Masten Vegetation Analysis and Fuels Treatment Plan

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Executive Summary

This paper analyzes the vegetation and the potential for an active crown fire (stand destroying) in the 1740 acre Masten project area on the Prineville District, Bureau of Land Management. Information used in the analysis was based on current fuel conditions, fire occurrences, and historic weather data. This paper develops fuel treatment alternatives that mitigate active crown fire potential and provide healthy, viable stands that are more resistant to fire, insects, and disease. These alternatives will be evaluated for economics and their ability to reduce the fire hazard. This project could have implications to similar areas within the La Pine and Bend urban interface and provide information for future project planning.

Management determined a need for implementing a fuels treatment within the Masten area based on visual inspection and professional experience. The task was to quantify the existing condition and determine the risks as it relates to the objectives.

PROBLEM

Past management of fuels and aggressive fire suppression, along with urban interface encroachment, have altered the fire regimes within the La Pine urban interface. In the event of a wildfire, lodgepole pine stand structure and associated fuel load build-up could threaten the La Pine community. The Fire Management Officer and District Manager of the Prineville BLM want to mitigate this risk to the community while maintaining a healthy forest.

GOAL

The project goal, in accordance with the National Fire Plan, District Fire Plan and the Brothers/La Pine Resource Management Plan, is to evaluate effective fuel treatments that best protect the La Pine urban interface community and promote healthy fire and insect/disease resistant forest stands.

OBJECTIVES

1) Evaluate and recommend a cost effective fuel treatment or combination of treatments that result in fire behavior with flame lengths of less than four feet and eliminate the probability of an active crown fire at 97^{th} percentile weather, by comparing present net value over a 70 year time period, where the treatments are:

   Alternative 1- "No Action" as a baseline alternative.
   Alternative 2- Contract Thin/Pile/Burn/Mow
   Alternative 3- Contract Excavator Mastication System.

The analysis began by determining the current fuel condition within the project area with a stand inventory in order to understand the component and structural attributes. The same was done for dead and down woody fuel in order to understand the surface fuel profile. The stand inventory plots and dead and down inventory plots were then entered into Fire Management Analysis Plus: CrownMass and DDWoodyPC. Once the fuel information was completed, percentile weather, fuel conditions, and fire occurrence data were ascertained through FIREFAMILY PLUS. Historic fire occurrence data may also be gathered through GIS. Using information gathered thus far, surface fire behavior and crown fire behavior is determined by FMA Plus' fire behavior program in CrownMass. CrownMass is also employed to understand mortality and limits of acceptable fire intensities within the project area. Probability analysis was then performed using PROBACRE and a series of other calculations that are described within the paper.

The analysis determined 97th percentile seasonal fire behavior conditions would support transition of fire into the crown resulting in an active crown fire (stand destroying). The probability associated with active crown fire in the Masten project, given the above seasonal fire behavior conditions, is 20% at year 25, and 30% at year 50.

A recommended alternative is described that satisfies the fire behavior objectives as well as creating a healthy, viable stand. The recommended alternative has an associated cost of $13,464,109 and a Present Net Value of $28,266,605. Furthermore, this alternative will provide a fire safe condition in which the stand will survive unplanned ignitions and the spacing between leave trees will provide for ultimate growth.

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INTRODUCTION

The Masten project is a fuel treatment plan for the Bureau of Land Management (BLM). The project area is located one-half to three miles southwest of the community of La Pine in Central Oregon. It is dominated by young, 10-14 year old lodgepole pine on flat terrain. The primary purpose and scope of the project is to reduce fire hazard and promote a healthy forest stand, resistant to fire, insects and disease in an urban/forest zone within the BLM Brothers/La Pine Management Area. The project focuses on the 1740 acres covered by the Masten Forest Treatment Project Environmental Assessment. This project could have implications to similar areas within the La Pine and Bend urban interface and provide information for future project planning. The legal description is Township 22 S., Range 10 E., Sec. 15, 16, 17, 20, 21, 22, Willamette Meridian (Appendix A – Masten Project).

BACKGROUND

The proposed project is within the area of two previous timber sales, the TS-85 sale, completed in 1988 and the La Pine Core sale, completed in 1989. These two timber sales were part of the larger salvage/fire hazard reduction treatments initiated in the La Pine area after the mountain pine beetle epidemic of the late 1970's and 1980's. The silvicultural prescription for these two sales was "seed tree" harvest with the goal of reducing the fire hazard, salvaging dead timber, and removing overcrowded and diseased trees. Due to the low utilization standards of the time large amounts of woody debris were left on-site after the merchantable timber was removed. Subsequent fuel surveys by BLM fire management staff revealed that a significant fire hazard still remained. Housing developments border the project area to the north and to the west. A decision was made in 1992 to machine pile the residual material on the ground throughout the area of these two timber sales. An estimated 200 piles (30ft. x 30ft. x 8ft.) of woody material exist on 60% of the area within the project boundary (primarily in Sections 20, 21, and 22). Since 1992 many calls have come into the BLM from local small operators expressing an interest in salvaging this material for firewood or wood chips. More recently, there has been interest in using this woody material as well as new lodgepole growth for mulching materials, but at the government's expense. Some of the wood in the piles has been dead for more than 13 years and is beginning to decay, its value is diminishing over time.

In natural lodgepole pine stands during pre-settlement times, wildfires occurred anywhere from 35-100+ years. These fires would generally be stand-destroying fires and would prepare the site for natural regeneration by consuming woody debris and other vegetation competing against the seral communities. The result was typically a patchwork of even-aged stands across the landscape in various stages of development (Agee, 1993). This natural disturbance kept most stands in a relatively young and vigorous condition. The mountain pine beetle was a natural part of these stands but occurred in smaller numbers, in individual trees or isolated pockets. With aggressive fire suppression beginning at about the turn of the century, these lodgepole stands had been allowed to attain an over mature and over stocked condition. Dense stands of mature trees under stress make for ideal conditions for an outbreak of mountain pine beetle. This is the situation that occurred in this area resulting in a severe pine beetle outbreak in the late 1970's and 1980's. This insect attack killed a majority of the overstory trees (trees greater than 8 inches DBH). Dense stands of lodgepole pine are developing again in the project area and other areas around the town of La Pine. Without active management, pine beetle outbreaks and/or wildfire may again threaten the area. (Photos of the area are in Appendix H)

PROBLEM STATEMENT

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MANAGEMENT DIRECTION

Guidance for the management of the Masten project area is provided in the Brothers/La Pine Resource Management Plan (July, 1989). Relevant sections include:

Forestland and Woodlands: "…four primary objectives: 1) reduction of extreme fire hazard; 2) salvage of dead and dying timber; 3) successful reforestation and 4) increasing subsequent growth of commercial tree species.

Fire Management: "Aggressive suppression of wildfires will be provided on 506,000 acres (values at risk Classes 4 through 6)." The La Pine area is considered a Class 6, high values at risk.

This guidance from the RMP, along with the guidance from the National Fire Plan and the Central Oregon Fire Management Services' Fire Management Plan all give the direction to provide for protection of areas such as the Masten project in the La Pine community. By cutting, piling/burning and mowing the area or by mechanically masticating the area, each approach will reduce the fire hazard to an acceptable level and maintain or even enhance other environmental resources within the area.

AREA AND RESOURCE DESCRIPTION

Fire Regime

Fire-return intervals in lodgepole pine forests vary. On the western slope of the Cascade Range here in Oregon, stand-replacing fires may occur several hundred years apart. On the eastern slope where drier conditions prevail, like in the La Pine area, such fires may occur at intervals of less than 20 years (Atzet and McCrimmon, 1990). Natural ignitions within the lodgepole stands that result in large fires are relatively rare. There is a higher probability of fire to occur on the west edge of the unit where some old growth pine exists and may carry fire into the thicker stands of lodgepole. Fire exclusion and the mountain pine beetle epidemic have created conditions with more available fuels, increasing the opportunity for natural ignitions to spread in the Masten area. Appendix A has a map of the fire regimes and condition classes that are within the Masten Area.

Fire History

Wildfire protection in the La Pine Management Area is provided by the Deschutes National Forest. In return, the Prineville District, Bureau of Land Management protects the Maury Mountains, which is part of the Ochoco National Forest. Deschutes N. F. has three Ranger Districts and the La Pine Management Area is surrounded by two of them (Bend/Fort Rock and Crescent,). Historical fire data was collected for these Ranger Districts via KCFAST (Historical Fire and Weather internet site from Kansas City) and contained records from 1980 through 2000 (21 years). Data was entered into FIREFAMILY PLUS (USDA Forest Service, 1999) and general fire summary was queried (Appendix E). Also derived from this information were large fire (10+ acres) occurrences in the Bend, Crescent, and Fort Rock Ranger Districts (Appendix E). Table

1 shows the comparison between all fires and large fires. Table 2 shows the percentage of large fire acres by month.

Table 1. All Fires vs. Large Fires

Fire Type	Fires	Avg. Fire/ Yr	Total Acres	Avg. Acres /Yr	Avg. Fire Size	% of Fires in May	% of Fires in June	% of Fires in July	% of Fires in Aug.	% of Fires in Sept.	% of Fires in Oct.
All Fires	2879	131	58116	2767	20.2	6	13	26	31	15	7
Large Fires (10+ Acres)	70	3.3	57383	2733	820	13	6	29	36	8	0

Table 2. Large Fire Acres Burned by Month

	% of Acres May	% of Acres June	% of Acres July	% of Acres August	% of Acres September
Large Fires (10+ Acres)	4	2	8	79	7

Year after year, August poses the biggest wildfire threat, with July being second. The typical fire season runs from June 23 through September for the Central Oregon Fire Management Services (COFMS), which includes the Deschutes N.F., Prineville BLM, and Ochoco N.F. September 23 will be the fire season ending date for fire weather purposes, since this is the latest date of the year that any large fire has been recorded.

Climate

The climate can be described as warm and dry in the summer months and fairly cold and wet in the winter months. Snow pack remains from mid December to March or April. Average maximum temperatures ranges from 73° - 86° F and average minimum temperatures range from 44° - 55° F throughout the summer months. Precipitation averages about 13 inches annually. Peak season for lightning and thunderstorms corresponds with seasonal drying from June through early September. Later in the weather analysis section of the paper there is discussion about the 50^{th}, 90^{th}, and 97^{th} percentile weather. These percentiles can be approximated to seasonal fire behavior nomenclature where 50^{th} percentile equates to "normal condition", 90^{th} percentile equates to "drought conditions" and 97^{th} percentile equates to "severe drought conditions". This percentile weather data will help categorize the type of fire weather we can expect in worse case scenarios.

Soils

The La Pine area consists of sandy, light-colored, well-drained or somewhat excessively drained soils that were derived from pumice. The pumice came from volcanic material that erupted from Mt. Mazama and other former volcanoes (Williams, 1942). The Masten site is a relatively productive lodgepole pine site with high stocking and fast growth rates. Soils within the interior of stringer meadows (two meadows within the Masten area-estimated 20 acres total) are saturated for several months of the year. Impacts are discussed in Appendix G

Fisheries

Deschutes River flows 6 miles NW from the project area and Little Deschutes River, <1 mile NW (See Map in Appendix A) contain fisheries consisting of brown trout, rainbow trout, mountain whitefish, kokanee salmon, coho salmon, sculpin, tui chub and threespined stickelback. The native bull trout disappeared sometime in the 1950 to 1960 period. They were cutoff from spawning and rearing areas by Wickiup Dam, subjected to over fishing, exposed to severe competition from the introduced brown trout, and subjected to serious habitat loss by flow fluctuations. The rainbow trout, whitefish and sculpins are the only three indigenous species. According to Oregon Department of Fish and Wildlife personnel the brown trout population represents the best riverine population in Oregon in terms of numbers of large resident fish. It is one of the better riverine populations in the Pacific Northwest. There are no perennial or intermittent streams in the project area.

