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Fire and Fuels Resource Report

Westside Fire Recovery Project

Happy Camp Oak Knoll and Salmon/Scott River Ranger Districts
Klamath National Forest
Yreka, California

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Table of Contents

Executive Summary 1
Methodology 1
Overview of Methodology 1
Analysis Indicators 1
Spatial and Temporal Context 2
Affected Environment 2
Environmental Consequences 3
Alternative 1 3
Direct Effects and Indirect Effects 3
Cumulative Effects 4
Alternative 2 5
Direct Effects and Indirect Effects 5
Cumulative Effects 10
Alternative 3 11
Direct Effects and Indirect Effects 11
Cumulative Effects 11
Alternative 4 11
Direct Effects and Indirect Effects 11
Cumulative Effects 12
Alternative 5 12
Direct Effects and Indirect Effects 12
Cumulative Effects 12
Comparison of effects 13
Compliance with law, regulation, policy, and the Forest Plan 13
Fire and Fuels Report 14
Introduction 14
Methodology 14
FUELS 14
WEATHER 15
TOPOGRAPHY 15
Detailed Methodology 16
FUELS 17
WEATHER 19
FIRE MODELING 20
Analysis Indicators 21
Fire Hazard 22
Resistance to Control 23
Spatial and Temporal Bounding of Analysis Area 24
Affected Environment 24
Fire History 24
Fuels 27

Pre-fire Condition 27
Post Fire Conditions 29
Weather 32
Topography 33
Fire Behavior Synopsis 33
Resistance to Control 35
Environmental Consequences 35
Alternative 1 35
Direct and Indirect Effects 36
Cumulative Effects 52
Alternative 2 52
Direct and Indirect Effects 52
Cumulative Effects 77
Alternative 3 79
Direct Effects and Indirect Effects 79
Cumulative Effects 82
Alternative 4 83
Direct Effects and Indirect Effects 83
Cumulative Effects 84
Alternative 5 85
Direct Effects and Indirect Effects 85
Cumulative Effects 87
Literature Cited 88
Appendix A: Fire Modeling Assumptions 91
Forest Vegetation Simulator and Fire and Fuels Extension – FVS-FFE 91
Flammap 91
BehavePlus 92

List of Tables

Table S-1: Potential fire behavior (by acreage) over the span of 50 years within the Westside Fire Recovery Project Area 4
Table S- 2: Comparison of post-fire effects of alternatives on fire and fuels after 10 years 13
Table 1. Geospatial layers utilized to model fire behavior across the landscape and units proposed for treatment (Table definitions referenced from Landfire.gov). 16
Table 2. Scott and Burgan Standard (2005) Fire Behavior Fuel Model Parameters. 18
Table 3. Remote Automated Weather Stations Included in Climatological Analysis in determination of 90th percentile weather. 20
Table 4. 90th percentile weather conditions utilized for modeling fire behavior. 20
Table 5. Canopy fuel loading by size class. 21
Table 6. Relationship of flame length and fireline intensity to fire suppression actions. 23
Table 7. Line production rates for initial actions per person and sustained line production for Type 1 Handcrew in chains per hour. 23
Table 8. Resistance to control ratings based on tons per acre. 24
Table 9 . Wildfire ignition by cause and total acreage burned. 25
Table 10. Wildfire ignition by size class. 25
Table 11. Acreage burned by decade. 26

Table 12. Vegetation type in relation to potential fire behavior effects....28
Table 13. Fire (Vegetation Burn) Severity (Basal Area Loss) within the Westside Fire Recovery project area....29
Table 14. Predicted Fire Behavior 1-5 Years....36
Table 15. Projected fire behavior 10 to 20 years post fire with no disturbance activities. 38
Table 16. Potential fire behavior by vegetation type within high severity fire areas 10 years.. 38
Table 17. 10 to 20 Year potential flame length within the Westside Fire Recovery Project Area. 39
Table 18. 10 to 20 year potential fireline intensity within the Westside Project Area....39
Table 19. Future surface fuel loading and fire behavior potential over 50 years within the Beaver fire area. 41
Table 20. Future surface fuel loading potential over 50 years within the Happy Camp Complex. 44
Table 21. 50 year potential flame length within the Westside Project Area....47
Table 22. 50 year potential fireline intensity within the Westside Project Area....48
Table 24: Comparison of surface fuel loading between Alternatives 1 and 2 over 50 years in the Happy Camp Complex 61
Table 25. Comparison of fire behavior 1 to 5 years post fire. 68
Table 26. Potential fire behavior 10 years post treatment....69
Table 27. Crown fire initiation potential based on canopy base height and flame length. 70
Table 28. Comparison of potential flame length between Alternatives 1 and 2 over 10 years....73
Table 29. Comparison of potential fireline intensity between Alternatives 1 and 2 over 10 years. 73
Table 30. Salvage units that provide an additional fire management benefit. 76
Table 31. Ongoing and foreseeable projects reviewed for Cumulative Effects....77
Table 32. Comparison of potential flame length between Alternatives 1 and 2 greater than 20 years....78
Table 33. Comparison of potential fireline intensity between Alternatives 1 and 2 greater than 20 years. 78
Table 34. Comparison of project flame lengths 10 years post treatment....79
Table 35. Comparison of projected fireline intensities 10 years post treatment....80
Table 36. Salvage units that provide an additional fire management benefit. 82
Table 37. Salvage units that provide an additional fire management benefit. 84
Table 38. Comparison of projected flame lengths 10 years post treatment....84
Table 39. Comparison of projected fireline intensity 10 years post treatment. 84
Table 40. Comparison between alternatives of projected flame lengths 10 years post treatment. 85
Table 41. Comparison between alternatives of projected fireline intensity 10 years post treatment....85
Table 42. Salvage units that provide an additional fire management benefit. 86

List of Figures

Figure S-1: Representative stand from the Walker Creek Drainage with and without salvage harvest and treatment of activity fuels 7
Figure 1. Summary of the acreage burned by decade within the Westside Fire Recovery Project area....26
Figure 2. Spatial Large Fire History within and adjacent to the Westside Fire Recovery Project....27
Figure 3. Spatial Distribution of Pre-fire Vegetation across the Westside Fire Recovery Project 29
Figure 4. Example of high severity fire effects (Happy Camp Complex) 30
Figure 5. Canopy view of high fire severity patch (Whites Fire) 30
Figure 6. Moderate to High Severity Fire within surface and mid-story canopy fuels....31
Figure 7. Moderate to High Severity Fire within the canopy fuels....31
Figure 8. Low severity fire effects (Whites Fire)....32
Figure 9. Surface fire activity under inversion layer on the Beaver Fire occurred when the weather conditions and terrain created inversion layers trapping smoke above the fire resulting in decreased solar radiation, decreased temperatures and increased fuel moistures dampening fire behavior....34

Figure 10. Fire activity once inversion layer lifted during the Beaver Fire resulting in extreme fire behavior and subsequent high fire severity on approximately 40% of the Westside Fire areas (Photo from Plot 6 FBAT time lapse video)....35
Figure 11. Untreated fuels within the footprint of the 2002 Stanza Fire. Note the volume of standing and felled snags intermixed with brush. Photo taken June 2012, 10 years post fire....37
Figure 12. Paired photo from a fixed point in overlapping area of the Chips and Storrie fires (Photo from Chips Fire Behavior Case Study, 2012)....37
Figure 13. Potential flame lengths based on 90th percentile weather conditions 10 to 20 years post fire..40
Figure 14. Potential flame lengths based on 90th percentile weather conditions 50 years post fire....47
Figure 15. Firefighters survey multiple burning snags and employ tactics to safely build line to control the fire. The weakened trees pose a risk to firefighters, both from falling over and producing spot fires ahead of the main fire....49
Figure 16. Big Meadow Fire (2009) burning within the A-Rock Fire (1996) scar. Standing snags promoted spot fire ignition greater than .25 miles ahead of the main fire. Large downed fuels created fuel beds receptive to embers and burning intensely for long periods of time. 50
Figure 17. Indirect control line on the Butler Fire (2013), Klamath/Six Rivers National Forest. Note the standing snags and downed woody material intermixed with shrub fuels. Holding efforts on future fires will be difficult and require substantial aircraft and water support. 51
Figure 18. Salvage and site preparation activities on the KNF Salmon Salvage Project. Trees are cut, and removed from site with follow-up hand piling meeting surface fuel loading criteria sufficient for low intensity fire. 55
Figure 19. Pattern of tree fall and resulting fuel bed height....55
Figure 20. Masticated fuel bed. Brush and small trees mulched to reduce surface fuel bed depth to < 2 inches. 56
Figure 21. Comparison between projected flame lengths of Alternatives 1 and 2 and the critical flame lengths needed to initiate crown fire activity based on canopy base height. 71
Figure 22. Probability of mortality of ponderosa pine tree species based on 90th percentile weather conditions. 72
Figure 23. Probability of mortality of Douglas-fir tree species based on 90th percentile weather conditions. 72
Figure 24. Alternative 2 potential flame length 10 years post treatment. 74
Figure 25. Alternative 2 projected flame lengths > 20 years post treatment. 79
Figure 26. Potential flame length 10 years post treatment, Alternative 3. 81
Figure 27. Potential flame length (Alternative 3) greater than 20 years post treatment. 83
Figure 28. Potential flame length 10 years post treatment (Alternative 5). 86
Figure 29. Potential flame length (greater than 20 years) Alternative 5. 87

Executive Summary

This report provides a synopsis of the effects of the project on fire behavior potential and resistance to control of future wildland fire activity across the Westside Fire Recovery project area.

Methodology

Overview of Methodology

The fire and fuels report takes into consideration the three elements that affect fire behavior: fuels, weather and topography. The interactions of these elements present potential issues to vegetation and fire suppression capabilities. Although all of the elements are important, the project realistically can only affect the fuels element. A combination of field-collected data, geospatial data, fire modeling, professional judgment and literature review is used to provide a landscape level picture of potential fire behavior and analyze environmental consequences of the project to fire and fuels.

Using Behave Plus and FlamMap fire behavior modeling programs, fire behavior outputs are generated to compare alternatives over time. These variables include: flame length and fireline intensity.

Post-fire stand data were collected in areas that burned with high, moderate and low severity effects. The collected data were entered into the Fire Management Analyst (FMAPlus 3) model to quantify the canopy and tree bole biomass loading. These data were used to enter into a snag fall and decay model which quantifies potential surface fuel loadings overtime as snags weaken, break and/or fall over. Selected stands were also evaluated using the Forest Vegetation Simulator (FVS) along with the Fire and Fuels Extension of FVS to project future surface fuel loading overtime. Appendix A provides modeling assumptions of each program used within the fire and fuels report.

Literature and case studies were reviewed to examine similar landscapes with regard to fire behavior, severity and resistance to control.

Analysis Indicators

Analysis indicators used to evaluate effects of the project include potential fire hazard and resistance to control; these are measured by flame length, fireline intensity, rate of spread and surface fuel loading.

Fire hazard is defined as “a fuel complex, defined by volume, type condition, arrangement, and location, that determines the degree of ease of ignition and of resistance to control” (National Wildland Coordination Group, 2014).

Measurement indicators to assess fire hazard include flame length, fireline intensity and rate of spread as fire modeling predicts fire behavior based on surface fuels less than 3 inches in diameter. Fuels larger than 3” in diameter are not used in fire modeling programs to display potential fire behavior outputs but are important indicators of resistance to control.

Flame lengths are a visual indicator of fireline intensity; as flame lengths increase, fireline intensity increases (Table 6 in the body of the report).

Byram (1959) defined fireline intensity as the rate of heat energy release per unit time per unit length of fire front, regardless of the depth or width of the zone of active flaming combustion. With respect to fire suppression, fireline intensity is how hot the fire is burning and how close resources can be to the fire; fireline intensity is used to forecast whether to use direct or indirect firefighting tactics.

Resistance-to-control is generally viewed as an estimate of the suppression force required for controlling a unit of fire perimeter. For example, "high" resistance to control means "slow work for dozers, very difficult for hand crews; hand line will be difficult" (Brown, Reinhardt, & Kramer, 2003).

Surface fuel loading by fuel size category is evaluated as a measure of resistance to control. To quantify potential intensity of large fuels (> 3" diameter) we can use Byram's (1959) fireline intensity equation and surface fuel loadings (tons/acre) of 0 to 3" and 3 to 10" diameter material to measure resistance of control related to fireline production capabilities of fire suppression resources (Table 8 in the body of the report).

Spatial and Temporal Context

This analysis is limited to the spatial extent of the Westside Fire Recovery project area because effects on fire and fuels can be accurately estimated within this area.

Short-term analysis is considered at one to five years post-fire; long-term analysis extends out to greater than 20 years to model the potential effects of standing snags, downed wood and subsequent surface fuel loading over time.

Affected Environment

Few forested regions have historically experienced fires as frequently and with such high variability in fire severity as the Klamath Mountains Bioregion (Taylor & Skinner, 1998). Within the project area, lightning has accounted for 74% of ignitions and 82% of burned acres in the project area. Median fire return interval ranged from 8 to 38 years (Taylor, Skinner, & Agee, 2006). A great portion of the landscape has remained unburned between 20 to 100 years prior to the 2014 fires.

Approximately 26% of the fires experienced high severity fire effects. High severity fire areas experienced crown fire activity resulting in full consumption of ground, surface and aerial canopy fuels. High severity crown fires result in high levels of tree mortality, consuming leaves and small branches but leaving the boles largely intact (Ritchie, Knapp, & Skinner, 2012). At the ground and surface fuel level, duff and needle cast, small branches and large downed woody material were fully consumed; in the canopy full consumption of leaf and needle foliage occurred leaving standing dead trees and barren soils (Figure 4 and Figure 5 in main body of report). Overall, the impact led to high levels of tree mortality.

Low to moderate severity fire areas experienced a mix of mortality. Generally surface fuels within the understory were fully consumed along with burning smaller trees and understory vegetation. Where heavy concentrations of fuels burned under the overstory canopy, needles were scorched, turned brown and remain within the overstory fuel complex. Overtime, needle cast, and small branch wood will fall to the forest floor accumulating sufficient fuel loadings to support the ignition and spread of fire.

The high density of fire killed trees within the Westside Recovery Project Area, present a unique hazard to fire fighters and promote future problem fire behavior as these are both ember producers and receptors to fire ignition. Over time, fire hazard and resistance to control are expected to change as dead trees fall and new vegetation that establishes across the fire area contributing to surface fuel loading, fuel structure, arrangement and subsequent fire behavior.

Environmental Consequences

Alternative 1

Direct Effects and Indirect Effects

No direct effects are anticipated under Alternative 1 since no planned activities will occur. In the short term, fire spread and intensity are expected to be restricted due to a lack of surface fuel loadings to support fire spread and a lack of heavy fuel accumulations to affect fire intensities.

Indirect effects will occur over the course of a 10 to 20 year timeframe as a result of Alternative 1. Standing snags may retain a substantial amount of biomass that will contribute to surface fuels over time as snags fall (Ritchie, Knapp, & Skinner, 2012). Areas that supported high and moderate fire severity present future fire hazard within 10 years. Dead trees will continue to decay, break and fall contributing to surface fuel loading and increasing fire hazard. Table 19 and Table 20 (in main body of report) display projected fuel loadings over a 50 year time period. Fuel loading in the tables is separated by size class (less than 3” and greater than 3” diameter). Material less than 3” is a main driver of fire ignition and spread, and greater than 3” material influences fire intensity and resistance to control.

Forested vegetation that supported large trees intermixed with shade tolerant small diameter trees present a high hazard and subsequent high fire severity in the future, as smaller fuels accumulate to increase fire ignition and spread. Large fuels contribute to sustained ignition during the flaming front and subsequent duration burn down time as fuels smolder and consume retaining high intensities for longer periods of time.

Low severity fire areas where mortality rates within the understory are low have the least potential for increased surface fuel loading over time due to the lack of snags that accumulate on the surface and lack of shading to reduce shrub growth. Table S-1 provides a summary of flame length and intensity over a 50 year period and potential change in condition across the landscape with this alternative.

Over the course of a 50 year period, surface fuel accumulation is expected to occur from two sources: (1) new vegetation that establishes and grows over time and (2) accumulations from snags as they fall contributing to surface fuel loading. Forested areas are anticipated to re-establish into a non-forested vegetation composition of shrubs and forbs (see Vegetation section of the EIS) and in turn contribute to fire ignition and spread potential. Over the course of time, it is anticipated that fireline intensities from stored standing material that fall and accumulate on the surface will exceed intensities of 6,000 British Thermal Units per foot per second (btu/ft/sec). Where slow to moderate spread rates occur; intensities will be greater than 10,000 btu/ft/sec in extreme fire events. Referring to Table 6 in the body of the report, these are intensities that promote fire activity conducive to major fire runs, crown fire activity and spotting. Re-burn within these locations will have a high probability of burning at high severity again due to the fire intensity and duration as larger fuels consume after the flaming front has passed.

High fireline intensities and snags promote problem fire behavior and high resistance to control resulting in the need for large quantities and types of resources. Snags promote fire spread via spot fire ignition and, coupled with large down logs, present high resistance to control as fireline production rates (constructed fireline) are slower in areas with high fuel loads. Since lightning is the predominate cause of ignition in the project area, there is a future concern that small fires will be difficult to control and will have a high probability of requiring large quantities of suppression resources. Under Alternative 1, control of future large fires will be difficult and time consuming in areas that have high densities of snags and surface fuel loadings. Fire managers naturally gravitate to strategic ridge systems, roads and natural barriers such as rivers and streams to control large fires. Increased time will be required to prepare control lines in areas that have numerous snags and large woody downed material, and longer times will be needed to hold and mop-up control lines to secure the fire perimeter. Under Alternative 1, increased exposure to fire suppression resources will be anticipated due to increased line production and mitigating the increased densities of snags.

Table S-1: Potential fire behavior (by acreage) over the span of 50 years within the Westside Fire Recovery Project Area

		Flame Length				Fireline Intensity			
		< 4 feet	**4 to 8 feet**	**8 to 11 feet**	**> 11 feet**	**< 100 btu/ft/sec**	**100 to 500 btu/ft/sec**	**500 to 1000 btu/ft/sec**	**> 1000 btu/ft/sec**
Year	1	198,633	6,494	2,298	7,593	192,647	6,140	4,439	11,792
	10	80,739	98,039	10,875	25,365	75,407	108,685	17,659	13,267
	50	40,906	40,259	24,510	109,343	35,849	74,944	51,839	52,386

Cumulative Effects

Ongoing and foreseeable future actions in the project area are listed in appendix C of the EIS. Alternative 1 will not supplement other present and/or reasonably foreseeable future projects that are planned to improve forest health, old growth desired conditions, fire resilience, and suppression effectiveness across the landscape. Additionally, difficulties may preclude future projects from either continuing or being planned due to the high density of snags within or adjacent to the Westside Fire Recovery Project Area. Using fire as a management tool in both the planned (prescribed fire) and unplanned setting may not meet desired resource objectives due to future fuel loading potential as well as the hazard, cost and time needed to remove decaying hazard trees from planned control lines. This will be a limiting factor in future prescribed fire activities.

Concerns raised during public scoping regarding treating fuels adjacent to private lands, both those owned by timber companies and residential communities, will not be addressed. Fuel reduction activities planned by fire safe councils and other community organizations will occur. However, opportunities to develop fuel breaks on the Forest to connect with those proposed by adjacent land owners will not be recognized in Alternative 1.

The majority of the remaining burned area is owned by Fruit Growers Supply Company (FGS) and Michigan California Timber Company, and is located within the Beaver Fire Area. Both of these companies are either currently or planning to treat their land by conducting salvage

operations on their respective properties. It is understood that FGS is planning a series of fuel breaks within the ridge and road systems of the Beaver fire area; their lands are intermixed with National Forest System Land. Salvage operation of all trees is generally occurring on slopes less than 45% and commercial trees are being removed on slopes greater than 45%. After salvage operations are completed replanting is expected. It is also expected that herbicide treatments will be applied to the planted areas to reduce shrub growth. As a result of the operations expected on privately owned lands these lands are expected to be relatively fire safe. This is primarily due to the removal or reduction of most of the dead and dying trees on these lands.

Alternative 2

Direct Effects and Indirect Effects

Salvage, Site Preparation, Roadside, Hazardous Fuels Treatments

Alternative 2 implements multiple types of activities to reduce snag densities and surface fuel loading. Alternative 2 also increases future fire management actions and fire resiliency. Post-fire logging can serve as an effective tool for managing fuel loadings in forests regenerating after high severity wildfires (Peterson, Dodson, & Harrod, 2014). The direct effect of salvage harvest is reducing density of snags on the landscape (Ritchie, Knapp, & Skinner, 2012) and subsequently reducing future accumulations of large diameter surface fuels as trees fall to the forest floor.

Approximately 6,800 acres of salvage harvesting is proposed, which will reduce snag densities of trees equal to or greater than 14 inches in diameter at breast height (dbh). This action immediately removes larger diameter fire killed trees off-site while generally leaving un-merchantable tops and branches on the ground. Within these units, planned site preparation activities after salvage harvesting will cut remaining fire killed trees (≤ 14” dbh). To accomplish fuel reduction activities, slash remaining onsite will be reduced to a minimum of ten tons/acre (< 3” diameter fuels), and/or structure and composition of the fuel bed altered, and will utilize a combination of methods including, machine and hand piling, broadcast burning and/or mastication.

Harvesting of trees are planned utilizing ground based, cable and helicopter logging. It is anticipated that there will be a delay between harvesting activities and associated fuel reduction activities. During this time frame, greater accumulation of surface fuels due to logging activities would be anticipated especially within cable and helicopter units where whole tree yarding is not planned. The short term effect of logging is an elevated surface fuel loading from broken tops and branch wood. The greatest fuel loadings post-harvest is expected to occur within helicopter units, followed by cable and ground based units. However, post logging activity breaks the structure and composition of the fuel bed. Upon completion of fuel reduction activities, ground based units would be expected to reduce the greatest amounts of surface fuels due to the ease of facilitating piling and other fuels reduction activities on gentler slopes. Steeper slopes (greater than 40%) would be anticipated to require hand piling and or broadcast burning to achieve desired surface fuel loadings of less than 10 tons/acre. Compared to ground based and cable units, within helicopter units or those areas on steep slopes, larger diameter (> 3” diameter) fuels may have increased loadings as these fuels can be difficult to pile by hand.

Piling and burning activities reduces fuel loading and breaks the continuity of fuel beds. Techniques including lop and scatter, and chipping or mastication alter the fuel bed and structure

of fuels. Mastication is essentially the mulching or chipping of wood material. The direct effect of mastication includes changing the structure and composition of the fuel bed post fire. With no action taken, surface fuels will increase over time as trees fall. As these trees fall in random patterns, fuels will essentially "crisscross" and result in some fuels resting on top of others, effectively increasing fuel bed height (Figure 19 in main body of report). Higher surface fuel beds will be subject to wind and preheating of fuels lower in the surface fuel profile; thus, increasing potential fire behavior. Rather than having standing dead material that falls over time, chipped material will create a compact fuel bed in locations where mastication is identified as a treatment option under alternative 2 (Figure 20). Material will also be expected to decay faster with masticated material due to its proximity to the ground and being saturated for longer period of time during the winter months.

Additional units identified for site preparation generally occur within plantations and natural stands in which trees are generally less than or equal to 14" dbh. Similar effects related to reduction of fuel loadings will occur as described above due to the removal of trees during follow-up piling and burning activities.

Snag retention will occur within Riparian Reserves (RRs) and identified leave locations in units identified for treatment. No planned salvage harvest will occur in RRs. Snag retention outside of riparian zones will utilize a clumping pattern in order to retain snags which will promote decreased surface fuel loadings outside of these zones. Within snag retention areas and RRs, surface fuel loadings will mirror conditions outlined under Alternative 1 (Table 19).

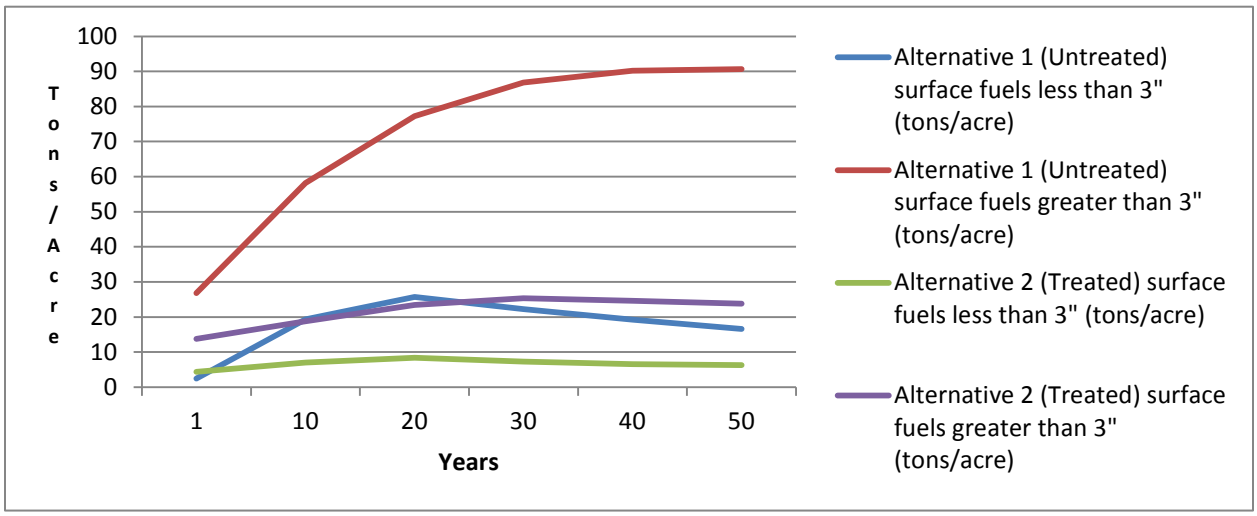
Treating surface fuels upon completion of cutting activities will have a direct effect on reducing surface fuel loading, breaking up of continuous fuel beds and reduction in fuel bed depth. Post-fire logging produces a transient pulse of elevated surface woody fuel loadings followed by a much longer period of reduced surface woody fuel loadings relative to burned stands that are were not logged. Peterson, Dodson, and Harrod (2014) found that post-fire logging altered post-fire fuel succession by (1) greatly accelerating the deposition of surface woody fuels from logged snags, (2) reducing peak loadings of large diameter woody fuels, and (3) initiating the woody fuel decay earlier.

Ritchie, Knapp and Skinner (2012), evaluated salvaged units following the Cone Fire on the Lassen National Forest. They found that after four years higher levels of surface fuel accumulations occurred in lower intensity salvage plots. The highest surface fuel accumulations occurred in unsalvaged plots four to eight years after the fire. Furthermore, the highest levels of large woody debris were associated with unsalvaged areas. A key finding observed by Ritchie, Knapp and Skinner (2012) found no support for the debate that post-fire salvage logging necessitates subsequent fuel treatment for elevated fuels. Under alternative 2, activity generated slash will be piled and burned reducing surface fuels to levels consistent with low severity fire effects.

Post-logging fuel treatments, such as piling and burning, can rapidly reduce total amounts and spatial continuity of surface woody fuels, and may allow logged stands to serve as fuel-breaks in a landscape-level fire management strategy (Peterson & Harrod, 2010). After the initiation and completion of alternative 2 surface fuels present will consist of the approximate tonnage in each of the size classes, not including large material (downed logs) left on site for wildlife or watershed purposes:

- 1 hour fuels (0” to ¼”) : .6 tons per acre
- 10 hour fuels (¼” to 1”) : 2.3 tons per acre
- 100 hour fuels (1” to 3”) : 3.4 tons per acre

Post treatment activities under Alternative 2 are expected to significantly reduce large surface fuel accumulations in the future compared to Alternative 1. Table 23 and Table 24 display projected surface fuel loadings predicted over a 50 year period, based on completion of implementation actions. While modeling predicts an expected increase in surface fuels less than 3” dbh as compared to the alternative 1, after implementation of proposed activities, modeling results predict that within 10 years Alternative 2 will continue to promote low accumulations of surface fuel loadings. Comparatively, taking no action significantly elevates surface fuels for decades.



Walker Creek Stand ID 050552ABCD001116414144205						Walker Creek Stand ID 050552ABCD001116414144205					
Year	Surface Fuel < 3" dbh (tons/acre)	Surface Fuels > 3" dbh (tons/acre)	Intensity (btu/ft/sec) 26 ch/hr	Intesity (btu/ft/sec) 40 ch/hr	Resistance to Control	Year	Surface Fuel < 3" dbh (tons/acre)	Surface Fuels > 3" dbh (tons/acre)	Intensity (btu/ft/sec) 26 ch/hr	Intesity (btu/ft/sec) 40 ch/hr	Resistance to Control
1	1.49	14.40	55	55	Low	1	3.48	12.90	70	70	Low
10	14.34	51.11	5259	8029	Extreme	10	4.59	17.12	1724	2632	Low
20	16.82	73.97	6912	10553	Extreme	20	5.01	18.89	1892	2889	Moderate
30	12.89	80.54	6567	10025	Extreme	30	4.95	18.14	1841	2811	Low
40	10.83	76.98	6013	9179	Extreme	40	5.80	15.60	1857	2835	Low
50	10.00	70.61	5526	8437	Extreme	50	8.08	14.53	2204	3365	Low

Figure S-1: Representative stand from the Walker Creek Drainage with and without salvage harvest and treatment of activity fuels

Roadside hazard treatments increase the safety of accessing the forest, by reducing the potential for dead trees to fall across National Forest roads and within recreation sites. Trees removed offsite reduce surface fuel loadings adjacent to road systems and allow for safe ingress/egress within fire area road systems.

Hazardous fuels treatments occur both within the WUI and strategic road and ridge systems which fire suppression resources used historically to control unplanned fires and implement prescribed fire activities.

Proposed thinning with follow up pile burning, lop and scatter or chipping decreases surface fuel loadings to a desired conditions of less than10 tons/acre (< 3" diameter fuels), removes small diameter trees which reduces ladder fuels, and increases canopy base heights of retained green trees. Reduction in surface fuels in conjunction with increasing canopy base heights will reduce flame lengths and crown fire initiation of natural or planted trees.

Prescribed fire as a "second-entry" post fire is planned on approximately 11,570 acres. A mixed severity burn pattern occurred within units proposed for burning. Direct effects of prescribed fire include the consumption and subsequent reduction in surface fuels. Prescribed fire activities naturally prune the lower branches of trees by burning the live and dead needles and small branch wood effectively increasing the canopy base heights. Depending on seasonality, 100 and 1000 hour fuels (> 1" diameter) and retained snags can be partially or fully consumed. A mosaic burn pattern will be expected due to post fire burn severity patterns.

Fire Behavior Synopsis

When compared to Alternative 1, proposed treatments in Alternative 2 effectively reduce fuel loading in the short and long term which in turn reduces fire behavior. Similar fire behavior is expected for the first one to three years due to the lack of surface fuels to support the spread of fire. However, immediate actions taken to reduce standing dead trees will reduce fire behavior (flame length, fireline intensity, and spot fire potential) long term.

Within 10 years, reductions in surface fuel loadings, as a result of planned activities, have the potential within proposed treatment areas to:

- Reduce flame lengths < 4 feet
- Reduce fireline intensity < 100 btu/ft/sec
- Decrease spot fire activity through removal of snags and future fuel loading
- Effectively produce fire behavior such that persons using handtools can generally attack fires at the head or flanks and handline is sufficient to hold the fire.

The type of fire behavior predicted under Alternative 2 will enable ground crews to use direct attack within the units proposed for treatment. Untreated portions of units, such as RRs, snag retention pockets or unburned islands from prescribed fire activities, will be expected to produce flame lengths less than four feet and fireline intensities less than 100 btu/ft/sec.

Reforestation efforts will have better chances of survival due to anticipated surface fuel load reductions within planted areas. Using empirical data for northern California forests, Weatherspoon and Skinner (1995) found that when wildfire in natural plantations 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 reburn and subsequent mortality, even under Alternative 2. 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, higher survival will be expected within stands that continue to have

management activities to maintain desired fuel conditions, and as trees increase in size and canopy base heights.

Utilizing projected flame lengths of Alternative 1 (Table 16 in main body of report) and Alternative 2 (Table 26 in main body of report) along with the relationship of critical flame length needed to generate crown fire activity based on canopy base height (Table 27 in main body of report), it is anticipated that fuel reduction treatment activities proposed will decrease potential crown fire activity as trees increase in size and shed their lower branches either naturally or through pruning activities. Figure 21 in main body of report displays predicted flame lengths of Alternatives 1 and 2 along with critical surface flame lengths required to generate crown fire activity based on the canopy base heights of trees. The reduction of surface fuel loading along with the change in the structure and composition of the fuel bed are anticipated to reduce fire behavior comparatively to taking no action, thus, allowing trees to have increased survivability as canopy base heights increase over time. Figure 21 in main body of report also shows the susceptibility of trees to fire; until trees are able to increase in size along with shedding their lower limbs increasing their separation from surface fuels they remain susceptible to fire caused mortality.

Fire Suppression Capabilities

Removal of roadside hazard trees provides for safe ingress and egress to fires. The reduction of snags and subsequent fuel loadings modifies flame length and fireline intensity which enables direct attack and increases fireline production rates. Increasing fireline production rates decreases resistance to control by removing large fuel accumulations. Moreover, a general reduction in snags will permit safer nighttime fireline operations. Table 23 and Table 24 (in main body of report) compare potential resistance to control based on projected surface fuel loadings.

Project design features that outline clumping snags effectively achieve fire suppression capability. Clumped snags will allow resources to locate control lines around these areas and safely engage a fire with limited need to fall high densities of snags. Snag retention is planned in areas that are rarely used by fire managers to contain a large fire; for example, the lower one-third of slopes, and away from roads and ridgetops which are typically utilized by fire managers to control large fires.

