Sierra Forest Legacy
Protecting Sierra Nevada Forests and Communities

May 29, 2015

**Environmental Protection Agency**
**Air and Radiation Docket ID No EPA-HQ-OAR-2013-0691**
**William Jefferson Clinton Building West**
**1301 Constitution Avenue, NW**
**Washington, D.C. 20004**

**Sent via e-mail to: a-and-r-docket@epa.gov**

**RE: Comments on the Proposed Rule for Implementing the National Air Quality Standards for Fine Particles (PM 2.5): State Implementation Plan Requirements**
**Air and Radiation Docket ID No EPA-HQ-OAR-2013-0691.**

**Federal Register 15340 3-23-15**

The following are comments from Sierra Forest Legacy, a conservation coalition of over 80 organizations focused on federal forest policy, including rulemaking that impacts science-based management of federal lands in the Sierra Nevada:

Sierra Forest Legacy's concern for clean air and public health is quite high as we will demonstrate below in our comments. While we do not dispute the need for regulation of fine particulate matter (PM 2.5), we are concerned about the proposed rule's impact on the use of prescribed fire and natural ignitions in the management of forest ecosystems in the strongly fire-associated forests throughout the U.S., in the West, and especially in California.

We also appreciated EPA's continued attention to the multiple benefits of prescribed fire and the use of natural ignitions for multiple resource benefits (FR 15372). We will provide comments and references to support the fact that a robust prescribed fire program, and use of natural ignitions, will enable the Forest Service, National Park Service and other agencies with fire programs to restore landscapes to a condition where large-scale, uncharacteristic high-severity fire and resulting mega-emissions will be less likely and public health impacts will be reduced.

## I. Fire and Ecosystem Resilience in California—the Natural Background Condition

Lightning fire and Native American burning conducted since the arrival of California's first inhabitants, (est. 10-25,000 BP) has shaped species composition, vegetation structure and function of California's ecosystems (Barbour and Major 1988). Frequent fire is indisputably a major component of natural background conditions in the state, similar to wind, precipitation and other common disturbance elements.

In the pre-1800s California landscape, fire had a much larger, natural role in ecosystem regulation. In a recent fire paper regarding pre-historic fire area and emissions (Stephens et al. 2007) UC Berkeley fire scientist Dr. Scott Stephens noted that, "estimates of prehistoric annual area burned in California is 88% of the total wildfire area in the entire US during a decade (1994-2004) characterized as 'extreme' regarding wildfires....The idea that US wildfire area of approximately 2 million ha annually is extreme **is certainly a 20th or 21st century perspective**." (Emphasis added). The researchers estimated average annual burned area as "approximately 1.8 million ha [4.5 million acres] burned annually in California prehistorically (pre-1800)." The approximate historic fire estimate for the forests of the Sierra Nevada is 500,000 acres/year. The emission outputs modeled in the above research used the First Order Fire Effects Model (FOFEM) version 5.21 and represents a cautious approach to fuel model selection and fire return interval, attempting to best represent pre-historic conditions for a wide range of forest, shrubland and grassland vegetation types based on Barbour and Major (1988).

EPA has requested comments on appropriate baseline levels of P.M 2.5 FR 15367; FR 15386 stating that the statute (CAA) "does not clearly establish an applicable baseline year." The point of introducing the information (above) is to call into question the fundamental assumption related to natural background (NB) levels of Fine Particulate Matter generated from fires in California and elsewhere in the U.S. Fire is a natural ecosystem process like precipitation. Fire has been operating in all fire-adapted ecosystems for thousands of years, shaping the characteristic vegetation types in the West and throughout the U.S. based on the range of fire return intervals, fuel loads, and annual areas burned for the various vegetation types on the landscape. Stephens et al. 2007 (Table 9) of the paper characterizes the various emissions and amounts from historic fire in California:

