of stoves to suit user needs as barriers to project implementation.

Lambe et al. (2015) also investigated what contribution offset revenues make to the overall project revenue. The study reviewed claims made in PDDs regarding the use of offset revenue and found that a majority of projects planned to use offset sale revenues to subsidize the price of improved cook stoves, as well as to cover operational costs, including maintenance and replacement of stoves, training of cook stove users, outreach and marketing to households, microcredit systems and distribution. Interviews of market actors affiliated with these projects by the authors found that while some projects were entirely dependent on offset revenue, others admitted that given the uncertainty in revenue from offsets it was advantageous not to depend on carbon revenues.

These conclusions raise substantial concerns about the additionality of improve cook stove projects under the CDM. Carbon revenues are more likely to be a primary financial enabler of projects in rural areas, where revenues are needed to subsidize the price of stoves. In urban areas, where households have a financial incentive to reduce their fuel purchasing costs, business models without carbon financing may be more viable. While these factors may reduce confidence in the additionality of cook stove projects in urban areas, low income urban households are unlikely to be able to afford more efficient and more costly cook stoves with a payback period of more than a few months.

4.12.4. Baseline emissions

In both types of cook stove projects – improved efficiency and fuel substitution – emission reductions are calculated as the product of the amount of woody biomass saved, the fraction that is considered non-renewable biomass, the net calorific value (NCV) of the biomass, and an emission factor for the fuel used. The net calorific value of the non-renewable biomass ($NCV_{biomass}$) is relatively straightforward – it is empirically measurable and a default value from the Intergovernmental Panel on Climate Change (IPCC) exists. However, Lee et al. (2013) concluded that there is uncertainty in the approaches to estimating the other parameters: biomass fuel consumption (B_y), fraction of non-renewable biomass (f_{NRB}), and emission factors for fuel combustion ($EF_{projected\_fossilfuel}$). A study by Johnson et al. (2010) assessed the relative contributions of these three variables to the overall uncertainty in carbon offset estimation for an improved cook stove project in Mexico and found that fuel consumption (B_y) contributed to 28% of the uncertainty, fraction of non-renewable biomass (f_{NRB}) contributed 47%, and emission factors ($EF_{projected\_fossilfuel}$) accounted for 25%.

The CDM methodology AMS-II.G presents project developers with three options for quantifying biomass fuel savings from improved stoves: the Kitchen Performance Test (KPT), the Water Boiling Test (WBT), and the Controlled Cooking Test (CCT). The WBT and CCT are laboratory-based methods, whereas the **Kitchen Performance Test** is done in the field, and can thus better represent stove users' actual cooking behaviour. The primary advantage of the **Water Boiling Test** is its simplicity and reduced costs; the laboratory-based method is standardized and replicable. However, the laboratory results on stove performance do not necessarily translate to cooking actual meals in households, and thus the accuracy of this method is frequently called into question (Abeliotis & Pakula 2013; Johnson et al. 2007). Meanwhile, the **Controlled Cooking Test** protocol provides a compromise, better representing local cooking while being conducted in a controlled environment. Berrueta et al. (2008), which evaluated the performance of a stove designed primarily for tortilla-making by using all three tests and found that the WBT "gave little indication of the overall performance of the stove in rural communities", while the CCT was somewhat more predictive of the fuel savings found by the KPT (44-65% for CCT vs. 67% for KPT). There may be options for reducing costs associated with the KPT, such as having local NGOs perform the tests rather than hiring expensive international consultants, as well as opportunities to improve the WBT. In recent years, more comprehensive and appropriate testing methods and performance standards are under development through both ANSI and ISO standardisation organisations. The CDM methodology provides default efficiency values for two traditional stove types – a three-stone fire, or a conventional system with no improved combustion – as well as a default efficiency value for devices with improved combustion air supply or flue gas ventilation. Experts interviewed by Lee et al. (2013) noted that these limited defaults do not cover the range of cook stoves in most countries. The CDM Small-Scale Working Group (CDM SSC WG) considered this in the past, but made the determination not to proceed with developing regional default efficiency values for traditional cook stoves because of the huge variability in values among the available data (UNFCCC 2012a). Lee et al. (2013) conclude that although the KPT is more logistically complicated, and time- and resource-intensive, testing stoves outside of a controlled laboratory setting and using a variety of typical cooking activities appears to be an important factor in ensuring accurate and credible results in the baseline or default analysis. Overall, evidence suggests the Water Boiling Test is not an appropriate tool for assessing baseline fuel consumption and should be removed from the CDM methodology. The methodology should require the use of either the Kitchen or Controlled Cooking Tests. AMS-I.E follows a similar approach for calculating baseline emissions from fuel substitution of cook stoves.

The factor f_{NRB} represents the fraction of woody biomass saved by the project activity in year y that can be established as non-renewable biomass and is a key variable in all current cook stove offset methodologies

Based on its definition of renewable biomass (UNFCCC 2006b), the EB has identified several indicators of scarcity to help identify non-renewable biomass. Woody biomass is considered non-renewable if at least two of the following indicators are shown to exist:

- A trend showing an increase in time spent or distance travelled for gathering fuelwood, by users (or fuelwood suppliers) or alternatively, a trend showing an increase in the distance the fuelwood is transported to the project area;
- Survey results, national or local statistics, studies, maps or other sources of information, such as remote-sensing data, that show that carbon stocks are depleting in the project area;

- Increasing trends in fuel wood prices indicating a scarcity of fuel-wood;
- Trends in the types of cooking fuel collected by users that indicate a scarcity of woody biomass (UNFCCC 2011a).

In 2012, the EB issued national default factors for f_{NRB} based on a highly aggregated approach, balancing the mean annual increment in biomass growth (MAI), the annual change in living forest biomass stocks (ΔF) and biomass growth in protected forest areas (UNFCCC 2012a). Under this approach, f_{NRB} values were calculated for nearly 100 countries, based on the total annual national biomass removals minus the portion of demonstrably renewable biomass from growth in protected reserve areas. The large majority (over four-fifths) of default values exceed 80%, with the remainder ranging from 40% to 77%. While Lee et al. (2013) noted that market actors interviewed characterize development of default f_{NRB} values as a 'huge triumph', there was also recognition by market actors and researchers interviewed that national-level forest growth and total forest harvest removal data alone do not necessarily capture the impact of fuelwood harvesting on carbon stocks. First, the approach does not distinguish removals for timber harvesting from those for fuelwood. Furthermore, there is no justification or validation of whether the change in national carbon stocks has any correlation to fuelwood harvesting. Second, according to this method, high values of f_{NRB} are calculated for countries with significant deforestation. However, deforestation could occur in different geographical areas and be driven by entirely other factors than fuel wood collection. In practice, renewable biomass may be extracted both from plantations and natural forests that are not under protection. The MAI approach is better suited to assess the fraction of harvested wood products that are renewable, rather than fuelwood. Using the change in carbon stocks due to harvested wood products has the potential to significantly overestimate the fraction of non-renewable biomass. Estimates published by de Miranda Carneiro et al. (2013), based on the use of a spatially-explicit land use model to examine the availability of fuelwood, suggest default values for f_{NRB} of wood-fuel on the order of 20-30%, much lower than the prior estimates. Bailis et al. (2015) estimate that 27–34% of woodfuel harvested was unsustainable, with large geographic variations, and conclude that cookstove methodologies probably overstate the climate benefits.

Under the CDM methodology AMS-II.G and AMS-I.E, the quantification of project emission reductions relies on the factor $EF_{projected\_fossilfuel}$, representing the fossil fuel emission factor of "substitution fuels likely to be used by similar users". Since emission reductions from the LULUCF sector can only be claimed from afforestation and reforestation under the CDM, the use of fossil fuel emission factors for baseline fuels represents something of a workaround. While the short-term emission reductions actually occur from avoiding the depletion of carbon stocks, such as avoiding deforestation, emission reductions are calculated using fossil fuel emission factors. One possible argument for this approach is that kerosene or LPG cook stoves might be used by the households if they had a higher income. In this regard, the consideration of emissions from fossil fuel based cooking devices might be regarded as a suppressed demand baseline. However, the approach combines the efficiency of fuel-wood cook stoves with the CO_2 emission factor of fossil fuels. This approach has been roundly criticized. Johnson et al. (2010) say it has "no scientific basis, given that wood emits approximately double the CO_2 per unit fuel energy compared to LPG or kerosene thus halving possible offsets from non-renewable harvesting of fuel". One could also argue that it leads to overestimating baseline emissions if one would assume the long-term suppressed demand baseline of using kerosene or LPG cook stoves. By combining the efficiency from inefficient fuel-wood cook stoves with the CO_2 emission factors from fossil fuels, the claimed baseline emissions are higher than if the households would use kerosene or LPG cook stoves. The CDM methodology AMS-II.G. suggests the use of a weighted average value of 81.6 tCO2/TJ[2], representing a mix of 50% coal, 25% kerosene, and 25% LPG. However, no justification for this fuel mix provided. Coal is not commonly used as a cooking fuel for households transitioning from traditional to modern biomass.

LPG is the dominant fossil fuel used in households transitioning to modern energy for household cooking. Assuming that households would use coal vs. LPG overestimates the emissions factor. For example, if we compare the emissions factor if the fuel mix was LPG vs. the current emission factor we find that the emissions are overestimated by 23%. For charcoal production, the simplification is stretched even further beyond reality. The methodologies permit calculating wood use by charcoal stoves by multiplying the charcoal volume by six, following the 1996 IPCC accounting guidelines to estimate total biomass consumed (IPCC/OECD/IEA 1996, p. 1.42). Then baseline emissions are estimated by applying the projected fossil fuel use emissions factor, which in effect assumes that the project displaces fossil fuel use for charcoal production, which likely significantly overestimates the baseline emissions (Lee et al. 2013).

4.12.5. Other issues

Improved cook stove projects are dependent on end users to achieve emission reductions: households must actually use the improved cook stoves instead of their traditional stoves. Carbon finance monitoring requirements include checking the efficiency of the stove and confirming at least every two years that the stove is still in use. Additional stove monitoring of the efficiency and usage rate is required annually or biannually. Monitoring requirements furthermore include sampling and surveying as specified in the applicable offset protocol. This has been a significant challenge. Carbon finance project monitoring requirements further specify that projects must either ensure that the improved stoves completely replace traditional stoves, or else the traditional stoves must be monitored and accounted for under the project calculations for emission reductions. Lambe et al. (2014) found in their review of projects in Kenya and India that this presented several challenges. In Kenya, where the predominant mode of traditional cooking is with a three-stone fire, the study found that many PDDs acknowledged that this form of traditional stove cannot really be removed or destroyed. In India, traditional stoves in several regions are known as chulhas. These stoves often have a religious significance and households often build the stoves themselves from locally available materials such as mud, brick, or cement (Lambe & Atteridge 2012). This form and construction makes it difficult to guarantee that a new chulha will not be made following the destruction of the old one. Lambe et al. (2014) found that many projects required households to destroy these existing cook stoves. In some cases, photographic evidence is used to demonstrate that the existing stoves have been destroyed. However, because of the challenges with removing traditional stoves and the barriers to ensuring adoption and sustained use of improved cook stoves, more often a stacking of stoves and fuels occurs where traditional and improved cook stoves are both used for different types of cooking (Ruiz-Mercado et al. 2011). While the methodologies contain monitoring guidance for adjusting the baseline fuel consumption if the traditional stove continues to be used, this adds further uncertainty to quantification of changes in fuel consumption. Use of temperature sensors to monitor usage of traditional and improved cook stoves have shown promising signs of helping to address this issue, but are not yet in widespread use in carbon market projects (Ruiz-Mercado et al. 2011).

There is a broader concern about crediting emission reductions from displacement of non-renewable biomass since the increased carbon storage from changes in carbon stocks may only lead to temporary reductions. The risk of non-permanence of emission reductions is addressed through appropriate accounting approaches for afforestation, reforestation, and carbon capture and storage project activities, but it is not addressed for improved cook stove project types. Under the CDM, there are projects promoting the use of biomass energy to displace fossil fuel, as well as improved cook stove projects aimed at decreasing biomass energy use. In theory, this does not present a conflict, assuming that biomass power projects are based in regions with increasing or stable carbon stocks and improved cook stove projects are located in regions with declining carbon stocks. However, looking at registered CDM projects there are several examples of provinces in which there are both biomass power and cook stove projects. This means that in the same province, there are simultaneously CDM projects getting credit for increasing the use of biomass, as well as reducing the use of biomass. For example, in the Henei province in China there are 9 biomass energy projects fuelled by agricultural residues (rice husk and other kinds) as well as 4 improved cook stove projects.

4.12.6. Summary of findings

Additionality	• CER revenues are insufficient to fully cover project costs, confidence in additionality may be low in urban settings where households are paying for improved stoves at the retail price
Over-crediting	• Uncertainty in some widely used approaches for estimating biomass savings • Significant uncertainty around the fraction of non-renewable biomass values, recent research suggests this parameter may be significantly overestimated. • Emissions intensity factors of fossil fuel likely underestimate emissions relative to wood-fuel used in the baseline. • Emissions factor for suppressed demand use of fossil fuel overestimate emissions; LPG is the appropriate substitute used by similar consumers, including coal and kerosene overestimate emission reductions.
Other issues	• Challenges in ensuring adoption and sustained use of improved cook stoves result can lead to over-crediting if traditional stoves continue to be used. • The use of biomass as a renewable energy sources is inconsistently accounted for under the CDM; the same region can have biomass power projects receiving credit for increasing biomass use and improved cook stove projects receiving credit for decreasing biomass use.

4.12.7. Recommendations for reform of CDM rules

We recommend revising the current methodologies as follows:

- Eliminate the use of the Water Boiling Test as a means of determining baseline emissions.
- Reconsider the use of default f_{NRB} factors based on the MAI approach.
- Revise the emission factor for the substitution of non-renewable biomass by similar consumers to one based solely on LPG.
- Explore options for incorporating temperature sensors in monitoring plans to improve reliable assessment of the adoption and sustained use of improved vs. traditional cook stoves in households.
- Review the use of biomass as an energy source under the CDM to ensure consistent accounting across project types and regions. The f_{NRB} should be considered in improved cook stove projects, as well as modern biomass energy projects to confirm that projects are not contributing to loss of carbon stocks. The CDM EB needs to provide justification for how both biomass energy and improved cook stove projects can be approved within a subregion.

4.13. Efficient lighting

4.13.1. Overview

For energy efficient lighting, we focus our analysis on the replacement of incandescent electrical bulbs with more efficient electric lighting, such as Compact Fluorescent Lamps (CFLs) or Light Emitting Diode (LED) lamps. This includes all projects registered under AM0046[79] and AMS II.J[80]

[79] Distribution of efficient light bulbs to households --- Version 2.0.
[80] Demand-side activities for efficient lighting technologies --- Version 6.0.

methodologies as well as projects registered under AMS II.C[81] that are labelled as 'lighting' and 'lighting in service' in UNEP DTU (2014).[82] This technology category was a late starter in the CDM – in mid-2010 there were only half a dozen registered projects and 3 registered PoAs. Recent growth in PoAs, particularly with larger PoAs, indicates a higher potential in the future – even beyond the current project activity and PoA pipeline. Energy efficient lighting projects are typically implemented by an entity (often public sector or linked to a utility) that distributes energy efficient lamps for free or for a nominal fee, and collects and disposes of the incandescent bulbs that have been displaced.

4.13.2. Potential CER volume

For CDM project activities, the 40 projects registered by the end of 2013 state that they will produce 1.4 million CERs per year. This would be 10.3 million CERs in the period of 2013 to 2020. However, the issuance success for the largest project activity, which is the only project using the large-scale methodology, amounted to only 12% in the first monitoring period. This could be related to the time required for the CFL distribution programme to reach full scale, however, and does not necessarily mean that other projects will have similar issuance rates (or that this rate will not increase over time). Other projects have been much more successful, but are considerably smaller. Project activities are dominated by a stream of small-scale projects in India and a single large-scale project in Ecuador – the only registered large-scale energy efficient lighting project – which account for almost 80% of the expected CERs. More than 80% of the small-scale projects use AMS II.J, which was designed specifically as a simplified approach to energy efficient lighting.

The largest volume of CERs for energy efficient lighting, however, could come from PoAs. Twenty-six PoAs had been registered for energy efficiency lighting by the end of 2013. Just from the CPAs already included in these registered PoAs as of the end of 2013, the volume of CERs is estimated by the project developers at 3.4 million per year, or two and a half times greater than for project activities. This could continue to grow, given that only four PoAs have more than one CPA. For PoAs, the main players are China, India, Mexico and Pakistan, with South Africa also hosting multiple PoAs (Table 4-10). The four PoAs with more than one CPA have large numbers of CPAs (e.g. 9 to 53). For some PoAs, the CPAs are delineated to have very similar emission reductions in each CPA (e.g. in Mexico, India, Bangladesh).

81 Demand-side energy efficiency activities for specific technologies --- Version 14.0.

82 This excludes one registered PoA under AMS II.C that focuses on street lighting and is labelled as sub-type "Street lighting".

Table 4-10: Number of energy efficient lighting PoAs and CERs by country and methodology

Country	Number of PoAs	Annual CERs (1,000)	CPAs per PoA	Annual CERs/CPA (1,000)	PoAs with >1 CPA
Bangladesh	1	124	9	14	1
China	14	443	1	32	
India	3	1,555	17	30	1
Kenya	1	31	1	31	
Mexico	1	607	25	24	1
Nigeria	1	29	1	29	
Pakistan	1	557	53	11	1
Senegal	1	4	1	4	
South Africa	3	80	1	27	
AMS-II.C.	6	668	5	22	
AMS-II.J.	20	2,762	6	21	
Total	**26**	**3,431**			**4**

Sources: UNEP DTU 2015b

All of the PoAs for lighting efficiency upgrades have moved to the newer methodology AMS II.J rather than AMS II.C (Table 4-10). No new energy efficient lighting PoAs have entered the pipeline since October 2012, and the new project activity pipeline largely stopped in January 2012, with only one new project activity starting validation in 2013 (in The Gambia).

4.13.3. Additionality

Because only one project activity uses the large-scale methodology, this entire technology area essentially uses SSC methodologies and additionality rules. For SSC projects and PoAs, additionality can be determined through several different routes: All SSC projects (or SSC CPAs within PoAs) must refer to the tool for “Demonstration of additionality of small-scale project activities” (Tool21, ver10.0). This includes the choice of using several different barriers to justify additionality (i.e. investment barrier, technology barrier, prevailing practice barrier, or other barriers). In addition, from July 2012, projects comprised entirely of units below 5% of the small-scale CDM threshold (i.e. 3000 MWh savings for energy efficiency) were considered automatically additional without any further justification. This new ‘positive list’ additionality argument has not been used by CDM project activities but has been used extensively by PoAs, as discussed further below. Most CDM project activities applying the SSC additionality tool cite investment barriers and use simple cost analysis to prove additionality (Table 4-11). This is because the organisations distributing the efficient lamps do not receive the energy savings, so they incur only costs without any revenue (other than a nominal fee from consumers in some cases).[83]

As mentioned above, since July 2012, the tool for additionality of SSC activities has allowed automatic additionality based on a ‘unit threshold’ described as “project activities solely composed of isolated units where the users of the technology/measure are households or communities or Small and Medium Enterprises (SMEs) and where the size of each unit is no larger than 5% of the small-

[83] The organisations that charge a nominal fee would be receiving less than the wholesale cost of the CFL, so would lose money on each bulb even though there is nominal revenue. In theory, any programme implemented by an electric utility should not be able to use simple cost analysis because the utility has avoided power generation costs (and deferred capital costs) that are a benefit stream to the project. Even where the project is implemented by a utility (e.g. South Africa’s Eskom), this is not addressed because the unit threshold positive list is used to justify additionality.

scale CDM thresholds." For energy efficiency, this threshold of 3000 MWh is roughly 46,000 CFLs. All projects and PoAs applying SSC methodologies may use this rule to qualify for automatic additionality.

Table 4-11: Additionality approaches used by efficient lighting CDM project activities

Additionality approach	Number of PAs	Total Annual CERs (1,000)
Investment barrier: Benchmark Analysis	2	71
Investment barrier: Investment Comparison Analysis	2	60
Investment barrier: Simple Cost Analysis	33	1.079
Investment barrier: Other	1	18
Positive list	2	44
Total	**40**	**1.272**

Sources: Authors' own compilation

Lighting PoAs have also made extensive use of this unit threshold for automatic additionality. A report by the UNFCCC Secretariat in mid-2014 (CDM-EB85-AA-A09) found that 28 of the registered lighting-related PoAs at that time had used either micro-scale or unit thresholds to qualify for automatically additionality. As an example, all 12 of the Chinese PoAs registered in December 2012 used the unit threshold for automatic additionality.

As one of the first 'top-down' large-scale methodologies, the EB published an energy efficiency lighting methodology in November 2013, which included a new approach for additionality demonstration:

- In countries with limited or no regulations supporting energy efficient lighting, as evidenced by a UNEP Global Lighting Map[84] survey of regulations and support for energy efficient lighting, CFLs are automatically additional.[85]
- For other countries (i.e. those with more regulatory support), the "Tool for the demonstration and assessment of additionality" must be used, with an investment analysis and common practice analysis. While the investment analysis may still use simple cost analysis (which would mean that almost all projects would be additional), any country with a higher than 20% penetration of CFLs is not additional under the common practice test.

This new approach essentially restricted CFL CDM projects to countries with limited regulatory support or low market penetration. Given that there are no new projects or PoAs entering the pipeline, however, this more recent methodology has not yet had an impact.

In November 2014, AMS II.J was also revised to only allow for automatic additionality for CFLs when there were limited or no regulations to support energy efficient lighting. However, for countries in which there is significant support for energy efficient lighting, the methodology says that additionality should be demonstrated using the latest version of the "Guidelines on the demonstration of additionality of small-scale project activities". This difference is critical, however, because any project participant may simply use the unit threshold in the "Guidelines on the demonstration of

84 http://map.enlighten-initiative.org/.
85 Countries coloured red on the map have limited or no support for energy efficient lighting.

additionality of small-scale project activities" to guarantee automatic additionality, whatever the market penetration in the host country.

The main concern with the additionality of energy efficient lighting in the CDM is whether some activities – at least projects involving CFLs and fluorescent tubes – were already common practice at the time of registration and therefore not additional. The use of micro-scale or unit threshold positive lists means that project activities and PoAs do not have to address this common practice issue at all when using the SSC methodologies. In other words, using the SSC methodologies would be a way of circumventing the higher stringency of the new large-scale methodology. Projects could simply define the size of each CPA in a way that they qualify as automatically additional, whatever the regulations and market penetration in the host country. To evaluate the additionality of the existing pipeline, it is useful to consider the two criteria from AM0113 and the revised AMS II.J: regulatory support and market penetration.

According to the 'en.lighten' initiative's Global Lighting Map referenced in the methodologies, regulatory support for efficient lighting is widespread, but varies greatly by country (Figure 4-9). For the countries with the most CDM PoA activity, the level of support is generally strong:

- China has already banned incandescent lighting[86] and implemented large state subsidy programmes since 2006.[87]
- India does not have a ban on incandescent bulbs, but does have awareness-raising programmes, energy service company initiatives, and consumer financing options.
- Pakistan's minimum energy performance standards also still allow incandescent bulbs, but the country has awareness-raising programmes, bulk procurement and tax incentives.
- South Africa has announced that incandescent bulbs will be phased out by 2016[88], and has testing and certification facilities. More importantly, the national utility, Eskom, distributed 30 million free CFLs between 2002 and 2010.[89]
- A regional report for Latin America on the en.lighten initiative's website notes that a Mexican regulation was passed in December 2010 prohibiting the sale of 100 watt and higher incandescent lamps for the residential sector after December 2011, and similar bans for 75 watt as of December 2012 and 40-60 watt as of December 2013.[90] The Mexican PoA was registered in July 2009, which preceded the passing of these regulations.
- In terms of their rating on minimum energy performance standards by the Global Lighting map, all of the countries with PoAs except Kenya and Malawi are orange (some/in progress) or green (advanced). This means that, in terms of the new large-scale methodology (AM0113), projects in all of the countries except Kenya and Malawi would not be automatically additional, but require the use of the additionality tool with investment analysis and the common practice threshold of 20%.

[86] Imports and sales of 100-watt-and-higher incandescent lamps are banned from 1 October 2012, 60-watt-and-above from 1 October 2014, and 15 watts or higher from 1 October 2016 http://www.chinadaily.com.cn/china/2011-11/04/content_14039321.htm.

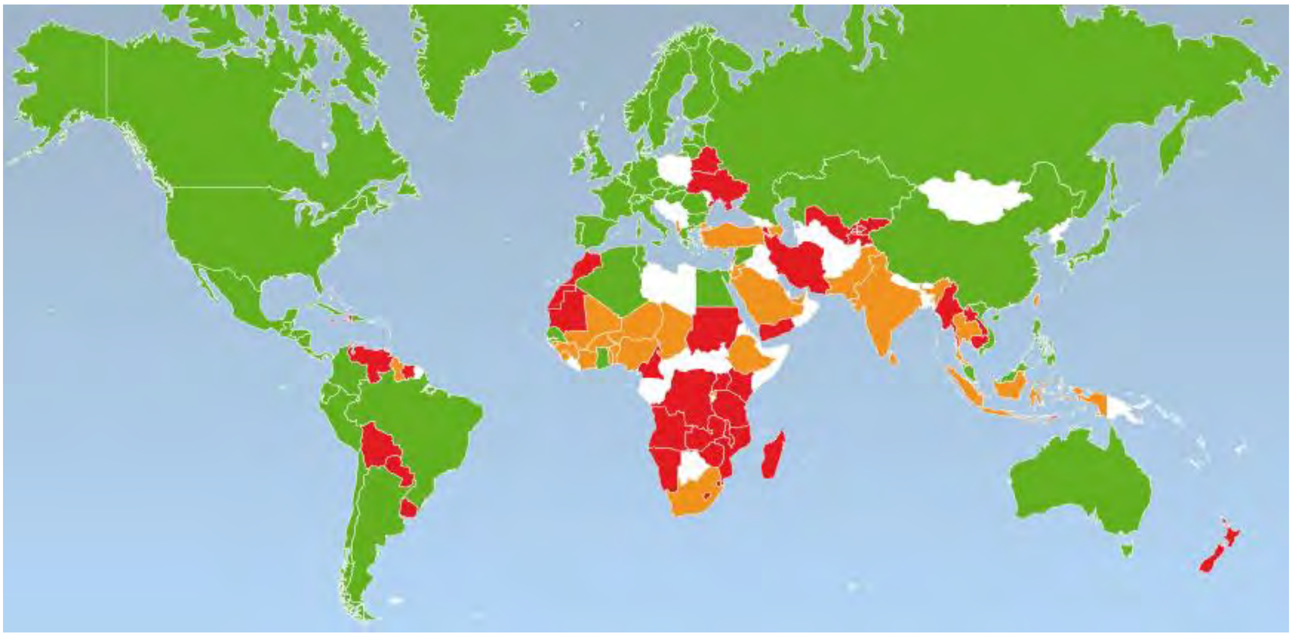
[87] http://www.sdpc.gov.cn/zjgx/t20080508_210093.htm.

[88] http://www.thegef.org/gef/content/phasing-out-inefficient-lighting-combat-climate-change-south-africa-announces-national-phase.

[89] http://www.eskom.co.za/OurCompany/SustainableDevelopment/ClimateChangeCOP17/Documents/The_Eskom_National_Efficient_Lighting_Programme_Compact_Fluorescent_Lamps_Clean_Development_Mechanism_Project.pdf.

[90] http://www.enlighten-initiative.org/portals/0/documents/country-support/regional-workshops/Regional%20Report%20LA%20&%20C%20Final%20Eng..pdf. The reference is to regulation "NOM- 028 – ENER – 2010 Energy Efficiency of Lamps for General Use".