Wildlife

Many species of wildlife can be found around the project area especially near the river corridors. These include almost all of the Forest Plan Management Indicator Species (MIS): Peregrine falcon, northern bald eagle, northern goshawk, three-toed woodpecker, American marten, osprey, elk, antelope, and mule deer. Management Indicator Species are important because their populations may be influenced by forest management activities and may serve as population and habitat trend indicators for many other wildlife species that utilize the same habitat types.

The northern bald eagle, a threatened species, is a migrant in the vicinity of the project area. The Peregrine falcon is strictly a winter migrant in the area. Suitable habitat for the northern goshawk and the great gray owl is limited to the mature stand west of the project area and potentially east of Highway 97, adjacent to Long Prairie (refer to Appendix A for local area map or aerial photo map). Other special status species may occur in the project area such as the western big-eared bat, several species of myotis, Lewis' woodpecker, pygmy nuthatch, and black-backed woodpecker.

The meadows in the project area provide important foraging habitat for goshawks and great gray owls. These species prefer to nest in mature stands that are directly adjacent to meadow openings where prey is frequently captured. Currently, encroachment of lodgepole pine reduces the size of the meadow's opening which in turn reduces the number of prey species within the meadows.

The most important wildlife habitat needs in the La Pine area are mule deer migration routes. All but 300 acres of the Masten project fall within this migration route which receives use by approximately 18,000 mule deer as they travel east west between their summer and winter ranges. The La Pine migration route has been impacted by the mountain pine beetle epidemic and subsequent timber harvest. Approximately 60% of the La Pine Management Area, including the project area, were treated with even-aged treatments, leaving large areas deficient in hiding cover. However, the quality and distribution of hiding cover has improved over time. Thick regeneration of lodgepole pine now provides hiding cover in portions of the project area. “Leave areas” from previous timber sales within the La Pine Management Area, including the Masten area, were left untreated to protect raptor’s nests, including red-tailed hawk’s nests. Wildlife surveys will be completed prior to any project implementation to a sure Forest Plan MIS compliance.

Vegetation

The plant community is predominately the lodgepole pine, bitterbrush, Idaho fescue association with the fescue yielding to needlegrass in some areas. This association is considered to be climax over a majority of the La Pine area due to soil and microclimate conditions. Timber stand species composition is pure or nearly pure lodgepole pine with minor inclusions of individual scattered old-growth ponderosa pine and small stands of mixed ponderosa and lodgepole pine. Lodgepole pine, a short-lived species, deteriorates relatively rapidly in pure stands in the absence of fire or fuels management. Within the Masten area, The timber stands consist of a few scattered larger (up to 14 inches DBH) lodgepole pine and dense seedling to pole-sized trees. The larger trees were left to serve as seed trees with the more recent timber harvests. Seedlings and saplings are generally new regeneration, which has occurred since the original harvests. A few sparse ponderosa pine exceeding 30 inches DBH also occur on the west side of the unit. The seedling and sapling component is becoming extremely dense with some areas containing more than 2000 trees per acre. These overstocked stands will decline in vigor within a few years as crown closure occurs. Some crown closure has already occurred in tightly packed stands leaving trees with an average of .3-.4 crown ratio and some trees already dead. As the average DBH (diameter at breast height) of a dense lodgepole pine stand approaches 6-7 inches, trees become increasingly stressed and susceptible to attack by mountain pine beetle. These conditions also increase fire hazards by increasing the amount of dead fuel available between the different strata of the stand, creating an even bigger risk for crown fire potential. For lodgepole pine, a viable stand requires approximatley 130 mature trees per acre for full growth potential and insect/disease resistance (according to District Forester). This will also provide more open spacing between trees creating less potential for crown fire and less risk to the La Pine community.

Two stringer meadows run through the east side of the Masten area (See map #1). The north meadow is approximately 10 acres and the south meadow is approximately 10 acres. These meadows are long and narrow averaging about 100 feet in width. The meadows typically contain saturated soils and standing water in the spring with the outer edges drying out by late summer. Species in the meadows include a variety of grasses, sedges and rushes with lodgepole pine of varying ages within and adjacent to the riparian areas. The lodgepole pine trees are encroaching upon the meadows and are shading out and competing with the native wetland grasses and shrubs.

Based on geographic location, special status plants suspected within the project area include *Astragalus peckii*, *Botrychium pumicola*, and *Carex hystericina*.

Astragalus peckii (Peck's milkvetch) is a Bureau Sensitive species endemic to the area. The nearest known location is 11 miles south of the Masten area. This plant prefers relatively open, flat basins that are characterized by deep, dry, loose Mazama pumice or ash soils. This early-seral, perennial member of the pea family occupies open, sunny sites in a coniferous (lodgepole pine) or shrub (big sagebrush-bitterbrush with western juniper) canopy. Flowering occurs late April through July, with plants identifiable into August. It would not be expected in the meadows planned for treatment. Information is lacking on the effects of thinning on this species, but it apparently can tolerate a significant amount of disturbance. Populations have been found colonizing disturbed sites, such as roadways and powerline corridors.

Botrychium pumicola (pumice grape fern) is a Bureau Sensitive species, which occurs on deep, pumice soils (Mazama pumice) in the La Pine basin and at other scattered locations in south central Oregon, primarily on sites dominated by lodgepole pine. The species, a member of the adder's-tongue family, is also known to grow in alpine pumice barrens and in some cases, sites dominated by ponderosa pine. Relatively inconspicuous, it is threatened by any activity, which would disturb the loose, pumice soils, and may be impacted by the existing forest health problems as related to suppression of natural fire. Deer, elk and rodents lightly browse the plants. In the Prineville District, it is known to be in the general area south and east of La Pine. Small populations were found three miles north and three miles east of the Masten area. It would not be expected in the area planned for treatment. Ground disturbance is generally believed to be detrimental to this species, although plants have been found in areas which have been logged. Research is ongoing to determine the effects of various levels of disturbance on the grape fern.

Carex hystericina (porcupine sedge) is a species that occurs in wet areas, such as springs, seeps, and along stream courses. It is presently listed as Threatened or Endangered in Oregon by the Natural Heritage Data Base, which makes it a BLM Assessment Species. It is known to be located two miles south of the Masten area, in meadows similar to those proposed for treatment. Limited botanical inventory has occurred in the project area, but there was a cursory inventory prior to the timber sales. Based on these inventories and the fact that the forested portion of the project area has been severely disturbed, it is unlikely that the suspected special status plants exist in the project area. It is possible, however, the plant exists in the meadow areas, but they should be undisturbed by any thinning treatment.

Insect and Disease

The mountain pine beetle (Dendroctonus ponderosae) is the most severe insect pest affecting lodgepole pine. Epidemics can kill 33 to 66 percent of large trees in a stand (Heinrichs, 1983). Infestations commonly last 5 to 7 years, and occur in 20- to 40-year cycles (Heinrichs, 1983). Mountain pine beetle outbreaks create a large amount of fuel build-up. Watersheds can release up to 30 percent more water because of the dead trees killed by mountain pine beetle (Heinrichs, 1983)

An outbreak of the mountain pine beetle occurred in the late 1970's and 1980's. Essentially all mature trees (5-11 inches DBH) and large senescent trees (>11 inches) were among the dead and dying. The "growth/stand competition/insect/fire" cycle is how the lodgepole pine is supposed to function in its natural fire regime. Due to the presence of the community, it becomes a wild urban interface concern and management needs to take action. Stand-replacing fires are related to insect attacks, particularly by mountain pine beetle, and declining vigor and high fuel loading in older stands (Heinrichs, 1983) Without active management, there is a high probability that a large outbreak would occur and the potential for large fires grows in accordance with the increase of dead fuels.

In addition to the mountain pine beetle, there are severe infestations of western gall rust, dwarf mistletoe, and pockets of root disease throughout the residual stands. These diseases have the potential to continue spreading into the seedlings and saplings as they emerge in the understory.

Cultural Resources

The Antiquities Act of 1906, the National Historic Preservation Act of 1966 and other federal acts, regulations and an Executive Order require that all Federal land be surveyed for cultural properties prior to any ground disturbing activity. All cultural properties must be evaluated for significance and the State Historic Preservation Office (SHPO) is given the opportunity to review and concur with the agency's findings. Six cultural resource surveys have been completed within the boundaries of the Masten area which accounts for a 100% coverage of the proposed treatment area. Reports for those surveys are on file at the BLM Prineville District Office. During the course of the field surveys, four previously unrecorded historic sites were documented. Cultural materials present at the sites consist primarily of refuse scatters. However, the remnants of small structures or features are also present at three of the historical site locations. Determinations of the historical significance of those sites have been deferred until a later time when a more thorough analysis of the materials can be completed.

Visual Resources

Masten Road, Highway 97, and the east side of the project area are within visual corridors designated in the Brothers/La Pine RMP. The RMP states that activities within the areas of high or sensitive visual quality may be permitted if they would not attract attention or leave long term adverse visual changes on the land.

The forested area around La Pine, including the Masten area, has been severely altered by the mountain pine beetle epidemic and subsequent timber harvests over the last 20 years. The BLM has received many calls and letters over the last several years commenting on the degraded visual character of this and other public lands visible to residents and the traveling public. Some of the impacts to scenic values include: slash piles, landings, roads, skid trails, dead/down/damaged/leaning trees, and the reduction of the large tree component. In addition, increased vehicle access has resulted in illegal dumping and destructible off-road vehicle travel in the area, further impacting visual quality. Local residents, utility companies, and State and County road departments also continue to express concerns regarding hazard trees (ie. Leaners and deteriorating dead trees) along roads, right-of ways, and property boundaries.

Air Quality

Air quality is generally excellent in the project area. The Oregon Department of Environmental Quality (DEQ) indicated Bend (31 miles north of La Pine) the only monitored city in Central Oregon area, exceeded the total suspended particulate standards twice during 1985, the last year this data was obtainable (Johannsen, 1993). Most air quality concerns, then and now, are associated with wood stoves and vehicle emissions.

Bend was added as a "Designated Area" to the Smoke Management Plan in 1987 (Oregon Report of Forestry, 1986). Therefore, no records of smoke intrusion from wildfire or prescribed burning exists.

Concerns regarding the effects of smoke particles generated during wildfire or prescribed fire situations to air quality include visibility in and around the La Pine management area and the small particulate matter (PM 10 and PM 2.5) in smoke which may adversely affect human health.

Current Public Use

Public uses of the Masten area include off-road vehicle travel, deer hunting, walking/hiking, and bicycle riding. Other recreational use such as camping, nature study, horseback riding, and photography may also occur in the area. This area, relatively close to the community of La Pine and thick with lodgepole pine saplings and seedlings, makes it an easy target for illegal dumping.

The Masten area contains the Yager grazing allotment, which is 420 acres with 33 animal units months of forage allocated to livestock. The permittee has chosen not to graze in the last few years.

ALTERNATIVES

Each action alternative to be evaluated is capable of meeting the objective of the project. The No Action Alternative is described in the context of providing baseline information on the affected resources. Further, the No Action alternative provides the base against which to compare the predicted effects of the action alternatives. Table 3 summarizes the potential impacts of the three alternatives. Appendix G shows the impacts in more detail.

Alternative 1- No Action

The No Action Alternative would let the lodgepole seedlings and saplings grow at their natural rate.
No type of maintenance program will be implemented. Ongoing programs such as grazing and protection of resources, including fire suppression, would continue.