Table 9
Summary of wildfire emissions (Tg) produced annually from California forests, woodlands, shrublands, and grasslands during the prehistoric period

| Fire interval | Emission type | | | | | | |
|---|---|---|---|---|---|---|---|
| | PM 10 | PM 2.5 | $CH_4$ | CO | $CO_2$ | NOX | $SO_2$ |
| MFRI | 1.512 | 1.281 | 0.768 | 16.728 | 89.667 | 0.039 | 0.069 |
| HFRI | 0.560 | 0.474 | 0.284 | 6.187 | 33.638 | 0.015 | 0.026 |

MFRI—median fire return interval; HFRI—high fire return interval; PM 10—10 μm particulates; and PM 2.5—2.5 μm particulates.

Historical eye witness accounts from the late 1800's suggest smoke and haze were the natural background conditions in the summer and fall in California. An eye-witness account of smoke in northern California forests (C.H. Merriam 1898, quoted in Morford, 1993) reported ''Of the hundreds of persons who visit the Pacific slope in California every summer to see the mountains,

few see more than the immediate foreground and a haze of smoke which even the strongest glass is unable to penetrate.'' C.H. Merriam traveled extensively in California and was Chief, Division of Biological Survey for the US (Stephens et al. 2007). The concept of "pristine" air quality in California is an artifact of limited knowledge of the cultural history and ecological function of the California landscape.

While it is correct, when characterizing California's fire landscape today, much of the state has been converted to farmland and expanding urbanization. This is generally not the case for California's historic forest lands which generally remain forested today. These forest remain fire adapted (thick bark, re-sprouting species, cones opening with fire and heat, seeds germinating in bare mineral soil) and fire dependent (frequent fire maintaining lower fuel loads).

We request the EPA articulate a baseline for fire-related Fine Particulate Emissions that is directly tied to the science-based fire regimes, fire return intervals and vegetation types in the remaining wildlands of California and elsewhere in the U.S. Understanding how wildland fire functioned prior to European settlement is critical because today's environments (forests, shrublands, and grasses, rare and at-risk species) result from many thousands of years of association with fire as a key ecological and evolutionary process. Where ecosystems remain relatively intact, understanding the fire return intervals, vegetation types and reasonable spatial fire patterns is an important step in setting a science-based ecological baseline. It is also critical to understand and articulate changes in fire frequency, intensity and extent of potential climate driven fire trends likely to occur in the near future. This understanding will help EPA set science-based Reasonable Available Control Measures (RACM) for prescribed burning and use of natural ignitions for multiple resource benefits AND these measures will better protect the public from the negative health impacts of mega-emissions events associated with uncharacteristic wildfire.

Attempting to severely suppress the natural ecological relationship between fire-vegetation-weather-topography in fire adapted systems in the U.S. will continue to result in larger, uncharacteristic fire and emissions events. FR 15372 (Stephens et al. 2013) "Fire policy that focuses on [wildfire] suppression only, delays the inevitable, promising more dangerous and destructive future . . . fires." And, of course, what also follows is more dangerous and destructive impacts to public health from mega-emissions tied to these events.

Finally, a natural benchmark or baseline emission characterizations for smoke-and-fire related PM outputs must be tied to science-based estimates of today's existing fire and vegetation conditions on each particular landscape and **not** pegged to an arbitrary statutory or policy-driven date or period. It is especially important when thinking about baseline conditions to avoid earlier fire suppression-era data for PM since vegetation and fire regime-based PM level are much higher natural background levels. Also, today's mega-fires are escaping suppression on a regular basis (Examples: Rim Fire 2013; King Fire 2014) in the central Sierra Nevada. The RACM policies should be based on the use all tools available to lower emissions from large, uncharacteristic events.