Figure 4-9: Minimum energy performance standards for lighting technologies



Notes: Green = Advanced/in place, Orange=In progress, Red=few/limited, white=no information available

Sources: http://map.enlighten-initiative.org/

In terms of assessing common practice, the available evidence suggested that CFLs are likely already common practice in most key CDM countries, and LEDs may be so in the next few years, though not in the poorest countries. The main CDM countries have the following market information:

- According to the "Regional Report on the Transition to Efficient Lighting in South Asia"[91] prepared by the Tata Energy Research Institute in 2014, the market share of CFLs in India amounted to 29% in 2012-2013. Three of the four Indian PoAs were registered in late 2012, while one was registered in early 2010. In addition, for the largest PoA – which was registered in 2010 and has 50 CPAs – the PoA DD states that, "[t]he penetration share of incandescent lamps for lighting in commercial and residential sector put together is thus nearly 80% in India."[92] The market share for CFLs, therefore, was almost certainly above 20% when the PoAs were registered.

- In China, a 2012 McKinsey & Company report estimates the penetration of LEDs (the more expensive alternative to CFLs) as 12% in 2011, rising to 46% by 2016. The report also notes that, "CFL is still the dominant technology in the residential segment."[93] This means that, at the time of registration of the PoAs, the market share of CFLs was almost certainly above 20%. China does not have any LED PoAs yet. If they were proposed, AMS II.J and AM0113 both consider LED lamps automatically additional in all countries until at least the end of 2016. Given the McKinsey projections presented above, automatic additionality for LEDs in China would not be appropriate.

91 http://www.enlighten-initiative.org/Portals/0/documents/country-support/Regional%20Report%20on%20the%20Transition%20to%20Efficient%20Lighting%20in%20South%20Asia.pdf.

92 http://cdm.unfccc.int/ProgrammeOfActivities/gotoPoA?id=CZ59J1XMR8K4ELUS6WY3BA0IVTGQ2F.

93 http://www.mckinsey.com/~/media/mckinsey/dotcom/client_service/automotive%20and%20assembly/lighting_the_way_perspectives_on_global_lighting_market_2012.ashx.

- The large PoA in Mexico states in the PoA DD that CFL penetration in 2007 was already at 20%, while the PoA was registered in June 2009.[94]
- In South Africa, even before the start of the Eskom free CFL distribution programme, the market share of CFLs was estimated at 7% in 2002 (Nkomo 2005). With 30 million CFLs distributed after this time,[95] in a country with less than 10 million households, the penetration of efficient lighting was almost certainly well above 20% when Eskom registered their CDM project activity and PoAs in 2012.
- For Pakistan, the "Regional Report on the Transition to Efficient Lighting in South Asia" cited above estimates the CFL market share at 8%, but also notes that linear fluorescent lamps make up 32% of the market.
- For Bangladesh, the same report puts the CFL market share at 25%, with linear tube fluorescent lamps at 18%. This market share could be for 2013 and the PoA was registered in May 2011, so there is a reasonable likelihood that the market share of CFLs was 20% at the time of registration.

This information suggests that the largest CDM PoA countries for energy efficient lighting would not pass the common practice test if the large-scale AM0013 methodology were applied, and so these PoAs would not qualify as additional. Bangladesh, China, India, South Africa and Mexico account for almost 80% of the expected CERs from PoAs, and yet these countries were likely above the 20% market share for CFLs when the PoAs were registered.

For off-grid lighting (AMS III.AR), the situation is quite different. Access to electricity in rural households in Sub-Saharan Africa, for example, is less than 10% (IEA et al. 2010; Legros et al. 2009). Between 2010 and 2015, the estimated number of unelectrified households in Africa was estimated to grow from 110 million to 120 million (Dalberg Global Development Adv. 2010) . The off-grid solar lamp market is expanding to address the 1.5 billion people who do not (and, in many cases, will not) have access to electricity (IFC 2012). While solar lantern and solar kit prices are decreasing, they still face major barriers in terms of distribution challenge, upfront costs (and lack of consumer financing), and successful business models for scaling up (ESMAP 2013; IFC 2012).

Assessing the economics of energy efficient lighting faces the classic problem of 'split incentives' (Spalding-Fecher et al. 2004). From an economic point of view, upgrades to energy efficient electric lighting are unquestionably economically beneficial (i.e. have large positive IRRs) (McKinsey & Company 2009) but the benefits do not accrue to those who pay for the additional costs if the project is funded by outside agencies. The economics of efficient lighting are more likely to be driven by electricity prices than carbon prices. For example, a 15 W CFL replacing a 60W incandescent lamp operated 3.5 hours per day could save 57 kWh per year. With a relatively carbon-intensive grid (e.g. 0.8 tCO_2/MWh), this would be 0.05 tCO_2e savings per year. Electricity prices to the consumer in developing countries vary widely, from \$50/MWh in heavily subsidized economies to more than \$170/MWh in more competitive emerging economies (EIA 2010; Winkler et al. 2011). This means an energy savings of \$2.87 to \$9.77/year. CFL costs have also declined rapidly, with current costs of \$1.50-\$2.50 in many countries (UNEP 2012). This would mean a typical payback period of much less than one year, before any carbon revenue was received. At current CER prices, carbon revenue would be less than two cents per year only, while at \$3-5/CER, revenue would be \$0.15-0.25, or less than 5% of energy savings.

94 http://cdm.unfccc.int/ProgrammeOfActivities/poa_db/17BH6AJX524TYQUZF8KGCWV3OIPSE9/view Annex 3.

95 http://www.eskom.co.za/OurCompany/SustainableDevelopment/ClimateChangeCOP17/Documents/The_Eskom_National_Efficient_Lighting_Programme_Compact_Fluorescent_Lamps_Clean_Development_Mechanism_Project.pdf.

In summary, CDM rules on additionality of efficient lighting projects vary considerably. Using market penetration and regulatory support as indicators for the likelihood seems a reasonable approach. The large-scale AM0113 methodology uses market penetration and regulatory support as indicators for demonstrating additionality; this approach seems reasonable and reflects the varying circumstances of host countries. AM0046 may provide for a suitable alternative by monitoring the market penetration of CFLs and LEDs in a control group outside the project boundary; however, the complexity and cost of monitoring under this methodology means that only one project has even chosen to utilise it – so the additionality approaches may not be relevant for the overall impact of this project category. In contrast, under small-scale methodologies, including the revised AMS II.J, this project type is, in practice, considered automatically additional, even if the use of CFLs is required by regulations and is widespread. However, for countries with regulations that have phased out incandescent bulbs or large subsidy programmes for CFLs, these existing registered projects are unlikely to be additional. If we take the 20% market share used in AM0113 as the point at which CFL programmes are no longer likely to be additional, then this would apply to most of the current CDM pipeline for energy efficient lighting.

4.13.4. Baseline emissions

In AMS II.J, AM0113 and AMS II.C (when used for lighting) the baseline is simply the use of the existing incandescent lamps – those which are collected and replaced within the project boundary.[96] Both AMS II.J and AM0113 take similar approaches, where emissions reductions are related to the difference in power between a CFL and baseline bulb, operating hours, lamp failure rates, a 'net-to-gross' adjustment, and the grid emissions factor (taking technical losses into account).[97] As a default, 3.5 operating hours per day are assumed. If project participants want to use operating hours greater than 3.5 per day, they must conduct a once-off survey at the start of the project to justify this. The lamp failure rates are also based on periodic surveys of the first group of bulbs installed, up to the end of their rated life. The methodologies require project participants to explain how they will collect and destroy baseline lamps. For off-grid lighting, an innovative 'deemed consumption' approach assigns a standard emissions reduction to each off-grid lighting unit, based on the fossil fuel alternative. The parameters and assumptions are conservative. Overall, the approaches to baseline emissions for efficient lighting are straightforward and conservative, and the improvements over the last two years have also simplified or clarified many of the sampling procedures.

4.13.5. Other issues

At 3-5 hours of use per day, a typical CFL would last anywhere from 3 to 10 years. This means that a crediting period of 10 years is almost certainly too long, unless the CDM project guarantees free replacements throughout the programme or restricts crediting to the measured life. The latter approach has been adopted under the CDM. Emission reductions do not accrue once the lamp failure rate reaches 100%, so if all lamps fail before the end of the crediting period and are not replaced, then no CERs would be issued. These provisions seem appropriate.

[96] AM46 also includes the possibility of some efficient lighting in the baseline, as a form of "autonomous efficiency improvement", but this methodology has only been used once and is unlikely to be used in the future.

[97] AMS II.C is not so specific, because the guidance was for all energy efficiency technologies, but the approach elaborated by the project participant would essentially be the same.

4.13.6. Summary of findings

Additio-nality	• Granting automatic additionality under small-scale methodologies to all energy efficient lighting programmes in the past was highly problematic because there were large PoAs in countries in which the move away from incandescent bulbs was well underway; the new large-scale AM0113 methodology appropriately addresses these problems but is not mandatory, while the remaining small-scale methodology could still allow for automatic additionality for CFL programmes, so it is unlikely that the large-scale methodology will be used. • In many countries with lower income or less regulatory support, however, efficient lighting still faces major barriers, even if it is potentially economic beneficial, and so projects may need the support of the CDM to be implemented; these projects currently form a very small part of the project pipeline but could grow in the future.
Over-crediting	• Over-crediting is unlikely, given the robust monitoring procedures.
Other issues	• None

4.13.7. Recommendations for reform of CDM rules

AMS II.J should be revised so that CFL programmes in countries with significant regulatory support may use the tool for “Demonstration of additionality of small-scale project activities” but may not use the paragraph referring to automatic additionality based on small unit size.

5. How additional is the CDM?

Based on the detailed analysis of individual project types in the previous chapter, this chapter provides an overall assessment of the environmental integrity of the CDM project portfolio available for the second commitment period of the Kyoto Protocol. Table 5-1 provides an overview of the summary of findings for each of the analyzed project types.

Table 5-1: Evaluation of project types

Project type	Additionality [1)]	Over-crediting [2)]	Other issues	Overall environmental integrity [3)]
HFC-23 (up to version 5)	• Likely to be additional	• Risk of perverse incentives	• None	Medium
HFC-23 (version 6)	• Likely to be additional	• Risk of perverse incentives largely addressed • Ambitious baseline could lead to under-crediting (net mitigation benefit)	• Low CER prices could jeopardize continued operation • Emissions could be addressed through Montreal Protocol	High
Adipic acid	• Likely to be additional	• Most recent methodology could lead to slight under-crediting • Leakage could lead to significant over-crediting in times of higher CER prices	• None	Medium
Nitric acid	• Likely to be additional	• Most recent methodologies lead to under-crediting • Overall, little risks of overall over-crediting	• None	High
Wind power	• CER revenue has only limited impact on profitablity • Investment costs decreased significantly in last years • In some cases competitive with fossil generation • Support schemes • Widespread in many countries	• Methodological assumptions may lead to both over- and under-crediting	• None	Low
Hydro power	• Common practice in many countries • CERs have only moderate impact on profitablity • Competitive with fossil generation in many cases	• Methodological assumptions may lead to both over- and under-crediting; over the lifetime of the project likely under-crediting	• Methane emissions from reservoirs may be important and may not be fully reflected by CDM methodologies	Low
Biomass power	• Significant impact of CER revenues on profitability for projects claiming methane avoidance • Competitive with fossil generation in many cases • Support schemes	• Demonstration of biomass decay/abundance of biomass is key • Risk of exaggerated claims of anaerobic decay	• None	Medium

Project type	Additionality 1)	Over-crediting 2)	Other issues	Overall environmental integrity 3)
Landfill gas	• Likely to be additional	• Default assumptions for the rate of methane captured historically have the potential to overestimate emission reductions • Default soil oxidation rates may underestimate emission reductions for uncovered landfills in humid subtropical and tropical regions • Perverse incentives for project developers to increase methane generation	• Perverse incentives for policy makers not to pursue less GHG intensive waste treatment methods	Medium
Coal mine methane	• Likely to be additional	• Potential concerns regarding increased mining	• Potential perverse incentives to dilute methane in order to avoid that abatement is required by regulations	Medium
Waste heat recovery	• CER revenues small compared to fossil fuel cost savings • Future fuel cost savings uncertain • Widespread in many countries	• Brownfield: risks for inflated baselines • Greenfield: modelling uncertain • Plant operation under the project different to baseline	• None	Low
Fossil fuel switch	• Use of barrier analysis allowed for small-sclae projects not appropriate • Investment analysis insufficient as choice of fuel depends not only on prices • CER revenues have a small impact	• Default values for upstream emissions not appropriate	• None	Low

Project type	Additionality [1]	Over-crediting [2]	Other issues	Overall environmental integrity [3]
Efficient cook stoves	• CER revenues are insufficient to fully cover project costs • Additionality questionable in urban areas	• Fraction of NRB likely to be overestimated • Water boiling test not appropriate • Emission intensity factors of fossil fuel likely underestimate emissions relative to wood-fuel used in the baseline • Emissions factors used for suppressed demand are unrealistic • Unrealistic assumptions for charcoal use • Over-crediting if traditional stoves continue to be used	• Inconsistent accounting: CDM credits in the same region both reduction and increase of biomass use	Low
Efficient lighting (AMS II.C AMS II.J)	• Shift to EE lighting well underway and/or mandates in most common PoA countries, and PoAs allowed to use SSC additionality 'loophole'	• Unlikely	• None	Low
Efficient lighting (AM0113, AM0046)	• Likely to be additional	• Unlikely	• None	High

Notes: [1] High/medium/low likelihood of projects being additional under current rules; [2] High/medium/low likelihood of avoiding over-crediting under current rules; [3] High/medium/low likelihood of emission reductions being additional and not over-credited under current rules.

Sources: Authors' own compilation

Overall, the table shows considerable differences between project types. Most energy-related project types (wind, hydro, waste heat recovery, fossil fuel switch and efficient lighting) are unlikely to be additional, irrespectively of whether they involve the increase of renewable energy, efficiency improvements or fossil fuel switch. An important reason that these projects types are unlikely to be additional is that for them the revenue from the CDM is small compared to the investment costs and other cost or revenue streams, even if the CER prices would be much higher than today. In addition, technological progress was much faster than expected, so that investment and generation costs have fallen considerably. Moreover, some project types are, in many instances, economically attractive (e.g. waste heat recovery, fossil fuel switch, hydropower), or supported through policies (e.g. wind power, efficient lighting), or mandatory due to regulations (e.g. efficient lighting). Some of these project types also have a medium likelihood of overestimating emission reductions, mainly due to risks of inflated baselines.

Industrial gas projects (HFC-23, adipic acid, nitric acid) can generally be considered likely to be additional as long as they are not promoted or mandated through policies. They use end-of-pipe-technology to abate emissions and thus do not generate revenues other than CERs. HFC-23 and adipic acid projects triggered strong criticism because of their relatively low abatement costs, which provided perverse incentives and generated huge profits for plant operators. In the case of HFC-

23, perverse incentives were addressed with the adoption of version 6 of AM0001, which uses an ambitious baseline that could lead to a net mitigation benefit. Similarly, concerns with perverse incentives for nitric acid plant operators not to use less GHG-intensive technologies were addressed. With regard to adipic acid projects, the risks of carbon leakage were not addressed.

Methane projects (landfill gas, coal mine methane) also have a high likelihood of being additional. This is mainly because carbon revenues have, due to the GWP of methane, a relatively large impact on the profitability of these project types. However, both project types face issues with regard to baseline emissions and perverse incentives and may thus lead to over-crediting.

Biomass power projects have a medium likelihood of being additional since their additionality very much depends on the local conditions of individual projects. In some cases, biomass power can already be competitive with fossil generation while in other cases domestic support schemes provide incentives for increased use of biomass in electricity generation. However, where these conditions are not prevalent, projects can be additional, particularly if CER revenues for methane avoidance can be claimed. Biomass projects also face other issues, in particular with regard to demonstrating that the biomass used is renewable.

The additionality efficient lighting project using small-scale methodologies is highly problematic because there were large PoAs in countries in which the move away from incandescent bulbs was well underway. The new methodologies address these problems but they are not mandatory and the small-scale methodologies are while the remaining small-scale methodology could still allow for automatic additionality for CFL programmes.

For cook stove projects, CDM revenues are often insufficient to cover the project costs and to make the project economically viable. In urban areas, however, the additionality of these project types is questionable. Cook stove projects are also likely considerably over-estimate the emission reductions due to a number of unrealistic assumptions and default values.

Based on these considerations we can estimate to which extent the CDM is likely to deliver additional emission reductions during the period of 2013 to 2020 (Table 5-2).

Table 5-2: How additional is the CDM?

	CDM projects			Potential CER supply 2013 to 2020		
	Low	Medium	High	Low	Medium	High
	… likelihood of emission reductions being real, measurable, additional					
	No. of projects			Mt CO_2e		
HFC-23 abatement from HCFC-22 production						
Version <6		5			191	
Verson >5			14			184
Adipic acid		4			257	
Nitric acid			97			175
Wind power	2.362			1.397		
Hydro power	2.010			1.669		
Biomass power		342			162	
Landfill gas		284			163	
Coal mine methane		83			170	
Waste heat recovery	277			222		
Fossil fuel switch	96			232		
Cook stoves	38			2		
Efficient lighting						
AMS II.C, AMS II.J	43			4		
AM0046, AM0113			0			0
Total	**4.826**	**718**	**111**	**3.527**	**943**	**359**

Sources: Authors' own calculations

Our analysis covers three quarters (76%) of the CDM projects and 85% of the potential CER supply during that period. 85% of the covered projects and 73% of the potential CER supply have a low likelihood of ensuring environmental integrity (i.e. ensuring that emission reductions are additional and not over-estimated). Only 2% of the projects and 7% of potential CER supply have a high likelihood of ensuring environmental integrity. The remainder, 13% of the projects and 20% of the potential CER supply, involve a medium likelihood of ensuring environmental integrity.

Has the performance of the CDM in terms of additionality improved over time? Several EB decisions have certainly improved the performance, particularly those which introduced ambitious baselines and/or addressed perverse incentives. However, Schneider (2007) estimated, "that additionality is unlikely or questionable for roughly 40% of the registered projects. These projects are expected to generate about 20% of the CERs". Schneider's methodological approach is not identical with the approach applied in this study but is, nevertheless, similar enough for a comparison of the overall results. Compared to earlier assessments of the environmental integrity of the CDM, our analysis suggests that the CDM's performance as a whole has anything but improved, despite improvements of a number of CDM standards. There are several reasons for this:

- The main reason is a shift in the project portfolio towards projects with more questionable additionality. In 2007, CERs from projects that do not have revenues other than CERs made up about two third of the project portfolio, whereas the 2013-2020 CER supply potential from these project types is only less than a quarter. This is mainly due the registration of many energy projects between 2011 and 2013, including both fossil and renewable projects, which represent the largest share of CDM projects and of potential CER supply today, many of which are unlikely to be additional. It can therefore be questioned whether the CDM is the appropriate incentive scheme for those project types, or more generally, whether these project types are appropriate for crediting schemes at all.

- A second reason is that the CDM EB not only improved rules but also made simplifications that undermined the integrity. For example, positive lists were introduced for many technologies, for some of which the additionality is questionable and some of which are promoted or required by policies and regulations in some regions (e.g. efficient lighting). Another example is biomass residue projects, for which requirements to demonstrate that the biomass is available in abundance were strongly simplified, making an over-estimation of emission reductions more likely.

- A third reason is that the CDM EB did not take effective steps to exclude project types with a low likelihood of additionality. While positive lists were introduced, project types with more questionable additionality were not excluded from the CDM. The common practice test is not effective as it stands. Standardized baselines can be optionally used as an alternative to project-specific baselines, which provides a further avenue for demonstrating additionality but does not reduce the number of projects wrongly claiming additionality. In conclusion, the improvements to the CDM mainly aimed at simplifying requirements and reducing the number of false negatives (projects that are additional but do not qualify under the CDM) but did not address the false positives (projects that are not additional but qualify under the CDM).

Our analysis of the environmental integrity of the CDM has focused on the quality of CERs in terms of ensuring emission reductions that are additional and not over-credited. The overall environmental outcome of the CDM is, however, also influenced by several overarching and indirect effects:

- **Awareness raising and capacity building**: The CDM has drawn attention to climate change and to options of how it can be mitigated and thus contributed to the issue of climate change being better understood and taken more seriously in many parts of the world. In this way it has helped to pave the way towards the global agreement achieved at COP 21 in Paris in December 2015.

- **Technological innovation**: The CDM has helped to spread and reduce costs of many GHG mitigation technologies such as renewable energy technologies or technologies to avoid methane emissions in many developing countries. This may have helped developing countries to avoid locking in carbon-intensive technologies. The increased application of these technologies has contributed to reducing their total cost, and the CDM has contributed to building the capacity on how these technologies can domestically be applied in many developing countries.

- **Length of crediting periods:** Certain projects may continue their operation beyond their crediting period and will not receive credits for the respective GHG reductions. This effect has been estimated to have a significant potential for under-crediting (Spalding-Fecher et al. 2012). However, over time the respective technologies often become economically viable without support and thus the common practice in many circumstances. The CDM may thus have contributed to advancing an investment, which would anyhow be conducted some years later, so that even the additionality of CERs generated in the late years of a crediting period could be questioned.

- **Rebound effects:** For CDM project developers and host countries, CER revenues are similar to subsidies, which often lower the cost of the product or service provided (e.g. electricity, cement, transportation), thereby inducing greater demand for the product or service. In contrast, carbon taxes or auctioning of allowances under the ETS generally provide incentives to reduce the demand for products or services. Calvin et al. (2015) show that ignoring such system-wide rebound effects in the power sector can lead to significant over-crediting compared to the actual reductions at system level. The overall mitigation outcome of crediting could be systematically over-estimated, even if projects are fully additional and the direct GHG emission impact of a project is quantified appropriately. This is mainly because credits subsidize the deployment of technologies with lower emissions instead of penalising the use of more emitting technologies and because CDM methodologies draw the boundary around a project and do not consider the wider rebound effects.

- **Perverse policy incentives:** In some instances, the CDM may provide an incentive to governments not to implement domestic policies to address emissions. For example, policy makers may have disincentives to introduce regulations requiring the capture of landfill gas or to further pursue landfilling instead of less GHG-intensive waste treatment methods, since they would otherwise lose revenues from CERs.

All these effects somehow influence the environmental outcome of the CDM, partly for the better and partly for the worse. The overall effect can hardly be determined. However, it is unlikely that these overarching and indirect effects fully compensate for the overall low environmental integrity of many projects and CERs. On the contrary, in a forward-looking perspective, comparing the situation in which the CDM continues to be used with a situation in which this would not be the case, it is rather likely that these overarching effects further undermine the environmental outcome of the CDM overall.

The result of our analysis suggests that the CDM still has fundamental flaws in terms of environmental integrity. It is likely that the large majority of the projects registered and CERs issued under the CDM are not providing real, measureable and additional emission reductions. Therefore, the experiences gathered so far with the CDM should be used to improve both the CDM rules for the remaining years and to avoid flaws in the design of new market mechanisms being established under the UNFCCC. In the following chapters we summarise how the existing CDM should be improved (Chapter 6) and what can be learned from the CDM experience for the future of market mechanisms in general (Chapter 7).

6. Summary of recommendations for further reform of the CDM

The recommendations for the further reform of the CDM can be distinguished according to improvements of the general rules and approaches how to determine additionality and to project type-related recommendations.

6.1. General rules and approaches for determining additionality

As mentioned above, for an additionality test to function effectively, it must be able to assess, with high confidence, whether the CDM was the deciding factor for the project investment. However, additionality tests can never fully avoid wrong conclusions. They cannot fully reflect the complexity of investment decisions. Additionality tests always look at part of the full picture and use simplified indicators, such as economic performance or market penetration, to make a judgment on whether or not a project is truly additional. Information asymmetry between project developers and regulators, combined with the economic incentives for project developers to qualify their project as additional, are a major challenge. The key policy question is how confident regulators should be that a project is additional. In other words, how should the number of false positives (projects that qualify as additional but are not) and false negatives (projects that are additional but do not pass the test) be balanced? We assessed the current additionality tests from the perspective that a high degree of confidence is required. The main reason is that the implications of false positives are much more severe than the implications of false negatives. A false positive leads to both an increase in global

GHG emissions and higher global costs of mitigating climate change, whereas a false negative does not affect global GHG emissions but only leads to higher costs of mitigating climate change (Schneider et al. 2014).

In Chapter 3 we thoroughly scrutinised the four main approaches used to determine additionality. Our analysis shows:

- **Prior consideration** is a necessary and important but insufficient step for ensuring additionality of CDM projects. This step works largely as intended (Section 3.1.4).
- The subjective nature of the **investment analysis** limits its ability to assess with high confidence whether a project is additional. It is possible that improvements could further decrease this subjectivity, e.g. by applying more complicated tests to assess the financial performance of the project. However, especially for project types in which the financial impact of CERs is relatively small compared to variations in other parameters such as large power projects, doubts remain as to whether investment analysis can provide a strong 'signal to noise' ratio (Section 3.2.4).
- To reduce the subjectivity of the **barrier analysis**, the *'Guidelines for objective demonstration and assessment of barriers'* require that barriers are monetized to the extent possible and integrated in the investment analysis. As a result of this, the barrier analysis has lost importance as a stand-alone approach of demonstrating additionality. However, barriers which are not monetized remain subjective and often difficult to verify by the DOEs (Section 3.4.4).
- In general, the **common practice analysis** can be considered a more objective approach than the barriers or investment analysis due to the fact that information on the sector as a whole is considered rather than specific information of a project only. It reduces the information asymmetry inherent in the investment and barrier analysis (Section 3.3.4). In this regard, expanding the use of common practice analysis could be a reasonable approach to assessing additionality more objectively. However, the presented analysis shows that the way common practice is currently assessed needs to be substantially reformed to provide a reasonable means of demonstrating additionality. Moreover, when expanding its use, it is important to reflect that market penetration is not a good proxy for all project types for the likelihood of additionality. The fact that few others have implemented the same project type is only an indication of the actual attractiveness. It should thus be only applied to those project types for which market penetration is a reasonable indicator.

Against this background we recommend that

- the **prior consideration** grace period for notification after the start of a CDM project should be shortened from 180 to 30 days to reduce the risk that projects apply for the CDM having only learned about this option after the start of the project,
- the **common practice analysis** is significantly reformed and receives a more prominent role in additionality determination,
- the **investment analysis** is excluded as an approach for demonstrating additionality for projects types for which the 'signal to noise' ratio is insufficient to determine additionality with the required confidence; while for those project types for which investment analysis would still be eligible, project participants must confirm that all information is true and accurate and that the investment analysis is consistent with the one presented to debt or equity funders, and

- the **barrier analysis** is entirely abolished as a separate approach in the determination of additionality at project level (though it may be used for determining additionality of project types); barriers which can be monetized should be addressed in the investment analysis while all other barriers should be addressed in the context of the reformed common practice analysis.

A prerequisite for expanding the use of the common practice analysis is significant improvements of its current shortcomings, most notably with regard to the following issues (Section 3.3.4):

- The project types and sectors covered by the CDM are very different in their technological and market structure. Determining what is deemed to be common practice must take into account these differences. Therefore, the 'one-size-fits-all' approach of determining common practice should be abandoned and be replaced by **sector or project-type specific guidance**, particularly with regard to distinguishing between different and similar technologies (appropriate level of dis-/aggregation) and with regard to the threshold for market penetration, which can have very different implications for the number of projects passing the test, depending on the features of the sectors or project types.

- The **technological potential** of a certain technology should also be taken into account in order to avoid that a project is deemed additional although the technological potential is already largely exploited in the respective country. However, results of studies on the technological potential depend strongly on their assumptions and may thus vary significantly. The exploitation rate should therefore only be considered one criterion among others in determining whether a technology is common practice; it should not form the only decisive criterion.

- The common practice analysis should at least cover the **entire country**. However, to ensure statistical confidence, the control group needs a minimum absolute number of activities or installations. If the observations in the host country do not exceed that minimum threshold, the scope needs to be extended to other countries (e.g. the neighbouring countries or the entire continent).

- Last but not least, all CDM projects should be included into the common practice analysis as a default, unless a methodology includes different requirements.