By strategically applying varying post-fire logging treatments within landscapes, post-fire logging could reduce woody fuels and help reduce threats of future wildlife behavior to human health, property, and ecosystem services (Peterson, Dodson, & Harrod, 2014).

The Kyburz Fire (Eldorado National Forest, 2013) provides an example of suppression success within a previously salvaged area. This fire started at the bottom of a slope within the South Fork American River. Diurnal winds fanned the fire up-drainage towards the community of Kyburz, (approximately 1 mile from the fire origin) and re-burned areas within the footprint of the Freds Fire (2004). Treatments within the Freds fire areas included post fire logging activities to help reduce future fuel loading and snag density. The lack of heavy dead and down fuels allowed fire suppression resources to continue to construct direct control lines, keeping a safety zone around them within the “black”. Salvage harvest activities in the previous Freds fire allowed for a lower intensity Kyburz fire, less exposure to hazard trees, and less exposure during mop-up activities (Johnson, 2013). If direct fire suppression tactics had not been available, as a result of post Freds fire treatment and snag reductions, indirect line would have been required during nighttime operations, which would have only allowed for indirect fire suppression tactics and an increase

in fire size (Jacobson, 2013). Resources, including aircraft, heavy equipment and personnel were safely able to drop water and retardant in open areas and construct line with minimal large woody debris. These tactics increased line production rates, and decreased resistance to control, allowing for resources to effectively work through the night to complete control lines and keep the fire from entering the community of Kyburz.

Fuel treatments within the Wildland Urban Interface promote safer firefighting actions and public evacuation, should a future large fire occur within the project area. Eliminating high snag densities and treating surface fuels within the WUI has an indirect effect on reducing sources for embers, spotting, and receptive fuel beds. These indirect effects are a benefit in Alternative 2, when compared to Alternative 1, where no action is taken to reduce future available material. Additionally, increased spotting and radiation would make structures more difficult to defend from crown fire, as opposed to surface fire. (Cohen & Butler, 1996) (Scott & Reinhardt, 2001).

Identified treatments in the WUI modify fire behavior such that fires are anticipated to spread slower, with flame lengths less than four feet, allowing responding resources to take direct action to control fires. These direct actions are effective due to the change in composition and structure of fuels, which promotes low resistance to control when compared to Alternative 1.

The 2012 Goff Fire highlights the benefits of fuel treatments in which the objective is to reduce surface fuel loading and modify fire spread and intensity within the WUI. The Seiad Creek Road Shaded Fuel Break project, completed in 2009, was utilized as a control line for the Goff Fire. Fuels treatment contributed to easier holding and burning along Seiad Creek Road, in the community of Seiad Valley (Osborne, 2015).

Both proposed salvage and hazardous fuels treatments outlined in Alternative 2 will produce similar fire behavior, which could support fire suppression resources. Suppression resources would have opportunities to burnout, hold fireline and safely take action on any identified spot fires in the advent of a future large fire occurrence.

Fuel treatments identified along strategic ridge and road systems will enhance future fire management activities including fire suppression, managing unplanned ignitions, and implementation of prescribed fire. Maintaining these treatments provides opportunities for fire managers to focus resources on priority locations, such as in the WUI. These treatments also provides opportunities to utilize confine and contain strategies on future fires where untreated areas still contain high densities of snags and inhibit safe work areas for fire suppression resources.

Cumulative Effects

The Westside Fire Recovery Project, in conjunction with ongoing and foreseeable actions, has the potential to increase fire resiliency by managing both unplanned and planned fire ignitions across the landscape, as compared to Alternative 1. Furthermore, fire suppression effectiveness is improved as future projects implemented adjacent to and within the project area increase the size and scale of treatments proposed under Alternative 2. At the stand scale, post-fire logging reduces surface fuels over the long term, particularly in the large diameter size classes (> 3” diameter), which should increase management options for applying prescribed fire treatments or allowing future wildfires to burn without causing excessive damage to the forest vegetation and soils (Peterson, Dodson, & Harrod, 2014).

Communities affected by the 2014 fires continue to reduce fuels on private property located adjacent to National Forest System Lands. Alternative 2 compliments many of these activities to improve fire resiliency, and provides opportunities to enhance the work performed by landowners to improve vegetation and fuel loadings. These combined actions promote less intense fire behavior and promote safer firefighting action in the future, within urban interface fires. The Scott Bar and Seiad Fire Safe Councils are active councils which have coordinated fuels treatments on private and public lands in the past and can be expected to continue these partnerships into the future.

Private timberlands are currently in the process of salvage operations on lands affected by the 2014 fires. Treatments adjacent to private timberlands will increase the size and scale of treatment activities under alternative 2, as well as provide fuel breaks on prominent ridge and road systems that stretch across private and forest system lands within the Beaver Fire. Christmas Tree and Buckhorn Ridge systems are prominent ridgelines within the Beaver fire area that have historically been used to control large fire and where planned activities adjoin private and National Forest lands.

Alternative 3

Direct Effects and Indirect Effects

The direct and indirect effects of alternative 3 are anticipated to be similar to those described within alternative 2, except on fewer acres of salvage harvest (about 5,800). Proposed activities are anticipated to reduce fire hazard and resistance to control. Additional snag recruitment may increase surface fuel loadings in the future where additional snags are left within units; however, within areas that receive treatment, surface fuel loading projections will be comparable to Alternative 2. Project design features outlined to leave snags in a clumping pattern, as well as away from strategic fire management features (ridges, roads, etc.), will provide safe and effective fire suppression activities. Similar effects to those of alternative 2 are anticipated within the project boundary of the Happy Camp Complex and Whites fire areas. The smaller size and scale of treatment units within these areas will not reduce the benefits of treatments proposed with alternative 3.

Cumulative Effects

Alternative 3 does not include salvage harvest activity within the Beaver Fire project boundary. Therefore opportunities to connect fuel treatments which adjoin private land, where salvage and fuel treatments are planned, to the treatments planned on private land are diminished due to the reduction of treatment activities. Ability to reduce fire spread and intensity across the landscape will be decreased. Adding the effects of alternative 3 to the effects of ongoing and reasonable foreseeable future actions is likely to have measurable effects on fire.

Alternative 4

Direct Effects and Indirect Effects

The direct and indirect effects of Alternative 4 are anticipated to be similar to those described within alternative 2, except for fewer acres of salvage harvest (about 5,900 acres). Proposed

activities are anticipated to reduce fire hazard and resistance to control where treatments occur, and fuels reduction activities to reduce fuel loadings to less than 10 ton/acre will occur.

Cumulative Effects

Adding the effects of Alternative 4 to the effects of ongoing and reasonable foreseeable future actions is likely to have measurable effects on fire similar to those of alternative 2. Treatments reduced under this alternative are intermixed within other proposed activities, which still allows for additional buffering to reduce fire spread and intensity adjacent to hazardous fuels treatments.

Alternative 5

Direct Effects and Indirect Effects

Within units that receive treatment, direct effects are comparable to those described within alternative 2 with respect to reduction in fire hazard and resistance to control. Indirect effects vary by fire area due to the reduction in size and scale of salvage harvest activities.

Within the Beaver fire area, additional fuel treatments added as proposed activities are anticipated to modify fire spread and intensity adjacent to private timberlands over a greater portion of the area when compared to Alternative 2. Fire managers will also have increased fuel breaks allowing future fire management options to control unplanned fires.

Salvage treatments that will not occur within late-successional reserves are expected to significantly reduce opportunities to modify fire spread; especially within the Happy Camp and Whites fire areas. Many of the units removed under Alternative 3 are located adjacent to strategic fire management features (ridges, roads, etc.). The reduction in the size and scale of treatments will most likely allow future fire activity to spread upslope due to anticipated fuel loading and subsequent fire behavior, which is expected to be comparable to alternative 1.

Approximately 3,600 acres are not treated in the WUI under alternative 5. Many of these areas are adjacent to critical control points and communities, for example Highway 96 and the community of Seiad. A primary concern is that any future fires that start above the community and within snag patches and areas with high fuel loading will be more difficult to control and require greater time and effort from resources.

Cumulative Effects

Varying effects are anticipated based on fire area. Similar effects as described under alternative 2 are expected within the Beaver fire area, as there is little late-successional reserve in that area. Also, the additional treatments added in Alternative 5 in the Beaver fire area will further enhance fuel treatment effectiveness at the landscape level due to the increase of size and scale of proposed treatments coupled with adjoin private land treatment activities.

Within areas that include sizeable acres of late-successional reserve, the reduction in salvage harvest activities will substantially reduce the size and scale of treatments at the landscape level. Future foreseeable fuels reduction projects may be precluded due to high density of snag patches left on the landscape, making some foreseeable projects difficult to implement. Adding the effects of Alternative 5 to the effects of ongoing and reasonable foreseeable future actions is likely to have measurable effects on fire.

Comparison of effects

Table S- 2: Comparison of post-fire effects of alternatives on fire and fuels after 10 years

Analysis Indicator	Measurement Indicator	Alternative 1	Alternative 2	Alternative 3	Alternative 4	Alternative 5
Fire Hazard:						
Fuel loading of small material (<3”)	Acres with < 10 tons per acre	14,000	44,800	40,800	41,100	35,200
Flame Lengths	Acres with flame lengths < 4’	14,000	44,800	40,800	41,100	35,200
Fireline Intensity	Acres with < 100 btu/ft/sec	14,000	44,800	40,800	41,100	35,200
Rate of Spread	Acres < 20ch/hr	14,000	44,800	40,800	41,100	35,200
Resistance to Control						
Fuel loading of large material (> 3”)	Acres with greater than 20 tons per acre	14,000	0	0	0	0

Compliance with law, regulation, policy, and the Forest Plan

All alternatives comply with law, regulation, policy and the Forest Plan pertinent to fire and fuels as displayed in the Forest Plan consistency checklist.

Fire and Fuels Report

Introduction

The report utilizes fire modeling and surface fuel loading projections to outline consequences of each alternative analyzed and provides a comparison of flame length, fireline intensity and resistance to control. This comparison is then used to quantify potential effects to fire and fuel management activities.

Methodology

The fire and fuels report takes into consideration the three elements that affect fire behavior: Fuels, Weather and Topography and how the interactions of these elements present potential issues for vegetation and fire suppression capabilities.

Problem fire behavior is fire activity that presents potential hazards to fireline personnel. Extreme fire behavior, the highest level of problem fire behavior, can be described with specific elements; rapid rate of spread, intense burning, spotting and crowning (National Wildfire Coordinating Group, 1994). Fireline personnel observe current fire behavior characteristics (i.e. flame length, rate of spread, crown fire activity, spotting) and numerous environmental conditions on a constant basis in order to anticipate and predict potential fire behavior, determine strategies and implement tactics to safely contain a wildland fire. Environmental conditions contributing to potential extreme fire behavior include fuel moistures less than 6%, temperatures greater than 85° F, and surface wind speeds greater than 10 mph (National Wildland Coordination Group, 2006).

These elements alone, or in combination, affect potential fire behavior and drive strategies that are developed and implemented by fire managers to safely deploy resources and contain unplanned fire ignitions.

FUELS

Size, type, vertical arrangement, horizontal continuity and packing ratio all contribute to a fuels ability to ignite and consume, as well as its contribution to fire spread and intensity. Key visual indicators of extreme fire behavior potential include: continuous fine fuels, heavy loading of dead and down fuels, ladder fuels, tight crown spacing; and special fuel conditions such as blow down, freeze damage/ frost killed trees, insect damage or other widespread disease that causes mortality.

When assessing fuel conditions, the concern is how a fire may burn given the current vegetation type, structure and arrangement of fuels. Fuels can be classified into three layers: ground, surface, and canopy fuel profiles. Ground fuels include those fuels within the duff layer; including roots, and decomposing material. Surface fuels consist of fuels that lye immediately on the ground and fuels that extend to approximately six feet above the ground, such as needle cast, oak litter, shrubs, brush and small trees. Canopy fuels consist of the multi-layer canopy which extends from the surface into the overstory canopy. It is the interaction between these fuel profiles that determines a fuels availability to ignite, spread, initiate and propagate into surface and crown fire behavior.

WEATHER

Weather influences the ignition, fire behavior, and severity of a wildland fire and is a dynamic component of wildland fire environment. Temperature, precipitation, and humidity determine the ability of fuel to ignite and sustain combustion. A direct relationship between fuel moisture (amount of moisture within dead fuel) and Relative Humidity exists and as Relative Humidity decreases, fuel moisture decreases. Wind patterns are normally slope driven with diurnal upslope/up-canyon occurring during daytime hours, and down slope/down-canyon occurring during nighttime hours. Other wind patterns which occur during the passage of frontal systems include North and East wind events and thunderstorms which produce lightning and erratic outflow winds.

TOPOGRAPHY

Topography affects fire behavior and is a relatively static component within the wildland fire environment.

Due to their ability to funnel wind and preheat fuels ahead of a fire, steep slopes, box canyons, chutes, saddles and narrow canyons promote the potential for extreme fire behavior and allow ignition of surface and aerial fuels to occur quicker as opposed to flat terrain. Diurnal slope driven wind patterns in combination with the drainage and canyon positioning contribute to alignment of wind and slope.

Aspect influences fire behavior in several areas. Time of day is an important consideration, as the ability for fuels to burn heavily depends on fuel temperature and shading. When the sun rises in the east, fuel temperatures will increase and fuel moisture will decrease. As the angle of the sun continue to rise and moves westerly, the sun's rays heat fuels on the south and west aspects. An East aspect will provide for lower fuel moistures compared to a west aspect, due to the angle of the sun on the slope and solar heating. Therefore a fire ignition that occurs at 9:00 am on a west aspect will react differently than that of a fire ignition that occurs on an east aspect at the same time.

Typically, the "hottest" weather conditions (high temperature, low relative humidity, low fuel moisture), occur between 2:00 pm and 4:00 pm. During this time of day solar radiation affects fuels temperature and any fuel that is available for the ignition and spread of a wildfire. During the "hottest" time of day south and west aspects are most susceptible to fire ignition and spread.

Elevation plays a role in the type of vegetation and forest structure present as well as length and duration of the fire season. Within the project area, the typical fire season occurs during the months of May through October. Precipitation during the fall, cool temperatures and higher relative humidity values decrease the chance for wildlife fire occurrence and growth from November through April.

Fuels, Weather and Topography work in combination to determine fire behavior. Visual indicators of extreme fire behavior include; rates of spread uncontrolled by suppression forces, a well-developed smoke column that exhibits similarities to thunderstorms and produce erratic wind conditions and down drafts, group tree torching, numerous spot fires that occur ahead of the main fire, and the presence of fire whirls.

Of the three environmental variables, fuels remain the one variable which can be used to minimize the potential for extreme fire behavior development and assist fire managers in localized areas to strategically contain a large wildfire.

Detailed Methodology

To evaluate the action and no action alternatives, a combination of field data, geospatial data, professional judgment and literature review is utilized to provide a landscape level analysis of potential fire behavior and the potential environmental consequences associated with each alternative.

Data sources include the Klamath National Forest GIS datasets and U.S. Geological Survey (USGS) Landfire geospatial data. Table 1 below, describes the data accessed and description of its use for fire modeling purposes. These layers can be used to build a “numeric” landscape for analysis of fire behavior within a 30x30 meter grid.

Table 1. Geospatial layers utilized to model fire behavior across the landscape and units proposed for treatment (Table definitions referenced from Landfire.gov).

Geospatial Dataset	Definition	Fire Modeling Input
Fuel Model	Represents distinct distributions of fuel loading found among surface fuel components (live and dead), size classes, and fuel types.	Provides surface fuel inputs into fire behavior modeling for use in providing fire behavior outputs including flame length and fireline intensity.
Forest Canopy Height	Average height of the top of the vegetated canopy in forested areas only.	Supplies information to fire behavior models to determine the probability of crown fire ignition , calculate wind reductions and compute the volume of crown fuel.
Canopy Base Height	Average height from the ground to a forest stand's canopy bottom.	Provides information to fire behavior models to determine areas in which a surface fire is likely to transition to a crown fire
Canopy Cover	Describes the percent cover of tree canopy in a stand.	Used in determining surface fuel shading for calculating dead fuel moistures and calculating wind reduction factors.
Canopy Bulk Density	Describes the density of available canopy fuel in a stand.	Supplies information to fire behavior models to determine the initiation and spread characteriscs of crown fires across landscapes.
Slope	Represents the percent change of elevation over a specific area	Supplies information to fire behavior models for use in determining fuel moistures and predict wildland fire behavior and effects.
Aspect	Represents the azimuth of the sloped surfaces across a landscape.	Supplies information to fire behavior models for use in determining fuel moistures and predict wildland fire behavior and effects.
Elevation	Elevation represents land height above mean sea level	Supplies information to fire behavior models for use in determining fuel moistures and predict wildland fire behavior and effects.

FUELS

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. To facilitate use in models and systems, fuelbed inputs have been formulated into fuel models. A fuel model is a set of fuelbed inputs needed by a particular fire behavior or fire effects model. Different types of fuel models are used in fire science; this analysis uses only fire behavior fuel models for use in the Rothermel (1972) surface fire spread model.

Fire behavior fuel models are used as input to the Rothermel (1972) fire spread model, which is used in a variety of fire behavior modeling systems. The fire behavior fuel model input set includes:

- fuel load by category (live and dead) and particle size class (0 - 0.25 inch, 0.25 - 1.0 inch, and 1.0 - 3.0 inches diameter),
- surface-area-to-volume (SAV) ratio by component and size class,
- heat content by category,
- fuelbed depth, and
- dead fuel moisture of extinction.

Rothermel (1972) defined a fire behavior fuel model as a “complete set of [fuel] inputs for the mathematical fire spread model”, and listed parameters for 11 fuel models. To assist in understanding the sensitivity of certain inputs, Rothermel held constant the fuel particle properties (total and effective mineral content, heat content, and particle density). Extinction moisture content was not listed for each fuel model separately, but instead held at 30 percent for all models. Thus, variation in predicted spread rate among models could be attributed to fuel load by size class, fuelbed depth, and fuel particle size. Parameters for 10- and 100- hr surface to area volume (SAV) were listed for each fuel model, but did not vary among models – 109 1/ft and 30 1/ft respectively.

The 2005 set of standard fire behavior fuel models (Scott & Burgan, Standard Fire Behavior Fuel Models: A Comprehensive Set for Use with Rothermel's Surface Fire Spread Model, 2005) were used in the Westside Fire Recovery Fuels Analysis.

Fuel model parameters in the Westside Fire Recovery fuels analysis include load by class and component, SAV ratio by class and component, fuel model type (static or dynamic), fuelbed depth, extinction moisture content, and fuel particle heat content (Table 2). Parameters not listed are constant for the entire set: 10-hr dead fuel SAV is 109 1/ft, and 100-hr SAV is 30 1/ft. Total mineral content is 5.55 percent; effective (silica-free) mineral content is 1.00 percent. Oven dry fuel particle density is 32 lb/ft3.

In the fuel models used, all fuel models with an herbaceous component are dynamic. In a dynamic fuel model, live herbaceous load is transferred to dead as a function of the live herbaceous moisture content; that is, as herbaceous fuel moisture percentages change, these fuels are either transferred to dead fuel loading or live based on calculation in the model (for example; 90% herbaceous moisture content transfers two-thirds of the herbaceous fuel loading to dead 1 hour fuel loading category).

The following are the parameters associated with each of the fuel models used in estimating fire behavior for the Westside Fire Recovery Project.

Table 2. Scott and Burgan Standard (2005) Fire Behavior Fuel Model Parameters.

Fuel Model	Fuel Load (tons per acre)					Fuel Model Typea	SAV Ratio (1/ft)b			Fuel Bed Depth (ft)	Moisture of Extinction (%)	Heat Content (btu/lb)c
	1 Hour	10 Hour	100 Hour	Herb.	Woody		Dead1 Hour	Live Herb.	Live Woody			
GR1	0.10	0	0.00	0.30	0.00	dynamic	2200	2000	N/A	0.4	15	8000
GR2	0.10	0	0.00	1.00	0.00	dynamic	2000	1800	N/A	1.0	15	8000
GR3	0.10	0.4	0.00	1.50	0.00	dynamic	1500	1300	N/A	2.0	30	8000
GR4	0.25	0	0.00	1.90	0.00	dynamic	2000	1800	N/A	2.0	15	8000
GR5	0.40	0	0.00	2.50	0.00	dynamic	1800	1600	N/A	1.5	40	8000
GR6	0.10	0	0.00	3.40	0.00	dynamic	2200	2000	N/A	1.5	40	9000
GR7	1.00	0	0.00	5.40	0.00	dynamic	2000	1800	N/A	3.0	15	8000
GR8	0.50	1	0.00	7.30	0.00	dynamic	1500	1300	N/A	4.0	30	8000
GR9	1.00	1	0.00	9.00	0.00	dynamic	1800	1600	N/A	5.0	40	8000
GS1	0.20	0	0.00	0.50	0.65	dynamic	2000	1800	1800	0.9	15	8000
GS2	0.50	0.5	0.00	0.60	1.00	dynamic	2000	1800	1800	1.5	15	8000
GS3	0.30	0.25	0.00	1.45	1.25	dynamic	1800	1600	1600	1.8	40	8000
GS4	1.90	0.3	0.10	3.40	7.10	dynamic	1800	1600	1600	2.1	40	8000
SH1	0.25	0.25	0.00	0.15	1.30	dynamic	2000	1800	1600	1.0	15	8000
SH2	1.35	2.4	0.75	0.00	3.85	N/A	2000	9999	1600	1.0	15	8000
SH3	0.45	3	0.00	0.00	6.20	N/A	1600	9999	1400	2.4	40	8000
SH4	0.85	1.15	0.20	0.00	2.55	N/A	2000	1800	1600	3.0	30	8000
SH5	3.60	2.1	0.00	0.00	2.90	N/A	750	9999	1600	6.0	15	8000
SH6	2.90	1.45	0.00	0.00	1.40	N/A	750	9999	1600	2.0	30	8000
SH7	3.50	5.3	2.20	0.00	3.40	N/A	750	9999	1600	6.0	15	8000
SH8	2.05	3.4	0.85	0.00	4.35	N/A	750	9999	1600	3.0	40	8000
SH9	4.50	2.45	0.00	1.55	7.00	dynamic	750	800	1500	4.4	40	8000
TU1	0.20	0.9	1.50	0.20	0.90	dynamic	2000	1800	1600	0.6	20	8000
TU2	0.95	1.8	1.25	0.00	0.20	N/A	2000	9999	1600	1.0	30	8000

Fuel Model	Fuel Load (tons per acre)					Fuel Model Typea	SAV Ratio (1/ft)b			Fuel Bed Depth (ft)	Moisture of Extinction (%)	Heat Content (btu/lb)c
	1 Hour	10 Hour	100 Hour	Herb.	Woody		Dead1 Hour	Live Herb.	Live Woody			
TU3	1.10	0.15	0.25	0.65	1.10	dynamic	1800	1600	1400	1.3	30	8000
TU4	4.50	0	0.00	0.00	2.00	N/A	2300	9999	2000	0.5	12	8000
TU5	4.00	4	3.00	0.00	3.00	N/A	1500	9999	750	1.0	25	8000
TL1	1.00	2.2	3.60	0.00	0.00	N/A	2000	9999	N/A	0.2	30	8000
TL2	1.40	2.3	2.20	0.00	0.00	N/A	2000	9999	N/A	0.2	25	8000
TL3	0.50	2.2	2.80	0.00	0.00	N/A	2000	9999	N/A	0.3	20	8000
TL4	0.50	1.5	4.20	0.00	0.00	N/A	2000	9999	N/A	0.4	25	8000
TL5	1.15	2.5	4.40	0.00	0.00	N/A	2000	9999	1600	0.6	25	8000
TL6	2.40	1.2	1.20	0.00	0.00	N/A	2000	9999	N/A	0.3	25	8000
TL7	0.30	1.4	8.10	0.00	0.00	N/A	2000	9999	N/A	0.4	25	8000
TL8	5.80	1.4	1.10	0.00	0.00	N/A	1800	9999	N/A	0.3	35	8000
TL9	6.65	3.3	4.15	0.00	0.00	N/A	1800	9999	1600	0.6	35	8000
SB1	1.50	3	11.00	0	0.00	N/A	2000	9999	9999	1.0	25	8000
SB2	4.50	4.25	4.00	0.00	0.00	N/A	2000	9999	9999	1.0	25	8000
SB3	5.50	2.75	3.00	0.00	0.00	N/A	2000	9999	9999	1.2	25	8000
SB4	5.25	3.5	5.25	0.00	0.00	N/A	2000	9999	9999	2.7	25	8000

a Fuel model type does not apply to fuel models without live herbaceous load

b N/A was assigned to in cases where there is no load in a particular fuel class or category.

c The same heat content value was applied to both live and dead fuel categories.

WEATHER

The Klamath National Forest (KNF) maintains a system of Remote Automated Weather Stations which record hourly weather observations on a daily basis and provide a historical weather archive. This archived weather is utilized along with the Fire Family Plus program to review a climatological analysis of weather and fuel conditions related to fire danger and fire occurrence. The KNF has reviewed historical weather and fire occurrence to define fire danger thresholds related to problem fire behavior and large fire growth and what associated weather and fuel conditions which foster problem fires that increase resistance to control and contribute to large fire growth. Weather and fuel variables indicate that 43rd percentile conditions can promote large fire growth (fires defined by the KNF as > 50 acres); this includes Temperatures > 75, Relative Humidity < 45% and wind speeds > 4 mph (National Wildland Coordination Group, 2000). The analysis incorporates what the Klamath National Forest identifies as its traditional fire season: May 1 to October 31. For this analysis it was decided to evaluate fire behavior conditions based

on 90th percentile weather conditions which is a standard indicator utilized in the application of designing fuel treatment effectiveness for fire behavior and suppression. The Klamath National Forest EIS (Appendix B Modeling and Analysis Process) utilizes 90th percentile weather in its evaluation of wildfire suppression capabilities. A combination of weather stations (Table 3) are utilized for climatological analysis in order to determine 90th percentile weather conditions across the project area. Table 4 displays 90th percentile weather conditions utilized as inputs into modeling fire behavior.

Table 3. Remote Automated Weather Stations Included in Climatological Analysis in determination of 90th percentile weather.

Remote Automated Weather Station	Years of Climatological Data Included in Analysis	Geographic Location	Elevation
Blue Ridge (KNF)	20	Ridgetop	5,859 ft
Oak Knoll	20	Valley Bottom	1,953 ft
Sawyers Bar	20	Valley Bottom	2,455 ft
Slater Butte	20	Ridgetop	4,621 ft
Collins Baldy LO	20	Ridgetop	5,456 ft

Table 4. 90th percentile weather conditions utilized for modeling fire behavior.

Variable	90th Percentile Value
Temperature	89.2°
Relative Humidity	17.4%
20 foot Wind Speed	6.5 mph
1 - Hour Dead Fuel Moisture	2.95%
10 - Hour Dead Fuel Moisture	3.9%
100 - Hour Dead Fuel Moisture	6.37%
1000 - Hour Dead Fuel Moisture	8%
Live Woody Fuel Moisture	69.6%
Herbaceous Fuel Moisture	18.7%

FIRE MODELING

A combination of modeling programs are utilized to display potential fire behavior and fuel loading projections. Behave Plus 5 and FlamMap 5 are utilized to model fire behavior (Flame Length and Fireline Intensity) along with thresholds of crown fire initiation. Behave Plus projects potential fire behavior and FlamMap is utilized to project potential fire behavior spatially within the project area.

FlamMap can be considered a static landscape model; this model allows the comparison of changes to fuel structure within each alternative with constant weather parameter inputs thereby allowing a comparison of effects based on same weather conditions. The importance here is each pixel is evaluated for fire behavior based on the fuel, canopy and topographic inputs. Adjacent pixels have no effect to potential fire behavior. FlamMap utilizes surface fuel model and canopy

fuel data in combination with topographic and weather data to spatial depict fire behavior on a geospatial landscape. Fire behavior is calculated for each pixel within the landscape file independently, so FlamMap does not calculate fire spread across a landscape (Finney M. , 2006). For the purposes of this analysis, a 60x60 meter grid was selected for spatial analysis. FlamMap can be considered a static landscape model; this model allows the comparison of changes to fuel structure within each alternative with constant weather parameter inputs thereby allowing a comparison of effects based on same weather conditions. The importance here is each pixel is evaluated for fire behavior based on the fuel, canopy and topographic input; that is adjacent pixels have no effect to potential fire behavior.

Fire behavior variables pertinent to fire and fuels analysis include flame length, and fireline intensity; these values will be used to measure effects of each alternative. Fire caused tree mortality has resulted in the creation of standing dead timber which over time is potential biomass that could influence surface fuel loading and subsequent fire intensity and severity. 1/50 acre plot data was collected within the project area; 15 plots were collected within High, Moderate and Low severity fire areas. Tree height, diameter (dbh), canopy base height, and proportion of the crown were recorded. Fire Management Analyst program (FMA Plus 3) is utilized to quantify the amount of fuel loading within the canopy based on fuel loading size classes (Table 5). By estimating canopy fuel profile we can estimate the weight of fuel loading by tons/acre within each category. This information is entered into a snag fall and decay program to estimate potential surface fuel loading overtime based on snag fall as trees weaken and decay. The snag fall and decay program was developed from the Snagfall submodel of the Sierra Nevada Forest Plan Growth and Yield Model (Wilson, 1999). A review of the calculations demonstrates that similar snag fall and decay rates can be expected in the Klamath Mountain region. What is not taken into account is regrowth of vegetation over the temporal range of the project adding to surface fuel accumulation and fire behavior.

Stand data from previous planned projects on the KNF were utilized within the Forest Vegetation Simulator (FVS) program in conjunction with the FVS Fire and Fuels Extension. The stand data was utilized to describe potential surface fuel loadings in portions of the Happy Camp and Whites fire area.

Appendix A within the report describes modeling limitations and assumptions of each model.

Table 5**. Canopy fuel loading by size class.**

Canopy Fuel Loading by Size Class	
Canopy Fuel Category	**Size (inch diameter)**
Foliage	Needles
1 hour	0-.25 inch
10 hour	.25 to 1 inch
10 hour	1 to 3 inch
1000 hour (tree boles)	3+ inch

Analysis Indicators

The Westside Fire Recovery Project is interested in quantifying potential fire behavior effects and future fire suppression capabilities. Analysis indicators used to evaluate effects of the project

are potential fire hazard and resistance to control; these are measured by flame length, fireline intensity, rate of spread, and surface fuel loading.

Fire Hazard

Fire hazard is defined as "a fuel complex, defined by volume, type condition, arrangement, and location, that determines the degree of ease of ignition and of resistance to control" (National Wildland Coordination Group, 2014). Flame length and fireline intensity are measures which can assess potential fire hazard based on surface and canopy fuel conditions.

Table 6 displays the relationship of Flame Length and Fireline intensity related to fire suppression capabilities (resistance to control) and potential fire behavior. These two variables can be visually identified and felt by fireline resources. As flame length and/or fireline intensity increases, suppression capability, resource type and tactics differ.

An important relationship that is difficult to quantify is the potential effects of large wood fuels (fuels > 3 inches diameter). The influence of small woody fuels on spread rate, intensity of surface fires and associated torching and crowning is substantial and can be estimated using widely accepted fire behavior models; methods for estimating and interpreting fire effects of large fuels are not well established. (Brown, Reinhardt, & Kramer, 2003).

To estimate potential BTU output (Fireline Intensity) from dead fuels that fall overtime as a result of fire caused mortality, fireline intensity was calculated using Byram (1959) fireline intensity equation described as follows:

$$I = H\,W\,R$$

Where: I = Intensity

H= Average heat content of fuel consumed (btu/lb)

W= Weight (load) of fuel consumed in the flaming front (lb/ft^2)

R= Forward rate of spread (ft/sec)

Byram (1959) defined fireline intensity as the rate of heat energy release per unit time per unit length of fire front, regardless of the depth or width of the zone of active flaming combustion. Essentially, with respect to fire suppression fire intensity is how hot the fire is burning and how close resources can be to the fire and can be used to forecast whether direct or indirect firefighting tactics can be utilized.

For this analysis, 8000 btu/lb was selected for average heat content consumed (H) as this value is utilized in surface fire models for fire behavior modeling. Fuel loading values were calculated from predicted snag fall and resulting biomass fall over time. Recognizing that full consumption of fuels is unlikely, large fuel consumption was estimated at 30% based on modeling within FOEFEM fire effects program under 90th percentile weather conditions. Initial post year forward spread rates were calculated using fuel models that represent recently burned areas while 10 to 50 year values were given a standard rate of spread of 26 chains per hour (ch/hr) and 40 ch/hr which were spread rates observed on several occasions during the Beaver, Happy Camp and Whites Gulch fires of 2014.

Table 6. Relationship of flame length and fireline intensity to fire suppression actions.

FLAME LENGTH (Feet)	FIRELINE INTENSITY (BTU/Ft/Sec)	INTERPRETATIONS
0-4	0-100	Persons using handtools can generally attack fires at the head or flanks. Handline should hold the fire
4-8	100-500	Fires are too intense for direct attack on the head by persons using handtools. Handline cannot be relied on to hold fire. Equipment such as dozers, engines, and retardant aircraft can be effective.
8-11	500-1,000	Fires may present serious control problems such as torching, crowning, and spotting. Control efforts at the head of the fire will probably be ineffective.
11+	1000+	Crowning, spotting, and major runs are common; control efforts at the head of the fire are ineffective.