**2. Recent Air Quality Science in California (2012-2014)**

New science requires a "hard look" at assumptions guiding air quality regulations and the role of ecological fire in forest ecosystems. In recent atmospheric pollution research (Cisneros et al. 2014), academic and Forest Service scientists focused on source pollution generated in particulate matter less than 2.5 microns in the Sierra Nevada compared to the Central Valley, a major non-attainment area in California. The authors found for air quality regulatory purposes, air quality throughout the southern Sierra Nevada is assumed to be similar to the Central Valley. But locations used in their study (2002 to 2009) ranging from 91 meters in the Central Valley to 2598 meters in the Sierra Nevada, at elevations above 500 meters are actually in compliance with federal standards for $PM_{2.5}$. Fires during the time of the study were typical of the historical size and intensity of fires in this area of the Sierra Nevada**.** The authors determined that, while fires during the study period had an impact on air quality, "they did not appear to be a major driver in exceeding the United States Federal $PM_{2.5}$ standard" in the southern Sierra Nevada.

In the section of the above paper discussing the policy implications of the effects of fire on $PM_{2.5}$, the authors state that based on monitoring information at locations in rural and undeveloped monitoring sites, these sites did not exceed "mean annual or $98^{th}$ percentile federal standards." Another key finding of the study was that monitoring sites located near the largest burn areas, "did not have the largest concentrations of $PM_{2.5}$." This suggests that "natural ignition fires burning at historic intensities and areas do not significantly contribute to violation of the current federal standards in many instances."

Regarding background conditions for $PM_{2.5}$ the author's note, "Considering the total area burned in California in 2008, the increase in $PM_{2.5}$ could be assumed as the historic level of non-anthropogenic $PM_{2.5}$ from fire during a normal year." EPA should fully examine the results and implications of this key research paper on current air regulatory policy.

In another fire management and air quality case study from the southern Sierra Nevada, (Schweizer and Cisneros 2014), the authors monitored the 8,370 ha (20,422 ac) Lion Fire in 2011 on the Sequoia National Forest for $PM_{2.5}$ levels at monitoring sites used to access exposure, public health impacts, and to quantify annual air quality during a year with a fire that was within the normal fire size and intensity for this area of the Sierra Nevada. While the Lion Fire burned for 2 months, the Air Quality Index readings of moderate to good were recorded at the most impacted sites of Johnsondale, Kernville, and Camp Nelson. Smoke impacts to $PM_{2.5}$ concentrations did not reach the Central Valley. The authors concluded, ". . . this type of fire can be implemented with minimal public health impacts thus allowing an opportunity for air and fire managers to alter policy to allow additional burning in an area with severe anthropogenic air pollution and where frequent widespread fire is both beneficial and inevitable."

In contrast to large, high severity fire the authors conclude that, "the more extensive air quality impacts documented with large high intensity fire may be averted by embracing the use of fire to prevent unwanted high intensity burns. A widespread increase of the use of fire for ecological benefit may provide the resiliency needed in the Sierra Nevada forests as well as be the most beneficial to public health through the reduction of single dose exposure to smoke and limiting impacts spatially."

Also, it is interesting to note in Schweizer and Cisneros (2014) that the forest communities captured in a larger designation of federal non-attainment including Kernville, Springville and Pinehurst, show typical federal non-exceedance levels of $PM_{2.5}$ when site-specific monitors record year-round concentrations adjacent to forest communities which do not coincide with higher unhealthy readings in the Central Valley. EPA should address these complications related to limited air quality monitoring and their impact on the use of ecological fire in the Sierra Nevada and elsewhere.

In contrast, the same authors joined with other health science and air quality experts in 2012 to analyze the effects of the 61,000 ha (150,000 ac) 2002 McNally Fire on air quality in the San Joaquin Valley and southern Sierra Nevada (Cisneros et al. 2012). The federal $PM_{10}$ standard was exceeded four times during the fire but violations of the California $PM_{10}$ standard "increased drastically during the fire." The authors noted that the California $PM_{10}$ standard was violated six times before the McNally Fire and 164 times during the fire.