Alternative 2- Contract Thin/Pile/Burn Piles/Mow (Map of Alternative 2 in Appendix A)

Treat 80-85% of the Masten project area. Leave 10-15% untreated for natural diversity and wildlife habitat. Treated areas will surround untreated areas to limit the potential damage from wildfire to resources and the community.

1. Within the 80-85% of the area to be treated mechanically thin 95% of the natural regeneration and residual pole-sized trees. Approximately 1400 acres would be thinned to an average of 130 trees per acre. This was based on the fire behavior objective (flame lengths of less than four feet and eliminate the probability of an active crown fire at 97^{th} percentile weather). Secondly, 130 trees/acre provides the best viable stand growth according to the District Forester. This takes into account a few extra leave trees, in case of incidental mortality during operations or pile burning. Spacing would be 18 x 18 feet with a 50 percent variance (for a range of 9 to 27 feet) to allow for selection of the best available leave trees and to provide for a more irregular stand. Larger lodgepole pine and all ponderosa pine would be left to emphasize the natural spacing in the large tree component in the stand. Slash will be grapple piled away from leave trees, and most piles (existing and new) will be burned in late fall or winter after needles have cured. Around 10% of the piles will remain evenly distributed throughout the project area for wildlife habitat. If a market for the slash piles develops, then piles will be utilized instead of burned.

2. Treat wet meadows (an estimated 20 acres). Thinning with chainsaw or any small rotary saw would be used to reduce the competition from lodgepole pine in portions of the two meadows within the project area. Portions of the fringe area would be thinned to maintain or promote the development of large tree habitat. Hand piling will only be used in the meadows. Heavy machinery will not be used in order to alleviate any damage to the soft, susceptible soils.

3. Mow areas with dense brush and/or lodgepole pine reproduction in high-risk areas along Highway 97, Masten Road, Sixth Street, and adjacent residential areas. Treatment areas would vary in width according to brush density and proximity to roads and homes, but would be no wider than 300 feet. Total mowing area would be approximately 250 acres.

4. Maintenance entries such as thinning or mowing will take place approximately every 15 years (thinning), while high-risk areas will be evaluated every five years for possible mowing needs. It will be assumed for economical purposes that mowing will occur every five years.

5. Close and rehabilitate unneeded roads. Barricading and/or disguising with existing slash would close approximately four miles of existing logging roads.

Alternative 3- Contract Mechanical Mastication System (Map of Alternative 3 in Appendix A)

Treat 80-85% of the Masten project area. Leave 10-15% untreated for natural diversity and resource benefits. Treated areas will surround untreated areas to limit there potential for damage to resources and the community.

1. Mechanically thin by mastication methods 95% of the natural regeneration and residual pole-sized trees. Masticate 90% of the existing machine piles leaving 10% evenly distributed throughout the project area for wildlife habitat. Same stand prescription and reasoning as Alternative 2. This meets fire behavior limits in the objective and provides for the most viable stand growth. If a market for the existing slash piles becomes economical, then piles will be utilized instead of burned.

2. Mechanically masticate areas including the brush component and/or lodgepole pine reproduction in high-risk areas along Highway 97, Masten Road, Sixth Street, and adjacent residential areas.

3. Treat wet meadows. Same treatment as alternative 2, since mastication machinery could damage soft, susceptible soils.

4. Maintenance thinning around high-risk areas will occur approximately every 5 years, and maintenance thinning of the interior of the project area will occur approximately every 15 years.

5. Close and rehabilitate unneeded roads. Barricading by falling whole trees and/or disguising with mulched material would help disguise approximately four miles of existing logging roads.

PRESCRIBED BURNING ALTERNATIVE- REASONS NOT EVALUATED

Prescribed burning the Masten area was an alternative considered by management but was dropped for further analysis due to these concerns:

1. Lodgepole pine's thin bark and shallow roots make it susceptible to fire damage. The project objective is not to kill all lodgepole in the area. "Fire only" would be a difficult tool to gain the desired spacing and character of the post-treatment stand.

2. Conditions in which prescribed fire would carry successfully are quite warm and dry. Control and safe operations under these conditions would be difficult, and the prescription window would be very narrow

3. The goal of the project, "protect the La Pine urban interface community and promote healthy fire and insect/disease resistant forest stands" would be compromised due to the warm and dry conditions under which it would have to be burned. In addition, smoke management issues, including air quality and visibility, in the La Pine area and along Highway 97 corridor are some of management's major concerns.

Table 3. Summary Comparison of Alternatives, Impacts on Resources. *Indicates best alternative

Resources Impacted	Alternative 1 No Action	Alternative 2 Thin/Pile/Burn Piles/Mow	Alternative 3 Masticate
Soils	Continued off-road vehicle traffic	Minor Impacts	*Beneficial Impacts
Fisheries	Over time, site will retain more water and less water into the streams. Low impact	No Impact	*No Impact
Wildlife	Long term impacts some good some bad- depends on species. Cover is good, but forage will eventually decrease.	*Beneficial impacts Creates a more diverse stand	Should be beneficial with increased nutrients to the soil for forage Creates a more diverse stand
Vegetation	High negative Impacts. Hazardous to the community	*Highly Beneficial Impacts. Provides "Defensible Space"	Beneficial Impact. Provides "Defensible Space"
Insects and Disease	Long term major negative impacts	*Effective in reducing stressed trees	Effective in reducing stressed trees
Cultural Resources	*No Impacts	No Impacts on recorded sites	No Impacts on recorded sites
Visual Resources	Eye-sore to the community	*Reduces illegal dumping	*Reduces illegal dumping
Air Quality	More smoke created during wildfires due to higher rate of spread and higher flame lengths	Will have impacts due to pile burning, but not beyond what is allowable by Oregon Dept. of Forestry.	*No impacts
Current Public Use	No roads closed = More places for illegal dumping	*Close unneeded roads reduces dumping and off-road driving	*Close unneeded roads reduces dumping and off-road driving
Social/Economic	Negative Impacts	*Beneficial	Beneficial

METHODOLOGY AND QUANTIFICATION OF EXISTING CONDITION

Stand Inventory

In order to understand the stand condition within the 1740-acre Masten project, a stand exam was conducted using the Forest Survey Handbook (USDI BLM, 1995). A statistical analysis was completed to determine the proper number of sample points needed to determine tree densities and fuel loading. The formula that was used for this is:

$$n = \frac{1}{4}\left(\frac{Za/2}{E}\right)^2$$

Where: n = required number of plots.

$za/2$ = number of standard errors associated with a specified probability.

E = percent error.

A determination can be made as to the sample size required. A 20% error will satisfy management due to the type and quality of the resources that are present in the La Pine Resource Management Plan area. Management wants to be able to assert with a probability of at least .95 that the error will not exceed 20%. Substituting: $za/2$ is .95 = 1.96, E = .20:

$$n = \frac{1}{4}\left(\frac{1.96}{.20}\right)^2 = 24\ samples$$

This means twenty-four inventory plots should be sufficient (if the distribution is normal) to determine fuel loading with a probability of at least .95 that the error will not exceed 20%.

In order to use a plot size that most efficiently samples the overstory, poles and saplings, seedlings, and other vegetation, a plot radius of 7.4 feet (1/250 acre) was used to compensate for the expected high tree count per plot. The plot distribution fell on a systematic grid, with a totally random beginning point, in order to determine the stand condition (Appendix A: Sample Plot Map). The information that was gathered from each plot was based on the data requirements to run a model in FMA Plus: CrownMass. This included: diameter breast height (DBH), species, height, crown ratio, trees per acre, structural stage and proportion of 1, 10, 100, and 1000 hr fuels in the crown. Table 4 shows the CrownMass results of the stand samples (Appendix B has the entire plot data)

Even though the statistical analysis of the sample size was 24, the results of the percent error were outside of the .95 probability that the error would not exceed 20%. This is likely a result of the two timber harvests that were conducted in 1988 and 1989. It was determined that foregoing any more plots would be prudent due to the onset of winter storms and snow.

Calculating stand inventory was determined using CrownMass for Alternative 2 and Alternative 3.

Alternative 2- Mechanically thins 95% of the natural regeneration and residual pole-sized trees. Approximately 1400 acres would be thinned to an average of 130 trees per acre. This was based on the fire behavior objective (flame lengths of less than four feet and reduced probability of an active crown fire at 97^{th} percentile weather). Secondly, 130 trees/acre provides the best opportunity for viable stand growth according to our District Forester, as well as a lower density for fire protection. This takes into account a few extra leave trees (See 2.4.4 Vegetation), in case of mortality during operations or pile burning. Spacing would be 18 x 18 feet with a 50 percent variance (for a range of 9 to 27 feet) to allow for selection of the best available leave trees and to provide for a more irregular stand.

Since the goal of the project is to protect the residential areas and roads in the community, the focus will be on the perimeters where flame lengths need to be below 4 feet and crown potential at zero. Therefore, the stand inventory takes into account thinning, piling, burning and mowing. In CrownMass, the only way to cut trees and pile without depositing any fuels to the surface is to eliminate them from the inventory. So 95% of the lodgepole pine trees were taken out of the inventory (represents piling), leaving 130 trees per acre by plot plus all ponderosa pine. The crown fuel load results for Alternative 2 are in Table 5 (Appendix B has complete data by plot). These fuel loadings do not consider the brush and grass components, so those fuel types were added to the fuel load.

Alternative 3- The same prescription as in Alternative 2 applies to this alternative except that there will be fuel from the crown layer added to the dead and down woody fuels. Therefore, all the fuel masticated will be deposited to the surface creating a higher fuel load then the other two alternatives.

Once again, since the goal of the project is to protect the residential areas and roads in the community, the focus will be on the perimeters where the brush is also masticated. CrownMass has the capability to simulate cutting a proportion of trees and depositing on the surface. The results of masticating 95% of the lodgepole pine stand are in Table 6 (Appendix B has complete data by plot).

Also, crown fuel characteristics (calculated by CrownMass) of each alternative are in Table 7 as well as in Appendix F on next page.

Table 4. Alternative 1 – No Action - CrownMass - Fuel Loading Outputs Report (only SD and % error for the actual inventoried plots)

Attribute	Foliage	1 Hour	10 Hour	100 Hour	1000 Hour	Total
Total Crown Fuel Loading (Tons/Ac)	**1.72**	**0.63**	**1.70**	**1.20**	**0.50**	**5.76**
Standard Deviation	3.57	1.01	5.61	5.79	2.47	N/A
Percent Error	42.33	32.8	67.17	98.61	100	N/A

Table 5. Alternative 2 – Thin/Pile - CrownMass - Fuel Loading Outputs Report

Attribute	Foliage	1 Hour	10 Hour	100 Hour	1000 Hour	Total
Total Crown Fuel Loading (Tons/Ac)	**0.81**	**0.13**	**1.13**	**1.02**	**0.50**	**3.60**

Table 6. Alternative 3 – Masticate - CrownMass - Fuel Loading Outputs Report

Attribute	Foliage	1 Hour	10 Hour	100 Hour	1000 Hour	Total
Crown Fuel Loading	0.82	0.13	1.13	1.02	0.50	3.60
Crowns Deposited to the Surface	0.90	0.71	0.49	0.00	0.00	2.11
Unmerchantable tops	0.00	0.00	0.15	2.16	0.13	2.44
Total Crown Fuel Loading (Tons/Ac)	**1.72**	**0.84**	**1.78**	**3.18**	**0.63**	**8.15**

Table 7. Crown Fuel Characteristics of each Alternative

Attributes	Alternative 1 No Action	Alternative 2 Thin/Pile	Alternative 3 Masticate
Canopy Base Height (ft)	1	1	1
Basal Area	41.50	22.7	22.8
Canopy Fuel Loading for Crowning (lbs)	2.03	0.88	0.88
Canopy Bulk Density Method: Maximum Canopy	0.01010	0.00170	0.00180

Assumptions:

1) Canopy Base Height is defined as the height above the ground of the first canopy layer where the density of the crown mass within the layer is high enough to support vertical movement of a fire. The canopy base heights that CrownMass had given did not take into account that the leave trees in Alternative 2 and 3 were to be the healthiest trees with the greatest crown ratio, hence, a canopy base height of 1 foot.
2) Alternative 1 was lowered from a 2 foot CBH to a 1 foot CBH because ocular estimates throughout the project area indicate a lower average than what CrownMass derived from the sample plot inventory.
3) Current assumptions (Reinhardt et. al. 2000) are that the needle fuel loading and 50% of the 1-hour timelag crown fuel loading contribute to the flaming portion of crown fire. The proportion of the 1-hour timelag crown fuel loading that contributes to the flaming portion of crown fire can be set here. The program default is 0.50. The sum of the needle fuel loading and the assumed proportion of 1-hour timelag fuel loading will be referred to as the crowning assessment canopy fuel (CACF). This is why alternative 3 has a higher crown loading than Alternative 1.