Resistance to Control

Resistance-to-control is generally viewed as an estimate of the suppression force required for controlling a unit of fire perimeter. For example, “high” resistance to control means “slow work for dozers, very difficult for hand crews; hand line will be difficult” (Brown, Reinhardt, & Kramer, 2003). Fuel type and loading, slope, flame length, and fireline intensity (Table 6) are primary considerations for measuring line production rates of various kinds and types of resources. Generally, line production rates are faster in stands with low fuel loading such as grass and slower in timber, brush, and slash fuels. Table 7 displays line production rates for hand crews. High and Extreme resistance to control ratings related to surface fuel loadings are provided in Table 8; in which as small diameter fuel loading (tons per acres) increases, lower amounts of large woody debris (tons per acres) is required to have high or extreme resistance to control.

Table 7. Line production rates for initial actions per person and sustained line production for Type 1 Handcrew in chains per hour.

Fire Behavior Fuel Model	Specific Conditions	Construction Rate – Initial Actions (in chains per person per hour)*	Sustained Line Production Rate 20 person Type 1 Crew (Chains per hours)**
1 Short Grass	Grass	4	17
2 Open Timber/Grass Understory	All	3	17
3 Tall Grass	All	0.7	17
4 Chaparral	Chaparral	0.4	6.6
5 Brush	All	0.7	6.6
6 Dormant Brush/Hardwood Slash	Brush	1	16.5
8 Closed Timber Litter	Conifers	2	10.5
8 Closed Timber Litter	Hardwoods	10	10.5
9 Hardwood Litter	Conifers	2	10.5
9 Hardwood Litter	Hardwoods	8	10.5
10 Timber (Litter & Understory)	All	1	10.5

Fire Behavior Fuel Model	Specific Conditions	Construction Rate – Initial Actions (in chains per person per hour)*	Sustained Line Production Rate 20 person Type 1 Crew (Chains per hours)**
11 Logging Slash, Light	All	1	15
12 Logging Slash, Medium	All	1	7
13 Logging Slash, Heavy	All	0.4	5

** Initial actions include scratch line, hotspotting.*
*** Sustained line production rates incorporate activities including line construction, holding and burnout operation activities.*

Table 8. Resistance to control ratings based on tons per acre.

0 to 3 inch diameter	3 to 10 inch diameter	
	High	Extreme
5	25	40
10	15	25
15	5	15

Spatial and Temporal Bounding of Analysis Area

This analysis is limited to the spatial extent of the Westside Fire Recovery project area because effects on fire and fuels can be accurately estimated within this area.

Short-term analysis is considered at one to five years post-fire; long-term analysis extends out to greater than 20 years to model the potential effects of standing snags, downed wood and subsequent surface fuel loading over time.

Affected Environment

Fire History

Few forested regions have historically experienced fires as frequently and with such high variability in fire severity as the Klamath Mountains Bioregion (Taylor & Skinner, 1998), this is primarily due to climatic variables and the diverse physical and biotic arrangement of the Klamath Mountains. South and west facing aspects and upper slope positions typically experienced higher severity fire than lower slopes and north- and east-facing aspects. On the eastern edge of the Klamath Mountains, median fire return intervals ranged from 8 to 38 years (Taylor, Skinner, & Agee, 2006). With frequent fire of low to mixed severity, fuel accumulations over most of the area were historically maintained at low levels, and landscape features such as ridge-tops and streams were often sufficient to impede fire spread.

Fire history data from 1911-2012 provides insight into fire cause and size to identify trends in fire patterns and relationships on the landscape. Table 9 displays fire ignitions by cause. Lightning accounts 74% of fire starts and 82% of the acres burned within the project area over a 101 year history highlighting the notion that fire will continue to be a factor across the project area. Table 10 outlines fire by size class indicating that 72% of all fires are less than .25 acres.

Table 9 . Wildfire ignition by cause and total acreage burned.

Fire Cause	Total Number of Ignitions	Total Reported Acres Burned
Lightning	1410	93,207
Human	355	15,605
Unknown	143	3,965
Grand Total	1908	112,776

Table 10. Wildfire ignition by size class.

Fire Size Class	Total Number of Fires
A (0-.25 acres)	1383
B (.25-1 acres)	397
C (1-10 acres)	76
D (10-100 acres)	18
E (100-1000 acres)	12
F (1000-5000 acres)	16
G (> 5000 acres)	6
Grand Total	1908

Figure 1 graphs acreage burned by decade. The data includes large fire history within the project area including the 2014 Beaver, Happy Camp Complex and Whites Fires. 2014 fires represent 59% of the acreage burned over the 103 year period. Table 11 displays the acreage burned by decade within the project area.

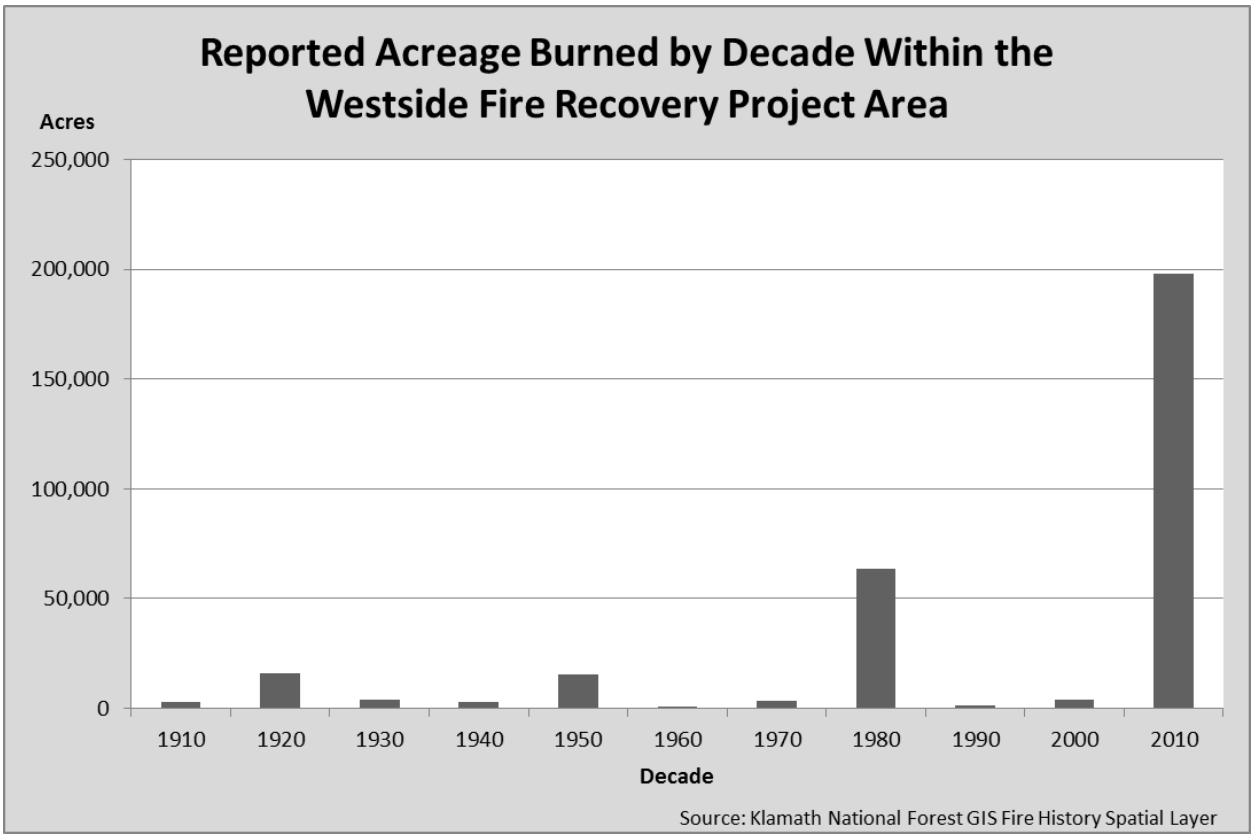


Figure 1. Summary of the acreage burned by decade within the Westside Fire Recovery Project area.

Table 11. Acreage burned by decade.

Decade	Acres Burned By Decade
1910	2,811
1920	15,914
1930	4,063
1940	2,660
1950	15,399
1960	103
1970	3,155
1980	63,287
1990	1,501
2000	3,882
2010	197,967
Total	310,743

Figure 2 provides a spatial representation of past fire history over a 103 year period time. What can be observed is that the fires within the Westside Fire Recovery Project have experienced long periods with an absence of fire on the landscape. A great portion of the landscape has not had large fire within the past 20 to 100 years within the project area.

Prior to the 2014 fires, much of the landscape within the project area had a long absence of fire. Fire history is rich and overlapping outside of the project area; moreover, fire will continue to be a presence on the landscape and shape future fuels and vegetation profiles within the project area in the future.

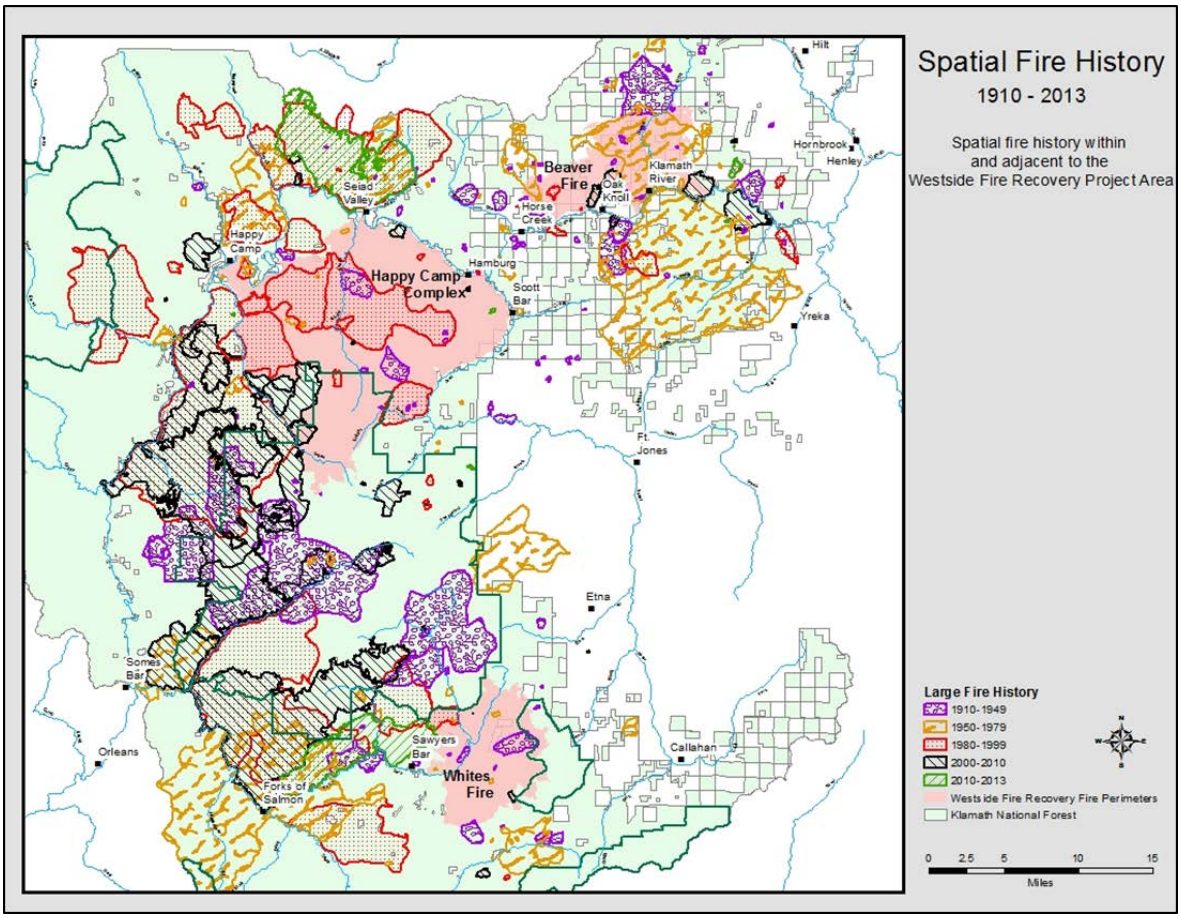


Figure 2. Spatial Large Fire History within and adjacent to the Westside Fire Recovery Project.

Fuels

Pre-fire Condition

A description of pre-fire conditions provides the understanding of fire severity effects on post fire conditions within the Westside Fire Recovery Project Area. Decades of fire exclusion lead to an increased accumulation in all fuel profiles across the landscape. Before fire suppression, fires of higher spatial complexity created openings of variable size within a matrix of forest that was generally open comparatively to today. This heterogeneous pattern has been replaced by a more homogenous pattern of smaller openings in a matrix of denser forests. Thus spatial complexity has been reduced (Taylor, Skinner, & Agee, 2006). Figure 3 spatially displays vegetation characteristics related to fuel loading which can be used in geospatial models, such as FlamMap, to display potential fire behavior including fireline intensity and flame length. Table 12 provides acreage and percent coverage over the project area of pre-fire vegetation related to fuels and potential fire behavior.

Pre-fire vegetation conditions within the Westside Fire Recovery Project Area were broadly uniform across the landscape with minimal variability in the fuel profile. Decades of fire suppression led to an increase in surface fuel loadings. Within the crown fuels, low canopy base heights of small diameter shade tolerant trees filled the mid-story canopy profile connecting the upper canopy layer of large dominant mixed conifers. This “ladder-effect” easily transitioned a surface fire into the tree crowns. Uniformity of vertical fuels led to sufficient aerial fuel loading to initiate and sustain crown fire activity.

Table 12. Vegetation type in relation to potential fire behavior effects

Vegetation Type	Acres	Percent of Project Area	Primary Carrier of Fire
Non Burnable Vegetation	6,232	2.90%	Barren Land, Rock, and Water
Low Load Grass	10,400	4.84%	Grass
Low Load Grass/Shrub	17,932	8.35%	Grass with small shrub influence
Low Load Shrub	7,975	3.71%	Shrubs less than 4 foot tall
High/Very High Shrub Load	21,012	9.78%	Shrubs greater than 4 foot tall
Low/Moderate Load Timber/Understory Shrub	1,561	0.73%	Bear Clover, small shrubs less than 2 feet
Very High Load Timber Understory Shrub	101,627	47.30%	Bear Clover with ladder fuels such as small trees and shrubs
Low/Moderate Load Conifer/Broadleaf Litter	3,967	1.85%	Needle Cast and small dead and downed fuels typically 10 hour fuels
High/Very High Conifer/Broadleaf Litter	44,141	20.55%	Needle Cast with heavy component of dead and down fuels
Total Acres	214,848	100%	

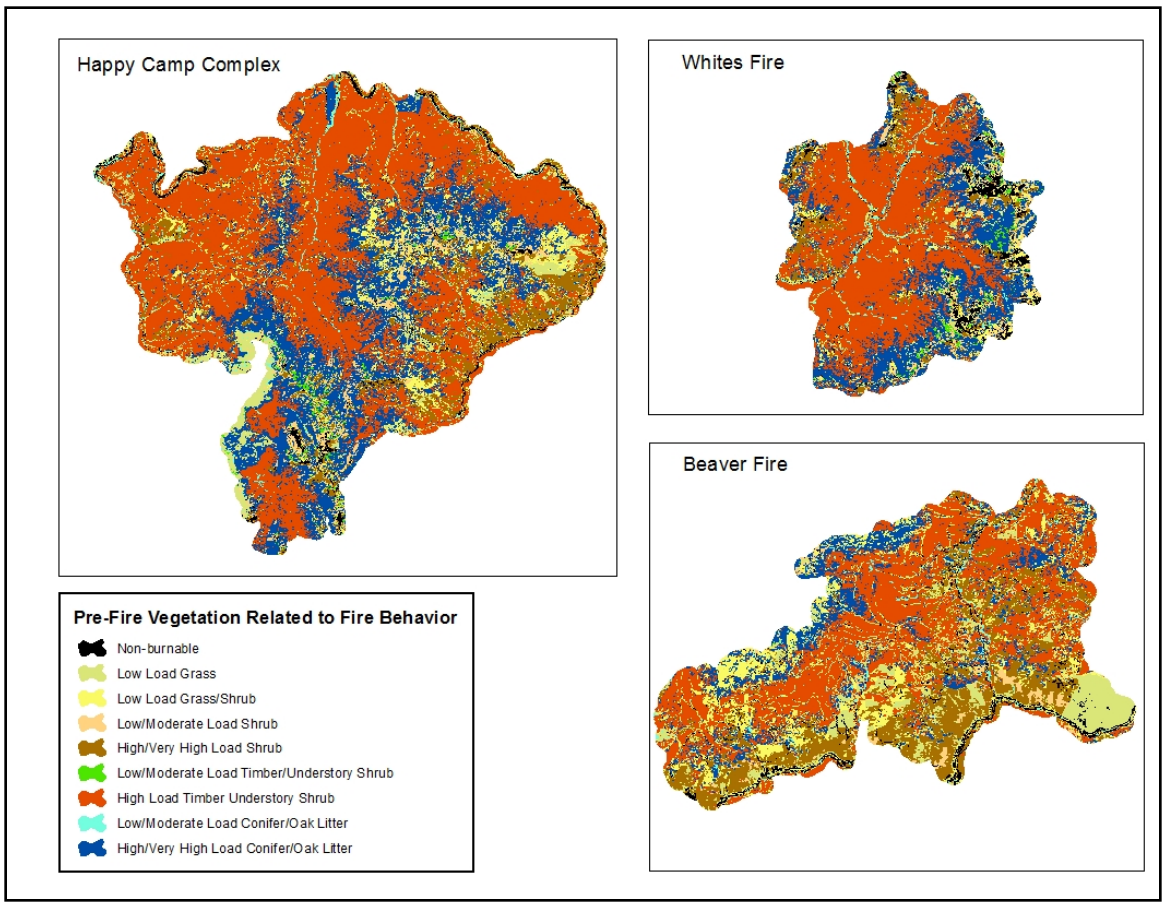


Figure 3. Spatial Distribution of Pre-fire Vegetation across the Westside Fire Recovery Project

Post Fire Conditions

The effects of uniform fuel beds at the surface and canopy in combination with weather and climatological conditions, led to significant fire growth and high severity fire effects on the Klamath National Forest during 2014. The resulting fires brought upon a mosaic mix of fire severity within each fire and across the project area (Table 13). High severity fire effects occurred over 26% of the project area resulting in 75 to 100% mortality of trees (based on tree basal area loss). Patch size within high severity fire areas ranged from < 1 acre to 3,890 acres in size; 37,325 acres within the project area have contiguous patch sizes > 100 acres.

Table 13. Fire (Vegetation Burn) Severity (Basal Area Loss) within the Westside Fire Recovery project area

Fire Severity	Beaver		Happy Camp Complex		Whites		Total	
	Acres	%	Acres	%	Acres	%	Acres	%
Low	14,310	43%	73,152	62%	21,666	63%	109,129	59%
Low/Moderate	3,139	10%	9,986	8%	2,087	6%	15,213	8%
Moderate/High	2,465	7%	7,305	6%	1,566	5%	11,336	6%
High	13,012	40%	27,334	23 %	8,889	26%	49,236	27%

High severity fire areas experienced crown fire activity resulting in full consumption of ground, surface and aerial canopy fuels. High severity crown fires result in high levels of tree mortality, consuming leaves and small branches but leaving the boles largely intact (Ritchie, Knapp, & Skinner, 2012). At the ground and surface fuel level, duff and needle cast, small branches and large downed woody material were fully consumed; in the canopy full consumption of leaf and needle foliage occurred leaving standing dead trees and barren soils (Figure 4, Figure 5). Overall, the impact led to high levels of tree mortality.

Figure 4. Example of high severity fire effects (Happy Camp Complex)

Figure 5. Canopy view of high fire severity patch (Whites Fire)

Moderate to high severity fire areas experienced similar conditions; surface fuel loadings were primarily fully consumed; pockets of larger downed fuels remain visible on the surface. Generally, full consumption within all categories of surface fuel loads were consumed (i.e. small branches, twigs, and large downed woody debris); dead needles continue to fall from the canopy covering the forest floor (Figure 6). The crown fuel profile varied with some trees being consumed by the fire and other trees retaining needles in the tree canopy (Figure 7). Overall, the majority of the overstory canopy burned intense enough resulting in brown needles with few green needles remaining on conifer trees with full consumption of hardwood species.

Figure 6. Moderate to High Severity Fire within surface and mid-story canopy fuels.

Figure 7. Moderate to High Severity Fire within the canopy fuels.

Low to moderate severity stands have a mix of live and dead trees remaining within the understory. Primarily, overstory crown fuels remain intact and survived the fire while surface fuels and small trees within the understory were consumed leading to small tree and shrub mortality (Figure 8).

Figure 8. Low severity fire effects (Whites Fire).

Weather

The climate of the Klamath Mountains is Mediterranean, characterized by wet, cool winters and dry, warm summers (Taylor, Skinner, & Agee, 2006). The interaction between weather patterns, topography and fuels are dynamic in the project area.

Weather patterns critical to fire ignition and spread include pre-frontal, post-frontal, thunderstorms and subtropical high conditions. Pre Frontal conditions typically are associated with increased winds along with increased humidity; post frontal conditions experience increased winds and combine with decreased humidity; subtropical conditions are associated with high pressure dominance where temperatures increase and humidity decreases. Thunderstorms occur in the dry season and lightning is a common cause of fire in the Klamath Mountains (Taylor & Skinner, 2003); outflow winds from thunderstorms can cause rapid spread rates and large fire growth in all directions. In the Klamath Mountains [subtropical] conditions lead to fires controlled mostly by local topography (Taylor, Skinner, & Agee, 2006).

Topography

The Westside Fire Recovery Project is filled with steep complex terrain with many prominent ridge systems. Elevations range from 1,000 to 8,000 feet; steep slopes dominate the land creating narrow canyons, chutes and long running drainages which enhance wind flow where alignment with slope and general wind patterns occur. Within the Beaver Creek drainage, the origins of the drainage begin high near the Siskiyou Summit in Oregon and funnel South to Southeast ending at the Klamath River Drainage. Strong downslope winds are funneled through here as cold air descends and increases as it is channeled down drainage to the confluence of the Klamath River (Ebert, Personal Observation, Beaver Fire August 1-13, 2014, 2014).

The prominent drainages which include the Klamath River, Scott River, Beaver, Grider, and Russian Creeks influence wind patterns as typical diurnal up-drainage and upslope winds occur during the daytime and downslope down canyon wind patterns overnight. Inversion layers (trapping of warm are between colder air above and below), due to a combination of weather and topography, play a role in dampening fire behavior as smoke fills into the drainages reducing air flow, decreasing solar radiation and increasing dead fuel moistures.

Fire Behavior Synopsis

The combination of fuels, weather and topography play a role in potential fire behavior across the landscape. It is known that weather and topography will continue to affect fire behavior, vegetation will regrow and dead fuels will contribute to surface fuel loads all contributing to sustain fire activity.

During the Beaver Fire, the Klamath River drainage winds created problem and extreme fire behavior as winds increased up to 10 mph daily from approximately 3:00 pm lasting into the early evening hours spreading fire; subsequently, this was also noted as the most active time of the burn period. As night fell over the fire area, winds calmed, transitioning to light downslope winds during the nighttime hours (Ebert, Personal Observation, Beaver Fire August 1-13, 2014, 2014).

With the recently burned areas experiencing a mix of severity, surface fuel loadings cannot sustain and carry fire.

In order to assess fire behavior and severity, a Fire Behavior Assessment Team (2014) sampled surface and canopy fuel loading pre and post fire within the Beaver Fire. These plots also were video recorded to observe fire behavior as well. Sampled plots revealed areas with the highest fuel loadings resulted in some of the highest post fire severity. Lightning caused fires have accounted for the most area burned in recent decades; widespread lightning events have contributed to situations where fires burn for weeks to months and cover very large areas (Taylor, Skinner, & Agee, 2006). Within the project area, the 1987 lightning caused fires, which occurred within and adjacent to the project area, is an example of widespread lightning and long duration fire events as is the fires within the Westside Fire Recovery Project. Outflow winds from thunderstorm activity can greatly enhance wind speeds in excess of 50 mph causing extreme fire behavior and high fire severity fire. On two occasions, outflow winds exceeding 40 mph were observed on the Beaver Fire resulting in significant changes in fire behavior with crown fire activity, rapid rates of spread up to 1 mile per hour, and spotting up to 1 mile ahead of the main fire (Ebert, 2014).

Inversions factor into fire behavior and severity across the landscape of the Klamath Mountains. Fires burning in narrow canyons, under relatively stable atmospheric conditions, are conducive to thermal inversions; this pattern of severity appears to be similar to historical patterns. However, when inversions break and/or strong winds accompanied by low humidity occur, large areas of severe burn are possible such as those that occurred in the Megram fire in 1999 and the Biscuit fire in 2002 (Taylor, Skinner, & Agee, 2006). Similar conditions prevailed during the 2014 fire season within the Westside Fire Recovery project; daily inversions kept fire behavior subdued resulting in predominate surface fire activity during morning and early afternoon (Figure 9). Once the inversion lifted, it allowed the preheating of through convection and increased winds creating a significant increase in fire activity resulting in crown fire activity and long range spotting (Figure 10). This highlights the fact that weather conditions will continue to influence fire behavior and severity across the landscape.

Figure 9. Surface fire activity under inversion layer on the Beaver Fire occurred when the weather conditions and terrain created inversion layers trapping smoke above the fire resulting in decreased solar radiation, decreased temperatures and increased fuel moistures dampening fire behavior.

Figure 10. Fire activity once inversion layer lifted during the Beaver Fire resulting in extreme fire behavior and subsequent high fire severity on approximately 40% of the Westside Fire areas (Photo from Plot 6 FBAT time lapse video).

Resistance to Control

The influence of fuels, weather and topography plays a role in the ability to effectively suppress unplanned ignitions. Topography and road access is the primary factor to resistance to control of fires in the Klamath National Forest. The high density of fire kill trees within the Westside Recovery Project Area, present a unique hazard to fire fighters and promote future problem fire behavior as these are both ember producers and receptors to fire ignition. Over time, dead trees fall and new vegetation that establishes across the fire area contribute to surface fuel loadings. The result is the need for additional kinds and type of fire equipment to control an unplanned ignition and increased fireline production rates.

Environmental Consequences

Alternative 1

Under alternative 1, there will be no action take to meet the purpose and need for the project and desired future conditions within the project area (see Chapter 1, Draft EIS).

Direct and Indirect Effects

No direct effects will occur under alternative 1 since no activities will be implemented as a result of the project. Immediate post fire effects in the Westside Fire Recovery Project are reduced fire spread and intensity due to the reduction of available surface fuels. Over the next 1 to 5 years flame lengths, fireline intensity and rate of spread are expected to remain in a condition that fire suppression resources will be capable of containing any unplanned ignition within the project area (Table 14).

From previous high severity fires on the KNF, vegetation typically begins to re-sprout and establish the year immediately after the fire. Grasses, forbs and shrubs, such as manzanita, sprout along with oak and madrone tree species. Forested stands which had low to moderate fire severity will be expected to maintain relatively shrub free due to the overstory canopy layer shading out these species. Over the next 1 to 5 years, dead tree branches, conifer and broadleaf litter, small trees and shrubs not entirely consumed by the fire will overtime fall to the surface and contribute to surface fuel loading. In lieu of a significant fire weather event, predominately surface fire activity with low severity fire effects (Table 14) are projected up to 5 years or longer.

Table 14. Predicted Fire Behavior 1-5 Years

Flame Length (ft)	Fireline Intensity (btu/ft/sec)	Rate of Spread (Ch/hr)	Interpretation
< 4	< 100	< 5	Persons using handtools can generally attack fires at the head or flanks. Handline should hold the fire

Over time, indirect effects of not taking any action will result in an increased potential high severity fire across the landscape again as vegetation reestablishes and grows. Within moderate to high severity fire areas, hundreds of dead trees with few live trees remaining characterize the post fire landscape. Indirect effects to future vegetation, fire behavior, spread and severity may be impacted as a result of taking no action and leaving standing dead trees on portions of the landscape. Standing snags may retain a substantial amount of biomass that will contribute to surface fuels over time as snags fall (Ritchie, Knapp, & Skinner, 2012).

Currently standing dead trees are storing an enormous loading of dead fuel. Within high severity fire areas, as time increases without disturbance (i.e. fire) to the fire area, it is expected that once forested areas will re-establish into non-forested vegetation predominately with shrub species. Figure 11 is a photo from the 2002 Stanza Fire located adjacent to the Happy Camp Complex. In a matter of 10 years fire hazard is expected to increase, and again susceptible to high severity fire. Shrubs, which can act as a “heat sink” with high live fuel moisture contents, can increase duration (or heating) required to ignite foliage; however, typical live fuel moisture patterns decrease moisture contents over time as seasonal drying and lack of precipitation continue through the summer months resulting in these fuels becoming a “heat source” and are susceptible to ignition, rapid spread rates and increased fireline intensities. The post fire effects of dead surface fuel conditions along with standing trees now add to the area’s susceptibility to fire.

Figure 11. Untreated fuels within the footprint of the 2002 Stanza Fire. Note the volume of standing and felled snags intermixed with brush. Photo taken June 2012, 10 years post fire.

The Chips (2012) fire on the Plumas and Lassen National Forests highlights reburn potential within a 12 year old fire scar. The Chips fire, while occurring in the Sierra Nevada, started and burned for a long period of time within steep drainages of the Feather River Canyon and was subject to daily thermal inversions. Shrub regrowth amongst standing snags created high severity fire effects within the footprint of the 2000 Storrie fire. Heavy consumption of shrub, herb, grass, snag and downed fuels is evident (Fites, Ewell, & Bauer, 2012). Figure 12 displays a pre- and post-fire photograph, note the complete consumption of shrubs along with a consumption of large fuels standing and fallen on the ground.

Figure 12. Paired photo from a fixed point in overlapping area of the Chips and Storrie fires (Photo from Chips Fire Behavior Case Study, 2012)

Table 15 provides potential surface fire behavior activity over the next 10 to 20 years within high and low severity fire areas. High severity fire areas will be expected to have uniform fuel beds of

grasses and shrubs in combination with downed woody fuels intermixed increasing potential fire intensities and subsequent severity.

Table 15. Projected fire behavior 10 to 20 years post fire with no disturbance activities.

Post Fire Severity Type	Flame Length (ft)	Fireline Intensity (btu/ft/sec)	Rate of Spread (Ch/hr)	Interpretation
High	4 to 11+	200 to 1100+	25 to 100+	Indirect attack methods will be needed along with equipment including aircraft and dozers. Potential control issues include crown fire activity and spot fire activity.
Low	< 4	< 100	< 20	Persons using handtools can generally attack fires at the head or flanks. Handline should hold the fire

Table 16 presents potential vegetation characteristics that are anticipated by vegetation type and expected primary carrier of fire. Expected flame lengths and fireline intensity associated with taking no action are such that within ten years flame lengths and fireline intensities are expected to be greater than four feet and 100 btu/ft/sec. Low severity fire areas are best represented by Low to high conifer/hardwood litter which would be expected to accumulate overtime from dead material that falls from mid- and overstory crowns. Shrub fuels and snag fall vegetation are the expected primary carrier of fuels within high severity stands.

Table 16. Potential fire behavior by vegetation type within high severity fire areas 10 years..

Vegetation	Flame Length (feet)	Fireline Intensity (btu/ft/sec)	Rate of Spread (ch/hr)	Description of Fuels Primarily Carrying Fire
Grass/Shrub	10	760	75	Grass with small shrub growth.
Low/Moderate Shrub Load	8	550	20	Shrubs generally less than 4 feet
High/Very High Shrub Load	22	5200	125	Shrubs greater than 4 feet
Low Load Timber Shrub	3	75	9	Conifer overstory with litter and small shrubs
High Load Timber Shrub	12	1300	25	Conifer overstory shrubs and small trees in understory
Low/Moderate Conifer/Hardwood litter	2	20	5	Needle cast and small dead/downed material primarily fuels < 1” diameter (10 hour).
High Conifer Litter/Hardwood Load	4	100	8	Needle cast with heavy component of dead downed material primarily 1 to 3’ diameter (10 and 100 hour) fuels.
Low Load Snag Fall	4	110	12	Natural accumulation of snag fall. Fuel bed depth < 1 foot.
High Load Snag Fall	15	2500	45	Natural accumulation of snag fall. Fuel bed depth > 1 foot.

FlamMap provides the ability to spatially predict fire behavior across the landscape. Fuel models are based on future vegetation utilizing fire history and vegetation regrowth after these fires. Within 10 to 20 years (Figure 13), approximately 60% of the landscape could see flame lengths greater than 4 feet and fireline intensities greater than 100 btu/ft/sec (**Error! Reference source not found.** and 18). FlamMap does not incorporate 1000 hour fuel loadings (fuels > 3” diameter)

into fire behavior modeling; within areas that have increased fuel loadings due to snag fall, fireline intensities could exceed 3000 btu/ft/sec.

Table 17. 10 to 20 Year potential flame length within the Westside Fire Recovery Project Area.

Flame Length (ft)	Acres	Percent of Project Area	Interpretation
< 4 Feet	80,739	37.55%	Persons using handtools can generally attack fires at the head or flanks. Handline should hold the fire
4 to 8 Feet	98,039	45.60%	Fires are too intense for direct attack on the head by persons using handtools. Handline cannot be relied on to hold fire. Equipment such as dozers, engines, and retardant aircraft can be effective.
8 to 11 Feet	10,875	5.06%	Fires may present serious control problems such as torching, crowning, and spotting. Control efforts at the head of the fire will probably be ineffective.
> 11 Feet	25,365	11.80%	Crowning, spotting, and major runs are common; control efforts at the head of the fire are ineffective.