In response to the potential increase in large, high intensity wildfires in combination with urban pollutants from the Central Valley impacting rural mountain communities the authors recommend "a network of densely distributed passive samplers aided by real-time portable **$O_3$** monitors and portable PM monitors is essential for evaluating effects of wildland fire on ambient air quality." They conclude with the recommendation that, "A return to historic fire size and intensity may be the best solution for reducing $O_3$ and PM exposure in the Sierra Nevada."

We ask that EPA explicitly address these issue with a clarity and depth consistent with the comments and the research cited.

**3) Reasonable Available Control Mechanisms (RACM) for prescribed fire and for wildfires managed for natural resource benefits**.

We ask that EPA, in conjunction with Forest Service, National Park Service, Bureau of Land Management and any other parties with active burn programs, consider the following practical, reasonable and available recommendation:

A. Start with an accurate characterization of the ecological baseline for fire in each ecosystem type for fire-associated ecosystems throughout the U.S., as mentioned above.

B. Adopt the 2005 Western Regional Air Partnership's recommendations for fire use in restored ecosystems where restoration treatments have occurred and now need to be maintained with fire into the future. Losing the ability to use regular fire in these restored areas will be a tragic loss of opportunity. Emissions are lower in these areas based upon reduced fuels and the costs of postponing treatments are immense compared with the per acre costs of prescribed burning. Future mechanical treatments are limited because the land is restored, leaving little wood fiber available to offset treatment costs. If uncharacteristic levels of vegetation and fuels accumulate and managers miss consecutive, ecosystem-based fire return intervals then use of fire as a management option become increasingly limited and emissions, risks of control, operational costs and other factors increase. We recommend as a RACM, that EPA establish maintenance

burning as a "natural" ignition event and allow land managers to treat the backlog of maintenance burning in California, the fire-adapted West and throughout the U.S. Additionally, we believe the whole idea of "natural" verses "anthropogenic" fire should be abandoned since it is an artificial construct. While lightning is certainly a "natural" ignition event the regulatory environment created around the permitting of prescribed fire use is a strongly cultural "anthropogenic" impact on our stared desire to use fire to avoid increasingly large fire and emission events. We just need to consider fire and all of its benefits and potential impacts in the most open, science-based (ecological and public health science) decision making process and use RACM recommendations to create resilient forests with functioning natural processes in place. This is the best pathway to protect human health.

C. Mechanical Treatments are not an available solution for much of the steeper, mountainous western landscape.

As mentioned in our recent (3-13-15) comment letter on the Proposed Rule for Ozone, recent research by forest ecologist Dr. Malcolm North and others (North et al. 2015) report that approximately 10.7 million acres of national forest ownership in the Sierra Nevada in California contain roughly 58 percent productive forest land, with 25 percent of those acres available for mechanical treatment. In other words, if we can only restore 25 percent of the Sierra Nevada using mechanical treatments which then need fire as a follow-up treatment to maintain lower fuels benefits, the remaining acres will either be "managed" by unplanned wildlife or the thoughtful, science-based use of natural ignitions and prescribed fire. In recent research (North et al. 2012), researchers in California were clear the current levels of mechanical treatments and limited use of burning were not going to accomplish the Forest Service's stated restoration goals in the Sierra Nevada where increased pace and scale, supported but active fire use is critical successful landscape restoration. In terms of air quality impacts of increase pace and scale of restoration, planned prescribed fire use or the appropriate management of natural ignitions significantly limits the precursor emissions from larger uncharacteristic events that contribute to ozone and particulate matter (PM) pollution (Schweizer and Cisneros 2014; Cisneros et al. 2014; Cisneros 2012).