Fuel Inventory

A fuel inventory was conducted to determine the amount of dead and down woody (DDWoody) debris that was present in the stand. The same 24 sample plots used in the stand inventory served as fuels inventory plots. The points were located at fixed intervals along two transects (10 chains apart) that lace regularly across the sample area in a uniform sampling grid). The transect's starting point was random, and followed an azimuth of 150°. There was a distance of 5 chains between plots determined by pacing. Table 8 displays the sampling plane lengths used at each plot.

Table 8. Sample Plan Lengths

	Diameter of Dead Down Woody Material		
Downed Material	0”-0.24” & 0.25”-0.99”	1”-2.99”	3”+
Discontinuous Light Slash	6 feet	12 feet	50 feet

Sampling plane lengths were based on discontinuous light slash and the material larger than 3 inches in diameter was scanty and unevenly distributed, requiring a longer sample plane. Each plot consisted of the following measurements: slope, fuel bed depth (3 locations), duff depth (2 locations), particle counts (0-.24”, .25”-.99” and 1”-2.99”), and 3”+ material by species count. Table 9 displays the dead and down woody fuel inventory.

Table 9. Dead and Down Woody Inventory

Attribute	**Mean (Tons/Acre)**	**% Error**
0”-.24”	0.65	12.42
.25”-.99”	2.78	23.55
1”-2.99”	3.70	15.13
3”+	3.40	21.79
Needles	0.00	0.00
Total <3”	7.12	14.41
Total	10.52	12.08
Avg. Duff Depth Inches	0.77	24.68
Avg. Fuelbed Depth Inches	2.14	16.91

Assumptions:

1) Slash piles are not taken into consideration in the DDWoody inventory since they are isolated piles and would not predict accurate fire behavior.
2) Needles have no tons/acre because of the age of the slash (over 14 years the needles have decomposed) and the young trees on site are still small. Over time, the needle tons/acre will increase and add to the fuel load.
3) Representative fuel models to the alternatives in CrownMass are slash models with no needle fuel loading as well.

The error of the 10-hour fuels and 1000-hour fuels are above 20 percent, which means there was a high variability between plots. This can be attributed, as in the stand inventory, to the timber sale activities in 1988 and 1989. However, the fuels measurements proceeded as planned for these reasons: 1) Both size classes in question were less than 4 percent of being within the desired twenty percent error. This is still an acceptable range for the purposes of this project; 2) The percent error from all fuels less than 3 inches and total fuels was 14.41% and 12.08%, respectively (well under the acceptable percent error); and 3) the time involved in putting in more plots, because of the variability relative to the statistical gain, was not prudent from a time management standpoint. Furthermore, the primary and intended use of the data was to select a fuel model out of CrownMass that best represents this project area.

The DDWoodyPC inventory results are the same for each of the three alternatives. Fire behavior results are based on the combination of the DDWoodyPC and the stand inventories for each alternative in 3.1.4 Fire Behavior Modeling.

Weather Analysis

Historical weather data was collected from the Lava Butte Weather Station (352618) via KCFAST and contained records from 1987 through 2000 (14 years). This station is approximately 20 miles NW of the project site and best represents the area's weather conditions.

Data was entered into FIREFAMILY PLUS (USDI BLM, 1999) and the typical fire season was defined as June 23 – September 23 (Stated in 2.1.2 Fire History). Modeling was then run for 50th, 90th, and 97th percentile day weather observations. As stated in the "climate" section, these percentiles can be approximated to seasonal fire behavior nomenclature where 50th percentile equates to "normal condition", 90th percentile equates to "drought conditions" and 97% percentile equates to "severe drought conditions". This nomenclature will be used throughout the remainder of the paper. Table 10 expresses percentile weather output from FIREFAMILY PLUS labeled as fire behavior condition and total results are in Appendix D.

Given an understanding of the weather conditions most likely to occur in the project area, it is possible to further interpret fire behavior and subsequent fire effects for each of the three alternatives.

Table 10. Seasonal (June 23 – September 23) Fire Behavior Condition Weather for Lava Butte Weather Station 352618

Attribute	Normal Condition	Drought Condition	Severe Drought Condition
1 Hour Fuel Moisture	4.9	3.0	2.5
10 Hour Fuel Moisture	7.0	4.1	3.3
100 Hour Fuel Moisture	10.0	6.9	5.9
20 Foot Winds	5	11	14
Effective Wind Speed	2.5	5.5	7
Herbaceous Fuel Moisture	63.1	39.4	35.0
Woody Fuel Moisture	91.2	67.4	61.8
Dry Bulb Temperature	75	86	90
Foliar Moisture Content	90	65	60

Assumptions

1) Foliar Moisture Content could only be entered into CrownMass in increments of five and is based off of the Woody Fuel Moisture.

Fire Behavior Modeling

The canopy bulk density and canopy base height characteristics coupled with identification of the surface fuel profile, topographic and environmental information can allow for the estimation of fire behavior and fire effects. CrownMass contains algorithms to display the fire behavior and fire effects values based on the work of Alexander (1988), Ryan and Reinhardt (1988), Beukema et al. (1999) Rothermel (1972), Andrews (1986), Andrews (1989) and Finney (1998). CrownMass uses the same equations and processes as BEHAVE (Andrews 1986, 1989; Rothermel 1972; Albini 1976) and BehavePlus to calculate: surface rate of spread, surface flame length, and surface fireline intensity.

The CrownMass program contains 109 fuel models that the user can select from to characterize the surface fuel profile. The Fuel Model Selection Assistant is designed to aid the user in selecting the most appropriate fuel model to represent the surface fuel profile in the fire behavior assessment. Table 11 shows the actual fuel loadings of each alternative along with the representative fuel models with their fuel loadings (Also in Appendix F).

CrownMass does not take into account the brush and grass component that is in the understory. The representative fuel model for alternative one reflects the additional fuel loads that are present. The representative fuel model for Alternative 2 is the best fit for three reasons; 1) the increase in grass, a 1 hour fuel load, that exists when lodgepole pine are thinned is represented; 2) pre-thinning 10 and 100 hour fuels may be added to the

Table 11. Alternatives' Surface Fuel Loadings and Representative Fuel Models' (RFM) Surface Fuel Loadings.

Attribute	Total Loading w/ Needles	Total Loading w/o Needles	Fuelbed bulk Depth (ft)	Needles	1 Hour	10 Hour	100 Hour
Alternative 1 - No Action Total Surface Fuel	7.13	7.13	0.90	0.00	0.65	2.78	3.70
RFM: 11DC-Light slash-FBPS-D-High Depth	8.99	1.02	1.17	0.00	1.17	3.52	4.30
Alternative 2 - Thin/Pile Total Surface Fuel	7.13	7.13	0.90	0.00	0.65	2.78	3.70
RFM: 11CA -Light slash-Low-C-Low Depth	0.00	6.50	0.39	0.00	.85	2.54	3.11
Alternative 3 - Masticate Total Surface Fuel	11.68	10.65	1.00	0.90	1.36	3.43	5.86
RFM: 11MA-Light slash-FBPS-M-Low Depth	0.00	11.52	0.70	0.00	1.50	4.51	5.51

piles reducing their fuel loads; and 3) fuel depth of 0.39 is more realistic than 0.90 since hardly any fuel will be added to the existing 0.20 fuel depth. The representative fuel model for Alternative 3 had the lowest weight percentage difference of all the fuel models provided. Fuel loadings were a little high but this fuel model does show that the 1 and 10 hour fuels will increase due to the mastication of some of the larger fuels. Given the weather analysis, the fire behavior surface models of each alternative and the crown inventory of each alternative, three modeling runs were made with each alternative using CrownMass. Table 12, 13, and 14 express the fire behavior output of CrownMass and is also included in Appendix F.

Alternatives 2 and Alternative 3 reduce the fire behavior to below 4-foot flame lengths, which meets the flame length portion of the objective of the project. Notice that without management action, flame lengths are above 4 feet in drought and severe drought conditions and rate of spread in severe drought conditions are over three times faster than Alternative 1 and almost twice as fast as Alternative 3.

Table 12. Alternative 1- No Action. Fire Behavior outputs from Fuels Management Analysis Plus: Crown Mass.

Attribute	Normal Condition	Drought Condition	Severe Drought Condition
Rate of Spread (Ch/Hr)	3.5	9.6	12.7
Flame Length (Ft) - Surface	2.5	4.2	4.8
Fireline Intensity (BTU/Ft/Sec)	41	126	171
Midflame Wind Speed (Mph)	3	6	7

Table 13. Alternative 2- Thin/Pile. Fire Behavior outputs from Fuels Management Analysis Plus: Crown Mass.

Attribute	Normal Condition	Drought Condition	Severe Drought Condition
Rate of Spread (Ch/Hr)	1.1	2.9	3.8
Flame Length (Ft) - Surface	1.1	1.9	2.1
Fireline Intensity (BTU/Ft/Sec)	7	22	30
Midflame Wind Speed (Mph)	3	6	7

Table 14. Alternative 3- Masticate. Fire Behavior outputs from Fuels Management Analysis Plus: Crown Mass.

Attribute	Normal Condition	Drought Condition	Severe Drought Condition
Rate of Spread (Ch/Hr)	2.0	5.2	6.9
Flame Length (Ft) - Surface	1.9	3.2	3.7
Fireline Intensity (BTU/Ft/Sec)	24	71	96
Midflame Wind Speed (Mph)	3	6	7

Assumptions:

1) A .5 wind reduction factor was used to model unsheltered fuel and sparse overstory.
2) Weather analysis was performed for dates June 23 – September 23, which define the fire season in the La Pine Resource Management Area.
3) Variable required weather input for FMA Plus: Crown Mass was determined by requesting frequency distribution reports from FIREFAMILY PLUS. This best described the "worst case" scenario.
4) The fire model describes fire behavior in the flaming front.
5) Primary carrier of the fire is the dead fuel less than one-quarter inch diameter (1 hour fuels).
6) The fire model assumes continuous fuel bed with fire advancing steadily, from a point, independent of the source of ignition.
7) Fuel, moisture, wind and slope are assumed to be constant during the time that the predictions are to be applied (Andrews, 1986)
8) Fire Behavior results for Alternatives 2 and 3 are based on the high-risk area fuel loadings after treatments. This includes mowing in Alternative 2 and masticating the brush layer in Alternative 3.
9) Weighing factors for suggesting fuel models in FMA Plus: Crown Mass: depth=.0, 1 hour=.1, Small (0-3)=.9.
10) The best representative fuel models for each alternative were:
    Alternative 1-11DC- Light Slash – FBPS-D-High Depth (28% Weight percent difference)
    Alternative 2- 11CA - Light Slash – Low-C-Low Depth (11% Weight percent difference)
    Alternative 3- 11MA- Light Slash – FBPS-M-Low Depth (8% Weight percent difference)

Crown Fire Potential

Van Wagner (1977, 1993) determined a threshold for transition from surface to crown fire. This threshold is defined as the critical fireline intensity, $I_{Critical}$, based on the independent variables crown base height (CBH) and the crown foliar moisture content (M)(FMAPlus, 1998).