In addition to the above-mentioned improvements of general approaches for determining additionality, we recommend further improvements to key general CDM rules:

- **Renewal and length of crediting periods:** At the renewal of the crediting period, not merely the validity of the baseline but the validity of the baseline scenario should be assessed for CDM projects that are potentially problematic in this regard. This is the case if the baseline is the 'continuation of the current practice' or if changes such as retrofits could also be implemented in the baseline scenario at a later stage. Crediting periods of project types or sectors that are highly dynamic or complex such as urban transport systems or data centres should be limited to one single period of 10 years maximum. Moreover, generally abolishing the renewal of crediting periods but allowing a somewhat longer single crediting period for project types which require a continuous stream of CER revenues to continue operation (e.g. landfill gas flaring) may also be considered (Section 3.5.4).

- **Positive Lists:** Some of the positive lists are now reviewed regularly, and have a clear basis for determining whether a technology should still be included in the lists. This review of validity should also be extended to project types covered by the microscale additionality tool. In addition, positive lists must address the impact of national policies and measures to support low emissions technologies (so-called E- policies). For positive lists to avoid the possibility of ‘false positives’ driven by national policies, some objective measure of renewable energy support may be needed as part of the evaluation process. A positive list that included renewables, for example, could be qualified by restricting its applicability to countries that did not have any support policies in place for that specific technology. Finally, to maintain environmental integrity of the CDM overall, positive lists should be accompanied by negative lists (Section 3.7).

- **Programmes of activities:** PoA rules allow that the total project size exceeds the small-scale or micro-scale thresholds while using the automatic additionality provision established for small-scale and micro-scale projects. This may increase the risk of registering non-additional projects. Reform of the CDM rules related to additionality for particular project types (Chapter 4) and positive lists (Section 3.7) will address any concerns about additionality of PoAs (Section 3.6.3). However, as long as these rules are not reformed accordingly, PoA have the potential to boost the number of non-additional project activities and CERs.

- **Standardized baselines:** These were introduced to reduce transaction costs while ensuring environmental integrity. In contrast to the general expectation, they do not increase the environmental integrity of the CDM. On the contrary, as long as they are not mandatory, once established, they lower the environmental integrity because they allow for increasing the number false positive projects. Therefore, their use should be made mandatory. Moreover, all CDM facilities should be included in the peer group used for the establishment of standardized baselines and clearer guidance needs to be provided for DNAs on how to determine the appropriate level for disaggregation. Finally, the practice of using the same methodological approach for the establishment of standardized baselines for all sectors, project types and locations should be abolished (Section 3.8).

- **Consideration of domestic policies (E+/E-):** The risk of undermining environmental integrity through over-crediting of emission reductions is likely to be larger than the creation of perverse incentives for not establishing E- policies. Therefore, adopted policies and regulations reducing GHG emissions (E-) should be included when setting or reviewing crediting baselines while policies that increase GHG emissions (E+) should be discouraged by their exclusion from the crediting baseline where possible (Section 3.9).

- **Suppressed demand:** In many cases, the Minimum Service Levels may be reached during the lifetime of CDM project. However, even if the suppressed demand does lead to some over-crediting, the overall impact is very small. An expert process should be established to balance the risks of over-crediting with the potential increased development benefits. In addition, the application of suppressed demand principles in methodologies could be restricted to countries in which development needs are highest and the potential for over-crediting is the smallest, such as LDCs (Section 3.10).

6.2. Project types

We note that even with ‘perfect’ rules for determining additionality as recommended in Section 6.1, many project types have fundamental problems with this determination. Drawing upon our findings for specific project types (Section 4), this section provides recommendations of which project types should remain eligible in the CDM. In doing so, we not only consider the environmental integrity under current rules, but also whether improvements of general or project type-specific rules could be implemented to ensure overall environmental integrity. We also include other considerations, such as whether the emission sources can be addressed more effectively by other policies.

Industrial gas projects: In contrast to conventional wisdom and their perception in the general public, our analysis shows that industrial gas projects provide for a high or medium environmental integrity. After issues related to perverse incentives have been successfully addressed through ambitious benchmarks, **HFC-23** and **nitric acid** projects now provide for a high degree of environmental integrity. They are very likely to be additional because they involve so-called 'end-of-the-pipe' technologies and do not have significant income other than CERs and because revenues from CERs have a large impact on the economic feasibility. Moreover, they partially use emission benchmarks as baselines which underestimate the actual emission reductions. The methodologies for HFC-23 and nitric acid projects have already been improved in the past and do not require further improvements (Sections 4.2.7 and 4.4.7). For **adipic acid**, the situation is different; this project type is also likely to be additional but concerns about carbon leakage due to high CER revenues have never been addressed. Adipic acid production is a highly globalised industry and all plants are very similar in structure and technology. A global benchmark of 30 kg/t applied to all plants would prevent carbon leakage, considerably reduce rents for plant operators, and allow the methodology to be simplified by eliminating the calculation of the N_2O formation rate (Section 4.3.7). Industrial gas projects provide for low cost mitigation options. Under current rules, HFC-23 and adipic acid projects may generate large rents for plant operators. These emission sources could therefore also be addressed through domestic policies, such as regulations or by including the emission sources in domestic or regional ETS, and help countries achieve their NDCs under the Paris Agreement. For example, China is introducing a domestic results-based finance policy aiming at incentivising HFC-23 emissions reductions. Parties to the Montreal Protocol also consider regulating HFC emissions. We therefore recommend that HFC-23 projects are not eligible under the CDM. A transition to address these emissions domestically may also be supported by bilateral or multilateral initiatives of (results-based) carbon finance.

Energy-related project types: Our analysis suggests that many energy-related project types provide for a low likelihood of overall environmental integrity, particularly **wind and hydropower** (Sections 4.5.7 and 4.6.7), **fossil fuel switch** (Section 4.11.7) and **supply-side energy efficiency project** types such as **waste heat recovery** (Section 4.10.7). The main reason for this assessment is that CER benefits are often relatively small compared to fuel cost savings, so that the impact of CER revenues on the economic feasibility is marginal (Section 2.4). Many projects are also supported through other policies, such as feed-in tariffs for renewable electricity or emerging ETSs. The costs for renewable power technologies are decreasing rapidly. In our assessment, the potential for addressing additionality concerns through improved tests are rather limited for these project types. Many projects are economically viable and even an improved investment analysis or common practice test may not be suitable to clearly distinguish additional from non-additional projects. We therefore recommend **that these project types should be no longer eligible in principle** under the CDM. However, in least developed countries, some project types, particularly wind and small-scale hydropower plants, may still face considerable technological and/or cost barriers (Section 4.5.3). These project types may thus remain eligible in least developed countries.

We recommend that some other energy-related project remain eligible if methodologies are improved. **Biomass power projects** can be competitive with fossil generation technologies under certain but not all circumstances. In cases in which power generation from biomass is not competitive with fossil generation technologies, CER revenues can have a significant impact on the profitability of a project, particularly if credits for methane avoidance are claimed as well. In these cases, the demonstration of abundance of biomass as well as of the claim that biomass is left to decay is key for avoiding any over-crediting of emissions. We therefore recommend that only biomass power projects avoiding methane emissions remain eligible under the CDM provided that the corresponding provisions in the applicable methodologies are revised appropriately (Section 4.7.7).

With regard **demand-side energy efficiency** project types with distributed sources – **cook stoves** and **efficient lighting** – we have identified concerns which question their overall environmental integrity. However, environmental integrity concerns could be addressed if cook stove methodologies were revised considerably, including more appropriate values for the fraction of non-renewable biomass (Section 4.12.7), and if approaches for determining the penetration rate of efficient lighting technologies as already established in AM0113 were made mandatory for all new projects and CPAs under these project types and the older methodologies were withdrawn (Section 4.13.7). As CER revenues can have a considerable impact and as barriers persist these projects, we recommend that they should remain eligible, subject to the improvements recommended.

Methane projects: Landfill gas and **coal mine methane** projects are likely to be additional. However, there are concerns in terms of over-crediting, which should be addressed through improvements of the respective methodologies, particularly by introducing region-specific soil oxidations factors and by requesting DOEs to verify that landfilling practices are not changed (Sections 4.8.7 and 4.9.7). For both project types, the CER revenues have a considerable impact on their economic performance. With regard to landfill gas, an important concern is that continued incentives for landfilling could delay the implementation of more sustainable waste management practices, such as recycling or compositing. We therefore recommend that this project type only be eligible in countries that have policies in place to transition to more sustainable waste management practices.

Table 6-1 summarises our recommendations for the specific project types assessed above.

Table 6-1: CDM eligibility of project types

Project type	Environmental integrity under current rules	Environmental integrity if rules were improved	Recommendations
HFC-23	Medium / High	High	Not eligible
Adipic acid	Medium	High	Eligible (with benchmark of 30 kg / t AA)
Nitric acid	High	High	Eligible
Wind power	Low	Low	Not eligible
Hydropower	Low	Low	Not eligible
Biomass power	Medium	Medium / High	Eligible (projects avoiding methane emissions)
Landfill gas	Medium	Medium / High	Eligible (subject to transition arrangements)
Coal mine methane	Medium	Medium / High	Eligible
Waste heat recovery	Low	Low	Not eligible
Fossil fuel switch	Low	Low	Not eligible
Efficient cook stoves	Low	Medium / High	Eligible
Efficient lighting	Low / High	Medium / High	Eligible

Sources: Authors' own compilation

7. Implications for the future role of the CDM and crediting mechanisms

In this section, we consider the implications of our analysis for the future role of the CDM and crediting mechanisms generally. We situate these implications not only in the context of the CDM but also the Paris Agreement and draw general conclusions for the design of international crediting mechanisms under the Paris Agreement as well as crediting policies established at national level.

The CDM has provided many benefits. It has brought innovative technologies and financial transfers to developing countries, helped identify untapped mitigation opportunities, contributed to technology transfer and may have facilitated leapfrogging the establishment of extensive fossil energy infrastructures. The CDM has also helped to build capacity and to raise awareness on climate change. It also created knowledge, institutions, and infrastructure that can facilitate further action on climate change. Some projects have provided significant sustainable development co-benefits. Despite these benefits, after well over a decade of considerable experience, the enduring limitations of GHG crediting mechanisms are apparent.

- Firstly, and most notably, the elusiveness of additionality for all but a limited set of project types is very difficult, if not impossible, to address. Our analysis shows that many CDM project types are unlikely to be additional. Information asymmetry between project participants and regulators remains a considerable challenge. This challenge is difficult to address through improvements of rules. Further standardisation can be helpful for reducing transaction costs but has a limited scope, particularly within the CDM, for resolving additionality concerns. The scope for added standardisation is limited by the number of amenable project types and the wide variation of conditions across CDM host countries. Standardisation approaches have been most successful in regional crediting programs such as California or

Australia, where they have focused on a limited number of suitable and largely non-energy project types, such as landfills or coal mines.[98] The overall integrity of the CDM could only be improved significantly if the mechanism were limited to those project types that have a high likelihood of providing additional emission reductions. In our assessment, this would require excluding most of the current CDM project types and focusing mainly on projects that abate other GHGs than CO_2.

- Secondly, international crediting mechanisms involve an inherent and unsolvable dilemma: either they might create perverse incentives for policy makers in host countries not to implement policies or regulations to address GHG emissions – since this would reduce the potential for international crediting – or they credit activities that are not additional because they are implemented due to policies or regulations. This well-known dilemma has been discussed by the CDM EB without a resolution.
- Thirdly, for many project types, the uncertainty of emission reductions is considerable. Our analysis shows that risks for over-crediting or perverse incentives for project owners to inflate emission reductions have only partially been addressed. It is also highly uncertain how long projects will reduce emissions, as they might anyhow be implemented at a later stage without incentives from a crediting mechanism – an issue that is not addressed at all under current CDM rules.
- A further overarching shortcoming of crediting mechanisms is that they do not make all polluters pay but rather subsidize the reduction of emissions. This lowers the cost of the product or service, inducing rebound effects that are not considered under CDM rules and that lead to over-crediting. Most of these shortcomings are inherent to using crediting mechanisms, which questions the effectiveness of international crediting mechanisms as a key policy tool for climate mitigation.

It should be noted that the results of the analysis provided here for the CDM are to a large extent also relevant and valid for other international carbon offset or crediting programs, such as the Japanese Joint Crediting Mechanism (JCM), the Climate Action Reserve (CAR), the Verified Carbon Standard (VCS) or the Gold Standard (GS). The results are also relevant for the mechanisms to be implemented under Article 6 of the Paris Agreement, any mechanism to be used for compliance under the Carbon Offset and Reduction Scheme for International Aviation (CORSIA) and to a certain extent for the Joint implementation (for an overview see Kollmuss et al. 2015a). Even though the programs differ in many aspects, generally speaking, the CDM has been the origin and the role model for these offset programs. In particular, the CDM's approaches to additionality testing and baseline setting have served as the main blueprint for most other programs. With the aim of reducing transaction costs, rules and methodologies for additionality that have been borrowed from the CDM have been simplified, which did not generally strengthen their environmental integrity. Therefore, the issues raised here in the context of the CDM will remain relevant for other international offset programs.

The future role of crediting mechanisms should be revisited in the light of the Paris Agreement. The CDM in its current form will end with the conclusion of the second commitment period of the Kyoto Protocol. Several elements of the CDM could, nevertheless, be used when implementing the mechanism established under Article 6.4 of the Paris Agreement or when implementing (bilateral) crediting mechanisms under Article 6.2. However, the context for using crediting mechanisms has fundamentally changed. The most important change to the Kyoto architecture is that all countries have to submit NDCs that include mitigation pledges or actions. As of 15 December 2015, 187

[98] http://wupperinst.org/en/projects/details/wi/p/s/pd/377/.

countries, covering around 95% of global emissions in 2010 and 98% of global population, have submitted NDCs (CAT 2015). Many mitigation pledges in NDCs cover economy-wide emissions or large parts of the economy. This implies that much of the current CDM project portfolio will fall within the scope of NDCs.

The Paris Agreement requires countries to adjust their reported GHG emissions for international transfers of mitigation outcomes in order to avoid double counting of emission reductions. This implies that the baseline, and therefore additionality, may be determined in relation to the mitigation pledges rather than using a 'counterfactual' scenario as under the CDM, and that countries could only transfer emission reductions that were beyond that which they had pledged under their NDCs. Double counting can occur, inter alia, if the same emission reductions are accounted by both the host country – as reflected in its GHG inventory – and the country using these credits towards achieving its mitigation pledge. Avoiding such double counting could imply that host countries will have to add internationally transferred credits to their reported GHG emissions if the emission reductions fall within the scope of their mitigation pledges. This has several important implications.

Firstly, issuing and transferring credits that do not represent additional emission reductions or are under- or over-credited has other implications for global GHG emissions. Under the Kyoto Protocol, non-additional CDM projects or over-crediting increase global GHG emissions, whereas under-crediting from additional projects provides a net mitigation benefit. The implications are different and more complex when the emission reductions fall within the scope of the NDC of the host country: they depend on whether the credited activities are additional, whether they are over- or under-credited, the ambition of the mitigation pledge of the host country, i.e. whether or not it is below BAU emissions, and whether the emission reductions are reflected in the host country's GHG inventory[99] (Kollmuss et al. 2015b). Compared to the situation in which international transfers of credits would not be allowed, global GHG emissions could not be affected, decrease or increase due to the transfer of credits, depending on the circumstances. For example, if the host country has an ambitious NDC, non-additionality and over-crediting may not necessarily increase global GHG emissions because the country would have to reduce other GHG emissions to compensate for the adjustments to its reported GHG emissions. For the same reasons, under-crediting would not necessarily lead to a global net mitigation benefit. Additionality and over-crediting mainly matter when host countries have weak mitigation pledges above BAU emissions.

A second important implication relates to the incentives for host countries to ensure integrity and participate in international crediting mechanisms. If mitigation pledges are ambitious, host countries might be cautious to 'give away' non-additional credits. To achieve its mitigation pledge, the host country would need to compensate for exports of non-additional credits, by further reducing its emissions. Host countries with ambitious and economy-wide mitigation pledges would thus have incentives to ensure that international transfers of credits are limited to activities with a high likelihood of delivering additional emission reductions. However, our analysis showed that only a few project types in the current CDM project portfolio have a high likelihood of providing additional emission reductions, whereas the environmental integrity is questionable and uncertain for most project types. For those project types with a high likelihood of additionality, the potential for further emission reductions is limited and it is unclear whether host countries would be willing to engage in crediting for this 'low-hanging fruit' mitigation potential. The experience with Joint Implementation showed that most credits originated from countries with 'hot air', i.e. where the emission pledge is less ambitious than BAU emissions, while the potential for crediting was quite limited in countries

99 Some emissions reductions may not be reflected in the country-wide GHG inventory, for example, because the country uses simple Tier 1 methods to estimate an emissions source which do not account for the emission reductions achieved through CDM projects or because the reductions occur in a sector that is not covered by the host country's GHG inventory.

with ambitious mitigation targets, also due to overlap with other climate policies (Kollmuss et al. 2015b). In conclusion, this suggests that the future supply of credits may mainly come either from emission sources not covered by mitigation pledges or from countries with weak mitigation pledges. In both cases, host countries would not have incentives to ensure integrity and credits lacking environmental integrity could increase global GHG emissions.

At the same time, demand for international credits is also uncertain. Only a few countries, including Japan, Norway and Switzerland, have indicated that they intend to use international credits to achieve their mitigation pledges. An important source of demand could come from the market-based approach pursued under the International Civil Aviation Organization (ICAO), and possibly from an approach pursued under the International Maritime Organization (IMO). For these demand sources, avoiding double counting with emission reductions under NDCs will be a challenge that is similar to that of avoiding double counting between countries.

A number of institutions are exploring the use of crediting mechanisms as a vehicle to disburse results-based climate finance without actually transferring any emission reduction units. This way of using crediting mechanisms could be more attractive to developing countries; they would not need to add exported credits to their reported GHG emissions, as long as the credits are not used by donors towards achieving mitigation pledges. The implications of non-additional credits are also different: they would not directly affect global GHG emissions, but could lead to a less effective use of climate finance, which could indirectly increase global GHG emissions compared to using the available resources more effectively. However, donors of climate finance aim to ensure that their funds be used for actions that would not go ahead without their support. They need to show that their investments *'make a difference'*. Given the considerable shortcomings with the approaches for assessing additionality, we recommend that donors should not rely on current CDM rules to assess the additionality of projects considered for funding.

Some countries pursue domestic crediting policies. South Korea allows companies to convert CERs from Korean projects into units eligible under its domestic emissions trading system. The Chinese and California-Quebec ETS allow the use of credits from domestic offsetting projects. Mexico, South Africa and Switzerland are pursuing polices that allow using domestic credits to meet tax or other obligations (see also the paragraph above on other offsetting programs). In these cases, using non-additional credits has no direct implication on global GHG emissions but will increase the country's costs towards achieving its NDC. In the long run, this provides incentives for these countries to limit crediting to project types with a high likelihood of additionality. However, meeting the ambitious long-term climate change mitigation goals of the UNFCCC and the Paris Agreement requires much stronger action and a rapid bridging of the emissions gap (UNEP 2015). It is hard to imagine that such ambitious goals could be achieved on a global level in a timely manner without a sharing of effort or burdens that could encompass some form of transfer of mitigation outcomes and/or results-based climate finance.

Taking into account this context and the findings of our analysis as well as other evaluations, we recommend that policy makers revisit the role of crediting in future climate policy:

- **Moving towards more effective climate policies:** We recommend focusing climate mitigation efforts on forms of carbon pricing that do not rely extensively on credits, and on measures such as results-based climate finance that do not necessarily serve to offset other emissions. If well designed, emission trading systems and carbon taxes have several advantages over crediting mechanisms: they do not require additionality to be assessed or hypothetical baselines to be set but rather rely on information on actual emissions for which information asymmetry is more manageable; in principle, they make the polluter pay rather than providing subsidies; and they expose all regulated entities to a carbon price, enabling up-scaled, sector-wide emission reductions. We recommend that international crediting mechanisms play a limited role after 2020 to address specific emission sources in countries that do not have the capacity to implement broader climate policies. Crediting should not be further pursued as a main tool for GHG mitigation.

- **Fundamental and far-ranging changes to the CDM:** To enhance the integrity of international crediting mechanisms such as the CDM and to make them more attractive to both buyers and host countries with ambitious NDCs, we recommend limiting the mechanism to project types that have a high likelihood of delivering additional emission reductions. We recommend reviewing methodologies systematically to address risks of over-crediting, as identified in this report. We further recommend revisiting the current approaches for additionality, with a view to abandoning subjective approaches and adopting more standardized approaches where possible. We also recommend curtailing the length of the crediting periods with no renewal. A larger question is whether the UNFCCC and CDM processes can create the consensus needed to make the fundamental changes needed to improve the integrity of the CDM in significant ways.

- **Purchase of CERs:** We recommend potential buyers of CERs to limit any purchase of CERs to either existing projects that are at risk of stopping GHG abatement ('vulnerable projects') or the few project types that have a high likelihood of ensuring environmental integrity. Continued purchase of CERs should be accompanied with a plan and support to host countries to transition to broader and more effective climate policies that ensure GHG abatement in the long-run. Purchase of CERs could also be used to deliver results-based finance in this context. Further, we recommend pursuing the purchase and cancellation of CERs, as a form of results-based climate finance, rather than using CERs for compliance towards meeting mitigation targets.

- **Mechanisms under Article 6 of the Paris Agreement:** Given the high integrity risks of crediting mechanisms, we recommend that Parties consider provisions that provide strong incentives to the Parties involved to ensure integrity of international transfers of mitigation outcomes. This includes robust accounting provisions, inter alia, to avoid double counting of emission reductions, but should also extend to other elements, such as comprehensive, transparent and ambitious mitigation pledges as a prerequisite to participating in international mechanisms.

In conclusion, we believe that the CDM had a very important role to play, in particular in countries that were not yet in a position to implement domestic climate policies. However, our assessment and other evaluations confirm the strong shortcomings inherent to crediting mechanisms. With the adoption of the Paris Agreement, implementing more effective climate policies including international cooperative actions becomes key to bringing down emissions quickly to a pathway consistent with well below 2°C. Our findings suggest that crediting approaches should play a time-limited and niche-specific role, where additionality can be relatively assured, and the mechanism can serve as stepping-stone to other, more effective policies to achieve cost-effective mitigation. In doing so, continued support to developing countries will be key. We recommend using new innovative sources of finance, such as revenues from auctioning of ETS allowances, rather than international crediting mechanisms, to support developing countries in implementing their NDCs.

8. Annex

8.1. Representative samples of CDM projects

8.1.1. Task

The population consists of 7,418 CDM projects which have 4 characteristics (location, technology, size, time), from which representative samples for three additionality approaches (investment analysis, barrier analysis and common practice analysis) should be drawn. One challenge consists of the fact that the additionality approaches are not directly known before the analysis. After some preliminary analyzes, we decided on a two-step approach.

1. Draw a representative sample with regard to all strata of the 4 characteristics of size 300. The additionality approaches are determined for the projects in this sample.
2. Draw sub-samples from the projects belonging to each of the three additionality approaches, which are representative for the strata of the 4 characteristics, as they occur for the projects of each additionality approach. The sub-samples shall consist of 50 projects each, which are to be further divided into one 30-project sample and two 10-project samples. The 30- and 10-project sample should each be representative of the strata and combine to the 50-project sample.

8.1.2. Approach

The challenge consists of the fact that the small sample sizes lead to less than one draw for many strata. In a first step, therefore, a randomised procedure is necessary to identify the strata from which to draw, such that the frequencies of the strata are best preserved from the population to the samples.

Drawing the 300-project sample

1. Randomly select strata from which to draw

   a) Calculate the target number of draws for each stratum as (stratum frequency) (population size) (sample size). These are decimal numbers and often below.

      In order to obtain an integer number of draws for a stratum, discretise its corresponding target number to the enclosing integers, e.g. 2.1 is randomly assigned either 2 or 3, where the probability of the assignment of the higher enclosing integer is weighted with (target number)^(lower enclosing integer). In the example, the probability that 2.1 becomes 3 is therefore weighted with 2.1 2 0.1. The number of target numbers assigned to the higher enclosing integer is determined such that the sum of all assigned lower enclosing integer and all assigned higher enclosing integer is as close as possible to the rounded sum of all respective target numbers.

      For example, assume 3 target numbers between 2 and 3, namely (2.1, 2.3, 2.9). Their rounded sum is 7. Drawing twice from two strata and three times from one strata yields the targeted 7 total draws. The third strata with the target number 2.9 has the highest chance of being chosen for the three draws.

   b) Strata with 0 frequency in the population have of course 0 frequency in the samples as well.

2. Randomly draw from the strata with the discretised target numbers of the previous steps.

Drawing sub-samples of the 300-project sample with the added additionality approach information

From the 300-project sample, we extract the projects that belong to each additionality approach, yielding three sub-samples. From each of these sub-samples, we draw samples of 50 projects, which are representative with regard to the strata of the 4 characteristics in the respective sub-sample. We employ the same approach as for drawing the 300-project sample (Section 2.1).

These three samples of 50 projects are ordered with respect to the strata of the 4 characteristics. Then we extract two sub-sets of 10 projects, one consisting of the 1st, 6th, 11th, 15th... project, the second consisting of the 3rd, 8th, 13th, 18th... project of the ordered sample. The 30-project sample consists of the remaining projects. This ensures that the strata within the 50-project sample are preserved in the smaller samples as well as possible.

8.1.3. Samples

Investment analysis: 69, 544, 1436, 1906, 2007, 2075, 2229, 2525, 3068, 3490, 3703, 4042, 4317, 4657, 5047, 5659, 5661, 5707, 5757, 6052, 6899, 7073, 7185, 7843, 7974, 8057, 8523, 8615, 8801, 9002

1875, 2315, 3033, 3186, 3799, 4600, 4687, 5843, 7024, 7551, 8903

1795, 2931, 4817, 5555, 6173, 6440, 7540, 8291, 8818, 8821

Barrier analysis: 244, 348, 582, 644, 1053, 1408, 1578, 1738, 2180, 2561, 3174, 3191, 3639, 3739, 3856, 4468, 4478, 4508, 4748, 5099, 5749, 5961, 6012, 6302, 6636, 7242, 7392, 7651, 8680, 9419

534, 831, 937, 1151, 1827, 2098, 4147, 5234, 7595, 8319

544, 2077, 2975, 3393, 4089, 5888, 6246, 7578, 8927, 9100

Common practice analysis: 69, 1227, 1602, 1737, 2007, 2075, 2098, 2109, 2302, 2315, 3068, 3186, 3642, 3670, 3799, 4687, 5006, 5359, 5659, 5843, 6173, 6553, 6899, 7648, 7936, 8125, 8140, 8506, 8636, 9699

588, 2486, 3994, 4317, 6440, 7400, 8093, 8505, 8523, 8879

366, 544, 1661, 1875, 3703, 4042, 4310, 5487, 7494, 8818

8.2. Information on suppressed demand in CDM methodologies

Table 8-1: Information on suppressed demand in CDM methodologies

Meth No.	Definition of baseline technology	Definition of MSL	Definition of baseline activity level
ACM0014	Methane Correction Factor of 0.4 for domestic wastewater	None	Project activity level (i.e. quantity of wastewater treated)
AMS I.A	Allows AMS I.L approach	Allows AMS I.L approach	Project activity level (i.e. quantity of electricity consumed)
AMS III.AR	Fossil fuel powered lamp	3.5 hrs per day x 2 CFL lamps (240 lux)	Deemed savings with fossil fuel lamp to match MSL, with annual growth in kerosene consumption
AMS II.G	Mix of fossil fuel cooking technologies	None	Project activity level (i.e. quantity of biomass saved)
AMS III.F	Unmanaged waste disposal with > 5m depth (methane Correction Factor of 0.8)	MSL is having a waste disposal site	Project activity level (i.e. quantity of waste converted to compost)
AMS I.E	Mix of fossil fuel cooking technologies	None	Project activity level (i.e. quantity of renewable energy used)
ACM0022	Unmanaged waste disposal with < 5m depth (methane correction factor of 0.4)	MSL is having a waste disposal site	Project activity level, although project proponent may propose another baseline
AMS I.L	Kerosene pressure lamp for lighting; car battery for appliances; diesel generator for larger loads	240 lux for lighting (50 kWh/yr using CFL), 195 kWh/yr for other appliances	Project activity level (i.e. quantity of electricity consumed) but with emissions factor of baseline technology
AMS III.BB	Kerosene pressure lamp for lighting; car battery for appliances; diesel generator for larger loads	240 lux for lighting (50 kWh/yr using CFL), 195 kWh/yr for other appliances	Project activity level (i.e. quantity of electricity consumed) but with emissions factor of baseline technology
AMS III.AV	Fossil fuel or non-renewable biomass to boil water (only requires justification if share of total population without access to improved drinking water is > 60%)	No minimum, but sets maximum level of 5.5 litres per person-day for crediting	Project activity level (i.e. quantity of water purified by project), but capped at 5.5 litres per person per day

Sources: Authors' own compilation

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EXHIBIT 55

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Carbon Credits Likely Worthless in Reducing Emissions, Study Says

Schemes allowed by the Paris climate agreement won't help countries reach their reduction targets, European report says, and should be phased out.

