Rim Fire Reforestation

Fire and Fuels Report

Air Quality Report

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Fire and Fuels Report

This report addresses the issues and opportunities for Fire and Fuels Management within the Rim Fire Reforestation project.

The Rim Fire started on August 17, 2013 in a remote area of the Stanislaus National Forest near the confluence of the Clavey and Tuolumne Rivers about 20 miles east of Sonora, California. Over the next several weeks it burned 257,314 acres, including 178,419 acres of National Forest System (NFS) lands and intermixed private lands. The remaining 78,895 acres are located within Yosemite National Park.

Large scale logging operations designed to mitigate hazardous dead trees adjacent to infrastructure, reduce long-term fuel loads and recover merchantable timber lost during the Rim Fire began soon after the fire was controlled and are ongoing.

Fuel levels, risk of injury and damage from wildfires are components of the Purpose and Need for the Rim Fire Reforestation project. Bringing fuel load levels and fuel arrangement to conditions that reduce the likelihood of stand-replacing fire in reforested stands, particularly during early stages of stand development will promote the long-term survival and growth of young conifers. Predicted increases in fire hazard in the reforested areas of the fire could be mitigated by removing fire-killed trees or slash and reducing the amount of dense vegetation regrowth.

Analysis Framework: Statute, Regulation, Forest Plan and Other Direction

The Forest Plan includes goals, strategies and objectives to move towards creating a fire resilient forest where fire is an integral part of the system, not a landscape altering force (USDA 2010a, p. 5-7, 11-15). The broad scale Forest Plan goals for fire and fuels that apply to this project include:

- Provide a cost-effective fire management program to protect Forest resources, life and property from the effects of wildfire. Maintain natural and activity fuels at levels commensurate with minimizing resource losses from wildfire (p. 5).
- Treat fuels in a manner that significantly reduces wildland fire intensity and rate of spread, thereby contributing to more effective fire suppression and fewer acres burned (p. 13).
- Treat hazardous fuels in a cost-efficient manner to maximize program effectiveness (p. 13).
- Strategically place treatment areas across landscapes to interrupt potential fire spread, removing sufficient material in treatment areas to cause a fire to burn at lower intensities and slower rates of spread compared to untreated areas, and considering cost-efficiency in designing treatments to maximize the number of acres that can be treated under a limited budget (p. 14).

In October 2013, Forest Service Fire and Fuels staff from the Stanislaus and Pacific Southwest Research Station compiled a strategy for the Rim Fire area within the Rim Fire Vegetation Resiliency Plan (project record). This strategy outlined conditions along with features on the landscape that could help reduce the size and severity of future fires, and specifically addressed reforestation.

The Forest Plan Compliance (project record) document identifies the Forest Plan Standards and Guidelines that specifically apply to this project and related information about compliance with the Forest Plan.

Forest Plan Direction

The Stanislaus National Forest “Forest Plan Direction” (USDA 2010) presents the current Forest Plan management direction, based on the original Stanislaus National Forest Land and Resource Management Plan (USDA, 1991), as amended.

The Forest Plan includes Goals, Strategies and Objectives for this project (pp. 5-7 and 11-15, USDA 2010). Create a fire resilient forest where fire is an integral part of the system, not a landscape altering

force. To sustain forests into the future, natural and prescribed fire will be an important tool to protect this area from another stand replacing event. Strategically place fuels treatments to modify wildfire effects, establish and maintain a pattern of area treatments that is effective in modifying wildfire effects. Reduce hazardous fuels in key areas to lessen the threat of high severity fire. Design economically efficient treatments to reduce hazardous fuels (pp. 191, USDA 2010).

FOREST GOAL FOR FIRE AND FUELS

Provide a cost-effective fire management program to protect Forest resources, life and property, from the effects of wildfire. Maintain natural and activity fuels at levels commensurate with minimizing resource losses from wildfire. In wilderness, fire is allowed to play as nearly as possible its natural ecological role.

FIRE AND FUELS MANAGEMENT PRACTICES

Smoke Management - Prescribed Fire. This practice is established for managing smoke from prescribed fire so that emissions meet applicable state and federal standards. Prescribed fire includes but is not limited to burning of timber residue, which improves wildlife habitat and range type conversion. Prescribed fires are managed by the local Air Pollution Control District (APCD) and the 1990 Clean Air Act (CAA) amendments, which require the application of Best Available Control Measures (BACMs) to reduce particulate emissions. BACMs are a combination of practices intended to reduce emissions to the lowest practicable amount. BACMs are accomplished by diluting or dispersing emissions, or by preventing potential emission sources whenever possible. Examples of BACMs include: 1) Reduce pollutants by: limiting the mass of material burned; burning under moist fuel conditions when broadcast burning; shorten the smoldering combustion period; and increase combustion efficiency by encourage the flaming stage of fire when burning piles. 2) Dilution of pollutant concentrations over time by: reducing the rate of release of emissions per unit area; burning during optimum conditions; and coordinate daily and seasonally with other burning permittees in the area to prevent standard exceedences.

STANDARDS AND GUIDELINES FOR FIRE AND FUELS

Strategically place area fuels treatments across the landscape to interrupt fire spread and achieve conditions that: 1) reduce the size and severity of wildfire and 2) result in stand densities necessary for healthy forests during drought conditions. Complete a landscape-level design of area treatment patterns prior to project- level analysis. Develop treatment patterns using a collaborative, multi-stakeholder approach. Determine the size, location, and orientation of area fuels treatments at a landscape-scale, using information about fire history, existing vegetation and fuels condition, prevailing wind direction, topography, suppression resources, attack times, and accessibility to design an effective treatment pattern. The spatial pattern of the treatments is designed to reduce rate of fire spread and fire intensity at the head of the fire.

Vegetation within treatment areas should be modified to meet desired surface ladder, and crown fuel conditions as well as stand densities necessary for healthy forests during drought conditions. Site specific prescriptions should be designed to reduce fire intensity, rate of fire spread, crown fire potential, mortality in dominant and co-dominant trees, and tree density. Managers should consider such variables as the topographic location of the treatment area, slope steepness, predominant wind direction, and the amount and arrangement of surface, ladder, and crown fuels in developing fuels treatment prescriptions. Where young plantations (generally Pacific Southwest Region size classes 0x, 1x, 2x) are included within area treatments, apply the necessary silvicultural and fuels reduction treatments to: (1) accelerate the development of key habitat and old forest characteristics, (2) increase stand heterogeneity, (3) promote hardwoods, and (4) reduce risk of loss to wildland fire. In size class 2x plantations, treatments should be designed to reduce fire intensity, rate of fire spread and tree mortality. Design a sequence of fuel reduction projects to achieve the standards below.

Plantations (0x-2x) 3 inches and smaller surface fuel load: less than 5 tons per acre, less than 0.5 foot fuel bed depth, stocking levels that provide well-spaced tree crowns (for example, approximately 200 trees per acre in 4 inch dbh trees), less than 50% surface area with live fuels (brush), and tree mortality less than 50% of the existing stocking under 90th percentile fire weather conditions (2x type).

Design mechanical treatments in brush and shrub patches to remove the material necessary to achieve the following outcomes from wildland fire under 90th percentile fire weather conditions: (1) wildland fires would burn with an average flame length of 4 feet or less and (2) fire line production rates would be doubled. Treatments should be effective for more than 5 to 10 years. Design a sequence of fuel reduction treatments in conifer forest types (including 3x plantation types) to achieve the following standards within the treatment area: An average of 4-foot flame length under 90th percentile fire weather conditions.

Surface and ladder fuels removed as needed to meet design criteria of less than 20 percent mortality in dominant and co-dominant trees under 90th percentile weather and fire behavior conditions.

Tree crowns thinned to meet design criteria of less than 20%probability of initiation of crown fire under 90th percentile weather conditions.

Activity Fuels

All management activities which generate woody residues will have an approved fuel treatment project plan. This plan will describe the methods of treatment to be used, the estimated total cost of treatment, method of funding, responsible parties to complete treatment, and necessary measures to maintain the acceptable fuel profile.

The scope of the plan should encompass the overall area affected by the activity and not be limited to each individual unit. The fuel treatments identified will meet the minimum level of treatment as described in the standards and guidelines.

The fuel bed will be expressed in terms of Resistance-to-Control (chains/person-hour handling construction rate) and Fire Intensity Levels (FIL).

Plantation Design and Fire Protection Planning

Fuel treatment and protection planning are incorporated into reforestation project plans for the establishment of plantations. The fuel treatment planning will comply with the standards set in the Activity Fuel Standards and Guidelines while still maintaining the productivity of the site. Minimum levels of protection planning are established in the following Standards and Guidelines; Prescribed Fire and Prescribed Natural Fire.

Prescribed fire will be considered as a management tool for all projects where it is shown to be cost effective and has the ability to meet resource management objectives.

Roadside Fuel Modification

To create a roadside fuel profile which will:

1. Limit the spread and intensity of roadside ignitions until initial attack units arrive.
2. Provide firefighter access to other fire defense systems.
3. Provide a line of defense for control of wildfire.

Effects Analysis Methodology

- The analysis area is the project area as described in Chapter 2.
- Duration of short-term effects is 20 years; duration of long-term effects is 40 years.
- The cumulative effects analysis area is the Rim Fire perimeter, including NFS lands and those under other ownership.