Figure 1. Van Wagner's Crown Fire Initiation Model.

$$I_{Critical} = (0.010*CBH*(460+25.9))^{3/2}$$

Alexander (1988) described the relationship as:

$$I_{Critical} = (.003096*CBH*(197.50+11.186*M))^{1.5}$$

Where:

$I_{Critical}$ = Critical fireline intensity in BTU/foot of fire front/second.
CBH = Crown base height in feet.
M = Foliar moisture content in percent (oven dry weight).

An integral measurement used to understand whether fire might transition into the crown is the height-to live crown from the surface. CrownMass indicated an average of 1 foot crown height from surface to be present based on the stand inventory. By incorporating the inputs from crown base height along with the foliar moisture content from Table 7, critical fireline intensities ($I_{Critical}$) can be determined. Those computations are as follows:

Normal Conditions M = 90% and CBH = 1 ft

$$I_{Critical} = (.003096*CBH*(197.50+11.186*M))^{1.5}$$
$$I_{Critical} = (.003096*1*(197.50+11.186*90))^{1.5}$$
$$I_{Critical} = 7.2 \text{ BTU/ft/sec}$$

Drought Condition M = 65% and CBH = 1 ft

$$I_{Critical} = (.003096*CBH*(197.50+11.186*M))^{1.5}$$
$$I_{Critical} = (.003096*1*(197.50+11.186*65))^{1.5}$$
$$I_{Critical} = 4.8 \text{ BTU/ft/sec}$$

Severe Drought Condition M = 60% and CBH = 1 ft

$$I_{Critical} = (.003096*CBH*(197.50+11.186*M))^{1.5}$$
$$I_{Critical} = (.003096*1*(197.50+11.186*60))^{1.5}$$
$$I_{Critical} = 4.4 \text{ BTU/ft/sec}$$

Fire transition into the crown can be determined if $I_{Surface}>I_{Critical}$. Table 15, 16, and 17 compares $I_{Surface}$ from Table 9, 10, and 11 (Fire Behavior outputs from Fuels Management Analysis Plus: Crown Mass) with newly calculated $I_{Critical}$ values.

Table 15. Alternative 1 – No Action. Potential Surface Intensities vs. Critical Intensities

Attribute	Normal Condition	Drought Condition	Severe Drought Condition
$I_{Surface}$	41	126	171
$I_{Critical}$	7	5	4
Fire Result	Crown Fire	Crown Fire	Crown Fire

Table 16. Alternative 2 – Thin/Pile. Potential Surface Intensities vs. Critical Intensities

Attribute	Normal Condition	Drought Condition	Severe Drought Condition
$I_{Surface}$	7	22	30
$I_{Critical}$	7	5	4
Fire Result	Surface	Crown Fire	Crown Fire

Table 17. Alternative 3 – Masticate. Potential Surface Intensities vs. Critical Intensities

Attribute	Normal Condition	Drought Condition	Severe Drought Condition
$I_{Surface}$	24	71	96
$I_{Critical}$	7	5	4
Fire Result	Crown Fire	Crown Fire	Crown Fire

It is shown in the tables above that in all conditions, except in normal conditions in Alternative 2, that $I_{Surface}>I_{Critical}$, therefore, transition of fire to the crown is assured in almost all conditions, but to what extent. Leave trees will still initiate crown fire, under all alternatives, but because tree density for Alternative 2 and 3 are so low this will be isolated torching (passive) not active.

This transition into the crown can be characterized as passive, active, or independent crown fire and may transition rapidly from passive to active to independent, or may remain in the passive or active stages without ever reaching the independent stage. The stages can be described as follows:

Surface Fire- A surface fire is one that burns only in the surface fuelbed.

Passive Crown Fire- A passive crown fire is traditionally called "torching." It is small scale, consuming single or small groups of trees or bushes. This stage of a crown fire reinforces the spread of the fire, but the main fire spread is still dependent upon surface fire behavior.

Occurs when $I_{Surface} > I_{Critical}$ and ROSCrown<RAC

Active Crown Fire- An active crown fire is associated with a "pulsing" spread. The surface fire ignites crowns and the fire spreads is able to propagate through the canopy. After a distance, the crown fire weakens due to a lack of reinforcing surface fire heat. When the surface fire catches up to where the crown fire died, the surface fire intensity again initiates a crown fire "pulse."
Occurs when $I_{Surface} > I_{Critical}$ and ROSCrown>RAC

There is a fourth type defined but it is not predicted by CrownMass. An independent crown fire can occur when conditions are such that fire will run through the crowns without support from an intense surface fire. The crown fire may race far ahead of surface fire spread. Van Wagner (1993) suggests these are very uncommon and short-lived.
Occurs when $I_{Surface} > I_{Critical}$ and ROSCrown>RAC, and when the actual energy flux is greater than the critical energy flux in the advancing direction if the fire.

Rate for Active Crowning (RAC)- The type of crown fire (Passive or Active) depends on the threshold for the "active fire spread rate" (Van Wagner, 1993):

RAC = 0.55861 / CBD

Where: RAC = Rate for active crowning (Ch/Hr)
CBD = Canopy Bulk Density (lbs/ft3)

Crown Rate of Spread (ROSCrown)- Van Wagner (1993) indicates that the actual active crown fire spread rate is:

ROSCrown = RSurface + CFB*(ROSMax Crown - RSurface)

Where: RSurface = the surface fire spread rate
CFB = Crown Fraction Burned
ROSMax Crown = Maximum crown fire rate of spread

Table 18, 19, and 20 display the fire behavior outputs of each alternative derived from CrownMass (Also included in Appendix F). **Alternatives 2 and Alternative 3 eliminate the probability of an active crown fire at 97th percentile weather (severe drought condition), which meets the crown fire probability objective of the project.** Notice that without management action, an active crown fire is present in severe drought conditions. The overall rate of spread in severe drought conditions is over 15 times faster than Alternative 1 and over 8 times faster than Alternative 3 under the same weather conditions. When comparing fire size after just one hour in severe drought conditions, Alternative 1 is over 101 acres, Alternative 2 is a mere 0.44 of an acre, and Alternative 3 is 1.46 acres.

Table 18. Alternative 1- No Action. Crown Fire Behavior outputs from Fuels Management Analysis Plus: Crown Mass.

Attribute	Normal Condition	Drought Condition	Severe Drought Condition
Crown Rate of Spread$_{average}$ (Ch/Hr)	8.1	38.3	57.5
Crown Rate of Spread$_{maximum}$ (Ch/Hr)	12.7	41.8	59.9
Rate for Active Crowning (Ch/Hr)	55.3	55.3	55.3
Overall Fire Rate of Spread (Ch/Hr)	3.5	9.6	57.5
Crown Fraction Burned	0.50	0.89	0.95
Elapsed Time (Hr)	1	1	1
Fire Size$_{elliptical}$ (Acres)	0.74	3.35	101.24
Fire Type	Passive Crown Fire	Passive Crown Fire	**Active Crown Fire**

Table 19. Alternative 2- Thin/Pile. Crown Fire Behavior outputs from Fuels Management Analysis Plus: Crown Mass.

Attribute	Normal Condition	Drought Condition	Severe Drought Condition
Crown Rate of Spread$_{average}$ (Ch/Hr)	1.1	19.2	34.1
Crown Rate of Spread$_{maximum}$ (Ch/Hr)	12.7	41.8	59.9
Rate for Active Crowning (Ch/Hr)	328.6	328.6	328.6
Overall Fire Rate of Spread (Ch/Hr)	1.1	2.9	3.8
Crown Fraction Burned	0.00	0.42	0.54
Elapsed Time (Hr)	1	1	1
Fire Size$_{elliptical}$ (Acres)	0.07	0.31	0.44
Fire Type	Surface Fire	Passive Crown Fire	Passive Crown Fire

Table 20. Alternative 3- Masticate. Crown Fire Behavior outputs from Fuels Management Analysis Plus: Crown Mass.

Attribute	Normal Condition	Drought Condition	Severe Drought Condition
Crown Rate of Spread$_{average}$ (Ch/Hr)	5.0	30.1	48.8
Crown Rate of Spread$_{maximum}$ (Ch/Hr)	12.7	41.8	59.9
Rate for Active Crowning (Ch/Hr)	310.3	310.3	310.3
Overall Fire Rate of Spread (Ch/Hr)	2.0	5.2	6.9
Crown Fraction Burned	0.28	0.68	0.79
Elapsed Time (Hr)	1	1	1
Fire Size$_{elliptical}$ (Acres)	.24	.98	1.46
Fire Type	Passive Crown Fire	Passive Crown Fire	Passive Crown Fire

Assumptions

1) The crown fire rate of spread calculation developed by Rothermel (1991) was done using data from fires that burned in Northern Rocky Mountains. Care should be given when applying this value to other areas.
2) Structural stage adjustments: dominant = 1.0; co-dominant = 0.8; intermediate = 0.6; suppressed = 0.4
3) Crown fire factors include: running mean window of 9 ft.; 1 hour contribution to crown fire is 0.50; critical canopy bulk density is .0023 lbs/ft^3

Fire Effects

CrownMass calculated the fire effects for the normal, drought, and severe drought seasonal fire behavior conditions for each alternative. Table 21 shows the fraction of crown burned, crown scorch height, mean crown scorch (%), and probability of mortality (%). Appendix F shows complete results.

Table 21. Fire Effects from Each Alternative

Attribute	Crown Fraction Burned	Crown Scorch Height	Mean Crown Scorch %	Prob. of Mortality %
Alternative 1 – Normal Condition (50%)	0.50	9.8	99%	100%
Alternative 1 – Drought Condition (90%)	0.89	19.3	99%	100%
Alternative 1 – Severe Drought Condition (97%)	0.95	22.4	99%	100%
Alternative 2 – Normal Condition (50%)	0.00	2.1	33%	85%
Alternative 2 – Drought Condition (90%)	0.42	3.1	56%	89%
Alternative 2 – Severe Drought Condition (97%)	0.54	3.4	63%	90%
Alternative 3 – Normal Condition (50%)	0.28	6.2	84%	93%
Alternative 3 – Drought Condition (90%)	0.68	10.9	90%	95%
Alternative 3 – Severe Drought Condition (97%)	0.79	12.3	91%	95%

The statistics confirm that lodgepole pine is susceptible to fire. But by providing a more viable stand the probability of mortality decreases. Even in severe drought conditions, Alternative 2 has a higher tolerance to fire than in normal conditions for Alternative 1 and 3. As the leave trees grow over time in Alternative 2 and 3, their resilience to fire will increase. In alternative 1, the crown scorch heights are extremely high in drought and severe drought conditions that no tree less than 23 feet will survive a fire. It is going to take existing 10-foot trees 10-12 years to even reach those heights if not suppressed first by over crowding. (Volland, 1976)

Conclusion of Hazard Assessment

Without management action, flame lengths are above 4 feet in drought and severe drought conditions and rate of spread in severe drought conditions are over three times faster than Alternative 2 and almost twice as fast as Alternative 3. Contrarily, Alternatives 2 and Alternative 3 reduce the fire behavior to below 4-foot flame lengths, which meets the flame length portion of the objective of the project.