Nicholas Kusnetz

By Nicholas Kusnetz

Follow @nkus
Apr 19, 2017

Trading emissions credits from clean energy projects don't help reduce emissions, a new study says. Credit: Getty Images

As nations grapple with how they can slash their emissions as part of the Paris climate agreement [1], some may use international credit schemes that were approved in the treaty process. A new report from the European Commission [2] casts serious doubts about such credits, however, concluding that the vast majority of them likely fail to actually reduce emissions.

The report, which was written last year but not published until this April, concludes that buying and selling emissions credits for overseas projects should be limited to a select list that meet rigorous standards, and used only as part of a transition to more effective policies for mitigating greenhouse gas emissions.

"Given the inherent shortcomings of crediting mechanisms, we recommend focusing climate mitigation efforts on forms of carbon pricing that do not rely extensively on credits," the report said, adding that credits should play only a limited role after 2020.

"It's a confirmation that offsetting is fundamentally problematic," said Aki Kachi, international policy director for Carbon Market Watch [3], an advocacy group in Brussels.

The study examined the Clean Development Mechanism [4], created under the Kyoto Protocol to allow countries to offset emissions by purchasing credits linked to green-energy projects on an international market. The system allows a power plant in Germany, for example, to buy credits for the emissions savings from a wind farm in India.

The problem, the report says, is that the Indian wind farm likely would have been built anyway, even without the credits purchased by the Germans. In emissions-trading lingo, the reduction would be considered not "additional."

"Overall, our results suggest that 85 percent of the projects covered in this analysis and 73 percent of the potential 2013-2020 Certified Emissions Reduction (CER) supply have a low likelihood that emission reductions are additional and are not over-estimated," said the report, which was prepared by the Öko-Institut e.V., a German research group. "Only 2 percent of the projects and 7 percent of potential CER supply have a high likelihood of ensuring that emission reductions are additional and are not over-estimated."

In short, the vast majority of credits are unlikely to actually reduce emissions. And while the report examined the Clean Development Mechanism specifically, it said that many of the problems are inherent to emissions crediting schemes, and that the lessons learned would likely apply elsewhere.

Carbon offset credits were included as part of the Kyoto Protocol, but have fallen out of favor after scandals in Europe and poor performance, Kachi said. Some countries now decline to use them and the European Union plans to prohibit international trading [5] after 2020.

The Paris Agreement left the door open on emissions trading, but it left the details undefined, Kachi said.

"Two years later we're supposed to have more detailed rules for how these things will work under the Paris Agreement, but there's been no progress," he said. "It's a controversial issue that the world definitely has found no consensus over."

Published Under:
Global Climate Treaty [6]
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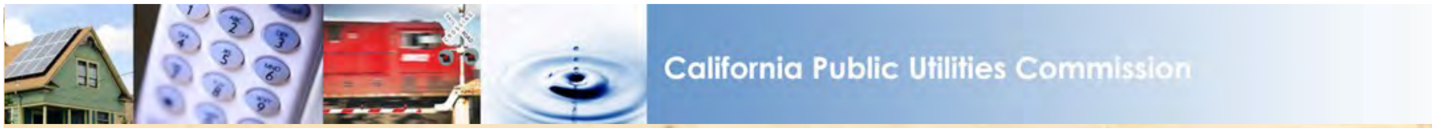
EXHIBIT 56



Energy Impacts of Cannabis Cultivation

Workshop Report and Staff Recommendations

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April 20, 2017

Contents

Energy Impacts of Cannabis Cultivation

Workshop Report

I. Executive Summary

Cannabis is an energy-intensive crop when grown indoors. According to a 2012 study, conducted when medical cannabis was legal in California but recreational cannabis was still prohibited, indoor cannabis cultivation is responsible for about 3% of California's electricity consumption, which is equivalent to the electricity consumption of one million California homes.[1]

On November 9, 2016, California voters approved Proposition 64, which legalized the recreational use of cannabis by adults. Other states have experienced an increase in electricity demand after legalizing recreational cannabis; for example, half of load growth in Colorado is now attributable to new cannabis cultivation.[2] Given the electricity use attributable to cannabis cultivation, an increase in cannabis cultivation associated with recreational legalization may be a significant driver of electricity consumption in California.

On February 28, 2017, the California Public Utilities Commission (Commission) held a workshop designed to explore opportunities for ensuring that any load growth associated with cannabis cultivation in California is consistent with California's clean energy goals. During the workshop, panelists from utility companies, cannabis growers and industry groups, regulators, and energy efficiency and standards-setting organizations discussed the cannabis-related energy impacts in states that have already legalized recreational cannabis, and the challenges and opportunities for making cannabis cultivation in California more energy efficient.

Key takeaways from the workshop include:

States that have legalized recreational cannabis have not necessarily seen an increase in energy consumption attributable to cannabis cultivation;

With respect to indoor cannabis cultivation, state building and/or energy codes sometimes result in cultivation operations that are less energy efficient than they could be, without any concomitant gains in safety;

[1] Mills, Evan. "The Carbon Footprint of Indoor Cannabis Production." *Energy Policy* 46 (2012), 58-67, at 59.

[2] https://www.theguardian.com/us-news/2016/feb/27/marijuana-industry-huge-energy-footprint (See also, e.g., outages in Oregon attributable to residential cannabis cultivation: https://www.pacificpower.net/about/nr/nr2015/marijuana.html, and cannabis-related load growth forecasts in Seattle: http://www.calmac.org/publications/SDG%26E_Cannabis_Ag_Energy_Demand_Final_Report_071516.pdf at 9).

What is energy efficient for one industry may not be energy efficient for another industry. For indoor cannabis cultivation, for example, insulation requirements may increase cooling needs, and HVAC economizers may increase the need for dehumidification and air filtration;

Indoor cultivation is generally accepted as the most energy intensive cultivation method, but is also potentially the most water-efficient method;

California's cannabis exports exceed in-state consumption by a factor as high as four-to-one. The looming market uncertainty from a reversal in federal policy on prosecution may result in a market demand reduction and negatively impact in-state production as export falls; and

The cannabis industry has not benefitted from publicly funded agricultural research on how to best optimize production across a variety of cultivation methods, unlike other valuable agricultural commodities in the state.

Staff concludes that the available data are not sufficiently robust to support specific policy recommendations. However, staff recommends engagement with the cannabis industry, California regulators, utility companies, local jurisdictions, and other stakeholders to explore options for ensuring that California cannabis cultivation is energy efficient. Staff are assembling a Cannabis Working Group to consider policy responses, up to and including the possibility of a specific energy tariff for cannabis cultivation.

The workshop is summarized in additional detail below.

II. Introductory Remarks

Michael Picker, President, California Public Utilities Commission

This workshop is part of the Commission's ongoing effort to understand new developments and consider changes as the world changes around us.

The fast growth in the cannabis industry presents a challenge and an opportunity to ensure that the choices made by the cannabis industry reflect California's climate goals. Commission staff convened this workshop in order to help understand what steps the Commission should take in order to ensure that California cannabis is the greenest in the nation. Specific questions include:

Should the Commission institute a distinct set of higher energy rates for cannabis cultivation?

How can the Commission ensure the most effective use of energy efficiency in the cannabis industry, and avoid over-procurement?

How can the Commission help cities and counties where cannabis is grown meet their sustainability and clean energy goals?

III. Panel One: Energy Impacts in Other States after Recreational Legalization

Voters in Washington and Colorado legalized recreational cannabis in 2012, and Oregon voters legalized recreational cannabis in 2014. Stakeholders discussed the experience in their respective states concerning the increase in cannabis cultivation, the increase in electricity consumption associated with cannabis cultivation, and energy efficiency measures that have been proposed and adopted.

John C. Morris, Vice President for Market Development at D+R International, and Co-Founder and Board Secretary of the Resource Innovation Institute, spoke about the benefits of stakeholder cooperation and ongoing challenges concerning access to data in Oregon; Alex Cooley, Co-Founder of Solstice, and National Cannabis Industry Board Member, offered his perspective as a cannabis cultivator in Washington; David Montgomery, Consulting Energy Management Engineer at Puget Sound Energy, provided a utility perspective on the challenges and opportunities for making cannabis cultivation in Washington more energy efficient; Jacob Policzer, President of the Cannabis Conservancy in Colorado, discussed recent trends in energy consumption and cannabis cultivation in Colorado, as well as his experience with cannabis cultivation sustainability certification and standards development; and Adam D. White, P.E., Team Lead Energy Efficiency Engineer at Xcel Energy, provided a utility perspective concerning energy consumption and adoption of energy efficiency measures by cannabis cultivators in Colorado.

During the panel discussion, certain major themes emerged: limitations on available data concerning energy consumption; stakeholder cooperation; challenges concerning access to information; and existing energy efficiency measures. The Panel One discussion is summarized by major theme, below, and the audience Q&A is presented separately.

Hard Data on Energy Usage Associated with Cannabis Cultivation

According to John Morris, there are 449 permitted recreational cultivators in Oregon; the Oregon Liquor Control Commission does not distinguish between indoor and outdoor cultivation facilities when reporting the number of permitted facilities. In addition, there are no studies concerning energy consumption associated with cannabis cultivation in Oregon. The lack of baseline data reflecting energy consumption for indoor cannabis cultivation represents a significant challenge to efforts to make the cannabis industry more energy efficient; as a consequence, California recreational cannabis licensing authorities should require energy and water forecasting and reporting by cannabis cultivators.

Alex Cooley reports that it is difficult to find data concerning cannabis cultivators' energy usage in Washington. State agencies have some information, but cultivators and associations have had limited success getting data from state agencies. Agencies such as the Commission might have an easier time getting information from sister state agencies.

In Washington, of the entire licensed cannabis cultivation canopy, 60% is indoor, less than 10% is greenhouse, and the balance is outdoor cultivation. According to the latest public data, indoor cultivators operating year-round were consuming about 150 W/sq. ft. of active canopy, greenhouses operating 30%-50% of the year were consuming about 60 W/sq. ft. of active canopy, and greenhouses operating 15% of the year were consuming <5 W/sq. ft. of active canopy. Cooley believes it is fair to assume that California will see similar percentages of indoor, outdoor, and greenhouse cultivation. The largest cannabis cultivation operation Cooley ever toured was an outdoor cultivation in California.

According to David Montgomery, Washington's Puget Sound Energy (PSE) is not tracking whether cannabis cultivation is affecting load growth, or how many cannabis cultivators there are. In addition, PSE has not seen a spike in demand attributable to recreational legalization. New cultivators have been coming on steadily and slowly for two years, starting small at 10,000 square feet of canopy and then expanding. PSE's service territory is cool and cloudy, and most cultivation is indoors.

Jacob Policzer notes that quality data concerning the energy consumption associated with cannabis cultivation in Colorado are scarce. According to Xcel Energy, between 2012 and 2013, Denver's electrical consumption increased by 1.2%, 50% of which is attributed to new cannabis cultivation. 2% of Denver's electric consumption is due to cannabis cultivation. The majority of cultivation operations in Colorado are indoor, largely a function of local rules, and 60% of Colorado's cannabis cultivation takes place in Denver.

In 2016, Colorado's recreational cannabis market saw a large increase in demand for edibles, currently 75% of the recreational market. In addition, 57% of caregivers requested an increase in the number of cannabis plants permitted for residential cultivation. Per the Cannabis Conservancy's research, daily/near daily users are those most likely to engage in home cultivation. In California, that amounts to about 265,000 individuals.

Xcel Energy's Adam White has seen a wide range in the size and capacity of cannabis cultivation in Colorado, ranging in size from the square footage of a big box retailer, to as small as a conference room.

A large percentage of total service requests made by cannabis cultivators in Xcel's territory have not come to fruition, and there is no clear explanation why. Many cultivators moved into one area of Denver, necessitating a new feeder in 2015, although some cultivators have succeeded in rotating their operations on 12 hour cycles. Of the requests that have been completed, cultivators tend to over-estimate their capacity needs. Among cannabis cultivators, Xcel has seen power load estimates of 200 W/sq. ft., and the actual is closer to 35 W/sq. ft. 68 W/sq. ft. is about the highest density of lighting they see, and that is for flower areas. Flower areas require more lighting than other cultivation areas, such as the veg and clone areas, so the average is 35 W/sq. ft.

Stakeholder Cooperation

John Morris reports that there are many organizations and agencies in Oregon that are actively pursuing efforts to increase the energy efficiency of the cannabis industry, including, e.g.:

> The Energy Trust of Oregon, which offers information and incentives for residential and commercial customers, including agriculture, and is actively recruiting cannabis cultivators;
>
> The Northwest Energy Efficiency Alliance, which tracks the cannabis sector but has no specific offerings to its members yet;
>
> The Northwest Power and Conservation Council, whose Seventh Power Plan accounts for the growth in indoor agriculture, and which conducts an annual cultivator survey to try to understand cultivators' energy usage;
>
> Oregon DOE, which developed a lighting calculator to help cultivators forecast their electricity needs;
>
> Oregon Liquor and Control Board, the cannabis licensing authority, which requires cultivators to forecast their energy and water needs and file annual usage reports;
>
> The HB 3400 Task Force, convened to examine at environmental best practices for cannabis cultivators. Among its other recommendations, it supports a voluntary market based certification standard; and
>
> The Resource Innovation Institute, which endeavors to establish best practices for energy and water use in cannabis facilities, using an open source data-sharing approach and collaboration with cultivators, builders, agencies, and other stakeholders.

In contrast, the Bonneville Power Administration provides power to a number of utility companies in the Pacific Northwest, but, as a federal agency, will not provide incentives for cannabis cultivators because federal law prohibits the cultivation and consumption of cannabis.

Jacob Policzer has observed a limited amount of interagency cooperation in Colorado. The Denver Department of Environmental Health has a working group developing best practices for indoor cultivation; the Colorado Energy Office has sponsored a cannabis industry energy use report, the results of which are not yet public.

Challenges and Opportunities Regarding Access to Information

John Morris reports that Oregon cultivators are not familiar with utility hook up process, and may underestimate their energy and water needs in order to start growing as quickly and inexpensively as possible, or may overestimate their needs because they contemplate becoming the "Budweiser of cannabis." Morris recommends that California utilities need to take a consistent approach to California cultivators, and both the energy efficiency and new connects departments need to coordinate their outreach to cultivators.

Alex Cooley states that the majority of cultivators in Washington care about energy efficiency, but their behaviors are inconsistent with environmental stewardship. Why? Because there is a steep learning curve for cultivators, and many cultivators are not aware that there are gaps in their knowledge, much less where to go for information. For example, cultivators might not be aware that they need to develop a working knowledge of Energy Code, or how to do so. In response, and in order to address the information deficit and help cultivators operate in a more energy efficient manner, it is crucial that utilities and other stakeholders meet the cultivators where they are. Hand out quick briefings on what cultivators need to know (e.g., permitting, code compliance) wherever the cultivators happen to be. Don't just make information available; physically hand the information to the cultivators, emphasizing that this is something they need to know.

Energy Efficiency Measures

Alex Cooley observed that some energy efficiency measures are inappropriate for cannabis cultivators. One practical example air conditioning economizers, which reduce air conditioning load by drawing in cool outside air. Some cultivators weld the vents shut because they do not want the humidity and potential contaminants such as mold associated with outside air, although this decreases the energy efficiency of the air conditioning system. Cooley argues that rebates are key in order to encourage cultivators to adopt efficiency measures. Encourage rebates per fixture, and encourage solar providers to offer incentives and flexible payment plans to cannabis cultivators.

David Montgomery notes that there is tremendous variability in the design of cannabis cultivation operations in Washington, anything from a few lights in a barn to cultivation approaching clean room environments. PSE has done over 70 energy efficiency projects for cannabis cultivators so far, all focused on lighting. PSE does not have a special energy efficiency program for cannabis; everything fits into PSE's existing lighting/custom retrofit/new construction programs.

Most of PSE's energy efficiency projects for cannabis cultivation are new construction rather than retrofits, as it is much more cost effective to install efficient lighting in the design phase rather than as a retrofit. PSE is still, however, struggling to understand what a baseline cannabis cultivation operation looks like from an HVAC standpoint. PSE asks cultivators for a baseline low cost design compliant with code, as well as a more efficient design; cultivators don't have the money for more efficient designs up front, so all PSE's incentives have been paid in lighting.

In the past 2+ years, PSE has completed about 70 energy efficiency projects with cannabis cultivators, which have saved between 35 and 40 million kWh, just from energy efficient lighting. When a cultivator installs more energy efficient lighting, the cultivator reduces the need for cooling and dehumidification. Despite the number of projects PSE has completed for the cannabis industry, Montgomery still meets cultivators who say they had no idea PSE could offer incentives.

Montgomery adds that cultivators have been reluctant to adopt LED lighting (especially in the flowering cycle) based on their experience with LEDs that were on the market ten years ago, but there have been advancements in LED technology. Cultivators report that they do lose some productivity with newer LEDs, but get higher THC concentrations in the finished crop.

Jacob Policzer points out that, in cannabis cultivation, upgrading to more energy efficient LEDs is not simply a case of swapping bulbs. The different bulbs require a different style of cultivation, which requires cultivator education and buy-in. Some Colorado cultivators are staggering grow rooms and trying to shift their usage to off peak hours, but these cultivators then experience labor issues, as it is more difficult to find labor at off peak hours.

Boulder County created an Energy Impact Offset Fund for cannabis cultivation, and assesses two cents per kWh. The fund pays for meter installation and analysis, and has the goal of ultimately supporting offset schemes. However, due to the lack of production data, it is not possible to evaluate how efficient these cultivation operations are.

Adam White reports that, in Colorado, upfront cost has been the main consideration of Xcel Energy's cultivator customers. These customers want to begin growing as quickly as possible and want a two or three year payback on investments in energy efficiency measures, so energy efficiency rebates have been critical.

Concerning industry trends, LED manufacturers are meeting cultivator preferences with respect to wavelength of delivered lighting. In the past year, several Colorado cultivators have switched to LED even in the flower cycle, because LED manufacturers are changing the wavelength provided during the flower cycle in response to customer demand. In addition, some cannabis cultivators are going vertical: imagine a big box store style with stacked pallets, and "green walls" that can be moved back and forth with grow lights projected horizontally.

Panel One Q&A

Question: Does variation in cultivator size complicate the ability to provide them with the necessary information?

Cooley: Play to the lowest common denominator, and "help outlaws become compliant with building code." Well capitalized cultivators have an easier time securing professionals to assist them with information and design, but people who started growing cannabis in their closets need information too. One way is via attention-getting fact sheets; simple, fun, engaging, one page per topic or a bound booklet, and physically hand the documents to the cultivators when they go to a government office or to a hydro shop.

Policzer: in California, many cultivator groups and collectives have formed, making it easier to meet them where they are. It is tougher to reach smaller cultivators, although cultivators are eager for the info. Go to cultivator groups and share information.

Question: Farmers still use pen and paper to collect data. What about metering and submetering for reliable data collection?

Montgomery: Very few cultivators have the money up front, making it difficult to get a baseline understanding. Some new cultivators are teachers growing in a shed behind their house, with no business plan.

Policzer: The Cannabis Conservancy requires metering and monitoring for their certification, energy and water audits are the first step. Because warehouses can vary widely in structure, many different types of meters are necessary. Getting cultivators to adopt monitoring can be challenging; they try not to make cultivators spend more than 15 minutes per day on energy data analysis.

Question: SMUD has experienced challenges getting the word out to cannabis cultivators about their incentive programs. Will that trend change?

Cooley: Cultivators have been breaking federal law. Be accommodating and understanding; the cultivators you are trying to reach have probably watched friends go to federal prison. Go to cultivator groups and ask for 5 minutes to speak about your programs. Go to the hydro store and to supply stores and say you want to offer incentives to their customers. Cultivators will be willing to talk about incentives if you meet them where they are.

Morris: Superbly well capitalized and sophisticated cultivators still don't understand how utility programs work. Work through efficiency programs AND hookup programs.

Montgomery: Establish relationships via information sharing. Once a couple of cultivators and lighting contractors get on board, they will all want to participate.

Policzer: The cannabis industry is legitimate and legal on paper, but still often not treated with respect as business owners. Approach your efficiency programs as a partnership and word will get around.

Question: Please clarify what you mean when you say your customers are growing.

White: Business acumen is improving, facilities are getting larger, projects are getting larger.

Policzer: In Colorado, licenses are being consolidated by a handful of companies. Cultivation operations are getting bigger, with economies of scale and uniformity. In Colorado, there used to be a deadline by which cultivators had to have product on the shelves after licensing, so cultivators were in a rush, although this pressure is easing.

Question: Are cannabis cultivation operations candidates for real time or time of use pricing? We found that cultivators had zero interest in this, they wanted to be in charge of when the lights are on.

Cooley: There is some interest, because the industry is maturing and normalizing. It will take time. Without measurement, cultivators don't see how significant the changes can be. Also, cultivators went from two month returns to two year returns, and the market price for cannabis is falling, increasing the interest in obtaining cost savings through energy efficiency.

Morris: In Washington, a small muni has a time of use rate for cannabis cultivators. They worked with their cultivators to help them understand the time of use rate, but there are no results available yet.

Question: Does hesitancy from federally chartered banks have any impact on program design or incentives?

White: Cannabis is legal in Colorado, we have a duty to serve our customers.

Cooley: Echo that with respect to Seattle utilities. The Seattle utility program is an indoor agriculture program, not a cannabis-specific program. The cannabis industry is seeing statements from federal agencies and programs, but not seeing engagement or enforcement per se.

Montgomery: Some public utilities have a problem because they get money from Bonneville Power Administration, so they create separate funds. This has not been a problem for PSE.

Question: Are there any building efficiency measures that work well in a general sense but pose a unique challenge for cannabis cultivators?

Cooley: Economizers pose a unique issue because indoor cultivators operate on a closed system, and economizers draw in outside air. In Washington's rainy climate, drawing in damp air created dehumidification problems and so the economizer ended up not saving any energy overall. Helping people with water side economizers, on the other hand, is helpful. Washington state challenges include building code occupancy standards; some municipalities say all cannabis greenhouses are F1 (factory) when under the building code they should be classified as U (miscellaneous, including agricultural). Solstice has appealed this classification to Washington State Building Council. F1 classification requires, e.g., sprinklers and 3 hour firewalls, but "the plants aren't flammable until after we dry them." Look at occupancy load *and* hazard load.

Question: California building code operates on a 3 year cyclical update. What is the best way to encourage participation by cultivators?

Cooley: Engage them where they are. The only way code improves is with involvement, get engineers and cultivators involved the process of updating the code.

Morris: A Portland medical cultivator was trying to comply with city building code, but the insulation requirements in the walls ended up increasing the cultivator's cooling needs. Sometimes when you think you're getting efficiency, you aren't.

White: Colorado is considering new lighting fixture baselines as part of its Energy Code; but the industry is already making these changes, and may get there before the Energy Code is updated.

Montgomery: Treat lighting like it is part of the growing process, not just as space lighting.

Policzer: Sometimes it is more energy efficient to design a system in a manner other than what the building code requires, and cultivators are seeking exemptions. When updating code, put proposals out there and seek input from cultivators.

Question: What incentive programs have worked to get cultivators to do the right thing?

White: The incentive for agriculture is part of the lighting program. Xcel tried a kWh per pound production efficiency approach, but it became too difficult and expensive to run because of too many variables -- strains, nutrients, water, and people—to control. The new incentive program is based on equivalent photosynthetic photon flux density, plant-food-light at the canopy. Micromoles per joule as a measurement does not work because it does not allow for the directional nature of light fixtures, and some lights are better at pointing light at the canopy. Xcel uses quantum sensors to measure light at the canopy, and that's how they quantify the basis for the incentives they offer. Cultivators have not proven interested in hearing about HVAC incentives, because the payback period is too long.

Montgomery: We push new construction approach before they start installing less efficient lighting, using what they want to install as a baseline. 20 cents per annual kWh saved in new construction lighting is the incentive offered; PSE has not had any cultivator take non-lighting incentives, currently offered at 30 cents per annual kWh saved.

Cooley: Solstice took advantage of a mechanical watts-in, watts-out incentive, but very few cultivators do because it is very expensive and has a ten year return on investment. Consider rebates by fixture, not by kWh saved, because there can be less energy savings realized in different parts of a grow, i.e., flowering and veg and transitioning spaces.

Question: What tools do we need to give you to encourage compliance, participation in reporting, energy efficiency measures, and changes to rules and standards?

Cooley: If I'm bound by law I'm going to comply, but it would be even easier if someone could do it for me. Be cooperative, collaborative, and do the work for the cultivators by automating as much as possible.

Morris: Many cultivators are not willing to share energy data, they regard energy usage as part of their proprietary technique. Market transformation is rooted in education and outreach, every cultivator is different in their willingness and ability to engage.

Policzer: Not an easy process in Boulder, had to learn how to approach cultivators via stakeholder engagement. We have experts on our sustainability committee in Denver.

Key Takeaways from Panel One Presentations and Q&A

States that have legalized recreational cannabis have not necessarily seen an increase in energy consumption attributable to cannabis cultivation.

With respect to indoor cannabis cultivation, state building and/or energy codes sometimes result in cultivation operations that are less energy efficient than they could be, without any concomitant gains in safety.

What is energy efficient for one industry may not be energy efficient for another industry. For indoor cannabis cultivation, for example, insulation requirements may increase cooling needs, and HVAC economizers may increase the need for dehumidification and air filtration.

Market participants and third party organizations are already reducing the energy footprint of cannabis cultivation without government mandate. For example, in Colorado, utilities and cultivators have already adopted more efficient lighting technologies that are only currently being considered for inclusion in the Energy Code.

Information on the energy consumption associated with cannabis cultivation is scarce. The dearth of information creates difficulties for: cultivators trying to anticipate their energy needs and understand the benefits of conservation; utilities trying to plan for infrastructure and energy procurement needs associated with new cannabis cultivation; cities and towns trying to meet their sustainability and clean energy goals while accommodating cannabis cultivation; and regulators trying to ensure compliance with statewide climate goals.

To date, cannabis cultivators have been significantly more receptive to lighting efficiency incentives than HVAC efficiency incentives due to upfront cost and length of payback period.

For cannabis cultivation, adopting more efficient lighting such as LEDs necessitates a change in cultivation techniques, and therefore will require education and buy-in.

The wide variety in the size of cannabis cultivation operations and the sophistication of the cultivators will create challenges for education and outreach concerning energy efficiency measures, and for cultivator engagement with mandatory reporting and other forms of data sharing.

IV. Panel Two: Cannabis Cultivation in California, Challenges and Opportunities

California cannabis stakeholders have been working toward a statewide regulatory framework for many years. Since the passage of Proposition 215 in 1996, which legalized medical cannabis use, in-state cannabis stakeholders have worked toward the passage of the Medical Cannabis Regulation and Safety Act of 2014, and the Adult Use of Marijuana Act of 2016 (Proposition 64). Representatives of key stakeholder groups discussed their experience, insights, and tasks underway to meet new legislative requirements.

California panelists included Hezekiah Allen, the Executive Director for the California Cultivators Association; Kristin Nevedal, Program Director for Americans for Safe Access and Board Member of the California Cannabis Industry Association; Nick Caston of CannaCraft, a cannabis product manufacturer and distribution company; Amber Morris, Branch Chief of CalCannabis Cultivation Licensing at the California Department of Food and Agriculture; Cody

Coeckelenbergh, Director of Program Services at Lincus Energy, an energy efficiency service provider; and Jesse Emge, Supervisor of Evaluation, Measurement, and Verification at San Diego Gas and Electric.