The Proposed SIP Requirements for Fire Particulate Matter (FR 15372) suggests that wildfire is a threat that can be mitigated "through the management of woodland vegetation." There is no debate on this issue. But EPA should explore this issue more deeply. In California's Sierra Nevada, with only 25 percent of the productive forest lands available for mechanical treatment, there are only two other choices for the "management of woodland vegetation." One choice is to let increasingly intense wildfire make the decisions for us, or a second choice is to expand support for an active and robust program of prescribed fire and use of natural ignitions, of appropriate ecological scale, for specific fire regimes in the forests of California and throughout the U.S. We recommend managing the remaining wild and semi-wild landscapes in a manner that robustly integrates fire back into these fire-adapted systems for the benefit of natural resources, the ecological services they provide humans and to benefit public health from lower wildfire emissions.

D. Concerns over relying on the Exceptional Events Rule to support fire use.

The Exceptional Events Rule (EER) is cited in the proposed language as a potential pathway for exempting beneficial fire under the new standards (FR 15438, footnote 270). We are concerned about the ability of the EER to allow for natural, beneficial fire to play a role to the extent that it is needed. Currently, the EER only treats wildfire and prescribed fire as exceptions under very particular circumstances that are not necessarily consistent with restoration and management goals fire-adapted landscapes. For example, the EER can be used to exempt fires that are one-time events and not expected to occur again at the same location, but this contradicts management needs, where repeated application is necessary to restore frequent fire regime events and to maintain resilience. While repeat burning may not be occurring under the same fuel conditions, it is essential that fire occur across the landscape consistent with the fire return intervals and natural range of variation in patch size and intensity. This reiterates the need for ecological and cultural burns and their emissions to be classified as natural background emissions sources and treated differently than other industrial and anthropogenic sources. Also, the process to monitor and apply for the EER is cost prohibitive and cumbersome; this is especially true for prescribed fire, and as a result, the rule is rarely used for that purpose. While we appreciate EPAs commitment (made in the recent Ozone Rule Notice) to "working with federal land managers, tribes and states to effectively manage prescribed fire use to reduce the impact of wildland fire related emissions on ozone" (FR 75384) to our knowledge, the EER has never been used to exempt prescribed fire in California.

We believe that beneficial fire use should be the primary component of any practical strategy to restore and maintain forest resilience, on a landscape scale, and also protect the public from severe wildfire events and related pollutants. The current regulatory environment limits the duration of planned burns, limits burn windows, limits burn seasons, and makes the process more costly and politically risky for managers to attempt. EPA understands the benefits of using prescribed fire to limit emissions from larger, uncharacteristic fires. Whether in this proposed rule-making or in the upcoming revisions to the Exceptional Events Rule later this year it is time for EPA to offer a more streamlined, less costly and cumbersome process that fosters the use of beneficial fire. Promoting landscape fire plans, smoke management BMPs, collaborative coordination between stakeholders, fire managers, air regulators, scientists and public health officials is the best path forward. Finally, we must cease fostering the false dichotomy in recent rule language that suggests human beings somehow live outside the environment that sustains us all. The use of such terminology as "natural" verses "anthropogenic" sources or causes is outdated and confusing framing that is stuck in the past. Fire is an inevitable and natural part of California's future. We must accept that there are emissions trade-offs, learn how better to live with that fact and get on with the work of large scale restoration of fire-adapted ecosystems.

One of the key issues in the lingering debate over smoke impacts and the need for fire in fire-adapted ecosystems is EPA's determination that wildfire smoke is "natural" and therefore excludible under the Exceptional Events policy. This is not statutorily required. There is nothing in the legislative history of the Clean Air Act, as amended, where Congress identified a regulatory exclusion of air quality pollution measurements influenced by wildlife. Nor did Congress specify a definition of "natural events" or identify wildfires as a "natural events." (Engel, K. 2013 Ecological Law Quarterly). At the same time EPA is increasing the regulatory controls over the use of prescribed fire for natural resource benefit—the one critical tool that offers the possibility to provide landscape treatments that could mitigate uncharacteristic wildfire and its impacts on public health. It is time to abandon the false distinction between "natural" and

"anthropogenic" fires and allow land managers to implement expanded prescribed burn programs (based upon the appropriate natural fire return intervals and fire regimes) to "minimize" resource damage and harm to public health from uncharacteristic "mega-fires".