Stand profiles (i.e. the vertical cross section of a fuel bed down to mineral earth showing fuel types, size and amount) were gathered and analyzed using representative 1/50th acre plots throughout the project area. The data was used to compare current fuel loading to projected future conditions.

The dynamics between vegetation and fire and fuels are inherently linked. Fire has a profound effect on vegetation establishment and development and conversely, vegetation treatments (and the absence thereof) have a profound effect on fuels accumulations and tree mortality. The analysis considers forest vegetation, fuels, and fire at the stand level.

Predicted tree mortality from fire is heavily influenced by tree species, size and height. Increased scorch heights and percentage of crown scorched correlate closely to higher tree mortality. Scorch height is influenced in part by fuel type, fuel arrangement, fuel moisture and weather conditions.

Predicted fire effects are estimated using the predicted length of flame measured in feet and the predicted fireline intensity measured in British Thermal Units (BTU) per foot per second at the head of the fire. Increased flame lengths can increase the likelihood of torching events and crown fires. Flame length, like scorch height, is influenced in part by fuel type, fuel arrangement, fuel moisture and weather conditions. Resistance-to-control, flame length and fireline intensity influence how fast firelines can be constructed by different suppression resources, including hand crews and mechanical equipment.

Flame lengths over 4 feet, fireline intensities over 100 BTU per foot per second, or high resistance-to-control may present serious control problems. These conditions are too dangerous to be directly contained by hand crews (Schlobohm and Brain 2002; Andrews and Rothermel 1982). Flame lengths over 8 feet or fireline intensities over 500 BTU per foot per second are generally not controllable by ground-based equipment or aerial retardant and present serious control problems including torching, crowning and spotting.

Increased flame lengths increase the likelihood flame length and fireline intensity directly affecting suppression tactics. Table FFR-3 outlines how flame lengths and fireline intensities influence fire suppression actions (Andrews et al. 2011). Predicting the potential behavior and effects of wildland fire is an essential task in fire management. Mathematical surface fire behavior and fire effects models and prediction systems are driven in part by fuelbed inputs such as load, bulk density, fuel particle size, heat content and moisture of extinction.

Assumptions Specific to Fire and Fuels

- The Rim Recovery project required units to be at 10 to 20 tons per acre post implementation.
- Vegetation condition in areas not covered under the Rim Recovery project will be similar to past fires in this area that were not salvaged or did not have fuel reduction treatments.
- Historical weather represents future conditions in these locations. This assumption is a conservative estimate of future weather conditions as climate change is predicted to increase surface air temperatures increasing the size and severity of fires in the Sierra Nevada (Miller et al. 2009; Miller and Safford 2012; Safford 2013).

Data Sources

- Vegetation Plots for Reforestation in proposed units
- Stand Profiles within the Rim Fire
- FlamMap fire behavior modeling
- FOFEM version 6.0 tree mortality modeling
- LANDFIRE Data Access Tool (2014)
- Forest GIS shapefiles displaying information within the Rim Fire

Fire and Fuels Indicators

- **Tree Mortality**: tree mortality from wildfire and prescribed fire can be measured using crown scorch volume. Crown scorch volume is determined by the percentage of crown scorched on a tree represented as a fraction of the crown. Low-intensity fires readily kill seedlings less than 12 inches in height, while larger seedlings, saplings and pole-sized trees may be damaged but not killed, especially if the burn occurred during the dormant season (Reinhardt and Ryan; 1988).
- **Flame Length**: the length of flame measured in feet. Increased flame lengths increase resistance-to-control and likelihood of torching events and crown fires.
- **Fireline Intensity**: the rate of energy or heat release per unit length of fire front.
- **Fuel Loading**: the amount of flammable material that surrounds a fire. Fuel load is measured by the amount of available fuel per unit area, usually tons per acre.

Type and Duration of Effects

Direct Effects: These are effects on forest vegetation and air quality that are directly caused by treatment implementation or, as with the No Action Alternative, a lack of treatment.

Indirect Effects: These are effects on forest vegetation and air quality that are in response to the direct effects of treatment implementation or, as with the No Action Alternative, a lack of treatment.

Duration of Effects: Direct effects would likely be limited to the project implementation phase. Indirect effects would last beyond the implementation period and occur within the temporal bound of the cumulative effect analysis described above in the Methodology section (Geographic Area Evaluated for Impacts) for forest vegetation. The air quality cumulative effects analysis boundary are described in the air quality report.

Predicted fire effects: The predicted length of flame measured in feet and the predicted fireline intensity measured in BTU per foot per second at the head of the fire. Fuel type, flame length, and fireline intensity influence production rates, or how fast firelines can be constructed by different suppression resources, including hand crews and mechanical equipment. Flame lengths over 4 feet and/or fireline intensities over 100 BTU/FT/sec. may present serious control problems—they are too dangerous to be directly contained by hand crews (Schlobohm and Brain 2002; Andrews and Rothermel 1982). Flame lengths over 8 feet and/or fireline intensities over 500 BTU/FT/sec. are generally not controllable by ground-based equipment or aerial retardant and present serious control problems including torching, crowning, and spotting.

Predicting the potential behavior and effects of wildland fire is an essential task in fire management. Mathematical surface fire effects and fire effects models and prediction systems are driven in part by fuelbed inputs such as load, bulk density, fuel particle size, heat content, and moisture of extinction. To facilitate use in models and systems, fuelbed inputs have been formulated into fuel models (Scott and Burgan 2005).Table FFR-2 below displays lists of fuel models that are or can be expected to be in the project area over the next 20 years.

Table FFR-1 Probability of fire-induced mortality for ponderosa pine

	CROWN SCORCH VOLUME (PERCENT)									
DBH	**10**	**20**	**30**	**40**	**50**	**60**	**70**	**80**	**90**	**100**
5	49%	53%	60%	68%	78%	86%	93%	97%	99%	99%
6	42%	46%	53%	62%	72%	83%	90%	95%	98%	99%
7	36%	40%	46%	55%	67%	78%	88%	94%	98%	99%
8	30%	34%	40%	49%	61%	74%	85%	93%	97%	99%
9	25%	28%	34%	43%	55%	69%	82%	91%	96%	99%
10	21%	24%	29%	37%	49%	64%	78%	89%	95%	98%
12	15%	17%	21%	28%	39%	53%	69%	84%	93%	97%
14	11%	12%	10%	21%	30%	43%	61%	77%	90%	96%
16	8%	9%	7%	16%	23%	35%	52%	71%	86%	94%
18	6%	7%	6%	12%	18%	29%	45%	65%	82%	93%
20	5%	5%	4%	10%	15%	24%	39%	59%	78%	91%
22	4%	4%	4%	8%	13%	21%	34%	54%	74%	89%
24	3%	4%	3%	7%	11%	18%	31%	50%	71%	87%
26	3%	3%	3%	6%	10%	16%	28%	47%	69%	86%
28	3%	3%	3%	6%	9%	15%	27%	45%	67%	85%
30	3%	3%	3%	6%	9%	15%	26%	44%	67%	85%

Sources/Notes: Table developed by David C. Powell, Forest Silviculturist, Umatilla National Forest, Pendleton, OR. These values are probabilities, expressed as a percent, of ponderosa pine of various diameters being killed by fire. They are based on an equation from Reinhardt and Ryan (1989) and a bark thickness factor from Keane et al. (1989). See Steele et al. (1996) for a description of the calculation methodology. White values on a black background denote combinations of crown scorch and DBH with a mortality probability ≥ 50%.

FOFEM - A First Order Fire Effects Model - is a computer program that was developed to meet needs of resource managers, planners, and analysts in predicting and planning for fire effects. First order fire effects are those that concern the direct or indirect or immediate consequences of fire. First order fire effects form an important basis for prediction secondary effects such as tree regeneration plant succession, and changes in site productivity, but these long-term effects generally involve interaction with many variables (for example, weather, animal use, insects, and disease) and are not predicted by this program. Currently, FOFEM provides quantitative fire effects information for tree mortality, fuel consumption mineral soil exposure, smoke and soil heating.

Table FFR-2 Fuel Models

Fuel Model	Description	Predicted Flame Length (Feet)	Fireline Intensity (BTU/FT/second)
NB9	Bare Ground	0	0
GR1	Short Grass Low Load	0-3	45
GR2	Short Grass Moderate Load	1-8	300
GS2	Grass and Shrub	4-8	500
SH1	Low Load Shrub	0-1	125
SH2	Moderate Load Shrub	1-4	400
SH5	High Load Shrub	12-25	3700
TU1	Low Load Dry Climate Timber-Grass-Shrub	1-4	80
TL1	Recently Burned	0-1	5
TL2	Low Load Broadleaf Litter	0-1	7
TL4	Small Down Log	1-4	25
TL5	High Load Conifer Litter	1-4	50
TL7	Large Down Logs	1-4	50
TL8	Timber Litter	1-4	150
SB4	Blowdown with brush and small tree intermixed	12-25	3000

BehavePlus -The BehavePlus fire modeling system is a PC-based program that is a collection of models that describe fire and the fire environment. BehavePlus is the successor to the BEHAVE fire behavior prediction and fuel modeling system (Andrews 1986, Andrews and Chase 1989, Burgan and Rothermel 1984, Andrews and Bradshaw 1990). It is called the BehavePlus fire modeling system to reflect its expanded scope (Andrews 2007, Andrews and Bevins 1999).