The Q&A session of the second panel benefitted from participation from various individual cultivators, engineering consulting firms, representatives of key organizations such as Sacramento Municipal Utility District, Pacific Gas & Electric, California Energy Commission, energy policy professionals from the energy efficiency and renewable energy industry.

Panelists spoke to key California-specific attributes that set the state apart from Washington, Oregon, and Colorado. Because Panel Two was limited to an examination of the California experience, a number of major themes emerged during the panel discussion, and therefore the synopsis is presented by theme rather than by individual panelist.

California Market Trends

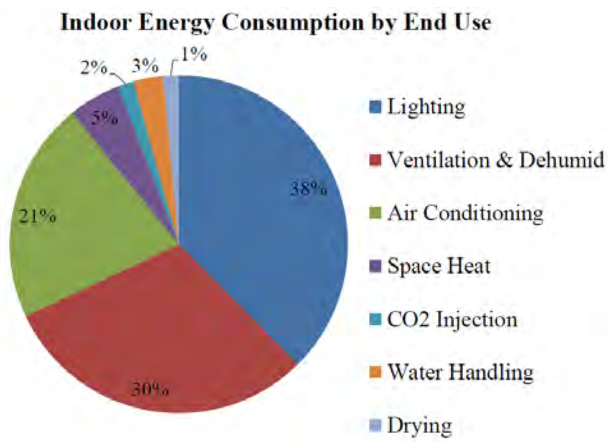
Cannabis is currently grown across California at varying levels of energy use for both in-state consumption and export, constituting a multi-billion market. Hezekiah Allen estimates California's cannabis exports exceed in-state consumption by a factor as high as four-to-one. The looming market uncertainty from a reversal in federal policy on prosecution may result in a market demand reduction and negatively impact in-state production as export falls.

Kristin Nevedal and Hezekiah Allen both pointed out that from a horticultural perspective, cannabis can be grown in a variety of settings in California, ranging from open field, to greenhouses, to a completely indoor setting using a number of different irrigation methods (e.g., dry farming, drip irrigation, flood irrigation, and hydroponics). The combinations of different cultivation methods using varying lighting and irrigation techniques are numerous. When asked whether cultivators across the state have a preference for a particular style of cultivation, Hezekiah Allen responded by observing that whatever method of cultivation is currently preferred by an existing cultivator may likely be that cultivator's preference in the future, but added the caveat that California's higher electricity rates will pose a constraint on the expansion of indoor cultivation.

Kristin Nevedal pointed out that decades of prohibition have reinforced the adoption of indoor cultivation methods, where cultivators are forced to hide their cultivation, even when California's natural climate is conducive for open field cultivation. Members of the audience highlighted that indoor cultivation practices also resulted from a preference for higher yield potential and industrialized quality control offered by indoor facilities. Nadia Sabeh, an agricultural facilities engineer from the audience, pointed out that unlike other high-value California crops such as almonds and wine grapes, the cannabis industry has not benefitted from publicly funded agricultural research on how to better optimize production in a variety of cultivation settings. Other members of the audience affirmed that existing industry practice on energy and water use has emerged solely based on information sharing between cultivators.

Metrics of Energy Intensity for Cannabis Cultivation

There was no disagreement among panelists and the audience that indoor cultivation is indeed more energy intensive. However, Hezekiah Allen and Cody Coeckelenbergh stated that indoor cultivation is less water intensive. Indoor cultivation methods benefit from reduced evaporation that would otherwise occur in an outdoor environment. Using artificial lighting to support plant growth and HVAC equipment to control temperature, air flow, and humidity require a significant amount of electricity, and Cody Coeckelenbergh presented a breakdown of such indoor energy demand sourced from the 2012 Evan Mills study. Both Kristin Nevedal and Nick Caston spoke to the hybrid approach of using a mix of sunlight and artificial lighting in a greenhouse setting as an ideal environmentally sustainable middle ground to boost yield without sharply increasing electricity consumption.



Source: Evan Mills, 2012, presented by Lincus Energy

Kristin Nevedal further elaborated that California's agricultural environment, rich sun exposure, and temperate climate provide an ideal setting to shift toward less energy intensive open field or mixed-light cultivation. She also added, however, she had observed a higher sales volume of indoor cultivation equipment, as cultivators may be shifting from lower-yield outdoor cultivation to higher-yield indoor cultivation in order to increase revenue to either offset or avoid regulatory compliance costs.

There are differences of opinion on how exactly to measure the energy intensity of cannabis cultivation. Cody Coeckelenbergh presented a per-plant metric in his presentation based on the approach taken in the 2012 Evan Mills study. However, both Hezekiah Allen and Kristin Nevedal rebutted that the energy and water intensity for cultivation actually depends on plant size, plant density, and crop yield. High-density planting for any cultivation method would significantly change the energy or water intensity calculation. A more accurate metric for energy or water intensity, Allen and Nevedal explain, would be one that measures yield per square footage per flowering cycle, similar to how other crop productions are measured.

According to an internal cost study based on 2016 data, Nick Caston estimated that the energy cost differential between indoor versus greenhouse versus outdoor cultivation to be 78 to 1 to 0.

Status of State Regulatory Implementation

The CalCannabis Cultivation Licensing Office (CalCannabis) at the Department of Food and Agriculture is (CDFA) is currently developing regulations to license the cultivation of medical and adult-use recreational cannabis to comply with Proposition 64 and recent medical cannabis legislation. As Amber Morris explained, CalCannabis is developing a track-and-trace technology platform to prevent the comingling of legally-grown and illegally-grown cannabis products in the marketplace, such that legally-grown cannabis is not spread into the black market, and that illegally grown cannabis products will not be legally sold. Beginning January 1, 2018, CDFA will accept applications for cultivation licenses in three tiers differentiated by square footage and cultivation methods:

California Cannabis License Tiers

	Outdoor (no artificial light)	Indoor (exclusively artificial light)	Mixed-Light (como of natural & supplemental artificial light)
Special Cultivator	**Type 1** Up to 5,000 sq. ft. or up to 50 mature plants on noncontiguous plots	**Type 1a** Up to 5,000 sq. ft.	**Type 1b** Up to 5,000 sq. ft.
Small Cultivator	**Type 2** 5,001 - 10,000 sq. ft.	**Type 2a** 5,001 - 10,000 sq. ft.	**Type 2b** 5,001 - 10,000 sq. ft.
Medium Cultivator	**Type 3** 10,001 sq. ft. to one acre	**Type 3a** 10,001 - 22,000 sq. ft.	**Type 3b** 10,001 - 22,000 sq. ft.
Nursery	**Type 4** Up to one acre	**Type 4** Up to one acre	**Type 4** Up to one acre

Source: CalCannabis at California Department of Food & Agriculture

In August 2016, CalCannabis conducted a month-long statewide industry survey on the location and type of licenses cannabis cultivators plan to seek. The survey result is available by county, and reflects business development interest in cultivation across all counties of the state.[3] Amber Morris summarizes that about 45 percent of respondents indicated preference for indoor cultivation.

[3] CalCannabis August 16 survey results available at https://www.cdfa.ca.gov/is/mccp/news/36

Due to the correlation between license type and on-site energy use, the availability of indoor and mixed-light licenses across localities could provide utility planners with valuable information on load growth potentials attributable to commercial cannabis cultivation. Hezekiah Allen emphasized that, unlike other states that have legalized commercial cannabis cultivation, California utilities and regulators will have better data access to ascertain and respond to any potential energy impact of cannabis cultivation due to the inherent structure of the state's regulatory framework. He further emphasized that the electricity demand spikes experienced by states such as Washington and Colorado are not likely be replicated in California due to limited license availability and California's higher electricity rates. "California is a not a cheap electricity market. California is not going to cost competitive at a large scale with indoor cultivation only," Allen said. "Impacts can be allocated based on the [cannabis] regulatory structure."

Amber Morris explained that CalCannabis is currently conducting a statewide programmatic environmental impact report (PEIR) under California Environmental Quality Act (CEQA) to understand and mitigate the statewide effects of cannabis cultivation. The goal of CalCannabis is to certify this environmental review by the end of 2017, and the department is working in consultation with other state agencies tasked with other responsibilities under Proposition 64. This environmental assessment will differentiate the impact and potential mitigation by license type, thus setting a baseline for cultivation site-specific CEQA assessment. Local government will then determine whether the PIER analysis is sufficient for adopting local land-use policy or conducting site-specific CEQA review.

Impacts of Local Land Use Policy

Nick Caston points out that local land use decisions predominantly determine the method of cultivation within a municipal jurisdiction. Currently only a handful of California counties allow cannabis cultivation within unincorporated areas. Citing experience with Sonoma County, Nick Caston stated that local authorities often cite aesthetic concerns and ignore the environmental impact of indoor cultivation when passing local ordinances prohibiting outdoor and mixed-light commercial cultivation facilities.

Proposition 64 does not allow local government to ban cultivation for personal use, but local government may restrict the method by which these personal plants are cultivated. The City of Sacramento recently approved a city ordinance to allow only indoor cultivation for personal use. A representative from SMUD in the audience cited concerns with assessing and identifying the location and magnitude of residential energy load as a result of this local ordinance. Hezekiah Allen responded by stating there may already be existing load to grow cannabis indoors for personal use, so it may not be additive load. "Six plants are not going to be an obvious load to detect," he said.

Most California cities and county governments have either prohibited cultivation, or are still in the process of developing land use requirements for cannabis. In agriculture-rich counties such as Sonoma, cannabis cultivation permits for both personal and commercial purposes are authorized on the condition that the cultivation is indoors. All three cannabis industry representatives on the panel expressed similar frustration on the lack of environmental consideration when local authorities prohibit outdoor or greenhouse cultivation outright. "Whose job is it to watchdog these local agencies?" asked Hezekiah Allen. In response, Nick Caston cited a precedent with state-level enforcement during Jerry Brown's term as Attorney General in litigating against local authorities for noncompliance with SB 375 on sustainable land use.

Amber Morris, in discussions pertaining to the impact of land use policy, repeatedly stressed that current state legislation allows for local control in determining how cultivation sites are permitted. While CalCannabis will produce a CEQA analysis by license type, it is ultimately up to local government to determine the conditions by which local permits are granted.

California Utility Experience and Energy Programs

With regards to the variety of energy management incentive programs in California, Nick Caston stated that while incentives programs may work for the cannabis sector, the bigger barrier is the inability for the industry to obtain financing due to federal banking and lending constraints. Financing tools such as the Property Assessment Clean Energy (PACE) program would be a welcome approach.

Utility representatives of SDG&E, PG&E, and SMUD all echoed the common theme of the need for more data. Joe Horak from PG&E announced that PG&E is actively recruiting cannabis cultivators to sign up for the agricultural rate schedule, rather than the commercial rate schedule, through an informal customer working group. This announcement was met with positive response from cultivators in the audience. When inquired on the difference between cannabis and other agricultural energy use patterns, Joe Horak stated that PG&E currently does not have enough data to make that determination. Jesse Emge of SDG&E explained that while internal stakeholders within his company know the energy impacts of cannabis cultivation should not be ignored, there is simply not a lot of data to determine what to do next.

Key Takeaways from Panel Two Presentations and Q&A

California cannabis cultivators have developed diverging preferences on pursuing indoor, mixed-light versus outdoor cultivation. Optimizing between increased crop yield and increased energy costs is a business decision affected by revenue potential and other costs of doing business.

The cannabis industry has not benefitted from publicly funded agricultural research on how to best optimize production across a variety of cultivation methods, unlike other valuable agricultural commodities in the state.

Indoor cultivation is generally accepted as the most energy intensive cultivation method, but is also potentially the most water-efficient method.

California's high energy rates may pose a constraint on the expansion of indoor cultivation.

When calculating the resource impact of cannabis cultivation, a per-plant metric does not account for planting density, yield potential, or growing cycle.

California's statewide licensing tiers are differentiated by square footage and cultivation setting (indoor, outdoor mixed-light), leading to potentially easier access to locational data on where increased energy load might occur.

California Department of Food and Agriculture is conducting a statewide programmatic environmental impact review by license type. Local government entities will determine whether this assessment is sufficient for adopting local land-use policies or site-specific CEQA review.

Local land-use permits, when granted, often require a specific type of cultivation setting. Many local jurisdictions have banned outdoor or greenhouse commercial cultivation, or banned commercial cultivation completely. It is unclear whether local jurisdictions are aware of the energy consequences of mandating indoor cannabis cultivation.

Local government entities cannot prohibit cultivation for personal use under Proposition 64. They can, however, place restrictions on outdoor or greenhouse personal cultivation. Sacramento is one city which allows residents to grow cannabis for personal use, but only when grown indoors.

California's cannabis exports exceed in-state consumption by a factor as high as four-to-one. The looming market uncertainty from a reversal in federal policy on prosecution may result in a market demand reduction and negatively impact in-state production as export falls.

California utilities do not currently have sufficient data to identify new load patterns attributable to cannabis cultivation.

V. Staff Recommendations

Staff concludes that the available data are not sufficiently robust to support recommending a special cannabis tariff. In the near term, staff recommends increased data collection.

Oregon requires licensed cannabis cultivators to forecast their energy needs before commencing operation, and to submit annual reports of energy usage. It may be helpful for the Commission to engage the CDFA in consultation with CEC and ARB concerning whether a similar reporting requirement would be beneficial in California.

Commission staff should consult with cultivators and other industry stakeholders concerning the availability and development of informational materials for cultivators.

Commission staff should facilitate constructive engagement between cannabis cultivators and the CEC concerning California's Building Code and Energy Code in order to determine whether particular provisions enhance or diminish the energy efficiency and safety of cannabis cultivation.

Because some local jurisdictions require that cannabis cultivation take place indoors, it may be beneficial for the Commission to engage with local jurisdictions to share information on the energy intensity of different means of cannabis cultivation and to discuss means of balancing public safety, aesthetics, and climate policy.

Commission staff should conduct a review of available energy efficiency/demand-side management programs and make program information available to cultivators, CDFA, and other stakeholders.

Commission staff should study the most appropriate energy efficiency metrics applicable to cannabis cultivation. Should efficiency be measured by plant, by square foot of canopy, by annual kWh saved, or by some other measure?

Commission staff can work to make data concerning embedded carbon intensity of electricity more easily accessible by local government entities for the purpose of local CEQA review.

Commission staff should assemble a Cannabis Working Group to consider options for ensuring that California cannabis cultivation is energy efficient, up to and including the possibility of a specific energy tariff for cannabis cultivation.

After the release of this Staff Workshop Report, Commission staff should attend a cultivator's association meeting and/or utility working group and discuss the results.

EXHIBIT 57

Trends and Observations of Energy Use in the Cannabis Industry

Jesse Remillard, PE, and Nick Collins, PE, ERS

ABSTRACT

With nine states presenting marijuana legalization measures in the 2016 election, the marijuana industry is poised to become one of the largest emerging industries in the indoor agricultural market. In recognition of the potential load growth associated with the expanding U.S. medicinal and recreational cannabis industry, this paper seeks to characterize the state of the market, including common industry practices, trends, and energy efficiency opportunities. To date, only limited research-based literature has been published on the energy consumption impacts of marijuana legalization and indoor cannabis growing. This paper seeks to build on previous investigations by presenting primary research that has been conducted on regional industry standard practices and measure costs. The authors have found LED grow lights, dehumidification, and space-conditioning end uses to be the primary energy efficiency opportunities available for the indoor cannabis industry. The authors will present an industry specific analysis of LED lighting energy savings, as well as the primary cost research for baseline and LED grow-light fixtures. The authors also conducted interviews with HVAC engineers specializing in indoor cannabis-growing operations and identified several energy savings opportunities.

Introduction

On November 8, 2016, four new states legalized cannabis for recreational use, and another three for medical use. This brought the total number of states with laws for the sale and use of recreational marijuana to eight, with another twenty-eight allowing it for medicinal use. The electrical load growth associated with new indoor grow operations because of this legislation is significant.

According to a recent study by Evergreen Economics, Seattle Light and Power estimates a 3% increase in overall electric demand as a result of legal cannabis production, and a utility interviewee from Colorado estimated that the total load growth for the state attributable to cannabis production since 2013 was between 0.5% and 1% (Evergreen Economics 2016, 9; 16). In 2015, *Bloomberg* researchers estimated that cannabis grow facilities made up almost 50% of the new power demand in Colorado (Oldham 2015).

To illustrate this impact in another way, it is estimated that between 20% (Sevcenko 2016) and 50% (Oldham 2015) of the costs of marijuana production are energy costs. The energy intensity of indoor cannabis production is known to be similar to data centers, at nearly 200 W/square foot (Crandall 2016; Mills 2012). Aluminum production consumes around 7 kWh/lb to produce, while indoor cannabis production consumes on the order of 2,000 kWh/lb to produce (Jourabchi and Lahet 2014; Mills 2012; O'Hare, Sanchez, and Alstone 2013).

The electric loads are dominated by lighting, dehumidification, and air-conditioning equipment as estimated in the widely referenced work by Evan Mills (2012), "The Carbon Footprint of Indoor Cannabis Production," published in *Energy Policy*. Of particular merit for the report is the transparency of the detailed model that Mills uses in making his estimations. Mills calculates that it takes approximately 13,000 kWh per year to operate a standard production module that is 4′×4′×8′ (Mills 2012, 59). This is based on a production cycle of 78 days, for 4.7 cycles per year, and simple assumptions about the equipment capacities and use. A breakdown of his estimates for the energy use associated with indoor cannabis production is shown in Figure 1.

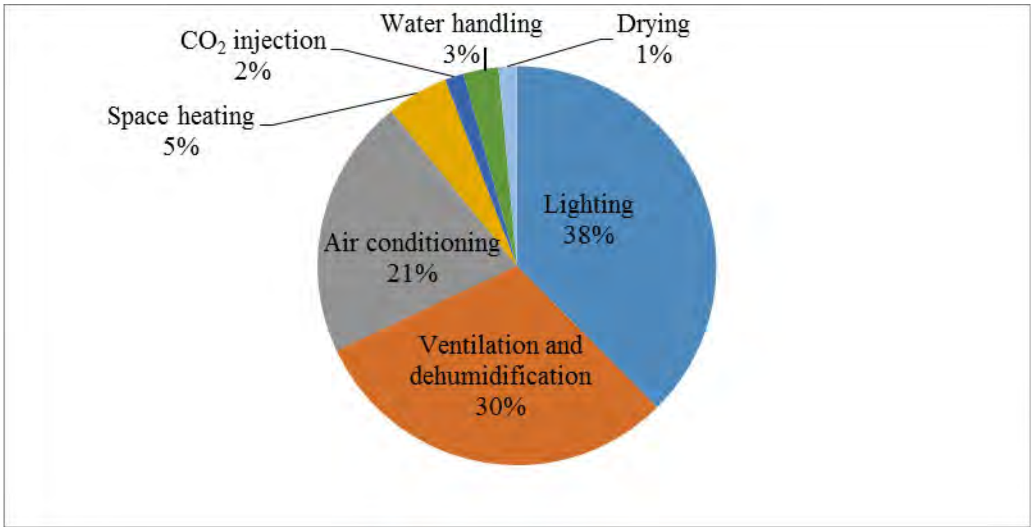


Figure 1. Breakdown of energy use for indoor cannabis production. *Source*: Mills 2012.

While high production costs are sustainable in emerging markets, more mature markets have seen a substantial reduction in product prices. Since Colorado legalized marijuana in 2014, the wholesale price of cannabis in that state has fallen from $2,500/lb. to about $1,000/lb (Borchardt 2017). Falling product prices will drive the need for more competitive operation costs, which will largely be presented in the form of energy efficiency.

For this paper, the authors interviewed owners/operators of legal medical grow facilities and equipment suppliers in the Northeast. A summary of the interviews conducted is shown in Table 1.

Table 1. Interviews with industry contacts

Type	Number
Owner/operator	7
Lighting manufacturer	3
Equipment supplier	2
HVAC equipment manufacturer	1
HVAC system designer	1

Growing cannabis is an agricultural production process where space conditions, temperature, and humidity are tightly controlled to optimize quality and mitigate crop loss due to pests, mold, and mildew. The quality and amount of light provided is the primary driver of the yield and quality once air temperature and humidity needs are met. In commercial operations, growers clone mother plants by taking small cuttings. The seedlings are usually grown in racks stacked vertically with fluorescent lighting (T5HO) until they are mature enough to be repotted and placed in grow rooms with high-intensity discharge (HID) fixtures. The plants are then grown in a vegetative state for 18 to 24 hours per day until the photoperiod is shortened, which induces the plant to begin flowering. A full cycle from clone to harvested plant takes 3 to 4 months but can vary depending on the particular strain of cannabis (Caulkins, Cohen, and Zamarra 2014).

The following sections of this report detail the industry standard practices, cost trends, and energy efficiency opportunities for lighting, dehumidification, and air-conditioning needs in the indoor cannabis industry.

Lighting

Traditional winter agriculture has taken place in greenhouses due to the high costs associated with indoor horticulture. The high value of cannabis has driven its indoor production for many years, especially in areas with shorter outdoor grow seasons. Lighting is the single most important piece of equipment for indoor growers, as it drives the photosynthesis and growth of the plants.

Industry Standard Practice for Lighting

The standard practices for each stage of the growing cycle are described below. Often, cannabis is considered to have only two growth stages, but the seedlings are shown as their own stage here in order to recognize the different type of lighting used for those plants.

- **Seedling cycle –** T5HO fluorescents are preferred for the early stages of plant growth because they can be placed close to the plant and stacked vertically, and their limited heat and light intensity reduces the chance of damaging the seedlings.
- **Vegetative cycle –** For vegetative growth, 600 W or 1000 W metal halide (MH) HID fixtures are preferred because their spectra contains more blue, but high pressure sodium (HPS) fixtures are also used. For vegetative growth, lighting is typically used for 18 to 24 hours per day. In instances where vegetative light fixtures had the capacity for variable output, interviewees indicated that plants in the vegetative state were given approximately 60% or 70% of the light used for flowering plants.
- **Flowering cycle –** The industry standard practice for the flowering cycle is the use of 1000 W HPS fixtures. HPS fixtures can be used for all stages of the growing cycle, but they are widely preferred for the flowering stage because of their concentration of yellow or red spectra. In the flowering stage, lights are typically used at their maximum output for 12 hours per day. A recent emergence to the industry is double-ended (DE) HPS lights, which output significantly more light than their single-ended counterparts. A recent study at Utah State University measured the output of traditional single-ended HPS fixtures at 1.02 µMol/sec and the output of DE grow fixtures at 1.66 to 1.70 µMol/sec (Nelson and Bugbee 2014). For an explanation of the difference between traditional lighting lumens, and micro-moles of light output, please see the section further in this report titled “Lumens are for Humans”. Interviewees indicated that the majority of growers are now purchasing DE fixtures and lamps.
    - Each DE 1000 W HPS fixture typically serves a 4′×4′ area of plant canopy (Jourabchi and Lahet 2014).
    - Each 4′×4′ of canopy contains approximately two to four flowering plants.

- A constant-output 1000 W HPS grow light fixture can be bought for $200 to $300. DE 1000 W HPS fixtures with dimmable or specialized output cost $400 to $600.

MH and HPS lights use interchangeable fixtures and are readily available online. Data collected from Amazon, The Grower's Warehouse, and Grower's Ace is shown in Figure 2.

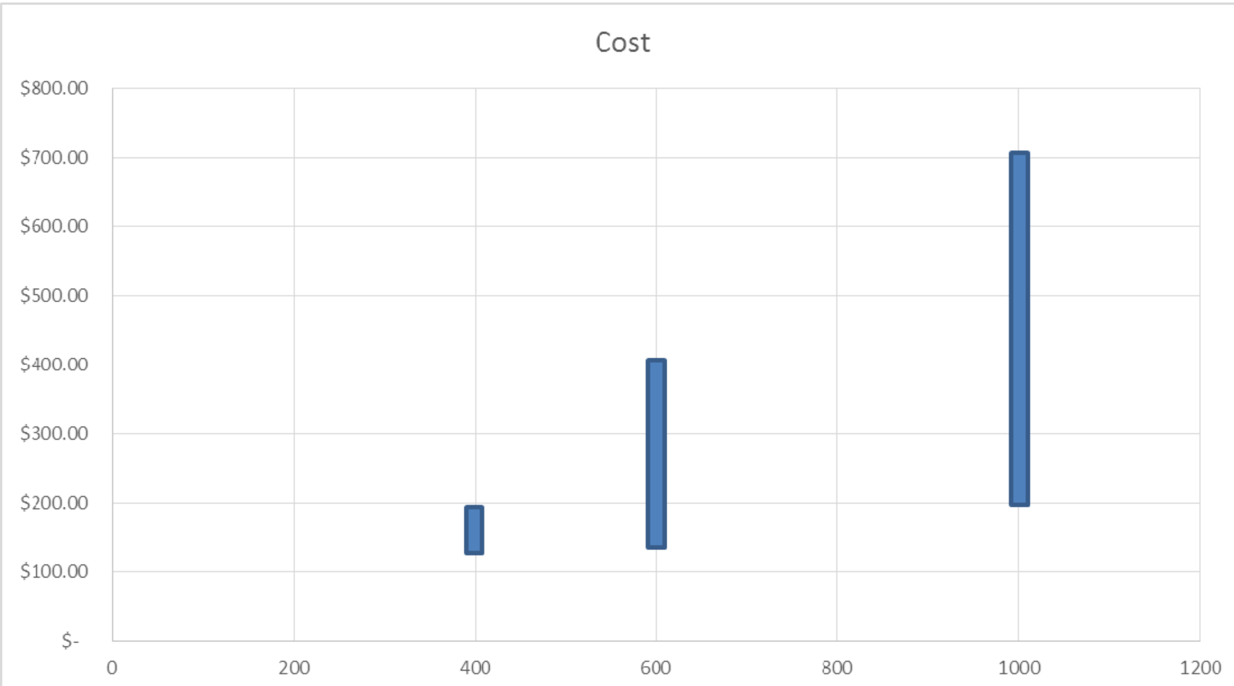


Figure 2. HID cost information

A summary of the industry standard practice results are shown in Table 2.

Table 2. Industry standard practices for lighting

Stage	Fixture	Hours of use	Cost
Seedling	4-foot 220 W 4 lamp T5 fluorescent	24	$100–$200
Vegetative	600 W MH	18–24	$200
Flowering	1000 W DE HPS	12	$400–$500

Lighting Efficiency Opportunities

LED grow lighting has been identified as the primary energy efficiency opportunity for indoor grow facilities, but the industry has been slow to adopt the technology due to the cost premium associated with LEDs, as well as concerns about the effectiveness of the fixtures in terms of product yield and quality.

The LED grow lighting technology is still emerging, and independent studies verifying the effectiveness of LED grow lighting compared to HID lighting are not widely available. The authors are aware that DesignLights Consortium (DLC) is in the process of developing criteria for horticultural lighting (G. Chan, Business Development Manager, Lumigrow, pers. comm., February 17, 2017). Direct comparisons between the yield of HID and LED lighting are challenging to establish since even under the exact same growing conditions and the exact same plant genetics, a 10%-20% variation in yield is to be expected (Caulkins J., Cohen, and Zamarra 2014). This makes it difficult to assess if differences in yield are due to the different lighting technologies, or are inherent to the growth of an agricultural product.

As indoor agricultural lighting matures, it is expected to become the standard for indoor cannabis operations as it has for other lighting applications. Most manufacturers market LED lights as a 40% reduction in power and energy use over traditional HID fixtures. This value represents a comparison of the connected load of the fixtures and does not include interactive savings from the reduced heat rejection into the air-conditioned space.