E. Adopt a robust Health Alert Notification System to better protect public health.

Burning and Protecting Public Health are not mutually exclusive. Through increased collaboration with the public health sector and with the use of new monitoring and modeling tools we can reach those most impacted by ecological burning.

Sierra Forest Legacy and the Forest Service in Region 5 (Sequoia National Forest-Hume Lake District) have recently partnered with the Fresno-Madera Medical Society and others to establish a Health Alert Notification System to utilize timely and best available weather information to make direct contact with the air-quality challenged communities of the southern Sierra Nevada through their physicians, school nurses and the public health community. The purpose is to alert these individuals to a pending prescribed fire, the ecological need for such fire as a restoration tool and to give them advanced notification of the event so they can better protect themselves and their families from the impacts of short-duration smoke in their communities. There has been a very positive response from San Joaquin Air Board staff and the Fresno Area Lung Association in developing this notification system.

An early alert system was designed for the Boulder Prescribed Burn and the two notices used for the project can be downloaded at:
http://www.sierraforestlegacy.org/CF_ManagingFire/AirQualityPolicy.php
The Boulder project is located in an area with no mechanical treatment options. Managed fire is the appropriate tool for this landscape. These notification alert examples are the first run of what should be a much broader, collaborative effort between land managers, air regulatory, public health officials, air quality scientists and modelers, conservation groups and the general public. One aspect of collaborative work is exemplified by the use of integrated, linked models to assess a variety of fuel, emissions and weather conditions to predict smoke intensity, dispersion and duration on impacted landscapes. BlueSky is one such modeling framework:

BlueSky modularly links a variety of independent models of fire information, fuel loading, fire consumption, fire emissions, and smoke dispersion (http://www.airfire.org/bluesky/)

While BlueSky and other predictive tools are currently in use, SFL, Forest Service, public health organizations, air regulators, scientists and conservation organizations seek a significantly expanded outreach, education and communication systems to better notify and protect public health—especially those most at-risk from short-duration smoke impacts. There is plenty of opportunity for good work on this front. What we seek and ask EPA to consider, as a RACM approach in this rule-making, is to recommend collaborative, working groups in fire-adapted landscapes whose task it is to continually refine and expand public education and outreach using the best available science (ecological, public health, air quality and emissions prediction), best collaborative practices, and the best multi-media, multi-stakeholder effort that marries the need

for fire in fire-adapted systems to the need and shared desire to protect and enhance public health. These issues should no longer be viewed as antagonistic (fire versus health) but instead as challenging but workable mutual goals that are supported by our best actions and intentions.

Recommendations for EPA to Consider:

- Intensified outreach to local and regional public health communities with a goal of expanding the timely notification system targeting at-risk respiratory patients and families via their physicians, public health workers, hospitals, school nurses and other caregivers.
- Intensify education efforts on why fire is a key aspect of ecosystem management and resilience through a multi-media outreach effort.
- Intensify multi-media tools to reach the general public and to rapidly alert those willing to sign-up for notification of fire events and expanded options for health protection.
- Expand collaborative work between air regulators and air quality experts, fire scientists, land managers and public health officials before, during and after burns. This should include collaborative media presentations, webinars, and in-service education among professionals in these different fields.
- Expand Air Quality monitoring in remote areas to better identify, source, and assess smoke impacts in rural areas (See policy recommendations in Schweizer and Cisneros 2014; Cisneros et al. 2014; and Cisneros et al. 2012).
- Expand the understanding of cultural burning and its relevance to many aspects of Native American culture from food gathering and site preparation, maintaining basket weaving materials, ceremonial and religious practices, as a right of First Nations people among the public, air regulators, and land managers.
- Clarify commitment to reduction of smoke impacts and smoke management planning by asserting EPA's desire to see increased collaborative engagement in the effort to "minimize exposure to sensitive populations" and ensure that burners are educated in smoke BMPs as per the 2007 Exceptional Events Rule March 22, 2007 (FR 13567).