Table 18. 10 to 20 year potential fireline intensity within the Westside Project Area.

Fireline Intensity (btu/sec/ft)	Acres	Percent of Project Area	Interpretation
< 100	75,407	35.07%	Persons using handtools can generally attack fires at the head or flanks. Handline should hold the fire
100 to 500	108,685	50.55%	Fires are too intense for direct attack on the head by persons using handtools. Handline cannot be relied on to hold fire. Equipment such as dozers, engines, and retardant aircraft can be effective.
500 to 1000	17,659	8.21%	Fires may present serious control problems such as torching, crowning, and spotting. Control efforts at the head of the fire will probably be ineffective.
> 1000	13,267	6.17%	Crowning, spotting, and major runs are common; control efforts at the head of the fire are ineffective.

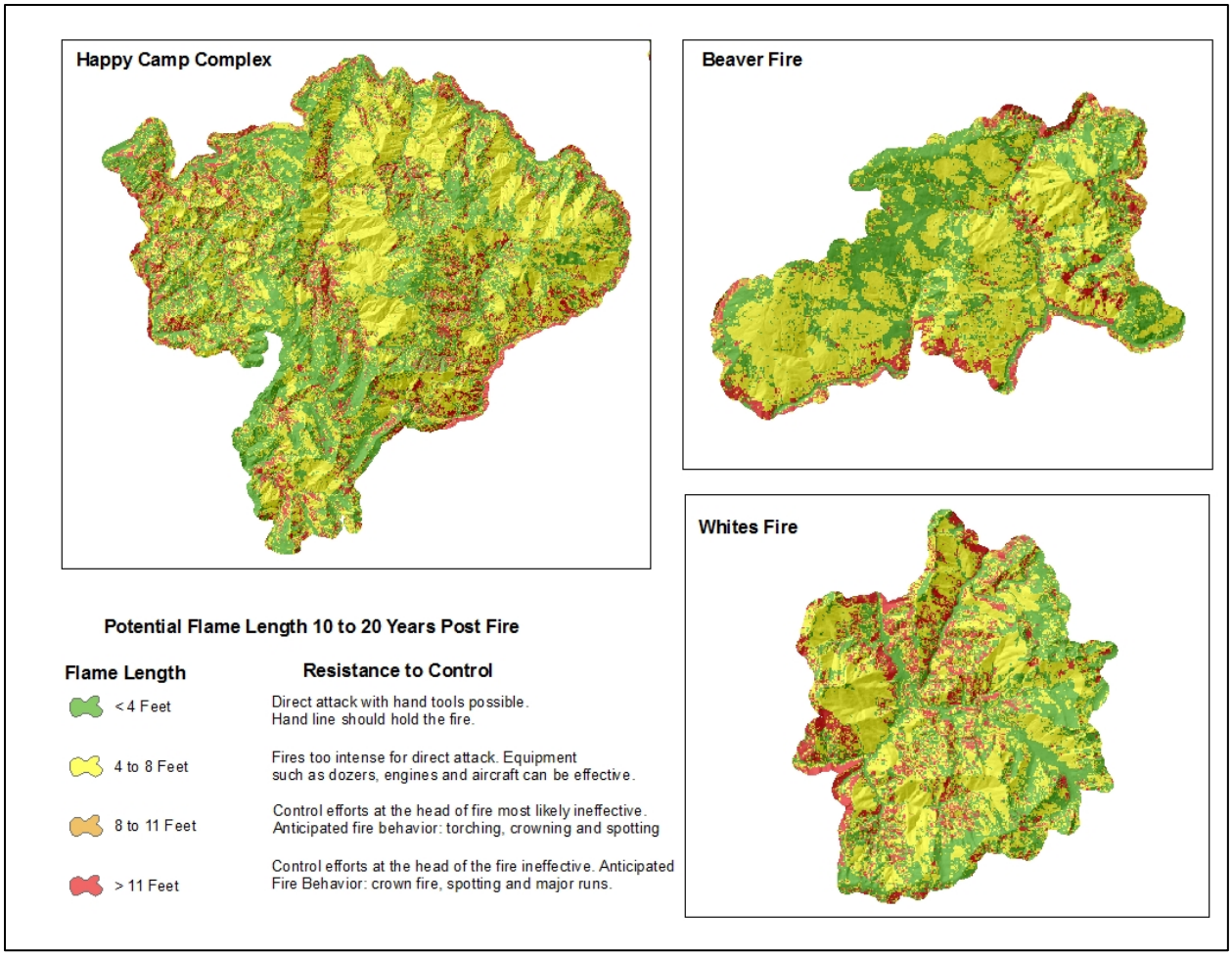


Figure 13. Potential flame lengths based on 90th percentile weather conditions 10 to 20 years post fire.

Fire persistence, resistance-to-control, and burnout time (which affects soil heating) are significantly influenced by loading, size and decay state of large woody material (Brown, Reinhardt, & Kramer, 2003). Large woody material can contribute to fire behavior and fire spread by acting as a source of embers, both directly by lofting from burning snags and indirectly through torching of trees preheated by burning of heavy fuels on the forest floor (Ritchie, Knapp, & Skinner, 2012). To quantify potential future fire behavior and resistance to control, Table 19 displays potential surface fuel loadings over time within various mortality levels at 15 sample plots in the fire area.

Surface fuel loading values (1-, 10- 100-, and 1000-hour fuel categories) in Table 19 and Table 20 are potential surface fuel loading over time from standing dead trees that fall to the ground. These values do not incorporate vegetation that will reestablish over time as added surface fuel loading. As standing snags fall, they contribute to surface fuel loading and increase subsequent fire behavior potential. Intensity is calculated based on two scenarios with moderate and rapid spread rates, both of which were observed on previous fires. Within 10 years, large fuels have the potential to produce conditions resulting in high intensities, high severity fire effects and increased resistance to control of wildland fires. This is especially the case where forested vegetation supported large trees intermixed with shade tolerant small diameter trees. These area's present a high hazard to future fire effects as smaller fuels accumulate to increase fire

ignition and spread and large fuels contribute to sustained ignition during the flaming front and subsequent long duration burn down time; large fuels smolder and consume retaining high intensities for longer periods of time.

Table 19. Future surface fuel loading and fire behavior potential over 50 years within the Beaver fire area.

Plot 1 90% Mortality							
Year	1 Hour Fuels Present In Year (tons/acre)	10 Hour Fuels Present In Year (tons/acre)	100 Hour Fuels Present In Year (tons/acre)	1000 Hour Fuels Present In Year (tons/acre)	Intensity (btu/ft/sec) 26 ch/hr	Intensity (btu/ft/sec) 40 ch/hr	Resistance to Control
1	0.31	0.28	0.48	2.35	11	17	Low
10	1.68	1.56	2.65	13.79	1777	2713	High
20	1.83	1.7	2.89	16.48	2014	3074	High
30	1.59	1.47	2.5	15.89	1830	2794	High
40	1.28	1.19	2.02	14.43	1563	2386	High
50	1.01	0.94	1.6	12.86	1313	2004	High
Plot 2 100% Mortality							
Year	1 Hour Fuels Present In Year (tons/acre)	10 Hour Fuels Present In Year (tons/acre)	100 Hour Fuels Present In Year (tons/acre)	1000 Hour Fuels Present In Year (tons/acre)	Intensity (btu/ft/sec) 26 ch/hr	Intensity (btu/ft/sec) 40 ch/hr	Resistance to Control
1	0.04	0.76	0.58	4.97	15	27	Low
10	0.26	4.9	3.72	34.52	3409	5204	Extreme
20	0.3	6.15	4.66	47.41	4489	6854	Extreme
30	0.27	5.92	4.48	50.22	4561	6963	Extreme
40	0.22	5.16	3.9	48.46	4221	6444	Extreme
50	0.18	4.28	3.24	44.82	3747	5721	Extreme
Plot 3 100% Mortality							
Year	1 Hour Fuels Present In Year (tons/acre)	10 Hour Fuels Present In Year (tons/acre)	100 Hour Fuels Present In Year (tons/acre)	1000 Hour Fuels Present In Year (tons/acre)	Intensity (btu/ft/sec) 26 ch/hr	Intensity (btu/ft/sec) 40 ch/hr	Resistance to Control
1	0.13	0.64	0.58	9.58	15	40	Low
10	0.87	4.2	3.84	67.26	5155	7870	Extreme
20	1.11	5.36	4.91	93.04	6963	10630	Extreme
30	1.08	5.22	4.78	98.96	7224	11030	Extreme
40	0.95	4.58	4.19	95.75	6813	10401	Extreme
50	0.79	3.82	3.5	88.69	6152	9393	Extreme
Plot 4 100% Mortality							
Year	1 Hour Fuels Present In Year (tons/acre)	10 Hour Fuels Present In Year (tons/acre)	100 Hour Fuels Present In Year (tons/acre)	1000 Hour Fuels Present In Year (tons/acre)	Intensity (btu/ft/sec) 26 ch/hr	Intensity (btu/ft/sec) 40 ch/hr	Resistance to Control
1	0.29	0.85	1.17	2.36	24	29	Low
10	1.76	5.67	8.37	14.43	3567	5446	Extreme
20	2.19	7.68	12.1	18.16	4859	7418	Extreme
30	2.14	8.18	13.51	18.43	5203	7943	Extreme

40	1.93	7.98	13.66	17.59	5112	7804	Extreme
50	1.69	7.45	13.1	16.39	4812	7347	Extreme
Plot 5 40% Mortality							
Year	**1 Hour Fuels Present In Year (tons/acre)**	**10 Hour Fuels Present In Year (tons/acre)**	**100 Hour Fuels Present In Year (tons/acre)**	**1000 Hour Fuels Present In Year (tons/acre)**	**Intensity (btu/ft/sec) 26 ch/hr**	**Intensity (btu/ft/sec) 40 ch/hr**	**Resistance to Control**
1	0.05	0.27	0.26	2.43	6	12	Low
10	0.36	1.57	1.55	15.81	1457	2225	High
20	0.48	1.84	1.88	20.72	1846	2818	High
30	0.49	1.7	1.79	21.31	1838	2806	High
40	0.45	1.45	1.57	20.21	1689	2579	High
50	0.4	1.21	1.33	18.5	1504	2297	Moderate
Plot 6 10% Mortality							
Year	**1 Hour Fuels Present In Year (tons/acre)**	**10 Hour Fuels Present In Year (tons/acre)**	**100 Hour Fuels Present In Year (tons/acre)**	**1000 Hour Fuels Present In Year (tons/acre)**	**Intensity (btu/ft/sec) 26 ch/hr**	**Intensity (btu/ft/sec) 40 ch/hr**	**Resistance to Control**
1	0.02	0.1	0.11	2.04	2	8	Low
10	0.14	0.64	0.78	16.21	1138	1738	Moderate
20	0.19	0.86	1.09	25.83	1752	2675	Moderate
30	0.21	0.9	1.18	31.43	2077	3171	Moderate
40	0.2	0.86	1.17	34.4	2224	3395	Moderate
50	0.19	0.79	1.1	35.59	2261	3451	Moderate
Plot 7 10% Mortality							
Year	**1 Hour Fuels Present In Year (tons/acre)**	**10 Hour Fuels Present In Year (tons/acre)**	**100 Hour Fuels Present In Year (tons/acre)**	**1000 Hour Fuels Present In Year (tons/acre)**	**Intensity (btu/ft/sec) 26 ch/hr**	**Intensity (btu/ft/sec) 40 ch/hr**	**Resistance to Control**
1	0.06	0.12	0.13	0.46	3	4	Low
10	0.38	0.8	0.88	2.88	518	791	Low
20	0.48	1.09	1.24	3.7	695	1061	Low
30	0.48	1.16	1.36	3.83	735	1123	Low
40	0.45	1.14	1.35	3.73	719	1098	Low
50	0.4	1.06	1.28	3.53	673	1028	Low
Plot 8 100% Mortality							
Year	**1 Hour Fuels Present In Year (tons/acre)**	**10 Hour Fuels Present In Year (tons/acre)**	**100 Hour Fuels Present In Year (tons/acre)**	**1000 Hour Fuels Present In Year (tons/acre)**	**Intensity (btu/ft/sec) 26 ch/hr**	**Intensity (btu/ft/sec) 40 ch/hr**	**Resistance to Control**
1	0.14	0.76	0.58	0.47	16	15	Low
10	0.89	4.9	3.72	2.97	1843	2814	Moderate
20	1.11	6.15	4.66	3.77	2313	3531	Moderate
30	1.06	5.92	4.48	3.8	2233	3409	Moderate
40	0.91	5.16	3.9	3.55	1955	2985	Moderate
50	0.76	4.28	3.24	3.22	1638	2501	Moderate
Plot 9 50% Mortality							
Year	**1 Hour Fuels**	**10 Hour**	**100 Hour**	**1000 Hour**	**Intensity**	**Intensity**	**Resistance**

	Present In Year (tons/acre)	Fuels Present In Year (tons/acre)	Fuels Present In Year (tons/acre)	Fuels Present In Year (tons/acre)	(btu/ft/sec) 26 ch/hr	(btu/ft/sec) 40 ch/hr	to Control
1	0.04	0.1	0.11	0.83	3	5	Low
10	0.25	0.59	0.6	5.34	539	823	Moderate
20	0.3	0.69	0.68	6.92	664	1013	Moderate
30	0.27	0.63	0.61	7.07	643	982	Moderate
40	0.23	0.53	0.51	6.67	580	885	Moderate
50	0.19	0.43	0.41	6.09	506	773	Moderate
Plot 10 5% Mortality							
Year	**1 Hour Fuels Present In Year (tons/acre)**	**10 Hour Fuels Present In Year (tons/acre)**	**100 Hour Fuels Present In Year (tons/acre)**	**1000 Hour Fuels Present In Year (tons/acre)**	**Intensity (btu/ft/sec) 26 ch/hr**	**Intensity (btu/ft/sec) 40 ch/hr**	**Resistance to Control**
1	0	0.01	0.01	0.19	0	1	Low
10	0.03	0.04	0.06	1.57	107	163	Low
20	0.04	0.06	0.08	2.49	164	251	Low
30	0.05	0.07	0.09	2.97	195	298	Low
40	0.05	0.07	0.08	3.17	204	311	Low
50	0.04	0.06	0.08	3.18	201	307	Low
Plot 11 5% Mortality							
Year	**1 Hour Fuels Present In Year (tons/acre)**	**10 Hour Fuels Present In Year (tons/acre)**	**100 Hour Fuels Present In Year (tons/acre)**	**1000 Hour Fuels Present In Year (tons/acre)**	**Intensity (btu/ft/sec) 26 ch/hr**	**Intensity (btu/ft/sec) 40 ch/hr**	**Resistance to Control**
1	0.01	0.01	0.01	0.12	0	1	Low
10	0.03	0.08	0.05	0.85	74	112	Low
20	0.04	0.1	0.07	1.17	99	152	Low
30	0.04	0.1	0.07	1.25	104	158	Low
40	0.04	0.09	0.06	1.2	97	149	Low
50	0.03	0.07	0.05	1.12	86	131	Low
Plot 12 90% Mortality							
Year	**1 Hour Fuels Present In Year (tons/acre)**	**10 Hour Fuels Present In Year (tons/acre)**	**100 Hour Fuels Present In Year (tons/acre)**	**1000 Hour Fuels Present In Year (tons/acre)**	**Intensity (btu/ft/sec) 26 ch/hr**	**Intensity (btu/ft/sec) 40 ch/hr**	**Resistance to Control**
1	0.22	0.43	0.46	10.22	12	40	Low
10	1.47	2.93	3.17	77.74	5474	8358	Extreme
20	1.98	3.9	4.32	117.05	8030	12260	Extreme
30	2.04	4	4.49	134.45	9014	13761	Extreme
40	1.9	3.71	4.23	139.16	9142	13957	Extreme
50	1.68	3.27	3.77	136.54	8804	13441	Extreme
Plot 13 50% Mortality							
Year	**1 Hour Fuels Present In Year (tons/acre)**	**10 Hour Fuels Present In Year (tons/acre)**	**100 Hour Fuels Present In Year (tons/acre)**	**1000 Hour Fuels Present In Year (tons/acre)**	**Intensity (btu/ft/sec) 26 ch/hr**	**Intensity (btu/ft/sec) 40 ch/hr**	**Resistance to Control**

1	0.1	0.16	0.22	6.68	5	24	Low
10	0.69	1.12	1.58	53.03	3420	5221	Extreme
20	0.98	1.55	2.24	83.78	5299	8090	Extreme
30	1.07	1.66	2.45	100.59	6266	9566	Extreme
40	1.05	1.6	2.41	108.33	6656	10161	Extreme
50	0.98	1.48	2.25	110.09	6687	10210	Extreme
Plot 14 100% Mortality							
Year	**1 Hour Fuels Present In Year (tons/acre)**	**10 Hour Fuels Present In Year (tons/acre)**	**100 Hour Fuels Present In Year (tons/acre)**	**1000 Hour Fuels Present In Year (tons/acre)**	**Intensity (btu/ft/sec) 26 ch/hr**	**Intensity (btu/ft/sec) 40 ch/hr**	**Resistance to Control**
1	0.09	0.53	0.37	1.53	11	14	Low
10	0.49	2.9	2.04	8.94	1438	2195	Moderate
20	0.54	3.16	2.22	10.68	1617	2468	Moderate
30	0.46	2.74	1.93	10.3	1457	2224	Moderate
40	0.38	2.22	1.56	9.36	1235	1885	Moderate
50	0.3	1.75	1.23	8.34	1025	1564	Moderate
Plot 15 50% Mortality							
Year	**1 Hour Fuels Present In Year (tons/acre)**	**10 Hour Fuels Present In Year (tons/acre)**	**100 Hour Fuels Present In Year (tons/acre)**	**1000 Hour Fuels Present In Year (tons/acre)**	**Intensity (btu/ft/sec) 26 ch/hr**	**Intensity (btu/ft/sec) 40 ch/hr**	**Resistance to Control**
1	0.02	0.17	0.23	4.45	4	17	Low
10	0.12	1.25	1.6	33.07	2284	3488	Extreme
20	0.16	1.76	2.17	48.61	3309	5052	Extreme
30	0.15	1.87	2.26	54.64	3663	5593	Extreme
40	0.14	1.79	2.13	55.52	3671	5605	Extreme
50	0.12	1.61	1.9	53.64	3495	5336	Extreme

Table 20. Future surface fuel loading potential over 50 years within the Happy Camp Complex.

Grider Creek			**Stand ID 05055200520006**		
Year	**Surface Fuel < 3" dbh (tons/acre)**	**Surface Fuels > 3" dbh (tons/acre)**	**Intensity (btu/ft/sec) 26 ch/hr**	**Intesity (btu/ft/sec) 40 ch/hr**	**Resistance to Control**
1	1.23	11.63	45	45	Low
10	10.56	44.91	4259	6502	Extreme
20	13.46	53.97	5255	8023	Extreme
30	19.22	56.14	6391	9757	Extreme
40	27.27	66.34	8359	12762	Extreme
50	34.16	79.83	10298	15721	Extreme
Grider Creek			**Stand ID 05055200520016**		
Year	**Surface Fuel < 3" dbh (tons/acre)**	**Surface Fuels > 3" dbh (tons/acre)**	**Intensity (btu/ft/sec) 26 ch/hr**	**Intesity (btu/ft/sec) 40 ch/hr**	**Resistance to Control**
1	0.89	3.76	19	19	Low
10	9.45	18.85	2677	4088	High
20	11.88	36.38	4040	6168	Extreme
30	8.92	43.75	3907	5964	Extreme

40	6.85	46.86	3704	5656	Extreme
50	5.35	47.14	3454	5273	Extreme
Scott River			**Stand ID 05055518010208060009**		
Year	**Surface Fuel < 3" dbh (tons/acre)**	**Surface Fuels > 3" dbh (tons/acre)**	**Intensity (btu/ft/sec) 26 ch/hr**	**Intesity (btu/ft/sec) 40 ch/hr**	**Resistance to Control**
1	1.15	19.32	66	66	Low
10	17.04	49.41	5647	8622	Extreme
20	19.48	74.90	7434	11349	Extreme
30	17.28	84.58	7559	11540	Extreme
40	15.33	89.31	7464	11395	Extreme
50	13.65	89.70	7187	10973	Extreme
Scott River			**Stand ID 05055555290003**		
Year	**Surface Fuel < 3" dbh (tons/acre)**	**Surface Fuels > 3" dbh (tons/acre)**	**Intensity (btu/ft/sec) 26 ch/hr**	**Intesity (btu/ft/sec) 40 ch/hr**	**Resistance to Control**
1	0.76	4.53	20	20	Low
10	11.66	23.90	3338	5095	High
20	10.76	41.86	4132	6308	Extreme
30	8.03	47.75	3962	6049	Extreme
40	5.96	49.83	3705	5656	Extreme
50	4.44	48.88	3385	5168	Extreme
Scott River			**Stand ID 05055518010208060044**		
Year	**Surface Fuel < 3" dbh (tons/acre)**	**Surface Fuels > 3" dbh (tons/acre)**	**Intensity (btu/ft/sec) 26 ch/hr**	**Intesity (btu/ft/sec) 40 ch/hr**	**Resistance to Control**
1	2.43	26.80	99	99	Low
10	19.38	58.23	6530	9969	Extreme
20	25.75	77.24	8670	13236	Extreme
30	22.30	86.84	8568	13080	Extreme
40	19.26	90.23	8211	12536	Extreme
50	16.62	90.65	7764	11853	Extreme
Walker Creek			**Stand ID 050552ABCD001116414144205**		
Year	**Surface Fuel < 3" dbh (tons/acre)**	**Surface Fuels > 3" dbh (tons/acre)**	**Intensity (btu/ft/sec) 26 ch/hr**	**Intesity (btu/ft/sec) 40 ch/hr**	**Resistance to Control**
1	1.49	14.40	55	55	Low
10	14.34	51.11	5259	8029	Extreme
20	16.82	73.97	6912	10553	Extreme
30	12.89	80.54	6567	10025	Extreme
40	10.83	76.98	6013	9179	Extreme
50	10.00	70.61	5526	8437	Extreme
Walker Creek			**Stand ID 050552ABCD027746277**		
Year	**Surface Fuel < 3" dbh (tons/acre)**	**Surface Fuels > 3" dbh (tons/acre)**	**Intensity (btu/ft/sec) 26 ch/hr**	**Intesity (btu/ft/sec) 40 ch/hr**	**Resistance to Control**
1	1.53	20.07	71	71	Low
10	15.95	49.63	5464	8343	Extreme
20	19.53	81.82	7811	11925	Extreme
30	14.94	96.55	7781	11880	Extreme

40	11.38	103.17	7501	11452	Extreme
50	8.64	103.31	7024	10724	Extreme
Walker Creek			**Stand ID 050552ABCD0292**		
Year	**Surface Fuel < 3" dbh (tons/acre)**	**Surface Fuels > 3" dbh (tons/acre)**	**Intensity (btu/ft/sec) 26 ch/hr**	**Intesity (btu/ft/sec) 40 ch/hr**	**Resistance to Control**
1	2.10	23.61	87	87	Low
10	14.95	51.34	5379	8213	Extreme
20	18.57	73.51	7199	10991	Extreme
30	14.20	82.47	6902	10537	Extreme
40	10.81	82.30	6291	9605	Extreme
50	8.21	78.92	5650	8626	Extreme

Table 19 and Table 20 provide the ability to quantify potential surface fuel loading from standing dead timber. Low severity areas have the least amount of increase in surface fuel accumulations due to the relatively low mortality levels. Over the course of the next 50 years, without fire or other disturbance activities, low severity fire areas should be expected to look similar to pre-fire conditions. Odion et. al. (2004) and Thompson et. al. (2007) highlight this in the 1987 KNF fires and Biscuit fire areas respectively. Both studies found that where low severity fire areas occurred in the past, re-burned at low severity again.

However, there is concern in high and moderate severity stands. Large accumulations of fuels have the potential to exhibit intensities greater than 6000 btu/ft/sec over the course of 50 years. It is anticipated that these intensities could exhibit higher outputs based on the type of vegetation that establishes and intermixes within these large fuel accumulations. Two problem areas are potential reburn and increased resistance to control over time. Much of the high severity fire areas were Mixed Conifer stands with closed canopies. Within areas of high severity that fully consumed forested canopies, it can be expected that non-forested conditions consisting of shrubs and grasses will persist.

The probability of a reburn is higher, to an unknown extent, in heavy accumulations of coarse woody debris because of the high fire persistence that characterizes coarse woody debris (Brown, Reinhardt, & Kramer, 2003). Beyond the initial flaming front, is consideration for residence time as large fuels smolder for long periods, through radiation and conduction, into soils and surrounding vegetation. The Fire Behavior Assessment Report from the Beaver Fire (2014) provides an example of temperature from initial flaming front through residence burn down time of larger fuels. Within the plot, estimated surface fuel loading was 70 tons/acre. The initial flaming front spiked temperatures to 1000°C then subsided to above 200 °C but sustained those temperatures for 30 minutes. Long-term smoldering can cause extended high soil heating, frequently above 140 °F, which is the temperature required to kill plant tissue (Hood, 2010). Ground fires and consumption of large-diameter surface fuels can cause root and basal stem injury by consuming fine roots growing in the duff layer and through long-term heating of the soil and cambium at the tree base (Hood, 2010). As conifers reestablish within shrub fuels, they will be at risk of reburn at high severity and extended periods of heating (residence time) as large fuels burn down and smolder.

The same future conditions may exist over the course of a 50 year time period as shrubs establish and grow. Standing snags fall and contribute dead fuel loading and trees begin to intermix among the shrubs directly correlating to increased flame lengths, fireline intensity and subsequent fire

severity from prolonged heating (residence time) of large surface fuels. Torching, crowning, and spotting, which contribute to large fire growth, are greater where large woody fuels have accumulated under a forest canopy and contribute to surface fire heat release (Brown, Reinhardt, & Kramer, 2003). Over time, it can be expected that the potential for high severity fire to occur where non-forested vegetation continues to grow and areas of high tree mortality continue to add to surface fuel loadings, especially where larger trees fall and decay. After enough fuels have accumulated, fire hazard likely increase with time as fuels accumulate and coarse woody debris rots, increasing its flammability (Monsanto & Agee, 2008; Peterson & Harrod, 2010). Within 50 years, approximately 80 percent of the project area (Figure 14) could exhibit flame lengths greater than 4 feet and fireline intensities greater than 100 feet (Table 21 and Table 22). At this point in time, any new trees that have had the opportunity to establish in the post fire burn area will again be susceptible to crown fire activity.

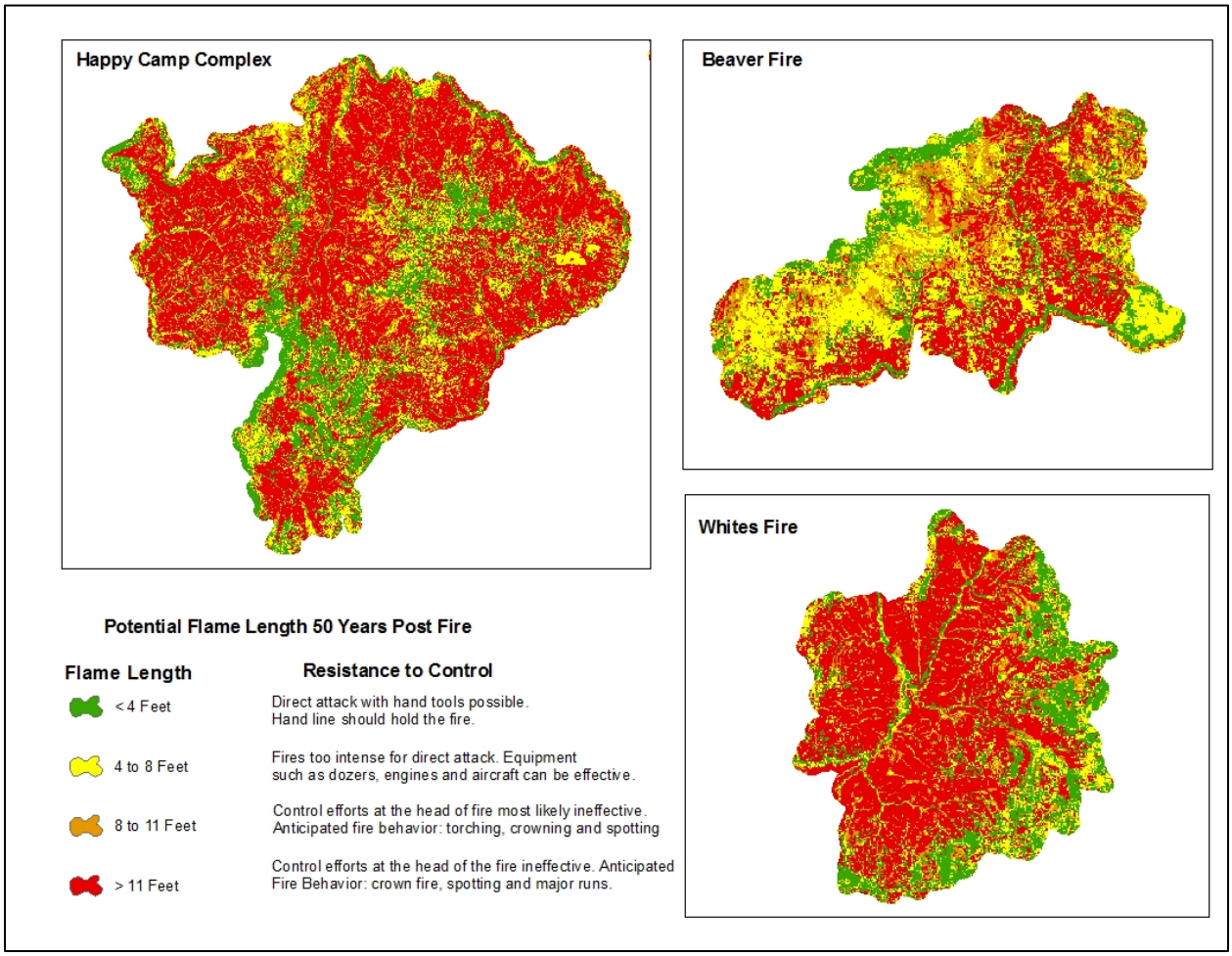


Figure 14. Potential flame lengths based on 90th percentile weather conditions 50 years post fire.

Table 21. 50 year potential flame length within the Westside Project Area.

Flame Length (ft)	Acres	Percent of Project Area	Interpretation
< 4 Feet	40,906	19.02%	Persons using handtools can generally attack fires at the head or flanks. Handline should hold the fire

Flame Length (ft)	Acres	Percent of Project Area	Interpretation
4 to 8 Feet	40,259	18.72%	Fires are too intense for direct attack on the head by persons using handtools. Handline cannot be relied on to hold fire. Equipment such as dozers, engines, and retardant aircraft can be effective.
8 to 11 Feet	24,510	11.40%	Fires may present serious control problems such as torching, crowning, and spotting. Control efforts at the head of the fire will probably be ineffective.
> 11 Feet	109,343	50.85%	Crowning, spotting, and major runs are common; control efforts at the head of the fire are ineffective.

Table 22. 50 year potential fireline intensity within the Westside Project Area.

Fireline Intensity (btu/sec/ft)	Acres	Percent of Project Area	Interpretation
< 100	35,849	16.67%	Persons using handtools can generally attack fires at the head or flanks. Handline should hold the fire
100 to 500	74,944	34.85%	Fires are too intense for direct attack on the head by persons using handtools. Handline cannot be relied on to hold fire. Equipment such as dozers, engines, and retardant aircraft can be effective.
500 to 1000	51,839	24.11%	Fires may present serious control problems such as torching, crowning, and spotting. Control efforts at the head of the fire will probably be ineffective.
> 1000	52,386	24.36%	Crowning, spotting, and major runs are common; control efforts at the head of the fire are ineffective.

Fire Suppression Capability

Snags are present within the wildland urban interface, road systems and strategic locations that have historically been used as primary control lines to contain previous large fire events. The impact of standing dead timber and subsequent surface fuel loading within moderate and high severity fire areas upon firefighter safety and wildland fire containment will increase resistance to control over the course of 50 years (Table 19 and 20). In high severity fire areas, sampled tree data reveals snag ranging from 200 to 1500 snags per acre.

It is anticipated that snags and increased surface fuels will subsequently increase suppression resource needs and time to control a wildland fire even a small lightning caused fire. If a fire were to start in the project area in 10 to 50 years, large downed fuel will present an increased resistance to control along with snags taking additional time and effort to control a fire. Large fuels require heavy mop-up utilizing engines or helicopters for water support to cool down the area as these fuels take time to consume and emit high fireline intensities and increase firefighter exposure to other environmental and physical factors.

To safely attack and contain a large fire in the future will also be difficult, time consuming, and require large amounts of suppression resources. Fires which start in surrounding snag patches may require indirect suppression tactics due to safety (Figure 15). When fire suppression resources encounter snags, falling the tree is an option; however, when numerous standing snags exist, resources may decide to relocate control lines away from the hazards adding unburned fuel between resources and the fire, adding a new hazard. This added element generally means constructing safety zones and control lines cleared to mineral soil with equipment such as dozers

and feller bunchers. It is not uncommon to build indirect control lines 20 to 30 feet wide and safety zones 5 to 10 acres in size utilized by firefighters as place to escape to should fire behavior be such to warrant withdrawal. When control lines are constructed by heavy equipment, the understory vegetation is pushed aside and piled without regard to consideration of other resources including archeological, soils and other sensitive features. After the fire, extensive time and energy goes into suppression repair to remove and repair control lines.