FlamMap (Finney, M. A. 2006.) is designed to examine the spatial variability in fire effects assuming that fuel moisture, wind speed and wind direction are held constant in time thereby allowing for more direct comparison of fuel treatment effects. FlamMap's features allow the user to easily characterize fuel hazard and potential fire effects, as well as investigate fire movement and fuel treatment interactions. The fuel models that are used in this analysis are from publication, Scott and Burgan 2005. Fuel models used are estimates of what the fuel loading and fire effects are currently and what is predicted in the future. The results of the calculations and estimates are intended to show trends and potential effects and are not statistically accurate.

Fire effects modeling uses input variables to calculate fire effects. The three primary variables are fuels, topography and weather. Because fuels are the primary variable that management activity can influence it will be the variable for this analysis.

Table FFR-3 Relationship of Surface Fire Flame Length and Fireline Intensity to Suppression interpretations

Flame length		Fireline intensity		Interpretation
feet	meters	Btu/ft./s	kJ/m/s	
< 4	< 1.2	< 100	<350	• Fires can generally be attacked at the head or flanks by persons using hand tools. • Hand line should hold the fire.
4 – 8	1.2 – 2.4	100 – 500	350 – 1700	• Fires are too intense for direct attack on the head by persons using hand tools. • Hand line cannot be relied on to hold the fire. • Equipment such as dozers, pumpers, and retardant aircraft can be effective.
8 – 11	2.4 – 3.4	500 – 1000	1700 – 3500	• Fires may present serious control problems—torching out, crowning, and spotting. • Control efforts at the fire head will probably be ineffective
> 11	> 3.4	> 1000	> 3500	• Crowning, spotting, and major fire runs are probable. • Control efforts at head of fire are ineffective.

FIRE WEATHER DISCUSSION AND ASSUMPTIONS

For modeling purposes fire weather adjective defined as High (90th percentile weather) was used to predict fire effects in project area. Table FFR-4 below displays the 90th percentile values taking from the Fire Family Plus (Main et. al., 1990) program using the Mount Elizabeth Remote Automated Weather Station during the period of April 1st, 1970 to October 31st, 2013.

Fuel moistures are the rate of change of the moisture content is dependent on the diameter of the woody fuel particle and the amount of change in environment conditions. Historically, the diameters of the woody fuel particles have been classified according to their "time lag". Time lag refers to the length of time that a particle responds to within 63.2% (1-1/e) of the new equilibrium moisture content (either drying or wetting). Larger diameter fuels generally have longer time-lags, meaning they respond more slowly to changes in environmental conditions. The time lag categories traditionally used for fire behavior and fire danger rating are specified as: 1hr, 10hr, 100hr, and 1000hr and correspond to round woody fuels in the size range of: 0-¼", ¼"-1", 1"-3", and 3"-8" (0-.635cm, 0.635-2.54cm, 2.54-7.62cm, and 7.62-20.32cm) respectively. Loadings (weight/area) of dead fuels in these size-classes are required to describe surface fuels for fire modeling (Anderson 1982).

Table FFR-4 Weather Parameters High Conditions (90th Percentile Weather)

Parameter	Value
1 hour fuel moisture (0”-1/4” diameter)	4%
10 hour fuel moisture (1/4”-1” diameter)	5%
100 hour fuel moisture (1”-3” diameter)	7%
1000 hour fuel moisture (3”+ diameter, CWD)	9%
Herbaceous fuel moisture	30%
Woody fuel moisture	70%
20’ wind speed	10mph

Affected Environment

Plant communities within the project boundaries included Westside Ponderosa Pine Forest, Sierran Mixed Conifer Forest, several different chaparral communities such as Montane Manzanita Chaparral and Northern Mixed Chaparral, Montane Meadow, White Alder Riparian Forest, Aspen Riparian Forest, Blue Oak Woodland, and other oak woodland communities (Holland 1986). Many of them burned with a moderate to high intensity in the Rim Fire where the conifer overstory was completely killed.

In addition, past wildfires (prior to the Rim Fire) and the subsequent salvage logging and reforestation activities created over 20,000 acres of young plantations. Many plantations were in various phases of growth and had been thinned in the past 15 years. Due to their mostly early seral nature, the plantation understories had low native plant diversity and were primarily composed of disturbance followers such as non-native annual grasses and native shrubs like deerbrush (Ceanothus integerrimus), manzanita (Arctostaphylos sp.), bearclover (Chamaebatia foliolosa) and Sierra gooseberry (Ribes roezlii).

Pre-Fire Conditions

As with many areas in the Sierra Nevada, the landscape through which the Rim Fire burned has been heavily influenced over the last 150 years by past management activities and natural occurrences that include mining, grazing, harvesting, fire exclusion, large high-severity fires and more recent drought-related mortality during the late 1980’s and early 1990’s. At the stand level, the combination of past management activities, fire exclusion and extensive drought related mortality had created relatively homogeneous areas typified by small trees existing at high densities (Oliver et al. 1996).

Existing Conditions

Existing conditions include past projects (salvage logging, fuels reduction, wildfires and other activities) and present and future projects as listed in Appendix B. This timeframe allows the comparison of alternatives during the time when fuel profiles change significantly after a wildfire and during reforestation and is representative of the fire return interval for the project area.

The 2013 Rim Fire and the salvage and fuel treatments that occurred post fire created low fuel loadings (10 to 20 tons per acre depending on landscape location) within the majority of the reforestation and natural regeneration units, over 20,000 acres. Those units outside of these areas have standing dead small trees and sprouting brush remaining on site and are proposed for initial site preparation (fuels reduction) treatments to remove those fuels Snags and large logs are present in the units to meet resource needs and Forest Plan direction. Duff and litter layers are currently not present at a level that would affect fire behavior. Sprouting vegetation including oaks, bear clover, manzanita and deer brush are abundant throughout the burned area two years post-fire. Out-year fire effects are expected to be dominated by young shrubs, small trees and hardwoods reoccupying the site.

Although burned in the Rim Fire, few of the deer habitat enhancement units were salvage logged post Rim Fire. These areas are on and adjacent to an open lava cap with oak/grasslands, existing plantations and brush fields.

Within the existing plantations, trees range in size from 2 to 16 inches dbh and up to 30 feet tall. The understory vegetation is low, but many plantations are over stocked and have overlapping crowns. Duff layers exist, but are shallow, primarily developing from needle cast and dead woody brush.

Noxious weeds are abundant throughout the project area, some of which create a more flashy fuel situation. As the weeds spread and increase in volume, an increase in ladder fuels occurs. Weeds such as Scotch broom, Medusahead, barbed goatgrass, yellow star-thistle and others, change the arrangement of vegetation, the amount of soil moisture at specific times of the year, the amount of fuel available to burn and how fire behaves (Keeley et al. 2011). Table FFR-5 displays the projected tree mortality within treatment units using the FOFEM 6 modeling program.

Table FFR-5 Projected tree mortality within treatment units by species and size

Species[1]	**DBH Class**	**Average Trees Per Acre**	**Average Tree DBH** (Inches)	**Average Tree Height** (Feet)	**Average Crown Ratio** (Percent)	**Mortality with 2-Foot Flame Length** (Percent)	**Mortality with 4-Foot Flame Length** (Percent)	**Mortality with 10-Foot Flame Length** (Percent)
WF	<1	3.5	0.4	4.4	54	99.0	99.0	99.0
	1	4.3	1.5	7.9	41	99.0	99.0	99.0
	2	1.4	2.5	12.9	38	6.0	99.0	99.0
IC	<1	6.3	0.3	3.7	61	95.0	95.0	95.0
	1	3.3	1.4	7.6	49	95.0	95.0	95.0
	2	1.4	2.4	10.6	47	11.0	95.0	95.0
SP	<1	1.3	0.2	3.6	61	100.0	100.0	100.0
	1	1.5	1.5	7.8	61	100.0	100.0	100.0
	2	0.7	2.5	13.7	38	11.0	100.0	100.0
PP	<1	4.2	0.4	4.5	55	80.0	80.0	80.0
	1	2.8	1.5	9.7	49	79.0	80.0	80.0
	2	2.5	2.4	12.4	59	21.0	80.0	80.0
	3	1.5	3.6	16.0	55	6.0	80.0	80.0
	4	1.2	4.5	20.0	55	6.0	80.0	80.0
	5	1.0	5.5	23.9	62	6.0	80.0	80.0
	6	1.2	6.5	28.1	62	6.0	66.0	80.0
	8	1.1	8.3	35.2	68	6.0	23.0	80.0
DF	<1	3.0	0.3	4.5	80	98.0	98.0	98.0
	1	1.3	1.4	9.7	75	98.0	98.0	98.0
	2	1.0	2.6	14.4	74	52.0	98.0	98.0

Post Fire Conditions

The Rim Fire burned with a range of severities. Within the approximate 257,314 acre fire area: 12, 120 acres were not burned, 50,609 acres were low severity, 87,966 acres were mixed severity, and 106,618 acres were high severity. Trees that were killed by the Rim Fire pose a hazard to the public and forest workers visiting, traveling, and working in these areas (Long 2014). As these snags age, they become less stable and increase the risk to all forest users (Ritchie et. Al. 2013). Once this material is on the ground, fire effects are likely to increase (Long et al 2010). Because of the higher fire effects and risk of hazard trees, suppression strategies will be limited.