It is expected that 600 W LED grow lights will be the most commonly proposed measure for energy efficiency at grow facilities due to the current industry standard practice of using 1000 W MH and HPS fixtures. Through the conducted interviews and review of cannabis industry magazines, the authors have identified the following LED grow light manufacturers as industry leaders in the United States:

- Black Dog LED – www.blackdogled.com/
- Heliospectra – www.heliospectra.com/
- LumiGrow – www.lumigrow.com/
- California LightWorks – www.californialightworks.com/
- Fluence Bioengineering – https://fluence.science/
- VividGro – www.vividgro.com/

Most manufacturers list product prices and sell their fixtures directly through their websites, but additional cost information was gathered through interviews with lighting manufacturers. The costs for fixtures from the industry-leading LED manufacturers are shown in Figure 3. Most LED manufactures interviewed indicated that they offer a 10% discount for bulk purchases, which is not accounted for in these values. Similar to HID fixtures, dimmable or spectrum control features are an additional cost.

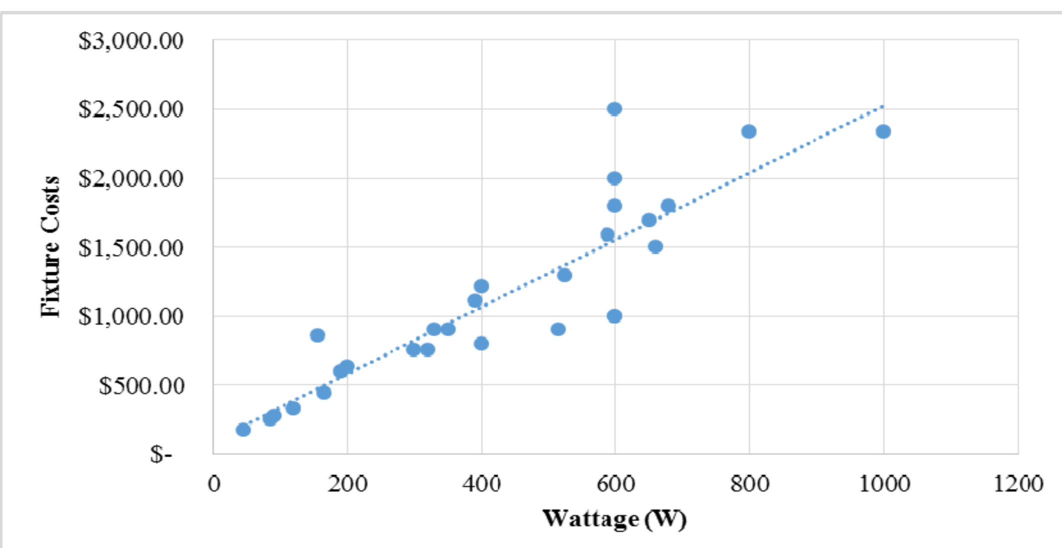


Figure 3. LED fixture costs

Lighting Energy Savings

The annual energy savings for implementing LED lighting in a grow operation can be calculated through the following formula.

$$kWh\ savings = Lighting\ kWh\ savings + HVAC\ Interactive$$

where,

$$Lighting\ kWh\ savings = (HID\ wattage - LED\ wattage) \times Annual\ Operating\ Hours$$

and,

$$HVAC\ Interactive = Lighting\ kWh\ savings \times \frac{3412\ Btus}{kWh} \div 12{,}000 \frac{tons}{Btu} \times HVAC\ kW/ton$$

The typical energy savings per fixture in vegetative and flower rooms can be calculated using the following assumptions, as shown in Table 3. The annual operating hours are calculated as the daily operating hours multiplied by 365 days.

- Vegetative room lights are on for 18 hours per day.
- Flower room lights are on for 12 hours per day.
- Fixtures are assumed to operate 365 days a year
- HID wattages from Table 2, above
- LED wattages of 300 W and 600 W for vegetative and flower rooms, respectively
- HVAC efficiency of 1.2 kW/ton or 10 SEER
- Cooling in the grow room is assumed to be required year round while lights are on
- Blended electric rate of $0.12/kWh

Table 3. LED energy savings summary

Stage	HID wattage	LED wattage	Demand impact	Annual energy savings	LED fixture costs	Simple payback[1]
Vegetative	600 W	300 W	300 W	2,600 kWh	$700–$1,000	2-3 years
Flowering	1000 W	600 W	400 W	2,300 kWh	$1,000–$1,600+	3-4 years

For simplicity, the nameplate wattages are used in the above calculations. The actual input wattages for both fixture types vary. HID input wattages are greater than the nameplate wattage, and LED input wattages could be greater than or less than their nameplate wattage depending on the manufacturer.

The above calculations also assume that LED fixtures can truly replace HID fixtures one-for-one. This assumption may be invalid.

"Lumens are for Humans"

The above quote is a phrase often heard when discussing agricultural lighting. It indicates that lumens, the typical measure of light output associated with interior or exterior space lighting,

[1] Assumes a retrofit scenario where incremental cost is not a factor

is not an appropriate measure of light output for agricultural applications. What matters to plants and photosynthesis is the amount of photons delivered to the plants within the photosynthetically active radiation (PAR) spectrum from 400 to 700 nanometers. Photon delivery is expressed as photosynthetic photon flux (PPF) in the unit of μMol/sec. The μMol/sec of LED fixtures varies by manufacturer and is typically 40%–50% less than the μMol/sec output of a DE 1000 W HPS fixture. This comparison can't be made so directly or easily, however.

The output of a given fixture does not directly equate to the amount of μMol/sec delivered to the plant. By varying the mounting height of a fixture, the output can be "concentrated" on a smaller area of canopy, yielding a greater density of μMol/sec delivered for a given fixture. This value is referred to as photoactive photon flux density (PPFD). This value appears to be the key metric for comparing effective PAR output from various fixture technologies. Since LED fixtures give off substantially less heat than HID fixtures, they can be mounted much closer to the plant canopy, effectively increasing their PPFD. Depending on the LED fixture design, lowering the mounting height may result in canopy coverage of less than the standard of 4′×4′, which in turn may result in a greater number of LED fixtures being required to provide sufficient coverage at the desired level or HID-equivalent PPFD value. This is a topic of ongoing discussion between the authors and various LED manufactures and medicinal cannabis producers.

Dehumidification and Air Conditioning

Because plants release water vapor through transpiration, indoor grow facilities require substantial dehumidification to maintain approximately 50% to 60% relative humidity. If excess humidity is left unregulated, it can cause mold or mildew, potentially ruining a crop. Dehumidification is generally achieved mechanically by sub-cooling the air to remove water and then reheating the air to the desired supply air temperature through traditional dehumidification units or by absorbing moisture in the air through a desiccant dehumidifier. Hot, dry air – typically produced by fuel-burning or electric-resistance heaters – is then used to "recharge" the desiccant wheel.

Closed-ventilation systems appear to be common in commercial cannabis enterprises and represent the industry's fear of mold, mildew, mites, and uncontrolled fertilization. With proper air filtration (MERV 14 or greater), outside air can be used without introducing outside contaminants. Closed-ventilation systems also require supplementary CO_2 from either direct combustion or liquid systems. Conversely, operations that introduce CO_2 into the grow space are all but required to employ closed-loop systems since the introduced CO_2 would be exhausted from the space with an open-loop configuration.

Cannabis plants grow best in the 70°F to 80°F temperature range. Due to the use of closed-ventilation systems and HID lights, which reject large amounts of heat within the production space, indoor grow rooms are cooling-dominated environments. Household mini-splits are common in smaller operations, while rooftop units, computer room air conditioners, or air-cooled chillers are typically used for larger operations.

The authors have observed a trend toward lowest first cost options for HVAC systems serving grow spaces. The interviews conducted also indicate that HVAC systems are not being thoughtfully designed for the unique conditions for the grow spaces, resulting in difficulty controlling the environment, frustration with the installed systems, and a "Band-Aid" approach to fixing the problem where more and more standalone dehumidifying equipment is added until the desired conditions are met, which ultimately increases the energy use associated with production.

Dehumidification and Air-Conditioning Efficiency Opportunities

After LED grow lighting, dehumidification and air conditioning represent the largest opportunities for energy savings (Figure 1). Two approaches are currently known to minimize the energy consumption associated with maintaining indoor grow space conditions: 1) utilization of outdoor air economizing through the supply of filtered outdoor air or a dry cooling tower, and 2) high efficient dehumidification through air-to-air heat exchangers.

High efficiency dehumidification is accomplished by circulating air in a closed loop through a heat exchanger before and after mechanical cooling. Heat is exchanged between the same air stream to both precool the incoming air and preheat the outgoing dehumidified air.

The Western Cooling Efficiency Center at the University of California, Davis, performed research on such a system made by MSP Technology and found savings between 30% and 50% over traditional systems without heat recovery (Pistochini et al. 2016).

The authors present the following additional potential efficiency measures for maintaining humidity and air conditioning in indoor grow rooms:

- Reheating needs can be served by heat recovery off the condenser side of cooling equipment.
- If waste heat is available, it can be used to recharge (fully or partially) desiccant wheels for efficient dehumidification.

Conclusions

Lighting, cooling, and dehumidification are the largest energy end uses and represent the primary areas for potential improvements in energy performance for indoor grow facilities.

- **Lighting –** The industry appears poised to accept LED lighting for the vegetative stage as some interview respondents indicated that LEDs perform as good as or better than HIDs for this stage. The industry does not appear ready to accept LED lights for the flowering period, however, as anecdotes indicate reduced yields compared with HPS fixtures. Additionally, the perception of growers has been tainted by early low-quality versions of LED grow lighting, and there are not enough published field trials proving the effectiveness of modern LED equipment. Although LED manufacturers claim equal or superior flowering performance, definitive data in support of these claims appears to be lacking. The emergence of a DLC category for LED grow lighting is expected in the next 12 to 18 months and would provide a much-needed third-party verification of LED grow light performance. Due to the value of the product they produce, cannabis growers are widely focused on yield and production over energy use, which severely hinders the adoption of energy efficient equipment.
- **HVAC and dehumidification –** The primary opportunity identified for dehumidification and HVAC systems lies in the use of high efficiency equipment coupled with detailed site-specific design. These spaces have very specific requirements and loads, and an improperly designed system could require additional equipment to meet space conditions that would likely consume more energy than is required for the task.

Virtually all of the growers that the authors spoke with are adding grow rooms or expanding their operations in response to the rising demand for medical cannabis, and in anticipation of increasing cannabis demand in states that recently passed legalization laws such as Maine, Massachusetts, Nevada, and California. Utilities from the SDG&E study report a lag time of 6 to 12 months before seeing the impacts of legalization on energy grids, and growers express a need to expedite facility set up. Growers are also not typically experienced in facility management, which often leads to poor HVAC and lighting design choices. Efficiency programs have the opportunity to influence the choices and direction of this emerging industry toward more efficient designs by engaging growers and providing guidance and incentives.

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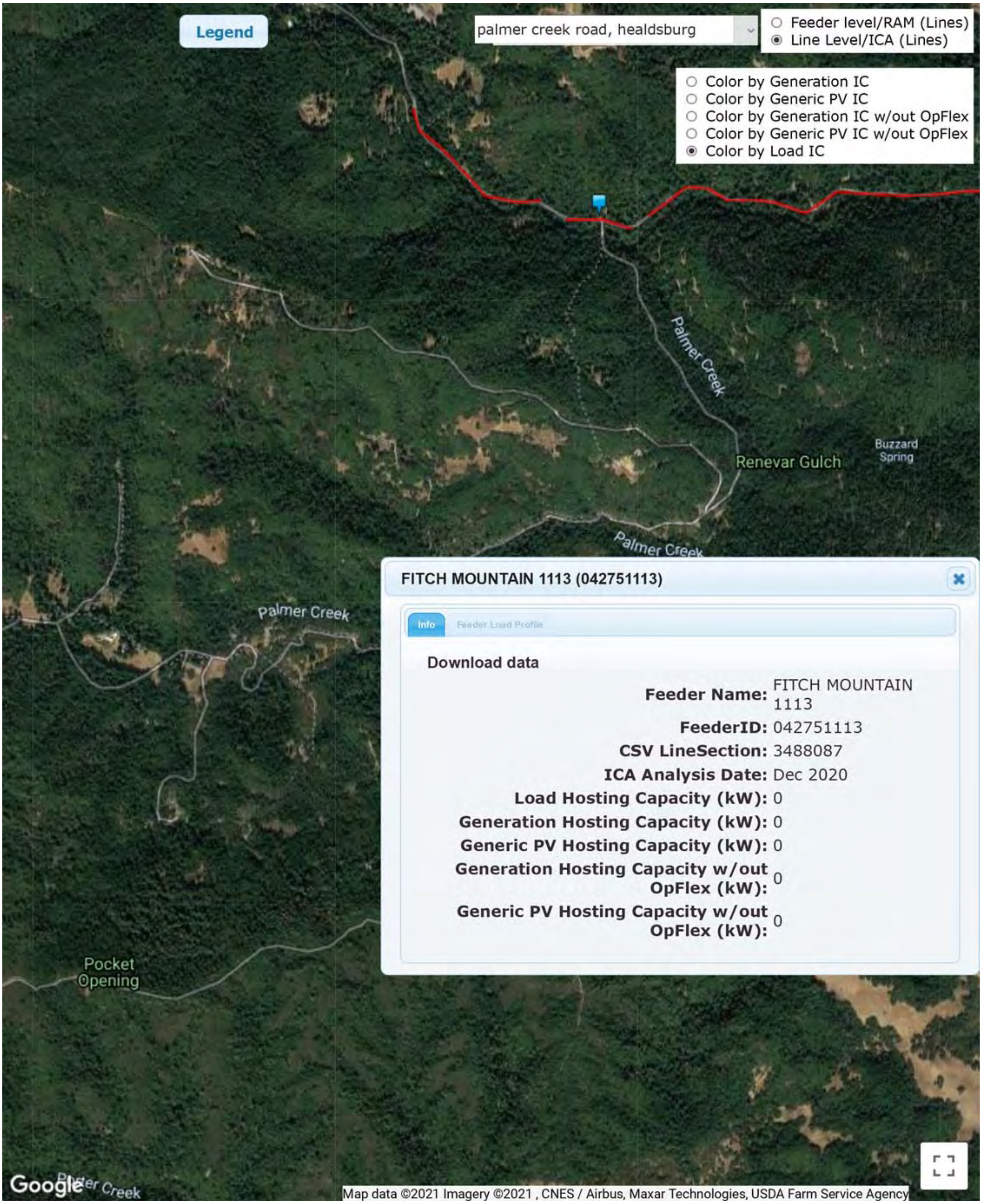
EXHIBIT 58

Integration Capacity Analysis (ICA) Map

User Guide
Download Spatial Data



FITCH MOUNTAIN 1113 (042751113)

Info | Feeder Load Profile

Download data

Feeder Name: FITCH MOUNTAIN 1113
FeederID: 042751113
CSV LineSection: 3488087
ICA Analysis Date: Dec 2020
Load Hosting Capacity (kW): 0
Generation Hosting Capacity (kW): 0
Generic PV Hosting Capacity (kW): 0
Generation Hosting Capacity w/out OpFlex (kW): 0
Generic PV Hosting Capacity w/out OpFlex (kW): 0

EXHIBIT 59

PG&E Integration Capacity Analysis (ICA) Map User Guide

Version 1.5

June 15, 2020

Document Change History

Version	Date	Description of Changes
1.0	03/11/19	• Created document
1.1	05/31/19	• Expanded OpFlex definition and FAQ answer • Expanded Overview description • Added single phase and incomplete solution set description and expanded FAQ answer • Added ICA Analysis Date description • Updated Appendix screenshots
1.2	09/05/19	• Updated Overview disclaimer language • Updated search box functionality description • Added Spatial Data Download instructions • Added API instructions
1.3	10/23/19	• Added Document Change History • Added ungrounded banks description • Expanded Spatial Data Download instructions • Expanded single phase FAQ answer
1.4	12/13/19	• Added table mapping terminology across IOUs and updated terminology where applicable.
1.5	06/15/20	• Added explanation of networked secondary system

Table of Contents

Table of Acronyms

API	Application Programming Interface
DER	Distributed Energy Resource
DG	Distributed Generation
DRP	Distribution Resources Planning
IC	Integration Capacity
ICA	Integration Capacity Analysis
IOU	Investor-Owned Utility
kV	kilovolt
kW	kilowatt
OpFlex	Operational Flexibility: OpFlex limits reverse power flow on certain types of equipment, including reclosers and circuit breakers. When OpFlex is included in the ICA study, reverse flow is prevented, which may result in a lower integration capacity. When OpFlex is not included in the ICA study, reverse flow is allowed, which may result in a higher integration capacity.
PG&E	Pacific Gas and Electric Company
PV	Photovoltaic
SCE	Southern California Edison
SDG&E	San Diego Gas and Electric

Purpose

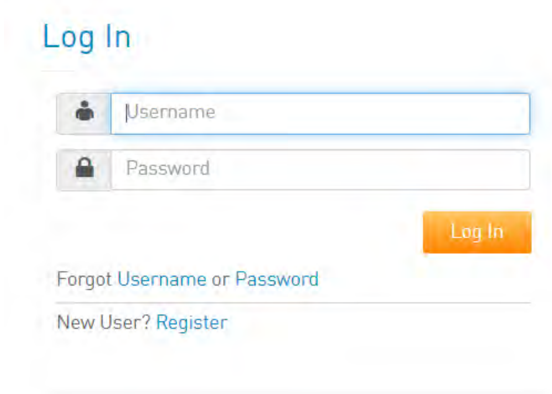
PG&E's Integration Capacity Analysis (ICA) map is designed to help contractors and developers find information on potential project sites for distributed energy resources (DERs). ICA is a complex modeling study that uses detailed information about the electric distribution system, which includes items such as physical infrastructure, load performance, and existing and queued generators. The analysis simulates the ability of individual distribution line sections to accommodate additional DERs without potentially causing issues that would impact customer reliability and power quality. Potential issues could result in distribution line upgrade requirements that would impact cost and/or timeline for DER interconnections[1]

[1] ICA values are updated monthly when significant changes to the feeder occur. ICA values should not be added together across line sections and feeders. ICA values do not account for possible capacity constraints and impacts to the transmission system. ICA values are intended for informational use for interconnection and should not be used to identify opportunities for deferral. ICA values do not guarantee Fast Track approval in the interconnection process and/or do not exempt customers from the interconnection process.

Access

PG&E requires a login to access the map and data. Users may use their pge.com login credentials or create a login directly through the login interface:

1. Go to PG&E's Distribution Resource Planning (DRP) Data Portal web page.
2. Review information, then select "LOG IN TO VIEW THE ICA MAP".
3. Log in:
   a. If using an existing PG&E account, enter Username and Password.
   b. If creating a new account, select "Register" Fill out form completely and Submit. Return to the map page and log in to view the map.



Overview

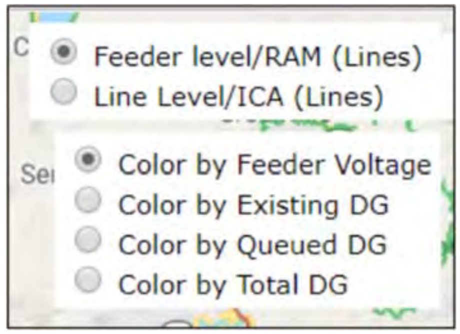
The ICA map uses a Google Maps™ interface and provides similar functionality:

- Type an address, coordinate, substation name, feeder name or number, or line section number in the text box on the top left corner of the map to navigate to a specific location.
- Click the plus or minus sign on the bottom right corner of the map to zoom in or out, respectively. A mouse wheel can also be used for zooming.
- View latitude and longitude on the bottom left corner of the map when hovering over a location.
- Click "Map" or "Satellite" on the top left corner of the map to change map background.

The ICA map provides two types of information: feeder level and line section level. The feeder level displays information for entire feeders including voltage, generation, and customer count to help users understand the grid at a macro level. The line section level displays ICA results for line sections, or segments of a feeder. This information is visualized on the map through several layers that are explained in the following sections. The levels can be accessed by clicking the first set of radio buttons on the top right corner of the map. Alternatively, zooming in automatically switches the map to the line section level, and zooming out switches to the feeder level. The layers can also be accessed using the second set of radio buttons.

Clicking on either a feeder/line section or substation returns a pop-up box with detailed information about the asset and loading information. Downloadable ICA data is also accessible through the line section pop-up. The pop-up boxes and downloadable ICA data are explained in the following sections.

Feeder Level



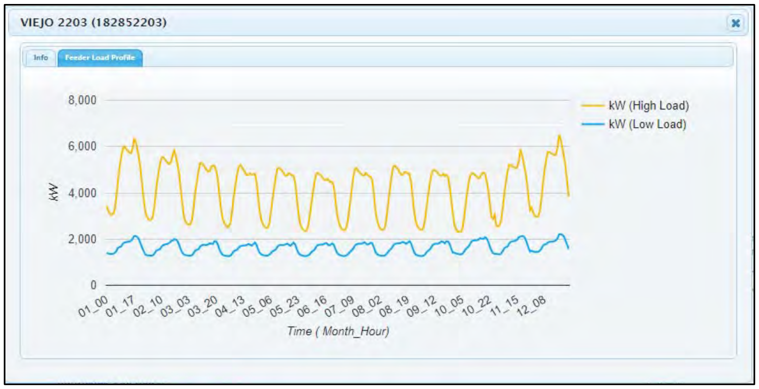
The feeder level provides information for entire feeders. The map legend can be accessed by clicking “Legend” in the top left corner of the map. In the top right corner, “Color by Feeder Voltage” can be selected and uses the “Feeder Detail Voltage” legend. “Color by Existing/Queued/Total DG” use the “Line Detail” legend. The map layers for this level are outlined in the following table. See appendix for graphics of the different views.

Color by Feeder Voltage	Nominal voltage of feeder
Color by Existing DG	Amount of installed generation
Color by Queued DG	Amount of queued generation
Color by Total DG	Total generation (installed and queued)

This information and additional information is available on the “Info” tab of the pop-up that appears when clicking on a feeder:

Substation	Name of substation
Feeder Name	Name of feeder
Feeder ID	ID of feeder
Nominal Voltage	Nominal voltage of feeder
Load Profile Redaction	Indicates whether the feeder load profile was redacted for customer confidentiality
Existing Generation	Amount of installed generation
Queued Generation	Amount of queued generation
Total Generation	Total generation (installed and queued)
Customer Proportions	Proportions of customer counts by customer class: residential, commercial, industrial, agricultural, other

The “Feeder Load Profile” tab shows a summary of the load profile for the feeder. There are two data series: the first (in orange) represents the expected higher loading conditions and the second (in blue) shows the lower loading conditions. There are 288 data points for each series that represent the high and low load values based on a statistical sampling resulting in a 24-hour period for each month (24 x 12 = 288).

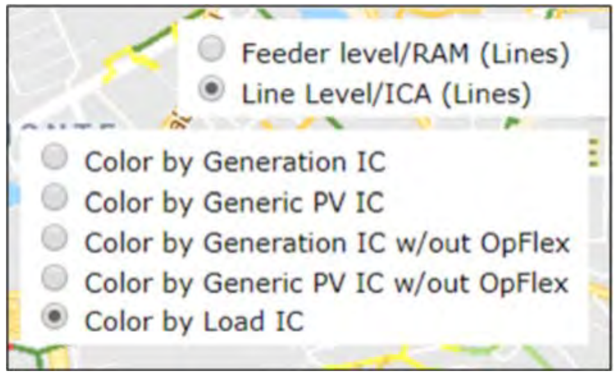


Similarly, substation information and load profile data appear in a pop-up when clicking on a red triangle substation icon:

Substation Name	Name of substation
Substation ID	ID of substation
Nominal Voltage	Nominal voltage of substation
Load Profile Redaction	Indicates whether the substation load profile was redacted due to customer confidentiality concerns
Ungrounded Banks	Bank number for bank(s) on the substation that are ungrounded. Installing downstream of an ungrounded bank may introduce equipment concerns, which could result in an increased cost and timeline to install.

ICA Level

The line level provides ICA results for single line sections. The map legend can be accessed by clicking “Legend” in the top left corner of the map. Line sections that have associated ICA values are defined in the “Line Detail” section. Line sections that do not have associated ICA values are defined in the “ICA Not Available” section. This includes all single-phase and networked secondary system lines, on which ICA is not performed, and three-phase lines that have an incomplete ICA solution set. The map layers for this level are outlined in the following table. See appendix for graphics of the different views.

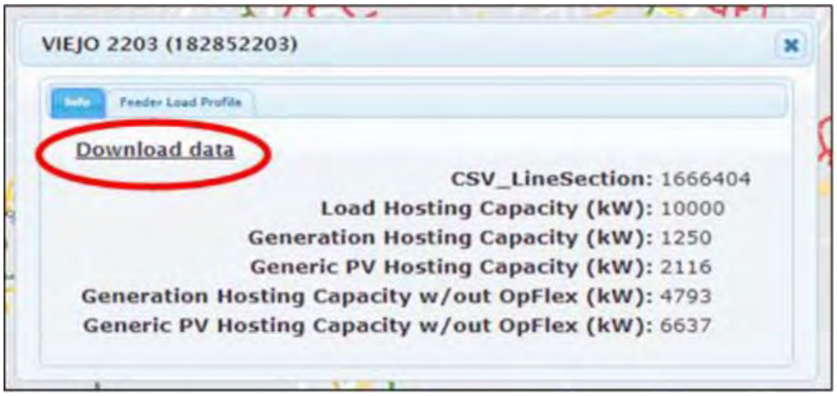


Color by Generation IC	Amount of **generation (fixed output)** that can be installed at that location without any thermal, voltage, distribution protection, <u>or operational flexibility violations</u> at the time the integration capacity analysis was performed.
Color by Generic PV IC	Amount of **PV generation** that can be installed at that location without any thermal, voltage, distribution protection, <u>or operational flexibility violations</u> at the time the integration capacity analysis was performed.
Color by Generation IC w/out OpFlex	Amount of **generation (fixed output)** that can be installed at that location without any thermal, voltage, or distribution protection violations <u>(NOT considering operational flexibility)</u> at the time the integration capacity analysis was performed.
Color by Generic PV IC w/out OpFlex	Amount of **PV generation** that can be installed at that location without any thermal, voltage, or distribution protection violations <u>(NOT considering operational flexibility)</u> at the time the integration capacity analysis was performed.
Color by Load IC	Amount of **load** that can be installed at that location without any thermal or voltage violations at the time the integration capacity analysis was performed.

This information is also available on the “Info” tab of the pop-up that appears when clicking on a line section as well as “ICA Analysis Date,” which marks when the ICA was performed for the line section. Additionally, this tab provides a link to “Download data”. This data is explained in the following section. The “Feeder Load Profile” tab shows a summary of the load profile for the feeder.

ICA Data Download

ICA map data shows a simplified version of ICA results for easier consumption and use. Detailed hourly integration capacity information is available to download from the line section pop-up on the ICA level (as explained in the previous section) for line sections with a complete solution set. This returns a CSV file with ICA results for every line section on the selected feeder, which can be filtered to the desired line section's results.



The following is the information provided within the downloadable file:

Line Section ID	ID of line section where the integration capacity analysis is conducted
Load or Generation	Indicates the ICA values are for generation or load resources
Month-Hour	Specifies the month and hour of load conditions that was used in calculating the ICA values
IC Thermal	Amount of generation that can be installed without causing thermal violations at the time the integration capacity analysis was performed
IC Voltage	Amount of generation that can be installed without causing voltage violations at the time the integration capacity analysis was performed
IC Protection	Amount of generation that can be installed without causing protection violations at the time the integration capacity analysis was performed
IC Safety	Amount of generation that can be installed without causing reverse power flow at SCADA devices at the time the integration capacity analysis was performed

Spatial Data Download

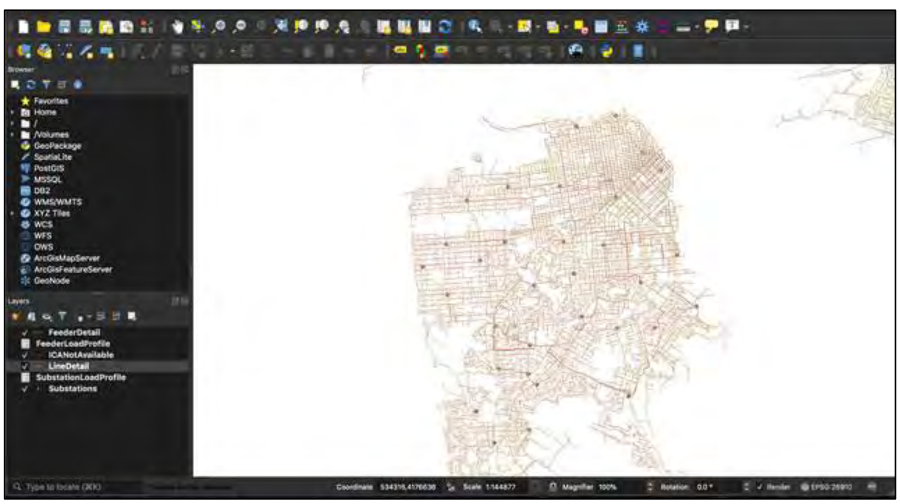
The spatial data shown on the map is available to download via a zipped Esri file geodatabase. GIS software such as QGIS or ArcMap should be able to utilize the file.