Figure 15. Firefighters survey multiple burning snags and employ tactics to safely build line to control the fire. The weakened trees pose a risk to firefighters, both from falling over and producing spot fires ahead of the main fire.

Large dead fuels that continue to decay increase their availability to ignite and consume due to increased surface area for direct flames impingement subsequently increase fireline intensity and resistance to control. Several previous fires within pre-existing fire scars have shown that large quantities of resources and indirect firefighting tactics are utilized to reduce exposure to snags. The Chips (Plumas/Lassen NF, 2012), Big Meadow (Yosemite NP, 2009), Backbone (Shasta-Trinity NF, 2009) and Corral Complex (Six Rivers NF, 2012) are examples where indirect strategies were utilized due to the presence of high amounts of snags. In these previous fire scars, fire suppression resources cut down snags along control lines to reduce aerial hazards and spot

fire potential adjacent to control lines. The consequences surface fuel loadings are significantly increased adjacent to planned control lines. This results in high quantities of large fuels and subsequent potential for increased surface fireline intensities. The outcome requires equipment such as engines, dozers and aircraft to prep indirect control lines and hold burnout operations Table 19 estimates potential resistance to control over the 50 year period; high to extreme resistance to control are estimated based on plots sampled within the fire area.

Snags, both ember producers and receptors in the wildland fire environment promote problem fire behavior (Figure 16). During the Big Meadow Fire, snags exhibited problem fire behavior as spot fires were emitted more than .25 miles ahead of the main fire and falling into receptive dead and down coarse woody debris from the 1996 A-Rock Fire scar. This result in the inability of fire suppression resources to safely construct fireline utilizing direct line tactics as the fire quickly increased in size as spot fire generated ahead of the main fire growing in size.

A case study on the Chips fire (2012) discussed resistance to control issues due to steep slopes hampering containment efforts However, once the fire burned into an area with a high density of snags, downed logs and shrub regrowth, fire intensity increased and large column development occurred causing fire suppression resource to withdrawal from direct attack and move to safer distances to construct control lines. Fireline construction on the Chips fire required great effort due to the steep terrain, heavy fuels and snags which hindered line construction. Much like the Chips fire, the Westside Fire Recovery Project Area contains steep slopes. Within the course of 10 to 50 years the project area has the potential for significant fuel loading resulting in extreme fire behavior potential.

Figure 16. Big Meadow Fire (2009) burning within the A-Rock Fire (1996) scar. Standing snags promoted spot fire ignition greater than .25 miles ahead of the main fire. Large downed fuels created fuel beds receptive to embers and burning intensely for long periods of time.

Wildland Urban Interface (WUI)/Strategic Fire Management Areas

Within the Westside project area, numerous communities, infrastructure and private timberlands are located adjacent to National Forest System lands. With regards to the WUI, snags can jeopardize road systems as a serious ingress/egress issues during access to a fire and/or leaving the area in an emergency. Heavy fuel loads within WUI areas increases the likelihood of accelerated spread rates and higher resistance to control as a result of spot fire ignition, high intensities and large quantities of suppression resources to control a fire.

Fire suppression managers have identified and utilized strategic areas to control large fires. Many of the areas including natural barriers, ridge systems, and roads used to contain the 2014 fires had been used in previous fires on the KNF. It is reasonable to assume fire managers will gravitate to these locations to control an unplanned ignition. The King Fire (2014) on the Eldorado National Forest is an example of how fire managers utilized historic fire lines from the Ralston (2006) and Star (2001) fires in planning their containment efforts. Taking no action in the project area will make future efforts to utilize these locations as effective control lines risky (Figure 17). Cutting snags increases the surface fuel loading adjacent to control lines and presents serious hazards to firefighters. Trees felled have been in a state of decay and weakened further subjecting hazards to falling teams (Sawyers who utilize chainsaws to fall trees) who cut down the trees. The increased fuel loading makes holding control lines difficult due to increased intensity as fuels continue to burn down igniting fires adjacent to control lines. Under alternative 1, we can expect similar conditions along the ridge systems where high severity fire occurred.

Figure 17. Indirect control line on the Butler Fire (2013), Klamath/Six Rivers National Forest. Note the standing snags and downed woody material intermixed with shrub fuels. Holding efforts on future fires will be difficult and require substantial aircraft and water support.

Cumulative Effects

Alternative 1 will not supplement other present and/or reasonably foreseeable future projects that are planned to improve forest health, old growth desired conditions, fire resilience, and suppression effectiveness across the landscape. Additionally, difficulties may preclude future projects from either continuing or being planned due to the high density of snags within or adjacent to the Westside Fire Recovery Project Area. Utilizing fire as a management tool in both the planned (prescribed fire) and unplanned setting may not meet desired resource objectives due to future fuel loading potential as well as the hazard, cost and time consuming activities necessary to remove decaying hazard trees from planned control lines will be a limiting factor in future prescribed fire activities.

Concerns raised during public scoping regarding treating fuels adjacent to private lands, both timber and residential communities will not be addressed. Furthermore, Alternative 1 does not provide for opportunities to work to develop fuel breaks cooperatively with adjacent land owners.

The majority of the rest of the burned area is owned by Fruit Growers Supply Company (FGS) and Michigan California Timber Company and located within the Beaver Fire Area. Both of these companies are either currently or planning to treat their land by conducting salvage operations on their respective properties. It is understood that FGS is planning a series of fuel breaks within the ridge and road systems of the Beaver fire area; there lands are intermixed between National Forest System Land. Salvage operation of all trees are generally occurring on slopes less than 45% and commercial trees are being removed on slopes greater than 45%. After salvage operations are completed replanting is expected. It is also expected that herbicide treatments will be applied to the planted areas to reduce shrub growth. As a result of the operations expected on the privately owned lands these lands are expected to be relatively fire safe. This is primarily due to the removal or reduction of most of the dead and dying trees on these lands.

Alternative 2

Direct and Indirect Effects

Alternative 2 uses a variety of treatments to increase safety to public and forest users, reduce future surface fuel loadings, alter fire behavior and subsequently increase fire resilience over the long term as compared to taking no action. Alternative 2 includes salvage, site preparation, planting and release, hazardous fuels and roadside hazard treatments to meet the purpose and need of the project and Fire Management Standards and Guides contained within the Klamath National Forest Land and Resource Management Plan (2010).

Salvage Harvest & Site Preparation, Planting and Release

Post-fire logging can serve as an effective tool for managing fuel loadings in the forests regenerating after high severity wildfires (Peterson, Dodson, & Harrod, 2014). Approximately 6,800 acres proposed for treatment (of the 11,700 acres in the salvage harvest units) removes trees $\geq$ 14” dbh. The direct effect of salvage harvest is in reducing density of snags on the landscape (Ritchie, Knapp, & Skinner, 2012) and subsequently reducing future accumulations of large diameter surface fuels as trees fall to the forest floor.

Within units identified for treatment, snag retention will occur within Riparian Reserves (RRs) and identified leave locations. No planned salvage harvest will occur in RRs. Snag retention outside of riparian zones will utilize a clumping pattern to retain snags which will promote decreased surface fuel loadings outside of these zones. Within snag retention areas and RRs, surface fuel loadings will mirror conditions outlined under Alternative 1 (Table 19).

About 14,200 acres of reforestation are planned under alternative 2 which encompasses all units proposed for salvage. Where salvage treatments occur reducing trees ≥ 14" dbh, site preparation activities remove small un-merchantable sized trees ≤ 12"dbh. Piling of activity slash with follow-up burning will reduce surface fuel loadings in all size classes (1-, 10-, 100-, 1000-hour fuels).

Additional units identified for site preparation generally occur within plantations and natural stands in which trees are generally ≤ 14" dbh. Similar effects related to reduction of fuel loadings will occur as described above due to the removal of trees with follow-up piling and burning.

Post-fire logging produces a transient pulse of elevated surface woody fuel loadings followed by a much longer period of reduced surface woody fuel loadings relative to burned stands that are were not logged. Peterson, Dodson, and Harrod (2014) found that post-fire logging altered post-fire fuel succession by (1) greatly accelerating the deposition of surface woody fuels from logged snags, (2) reducing peak loadings of large diameter woody fuels, and (3) initiating the woody fuel decay earlier. Ritchie, Knapp and Skinner (2012), evaluated salvaged units following the Cone Fire on the Lassen National Forest. They found that after 4 years higher levels of surface fuel accumulations occurred in lower intensity salvage plots. The highest surface fuel accumulations occurred in un-salvaged plots 4 to 8 years after the fire; furthermore, the highest levels of large woody debris were associated with un-salvaged areas. A key observation by Ritchie, Knapp and Skinner (2012) was finding no support for the contention that post-fire salvage logging necessitates subsequent fuel treatment for elevated fuels. Under alternative 2, activity generated slash will be piled and burned reducing surface fuels to levels consistent with low fire hazard.

Harvesting of trees are planned utilizing ground based, cable and helicopter logging. It is anticipated that there will be a delay between harvesting activities and associated fuel reduction activities. During this time frame, greater accumulation of surface fuels due to logging activities would be anticipated especially within cable and helicopter units where whole tree yarding is not planned. The short term effect of logging is an elevated surface fuel loading from broken tops and branch wood. The greatest fuel loadings post-harvest is expected to occur within helicopter units, followed by cable and ground based units. However, post logging activity breaks the structure and composition of the fuel bed. Upon completion of fuel reduction activities, the ground based units would be expected to reduce the greatest amounts of surface fuels due to the ease of facilitating piling and other fuels reduction activities on gentler slopes. Steeper slopes (greater than 40%) would be anticipated to require hand piling and/or broad cast burning to achieve desired surface fuel loadings of less than 10 tons/acre. Compared to ground based and cable units, within helicopter units or those areas on steep slopes, larger diameter (> 3" diameter) fuels may have increased loadings as these fuels can be difficult to pile by hand.

Figure 18 displays salvage and site preparation activities on the Salmon Salvage Project located on the KNF, Salmon River Ranger District (Adjacent to the Whites fire area). Note the activity fuels are piled for burning; snags within the area will fall over time and contribute to surface fuel

loading; however, it is anticipated to accumulate at significantly lower levels compared to taking no action.

After the initiation and completion of alternative 2, surface fuels present will consist of the following approximate tonnage in each of the size classes, not including large material (downed logs) left on site for wildlife or watershed purposes:

- 1 hour fuels (0” to ¼”) : .6 tons per acre
- 10 hour fuels (¼” to 1”) : 2.3 tons per acre
- 100 hour fuels (1” to 3”) : 3.4 tons per acre

Table 23 provides a comparison between Alternatives 1 and 2 with respect to potential surface fuel accumulations over time from retained snags that fall to the surface within the Beaver Fire Area. An estimated 10% retention of standing snags will occur within treatment units. Table 24 contains FVS data which utilizes previous silviculture stand exams across portions of the Happy Camp Complex. Post implementation surface fuel loadings are projected in these values resulting from residual activity slash onsite. While the tables do not contain descriptions of all of the distinct areas within the project area, they do demonstrate the range of conditions that are predicted to exist.

Post treatment activities under alternative 2 are expected to significantly reduce large surface fuel accumulations in the future compared to alternative 1. Furthermore, while modeling predicts an expected increase in surface fuels < 3” dbh compared to the Alternative 1, after implementation of proposed activities, modeling results predict that within 10 years Alternative 2 will continue to promote low accumulations of surface fuel loadings. Comparatively, taking no action significantly elevates surface fuels for decades. Post-logging fuel treatments, such as piling and burning, can rapidly reduce total amounts and spatial continuity of surface woody fuels, and may allow logged stands to serve as fuel-breaks in a landscape-level fire management strategy (Peterson & Harrod, 2010).

The combination of anticipated residual slash and future fuel loading from trees left standing is low enough so that the accumulation of additional surface fuels from the predicted snag fall of the snags left standing for wildlife and watershed purposes will not present a large fuels buildup over time and contribute to fire suppression difficulties.

Mastication may be utilized in selected stands to reduce high snag densities in lieu of piling stands. Mastication is essentially the mulching or chipping of wood material. The direct effect of mastication is changing the structure and composition of the fuel bed post fire. With no action taken, surface fuels will increase over time as trees fall. As trees fall over in random patterns, fuels will essentially “crisscross” as they fall with some fuels resting on top of others effectively increasing fuel bed height (Figure 19). Higher surface fuel beds will be subject to wind and preheating of fuels lower in the surface fuel profile; thus, increasing fire behavior potential. Rather than having standing dead material that falls overtime, where mastication is identified as a treatment option under alternative 2, chipped material will create a compact fuel bed (Figure 20). Material will also be expected to decay faster with masticated material due to its proximity to the ground and being saturated for longer period of time during the winter months.

Figure 18. Salvage and site preparation activities on the KNF Salmon Salvage Project. Trees are cut, and removed from site with follow-up hand piling meeting surface fuel loading criteria sufficient for low intensity fire.

Figure 19. Pattern of tree fall and resulting fuel bed height.

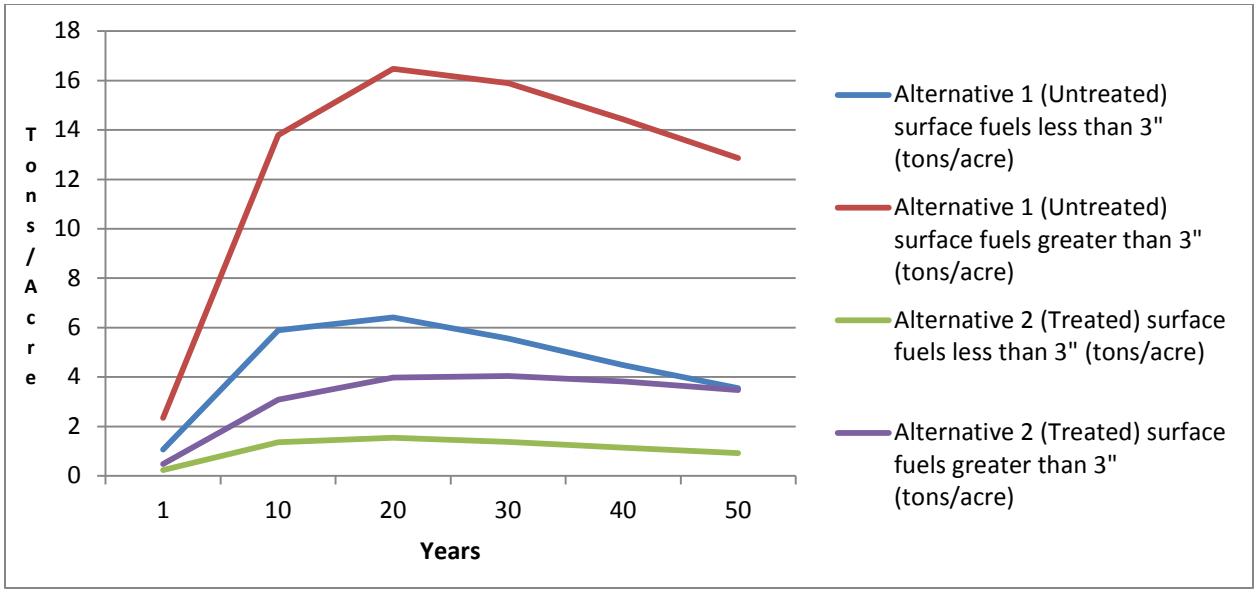
Figure 20. Masticated fuel bed. Brush and small trees mulched to reduce surface fuel bed depth to < 2 inches.

Roadside Hazard Treatments

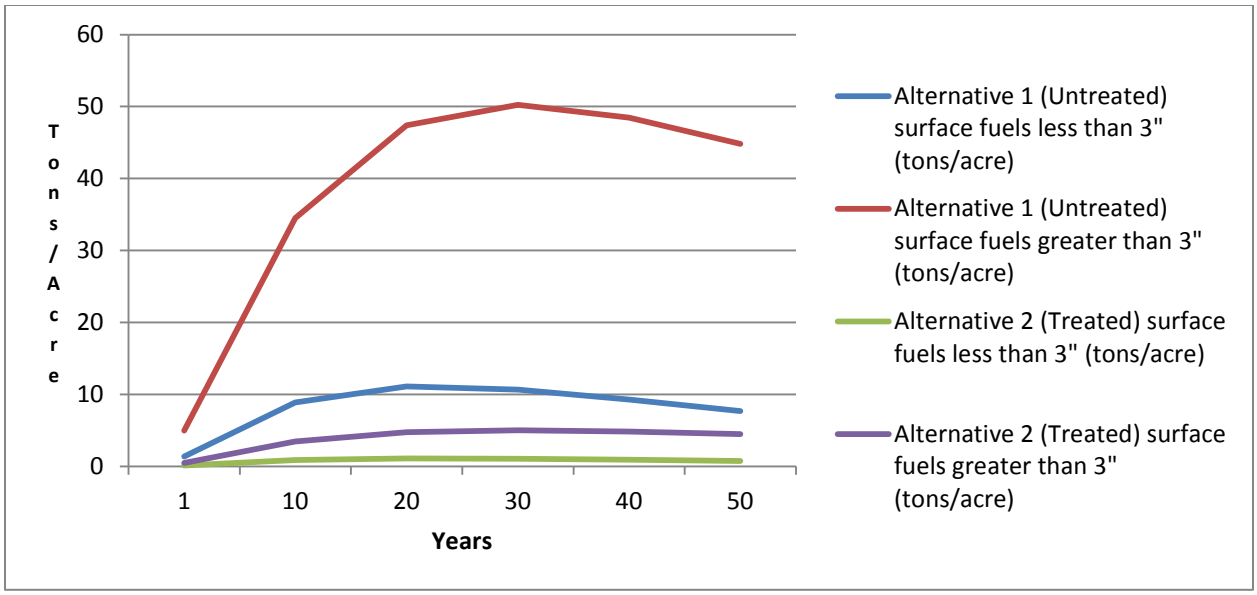
Roadside hazard treatments increase the safety of accessing the forest reducing the potential for dead trees to fall across National Forest roads and within recreation sites. Trees removed offsite reduce surface fuel loadings adjacent to road systems and allow for safe ingress/egress within fire area road systems.

Table 23: Comparison of surface fuel loading between Alternatives 1 and 2 over 50 years in the Beaver Fire Area

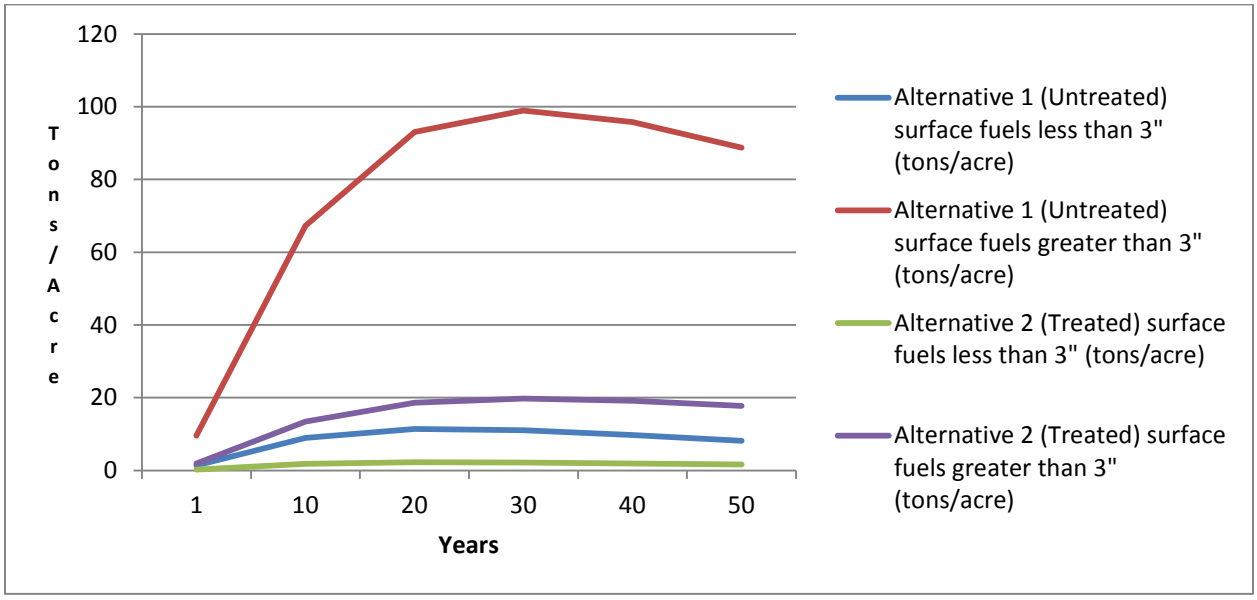
Alternative 1						Alternative 2					
Plot 1 90% Mortality						**Plot 1 90% Mortality**					
Year	**Surface Fuel < 3" dbh (tons/acre)**	**Surface Fuels > 3" dbh (tons/acre)**	**Intensity (btu/ft/sec) 26 ch/hr**	**Intesity (btu/ft/sec) 40 ch/hr**	**Resistance to Control**	**Year**	**Surface Fuel < 3" dbh (tons/acre)**	**Surface Fuels > 3" dbh (tons/acre)**	**Intensity (btu/ft/sec) 26 ch/hr**	**Intesity (btu/ft/sec) 40 ch/hr**	**Resistance to Control**
1	1.07	2.35	17	17	Low	1	0.24	0.48	4	4	Low
10	5.89	13.79	1777	2713	High	10	1.36	3.09	975	1488	Low
20	6.42	16.48	2014	3074	High	20	1.55	3.98	1150	1756	Low
30	5.56	15.89	1830	2794	High	30	1.38	4.05	1090	1664	Low
40	4.49	14.43	1563	2386	High	40	1.15	3.82	971	1482	Low
50	3.55	12.86	1313	2004	High	50	0.92	3.48	847	1293	Low



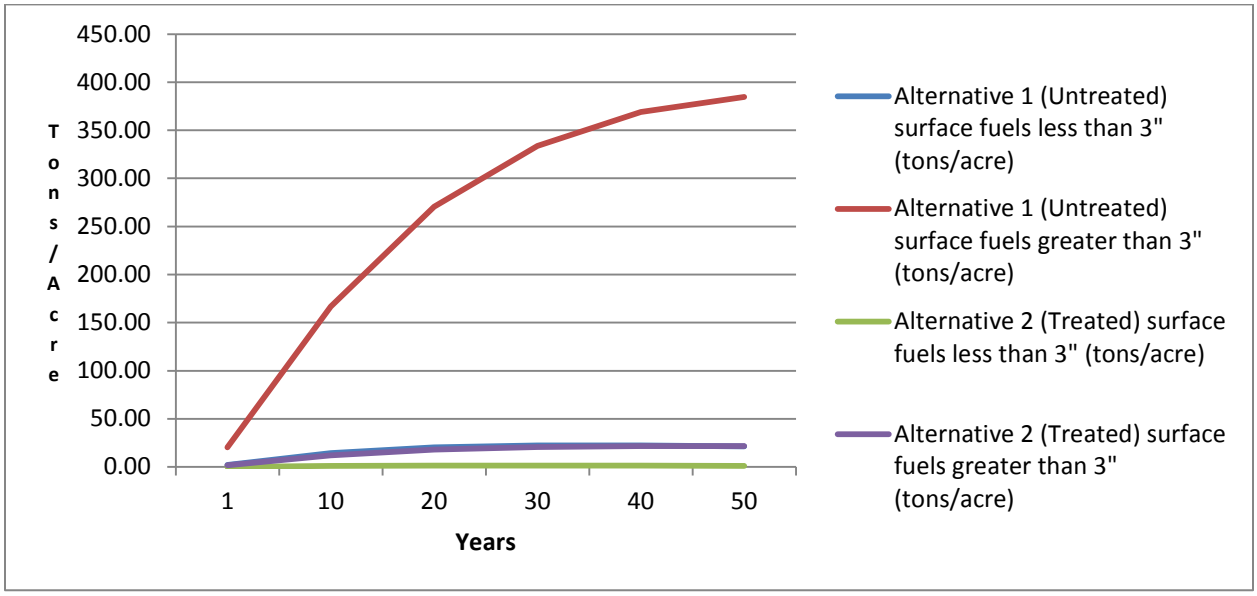
Plot 2 100% Mortality						Plot 2 100% Mortality					
Year	**Surface Fuel < 3" dbh (tons/acre)**	**Surface Fuels > 3" dbh (tons/acre)**	**Intensity (btu/ft/sec) 26 ch/hr**	**Intesity (btu/ft/sec) 40 ch/hr**	**Resistance to Control**	**Year**	**Surface Fuel < 3" dbh (tons/acre)**	**Surface Fuels > 3" dbh (tons/acre)**	**Intensity (btu/ft/sec) 26 ch/hr**	**Intesity (btu/ft/sec) 40 ch/hr**	**Resistance to Control**
1	1.38	4.97	27	27	Low	1	0.14	0.50	3	3	Low
10	8.88	34.52	3409	5204	Extreme	10	0.88	3.45	339	518	Low
20	11.11	47.41	4489	6854	Extreme	20	1.10	4.74	447	683	Low
30	10.67	50.22	4561	6963	Extreme	30	1.06	5.02	455	694	Low
40	9.28	48.46	4221	6444	Extreme	40	0.92	4.85	421	643	Low
50	7.7	44.82	3747	5721	Extreme	50	0.77	4.48	374	571	Low



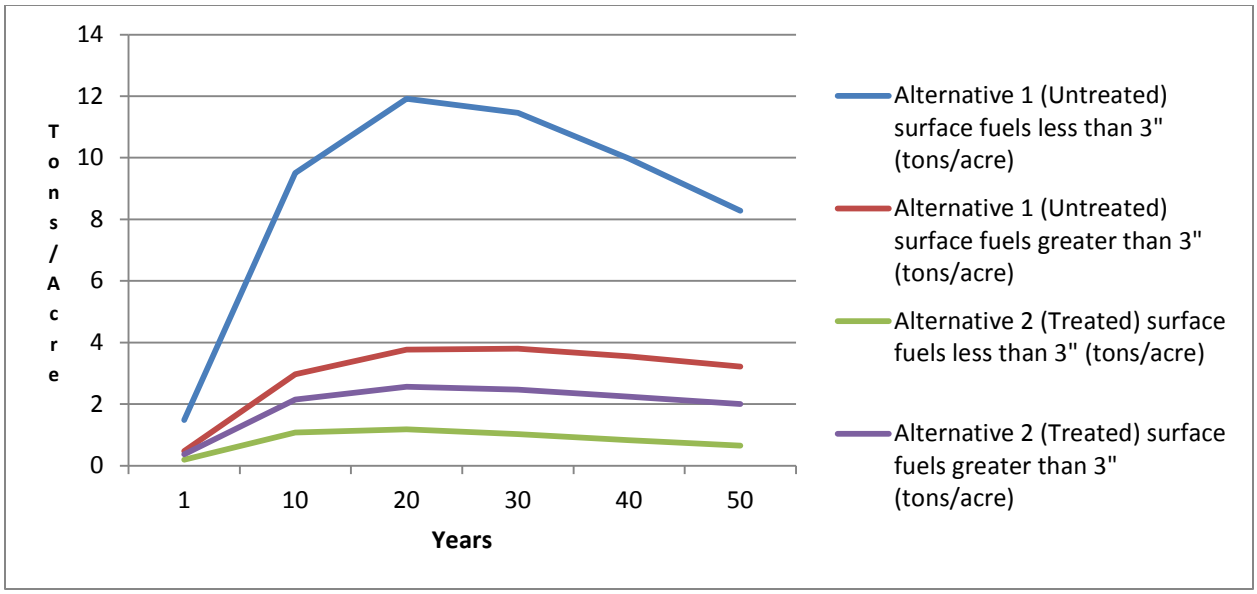
Plot 3 100% Mortality						Plot 3 100% Mortality					
Year	Surface Fuel < 3" dbh (tons/acre)	Surface Fuels > 3" dbh (tons/acre)	Intensity (btu/ft/sec) 26 ch/hr	Intesity (btu/ft/sec) 40 ch/hr	Resistance to Control	Year	Surface Fuel < 3" dbh (tons/acre)	Surface Fuels > 3" dbh (tons/acre)	Intensity (btu/ft/sec) 26 ch/hr	Intesity (btu/ft/sec) 40 ch/hr	Resistance to Control
1	1.35	9.58	40	40	Low	1	0.27	1.92	8	8	Low
10	8.91	67.26	5155	7870	Extreme	10	1.78	13.45	1030	1572	Low
20	11.38	93.04	6963	10630	Extreme	20	2.27	18.61	1391	2124	Low
30	11.08	98.96	7224	11030	Extreme	30	2.21	19.79	1443	2204	Low
40	9.72	95.75	6813	10401	Extreme	40	1.94	19.15	1361	2079	Low
50	8.11	88.69	6152	9393	Extreme	50	1.62	17.74	1230	1877	Low



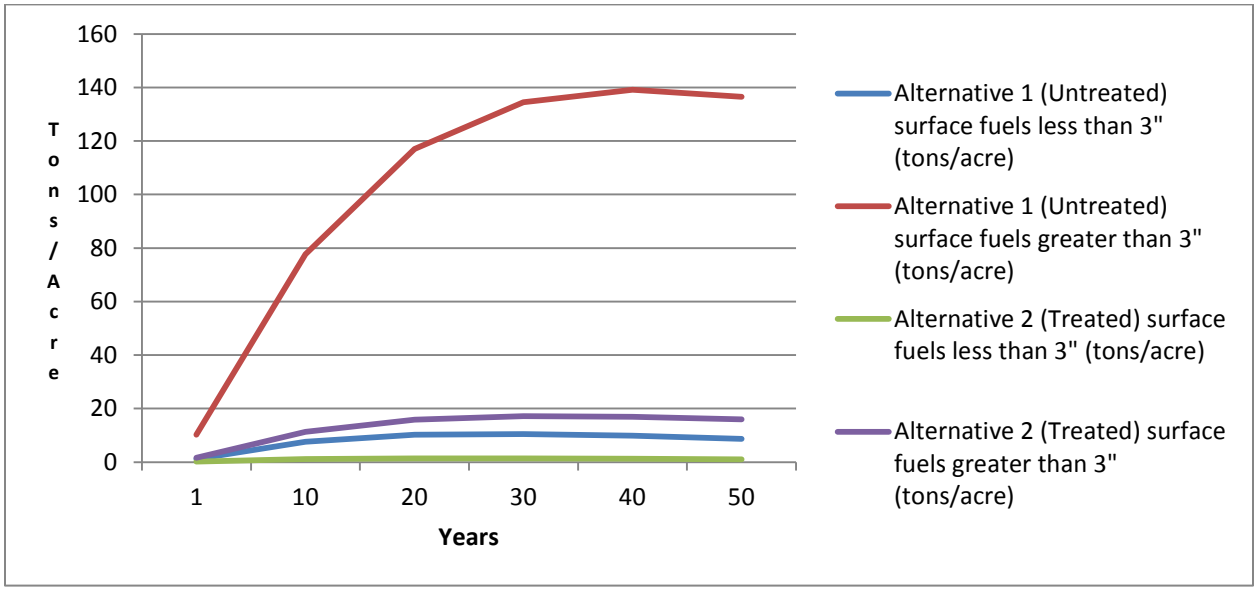
Plot 4 100% Mortality						Plot 4 100% Mortality					
Year	Surface Fuel < 3" dbh (tons/acre)	Surface Fuels > 3" dbh (tons/acre)	Intensity (btu/ft/sec) 26 ch/hr	Intesity (btu/ft/sec) 40 ch/hr	Resistance to Control	Year	Surface Fuel < 3" dbh (tons/acre)	Surface Fuels > 3" dbh (tons/acre)	Intensity (btu/ft/sec) 26 ch/hr	Intesity (btu/ft/sec) 40 ch/hr	Resistance to Control
1	2.08	20.53	78	78	Low	1	0.18	1.63	6	6	Low
10	14.51	166.90	11445	17473	Extreme	10	1.17	12.10	850	1298	Low
20	20.50	270.72	18024	27518	Extreme	20	1.51	18.05	1227	1873	Moderate
30	22.50	333.80	21733	33181	Extreme	30	1.52	20.80	1375	2099	Moderate
40	22.47	368.98	23597	36027	Extreme	40	1.41	21.77	1406	2147	Moderate
50	21.35	384.54	24226	36986	Extreme	50	1.25	21.71	1376	2101	Moderate



Plot 8 100% Mortality						Plot 8 100% Mortality					
Year	Surface Fuel < 3" dbh (tons/acre)	Surface Fuels > 3" dbh (tons/acre)	Intensity (btu/ft/sec) 26 ch/hr	Intesity (btu/ft/sec) 40 ch/hr	Resistance to Control	Year	Surface Fuel < 3" dbh (tons/acre)	Surface Fuels > 3" dbh (tons/acre)	Intensity (btu/ft/sec) 26 ch/hr	Intesity (btu/ft/sec) 40 ch/hr	Resistance to Control
1	1.48	0.47	15	15	Low	1	0.20	0.37	3	3	Low
10	9.51	2.97	1843	2814	Moderate	10	1.08	2.14	305	466	Low
20	11.92	3.77	2313	3531	Moderate	20	1.18	2.56	345	526	Low
30	11.46	3.8	2233	3409	Moderate	30	1.02	2.47	312	476	Low
40	9.97	3.55	1955	2985	Moderate	40	0.82	2.24	265	405	Low
50	8.28	3.22	1638	2501	Moderate	50	0.65	2.00	222	338	Low