In the high severity portions of the fire (approximately 106,618 acres) there are no surface fuels other than occasional patches of shrub, duff, and litter that remain. The standing material consists mainly of scorched trees. The patches of litter that remain will burn but there is no continuity for fire spread.

Ladder fuels and the standing trees were either completely consumed or resulted in only boles remaining. These areas of the fire will not currently support a new large fire or a crown fire.

In the remainder of the burned areas (approximately 150,694 acres) the fire created a mosaic, leaving trees with brown needles and surviving trees as well as surface fuels ranging from completely consumed to pre- fire levels. Fires in this area of the project will burn as a mixed severity fire. A mixed-severity fire exhibits a wide range of effects on the dominant vegetation from little effect on soil heating or overstory vegetation to complete canopy mortality or extensive soil heating.

The Rim Recovery project will treat about 26,893 acres to reduce the existing fuel load of standing dead trees to provide for safe recreation and working conditions as well as to avoid another extreme fire like Rim, which had so many adverse consequences (Long 2014). Many of the Rim Reforestation treatment units overlap the Rim Recovery treatment units.

Environmental Consequences

Alternative 1 (Proposed Action)

DIRECT AND INDIRECT EFFECTS

In Alternative 1, planted conifers would have a better chance of surviving future wildfires due to anticipated surface fuel load reductions through herbicide and other site preparation and release treatments and the incorporated fuelbreaks.

The FOFEM 6 modeling program was used to determine tree mortality within young plantations (approximately 10 years old) from prescribed or natural fire. The data shows that within young plantations where trees are less than 4.5 feet tall, short flame lengths (2 feet) would cause the same mortality (80 to 100% depending on species) as the higher flame lengths (10 feet). As trees grow, the effects of two foot flame lengths lessen quickly and by age 20 most species see less than 10% mortality, but have the same range of mortality (80 to 100%) for 10 foot flame lengths. Ponderosa pine has the lowest mortality as trees grow through time and even by age 10 are seeing this drop in the shorter flame lengths. This species also grows the fastest within young plantations allowing it to reach these larger diameters and heights sooner.

Using empirical data for northern California forests, Weatherspoon and Skinner (1995) found that when wildfire in natural stands spreads to an adjacent plantation, fire intensity and damage to the overstory are much lower in plantations where slash has been removed following logging (Peterson et al. 2009). Until tree age and canopy base heights increase, younger conifer and hardwood stands would be susceptible to increased mortality. Younger trees have thinner bark and low canopy base heights allowing for easier transition to crown fire, even with predicted flame lengths at less than four feet over the majority of the proposed units. Maintaining lower surface fuel levels through follow-up herbicide release treatments on competing vegetation would help reduce tree mortality.

Proposed treatments would alter the spread and effect of fire in the project area. Units were strategically placed to affect fire movement on the landscape and provide advantageous areas for fire suppression actions. As managers continue to move the forest toward the desired condition, fire would be able to resume its natural role in developing and sustaining these ecosystems. Continued management practices can and will alter the effects of wildland fire (Agee and Skinner 2005).

As the vegetation matures, fuel loadings would increase. Continued maintenance through prescribed fire is designed to achieve the desired condition that would maintain fuel profiles allowing fire to resume its ecological role and meet Forest Plan Direction.

Suppression actions would not be restricted by fire behavior; thus direct suppression actions would be possible within the young plantations (Fites et al. 2010).

The effect on fire suppression forces beyond year 20 would depend on the continued maintenance of the plantations. Proposed site preparation and release treatments be followed by the reintroduction of fire into these young stands would help maintain the desired condition and not adversely impact future suppression. FlamMap 5.0 modeling program was used to project fire effects and production rates for Alternative 1. Predicted flame lengths would be less than or equal to four feet for the first 20 years post implementation. Fireline intensity (the rate of energy or heat release per unit length of fire front) would be less than 100 BTU over the next 20 years. This means fires can generally be attacked at the head or flanks by persons using hand tools and hand line should hold the fire.

Alternative 1 utilizes a variety of planting patterns including low density and widely spaced patterns on fuelbreaks and adjacent to emergency travel routes and fewer trees per acre in clumpy patterns in the majority of the landscape where Open Forest Mosaic is the desired future condition. Short-term, within the first 20 years, these different spatial patterns do not lessen tree mortality because of seedling size and the amount of brush present post-reforestation treatments. These patterns also have no effect on flame length, fireline intensity or fuel loading because at this stage of development either small trees or brush will occupy the site and both have similar flammability and burn patterns.

Maintaining fuelbreaks over time would potentially reduce fire size, increase tree survivability and create potential anchor points and contingency lines for suppression resources. Emergency travel routes would create safe ingress/egress routes during wildfire events.

Long-term, the proposed units would create a fire resilient forest with a more historic heterogeneous structure where fire is an integral part of the system in the project area. Unit prescriptions and Strategic Fire Management Areas would affect fire movement on the landscape and provide advantageous areas for fire suppression actions. Commercial thinning could be used to maintain the desired stand structures and shaded fuel breaks as well as fuel treatments within the SFMAs, fuelbreaks and emergency travel routes.

Deer habitat enhancement units would have similar effects as the reforestation units discussed above because they would have similar treatments. In addition, this area calls for more prescribed fire to be utilized for brush reduction and within plantations to maintain smaller pockets of conifers for habitat needs. More frequent prescribed fire would keep the fuel loadings at a lower level.

Within existing plantations, thinning of densely planted stands into an ICO structure would increase survivability by reducing the continuity of fuels and the likelihood of crown fire. In addition, thinning these stands would encourage faster tree growth of the remaining trees, allowing them to become more resilient to future low intensity fires.

Invasive species alter the natural vegetative pattern, often providing more flammable fuels into the system. Eradication of the noxious weeds and their flashy fuel conditions would allow native vegetation to return to these landscapes beneficially affecting fire behavior.

Alternative 1 proposes treatments that would improve and maintain lower fuel levels within newly establishing forests which would not only promote the recovery of this landscape, but allow fire to be an integral part of it. It attempts to ensure long-term tree survival as well as protecting fire fighters and property.

Table FFR-5 displays the projected tree mortality within treatment units using the FOFEM 6 modeling program.

CUMULATIVE EFFECTS

Cumulative effects for Alternative 1 would lower tree mortality within treatment units. In addition, fuels treatments would improve the safety for all users. Fuelbreaks would potentially reduce fire size and increase tree survivability. Fuelbreaks would create safe ingress/egress routes during wildfire

events. Fuelbreaks would also create potential anchor points and contingency lines for suppression resources.

Alternative 1 would, in conjunction with implementation of the Rim Recovery project, enable effective fire suppression action to be conducted on both private and National Forest System (NFS) lands treated. Coordinated fire suppression tactics would be easier to implement across all ownerships.

Alternative 1 serves to enhance the opportunity to achieve the overall goal in the Stanislaus Forest Plan to reintroduce fire. Alternative 1 would serve to reduce fire suppression difficulties in the area as a whole.

Proposed units would alter the spread and effect of fire in the project area. Units were strategically placed to affect fire movement on the landscape and provide advantageous areas for fire suppression actions. As managers continue to move the forest toward the desired condition, fire would be able to resume its natural role in developing and sustaining these ecosystems. Continued management practices can and will alter the effects of wildland fire (Agee and Skinner 2005).

Fuel treatments in the stands would result in fuel characteristics reflective of desirable conditions, where prescribed fire could be used for maintenance and the likelihood of damage to succeeding stands would be reduced.

Previously implemented and foreseeable fire salvage, thinning and fuels treatments on both private and NFS lands, in conjunction with Alternative 1, would enable effective fire suppression action to be conducted. Incorporating fuelbreaks and emergency travel routes into the initial planting design under this alternative would provide connectivity of these features within previously implemented projects. Coordinated fire suppression tactics would be easier to implement across all ownerships. With these conditions, future fires would burn as surface fires with low flame lengths and fireline intensities. These lower-intensity fires could be suppressed using direct attack with handtools.

Table FFR-6 Fire behavior for alternative 1 (Proposed Action) over the next 20 years

Alternative	Post Activity		5 years		10 years		20 years	
	Flame Length (feet)	**Fireline Intensity** (BTU/ft/sec)	**Flame Length** (feet)	**Fireline Intensity** (BTU/ft/sec)	**Flame Length** (feet)	**Fireline Intensity** (BTU/ft/sec)	**Flame Length** (feet)	**Fireline Intensity** (BTU/ft/sec)
1	1	100	2	100	4	100	4	100

Alternative 2 (No Action)

DIRECT AND INDIRECT EFFECTS

In Alternative 2 no planting or associated site preparation and release treatments, which would maintain fuels at a relatively low density, would take place. Existing plantations would remain overstocked with dense contiguous canopies and ladder fuels. In addition, none of the noxious weed eradication or deer habitat enhancement would occur leaving less desirable non-native fuel types throughout the area.