The geodatabase contains featureClasses (shapes) for substations, feeder level results, and ICA (line) level results. Standalone tables with the Substation and Feeder Load Profile information are also included.

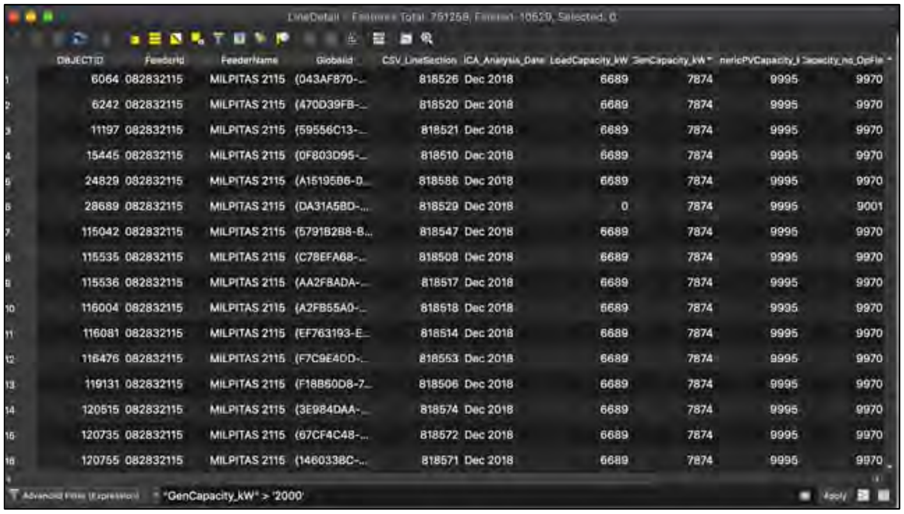
Name	Type
FeederDetail	File Geodatabase Feature Class
ICANotAvailable	File Geodatabase Feature Class
LineDetail	File Geodatabase Feature Class
Substations	File Geodatabase Feature Class
FeederLoadProfile	File Geodatabase Table
SubstationLoadProfile	File Geodatabase Table

How to Access the Spatial Data Attributes Table

1. Click on the “Download Spatial Data” link in the top right corner of the map to download the most recent ICA data (zipped file geodatabase (GDB) file – updated monthly)
2. Download and install a GIS software such as QGIS
3. Open GIS software
4. Drag and drop the GDB file into the GIS software window to open the file
5. Select the check boxes of the layers you want to display in the Layers box in the bottom left corner of the window
6. Select the Line Detail layer of the box to highlight



7. Select Layer > Open Attributes Table (or press F6)



	OBJECTID	FeederId	FeederName	GlobalId	CSV_LineSection	ICA_Analysis_Date	LoadCapacity_kW	GenCapacity_kW	nericPVCapacity_l	Capacity_no_OpFle
1	6064	082832115	MILPITAS 2115	{043AF870-...	818526	Dec 2018	6689	7874	9995	9970
2	6242	082832115	MILPITAS 2115	{470D39FB-...	818520	Dec 2018	6689	7874	9995	9970
3	11197	082832115	MILPITAS 2115	{59556C13-...	818521	Dec 2018	6689	7874	9995	9970
4	15445	082832115	MILPITAS 2115	{0F803D95-...	818510	Dec 2018	6689	7874	9995	9970
5	24829	082832115	MILPITAS 2115	{A15195B6-D...	818586	Dec 2018	6689	7874	9995	9970
6	28689	082832115	MILPITAS 2115	{DA31A5BD-...	818529	Dec 2018	0	7874	9995	9001
7	115042	082832115	MILPITAS 2115	{57918288-B...	818547	Dec 2018	6689	7874	9995	9970
8	115535	082832115	MILPITAS 2115	{C78EFA68-...	818508	Dec 2018	6689	7874	9995	9970
9	115536	082832115	MILPITAS 2115	{AA2F8ADA-...	818517	Dec 2018	6689	7874	9995	9970
10	116004	082832115	MILPITAS 2115	{A2FB55A0-...	818518	Dec 2018	6689	7874	9995	9970
11	116081	082832115	MILPITAS 2115	{EF763193-E...	818514	Dec 2018	6689	7874	9995	9970
12	116476	082832115	MILPITAS 2115	{F7C9E4DD-...	818553	Dec 2018	6689	7874	9995	9970
13	119131	082832115	MILPITAS 2115	{F18B60D8-7...	818506	Dec 2018	6689	7874	9995	9970
14	120515	082832115	MILPITAS 2115	{3E984DAA-...	818574	Dec 2018	6689	7874	9995	9970
15	120735	082832115	MILPITAS 2115	{67CF4C48-...	818572	Dec 2018	6689	7874	9995	9970
16	120755	082832115	MILPITAS 2115	{1460338C-...	818571	Dec 2018	6689	7874	9995	9970

a. Select what items are shown in the table using the drop down in the bottom left corner of the pop-up box
   i. Select "Field Filter" to filter by a single attribute OR
   ii. Select "Select/filter features using form" icon (or Ctrl+F) to view the full search form
   iii. Select "Select features using an expression" icon for more advanced functionality
b. Sort columns by clicking on the header
c. Select "Copy selected row to clipboard" icon (or Ctrl+C) and paste into Excel file to export data
d. Select "Pan/zoom map to the selected row" icon (or Ctrl+P/J) to update the map view with the selected data
e. Switch between table and form view using the icons on the bottom right corner of the pop-up box

Application Programming Interface (API)

All data on the ICA map is available via the ArcGIS REST API. The documentation is accessible via the PG&E portal (authentication required).

In a REST API, everything is a URL. For the ICA map, the REST endpoint to the map service is https://myportal.pge.com/arcgis/rest/services/ICADisplay/MapServer. A listing of the layers and the tables that are exposed by the map service are available here. Note that the substation layer (LayerID 0), five ICA level layers (LayerIds 1-5), and the four feeder level layers (LayerIds 6-9) each point to the same pair of base tables.

Layers:

- Substations (0)
- LineDetail (1)
- Line Detail Generic PV Hosting Capacity (2)
- Line Detail Generation Without OptFlex (3)
- Line Detail Generic PV Hosting Capacity w/out OpFlex (MW) (4)
- Line Detail Load Hosting Capacity (5)
- Feeder Detail Voltage (6)
- FeederDetail (7)
- Feeder Detail Queued DG (MW) (8)
- Feeder Detail Total DG (MW) (9)
- ICANotAvailable (10)

Tables:

- FeederLoadProfile (11)
- SubstationLoadProfile (12)

The ICA map uses a subset of what is available in the API. The map allows users to pan or zoom to view an area of interest (controlled by Google), enter an address or coordinate pair in the form at the top of the map (also controlled by Google), toggle the map layers to display either ICA Level or Feeder Level information (standard HTML and JavaScript plus a combination of Google and Esri APIs), and click on the map to reveal information about the data displayed on the map.

Frequently Asked Questions

ICA Questions

1. What is operational flexibility?

Operational flexibility limits reverse power flow on certain types of equipment, including reclosers and circuit breakers. When OpFlex is included in the ICA study, reverse flow is prevented, which may result in a lower integration capacity. When OpFlex is not included in the ICA study, reverse flow is allowed, which may result in a higher integration capacity.

2. What's the difference between the ICA values on the map and in the downloadable ICA file?

For each line section, ICA outputs 1152 values: 12 months * 24 hours * 2 load curves (high and low) * 2 installation types (load and generation) and 4 ICA categories: thermal, voltage, protection, and safety.

Downloadable ICA File: Through post-processing, the number of values is reduced to 576 values by selecting the minimum values between the high load and low load cases. These are the values shown in the downloadable ICA data.

Map Values: The data is further distilled for display on the map. For Generation IC and Generic PV IC, the minimum value out of thermal, voltage, protection, and safety is used. For Generation IC w/o OpFlex and Generic PV IC w/o OpFlex, the minimum value of thermal, voltage, and protection is used. A typical PV profile is used to create the PV values. For Load IC, the minimum value out of thermal and voltage is used. This is summarized in the table below. To get the ICA map layer (rows), take the minimum of the ICA download values (columns) marked with an X.

	IC Thermal	IC Voltage	IC Protection	IC Safety	PV Profile
Color by Generation IC	X	X	X	X	
Color by Generic PV IC	X	X	X	X	X
Color by Generation IC w/out OpFlex	X	X	X		
Color by Generic PV IC w/out OpFlex	X	X	X		X
Color by Load IC	X	X			

3. What does it mean when a location has less capacity than a proposed DER project?

As explained in the question above, the ICA value used for the map display is the minimum of the ICA results for that line section. Red on the map (i.e. an ICA output of zero) does not necessarily mean that there isn't integration capacity at that location – it means an engineer needs to review.

For example, a line section shows an ICA output of zero on the map. In looking at the downloadable ICA data, voltage is found to be the limiting factor. In going through the installation process, the engineer updates equipment settings to eliminate the voltage issue and allow for installation.

4. Why is the safety column in the downloadable ICA data sometimes redacted?

PG&E uses the 15-100-15 rule to protect customer load information and will redact load data if it contains fewer than 15 non-residential customers, fewer than 100 residential customers, or a single customer makes up more than 15% of the load. As defined today, IC Safety is equivalent to load data and will be redacted if it fails the 15-100-15 rule.

Map Questions

5. Why did the colors change when I zoomed in and out? Why can't I zoom out more on the ICA layer?

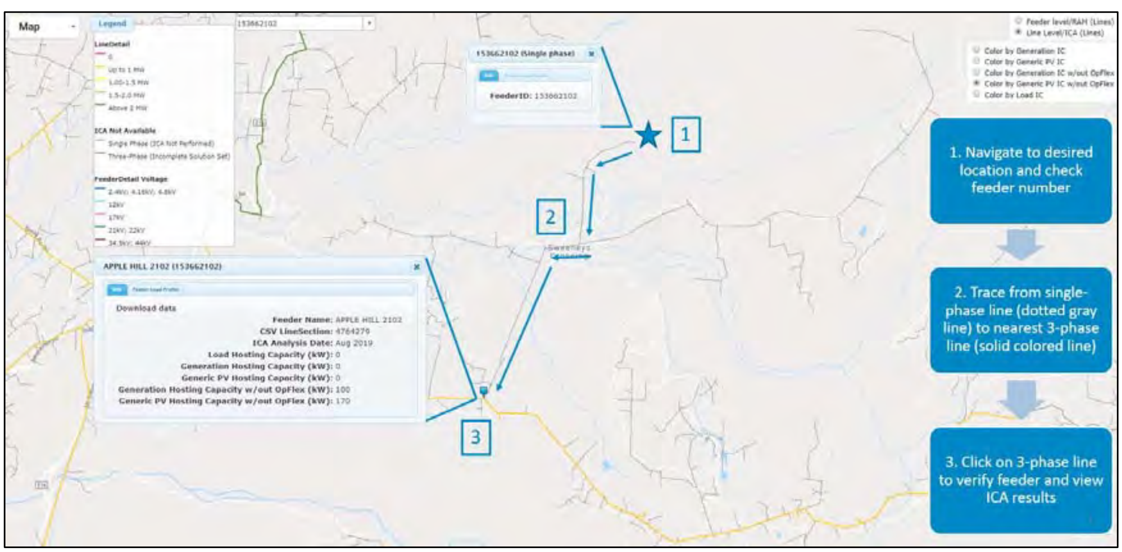
The ICA map automatically switches between the feeder level and ICA level when zooming in or out. The zoom also automatically switches when clicking the radio buttons between feeder and ICA levels. This is due to the data provided at each level: the feeder level is at a more zoomed out level to display a larger geographic area for an entire feeder and the ICA level is at a more zoomed in level to provide better navigation capabilities and decrease loading time with the more granular line section level ICA data.

6. Where are the single-phase lines?

ICA values are not calculated for single-phase lines; however, single-phase lines are mapped on both the feeder level view and the line level view. On the feeder level view, single-phase and three-phase lines are not differentiated. On the line level view, single-phase lines are shown as dotted gray lines.

7. How can I tell where a single-phase line connects to a three-phase line?

A single-phase line can be traced to the nearest three-phase line. The pop-up box for the single-phase line lists the associated Feeder ID, which can be matched with the Feeder ID in the three-phase line's pop-up box. See graphic below for visual instructions.



8. Why do I not see ICA values on the networked secondary system?

ICA values are not calculated for the secondary network system; however, these lines are mapped on both the feeder level view and the line level view. On the feeder level view, they are not differentiated. On the line level view, they are shown as solid purple lines.

9. Why are some feeder and substation load profiles redacted?

PG&E uses the 15-100-15 rule to protect customer load information: if a feeder has fewer than 15 non-residential customers, fewer than 100 residential customers, or a single customer makes up more than 15% of the load, the load data must be redacted.

Please direct questions not answered by this guide to DRPdata@pge.com

Appendix

Terminology Mapping Between IOUs

The terminology and general definitions provided below are for context and terminology mapping between each IOU’s ICA map. See respective user guides for utility-specific definitions.

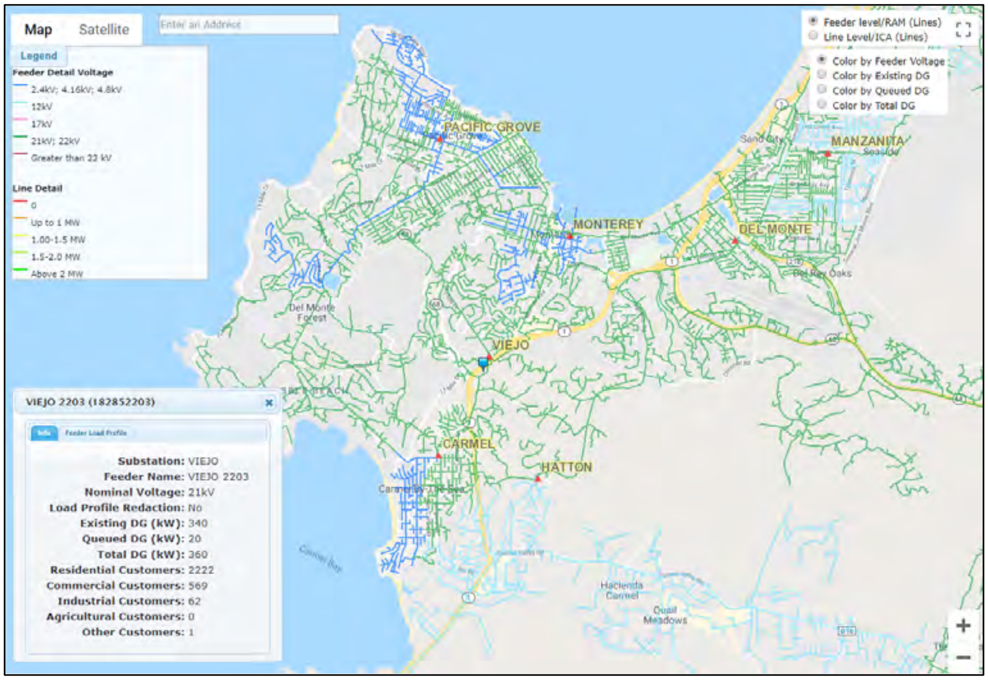
SCE	PG&E	SDG&E	Definition
Substation Name	Substation Name / ID	Substation Name	Unique ID of substation
Circuit Name	Feeder Name / ID	Feeder ID	Unique ID of circuit / feeder
Node ID / Line Section ID	Node ID / CSV Line Section	Node ID / Line Segment Number	Unique ID where the integration capacity analysis is conducted
Circuit Voltage (kV)	Nominal Voltage (kV)	Voltage (kV)	Nominal voltage of feeder or substation
Existing / Queued / Total Generation (MW)	Existing / Queued / Total DG (kW)	Existing / Queued / Total Generation (MW)	Amount of installed / queued / total (installed and queued) generation, respectively
Residential, Commercial, Industrial, Agricultural, Other (%)	Residential, Commercial, Industrial, Agricultural, Other (Count)	Residential, Commercial, Industrial, Agricultural (%)	Customer class designation
Month	Month	Month	Month used in calculating the ICA value
Hour	Hour	Hour of Day	Hour used in calculating the ICA value
Load Profile Type	Load Profile	Day Type	Typical minimum and maximum load profile / day type
Uniform Generation Op Flex	Generation IC	ICA Uniform Gen	Amount of **generation (fixed output)** that can be installed at that location without any thermal, voltage, distribution protection, or operational flexibility

			violations at the time the integration capacity analysis was performed
Uniform Generation	Generation IC w/out Op Flex	ICA Uniform Gen NOF	Amount of **generation (fixed output)** that can be installed at that location without any thermal, voltage, or distribution protection violations (NOT considering operational flexibility) at the time the integration capacity analysis was performed
Solar PV Op Flex	Generic PV IC	Solar PV	Amount of **PV generation** that can be installed at that location without any thermal, voltage, distribution protection, or operational flexibility violations at the time the integration capacity analysis was performed
Solar PV	Generic PV IC w/out Op Flex	Solar PV NOF	Amount of **PV generation** that can be installed at that location without any thermal, voltage, or distribution protection violations (NOT considering operational flexibility) at the time the integration capacity analysis was performed
Thermal	IC Thermal	ICA Thermal	Amount of generation that can be installed without causing thermal violations at the time the integration capacity analysis was performed
SSV	IC Voltage	ICA Voltage	Amount of generation that can be installed without causing steady state voltage violations at the time the integration capacity analysis was performed
Voltage Fluctuation		ICA Voltage Delta	Amount of generation that can be installed without causing voltage variation violation at the time the integration capacity analysis was performed
Protection	IC Protection	ICA Protection; ICA Reduction	Amount of generation that can be installed without causing protection violations at the time the integration capacity analysis was performed
ICA Operational Flexibility	IC Safety	ICA Operation Flex	Amount of generation that can be installed without causing reverse power flow at SCADA devices at the time the integration capacity analysis was performed
Uniform Load	Load IC	Load Uniform	Amount of load that can be installed at that location without any thermal or voltage violations at the time the integration capacity analysis was performed

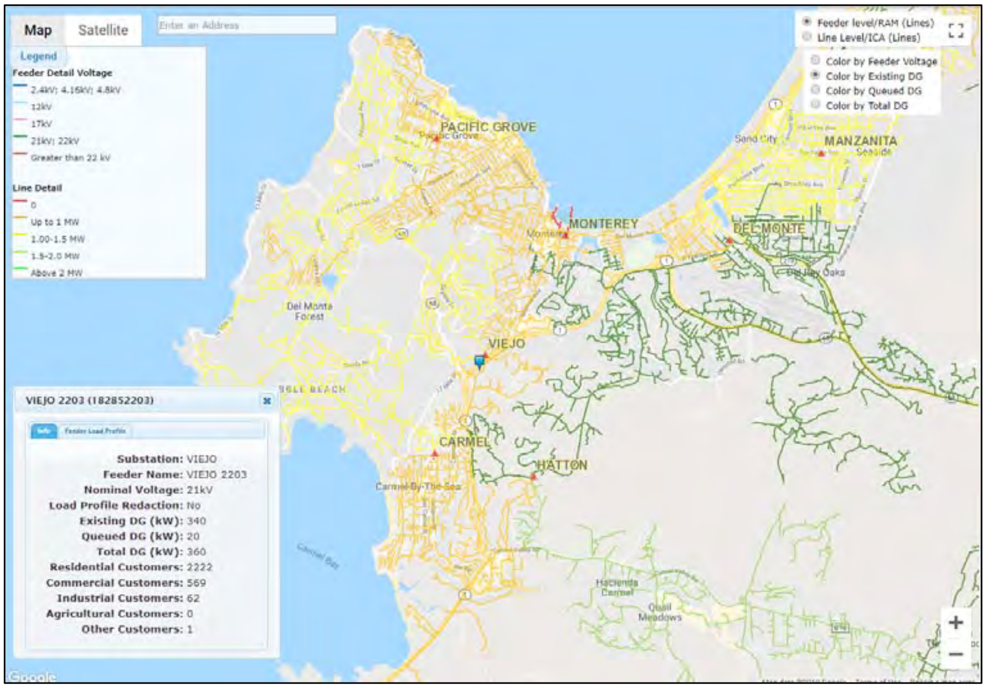
Thermal Load	IC Thermal	Load Thermal	Amount of load that can be installed without causing thermal violations at the time the integration capacity analysis was performed
Volt Variation Load	IC Voltage	Load Voltage	Amount of load that can be installed without causing steady state voltage violations at the time the integration capacity analysis was performed
SSV Load			Amount of load that can be installed without causing voltage variation violation at the time the integration capacity analysis was performed