Plot 12 90% Mortality						Plot 12 90% Mortality					
Year	Surface Fuel < 3" dbh (tons/acre)	Surface Fuels > 3" dbh (tons/acre)	Intensity (btu/ft/sec) 26 ch/hr	Intesity (btu/ft/sec) 40 ch/hr	Resistance to Control	Year	Surface Fuel < 3" dbh (tons/acre)	Surface Fuels > 3" dbh (tons/acre)	Intensity (btu/ft/sec) 26 ch/hr	Intesity (btu/ft/sec) 40 ch/hr	Resistance to Control
1	1.11	10.22	40	40	Low	1	0.18	1.61	6	6	Low
10	7.57	77.74	5474	8358	Extreme	10	1.16	11.35	808	1234	Extreme
20	10.2	117.05	8030	12260	Extreme	20	1.46	15.90	1105	1686	Moderate
30	10.53	134.45	9014	13761	Extreme	30	1.43	17.21	1168	1783	Moderate
40	9.84	139.16	9142	13957	Extreme	40	1.26	16.97	1126	1719	Moderate
50	8.72	136.54	8804	13441	Extreme	50	1.07	16.01	1040	1588	Moderate



Year	Surface Fuel < 3" dbh (tons/acre)	Surface Fuels > 3" dbh (tons/acre)	Intensity (btu/ft/sec) 26 ch/hr	Intesity (btu/ft/sec) 40 ch/hr	Resistance to Control	Year	Surface Fuel < 3" dbh (tons/acre)	Surface Fuels > 3" dbh (tons/acre)	Intensity (btu/ft/sec) 26 ch/hr	Intesity (btu/ft/sec) 40 ch/hr	Resistance to Control
1	0.42	1.53	8	8	Low	1	0.10	0.15	1	1	Low
10	2.97	8.94	1002	1529	Moderate	10	0.54	0.89	143	218	Low
20	4.09	10.68	1293	1973	Moderate	20	0.59	1.07	161	246	Low
30	4.28	10.3	1306	1994	Moderate	30	0.51	1.03	145	221	Low
40	4.06	9.36	1217	1858	Moderate	40	0.41	0.93	123	187	Low
50	3.63	8.34	1087	1659	Moderate	50	0.33	0.83	102	156	Low

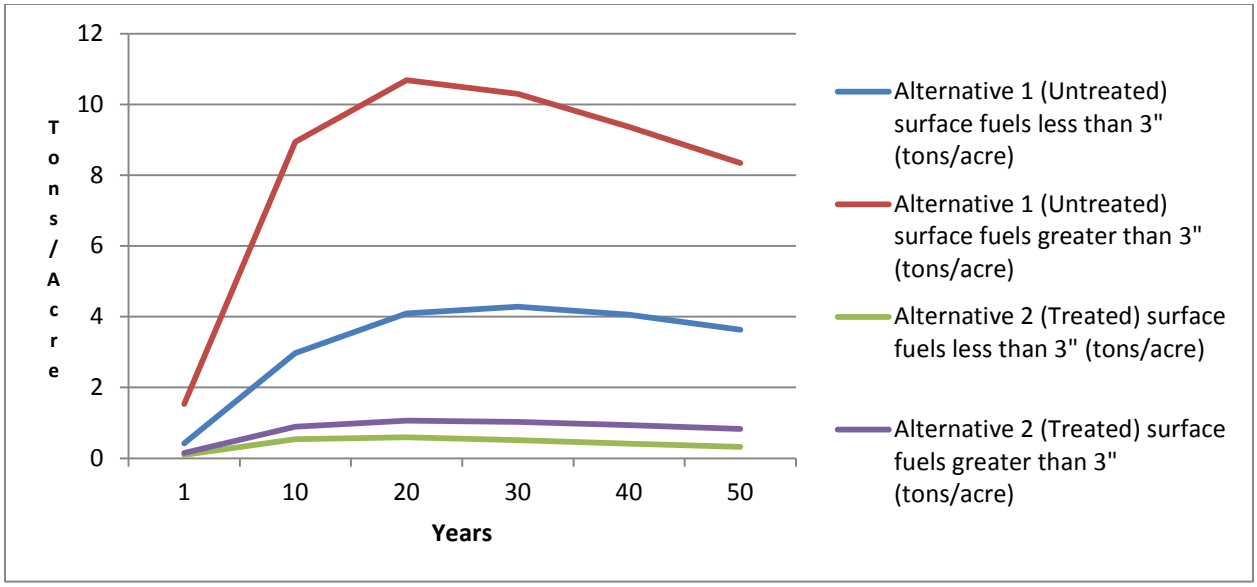
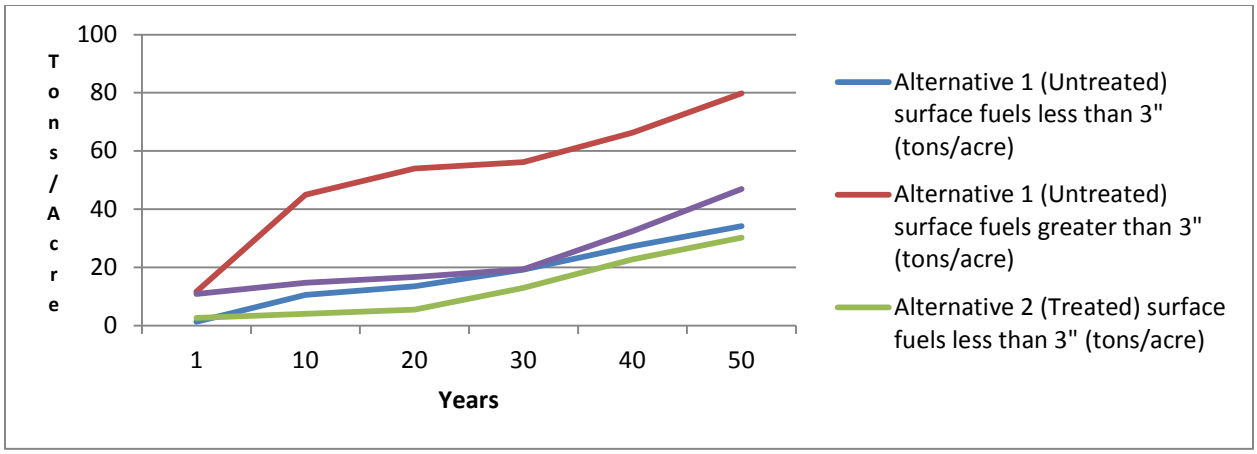
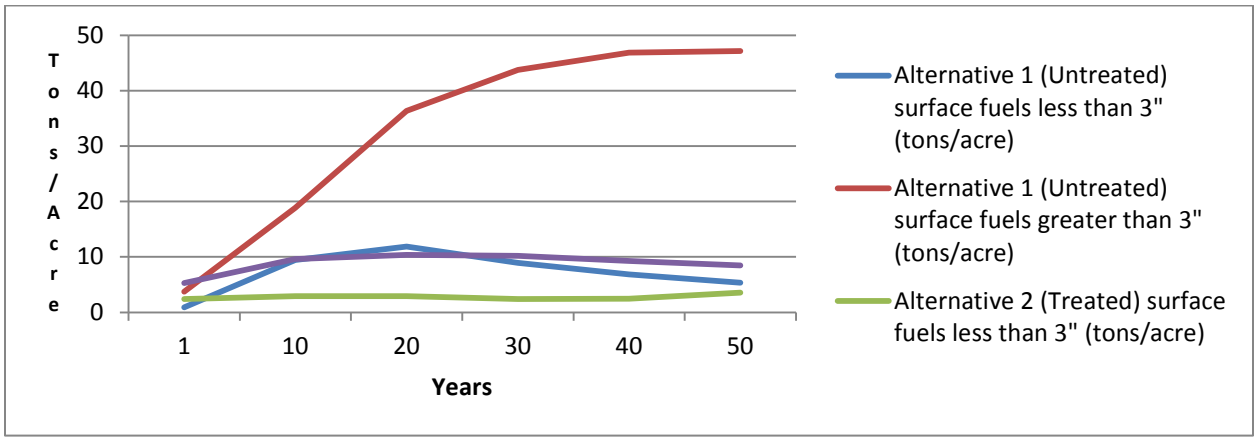


Table 24: Comparison of surface fuel loading between Alternatives 1 and 2 over 50 years in the Happy Camp Complex

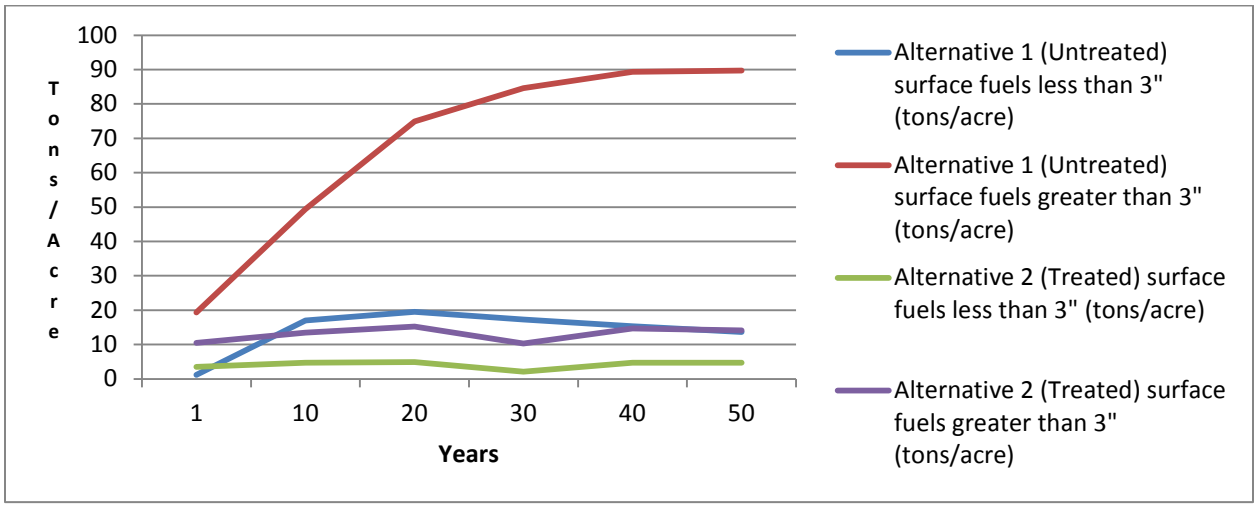
Alternative 1						Alternative 2					
Grider Creek Stand ID 05055200520006						Grider Creek Stand ID 05055200520006					
Year	Surface Fuel < 3" dbh (tons/acre)	Surface Fuels > 3" dbh (tons/acre)	Intensity (btu/ft/sec) 26 ch/hr	Intesity (btu/ft/sec) 40 ch/hr	Resistance to Control	Year	Surface Fuel < 3" dbh (tons/acre)	Surface Fuels > 3" dbh (tons/acre)	Intensity (btu/ft/sec) 26 ch/hr	Intesity (btu/ft/sec) 40 ch/hr	Resistance to Control
1	1.23	11.63	45	45	Low	1	2.56	10.83	55	55	Low
10	10.56	44.91	4259	6502	Extreme	10	4.02	14.65	1492	2277	Low
20	13.46	53.97	5255	8023	Extreme	20	5.51	16.70	1865	2847	High
30	19.22	56.14	6391	9757	Extreme	30	12.94	19.30	3319	5068	High
40	27.27	66.34	8359	12762	Extreme	40	22.68	32.41	5742	8766	Extreme
50	34.16	79.83	10298	15721	Extreme	50	30.19	46.92	7845	11977	Extreme



Grider Creek Stand ID 05055200520016						Grider Creek Stand ID 05055200520016					
Year	Surface Fuel < 3" dbh (tons/acre)	Surface Fuels > 3" dbh (tons/acre)	Intensity (btu/ft/sec) 26 ch/hr	Intesity (btu/ft/sec) 40 ch/hr	Resistance to Control	Year	Surface Fuel < 3" dbh (tons/acre)	Surface Fuels > 3" dbh (tons/acre)	Intensity (btu/ft/sec) 26 ch/hr	Intesity (btu/ft/sec) 40 ch/hr	Resistance to Control
1	0.89	3.76	19	19	Low	1	2.38	5.29	38	38	Low
10	9.45	18.85	2677	4088	High	10	2.92	9.61	1028	1569	Low
20	11.88	36.38	4040	6168	Extreme	20	2.94	10.37	1073	1638	Low
30	8.92	43.75	3907	5964	Extreme	30	2.38	10.18	963	1470	Low
40	6.85	46.86	3704	5656	Extreme	40	2.48	9.27	933	1424	Low
50	5.35	47.14	3454	5273	Extreme	50	3.54	8.45	1076	1643	Low



Scott River Stand ID 05055518010208060009						Scott River Stand ID 05055518010208060009					
Year	Surface Fuel < 3" dbh (tons/acre)	Surface Fuels > 3" dbh (tons/acre)	Intensity (btu/ft/sec) 26 ch/hr	Intesity (btu/ft/sec) 40 ch/hr	Resistance to Control	Year	Surface Fuel < 3" dbh (tons/acre)	Surface Fuels > 3" dbh (tons/acre)	Intensity (btu/ft/sec) 26 ch/hr	Intesity (btu/ft/sec) 40 ch/hr	Resistance to Control
1	1.15	19.32	66	66	Low	1	3.49	10.46	63	63	Low
10	17.04	49.41	5647	8622	Extreme	10	4.71	13.44	1549	2364	Low
20	19.48	74.90	7434	11349	Extreme	20	4.86	15.21	1669	2548	Low
30	17.28	84.58	7559	11540	Extreme	30	2.12	10.27	922	1408	Low
40	15.33	89.31	7464	11395	Extreme	40	4.71	14.64	1613	2463	Low
50	13.65	89.70	7187	10973	Extreme	50	4.69	14.12	1582	2416	Low



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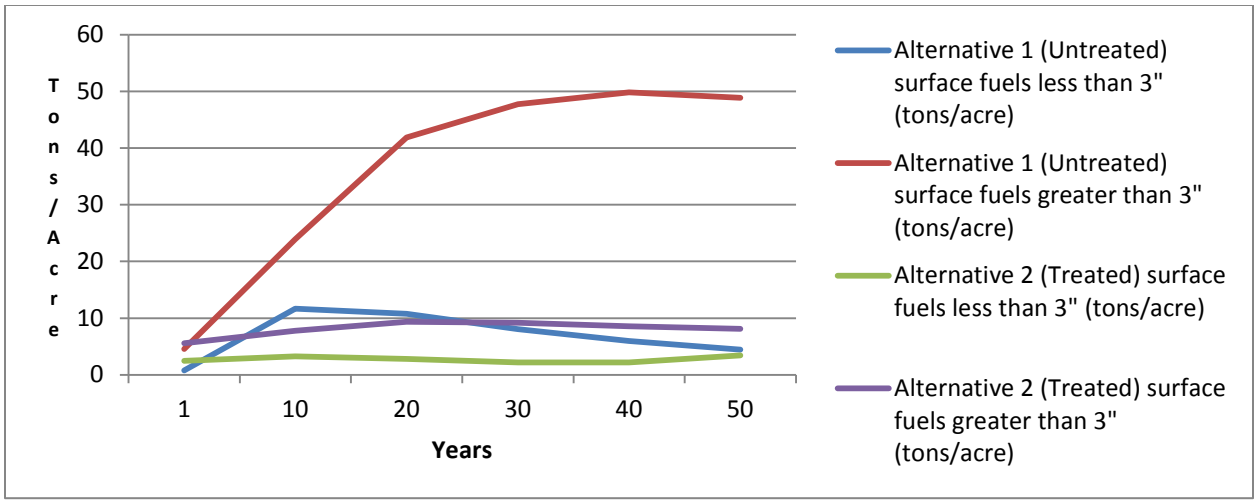
Year	Surface Fuel < 3" dbh (tons/acre)	Surface Fuels > 3" dbh (tons/acre)	Intensity (btu/ft/sec) 26 ch/hr	Intesity (btu/ft/sec) 40 ch/hr	Resistance to Control	Year	Surface Fuel < 3" dbh (tons/acre)	Surface Fuels > 3" dbh (tons/acre)	Intensity (btu/ft/sec) 26 ch/hr	Intesity (btu/ft/sec) 40 ch/hr	Resistance to Control
1	0.76	4.53	20	20	Low	1	2.45	5.58	39	39	Low
10	11.66	23.90	3338	5095	High	10	3.28	7.77	994	1518	Low
20	10.76	41.86	4132	6308	Extreme	20	2.79	9.35	992	1515	Low
30	8.03	47.75	3962	6049	Extreme	30	2.17	9.18	873	1332	Low
40	5.96	49.83	3705	5656	Extreme	40	2.20	8.57	846	1291	Low
50	4.44	48.88	3385	5168	Extreme	50	3.41	8.11	1036	1582	Low



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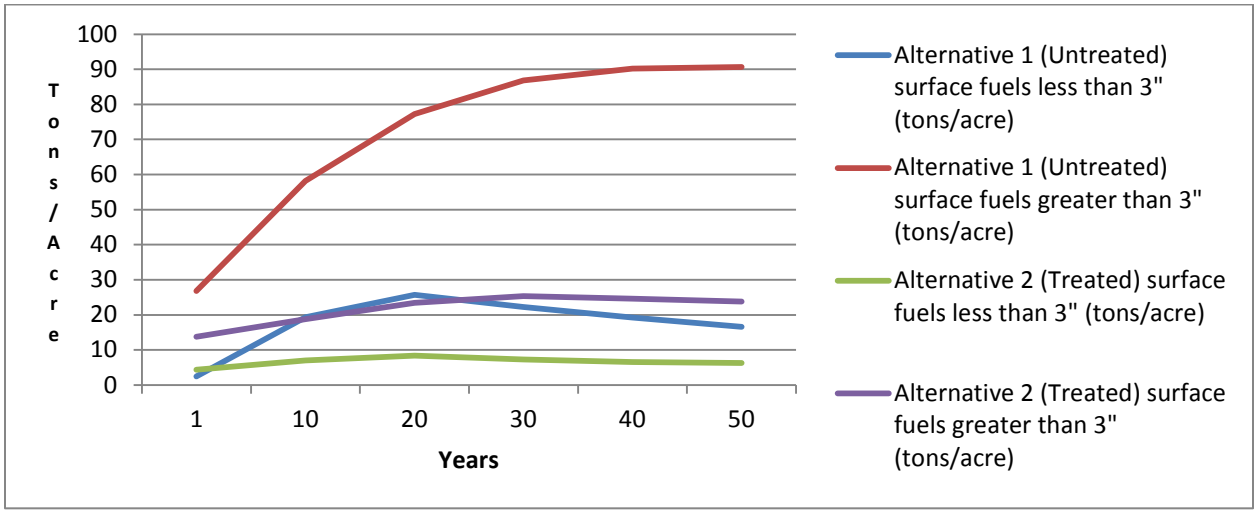
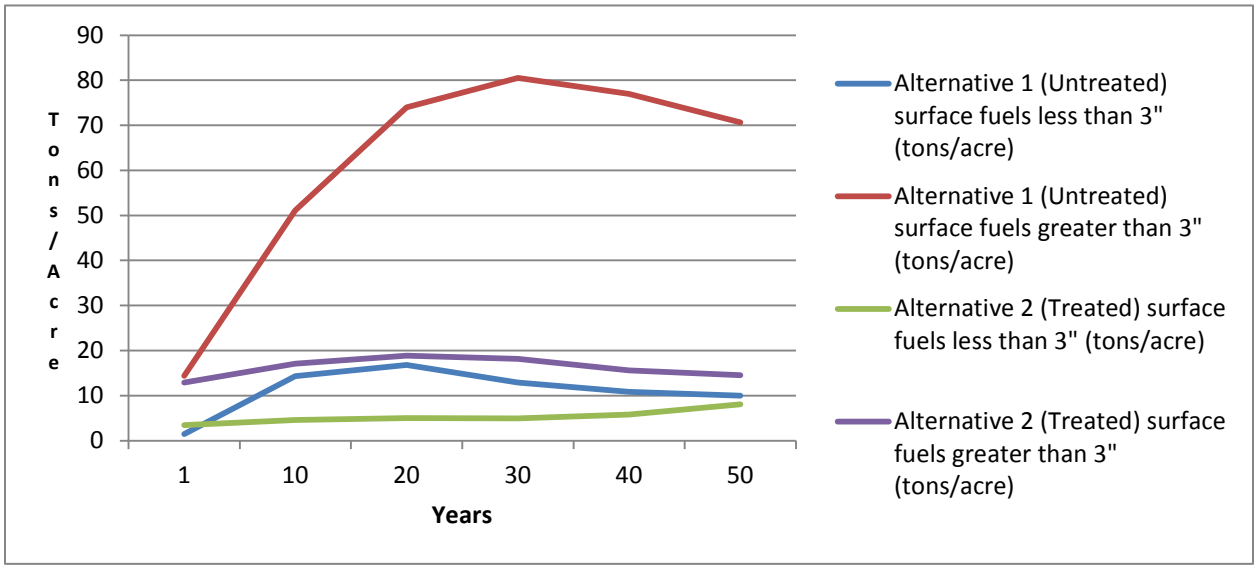
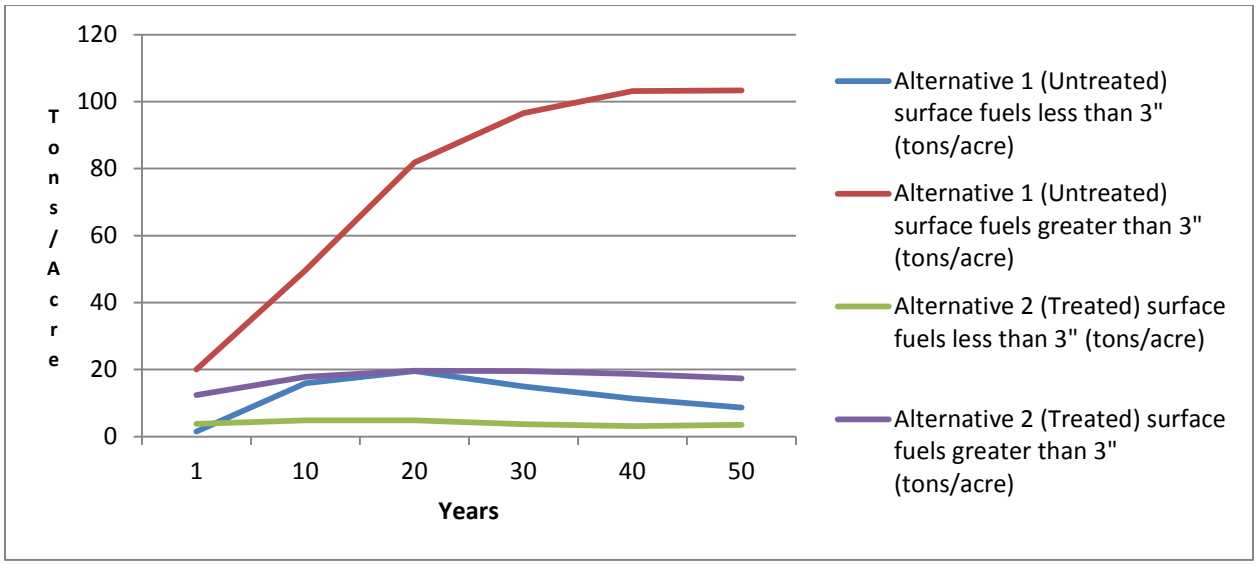
Year	Surface Fuel < 3" dbh (tons/acre)	Surface Fuels > 3" dbh (tons/acre)	Intensity (btu/ft/sec) 26 ch/hr	Intesity (btu/ft/sec) 40 ch/hr	Resistance to Control	Year	Surface Fuel < 3" dbh (tons/acre)	Surface Fuels > 3" dbh (tons/acre)	Intensity (btu/ft/sec) 26 ch/hr	Intesity (btu/ft/sec) 40 ch/hr	Resistance to Control
1	2.43	26.80	99	99	Low	1	4.35	13.74	80	80	Low
10	19.38	58.23	6530	9969	Extreme	10	7.01	18.83	2243	3425	Moderate
20	25.75	77.24	8670	13236	Extreme	20	8.42	23.44	2739	4181	Moderate
30	22.30	86.84	8568	13080	Extreme	30	7.33	25.35	2646	4040	High
40	19.26	90.23	8211	12536	Extreme	40	6.53	24.60	2465	3764	High
50	16.62	90.65	7764	11853	Extreme	50	6.27	23.77	2374	3625	Moderate



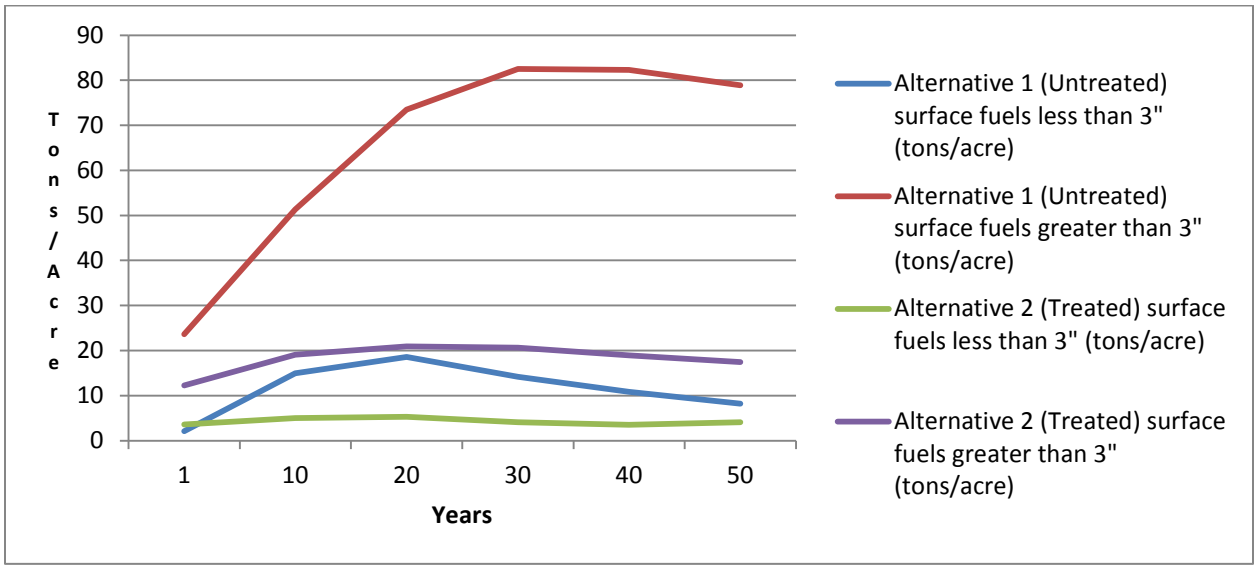
Walker Creek Stand ID 050552ABCD001116414144205						Walker Creek Stand ID 050552ABCD001116414144205					
Year	Surface Fuel < 3" dbh (tons/acre)	Surface Fuels > 3" dbh (tons/acre)	Intensity (btu/ft/sec) 26 ch/hr	Intesity (btu/ft/sec) 40 ch/hr	Resistance to Control	Year	Surface Fuel < 3" dbh (tons/acre)	Surface Fuels > 3" dbh (tons/acre)	Intensity (btu/ft/sec) 26 ch/hr	Intesity (btu/ft/sec) 40 ch/hr	Resistance to Control
1	1.49	14.40	55	55	Low	1	3.48	12.90	70	70	Low
10	14.34	51.11	5259	8029	Extreme	10	4.59	17.12	1724	2632	Low
20	16.82	73.97	6912	10553	Extreme	20	5.01	18.89	1892	2889	Moderate
30	12.89	80.54	6567	10025	Extreme	30	4.95	18.14	1841	2811	Low
40	10.83	76.98	6013	9179	Extreme	40	5.80	15.60	1857	2835	Low
50	10.00	70.61	5526	8437	Extreme	50	8.08	14.53	2204	3365	Low



Walker Creek Stand ID 050552ABCD027746277						Walker Creek Stand ID 050552ABCD027746277					
Year	Surface Fuel < 3" dbh (tons/acre)	Surface Fuels > 3" dbh (tons/acre)	Intensity (btu/ft/sec) 26 ch/hr	Intesity (btu/ft/sec) 40 ch/hr	Resistance to Control	Year	Surface Fuel < 3" dbh (tons/acre)	Surface Fuels > 3" dbh (tons/acre)	Intensity (btu/ft/sec) 26 ch/hr	Intesity (btu/ft/sec) 40 ch/hr	Resistance to Control
1	1.53	20.07	71	71	Low	1	3.82	12.34	71	71	Low
10	15.95	49.63	5464	8343	Extreme	10	4.83	17.83	1804	2754	Low
20	19.53	81.82	7811	11925	Extreme	20	4.83	19.69	1903	2905	Low
30	14.94	96.55	7781	11880	Extreme	30	3.74	19.56	1702	2599	Low
40	11.38	103.17	7501	11452	Extreme	40	3.16	18.65	1551	2368	Low
50	8.64	103.31	7024	10724	Extreme	50	3.49	17.32	1540	2351	Low



Walker Creek Stand ID 050552ABCD0292						Walker Creek Stand ID 050552ABCD0292					
Year	Surface Fuel < 3" dbh (tons/acre)	Surface Fuels > 3" dbh (tons/acre)	Intensity (btu/ft/sec) 26 ch/hr	Intesity (btu/ft/sec) 40 ch/hr	Resistance to Control	Year	Surface Fuel < 3" dbh (tons/acre)	Surface Fuels > 3" dbh (tons/acre)	Intensity (btu/ft/sec) 26 ch/hr	Intesity (btu/ft/sec) 40 ch/hr	Resistance to Control
1	2.10	23.61	87	87	Low	1	3.62	12.28	69	69	Low
10	14.95	51.34	5379	8213	Extreme	10	5.00	19.10	1901	2902	Moderate
20	18.57	73.51	7199	10991	Extreme	20	5.28	20.90	2046	3124	Moderate
30	14.20	82.47	6902	10537	Extreme	30	4.08	20.65	1821	2781	Low
40	10.81	82.30	6291	9605	Extreme	40	3.52	18.92	1630	2489	Low
50	8.21	78.92	5650	8626	Extreme	50	4.06	17.42	1645	2512	Low



Hazardous Fuels Treatments

In addition to units proposed for salvage harvest, hazardous fuels treatments are planned on approximately 22,900 acres. Units proposed for treatment occur both within the WUI and strategic road and ridge systems in which fire suppression resources utilized historically to control unplanned fires and implement prescribed fire activities. Any hazardous fuels treatment not meeting desired conditions can be maintained with future treatment.

Proposed thinning with follow up pile burning, lop and scatter or chipping decreases surface fuel loadings to desired conditions of <7 tons/acre (0-3” diameter fuels), removes small diameter trees reducing ladder fuels, and increases canopy base heights of retained green trees. Reduction in surface fuels in conjunction with increasing canopy base heights will reduce flame lengths and crown fire initiation.

The objective of fuel reduction in the Wildland Urban Interface (WUI) is to reduce fuel loading and minimize ladder fuels in order to create a more defensible WUI during future fire events. Both live and dead understory vegetation (less than 14 inches in diameter at breast height (dbh)) will be altered or removed to reduce potential flame length, potential fire intensity, and the potential for crown fire activity. Identified treatment areas may receive either mechanical or hand methods of fuel reduction. Mechanical treatments, other than mastication, will be followed with piling and burning of activity slash. Mastication treatments are not expected to result in activity slash that is suitable for piling and will only be used in situations where the resulting fuel bed is not determined to pose a risk to fire control or fire ecology objectives. Activity slash resulting from hand treatment will be piled and burned, chipped, or lopped and scattered. Dead trees greater than 14 inches in diameter can be cut and used for firewood, piled and burned, or lopped and scattered.

Strategic ridge systems are features on the landscape that can aid in containing future wildfires. To accomplish this, strategic ridge systems will maintain existing (used in the 2014 wildfires) and historic control lines by altering or removing live and dead understory vegetation up to 12 inches in dbh. Strategic ridge systems will also include pruning of retained trees up to 7 feet above ground level, in order to increase canopy base height and reduce ladder fuels, thus limiting the potential for crown fire initiation. Similarly to WUI treatments, treatment areas may receive either mechanical, hand or combination of both methods of fuel reduction. Activity slash resulting from hand treatment will be piled and burned, chipped, or lopped and scattered. Mechanical or mastication equipment may be used to treat activity slash within these areas in addition to, or in lieu of, hand work.

Approximately 11,570 acres of understory prescribed burning are planned as a second entry treatment within portions of the Beaver, Whites and Happy Camp Complex fires. Post fire conditions are such that fuel loadings will be expected to recover to sufficient levels to implement low intensity fire to mimic a frequent fire return interval as dead vegetation falls from the canopy over the next 3 to 6 years. Many of the prescribed burn locations will use existing control lines established in recent large fires wihin the project area. Line construction activities will occur around the perimeter of the prescribed fire unit, and will include using dozers to re-scrape control lines to mineral soil; where mechanized equipment has no access, is impractical, or for some other reason is not available, hand-line construction to mineral soil will occur. Removal of understory vegetation (12 inches diameter or less) along control lines may occur in order to facilitate holding operations during prescribed fire implementation.

Direct effects of prescribed fire are the consumption and subsequent reduction in surface fuels. Typically 70% of dead surface fuel is consumed within the 1 and 10 hour dead fuel category (0-1 inch fuels). Dependent on seasonality, 100 and 1000 hour fuels (>1" diameter) can be partially and/or fully consumed. Retained snags within the prescribed fire area will potentially be partially consumed reducing future large fuel accumulations.

Prescribed fire activities naturally prune the lower branches of trees by burning the live and dead needles and small branch wood effectively increasing the canopy base heights. Overall canopy bulk density will be expected to be comparable to current conditions since mid-story and overstory canopies will remain mostly intact. A mosaic burn pattern will be expected due to post fire burn severity patterns.