Without management action, an active crown fire can be expected in severe drought conditions (97% weather). Alternative 2 and Alternative 3 eliminate the probability of an active crown fire at 97^{th} percentile weather (severe drought condition), which meets the crown fire probability objective of the project.

METHODOLOGY AND QUANTIFICATION OF RISK ANALYSIS

To determine the probability of an unplanned ignition that results in an active crown fire occurring in the Masten project area two steps had to occur. The first step was to determine the annual fire frequency for the project area. The second step was to determine the probability of fire occurrence over a thirty year planning horizon.

Annual Fire Frequency (Step One)

To start to determine the annual fire frequency for the project area, data stored in the in the Geographical Information System (GIS) was used to locate the fire starts, as points, and to find the fire sizes within the La Pine Resource Management Plan area. Next, the number of fires in each size class was then divided by 12 (recorded years of fire history in GIS) to determine the annual fire frequency. To determine the number of fires in the Masten project area the formula for the expected value was used (Figure 2). Masten's annual fire frequency is displayed in Table 23.

Figure 2. Expected Value

Expected Value = sum {x * *f* (x)}

Where:

E.V. = expected number of fires in project area

x = number of fires during the year

f (x) = probability of a fire occurring

Table 22 shows the conversion of fire size classes into Fire Intensity Levels (FIL) in addition to the associated flame lengths of the FILs as used by NFMAS. For the remainder of this risk analysis, FILs will be used to describe fire class sizes and flame lengths. Table 23 shows the annual fire frequency based on FILs within the Masten project area.

Since Alternative 1, under severe drought conditions, produces a 101.24 acre active crown fire after 1 hour (Table 18) it will be assumed that a FIL4 (100-299 acres) fire will be an active crown fire.

Table 22. NFMAS Fire Intensity Level Associations

Fire Intensity Level (FIL)	Associated Fire Size Class	Associated Fire Size (Acres)	Associated Flame Lengths
1	A	0.0 - .25	0-2
2	B	.25 - 9.9	2-3
3	C	10 - 99.9	3-4
4	D	100 - 299.9	4-8

Table 23. Fires in the Masten Project Boundary

Fire Intensity Level	Fire Size Classes	Number of Fires	Total Acreage Burned	Annual Fire Frequency
1	A	2	.2	.167
2	B	.75	2.7	.06
3	C	.33	11.53	.03
4	D	.12	63.98	.01
Totals	All	3.20	78.41	.267

Probability of Fire Occurrence (Step Two)

To determine the probability of an unplanned ignition in the analysis area, the program PROBACRE, a computer program to assess the risk of cumulative burned acreage, was applied. The program makes probability estimates based on the Poisson probability model (Figure 3) to determine output. Risk assessment is calculated for both major single fire events and the long term probability of combinations of fire events, both large and small, that result in total burned acres exceeding threshold values within an analysis area (Wiitala, 1992).

Figure 3. Poisson Probability Model

$$f(x) = (l^x * e^{-l}) / x!$$

Where:

$f(x)$ = probability

l = Mean number of successes in a given time interval (ie. annual fire frequency)

x = random variable with possible values 0,1,2,3...

e = 2.71828...

For the Masten project, PROBACRE was used to determine the probability of an FIL4 fire occurrence within the project area over the next 70 years. It was also be used to determine the number of total fire occurrences by size class and the probability of total burned acres by year 70. Table 24 displays the probability distribution of FIL4 fire occurrence and fire size class and frequency within the Masten project area for a 70 year period.

Table 24. Probability Distribution of FIL4 Fire Occurrence and Fire Size Class and Frequency within the Masten project area for a 70 year period in increments of 5 years.

Years	0	1	2	>3	IFPL 1	IFPL 2	IFPL 3	IFPL 4
5	0.95	0.05	0	0	0.8	0.3	0.2	0.1
10	0.90	0.09	0.01	0	1.7	0.6	0.3	0.1
15	0.86	0.13	0.01	0	2.5	0.9	0.5	0.2
20	0.82	0.16	0.02	0	3.3	1.2	0.6	0.2
25	0.78	0.20	0.02	0	4.1	1.5	0.8	0.3
30	0.74	0.23	0.03	0	5.0	1.8	0.9	0.3
35	0.70	0.25	0.04	0.01	5.8	2.1	1.1	0.4
40	0.67	0.27	0.05	0.01	6.7	2.4	1.2	0.4
45	0.64	0.29	0.06	0.01	7.5	2.7	1.4	0.5
50	0.61	0.30	0.08	0.01	8.4	3.0	1.5	0.5
55	0.57	0.32	0.09	0.02	9.2	3.3	1.7	0.6
60	0.55	0.33	0.10	0.02	10.0	3.6	1.8	0.6
65	0.53	0.34	0.11	0.02	10.9	3.9	2.0	0.7
70	0.50	0.35	0.12	0.03	11.7	4.2	2.1	0.7

Assumptions:

1) FIL and size classes are considered the same for the purpose of this analysis. This was the guiding premise in fire classification for the Deschutes National Forest in designing its National Fire Management Analysis System (NFMAS) input.
2) The source of ignitions is assumed to remain constant from historical occurrences
3) Ignitions are both natural (58%) and person-caused (42%), and are assumed to remain constant.
4) 0.01 FIL4 ignitions historically occurred annually across the analysis area and are expected to continue at that frequency.

Risk Analysis Conclusion

Based on the historical annual fire occurrence for Fire Intensity Level 4 fires within the Masten project area, it can be concluded that the risk of a crown fire occurring on the 1740 acre project area ranges from 5 percent in year 5 to 35 percent by year 70, with risk increasing as the time period increases. Over the 70 year period, PROBACRE predicted that there would be 11.7 IFPL1 fires, 4.2 IFPL2 fires, 2.1 IFPL3 fires, and 0.7 IFPL4 fires. Due to this increasing risk, the Masten project area will eventually experience a crown fire if the current fuel condition is left untreated.

ECONOMIC ANALYSIS

The economic analysis was conducted by determining the cost of each alternative along with the value lost if an active crown fire or natural suppression due to overstocking occurred within the Masten project area. The value of a viable lodgepole pine stand along with the probability of a crown fire over a seventy year period were used as the values for this economic analysis.

Project Area Value

Cole (1975) has shown the importance of stocking control and precommercial thinning for lodgepole pine. When such practices are used, stands can produce maximum yield of cubic volume per acre per year – within 80 years (Cole, 1975). As stated by Heinrichs (1983), infestations from mountain pine beetle will commonly last 5 to 7 years, and occur in 20- to 40-year cycles. It has been approximately 13 years since the last epidemic, and if the trees are left untreated it will most likely happen again within the next seventy years (Approximately 80 years since the harvest). For lodgepole pine rotations much longer than80 years increase the risk that mountain pine beetles will destroy or damage a significant proportion of the planned timber yield (Amman, 1978; Cole, 1989; Shore and Safranyik, 1992). Also, as each year passes by, the stand becomes more susceptible to fire and more stressed due to the overcrowding. Since two harvests were already completed (1988 and 1989), the value (MMB/acre) associated with them was carried forward to the present using the compounding formula (Figure 4) to find the present value to represent the untreated stand. After using the compounding formula, the present value of the untreated stand (Alternative 1) was $530,934.

Figure 4. Compounding Formula

$$V_n = V_o (1+i)^n$$

Where:

V_o = Present Value

V_n = Value in year "n"

i = Interest Rate

The present value of Alternative 1 was then determined for years 10-70 (increments of 20) during a 70 year planning cycle using the terminable annuity formula. The terminable annuity formula will determine a discounted present value for a series of equal payments. In this case the value of the timber stand over a specified time period. Table 25 expresses the present value of timber stand for the 70 year planning cycle of Alternative 1. Figures 5 and 6 show the formulas used to determine present values of timber stands and treatment costs associated with each alternative.

Figure 5. Terminable Periodic Series Formula

$$V_o = \frac{a\{1-(1+i)^{-n}\}}{(1+i)^t - 1}$$

Where:

V_o = Present Value
a = period payment
i = discount rate = .04
n= number of years to the end of the series, payments x periods
t = the period that "*a*" repeats

Figure 6. Discounting Formula

$$V_o = V_n (1+i)^{-n}$$

Where:

V_o = Present Value
V_n = Value in year "n"
i = Interest Rate

The rotation of 80 years, along with the prescription of 130 trees per acre (TPA) (18 x 18 spacing), will provide optimum growth and a low density for fire protection in Alternative 2 and Alternative 3. According to Volland (1976), the productivity level of a lodgepole pine/bitterbrush/fescue community, implicative of the Masten plant community, has a Site Index (SI) of 75. Site Index is based on average height of dominance at age 100 for lodgepole pine. Cole and Koch (1995) created management regimes for attainable rotations in lodgepole pine, for stands with a site index of 50, 60, and 70. SI 70 table was used to determine how much merchantable volume would be produced with a 130 TPA in 80 years. The merchantable volume can then be multiplied by the current rate of $200/MBF (compounded at 4% interest for seventy years = $3114/ MBF) for optimum trees and the 1400 acres treated. 2393 ~~Ft~~^{3}/~~Acre~~ x 4 ~~Ft~~/ ~~Ft~~^{3} x 1400 ~~Acres~~ / 1000 MBF = 13401 MBF x $3114 = $41,730,714 in year 70. The present value of the stand in alternative 2 and 3 using the discounting formula is $2,679,921 (Table 26).

Table 25. Present Value of Alternative 1 Timber Stand

Year in Planning Cycle	Present Value
0	$530,934
10	$785,912
30	$1,722,030
50	$3,773,180
70	$8,267,506

Table 26. Present Value of Alternative 2 and Alternative 3 Timber Stands.

Year in Planning Cycle	Present Value
0	$2,679,921
70	$41,730,714

Assumptions:

1) The number of board feet per cubic foot used for the stand average diameter of 12.2 inches was 4. This was used to convert Ft^3/Acre to MBF.
2) In table 4, on page 9 of Cole and Koch (1995), the "Stand at 10 years after stocking control" for TPA was 215 and the merchantable volume at 80 years was 3,955 Ft^3/Acre. 130 TPA divided by 215 equals 0.605. 3,955 x 0.605 = 2393 Ft^3/Acre is the merchantable volume in the stands created in Alternative 2 and Alternative 3.

Treatment Costs

A variety of treatment costs needed to be calculated over a seventy year planning horizon. Costs per acre were determined through discussions with the District Forester and Contract Specialists from the Deschutes National Forest, as well as reviewing past contracts, sites, fuel loads and comparing costs and production rates if noted. Table 27 and Table 28 includes costs associated with treatments from Alternative 2 and 3.