Existing conditions would persist and develop unaltered by active management. It is a reasonable expectation that areas within the Rim Fire would develop in a similar manner as those non-planted areas in other recent local fires. Examples of such fires include the Big Meadow Fire (2009), North Mountain Fire (2008), Early Fire (2004), the Ackerson Fire (1996) and Larson Fire (1987). In those areas, grasses such as cheat grass (Bromus tectorum) and various shrubs including ceanothus (C. cordulatus, C. velutinus) and manzanita (Arctostaphylos patula) now fully occupy the site and limited amounts of conifers have returned. Post-fire vegetation plots taken in proposed reforestation and

natural regeneration units within high burn severity areas show that an average of more than 70% vegetative cover has returned to these areas and less than 40% (including the proposed natural regeneration units) have any natural regeneration.

Figure FFR-1 shows shrub regeneration two years after the Rim Fire. Very few live trees per acre characterize the forest structure following a high-intensity fire, resulting in limited natural conifer regeneration. Over time, ladder and crown fuels would develop where natural regeneration established.

Figure FFR-1 Shrub Regeneration Two Years after the 2013 Rim Fire

Not implementing treatments would result in increased surface fuels and increased crown scorch volume resulting in higher tree mortality on the natural regeneration that does return. Overall, Alternative 2 would not reduce future surface fuels or predicted fire effects in both the reforestation and deer habitat enhancement areas.

None of the proposed fuelbreaks, emergency travel routes, or SFMAs would be maintained over time creating less safe ingress/egress routes for fire firefighters during wildfire events and fewer anchor points for suppression.

Existing over-stocked plantations would remain vulnerable to wildfire since they would not be thinned to the desired ICO structure. Tree mortality would be far higher in these stands where contiguous interlocking crowns would carry wildfire. These unthinned stands would also have higher flame lengths, higher fireline intensity and much higher fuel loading than those thinned in the action alternatives where the ICO structure would create openings and heterogeneity in the fuels across these units. Eradication of noxious weeds and their flashy fuel conditions would not occur. Invasive species would continue to provide more flammable fuels in these areas negatively affecting fire behavior. In the event of a wildfire this would create high tree mortality in the few established trees serious control problems, high suppression costs, and high volumes of smoke emissions.

Over the long term (10+ years), not implementing treatments would result in increased surface fuels. Increased surface fuels would result in increased crown scorch volume. This would lead to increased tree mortality in natural regeneration, firefighter and public risk, and higher costs. Historically fires in the project area were low intensity with less than 25 percent of the stand being killed by fire. Fire

effects under the No Action Alternative would result in higher stand loss as seen in the Rim Fire, with over 50 percent of the stand killed. These fires are expected to kill natural regeneration and residual larger trees. Overall, the No Action Alternative would not reduce potential future surface fuels or predicted fire effects.

CUMULATIVE EFFECTS

Under Alternative 2, the salvage and fuels reduction treatments that occurred under the Rim HT and Rim Recovery projects would still remove hazard trees along Forest Service roads and accomplish the initial reduction of fuels to 10 to 20 tons per acre. Without the maintenance of these fuel levels and the reduction of brush from the action alternatives, much of the gain in the effects to fire behavior would be lost within a few years. When the effects of Alternative 2 are combined with the effects of implementing the foreseeable activities (EIS Appendix B), this alternative would not maintain the SFMAs. Neither would it aid in future fuels management, suppression, or beneficial fire planning objectives. The cumulative effects of No Action would be an increase in fire behavior over time and negative fire effects on the landscape.

Table FFR-7 Fire behavior for alternative 2 over the next 20 years

Alternative	Post Activity		5 years		10 years		20 years	
	Flame Length (feet)	**Fireline Intensity** (BTU/ft/sec)	**Flame Length** (feet)	**Fireline Intensity** (BTU/ft/sec)	**Flame Length** (feet)	**Fireline Intensity** (BTU/ft/sec)	**Flame Length** (feet)	**Fireline Intensity** (BTU/ft/sec)
2*	2	100	4	500	10	Over 1,000	13	Over 1,000
* reflects fire behavior outside Rim Recovery units								

Predicted flame lengths and fireline intensities are displayed in Table FFR-7. Under the Alternative 2, flame lengths exceed 4 feet after five years and are projected to exceed 10 feet within 20 years. Fireline Intensities will exceed 500 BTU/FT/sec after five years and are projected to exceed 1,000 BTU/FT/sec after ten years. Resistance-to-control would be high within the first 10 years and extreme after 20 years. These increased flame lengths, fireline intensities, and resistance-to-control are a direct result of fire burning in dead and down logs, branches, and shrubs. Fires burning in stands under 90th percentile weather conditions in the Alternative 1 are expected to result in serious control problems and high mortality rates of existing stands. Fires may be too intense for direct attack on the head by persons using hand tools. Handline may not be relied on to hold the fire. Fires may present serious control problems torching out, crowning, and spotting, and control efforts at the fire head will probably be ineffective. Under the No Action Alternative, this general trend in high flame lengths (>10 feet), corresponding high fireline intensities, and extreme resistance-to-control problems is expected to continue at least 20 years into the future.

In Alternative 2, survival and growth of natural regeneration that does become established would likely be reduced due to competing vegetation. These sites would be dominated by brush very similar to those effects seen on public lands in the Big Meadow Fire of 2009 and observed in past fires (North Mountain Fire, 2008; Early Fire, 2004; Stanislaus Complex Fire, 1987; and the Ackerson Fire, 1996). This could effectively function as a vegetation type conversion from forest cover to brush cover for nearly a century based on observations from areas left to naturally regenerate in the Wright Creek Fire 1949. Over sixty years later, these areas support natural establishment of white fire, incense cedar, ponderosa pine, and sugar pine; however, the area is dominated by brush species and the tree cover is not sufficient to qualify as forest cover.

Alternative 3

DIRECT AND INDIRECT EFFECTS

Alternative 3 differs from Alternative 1 in the number of acres that would have site preparation and the methods of treatment. No herbicides would be used under this alternative which reduces the site preparation acres by 12,407 and the noxious weed treatments by 2,565 acres, but would treat the same number of deer habitat enhancement acres. In addition, the release treatments would only be grubbing vegetation in five foot radius circles around each seedling which means less than half of the area would have vegetation removed during each treatment (e.g. a unit with 250 seedlings per acre would only grub 45% of the area). This would leave the vegetation adjacent to these circles free to grow uninhibited. Although many of the effects would be similar to Alternative 1, these differences in the amount and size of vegetation on site would likely negatively affect tree mortality, flame length, fireline intensity and fuel loading. The five foot radius circles should break up the continuity enough to make these affects minor within the first 10 years of plantation development.

This alternative proposes to establish fuelbreaks and SFMAs throughout the landscape similar to Alternative 1; the difference is in the fuelbreak design. It proposes increasing the amount of non-planted area within the fuelbreak for ease of maintenance and fire fighter safety during wildfires.

Reforested areas will have a better chance of surviving future wildfires due to anticipated surface fuel load reductions through site preparation. Using empirical data for northern California forests, Weatherspoon and Skinner (1995) found that when wildfire in natural stands spreads to an adjacent plantation, fire intensity and damage to the overstory are much lower in plantations where slash has been removed following logging (Peterson et al. 2009). Until tree age and canopy base heights increase, younger conifer and hardwood stands will be susceptible to increased mortality. Younger trees have thinner bark and low canopy base heights allowing for easier transition to crown fire, even with predicted flame lengths at less than four feet over the majority of the proposed units. However, after the removal of large surface fuels and follow up treatments of competing vegetation, higher survival rates would be expected as trees increase in size and canopy base heights.

Table FFR-5 displays the projected tree mortality within treatment units using the FOFEM 6 modeling program.

CUMULATIVE EFFECTS

Same as Alternative 1.

Table FFR-8 Fire behavior for alternative 3 over the next 20 years

Alternative	Post Activity		5 years		10 years		20 years	
	Flame Length (feet)	**Fireline Intensity** (BTU/ft/sec)	**Flame Length** (feet)	**Fireline Intensity** (BTU/ft/sec)	**Flame Length** (feet)	**Fireline Intensity** (BTU/ft/sec)	**Flame Length** (feet)	**Fireline Intensity** (BTU/ft/sec)
3	1	100	2	100	4	100	4	100

Alternative 4

DIRECT AND INDIRECT EFFECTS

Alternative 4 serves to enhance the opportunity to achieve the overall goal in the Forest Plan to reintroduce fire by proposing prescribed burning on more than 17,000 additional acres within the project area. As managers continue to move the forest toward the desired future condition, fire would be able to resume its natural role in developing and sustaining these ecosystems. Alternative 4 proposes only planting 20% of the area in 2 to 10 acre blocks, but burning the adjacent areas (almost 32,000 acres) every 20 years. It does not propose re-introducing fire into the young plantations at year

10 or creating SFMA areas or features. However, utilizing prescribed fire outside of the reforestation areas to maintain low fuel levels would result in desirable fuel conditions across this landscape and likely prevent damage to young plantation during wildfires. Within the founder stands, none to limited tree mortality would be expected because these areas are being treated with herbicide to maintain a low brush component and provide a treated buffer enabling fire crews to protect them during implementation. However, the founder stand concept of natural regeneration occurring adjacent to these areas as planted trees mature and seed spreads would have high seedling mortality during prescribed fire operations. Burning in a mosaic pattern across the landscape would enable some trees to survive to maturity over time, but most would be lost during implementation. Table FFR-5 displays the projected tree mortality within treatment units using the FOFEM 6 modeling program.