In Conclusion: Regarding PM 2.5 and other fire-related pollutants, it is critical that EPA support changes in policy to allow fire as a restoration tool in the fire-associated areas of the U.S. "A Future With Fire" should become the new model for permitting and reporting on fire use. It is past time to dismantle the old thinking about wildland fire suppression and efforts to eliminate fire from fire-adapted ecosystems. It is also past time to abandon the "natural" verses "anthropogenic" dichotomy that grants EPA a pass from counting emissions from wildfires (which are growing ever-larger) while making it harder for managers to burn significant acres on an annual basis. We acknowledge that this is not just an EPA problem. Forest Service culture and budgets are also part of the reason for limited prescribed burn accomplishments (Silvas-Bellanca, 2011). EPA's RACM recommendations supporting prescribed burning and appropriate use of natural ignitions should be based on ecological need to restore current landscapes and their fire return intervals and not delay fire's role only to result in mega-emissions for future generations.

Thank you for this opportunity to comment on the new Proposed Rule for SIP Requirements for Fire Particulate Matter (PM 2.5).

Sincerely,

Craig Thomas, Conservation Director
Sierra Forest Legacy
P.O. Box 244
Garden Valley, CA 95633
craig@sierraforestlegacy.org
(916) 708-9409

**References**

Barbour, M.G. Major, J., 1988. Terrestrial Vegetation of California, expanded edition. California Native Plant Society Special Publication 9. Sacramento, California, pp. 3–10.

Cisneros, R., Schweizer, D., Zhong, S., Hammond, K., Perez, M.A., Gou, Q., Traina, S., Bytnerowicz, A., Bennett, D.H. 2012. Analyzing the effects of the 2002 McNally fire on air quality in the San Joaquin Valley and southern Sierra Nevada, California. *International Journal of Wildland Fire* 21, 1065-1075.

Cisneros, R., Schweizer, D., Preisler, H., Bennett, D.H., Shaw, G., Bytnerowicz, A. 2014. Spatial and seasonal patterns of particulate matter less than 2.5 microns in the Sierra Nevada Mountains, California. *Atmospheric Pollution Research* 5 (2014) 581-590.

Engel, K. 2013. Perverse Incentives: The Case of Wildfire Smoke Regulation. Ecological Law Quarterly Vol 40:623. University of California

Morford, L., 1993. 100 Years of Wildland Fires in Siskiyou County, California. International Association of Wildland Fire, Fairfield, Washington, 124 pp.

North, M. et al. 2015. Restraints on mechanized treatment significantly limit mechanical fuels reduction extent in the Sierra Nevada. J. Forestry 113(1):40-48.

North, M., Collins, B. M., and Stephens, S. 2012. Using fire to increase the scale, benefits, and future maintenance of fuel treatments. J. For. 110(7): 392-401.

Schweizer, D. and Cisneros, R. 2014. Wildland fire management and air quality in the southern Sierra Nevada: Using the Lion Fire as a case study with a multi-year perspective on $PM_{2.5}$ impacts and fire policy. *Journal of Environmental Management* 144 (2014) 265-278.

Silvas-Bellanca, K. 2011. Ecological Burning in the Sierra Nevada: Actions to Achieve Restoration. Sierra Forest Legacy 2011. http://www.sierraforestlegacy.org/CF_ManagingFire/FirePolicy.php

Stephens, S.L.., Martin, R.E., and Clinton, N.E. 2007. Prehistoric fire area and emissions from California's forests, woodlands, shrublands, and grasslands. *Forest Ecology and Management 251 (3): 205-216.*

Western Regional Air Partnership-Fire Emissions Joint Forum November (2005)
http://www.wrapair.org/forums/fejf/documents/nbtt/WRAPFEJFNAGuidance.pdf