Table 27. Alternative 2 Treatment Costs/Acre During One 15-year Interval (4 intervals in 70 years)

Treatment	Cost/Acre	Treatment Cost-Year 0	Treatment Cost-Year 5	Treatment Cost-Year 10	Treatment Cost-Year 15
Thinning (1400 acres)	$140.00	$196,000			$196,000
Grapple Pile (1400 acres)	$100.00	$140,000			$140,000
Burn Piles (1400 acres)	$50.00	$70,000			$70,000
Administration (1150 acres)	$20.00	$23,000			$23,000
15 YR Intervals Total		**$429,000**			**$429,000**
Mowing (250 acres)	$200.00	$50,000	$50,000	$50,000	$50,000
Administration (250 acres)	$20.00	$5,000	$5,000	$5,000	$5,000
5 YR Intervals Total		**$55,000**	**$55,000**	**$55,000**	**$55,000**

Table 28. Alternative 3 Treatment Costs/Acre During One 15-year Interval (4 intervals in 70 years)

Treatment	Cost/Acre	Treatment Cost-Year 0	Treatment Cost-Year 5	Treatment Cost-Year 10	Treatment Cost-Year 15
Masticating (1150 acres)	$200.00	$230,000			$230,000
Administration (1150 acres)	$20.00	$23,000			$23,000
15 YR Intervals Total		**$253,000**			**$253,000**
Masticating (250 acres)	$225.00	$56,250	$56,250	$56,250	$56,250
Administration (250 acres)	$20.00	$5,000	$5,000	$5,000	$5,000
5 YR Intervals Total		**$61,250**	**$61,250**	**$61,250**	**$61,250**

Using the cost per acre for each treatment, the total cost was then determined for each alternative;

Alternative 1) No Action

- No planned costs related in Alternative 1

Alternative 2) Thin/Pile/Burn/Mow

- Thin/Grapple Pile/Burn Piles/Administration occurs in years 0, 15, 30, 45, and 60 with a present cost of $913,702. Terminable periodic series was used.
- Mowing/Administration occurs every five years from 0-70 years with a present cost of $292,559. Terminable periodic series was used.
- Total present cost for Alternative 2 is $1,206,261

Alternative 3) Masticate

- Masticate/Administration occurs in years 0, 15, 30, 45, and 60 with a present cost of $538,850. Terminable periodic series was used.
- Masticate/Administration occurs every five years from 0-70 years with a present cost of $325,807
- Total present cost for Alternative 3 is $864,657.

Expected Value of the Risk

To determine the timber value that would be lost if an active crown fire occurred within the Masten project area, the expected value of the risk needs to be computed. Expected value of the risk is the probability of something happening, in this case, the probability of a FIL4 fire occurring within the project area, multiplied by the present value (Rideout and Hesseln, 1997).

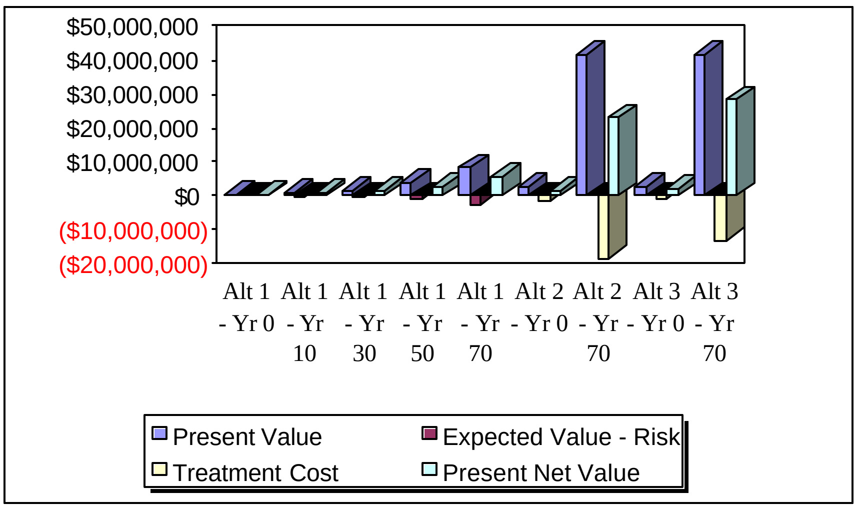
In the No Action Alternative, it was shown in the "methodology and quantification of risk analysis" that a FIL4 fire occurring during severe drought conditions will result in an active crown (stand destroying) fire, and the loss of timber value for the project area. Therefore, the probability of a FIL4 fire occurring in the project area was used to determine the expected value of the risk. In the other two alternatives, the fuel treatments would eliminate the probability of an active crown fire. This would create conditions where the probability of a FIL4 fire occurring is zero, in all fire behavior conditions. Thus, the expected value of the risk for these alternatives are zeros. Table 29 and Chart 1 illustrates the present net value for each alternative based on year, present value of the Masten project area, expected value of risk, and treatment cost.

Table 29. Present Net Value of Each Alternative

Alternative	Year	Present Value	Associated Probability	Expected $Value_{Risk}$	Treatment Cost	Present Net Value
1	0	$530,934	0	$0.00	0	$530,934
1	10	$785,912	0.09	($70,732)	0	$715,180
1	30	$1,722,030	0.23	($396,067)	0	$1,325,963
1	50	$3,773,180	0.30	($1,131,954)	0	$2,641,226
1	70	$8,267,506	0.35	($2,893,627)	0	$5,373,879
2	0	$2,679,921	0	$0.00	($1,206,261)	$1,473,660
2	70	$41,730,714	0	$0.00	($18,783,436)	$22,947,278
3	0	$2,679,921	0	$0.00	($864,657)	$1,815,264
3	70	$41,730,714	0	$0.00	($13,464,109)	$28,266,605

Note: Values in parenthesis are negative.

Chart 1. Graphical Display of the Present Value, Expected Value – Risk,



Treatment Cost, and Present Net Value of Each Alternative

Assumptions:

1) Interest rates and discount rates are 0.04.
2) Treatment and administration costs remain static over the seventy year planning horizon.
3) Economic analysis is conducted integrating seasonal fire behavior conditions, probability analysis and fire behavior modeling.

CONSIDERATION OF ALTERNATIVES AS RELATED TO OBJECTIVES

Alternative 1- No Action

Under this alternative no treatment of the current fuel condition would take place. Flame lengths above 4 feet occur in drought and severe drought fire conditions. With the current conditions a FIL4 fire burning during severe drought fire conditions would result in a stand destroying crown fire. This type of fire would lead to a loss of natural resources and threaten the community and residential areas in La Pine.
Additionally, because the natural fire regime has changed due to the mountain pine beetle infestation which resulted in two timber sales, a change in fuel loading and species composition has occurred throughout the stand in the project area. Under this alternative these conditions would continue as they currently are, with fuel loads and fire danger continuing to increase while resource quality in the area continuing to decrease.

This alternative has the highest expected value risk along with the lowest present net value of the three alternatives proposed at the end of the seventy-year planning cycle. This alternative doesn't meet any of the goals or objectives of the Masten project.

Alternative 2- Contract Thin/Pile/Burn

This alternative would limit an unplanned ignition in the project area to a surface fire (0.07 ac.) in normal conditions and a small size passive crown fire in drought (0.31 ac.) and severe drought (0.44 ac.) fire conditions as modeled by the fire behave runs in FMA Plus: CrownMass. By eliminating all probability of an active crown fire and by reducing flame lengths to 2.1 feet in severe drought conditions, the fire behavior objectives of the project have been accomplished. Additionally, thinning of the lodgepole pine stand will help promote healthy, viable trees by providing more open space, reducing competition and allowing full growth potential.

This alternative has a the lowest expected value risk, equal to that of Alternate 3 and the second highest present net value for the seventy-year planning horizon of the three alternatives. Alternative 2 is an effective fuel treatment that protects the La Pine urban interface community and promotes healthy, fire and insect/disease resistant forest stands which is the goal of the project.

Alternative 3- Contract Excavator Mastication System

This alternative would limit an unplanned ignition in the project area to a small passive crown fire in normal conditions (0.24 ac.), drought conditions (0.98 ac.), and severe drought conditions (1.46 ac.) as modeled by the fire behave runs in FMA Plus: CrownMass. By eliminating all probability of an active crown fire and by reducing flame lengths to 3.7 feet in severe drought conditions, the fire behavior objectives of the project have been accomplished. As with Alternative 2, thinning of the lodgepole pine stand will help promote healthy, viable trees by providing more open space by reducing competition and allowing full growth potential.

This alternative has a the lowest expected value risk, equal to that of Alternate 2 and the highest present net value for the seventy-year planning horizon of the three alternatives. Alternative 3 is an effective fuel treatment that protects the La Pine urban interface community and promotes healthy, fire and insect/disease resistant forest stands which is the goal of the project.

RECOMMENDATION AND RATIONAL

The recommended alternative for fuels treatment within the Masten project area is Alternative 3, the excavator mastication system. This alternative meets the goal as measured by the criteria of all the objectives. Flame lengths were below four feet and active crown fire was eliminated during severe drought seasonal fire behavior conditions. Alternative 3 adheres to the goal of the project "to provide an effective fuel treatment that best protects the La Pine urban interface community and promotes healthy, fire and insect/disease resistant forest".

Up to this point Alternative 2 was just as good a choice or even better than Alternative 3. However, it was four issues that put Alternative 3 ahead:

1. The present net value of Alternative 3 in year 70 was $28,266,605 compared to Alternative 2 which was $22,947,278. This was one part of the project's objectives and Alternative 3 was approximately 19 % more cost effective.

2. No smoke management issues or regulations, since piles will not be burned

3. Mowing instead of masticating the high-risk areas in Alternative 3 would lower the costs slightly and potentially lower the fire behavior even more.

4. There are not as many parts to the whole operation and it can all be taken care of in one passing for less impact on other resources.

CONCLUSION

Based upon the current fuel conditions within the Masten project area and the historical weather, the possibility exists that during a severe drought condition an active crown fire will occur. If these fuel conditions are left untreated, the probability of an active crown fire increases over time. The probabilities of 20% at year 25, and 30% at year 50 illustrate this point. The occurrence of an active crown fire could result in the loss homes or lives and would most definitely result in the loss of valuable resources.

To mitigate the possibility of an unplanned ignition that would result in an active crown fire, a fuels treatment should be implemented. This fuels treatment would manipulate the fuel loading and arrangement to levels that would not allow an active crown fire under drought or severe drought conditions. Additionally, this fuel treatment should provide healthy, viable stands that are more resistant to fire, insects, and disease.

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Fuel Treatment Impacts by Alternative

Soil Impacts

Alternative 1 (No Action) – There would be no operational impacts to soils. Surface erosion would continue from uncontrolled off-road vehicle traffic.

Alternative 2 Thin/Pile/Burn Piles/Mow– Impacts to soils would generally be confined to existing roads, landings and skid trails. Some additional displacement and compaction of soils would occur during the mowing and thinning operations in small diameter stands that only received light traffic during the previous harvest entry. The District forester stated that seven pounds per square inch is the maximum allowed in the Masten area and all equipment that will be used is under five lbs/in^2. Operations would also be confined to the dry season or while the ground is frozen to limit soil impacts. Pile burning will occur during the wet season or while snow is on the ground (late fall, winter). Moist soil generally experiences less temperature rises than dry soil, given the same heat input. This will lessen the impacts on nutrients and microorganisms in the soil. Closing and barricading the unneeded roads will help mitigate off road travel and help in soil erosion. Considering the flat terrain, sandy soils, and seasonal restrictions (operations and burning) soil impacts would be relatively minor from this alternative.

Alternative 3 Masticate – Seasonal restrictions are the same as Alternative 2. The mechanical mastication process has a slightly higher average soil compaction level (5-6 lbs/in^2), but may have reduced soil impacts if operating on the previously created mulch layer. Direct application of mulch provides immediate ground cover, which will aid in protecting exposed surface soils and help hide, otherwise noticeable, roads. The deeper the mulch layer the higher probability to control erosion. The mulched material created from the live and dead fuels will be recycled back into the soil, which will maintain or even increase the amount of nutrients available in the soil. The impacts to the soil would be relatively minor and may prove to be very beneficial.