CUMULATIVE EFFECTS

Even though no fuelbreaks or emergency travel routes are proposed in this alternative the amount of prescribed burning throughout the area would provide connectivity of these features within previously implemented and future projects. Coordinated fire suppression tactics would be easier to implement across all ownerships, similar to Alternative 1.

Table FFR-9 Fire behavior for alternative 4 over the next 20 years

Alternative	Post Activity		5 years		10 years		20 years	
	Flame Length (feet)	**Fireline Intensity** (BTU/ft/sec)	**Flame Length** (feet)	**Fireline Intensity** (BTU/ft/sec)	**Flame Length** (feet)	**Fireline Intensity** (BTU/ft/sec)	**Flame Length** (feet)	**Fireline Intensity** (BTU/ft/sec)
4	1	100	2	100	4	100	4	100

Alternative 5

DIRECT AND INDIRECT EFFECTS

Alternative 5 is similar to Alternative 1. Although the initial planting design does not propose Strategic Fire Management Areas or Features, the pre-commercial thinning at age 7 would create these desired structures. Not re-introducing fire into the plantations would lower the tree mortality in these stands in the short-term, but in the long-term increase the flame length, fireline intensity and fuel loading.

Reforested areas will have a better chance of surviving future wildfires due to anticipated surface fuel load reductions through site preparation. Using empirical data for northern California forests, Weatherspoon and Skinner (1995) found that when wildfire in natural stands spreads to an adjacent plantation, fire intensity and damage to the overstory are much lower in plantations where slash has been removed following logging (Peterson et al. 2009). Until tree age and canopy base heights increase, younger conifer and hardwood stands will be susceptible to increased mortality. Younger trees have thinner bark and low canopy base heights allowing for easier transition to crown fire, even with predicted flame lengths at less than four feet over the majority of the proposed units. However, after the removal of large surface fuels and follow up treatments of competing vegetation, higher survival rates would be expected as trees increase in size and canopy base heights. Table FFR-5 displays the projected tree mortality within treatment units using the FOFEM 6 modeling program.

CUMULATIVE EFFECTS

Same as Alternative 1.

Table FFR-10 Fire behavior for alternative 5 over the next 20 years

Alternative	Post Activity		5 years		10 years		20 years	
	Flame Length (feet)	**Fireline Intensity** (BTU/ft/sec)	**Flame Length** (feet)	**Fireline Intensity** (BTU/ft/sec)	**Flame Length** (feet)	**Fireline Intensity** (BTU/ft/sec)	**Flame Length** (feet)	**Fireline Intensity** (BTU/ft/sec)
5	1	100	2	100	4	100	4	100

Summary of Effects Analysis across All Alternatives

All action alternatives serve to lower fire behavior and reduce fire effects by increasing the opportunities for suppression resources to contain fires spreading between the private and public interface. Fire effects are negligible under all action alternatives as fires can be contained by handline. All action alternatives would have the same flame length over first 20 years post planting. Alternative 2 is projected to have double the flame length over the first 5 years and over three times the flame length by year 20 (13 feet compared to only 4 feet). Fireline intensity inside treated units would be the same for all action alternatives, but Alternative 2 would be far higher after just five years (100 versus 500) and by age 20 it is projected to be 10 times the rate present in the treated units.

Table FFR-11 Fire effects by Alternative over the next 20 years

Alternative		Post Activity		5 years		10 years		20 years	
		Flame Length (feet)	**Fireline Intensity (BTU/ft/sec)**	**Flame Length (feet)**	**Fireline Intensity (BTU/ft/sec)**	**Flame Length (feet)**	**Fireline Intensity (BTU/ft/sec)**	**Flame Length (feet)**	**Fireline Intensity (BTU/ft/sec)**
1	Ac	1	100	2	100	4	100	4	100
2*	Ac	2	100	4	500	10	Over 1,000	13	Over 1,000
3	Ac	1	100	2	100	4	100	4	100
4	Ac	1	100	2	100	4	100	4	100
5	Ac.	1	100	2	100	4	100	4	100
* reflects fire behavior outside Rim Recovery units									

In the short-term (20 years) the difference in tree characteristics effecting fire related mortality between alternatives is negligible. However, the action alternatives are designed to help protect forest stands through the incorporation of fuelbreaks and travel routes or vegetation control that would aid in fire suppression effectiveness and increase the likelihood of tree survival.

Table FFR-12 Predicted average tree mortality

Approximate Tree Mortality										
Species	**0 to 1 inch dbh**		**2 to 6 inch dbh**		**7to 11 inch dbh**		**12 to 24 inch dbh**		**> 24 inch dbh**	
	2' FL	**4' FL**	**2' FL**	**4' FL**	**2' FL**	**4' FL**	**2' FL**	**4' FL**	**2' FL**	**4' FL**
ABCO - White Fir	99%	99%	14%	99%	3%	12%	3%	3%	3%	3%
CADE27 - Incense Cedar	95%	95%	6%	95%	1%	90%	1%	1%	1%	1%
PILA - Sugar Pine	100%	100%	24%	100%	11%	32%	11%	11%	11%	11%
PIPO - Ponderosa Pine	80%	80%	7%	80%	6%	18%	6%	6%	6%	6%
PSME - Douglas Fir	98%	98%	76%	98%	12%	98%	12%	12%	12%	12%

Alternative 2, no action, surface fuels are projected to average 46 tons per acre outside of Rim Recovery project units within 10 years and 78 tons per acre within 30 years. The amount of fuels on the ground would rate this alternative as an extreme resistance-to-control problem (Brown et. Al. 2003). Alternative 2 would be colonized by grasses, forbs, and shrubs within three to five years. It is a reasonable expectation that non-reforested stands would develop comparable to that of similar non-reforested stands in local fires that burned in the recent past. In this alternative there would be a type conversion from forested stands to brush fields with little to no trees.

Air Quality Report

This report addresses the issues and opportunities for Air Quality within the Rim Fire Reforestation project.

Analysis Framework: Statute, Regulation, Forest Plan and Other Direction

The Federal Clean Air Act (CAA) of 1963, as amended in 1990, is the basis for national control of air pollution. The CAA was designed to "protect and enhance" the quality of the nation's air resources. Basic elements of the CAA include national ambient air quality standards (NAAQS) for criteria air pollutants, technology based emission control standards for hazardous air pollutants, state attainment plans, a comprehensive approach to reducing motor vehicle emissions, control standards and permit requirements for stationary air pollution sources, acid rain control measures, stratospheric ozone protection, and enforcement provisions.

The California Clean Air Act of 1988 provides the basis for air quality planning and regulation in California independent of federal regulations and establishes ambient air quality standards for the same criteria pollutants as the federal clean air legislation. Under the federal CAA, States can adopt air quality standards that are more stringent than the federal NAAQS. California adopted standards for criteria pollutants that are generally more restrictive than the federal standards. The California Air Resources Board (CARB) is the agency responsible for establishing California ambient air quality standards (CAAQS).

The Calaveras, Tuolumne and Mariposa County Air Pollution Control Districts (APCD) are responsible for implementing and regulating air quality programs in the Stanislaus National Forest.

The Forest Plan Compliance (project record) document identifies the Forest Plan Standards and Guidelines that specifically apply to this project and related information about compliance with the Forest Plan.

Air Quality Management Practices

Smoke from prescribed fire is managed so that emissions meet applicable state and federal standards. Prescribed fires are regulated and authorized by the local Air Pollution Control District (APCD) and the California Air Resources Board (CARB) under the process established by the California Smoke Management Program (Title 17). The legal basis of the program is found in the Smoke Management Guidelines for Agricultural and Prescribed Burning adopted by the CARB on March 23, 2001 (CARB 2001). The Guidelines provide the framework for State and local air district regulators to conduct the program. Elements of the program include:

- Registering and Permitting of Agricultural and Prescribed Burns
- Meteorological and Smoke Management Forecasting
- Daily Burn Authorization
- Enforcement

The 1990 Clean Air Act (CAA) amendments and the 1998 EPA Interim Policy on Wildland and Prescribed Fire form the federal requirements and guidance behind the California program (Ahuja et al. 2006). Burn days are allocated by the responsible air quality regulatory agency when dispersion conditions are most likely to prevent exposure to unhealthy smoke concentrations. Allocations are considered on a cumulative potential for the air basin by regulatory review of a unified reporting system, the Prescribed Fire Information Reporting System (PFIRS), maintained by the CARB (CARB 2012). The reporting system and a daily conference call between regulatory meteorologists, resource agency meteorologists, and resource agency fire managers allow for a daily discussion of ongoing events, smoke dispersion, allocations, and burn approval outlook. The objective of this system is to facilitate fuel treatment and minimize smoke exposure to the public.

In the spring of 2011, staff of the CARB, Federal and State Land Management Agencies, and Air Districts in California worked together to revise the policy that governs the management of naturally ignited fires. The protocol, entitled "Coordination and Communication Protocol for Naturally Ignited Fires" (CARB 2011), establishes a framework from which smoke and emission impacts from wildfires would be minimized through fire suppression techniques and improved public awareness.