Fire Behavior Synopsis

Without active post-fire fuel reduction treatments, fuel succession processes create high potential for subsequent high severity wildfire 20-40 years following wildfire in dry coniferous forests (Peterson & Harrod, 2010). Proposed treatments in Alternative 2 effectively reduce fuel loading in the short and long term which in turn reduces fire behavior when compared to Alternative 1. Fire hazard is diminished in the short term, 1 to 3 years, due to the lack of surface fuels to support the spread of fire (Table 25). However, actions taken to reduce standing dead trees now will reduce fire behavior (flame length, fireline intensity, and spot fire potential) and associated fire hazard in the long term.

Table 25. Comparison of fire behavior 1 to 5 years post fire.

Alternative	Flame Length (ft)	Fireline Intensity (btu/ft/sec)	Acres
1	< 4	< 100	44,760
2	< 4	< 100	44,760

Within 10 years, reductions in surface fuel loadings, as a result of planned activities, have the potential within proposed treatment areas to:

- Reduce flame lengths < 4 feet
- Reduce fireline intensity < 100 btu/ft/sec
- Decrease spot fire activity through removal of snags and future fuel loading
- Effectively produce fire behavior such that persons using hand tools can generally attack fires at the head or flanks and handline is sufficient to hold the fire.

Fire hazard, post treatment, is expected to be reduced due to the change in structure, continuity and composition of the fuel bed and reduction in long term fuel loadings (Table 23 and Table 24). Within areas that receive treatment, the primary carrier of the fire would be expected to consist of small diameter woody material, less than 3 inches diameter. Moderate load activity slash would be a representative fuel bed post-harvest prior to fuel reduction activities. The key difference from alternative 1 is the removal of snags and reduction of large woody debris. Upon completion of harvest and site preparation activities, fuel loadings would be consistent with a low load activity slash and/or low/moderate conifer/hardwood litter with the primary carrier of fire being small woody fuels compared to alternative 1 which would consist primarily of shrub

dominated species intermixed with accumulated dead woody fuels from snag fall and still standing snags (Figure 11).

Table 26. Potential fire behavior 10 years post treatment.

Vegetation	Flame Length (feet)	Fireline Intensity (btu/ft/sec)	Rate of Spread (ch/hr)	Description of Fuels Primarily Carrying Fire
Low Load Timber Shrub	3	75	9	Conifer overstory with litter and small shrubs
Low/Moderate Conifer/Hardwood litter	2	20	5	Needle cast and small dead/downed material primarily fuels < 1" diameter (10 hour).
High Conifer Litter/Hardwood Load	4	100	8	Needle cast with heavy component of dead downed material primarily 1 to 3' diameter (10 and 100 hour) fuels.
Low Load Activity Slash	4	110	12	Natural accumulation of snag fall. Fuel bed depth < 1 foot.
Moderate Load Activity Slash	5	185	45	Natural accumulation of snag fall. Fuel bed depth > 1 foot.

The type of fire behavior predicted under Alternative 2 will enable direct attack by ground crews within the units proposed for treatment. Untreated portions of units, such as RRs or snag retention pockets, will be expected to produce flame lengths > 4 feet and fireline intensities > 100 btu/ft/sec; additionally, with recognition that prescribed fire activities will produce a mosaic burn pattern, within these areas, potential increases in fire behavior will occur where fire did not burn.

When compared to Alternative 1, decreased accumulations of large surface fuel loads will reduce the duration of fuel consumption and associated long term heating to surrounding vegetation and soils resulting in less fire intensity and potential severity within treated areas (Figure 24).

Reforestation efforts will have better chances of survival due to anticipated surface fuel load reductions within planted areas. Using empirical data for northern California forests, Weatherspoon and Skinner (1995) found that when wildfire in natural plantations spreads to adjacent plantations, fire intensity and damage to the overstory are much lower in plantations where slash has been removed following logging (Peterson, et al., 2009). Younger conifer and hardwood stands will still be susceptible to reburn and subsequent mortality even with alternative 2 until tree age and canopy base heights increase. Younger trees have thinner bark and low canopy base heights allowing for easier transition to crown fire even with predicted flame lengths less than 4 feet over the majority of the proposed units. Table 27 displays fire flame lengths and fireline intensities needed to initiate crown fire activity based on canopy base height. The lower the canopy is to the surface, the lesser the fire behavior required to generate crown fire initiation. However, with the removal of large surface fuels, higher survival will be expected within stands that continued to have management activities to maintain desire fuel conditions as trees and canopy base heights increase in size.

Table 27. Crown fire initiation potential based on canopy base height and flame length.

	Canopy Base Height (feet)								
	1	**3**	**5**	**7**	**9**	**10**	**15**	**20**	**30**
Flame Length (feet)	1	2.5	3.6	4.5	5.1	5.8	7.6	9.3	12.3
Fireline Intensity (btu/ft/sec)	8	42	91	151	212	257	473	728	1338

Utilizing projected flame lengths of Alternative 1 (Table 16) and Alternative 2 (Table 26) along with the relation of critical flame length needed to generate crown fire activity based on canopy base height (Table 27), it is anticipated that fuel reduction treatment activities proposed will decrease potential crown fire activity as trees increase in size and shed their lower branches either naturally or through pruning activities. Figure 21 displays predicted flame lengths of Alternatives 1 and 2 along with critical surface flame lengths required to generate crown fire activity based on the canopy base heights of trees. The reduction of surface fuel loading along with the change in the structure and composition of the fuel bed are anticipated to reduce fire behavior compared to taking no action, thus allowing trees to have increased survivability as canopy base heights increase over time. Figure 21 also shows the susceptibility of trees to fire; until trees are able to increase in size along with shedding their lower limbs, and increasing their separation from surface fuels, they remain susceptible to fire caused mortality.

Thompson, Spies and Olsen (2011) identified plantation age as the most important predictor of canopy damage. Older plantations experienced lower levels of canopy damage; the fire resistance of Douglas-fir increases with age due to a continually thickening bark and increasing crown base heights which reduce the likelihood of torching or crown fires. Alternative 2 effectively reduces future surface fuel loadings, especially within large fuels. This reduction in loading translates to lower predicted intensity and subsequent reduction in long duration heating to surrounding vegetation and preheating of the canopy to reduce crown fire initiation potential; thus, planted trees have a higher probability of success compared to Alternative 1 (Thompson, Spies, & Olsen, 2011).

The additional importance of fuels treatments under alternative 2, related to reforestation, is reducing shrub growth, through grubbing, within areas planted breaks the uniformity and continuity of the fuel bed. However, without follow up maintenance, shrubs will be expected to reestablish and intermix within planted areas producing similar fire behavior characteristics as taking no action. This risk may remain high for several decades if shrubs and other surface fuels are not frequently reduced. Even though maturing trees can withstand increasingly greater heat from a surface fire, in stands without fuel reductions, both litter loads and ladder fuels result in continued high vulnerability (McGinnis, Keely, Stephens, & Roller, 2010). Figure 22 and Figure 23 display projected mortality within ponderosa pine and Douglas-fir tree species comparing projected fire behavior by vegetation category. Throughout the life of the project, it is anticipated that tree growth (either planted or natural regeneration) is expected to reachat least 50 feet tall with 6 to 10” dbh. Post treatment units are anticipated to consist of low/moderate load conifer litter or a low slash fuel loading resulting in less than 10% probability of mortality should a fire occur under 90th percentile weather conditions. Comparatively, under alternative 1, shrub regrowth intermixed with snag fall would be anticipated to have mortality potentials greater than 95%.

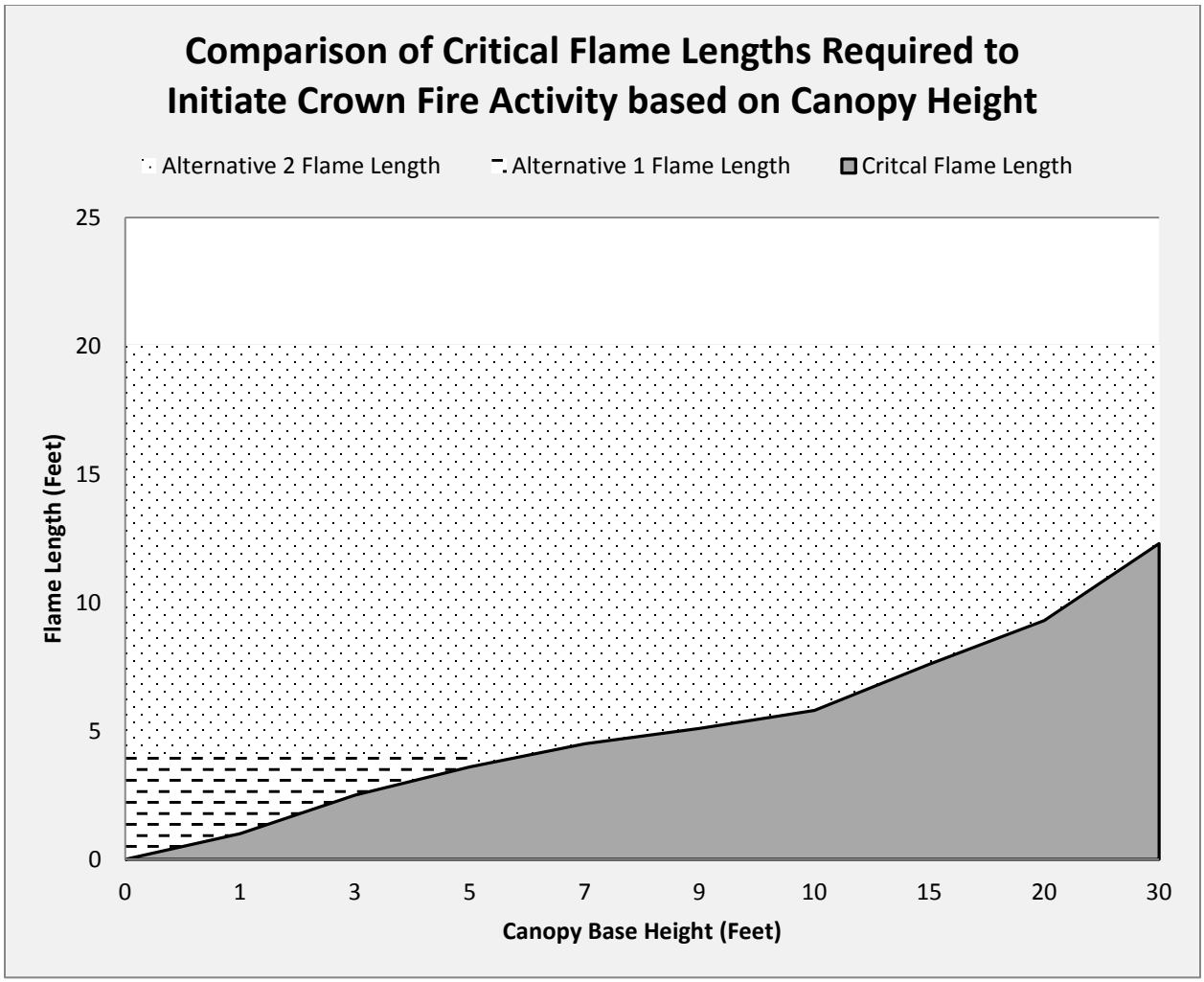


Figure 21. Comparison between projected flame lengths of Alternatives 1 and 2 and the critical flame lengths needed to initiate crown fire activity based on canopy base height.

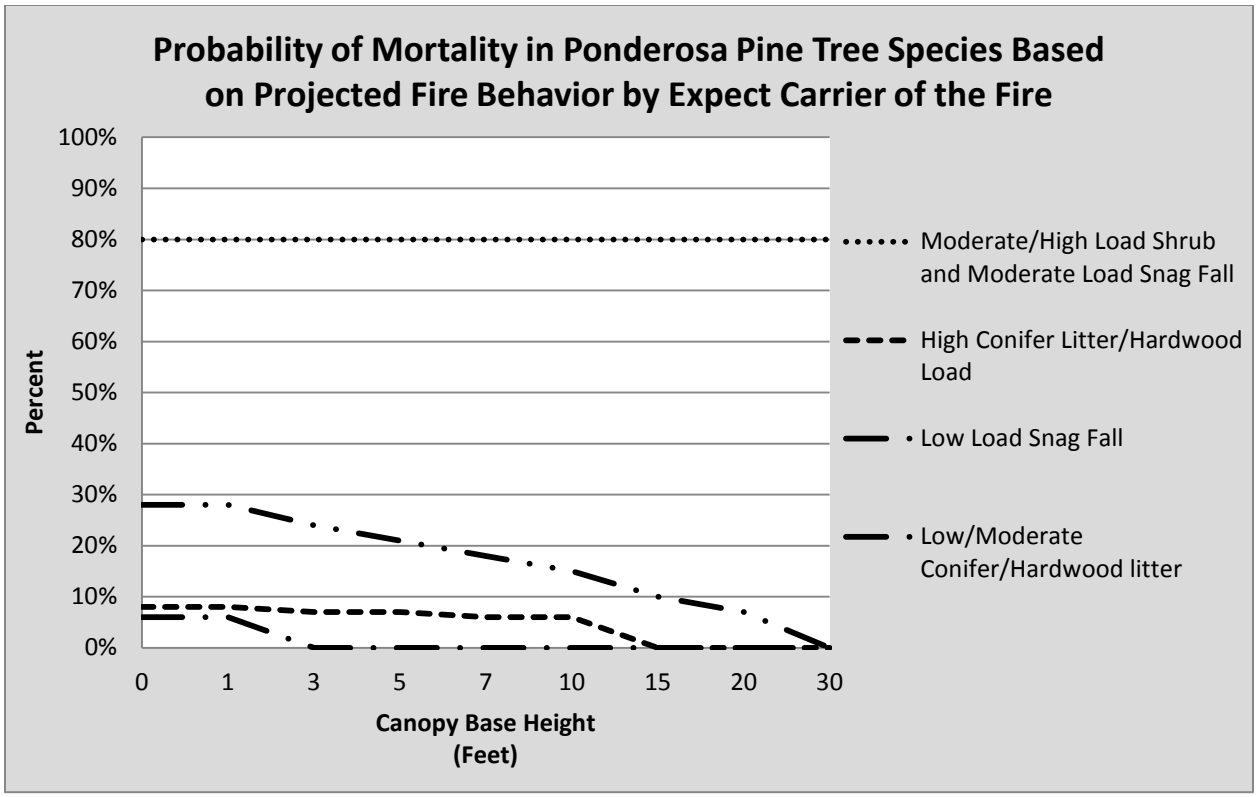


Figure 22. Probability of mortality of ponderosa pine tree species based on 90th percentile weather conditions.

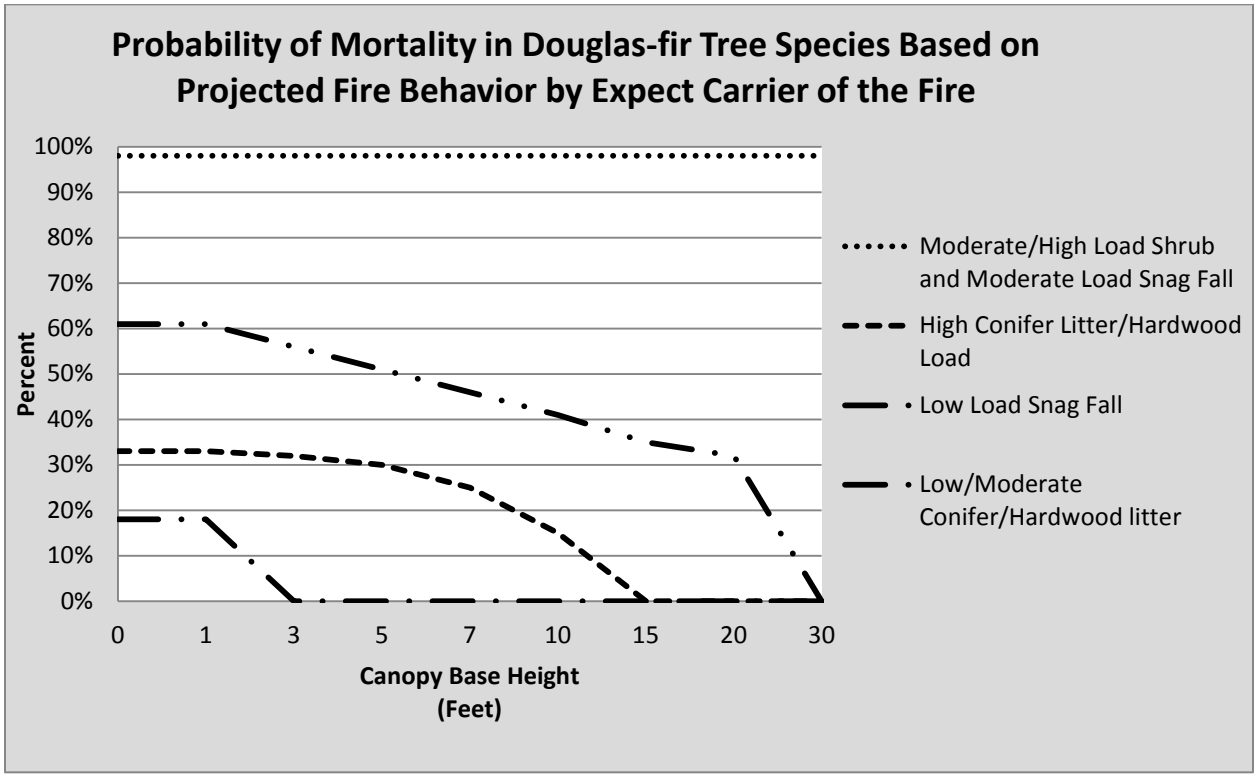


Figure 23. Probability of mortality of Douglas-fir tree species based on 90th percentile weather conditions.

Table 28. Comparison of potential flame length between Alternatives 1 and 2 over 10 years.

	Treatment Area		Project Area	
Flame Length	Alternative 1	Alternative 2	Alternative 1	Alternative 2
< 4 feet	14,014	44,760	80,739	111,486
4 to 8 feet	24,667	0	98,039	73,372
8 to 11 feet	1,945	0	10,857	8,930
> 11 feet	4,135	0	25,365	21,230

Table 29. Comparison of potential fireline intensity between Alternatives 1 and 2 over 10 years.

	Treatment Area		Project Area	
Fireline Intensity	Alternative 1	Alternative 2	Alternative 1	Alternative 2
< 100 btu/ft/sec	13,004	44,760	75,407	107,163
100 to 500 btu/ft/sec	26,088	0	108,685	82,597
500 to 1000 btu/ft/sec	3,853	0	17,659	13,806
> 1000 btu/ft/sec	1,815	0	13,267	11,452

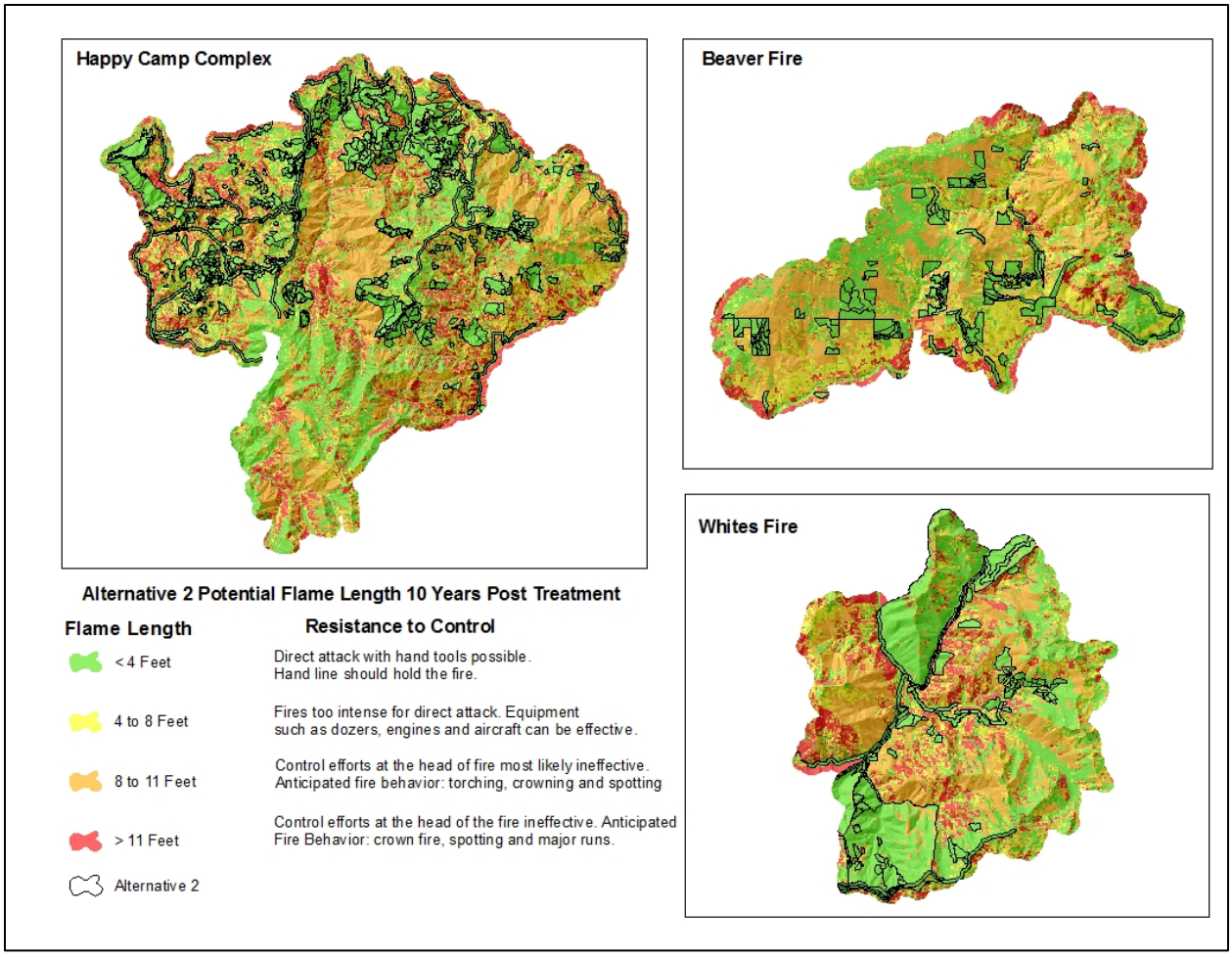


Figure 24. Alternative 2 potential flame length 10 years post treatment.

Fire Suppression Capabilities

Table 23 and Table 24 display future fuel loading and subsequent resistance to control between Alternatives 1 and 2. Safer and more efficient fire suppression actions are capable with activities planned under Alternative 2 when compared to Alternative 1. Removal of roadside hazard trees provides for safe ingress and egress to fires. The reduction of snags and subsequent fuel loadings modifies flame length and fireline intensity which enables direct attack and increases fireline production rates effectively decreasing resistance to control by removing large fuel accumulations. Moreover, a general lack of snags will permit safer nighttime fireline operations.

Project Design Features to clump snags effectively achieves fire suppression capability. Clumped snags will allow resources to locate control lines around these areas and safely engage a fire with limited need to fall high densities of snags. Snag retention is planned in areas that are rarely used by fire managers to contain a large fire; for example, lower 1/3 of slopes, away from roads and ridgetops.

The Kyburz Fire (Eldorado National Forest, 2013) provides an example of suppression success within a previous salvaged area. The fire started at the bottom of the slope within the South Fork American River; diurnal winds fanned the fire up-drainage toward the community of Kyburz, (approximately 1 mile from the fire origin) and reburning within the footprint of the Freds Fire

(2004). Portions of the Freds fire included post fire logging activity to reduce future fuel loading and snag density. The lack of heavy dead and down fuels allowed for fire suppression resources to continue to construct direct control lines keeping their safety zone with them as the "black". All things considered, salvage harvest lead to: lower intensity fire, less exposure to hazard trees, and less exposure during mop-up activities (Johnson, 2013). If direct tactics were not available as a result of an increase in snag densities, indirect line will have been required during nighttime operations requiring indirect tactics and increase in fire size (Jacobson, 2013). Resources including aircraft, heavy equipment and personnel were safely able to drop water and retardant in open areas and construct line with minimal large woody debris, which increased line production rates, and decreased resistance to control allowing for resources to effectively work through the night to complete control lines keeping the fire from entering the community of Kyburz.

Identified treatments in the WUI modify fire behavior such that fires are anticipated to spread slower, with flame lengths less than 4 feet, allowing responding resources to take direct action to control fires due to the change in the composition and structure of fuels which promotes low resistance to control when compared to Alternative 1.

Fuel treatments within the Wildland Urban Interface promote safer firefighting actions and evacuation of the public should a future large fire occur within the project area. An indirect effect of eliminating high snag densities and treating surface fuels within the WUI is a reduction in future material being available as a source of embers both as a spotting source and receptive fuel bed when compared to taking no action. Spotting and increased radiation make structures more difficult to defend from crown fire than surface fire (Cohen & Butler, 1996) (Scott & Reinhardt, 2001). Spot fires commonly occur at distances of .5 miles ahead of the main fire; however, observations greater than 1 mile have been observed during extreme fire behavior events; for example, on 2 occasions, the Beaver Fire (2014) experienced multiple spot fires 1+ miles ahead of the main fire.

Several case studies have documented the effects of fuels treatments within the WUI. Both the Grass Valley (Rogers, Hann, Martin, Nicolet, & Morgan., 2008) and Angora Fires (Murphy & Sexton, 2007) documented how fuel treatment effectiveness assisted with protection of structures, securing control lines, and reduction of fire behavior resulting in the ability to "pick-up" spot fires with direct actions. More importantly, Cohen and Butler (1996) noted that the degree of structure survival "results from a complex, interactive sequence of events involving the ignition and burning of vegetation and structures accompanied by varying fire protection efforts by homeowners and firefighters." Treatments proposed within Alternative 2 have projected surface fuel loadings to reduce fire behavior and allow for safe and effective fire suppression actions.

The 2012 Goff Fire highlights the benefits of fuel treatments in which the objective is to reduce surface fuel loading and modify fire spread and intensity within the WUI. The Seiad Creek Road Shaded Fuel Break project, completed in 2009, was utilized as a control line for the Goff Fire. Fuels treatment contributed to easier holding and burning along Seiad Creek Road, in the community of Seiad Valley (Osborne, 2015). Both proposed salvage and hazardous fuels treatments planned under alternative 2 will produce similar fire behavior that could support fire suppression resources with opportunities to burnout, hold fireline and safely take action on any identified spot fires in the advent of a large fire occurring after completion of the project.

Fuels treatments identified along strategic ridge and road systems will enhance future fire management activities including fire suppression, managing unplanned ignitions, and implementation of prescribed fire. Maintaining these treatments provides opportunities for fire managers to focus resources at priority locations (such as in the WUI) as well as provide options to utilize confine and contain strategies of future fires where untreated areas still contain high densities of snags which inhibit safe work areas for fire suppression resources.

In the advent of a future large fire, strategic ridge and road systems are identified as areas that could be used and maintained by fire suppression resources providing time and opportunity to ignite backfire operations ahead of the main fire. Salvage and Site Preparation units provide an added depth to hazardous fuels treatments by increasing the size and scale. For example, a large fire within an untreated portion of the landscape, spreading uphill toward a treated area, will not immediately decrease to predicted fire behavior. As fire enters the treated area, the fringes of the treatment will likely see increased fire behavior as a result of fire front entering the treatment.

As fire continues through the treated area, fire behavior is altered reducing the spread and intensity of the fire. This type of activity was observed on the King Fire (Eldorado National Forest, 2014); fire activity outside of the completed fuels treatment consisted of a running crown fire; as it entered the treated area, the fringes saw high mortality within the overstory trees and understory vegetation. However, approximately 50 to 100 feet into the unit, the fire transitioned to surface fire and eventually arrested in the fuels treatment. This area was a 50 year old plantation that was thinned (2010) and burned 1 year prior to the fire (Ebert, 2014).

By strategically applying and varying post-fire logging treatments within landscapes, post-fire logging could reduce woody fuels and help reduce threats to human health, property, and ecosystem services from unacceptable future wildfire behavior and effects (Peterson, Dodson, & Harrod, 2014). Table 30 displays units proposed for salvage and site preparation that increase fire suppression capabilities, both for fire suppression and managing future fire activity on the landscape. With approximately 98% of the post treated units exhibiting flame lengths less than four feet, these locations assist with “buffering” fuels treatments within WUI and identified strategic ridge and road systems. These areas provide locations that can be used as safety zones and anchor points to effectively engage future fires as well as implement prescribed fire activities.

Table 30. Salvage units that provide an additional fire management benefit.

Fire	Salvage Unit ID	Acres*	Fire Management Benefit
Beaver	1108, 1128, 1137, 1142, 1151	250	Wildland Urban Interface - Modify Fire Behavior (Spread, Intensity, Spot Fire Activity within WUI and adjacent to Hazardous Fuels Treatments.
Happy Camp	5, 13, 20, 21, 22, 23, 31, 32, 33, 34, 35, 36, 39, 40, 56, 58, 60, 61, 62, 64, 65, 203, 207, 215, 217, 219, 239, 240, 263, 265, 266, 501, 503, 505, 515, 536, 537, 539	5,595	
Whites	409, 410, 411, 414, 415	365	
WUI Acres		6,210	
Beaver	1109, 1110, 1129, 1136, 1140	445	Strategically Located Treatment - Units located adjacent to proposed hazardous fuels treatments along ridge and road systems or connect fuel treatments extending to private land to increase the size and scale of proposed
Happy Camp	3, 50, 51, 52, 53, 54, 55, 57, 59, 208, 209, 211, 223, 226, 227, 234, 243, 508, 509, 510, 520, 521, 522, 523, 524, 525, 528, 541, 545	3,370	

Fire	Salvage Unit ID	Acres*	Fire Management Benefit
Whites	417	185	ridge and road system treatments.
Strategic Treatment Acres		4,000	
Total Acres		10,210	

* Acres are approximation based on unit polygons derived from GIS layers. Acres are for salvage harvest units; <60% of these units will be salvage logged.

Cumulative Effects

The Westside Fire Recovery Project in conjunction with ongoing and foreseeable actions have the potential to increase fire resiliency with both managing unplanned and planned fire ignitions across the landscape compared to alternative 1. Furthermore, fire suppression effectiveness is improved as future projects implemented adjacent to and within the project area increase the size and scale of treatments proposed under Alternative 2. At the stand scale, post-fire logging reduces surface fuels over the long term, particularly in the large diameter size classes (> 3" diameter), which should increase management options for applying prescribed fire treatments or allowing future wildfires to burn without causing excessive damage to the forest vegetation and soils (Peterson, Dodson, & Harrod, 2014).

Table 31. Ongoing and foreseeable projects reviewed for Cumulative Effects.

Fire Area	Ongoing and Foreseeable Actions Related to Fire and Fuels Management
Beaver Fire	Private Land Timber and Salvage Harvest
Happy Camp Complex	Elk Thin, Elk Thin, Happy Camp Fire Protection-Phase 2, Johnny O'Neil LSR, Lovers Canyon, Tom Schinder, - Private Land Timber and Salvage Harvest
Whites Fire	Eddie LSR, Sawyers Bar Fuels Reduction Project, Private Land Salvage

Communities affected by the 2014 fires continue to reduce fuels on private property that is located adjacent to National Forest System Lands. Alternative 2 compliments many of these activities to improve fire resiliency and provide opportunities to enhance the work by landowner to improve vegetation and fuel loadings to promote less intense fire behavior and promote safer firefighting action in the future within urban interface fires. The Scott Bar and Seiad Fire Safe Councils are active fire safe councils which have coordinated fuels treatments on private and public lands in the past and can be expected to continue these partnerships into the future.

Private timberlands are currently in the process of salvage operations on lands affected by the 2014 fires. Treatments adjacent to private timberlands will increase the size and scale of treatment activities under Alternative 2 as well as provide fuel breaks on prominent ridge and road systems within the Beaver Fire that seamless stretch across private and forest systems lands. Christmas Tree and Buckhorn Ridge systems where planned activities within the Beaver Fire which adjoin private and National Forest lands.

Based on activities planned under Alternative 2, ongoing and foreseeable future activities, long term fire modeling projections (Table 32 and 31) are displayed based on the assumptions that units completed for treatment are reforested and fuels are maintained to desired conditions

encompassed through other ongoing activities and foreseeable actions, along with absence of disturbance activities including wildfire for the next 50 years.

Future changes to fire behavior on the landscape could reduce associated fire behavior compared to alternative 2 where fuels reduction activities and/or wildfire ignitions occur (Figure 25).

Table 32. Comparison of potential flame length between Alternatives 1 and 2 greater than 20 years.

	Treatment Area		Project Area	
Flame Length	Alternative 1	Alternative 2	Alternative 1	Alternative 2
< 4 feet	6,305	44,760	40,906	79,356
4 to 8 feet	7,995	0	40,259	32,264
8 to 11 feet	5,727	0	24,510	18,783
> 11 feet	24,728	0	109,343	84,615

Table 33. Comparison of potential fireline intensity between Alternatives 1 and 2 greater than 20 years.