Fisheries Impacts

Alternative 1 (No Action)

Fisheries will only be slightly impacted over time. As the seedling and saplings grow, it is assumed the vegetation on site, rather than filter into the ground water and into the streams and rivers, will utilize more water.

Alternative 2

Initially, less water will be retained on site releasing more water into the streams for fisheries. As the leave trees grow more water will remain on site. The overall impact is immeasurable but is projected to be extremely low.

Alternative 3

Same as Alternative 2.

Wildlife Impacts

Alternative 1 (No Action)

Lodgepole pine would develop into thick "doghair" stands without management. Over the long-term, stands would provide adequate canopy cover but would lack optimum stand structure to serve as nesting habitat for goshawks and great gray owls. The large tree component would not be improved and stand structure would not enhance under this alternative. As tree cover increases, a decline in understory condition would reduce productivity of prey species.

Alternative 2

Thinning would aid in meeting wildlife habitat objectives for the project area over the long-term. Nesting habitat for special status species, and habitat for other species associated with mature stands, would be improved in the long-term by increasing the large tree component within the stand. This will promote stand health, enhance stand structure, and provide the spacing for better "branching" for nest trees. Thinning would reduce hiding cover on some portions of the project area in the short-term, however, an estimated 15-20% of the project area would remain untreated. The original functioning designated cover areas left from previous timber harvest entries would be left untreated. In addition to the existing designated leave areas, other untreated leave areas of at least five acres would be left evenly distributed throughout the project area. Following thinning treatments, an increase in production and diversity of understory species would improve forage for big game and habitat for small mammals. An increase in understory habitat would also benefit productivity of prey species for nesting raptors.

Stable snags, snag replacement trees, and down logs with desired habitat characteristics would be retained. Girdling diseased green lodgepole pine trees would help create additional stable snags. Approximately 10% of the woodpiles would also be retained to serve as wildlife habitat.

There will be disturbance to wildlife during the operations. In order to avoid disturbance during the nesting season, timing of operations would take into consideration any active raptor nest sites within the project area.

Meadow treatments would provide more openness and increase forage habitat for goshawks, great gray owls, and other raptors. The increased cover of meadow grasses would provide forage for large and small mammals as well.

Alternative 3

It has the same impacts as Alternative 2, except that new piles will not be created and short-term vegetation coverage may occur due to mulching. Some areas within the Masten area that had been covered with a layer of chips or mulch in the past still are present with no vegetation. Approximately 4.5 tons per acre (TPA) of canopy fuels will be mulched onto the 7.1 TPA of existing surface fuel (63% increase). The existing fuel bed depth is 0.92 ft. After mulching, even though the fuel loading will be higher (7.1 TPA to 11.5 TPA), the fuel bed depth will be less than 0.7 ft. This compacted mulch layer may cover some existing vegetation, but in the long-term will provide more nutrients for vegetation, thus more forage for wildlife.

Vegetation Impacts

Alternative 1 (No Action)

There would be no immediate impacts to vegetation. Without management, lodgepole pine stands would continue to increase in density and decline in vigor. Over time, as dense thickets develop and average DBH approaches 6-7 inches, there would be a high probability that a mountain pine beetle outbreak would occur. As tree cover increases, understory shrubs, grasses, and herbs would decline in density and diversity. The potential for a catastrophic, crown fire will increase as the fuel loading in the stand increases. Life and property will become more at risk. Vegetation impacts will be very high without management.

Management of the lodgepole pine in the meadows would not take place. The two meadows would continue to be encroached upon by lodgepole pine, ultimately encompassing almost the entire meadow area over time. The vegetative diversity and associated habitat of the meadow area would continue to decline. Wet meadows may become drier due to large amounts of water used by lodgepole pine within and adjacent to the meadows.

Special status plants- There would be no direct short-term impacts to special status plants. Long-term impacts include the slow conversion of the meadows to a lodgepole pine forest, thereby reducing or eliminating habitat for *Carex hystericina*, should this species occur. In addition, the opportunity to improve potential habitat for *Botrychium pumicola* would be foregone.

Alternative 2

Some short-term damage to shrubs, grasses and herbaceous vegetation would occur. Understory species would be expected to become more vigorous and diverse following treatment. Lodgepole pine stands and scattered individual ponderosa pine trees would respond to thinning treatments with improved health and vigor. The stands would be more insect and disease resistant and would show improved growth rates. By thinning out smaller, suppressed, and diseased trees, limited resources (water, nutrients, light, and space) would be reallocated to the remaining trees left in the stand. The immediate and long-term result would be fewer, healthier trees, a larger average diameter, and a higher percentage of ponderosa pine. A three-stratum stand structure (larger overstory trees, poles, and seedlings/saplings) would be maintained and enhanced by the thinning treatments. The healthy lodgepole pine seed trees and all large ponderosa pine trees would be left. The pole-sized component would be thinned, leaving the healthiest trees with the larger crown ratio. Seedling density would be reduced due to some cutting and operational disturbances. Areas that are mowed will have a very low seedling density. Leave tree spacing in the seedlings and pole-sized trees would be variable based on availability of viable leave trees and hiding cover needs. Some natural thickets would be left untreated to further enhance horizontal and vertical structural diversity. Breaking up the stand structure with variable tree densities and strata would help control potential future epidemic insect and disease events and aid suppression of wildfires by having less dead and down, woody fuels available for fire spread. Fire hazard will decrease significantly since the fuel that is thinned is piled and off of the forest floor. Spacing of the overstory eliminates the potential of an active crown fire in high percentile weather.

<u>Special status plants</u>- It is unlikely that special status plants exist in the forested area planned for treatment. However, should *Astragalus peckii* exist, it is likely that there would be no detrimental impacts to this species. If *Botrychium pumicola*, were to exist in the area, operations could directly impact individual plants. However, removal of down/dead and young trees would enhance the plant's habitat by opening the forest and shrub canopy. In the long term, this treatment would likely improve habitat for this species and make it more attractive for recolonization. The treatment of the meadows could affect *Carex hystericina*, should it exist. Light hand on the land methods will help alleviate any concerns. Removal of the competing lodgepole pine and restoration of the meadow would have a positive effect on this riparian species.

Negative impacts are fairly minor and short-term while the overall impacts to vegetation would be very beneficial.

<u>Alternative 3</u>

Same impacts as alternative 2, but even more nutrients would be available to leave trees since the present vegetation will be recycled back into the soils. Also, the total surface fuel loading will increase with this procedure, since the crown loading will now be masticated and added to the existing surface fuel loading. Fuel bed bulk depth will decrease since the surface fuels will be more compacted due to mulching and driving over the mulch during operations. Fire hazard will decrease with more compacted fuels and the spacing of the overstory eliminates the potential of an active crown fire in high percentile weather.

<u>Special status plants</u> – Same as alternative 2, except for one difference. Putting a layer of mulch on the forest floor may cover up existing plants. However, dispersing of

down/dead and young trees, and providing a layer of mulch may enhance the plant's habitat by opening the forest and shrub canopy.

Insects and Disease Impacts

Alternative 1 (No Action)

Over time, as dense, stressed thickets develop and average DBH approaches 6-7 inches, there would be a high probability that a mountain pine beetle outbreak would again occur. Western gall rust, dwarf mistletoe, and pockets of root disease have the potential to continue spreading into the seedlings and saplings as they emerge in the understory. No management will increase the potential impacts of insects and diseases within the project area. Lacking fire (because suppression will continue) the other disturbance agents will try to compensate, attempting to set the stage for another stand-initiating event. It is inevitable that the stands will never reach full growth and full market value.

Alternative 2

Thinning the lodgepole pine, creating age-size diversity of the stand will strengthen the leave trees by reducing competition, providing a healthier stand that is more resistant to insect infestation and diseases.

Alternative 3

This alternative will have the same impacts on insects and disease as Alternative 2.

Cultural Resources Impacts

Alternative 1 (No Action)

No cultural resources will be impacted.

Alternative 2

Previously recorded cultural sites would be identified prior to operations and excluded from treatment areas. Any human remains or cultural and/or paleontological resources discovered during operations would be immediately reported to the authorized officer. All operations in the immediate vicinity of such discovery would be suspended until written notification to proceed is issued by the authorized officer. All appropriate actions to prevent the loss of significant cultural or scientific values will be taken. Overall, cultural resources will not be impacted.

Alternative 3

Same cultural impacts as Alternative 2.

Visual Resources Impacts

Alternative 1 (No Action)

Slash piles would remain. The general degraded appearance of the forest landscape would remain unchanged. Without thinning treatments, future stands would develop into "doghair" stands of small, suppressed trees. Vegetative and visual variety would decline further. Without piling slash in the unwanted roads or using the mulch to help hide the roads, off-road vehicle travel would continue to create some erosion and vegetative impacts which would affect visual quality

Alternative 2

Burning of the slash piles would result in the removal of 90% of this visually undesirable, human-created landscape feature. Thinning would remove many of the trees, which contribute the "shabby" visual character of the current stand appearance. Thinning would also create more visual diversity by providing greater contrast between the treated and untreated stands. Over the long-term, current proposed and future thinning treatments would promote stands containing fewer, larger trees which are generally considered more visually appealing than stands of dense, smaller trees. Piling of slash (not burned) in unwanted roads would aid erosion control and vegetation recovery which would also improve overall visual quality. Barricading and disguising of unneeded roads would reduce some illegal dumping.

Alternative 3

Instead of burning the slash piles as in Alternative 2, 90% of the piles will be masticated/mulched. Mulched material will be used to try and cover existing, unwanted roads. All other visual impacts are the same as in Alternative 2.

Air Quality Impacts

Alternative 1 (No Action)

No direct effects from this alternative. An indirect effect may be an increase in the potential for large, active crown fires as stands continue to develop. Wildfire would contribute large volumes of smoke that could impact visibility, creating a potential human health hazard to motorists on highway 97 and may adversely affect human health.

Alternative 2

Smoke management regulations will limit daily amounts of particulate matter emissions in the La Pine Management Area. Some short-term impacts to air quality are expected within limits imposed by the state smoke management agency. Mitigation measures (burning dry instead of wet, weather conditions, etc.) can minimize impacts.

Alternative 3

No burning will take place with this alternative. Exhaust from the equipment would be the only direct air quality impact, and this would be minimal. Similar to alt 1, but the potential for unplanned wildfire smoke impacts would be reduced.

Current Public Use Impacts

Alternative 1 (No Action)

Current public use of the area would remain unchanged. Access to illegal dumpsites remains unchanged, possible increasing cleanup costs and law enforcement costs over time.

Alternative 2

Closed and disguised unneeded roads would limit public dumping to fewer accessible sites and may reduce cleanup and law enforcement costs. Area would be more secluded and more appealing to the public for recreational activities

Alternative 3

Same impacts as Alternative 2.

Social/Economic *Impacts*

Alternative 1 (No Action)

This alternative would not provide any economic benefits to the local community. Without thinning treatments, future growth and yield of the stand would be reduced and future potential for wildfire would be much greater. There would be no mowing treatments to provide a defensible space near roads or homes.

Alternative 2

Implementing this alternative would provide economic benefits to the local community through employment and support supplies/services. There may be potential to use the slash piles for chips in the future, but it isn't feasible at the present time because of low-value chip market. Stand thinning would increase potential growth and timber yield, plus contribute to long-term fire protection. Mowing of small trees and brush would help create a defensible fire protection zone near major roads and residences.

Alternative 3

This alternative does not require as many equipment operators or employ as many people as Alternative 2. Slash piles would not be created for potential use they would be masticated/mulched. Stand thinning would increase potential growth and timber yield, plus contribute to long-term fire protection. Mastication of the brush component and/or lodgepole pine reproduction around high-risk areas would help create a defensible fire protection zone.