- The Forest Service utilizes Best Available Control Measures (BACMs) and Best Smoke Management Practices (BSMPS) to reduce particulate emissions (NRCS 2011). BACMs are a combination of practices intended to reduce emissions to the lowest practicable amount. BACMs are accomplished by diluting or dispersing emissions, or by preventing potential emission sources whenever possible. Examples of BACMs include: Reducing pollutants by limiting the mass of material burned, burning under moist fuel conditions when broadcast burning, shortening the smoldering combustion period, and increasing combustion efficiency by encouraging the flaming stage of fire when burning piles.
- Diluting pollutant concentrations over time by reducing the rate of release of emissions per unit area, burning during optimum conditions, and coordinating daily and seasonally with other burning permittees in the area to prevent standard exceedances.

Effects Analysis Methodology

Smoke emissions were calculated for machine pile burning, jackpot burning, understory burning and wildfires. Greenhouse gas emissions were calculated.

Assumptions Specific to Air Quality

- Emissions were calculated using the formula [$\mathbf{E_i}$ (tons) equals (**A** multiplied by **FL** multiplied by **percent C** multiplied by $\mathbf{EF_i}$) all divided by 2000 to convert pounds to tons]; where:
  - $\mathbf{E_i}$ equals Emissions in tons for the emission type (e.g. $PM_{2.5}$ or NOx or CH_4);
  - **A** equals Area in acres;
  - **FL** equals Fuel Loading in tons per acre;
  - **percent C** equals percent fuel consumed; and,
  - $\mathbf{EF_i}$ equals Emission factor for the type (in pounds per ton of dry fuel consumed).
- Percent combustion under pile burning is 100%.
- Percent combustion under jackpot burning is 50%.
- Percent combustion with understory burn is 50%.
- Jackpot burns are similar to understory burns.
- EFs for pile, understory burns and jackpot burns were derived from Hardy et al. 2001: PM_{10} equals (12.4, 25), $PM_{2.5}$ equals (10.8, 22), CH_4 equals (11.4, 8.2), NMHC equals (8, 6.4), CO equals (153, 178), CO_2 equals (3271, 3202), NO_x equals (6, 6), SO_x equals (2.4, .2.4).
- GWP (Global Warming Potential) factor for greenhouse gas conversion to CO_2 equivalent metric tons from IPCC 2007.
- Wildfire emissions were based on a wildfire burning under 90th percentile weather conditions at year 20 for all scenarios.

Data Sources

- First Order Fire Effects Monitoring Program
- CARB (2010)
- EPA (2012)
- Inciweb (2013)
- IPCC (2007)
- Placer County Air Pollution Control District (2008) and Executive Office et al. (2008)
- Springsteen et al. (2011)
- Tarnay (2014)

Air Quality Indicators

The Clean Air Act lists 189 hazardous air pollutants to be regulated. Some components of smoke, such as polycyclic aromatic hydrocarbons (PAH) are known to be carcinogenic. Probably the most carcinogenic component is benzo(a)pyrene (BaP). Other components, such as aldehydes, are acute irritants. In 1994 and 1997, 18 air toxins were assessed relative to the exposure of humans to smoke from prescribed and wildfires. The following seven pollutants are most commonly found in smoke from fire:

- **Particulate Matter** ($PM_{2.5}$ and PM_{10} a criteria pollutant): Particulates are the most prevalent air pollutant from fires and are of the most concern to regulators. Research indicates a correlation between hospitalizations for respiratory problems and high concentrations of fine particulates. $PM_{2.5}$ are fine particles that are 2.5 microns in diameter or less in size. PM_{10} are fine particles that are between 10 and 2.5 microns in diameter or less in size. Particulates can include carcinogens and other toxic compounds. Overexposure to particulates can cause irritation of mucous membranes, decreased lung capacity and impaired lung function.
- **Methane** (CH_4): Methane is an odorless, colorless flammable gas. Short-term exposure to methane may result in feeling tired, dizziness and headache. No long-term health effects are currently associated with exposure to methane. Methane is a greenhouse gas (GHG) and contributes to global climate warming (IPCC 2007).
- **Carbon Monoxide** (CO a criteria pollutant): Carbon monoxide reduces the oxygen carrying capacity of the blood, a reversible effect. Low exposures can cause loss of time awareness, motor skills and mental acuity. Also, exposure can lead to heart attacks, especially for persons with heart disease. High exposures can lead to death due to lack of oxygen.
- **Carbon Dioxide** (CO_2): Carbon dioxide is a colorless, odorless and non-poisonous gas formed by combustion of carbon and in the respiration of living organisms. Carbon dioxide is the primary GHG emitted through human activities. Greenhouse gases act like a blanket around the Earth, trapping energy in the atmosphere and causing it to warm. The buildup of GHGs can change the Earth's climate and result in dangerous effects to human health and welfare and to ecosystems (IPCC 2007).
- **Nitrogen Oxide** (NO_x a precursor to O_3): Nitrogen oxide is a group of different gases made up of different levels of oxygen and nitrogen. Nitrogen dioxide (NO_2 a criteria pollutant) is a reddish-brown gas. Small levels can cause nausea, irritated eyes and/or nose, fluid forming in lungs and shortness of breath. Breathing in high levels can lead to rapid, burning spasms, swelling of throat, reduced oxygen intake, a larger buildup of fluids in lungs and/or death. N_2O is a GHG and contributes to global warming.
- **Ozone** (O_3 a criteria pollutant) is the most widespread air quality problem in the state according to the CARB (2010). It is not emitted directly but is formed from reactions of hydrocarbons and NO_x in the presence of sunlight. It can cause reduced lung function and irritated eyes, nose and throat. It is known to cause damage to some vegetation, including ponderosa pine and Jeffrey pine trees (Procter et al. 2003).
- **Sulfur Oxide** (SO_x a criteria pollutant): Short-term exposure to high enough levels of sulfur dioxide (SO_2) can be life threatening. Generally, exposures to SO_2 cause a burning sensation in the nose and throat. SO_2 exposure can cause difficulty breathing, including changes in the body's ability to take a breath or breathe deeply, or take in as much air per breath. Long-term exposure to sulfur dioxide can cause changes in lung function and aggravate existing heart disease. Asthmatics may be sensitive to changes in respiratory effects due to SO_2 exposure at low concentrations. Sulfur dioxide is not classified as a human carcinogen (it has not been shown to cause cancer in humans). SO_x is not an issue in the state and has not been analyzed.

The Rim Reforestation project area is located in Tuolumne County and Mariposa County, California. The direct, indirect and cumulative effects analysis area for the air quality section of this report is the Tuolumne and Mariposa APCDs located in the Mountain Counties Air Basin.

Affected Environment

Existing Conditions

According to the EPA Green Book, updated January 30, 2015, Tuolumne and Mariposa counties are Designated Non-Attainment Areas for ozone; the project area falls within these two counties. The Emigrant Wilderness and Yosemite National Park are Federal Class 1 areas adjacent to the project area. The San Joaquin Valley, a non-attainment area, runs along the western boundary of the project area. The Forest Service follows the guidelines assigned by the CARB [ozone State Implementation Plan (SIP), visibility SIPs, and Title 17] to limit state-wide exposure on a cumulative basis, in compliance with the Clean Air Act (CARB 2001; 2008).

Air quality from the Rim Fire reached unhealthy levels from Yosemite to the San Joaquin Valley, according to an alert from the National Weather Service. People were advised to avoid strenuous outdoor activity or to remain indoors because fine particles in smoke can irritate the eyes and respiratory system and aggravate chronic heart and lung disease. Figure AQR-1 shows the smoke from the Rim Fire in the Groveland area and how people responded by wearing filtering devices.

Figure AQR-1 Smoke from the Rim Fire billows over Groveland and affects air quality

Environmental Consequences

Effects Common to all Alternatives

Implementation of the initial site preparation activities of either pile burning or understory/jackpot burning depends on seasonal climate conditions and budget. Emissions comparisons are based on understory/jackpot burning which produce the highest emissions of analyzed prescribed fire treatments. Although understory/jackpot burning have the highest prescribed fire emissions, they are still lower than wildfire emissions as shown in the tables below. Emissions for all the alternatives including Alternative 2 (the no action alternative serves as the control) are shown the following tables grouped by treatments: Prescribed Fire in Table AQR-1; Wildfires in Table AQR-2; and, Greenhouse Gases in Table AQR-3 and Table AQR-4.

DIRECT AND INDIRECT EFFECTS

Prescribed Fires

Table AQR-1 displays emissions for understory/jackpot burning. Burning would be completed under approved burn and smoke management plans. Given the ability to control ignition times to favor good smoke dispersion, it is not anticipated that prescribed burning would impact the local communities. Smoke would be transported to the northeast by typically southwest winds during the day. At night, some smoke from smoldering burns in the project area may move down drainages. Piles would be burned under weather conditions that would allow efficient combustion.