Screenshots

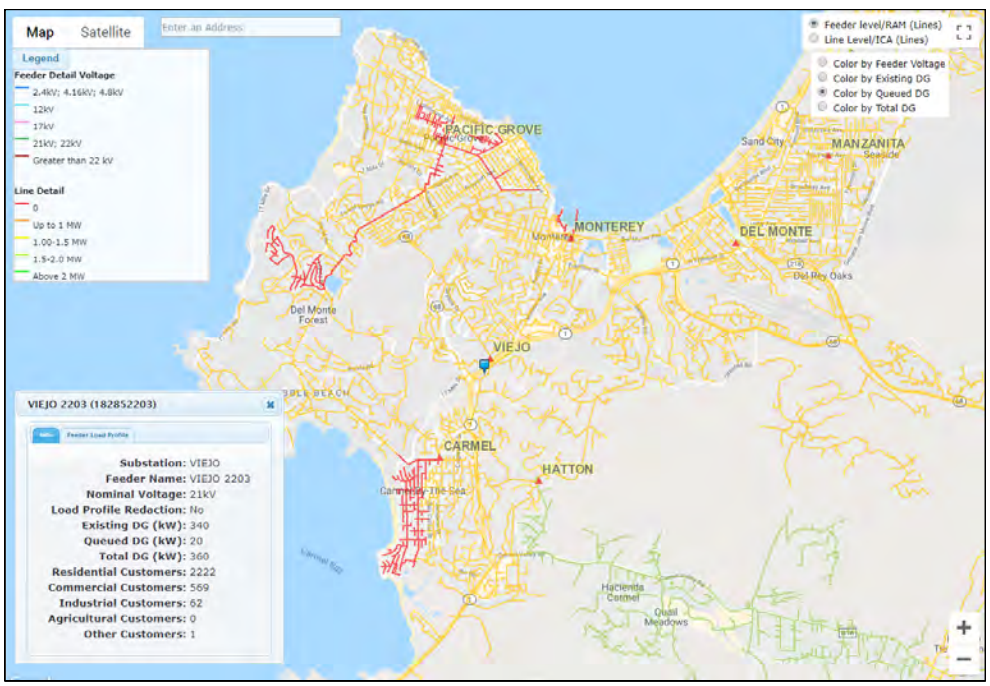
Color by Feeder Voltage



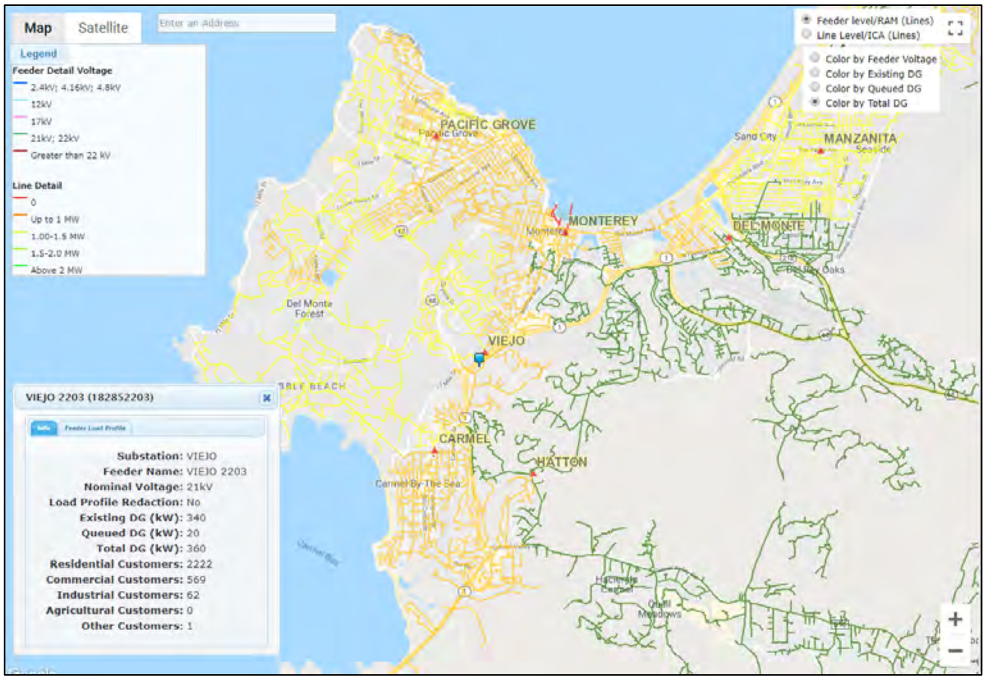
Color by Existing DG



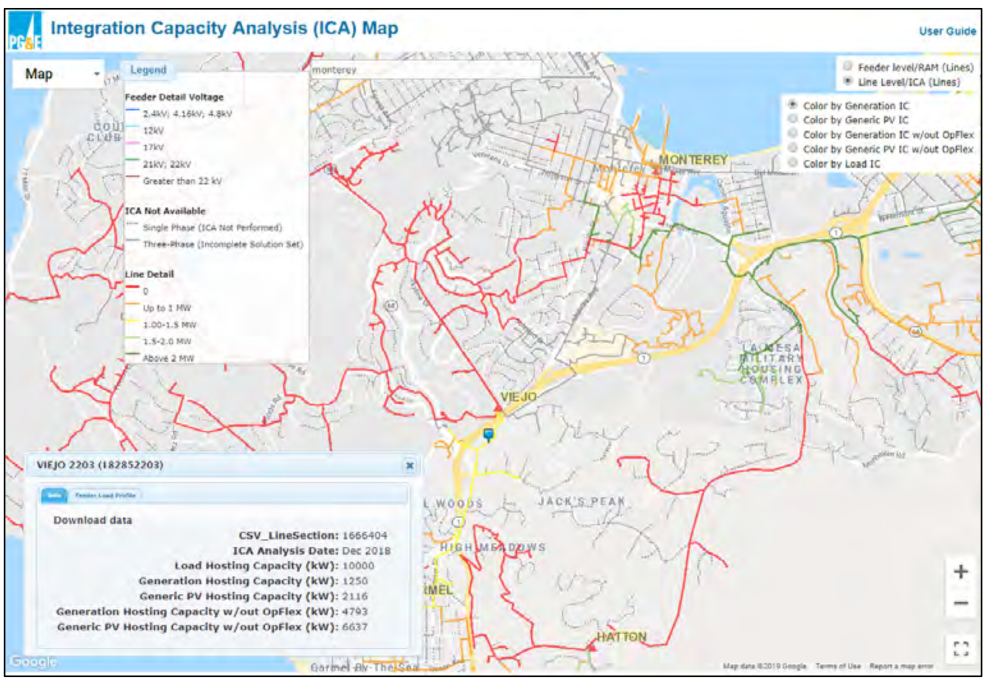
Color by Queued DG



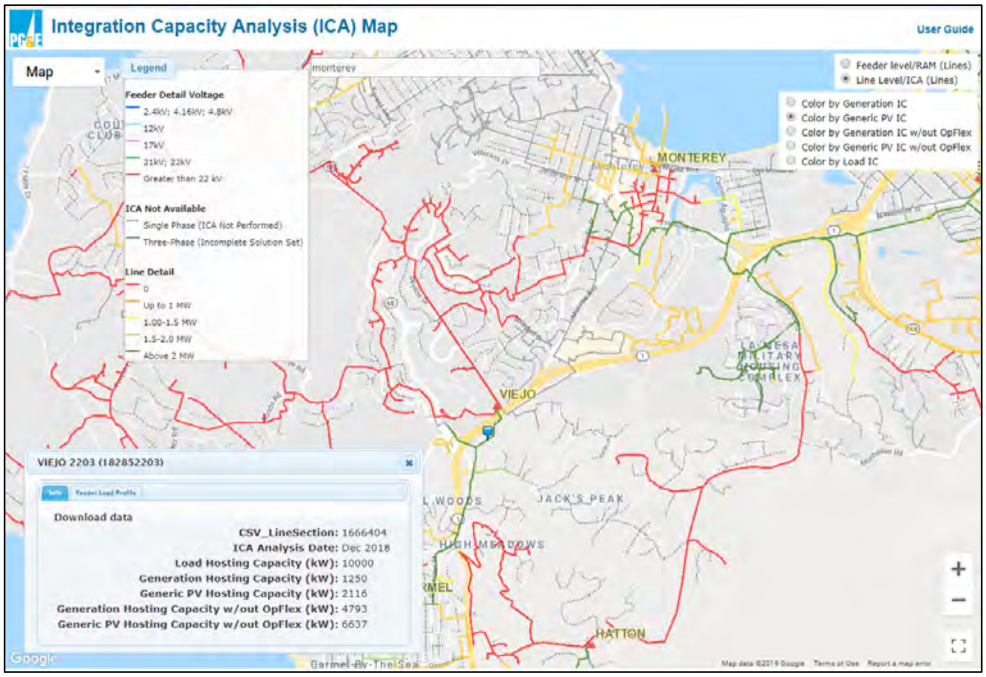
Color by Total DG



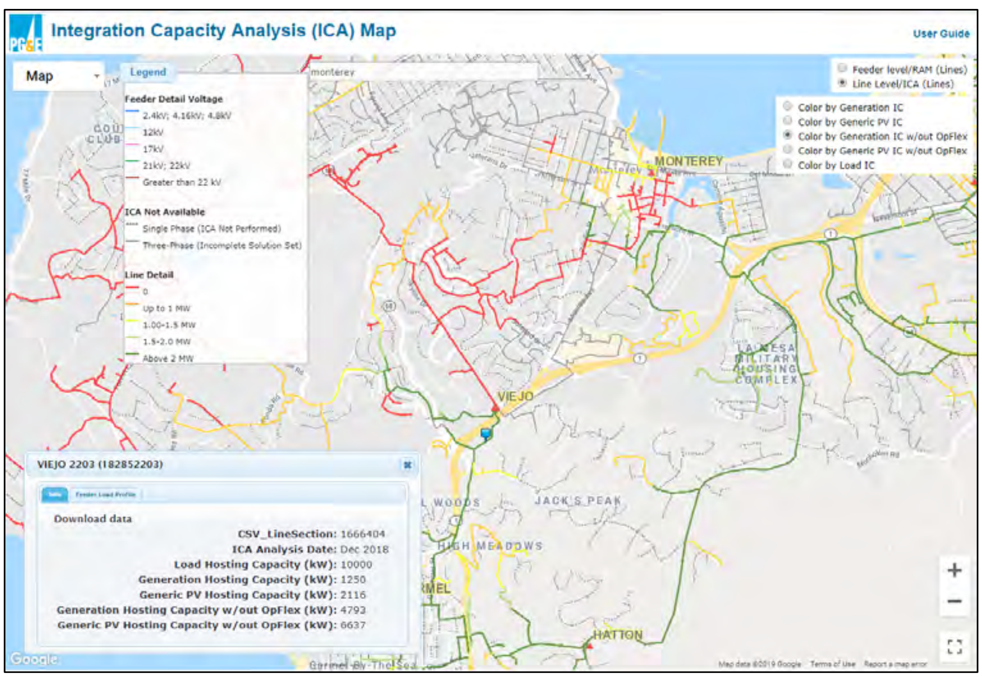
Color by Generation IC



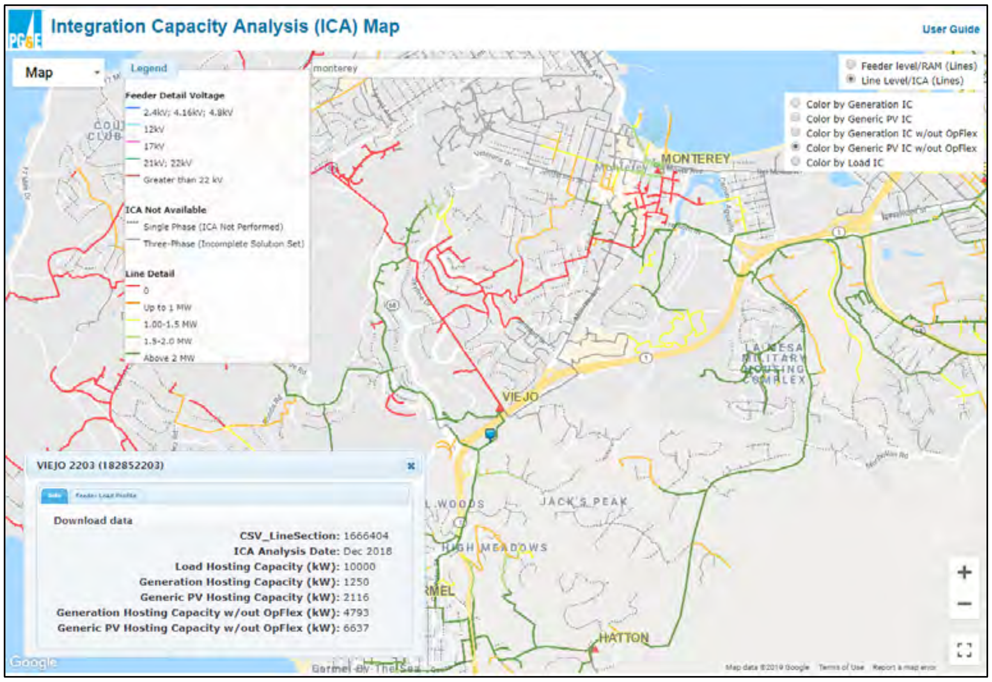
Color by Generic PV IC



Color by Generation IC w/o OpFlex



Color by Generic PV IC w/o OpFlex



Color by Load IC

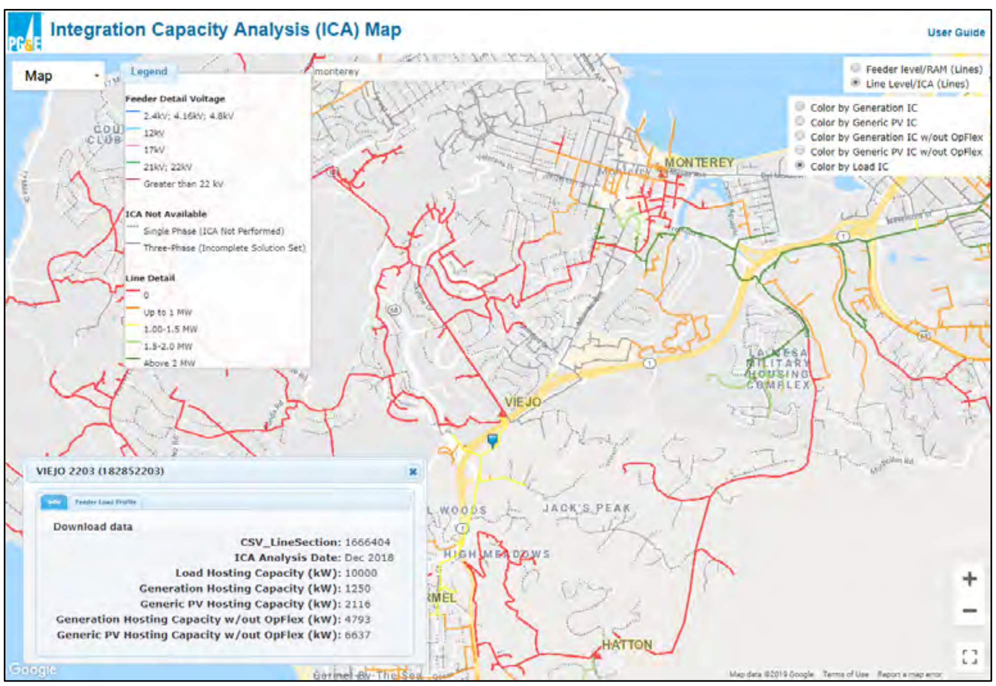


EXHIBIT 60

ORDINANCE NO. _____

An Ordinance Of The Board Of Supervisors Of The County Of Sonoma, State Of California, Adopting a Negative Declaration and Amending Text Of Chapter 26 (Zoning Ordinance) Of The Sonoma County Code To Allow Personal Cultivation of Cannabis and Permit Cultivation of Commercial Medical Cannabis and Support Land Uses in Various Zoning Districts, Adopting New Definitions and Establishing Special Use Regulations.

The Board of Supervisors of the County of Sonoma, State of California, ordains as follows:

SECTION I. Findings. The Board finds and declares the following:

A. The adoption of this Ordinance is necessary and desirable to protect the public health, safety and environmental resources, ensure safe access to medical cannabis for patients, provide a regulatory path to permit an existing underground industry, foster a healthy, diverse and economically viable medical cannabis industry that contributes to the local economy, provide opportunity to help stabilize farm incomes, enhance enforcement methods for unpermitted and trespass cannabis cultivation, and ensure that environmental, public health, safety and nuisance factors related to the cannabis industry are adequately addressed.

B. The Federal Controlled Substances Act, 21 U.S.C. §§ 801 et seq., classifies cannabis as a Schedule I Drug; as such, it is unlawful, under federal law, for any person to cultivate, manufacture, distribute or dispense, or possess with intent to manufacture, distribute or dispense, marijuana. There is no federal exemption for the cultivation, manufacture, distribution, dispensation, or possession of cannabis for medical purposes.

C. In 1996, the voters of the State of California approved Proposition 215, "The Compassionate Use Act" (codified as Health and Safety Code Section 11362.5), which was intended to decriminalize cultivation and possession of medical marijuana by a seriously ill patient, or the patient's primary caregiver, for the patient's personal use, and to create a limited defense to the crimes of possessing or cultivating cannabis. The Compassionate Use Act further provided that nothing in it shall be construed to supersede legislation prohibiting persons from engaging in conduct that endangers others, or to condone the diversion of cannabis for non-medical purposes.

D. The State enacted SB 420 in 2004 (known as the "Medical Marijuana Program Act", codified as Health and Safety Code Section 11362.7 et seq.) to expand and clarify the scope of The Compassionate Use Act of 1996 by creating the Medical Marijuana Identification Card program, creating reasonable regulations for cultivating, processing, transporting and administering medical cannabis, as well as limiting the amount of medical cannabis a qualified individual may possess.

E. The Medical Marijuana Program Act defines a "primary caregiver" as an individual who is designated by a qualified patient or by a person with an identification card, and who has consistently assumed responsibility for the housing, health, or safety of that patient or person and is further defined in the California Supreme Court decision *People v. Mentch* (2008) 45 Cal.4th 274.

F. The Sonoma County Board of Supervisors adopted Medical Marijuana Possession and Cultivation Guidelines on September 26, 2006 by Resolution 06-0846. The Guidelines provide a limited defense to prosecution or other sanction by the County of Sonoma which is only available to someone who possesses or cultivates marijuana for personal medical use. These Guidelines are not zoning code regulations, and they do not allow and do not regulate any manner of cultivation, growing, or delivery of marijuana.

G. The State enacted the Medical Marijuana Regulation and Safety Act (MMRSA) on September 11, 2015 (SB 643, AB 266, and AB 243), instituting a comprehensive state-level licensure and regulatory scheme for cultivation, manufacturing, distribution, transportation, laboratory testing, and dispensing of medical cannabis through numerous changes and additions to the Business & Professions Code and the Health and Safety Code. MMRSA legalizes and regulates for-profit commercial activity related to medical marijuana in California. MMRSA provides that cities and counties retain local regulatory authority over medical cannabis.

H. On June 27, 2016 the Governor signed SB 837, changing the term "marijuana" to "cannabis" and renaming the Medical Cannabis Regulation and Safety Act (Cannabis Act).

I. The Cannabis Act and the proposed zoning ordinance both distinguish cannabis from other types of agriculture. This is due to the federal classification as a Schedule I drug, the security concerns associated with a high value crop, and the unique characteristics of the cannabis cultivation operations. Cannabis cultivation operations are not protected under the Right to Farm Ordinance which is intended to protect agricultural operations from being considered a nuisance. The siting and operational standards within this Ordinance are not intended to apply to agricultural enterprises already in existence within Sonoma County.

J. The State's adoption of a comprehensive statewide licensing and enforcement scheme for medical cannabis operations will facilitate local jurisdictions to regulate medical cannabis at the local level, and permit fees will help pay for additional enforcement staff.

K. Although Sonoma County's zoning ordinance does not permit cannabis cultivation or other medical cannabis activities besides dispensaries within the unincorporated area of the County, there are an estimated several thousand unregulated cannabis cultivation sites within the County that are unlawful under the permissive zoning of the County Code. The County has long had insufficient resources to bring code enforcement or nuisance actions against the vast majority of these cultivation sites.

L. On February 2, 2016, the Board of Supervisors, at an open public meeting, directed staff to bring forward a zoning ordinance allowing but regulating cannabis cultivation and related commercial support uses within the jurisdictional boundaries of Sonoma County.

M. On November 8, 2016 the voters of California adopted Proposition 64 which legalized the use of cannabis for adult use and established a maximum cultivation allowance of 6 plants for personal use. The Proposition allows for local control of adult use cannabis land uses, and reasonable regulation of personal cultivation of up to 6 plants per residence.

N. Children (minors under the age of 18) are particularly vulnerable to the effects of cannabis use, and the presence of cannabis plants or products is an attractive nuisance for children, creating an unreasonable hazard in areas frequented by children (including schools, parks, and other similar locations).

O. The unregulated cultivation of cannabis in the unincorporated area of Sonoma County can adversely affect the health, safety, and well-being of the County, its residents and environment. Comprehensive civil regulation of premises used for cannabis cultivation, including zoning regulation, is proper and necessary to reduce the risks of criminal activity, degradation of the natural environment, malodorous smells, and indoor electrical fire hazards that may result from unregulated cannabis cultivation.

P. Comprehensive regulation of premises used for cannabis cultivation or commercial activities related to cannabis is proper and necessary to address the risks and adverse impacts as stated herein.

Q. Outdoor cannabis cultivation, especially within the remote hillside areas, is creating devastating impacts to California's surface and groundwater resources. The State Water Resources Control Board, the North Coast Regional Water Quality Control Board, the Central Valley Regional Water Quality Control Board and the Department of Fish and Wildlife have seen a dramatic increase in the number of cannabis cultivation operations, and corresponding increases in impacts to water supply and water quality, including the discharges into water of sediments, pesticides, fertilizers, petroleum hydrocarbons, trash and human waste. These impacts result from unpermitted and unregulated timber clearing, road development, stream diversion for irrigation, land grading, erosion of disturbed surfaces and stream banks, and temporary human occupancy without proper sanitary facilities.

R. The defense to prosecution provided to qualified patients and their primary caregivers under the Compassionate Use Act and the Board's prior Resolution to cultivate cannabis plants for medical purposes does not confer the right to establish a land use not expressly allowed in zoning or to create or maintain a public nuisance. By adopting the regulations contained in this Ordinance in coordination with the Cannabis Act, the County intends to minimize the risks and complaints regarding fire, odor, crime and pollution caused or threatened by the unregulated cultivation of cannabis in the unincorporated area of Sonoma County.

S. Nothing in this Ordinance shall be construed to allow the use of cannabis or allow any activity relating to the cultivation or consumption of cannabis that is otherwise not expressly allowed in the Sonoma County Code or is illegal under

State law.

T. This ordinance is intended to be Phase I of this policy effort to provide an initial opportunity to legalize existing unpermitted medical cannabis operations, where appropriate and steer the industry to appropriate locations. The Board may consider expanded opportunities for additional commercial cannabis operations in Phase II.

U. This ordinance is consistent with the overall goals, objectives, policies and programs of the General Plan to promote a healthy and competitive agricultural, stabilize farm incomes and provide opportunities for diversification of agricultural products; protect Important Farmlands; preserve biotic resources; promote energy conservation and use of renewable energy; minimize discharge of sediment, waste and other pollutants into the drainage systems; protect groundwater resources; encourage graywater systems and use of recycled water.

V. An Initial Study and Negative Declaration were prepared and circulated to the public for a 30-day period from September 30 to October 31, 2016. The Negative Declaration has been reviewed and considered, together with comments received during the public review process, in accordance with the California Environmental Quality Act (CEQA) and County CEQA Guidelines. The Board finds on the basis of the whole record before it that the Negative Declaration reflects the independent judgment and analysis of the Board and that there is no substantial evidence that the project will have a significant effect on the environment. The Director of Permit and Resource Management Department is directed to file a Notice of Determination in accordance with CEQA.

W. The Sonoma County Airport Land Use Commission reviewed the proposed Ordinance at its meeting on December 5, 2016 and adopted Resolution 16-01 finding the Medical Cannabis Land Use Ordinance consistent with the Sonoma County Comprehensive Airport Land Use Plan.

SECTION II. Chapter 26 of the Sonoma County Code is amended as follows:

A. Amendments to Definitions. Section 26-02-140 (Definitions) of Chapter 26 of the Sonoma County Code (Zoning Ordinance) is amended to replace and add the following definitions as shown in Exhibit A-1 attached hereto.

B. **Amendments to Zoning Districts for Commercial Medical Cannabis Uses**. The following Subsections of Chapter 26 of the Sonoma County Code are added for Permitted Uses:

Section 26-04-010 (o) – LIA Land Intensive Agriculture District
Section 26-06-010 (s) – LEA Land Extensive Agriculture District
Section 26-08-010 (r) – DA Diverse Agriculture District
Section 26-10-010 (ll) – RRD Rural and Resource Development District
Section 26-44-020 (u) – MP Industrial Park
Section 26-46-020 (t) – M1 Limited Urban Industrial
Section 26-48-020 (y) – M2 Heavy Industrial
Section 26-50-020 (r) – M3 Limited Rural Industrial

to read as follows:

"Commercial cannabis medical uses in compliance with Section 26-88-250 through 256"

C. The following Subsections of Chapter 26 of the Sonoma County Code are added for Uses Permitted with a Use Permit:

Section 26-04-020 (r) – LIA Land Intensive Agriculture
Section 26-06-020 (t) – LEA Land Extensive Agriculture
Section 26-08-020 (t) – DA Diverse Agriculture
Section 26-10-020 (tt) – RRD Rural and Resource Development
Section 26-16-020 (z) – AR Agriculture and Residential
Section 26-18-020 (y) – RR Rural Residential
Section 26-44-020 (q) – MP Industrial Park
Section 26-46-020 (aa) – M1 Limited Urban Industrial
Section 26-48-020 (z) – M2 Heavy Industrial
Section 26-50-020 (aa) – M3 Limited Rural Industrial
Section 26-34-020 (ll)- C3 General Commercial District
Section 26-36-020 (qq) – LC Limited Commercial

to read as follows:

"**Commercial cannabis medical uses in compliance with Section 26-88-250 through -256"**

D. **Standards for Commercial Cannabis Medical Uses.** Article 88 of Chapter 26 of the County Code is hereby amended to add Subsection 26-88-250 – 256 (Cannabis Cultivation and Related Land Uses) as shown in Exhibit B attached hereto.

E. **Medical Cannabis Dispensaries.** The following Subsections of Chapter 26 of the Sonoma County Code are amended

Section 26-30-020 (z) – C1 Neighborhood Commercial
Section 26-32-020 (ee) – C2 Retail Business and Service
Section 26-36-020 (oo) – LC Limited Commercial

to read as follows:

"**Medical Cannabis Dispensary, in compliance with Section 26-88-250 and 256"**

The following Subsections are deleted in their entirety

Section 26-32-020 (ff) – C2 Retail Business and Service
Section 26-36-020 (pp) – LC Limited Commercial

F. **Medical Cannabis Dispensary.** Article 88 of Chapter 26 of the County Code is hereby amended to delete Subsection 26-88-126 Medical Cannabis Dispensary in its entirety and replaced to add Subsection 26-88-256 Medical Cannabis Dispensary to read as shown in Exhibit A-3 attached hereto.

G. **Amendments to Zoning Districts for Personal Cannabis Use**. The following Subsections of Chapter 26 of the Sonoma County Code are added for Permitted Uses:

Section 26-04-010 (n) – LIA Land Intensive Agriculture District
Section 26-06-010 (r) – LEA Land Extensive Agriculture District
Section 26-08-010 (q) – DA Diverse Agriculture District
Section 26-10-010 (kk) – RRD Rural and Resource Development District
Section 26-16-010 (ff) – AR Agriculture and Residential District

Section 26-18-010 (bb) – RR Rural Residential
Section 26-20-010 (z) – R1 Low Density Residential District
Section 26-22-010 (u) – R2 Medium Density Residential District
Section 26-24-010 (z) – R3 High Density Residential District
Section 26-26-010 (t) (8) – PC Planned Community

to read as follows:

"Cannabis cultivation for personal use in compliance with Section 26-88-258"

H. **Standards for Personal Cannabis Use.** Article 88 of Chapter 26 of the County Code is hereby amended to add Subsection 26-88-258 (Cannabis Cultivation and Related Land Uses) as shown in Exhibit A-4 attached hereto.

I. **Amendments to Zoning Districts for Internal Consistency**. The following Subsections of Chapter 26 of the Sonoma County Code are amended for Permitted Uses:

Section 26-04-010 (d) – LIA Land Intensive Agriculture District
Section 26-06-010 (d) – LEA Land Extensive Agriculture District
Section 26-08-010 (d) – DA Diverse Agriculture District
Section 26-10-010 (d) – RRD Rural and Resource Development District
Section 26-16-010 (h) – AR Agriculture and Residential District
Section 26-18-010 (e) – RR Rural Residential

to read as follows:

"Outdoor crop production including wholesale nurseries, for growing and harvesting of shrubs, plants, flowers, trees, vines, fruits, vegetables, hay, grain and similar food and fiber crops other than cannabis, conducted and maintained in compliance with Article 65, RC Riparian Corridor Combining Zone;"

J. The following Subsections of Chapter 26 of the Sonoma County Code are amended for Permitted Uses:

Section 26-04-010 (o) – LIA Land Intensive Agriculture District
Section 26-06-010 (s) – LEA Land Extensive Agriculture District

Section 26-08-010 (r) – DA Diverse Agriculture District

to read as follows:

"Indoor crop production including wholesale nurseries for growing and harvesting of shrubs, plants, flowers, trees, vines, fruits, vegetables, hay, grain and similar food and fiber crops other than cannabis, in greenhouses or similar structures less than twenty five hundred (2,500) square feet, conducted and maintained in compliance with Article 65, RC Riparian Corridor Combining Zone";

K. The following Subsections of Chapter 26 of the Sonoma County Code are amended for Permitted Uses:

Section 26-10-010 (e) – RRD Rural and Resource Development District
Section 26-16-010 (i) – AR Agriculture and Residential District
Section 26-18-010 (g) – RR Rural Residential

to read as follows:

"Indoor growing and harvesting of shrubs, plants, flowers, trees, vines, fruits, vegetables, hay, grain and similar food and fiber crops other than cannabis, in greenhouse or similar structures less than eight hundred (800) square feet, conducted and maintained in compliance with Article 65, RC Riparian Corridor Combining Zone;"

L. The following Subsections of Chapter 26 of the Sonoma County Code are amended for Uses Permitted with a Use Permit:

Section 26-10-020 (h) – RRD Rural and Resource Development District
Section 26-16-020 (d) – AR Agriculture and Residential District

to read as follows:

"Indoor growing and harvesting of shrubs, plants, flowers, trees, vines, fruits, vegetables, hay, grain and similar food and fiber crops other than cannabis, in greenhouses or similar structures of eight hundred (800) square feet or more,

conducted and maintained in compliance with Article 65, RC Riparian Corridor Combining Zone;"

SECTION III. Transition Period. This ordinance hereby supersedes Resolution 06-0846. Existing cannabis cultivation cooperatives or collectives that demonstrate to the review authority that they were in operation before January 1, 2016 shall have until January 1, 2018 to come into compliance with this ordinance, provided that there has been no increase in the size of the cultivation area and the operations are in compliance with the best management practices and the operating standards.

SECTION IV. Adult Use of Marijuana Act. Chapter 26 of the County Code (Zoning Ordinance) is a permissive ordinance and the amendments adopted herein do not confer any rights or permits related to non-medical commercial cannabis uses, unless expressly stated as an allowed use in the zoning ordinance.

SECTION V. Severability. If any section, subsection, sentence, clause or phrase of this Ordinance is for any reason held to be unconstitutional and invalid, such decision shall not affect the validity of the remaining portion(s) of this Ordinance. The Board of Supervisors hereby declares that it would have passed this Ordinance and every section, subsection, sentence, clause or phrase thereof, irrespective of the fact that any one or more sections, subsections, sentences, clauses or phrases be declared unconstitutional or invalid.

SECTION VI. Effective Date. This Ordinance shall be and the same is hereby declared to be in full force and effect from and after thirty (30) days after the date of its passage. This Ordinance shall be published once before the expiration of fifteen (15) days after adoption, with the names of the Supervisors voting for or against the same, in *The Press Democrat*, a newspaper of general circulation published in the County of Sonoma, State of California. Pursuant to Government Code Section 25124, complete copies of Exhibits to this ordinance are on file with the Clerk of the Board of Supervisors and are available for public inspection and copying during regular business hours in the office of the Clerk of the Board of Supervisors, 575 Administration Drive, Room 100A, Santa Rosa, California. Complete copies of the Exhibits are also available for public review on the County's website at: http://sonomacounty.ca.gov/CAO/Cannabis/Proposed-Cannabis-Ordinance/

Applications for Commercial Cannabis Uses, other than Commercial Medical Cannabis Dispensaries in compliance with Section 26-88-250 and 256 shall not be accepted until a proposed Commercial Cannabis Tax is approved by the voters of Sonoma County, or a funding source has been established to provide the public service and code enforcement capacity to implement this ordinance.

SECTION VII. Inclusion and Exclusion Combining Zones. The Board of Supervisors hereby directs staff to bring back the Cannabis Inclusion and Exclusion Combining Zones for further consideration.

SECTION VIII. Custodian of Documents. The Clerk of the Board of Supervisors shall be the custodian of the documents and other materials which constitute the record of the proceedings upon which the Board's decision is based. These documents may be found at the office of the Clerk of the Board, 575 Administration Drive, Room 100-A, Santa Rosa, California 95403.

IN REGULAR SESSION of the Board of Supervisors of the County of Sonoma, introduced, passed, and adopted this twentieth day of December 2016, on regular roll call of the members of said Board by the following vote:

Supervisors:

Gorin: Rabbit: Zane: Gore: Carrillo:

Ayes: Noes: Absent: Abstain: 0

So Ordered.

WHEREUPON, the Chair declared the above foregoing Ordinance duly adopted and

SO ORDERED.

____
Chair, Board of Supervisors
County of Sonoma

ATTEST:

____
Sheryl Bratton

Clerk of the Board of Supervisors

ATTACHMENTS

Exhibit A-1 – Definitions Section 26-02-140
Exhibit A-2– Commercial Cannabis Medical Uses Section 26-88-250 through 254
Exhibit A-3 – Medical Cannabis Dispensary Section 26-88-256
Exhibit A-4 – Personal Cannabis Use Section 26-88-258