	Treatment Area		Project Area	
Fireline Intensity	Alternative 1	Alternative 2	Alternative 1	Alternative 2
< 100 btu/ft/sec	5,566	44,760	35,849	75,038
100 to 500 btu/ft/sec	15,875	0	74,944	59,069
500 to 1000 btu/ft/sec	13,111	0	51,839	38,728
> 1000 btu/ft/sec	10,203	0	52,386	42,183

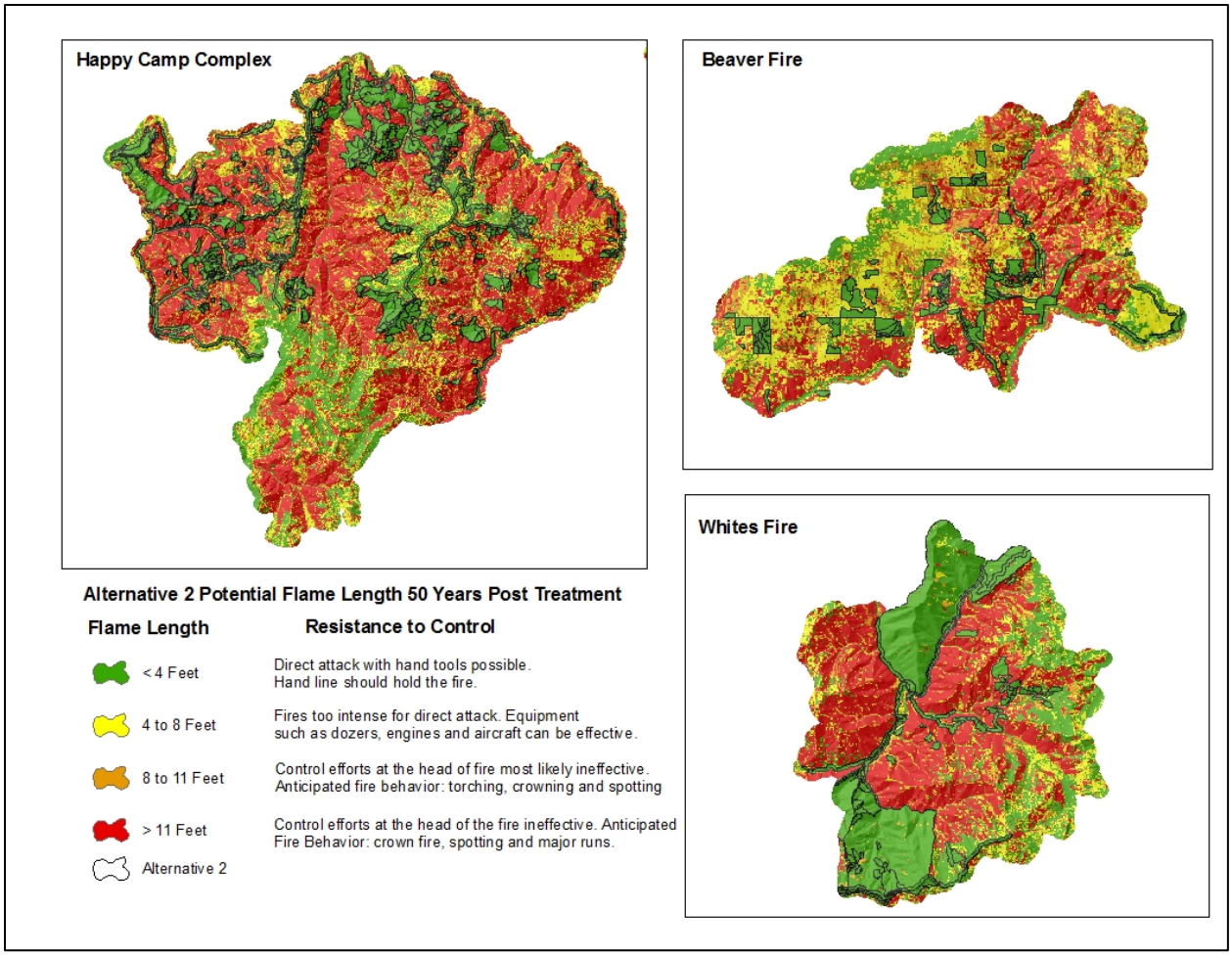


Figure 25. Alternative 2 projected flame lengths > 20 years post treatment.

Alternative 3

Direct Effects and Indirect Effects

The direct and indirect effects of this alternative are anticipated to be similar to those described within Alternative 2. Proposed activities are anticipated to reduce fire hazard and resistance to control. Additional snag recruitment may increase surface fuel loadings in the future where additional snags are left within units; however, within areas that receive treatment, surface fuel loading projections will be comparable to Alternative 2 and produce similar fire behavior (Table 34 and Table 35). Project design features to leave snags in a clumping pattern as well as away from strategic fire management features (ridges, roads, etc.) will still provide safe and effective fire suppression activities.

Table 34. Comparison of project flame lengths 10 years post treatment.

Flame Length	Alternative 1	Alternative 2	Alternative 3
< 4 feet	14,014	44,800	40,800
4 to 8 feet	24,667	0	0

Flame Length	Alternative 1	Alternative 2	Alternative 3
8 to 11 feet	1,945	0	0
> 11 feet	4,135	0	0

Table 35. Comparison of projected fireline intensities 10 years post treatment.

Fireline Intensity	Alternative 1	Alternative 2	Alternative 3
< 100 btu/ft/sec	13,000	44,800	40,800
100 to 500 btu/ft/sec	26,100	0	0
500 to 1000 btu/ft/sec	3,850	0	0
> 1000 btu/ft/sec	1,800	0	0

Salvage harvest units identified as strategic to fire management activities are reduced by approximately 2,000 acres compared to alternative 2 (

Table 36). Almost half of the change comes from the units eliminated within the Beaver fire area. Opportunities to reduce fire spread and intensity within these units that buffer strategic fire management features are lost.

Within the Happy Camp and Whites fire areas, salvage harvest treatments eliminated under this alternative intermix with other proposed activities which still allows for additional buffering to reduce fire spread and intensity adjacent to hazardous fuels treatments.

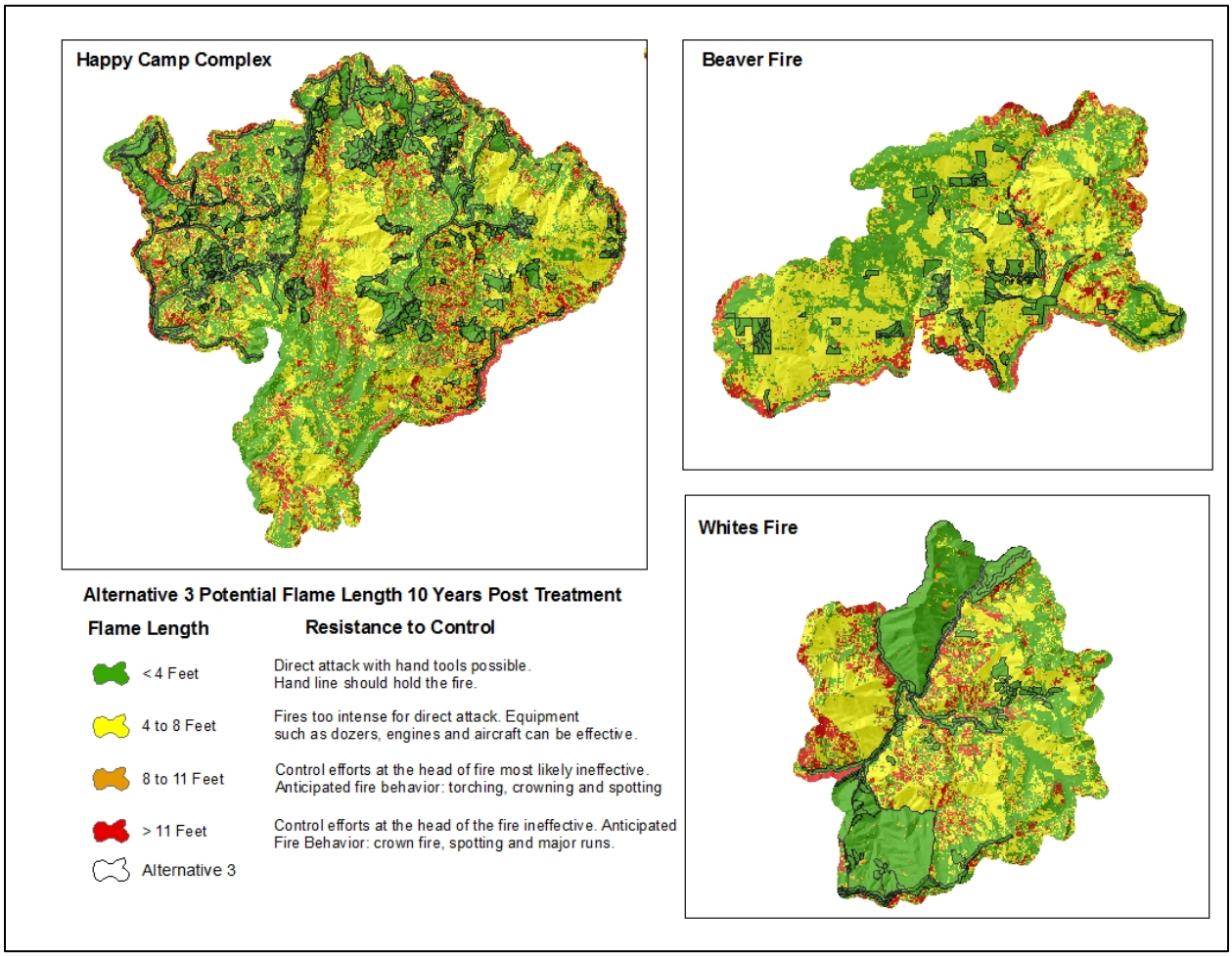


Figure 26. Potential flame length 10 years post treatment, Alternative 3.

Table 36. Salvage units that provide an additional fire management benefit.

Fire	Salvage Unit ID	Acres*	Fire Management Benefit
Beaver	No Treatments Occur	0	Wildland Urban Interface - Modify Fire Behavior (Spread, Intensity, Spot Fire Activity within WUI and adjacent to Hazardous Fuels Treatments.
Happy Camp	5, 13, 20, 21, 23, 31, 32, 33, 34, 36, 39, 40, 56, 58, 60, 61, 62, 64, 65, 203, 239, 263, 265, 266, 501, 503, 505, 515, 536, 537, 539	5,325	
Whites	409-411, 414, 415, 417	365	
WUI Acres		5,690	
Beaver	No Treatments Occur	0	Strategically Located Treatment - Units located adjacent to proposed hazardous fuels treatments along ridge and road systems or connect fuel treatments extending to private land to increase the size and scale of proposed ridge and road system treatments.
Happy Camp	3, 50, 51, 52, 53, 54, 55, 57, 59, 208, 211, 226, 227, 234, 243, 508, 509, 510, 520, 521, 522, 523, 524, 525, 528, 541, 545	3,240	
Whites	417	185	
Strategic Treatment Acres		3,425	
Total Acres		9,115	

* Acres are approximation based on unit polygons derived from GIS layers. Acres are for salvage harvest units; <60% of these units will be salvage logged.

Cumulative Effects

When compared to alternative 2, similar effects are anticipated within the project boundary of the Happy Camp Complex and Whites fire areas. The size and scale of treatment units reduced within these areas will not reduce the benefits of associated treatments still proposed with this alternative.

Alternative 3 eliminates all salvage harvest activity within the Beaver Fire project boundary (about 860 acres). Opportunities to connect fuel treatments which adjoin private land, where salvage and fuel treatments are planned are diminished due to the reduction of treatment activities. Opportunities to reduce fire spread and intensity across the landscape will be decreased as the size and spatial location of the treatments are eliminated. Figure 27 displays projected flame lengths 20 years and greater.

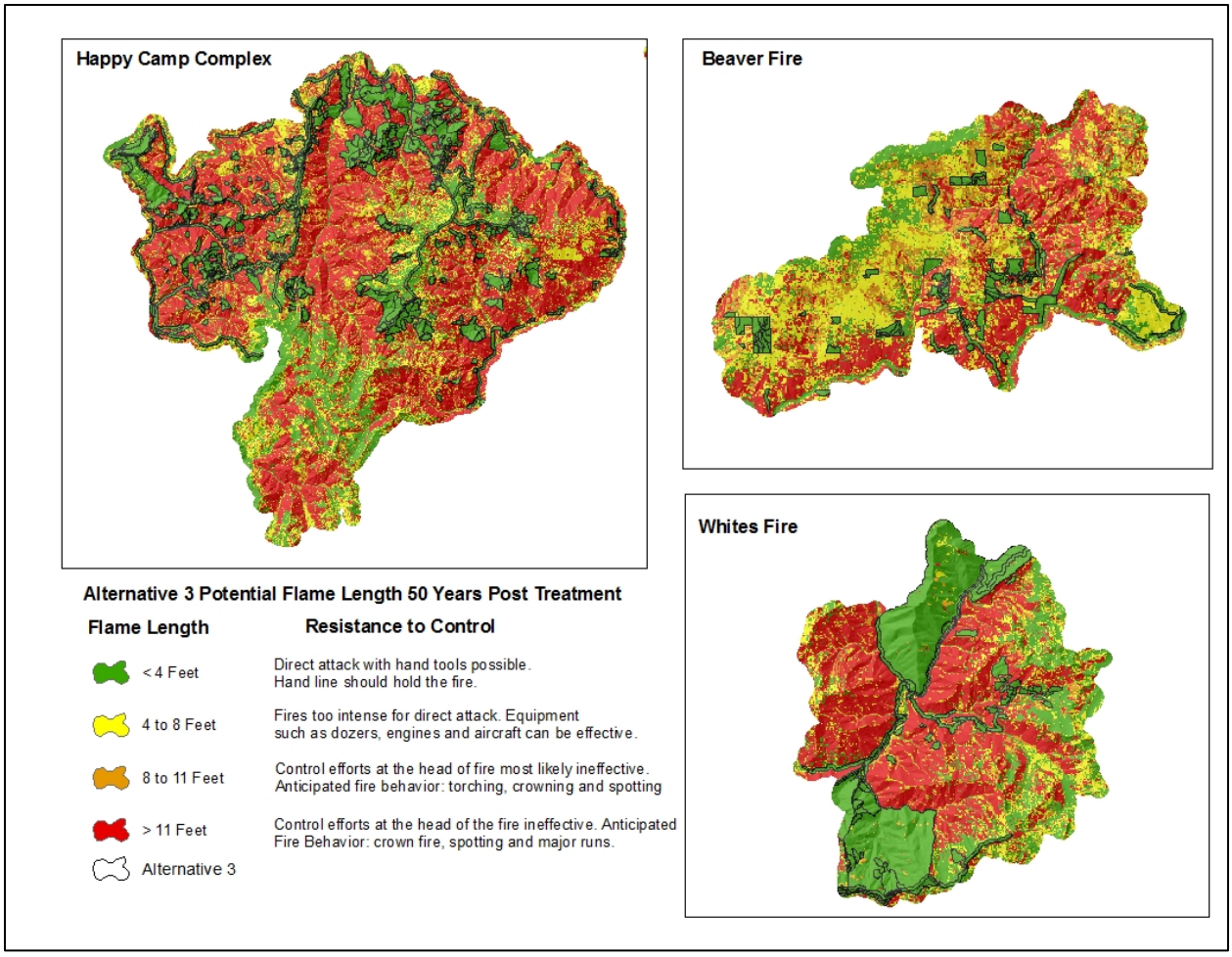


Figure 27. Potential flame length (Alternative 3) greater than 20 years post treatment.

Alternative 4

Direct Effects and Indirect Effects

The direct and indirect effects of this alternative are anticipated to be similar to those described within Alternative 2. Proposed activities are anticipated to reduce fire hazard (Table 38 and Table 39) and resistance to control as where treatments occur, fuels reduction activities to reduce fuel loadings to < 10 ton/acre will still occur.

Salvage harvest treatments eliminated under this alternative are intermixed within other proposed activities which still allows for additional buffering to reduce fire spread and intensity adjacent to hazardous fuels treatments. Compared to alternative 2, salvage harvest units identified as strategic to fire management are reduced by about 2,000 acres (Table 37).

Table **37. Salvage units that provide an additional fire management benefit.**

Fire	Salvage Unit ID	Acres*	Fire Management Benefit
Beaver	1108, 1128, 1137, 1142, 1151	250	Wildland Urban Interface - Modify Fire Behavior (Spread, Intensity, Spot Fire Activity within WUI and adjacent to Hazardous Fuels Treatments.
Happy Camp	5, 13, 20, 21, 22, 23, 31, 32, 33, 34, 35, 36, 39, 40, 56, 58, 60, 61, 62, 64, 65, 203, 207, 215, 217, 219, 239, 240, 263, 265, 266, 501, 503, 505, 515, 536, 537, 539	5,365	
Whites	409-411, 414, 415, 417	365	
	WUI Acres	5,980	
Beaver	1109, 1110, 1129, 1136, 1140	445	Strategically Located Treatment - Units located adjacent to proposed hazardous fuels treatments along ridge and road systems or connect fuel treatments extending to private land to increase the size and scale of proposed ridge and road system treatments.
Happy Camp	3, 50, 51, 52, 53, 54, 55, 57, 59, 209, 211, 223, 226, 227, 234, 508, 509, 510, 521, 522, 523, 525, 528, 541, 545	2,400	
Whites	417	185	
	Strategic Treatment Acres	3,030	
	Total Acres	8,395	

* Acres are approximation based on unit polygons derived from GIS layers. Acres are for salvage harvest units; <60% of these units will be salvage logged.

Table 38. Comparison of projected flame lengths 10 years post treatment.

Flame Length	Alternative 1	Alternative 2	Alternative 3	Alternative 4
< 4 feet	14,014	44,800	40,800	41,100
4 to 8 feet	24,667	0	0	0
8 to 11 feet	1,945	0	0	0
> 11 feet	4,135	0	0	0

Table 39. Comparison of projected fireline intensity 10 years post treatment.

Fireline Intensity	Alternative 1	Alternative 2	Alternative 3	Alternative 4
< 100 btu/ft/sec	13,000	44,800	40,800	41,100
100 to 500 btu/ft/sec	26,100	0	0	0
500 to 1000 btu/ft/sec	3,850	0	0	0
> 1000 btu/ft/sec	1,800	0	0	0

Cumulative Effects

Similar effects are anticipated as those described under Alternative 2. .

Alternative 5

Direct Effects and Indirect Effects

Within units that receive treatment, direct effects are comparable to those described within alternative 2 with respect to reduction in fire hazard and resistance to control (Table 40 Table 41). Indirect effects vary by fire area due to the reduction in the size and scale of salvage harvest activities.

Table 40. Comparison between alternatives of projected flame lengths 10 years post treatment.

Flame Length	Alternative 1	Alternative 2	Alternative 3	Alternative 4	Alternative 5
< 4 feet	14,014	44,800	40,800	41,100	35,200
4 to 8 feet	24,667	0	0	0	0
8 to 11 feet	1,945	0	0	0	0
> 11 feet	4,135	0	0	0	0

Table 41. Comparison between alternatives of projected fireline intensity 10 years post treatment.

Fireline Intensity	Alternative 1	Alternative 2	Alternative 3	Alternative 4	Alternative 5
< 100 btu/ft/sec	13,000	44,800	40,800	41,100	35,200
100 to 500 btu/ft/sec	26,100	0	0	0	0
500 to 1000 btu/ft/sec	3,850	0	0	0	0

Within the Beaver fire area, additional fuel treatments added as proposed activities are anticipated to modify fire spread and intensity. Fire managers will also have increased fuel breaks allowing future fire management options to control unplanned fires.

Salvage treatments removed within portions of the Happy Camp Complex will be expected to significantly reduce opportunities to modify fire spread. Many of the units removed under this alternative, are located adjacent to strategic fire management features (ridges, roads, etc.). The reduction in the size and scale of treatments will most likely allow future fire activity to spread upslope due to anticipated fuel loading and subsequent fire behavior, which is expected to be comparable to taking no action.

Approximately 3,600 acres of treatments (based on salvage harvest units, not actual acres of salvage harvest) are removed from the WUI under Alternative 5. Many of these areas are adjacent to critical control points and communities, for example Highway 96 and the community of Seiad. A primary concern will be any future fire starts above the community that start within snag patches; fires will be expected to be more difficult to control and require greater time and effort of resources due to the safety exposure to snags and increased fuel loadings and anticipated fire hazard where large accumulations of material accumulate. When compared to alternative 2, approximately 5,000 less acres of salvage harvest (7,000 acres of salvage harvest units) occurs in identified strategic fire management areas such as WUI and/or strategic ridge and road systems (Table 42). Figure 28 displays projected flame length 10 years post treatment.

Table 42. Salvage units that provide an additional fire management benefit.

Fire	Salvage Unit ID	Acres*	Fire Management Benefit
Beaver	1108, 1128, 1142, 1151	220	Wildland Urban Interface - Modify Fire Behavior (Spread, Intensity, Spot Fire Activity within WUI and adjacent to Hazardous Fuels Treatments.
Happy Camp	5, 13, 22, 23, 31, 32, 33, 34, 35, 36, 39, 40, 60, 203, 239, 240, 503, 515, 536, 537, 539	1,550	
Whites	410, 411	35	
	WUI Acres	1,805	
Beaver	1109, 1110, 1129, 1136, 1140	445	Strategically Located Treatment - Units located adjacent to proposed hazardous fuels treatments along ridge and road systems or connect fuel treatments extending to private land to increase the size and scale of proposed ridge and road system treatments.
Happy Camp	223, 234, 243, 508, 523, 528, 541	650	
Whites	No Treatment Units Identified	0	
	Strategic Treatment Acres	1,095	
	Total Acres	2,900	

* Acres are approximation based on unit polygons derived from GIS layers. Acres are for salvage harvest units; <60% of these units will be salvage logged.

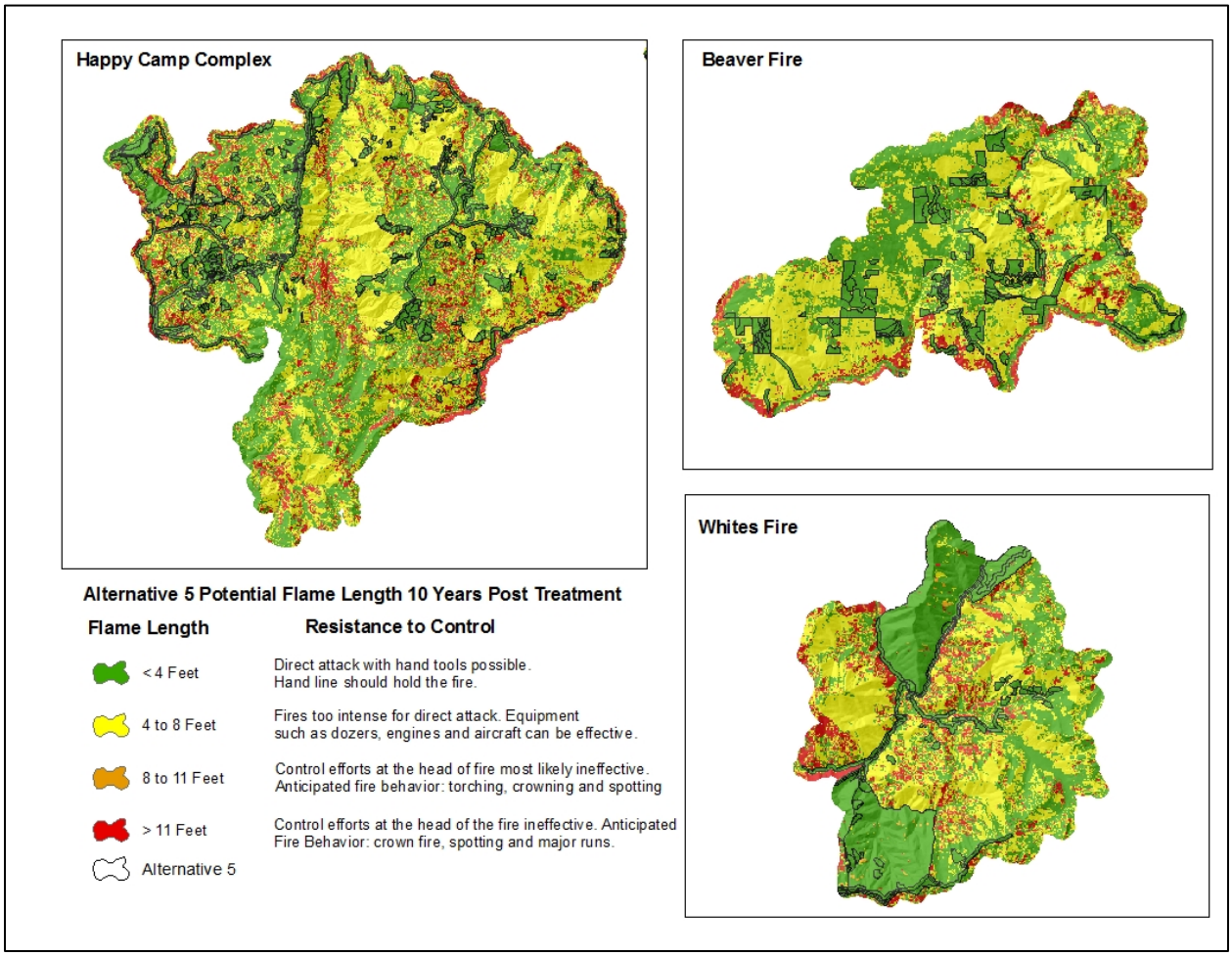


Figure 28. Potential flame length 10 years post treatment (Alternative 5).

Cumulative Effects

Variable effects are anticipated based on fire area. Similar effects as described under Alternative will be expected within the Whites and Beaver fire areas. Within the Beaver fire area, the additional treatments added under this alternative will further enhance fuel treatment effectiveness at the landscape level due to the increase of size and scale of proposed treatments coupled with adjoin private land treatment activities.

Within the Happy Camp Complex fire area, the reduction in salvage harvest activities greatly reduces the size and scale of treatments at the landscape level (Figure 29). Future foreseeable fuels reduction projects may be precluded due to high density of snag patches left on the landscape making some foreseeable projects difficult to implement.

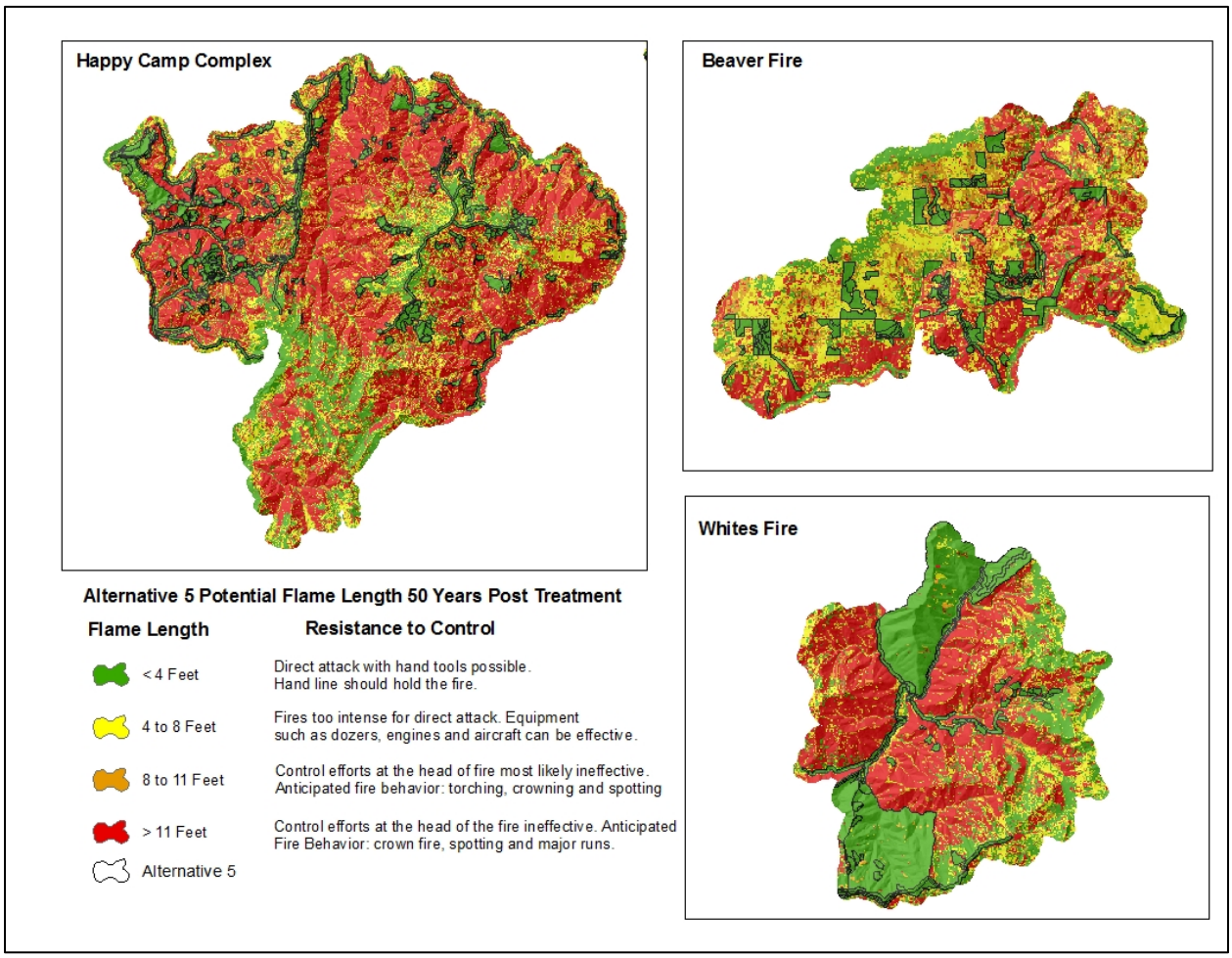


Figure 29. Potential flame length (greater than 20 years) Alternative 5.

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Appendix A: Fire Modeling Assumptions

Forest Vegetation Simulator and Fire and Fuels Extension – FVS-FFE

The Forest Vegetation Simulator (FVS) is used by forest managers throughout the United States and Canada to predict stand dynamics and the effects of various management actions on future forest conditions. It is an individual tree, distance-independent growth and yield model. The Fire Fuels Extension (FFE) was develop by integrating FVS with elements from existing models of fire behavior and fire effects (The FVS simulates tree growth, tree mortality and regeneration, and the impacts of a wide range of silviculture treatments). The Fire Fuels Extension simulates fuel accumulation from stand dynamics and management activities, and the removal of fuel through decay, mechanical treatments and prescribed or wildfires. (Beukema et al 2002).

FFE-FVS was developed by the Forest Service Research branch. The model is explained in depth in General Technical Report 116 from the Rocky Mountain Research Station (Reinhardt and Crookston 2003). FFE-FVS supports fuel management and post-fire treatment decisions in the context of other vegetation management concerns, including wildlife habitat, insect and pathogen hazards, and timber production. It allows forest management decisions to be assessed in a temporal context: not only short-term effects on fuels, stand dynamics, and potential fire behavior are modeled, but also the way in which these interacting ecosystem components may be expected to change over time.

FFE-FVS has a broad geographic scope. FVS variants have been developed for forested regions nation-wide. The fire fuels extension (FFE) has been modified for use with many of the variants used in the western United States, including Northern Idaho, Central Rockies, Utah, Eastern Montana, Western Sierra, Blue Mountains, Eastern Cascades, Central Idaho, Tetons and Southern Oregon/Northern California. Modifications were based on workshops and consultations with scientists and other fire experts familiar with conditions in each region. (Reinhardt and Crookston 2003).

Many of the components of FFE-FVS have long histories in both scientific and management communities. For example, the surface fire component used in the model was first presented by Rothermal in 1972, and the tree mortality and fuels consumption components were developed in the 1980s (Beukema et. al.1999).

A simulation tracks the biomass, growth and mortality of individual trees in a stand; litterfall from living trees and falldown of the snags determine woody fuels loads. Fire, if simulated, impacts surface fuels directly by consuming them, indirectly, over time, as fire-killed trees fall to the ground, and even more indirectly, by impacting future stand structure.

Flammap

Flammap is a fire behavior mapping and analysis program that computes fire behavior characteristics over a landscape of constant inputs of weather and fuels moisture conditions. Outputs consisted of fire type or crown fire potential (Scott and Reinhardt, 2001) and flame length potential (Finney 1998). In addition, all fire model runs were calculated using the California Fuels Landscape, which uses the vegetation layer to obtain fuel models. In addition to fuel models, the California Fuels Landscape is comprised of elevation, aspect, slope, canopy cover, stand height, canopy bulk density, and canopy base height to predict fire behavior potential.

Flammap employs the fire behavior model of Rothermel 1972. The Rothermel fire behavior model makes several assumptions such as: 1. The fire is free burning, 2. Fire behavior is predicted at the flaming front, 3. Fine fuels are the primary carrier of the initial fire front, and 4. Fuels are continuous and uniform.

Fire type is a measure of how severe a fire may become under specified conditions. Canopy characteristics (e.g. canopy base height, canopy bulk density, stand height, and foliar moisture content), ladder fuels, and fuel loading are all factors that determine fire type. The model assumes uniform canopy characteristics and makes independent fire behavior calculations for each raster landscape (90 m X 90 m cell). As a result of these assumptions, the model frequently under-predicts active crown fires (Fule et al., 2001; Scott and Reinhardt, 2001; Cruz et al., 2003; and Stratton, 2004) compared to field observations.

Fire behavior outputs generated from modeling exercises only reflect static conditions and do not take into account changing weather conditions. Any change in these factors could drastically affect fire behavior. Given the uncertainty of any modeling exercise, the results are best used to compare the relative effects of the alternatives, rather than as an indicator of absolute effects.

BehavePlus

The BehavePlus fire modeling system uses mathematical fire predictions similar to Flammap. Outputs can be used to predict fire behavior and fire effects. Each model calculation is based on the assumption that conditions are static for the projection. Fire behavior outputs generated from modeling exercises only reflect static conditions and do not take into account changing weather conditions. Any change in these factors could drastically affect fire behavior. Given the uncertainty of any modeling exercise, the results are best used to compare the relative effects of the alternatives, rather than as an indicator of absolute effects.