Table AQR-1 Alternatives 1, 2, 3, 4 and 5: Emissions under understory and jackpot burning (tons)

Emissions (tons)	**Alternative 1** (16,696 acres)	**Alternative 2** (0 acres)	**Alternative 3** (16,696 acres)	**Alternative 4** (19,362 acres)	**Alternative 5** (16,696 acres)
PM_{10}	3,131	0	3,131	4,175	3,131
$PM_{2.5}$	2,755	0	2,755	3,674	2,755
CH_4	1,027	0	1,027	1,369	1,027
NMHC	801	0	801	1,069	801
CO	22,289	0	22,289	29,726	22,289
CO_2	400,954	0	400,954	534,725	400,954
NO_x	751	0	751	1,002	751
Totals	**431,708**	**0**	**431,708**	**575,740**	**431,708**

Generally, $PM_{2.5}$ emissions are the dominant public health risk and can be viewed as the primary indicator. The total treatment acres and emissions displayed have value as a relative comparison of alternatives but not as an assessment of public exposure since the fuel treatments will take place over multiple years and multiple times during each year. Public exposure of smoke emissions will be mitigated by the daily burn day permission and allocation from the California Air Resources Board and the local air pollution control districts. The objective of this program is to mitigate public exposure below health risk thresholds. Most likely the total emissions occurring on any particular burn day may not be allowed to exceed 100 to 200 tons of $PM_{2.5}$ irrespective of the action alternative.

Wildfires

Emissions from wildfires within the project area were modeled. Table AQR-2 is based on the First Order Fire Effects Model (FOFEM 6.0), the 90th percentile weather for the project area and the estimated fuel loading under each Alternative at year 20 (Boucher 2014). For Alternative 2, the 19,362 acres identified in Alternative 4 were used for the smoke emission analysis. Alternative 2 generates the maximum emissions compared to all other alternatives. This demonstrates the emissions savings that can be generated from prescribed burn treatments as opposed to wildfire scenarios.

Table AQR-2 Alternatives 1, 2, 3, 4 and 5: Smoke Emissions at Year 20 (Wildfire Conditions, tons)

Emissions (tons)	**Alternative 1** (16,696 acres)	**Alternative 2** (19,362 acres)	**Alternative 3** (16,696 acres)	**Alternative 4** (19,362 acres)	**Alternative 5** (16,696 acres)
PM_{10}	3,757	10,020	3,757	5,010	3,757
$PM_{2.5}$	3,306	8,817	3,306	4,409	3,306
CH_4	1,232	3,287	1,232	1,643	1,232
NMHC	962	2,565	962	1,283	962
CO	26,747	71,341	26,747	35,671	26,747
CO_2	481,145	1,283,340	481,145	641,670	481,145
NO_x	902	2,405	902	1,202	902
Totals	**518,051**	**1,381,775**	**518,051**	**690,888**	**518,051**

Table AQR-3 displays the GHG produced from understory burning and jackpot burning. There are no GHGs generated under Alternative 2 because no jackpot or pile burning occurs.

Table AQR-3 Alternatives 1, 2, 3, 4 and 5: Greenhouse Gas Emissions (Prescribed Burning)

CO_2 Equivalent (metric tons)	**Alternative 1** (Proposed Action)	**Alternative 2** (No Action)	**Alternative 3**	**Alternative 4**	**Alternative 5**
CH_4	1,027	0	1,027	1,369	1,027
CO_2	400,954	0	400,954	534,725	400,954
N_2O	751	0	751	1,002	751
Totals	**402,732**	**0**	**402,732**	**537,096**	**402,732**

Table AQR-4 displays the GHG produced by wildfires for all alternatives.

Table AQR-4 Alternatives 1, 2, 3, 4 and 5: Greenhouse Gas Emissions (Wildfire Conditions)

CO_2 Equivalent (metric tons)	**Alternative 1** (Proposed Action)	**Alternative 2** (No Action)	**Alternative 3**	**Alternative 4**	**Alternative 5**
CH_4	1,232	3,287	1,232	1,643	1,232
CO_2	481,145	1,283,340	481,145	641,670	481,145
N_2O	902	2,405	902	1,202	902
Totals	**483,279**	**1,289,032**	**483,279**	**644,515**	**483,279**

CUMULATIVE EFFECTS

Additional projects within and adjacent to the project area utilizing prescribed burning include: Rim Recovery, Two-mile Ecological Restoration: Vegetation Management, Soldier Creek Timber Sale, Reynolds Creek Ecological Restoration and several thousand acres of pile burning on private land. California's Smoke Management Program (Title 17) is designed to prevent cumulative effects from prescribed fire operations. The program provides allocations of emissions based on the airshed capacity and forecasted dispersal characteristics. The allocation process considers all burn requests, meteorological conditions, forecasted air pollution levels (similar to the BSMPs described by the NRCS 2011) and uncontrollable events like wildfire. Wildfire emissions can overwhelm air basins and most prescribed burn requests are denied during wildfire events. As a result of the California Smoke Management Program and agency oversight, none of the action alternatives are expected to contribute toward air quality cumulative effects.

Alternative 1 (Proposed Action)

DIRECT AND INDIRECT EFFECTS

The wildfire emissions for $PM_{2.5}$ and other pollutants are lower under Alternative 1 as compared to Alternative 2. The total GHGs produced are 402,732 CO_2 equivalent metric tons from prescribed fire treatments.

CUMULATIVE EFFECTS

Cumulative Effects would be similar as described under Effects Common to all Alternatives

Alternative 2 (No Action)

DIRECT AND INDIRECT EFFECTS

Alternative 2 does not treat any acres and therefore no emissions are displayed for understory and jackpot burning. Under Alternative 2, no pile burning, understory burning or jackpot burning occur; therefore, smoke would not be directly generated from management activities. Lightning and human caused ignitions are expected to continue within the perimeter of the Rim Fire. Table AQR-2 shows

that under a wildfire scenario during 90th percentile weather conditions at year 20, $PM_{2.5}$ emissions for Alternative 2 would be 8,817 tons as compared to 3,306 tons under Alternative 1.

Although Alternative 2 would not produce GHGs tied to the management actions defined in the other alternatives it would likely produce the highest level of GHGs as a result of wildfires. The 2013 Rim Fire consumed about 257,000 acres and produced 11 million tons of GHGs as CO_2 equivalent metric tons (Tarnay 2014). Table AQR-4 shows about 1.3 million tons of GHG would be produced from 19,362 wildfire acres under Alternative 2.

Where wildfires cannot be contained and they burn into heavy fuels, it is expected that heavy smoke from fire burning or smoldering in downed logs would result. This smoke would be blown to the northeast towards Yosemite National Park, a Federal Class 1 area, by typical southwest winds during the day. At night, smoke from a fire in this area would move down the drainages and likely cause impacts to the San Joaquin Valley.

CUMULATIVE EFFECTS

The cumulative effects from other projects would be the same as described under Effects Common to all Alternatives. However, when the effects from Alternative 2 are added, the cumulative effects are also much higher than the action alternatives.

Alternative 3

DIRECT AND INDIRECT EFFECTS

Same as Alternative 1.

CUMULATIVE EFFECTS

Same as Alternative 1.

Alternative 4

DIRECT AND INDIRECT EFFECTS

Alternative 4 includes the highest amount of prescribed burning. Alternative 4 reintroduces fire to the landscape, but does not reduce the existing fuel loading as much as the other action alternatives. Under this Alternative, treatment emissions will be higher than Alternatives 1, 3 and 5. Alternative 4 will create the most emissions under a wildfire when compared to all other action alternatives. The wildfire emissions for $PM_{2.5}$ and other pollutants are lower under Alternative 4 as compared to Alternative 2. The total GHGs produced are 537,096 CO_2 equivalent metric tons from prescribed fire treatments.

CUMULATIVE EFFECTS

Cumulative effects would be similar as described under Effects Common to all Alternatives.

Alternative 5

DIRECT AND INDIRECT EFFECTS

Same as Alternative 1.

CUMULATIVE EFFECTS

Same as Alternative 1.

Summary of Effects Analysis across All Alternatives

Table AQR-1 displays total emissions for understory and jackpot burning for each alternative. Total emissions from wildfires were generated using the 90th percentile weather, fuel loading at year 20 and multiplied by the number of acres treated for each alternative except Alternative 2. For

Alternative 2, the 19,362 acres identified in Alternative 4 were used for the smoke emission analysis. Areas outside treatment units would experience similar fire behavior, which would result in similar emissions. The expected amount of smoke emissions under wildfire conditions outside of areas previously treated to meet desired fuel loading at year 20 would be 2.6 times more for all types of emissions, as shown in Table AQR-2.

The project is located in an area designated as non-attainment for ozone. Ozone is known to impact human respiratory function and the health and vigor of some vegetation including ponderosa and Jeffry pine (Procter et al, 2003). The burn treatments under Alternatives 1, 3, 4 and 5 will be conducted under an EPA approved California Smoke Management Program (SMP). Under the revised Conformity Rules the EPA has included a Presumption of Conformity for prescribed fires that are conducted in compliance with a SMP; therefore, the federal actions will be presumed to conform and no separate conformity determination will be made. The California Smoke Management Program provides for the allocation of emissions from biomass burning with respect to cumulative effects. Biomass burning projects are regulated and coordinated by air quality regulatory jurisdictions and all entities submitting burns for approval. In making those decisions, air quality regulators consider forecasts, dispersion conditions, locations of proposed projects and background air quality by air basin. These considerations have historical success in preventing cumulative effects of smoke.

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