Analysis of Proposed Bald Eagle Habitat Improvement Project in Bear Valley National Wildlife Refuge

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Assumptions:

Fuel conditions are assumed to be uniform throughout the study area.

Burning conditions are assumed to be uniform throughout the fire occurrence area. Fires starting anywhere within the area have the potential to impact the refuge.

Trees per acre from stand exam information are assumed to be uniform acre per acre throughout the refuge.

Costs for treatment and suppression are uniform throughout the study area.

Prescribed fire operations will occur under controlled conditions. Escape will not occur.

Current fuel loading is assumed to be represented by a fire behavior fuel model 10. Loading after treatment is assumed to be represented by a fire behavior fuel model 9.

Commercial timber values plus $1.00 are assumed to be the value of the refuge.

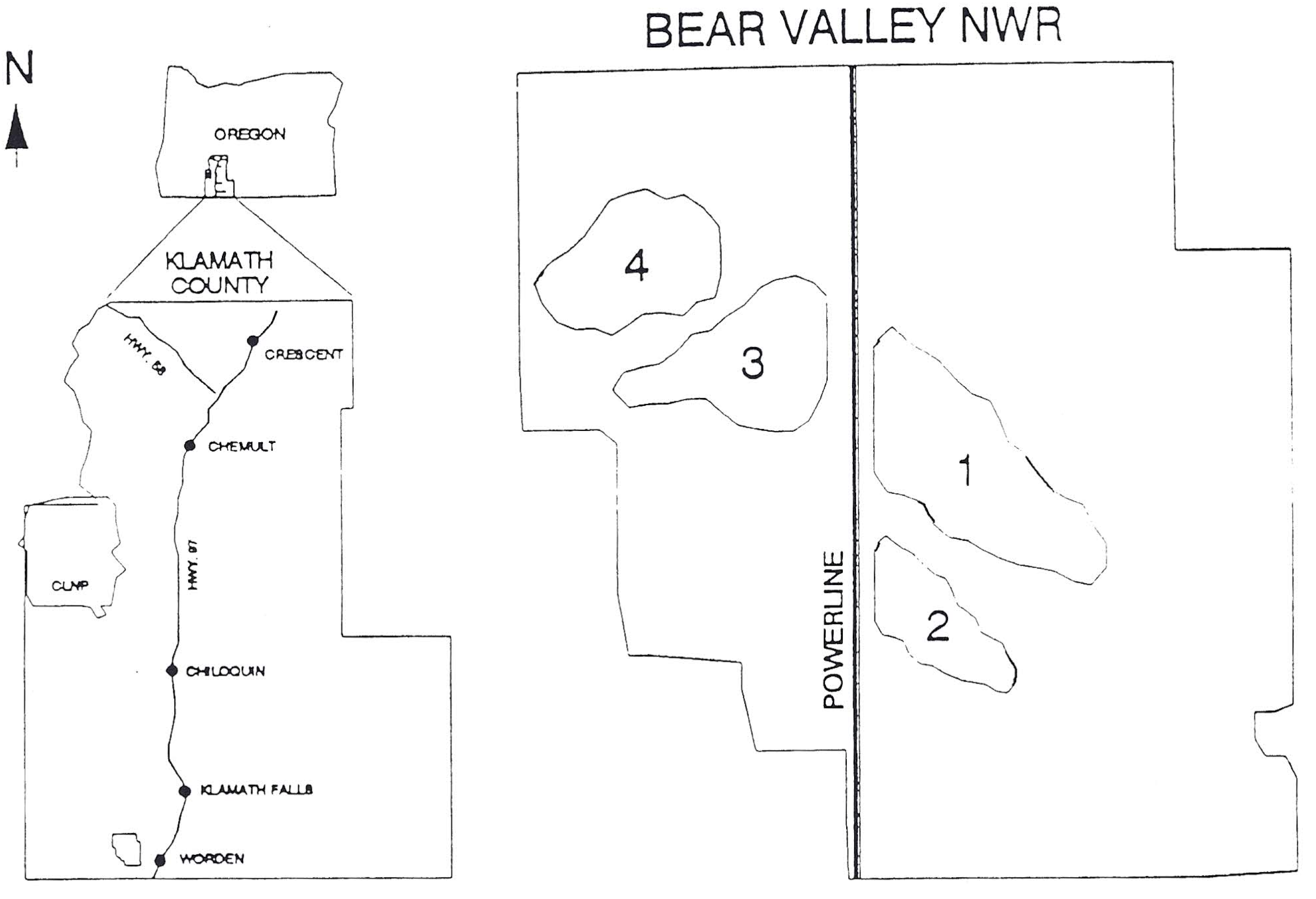
EXECUTIVE SUMMARY

The Bear Valley National Wildlife Refuge, located 12 miles southwest of Klamath Falls in south central Oregon is an important bald eagle, *Haliaeetus leucocephalis*, winter roosting area. The refuge, which was established to protect bald eagle habitat from destructive land use practices, is recognized as one of the most important winter roosting sites in the continental United States.

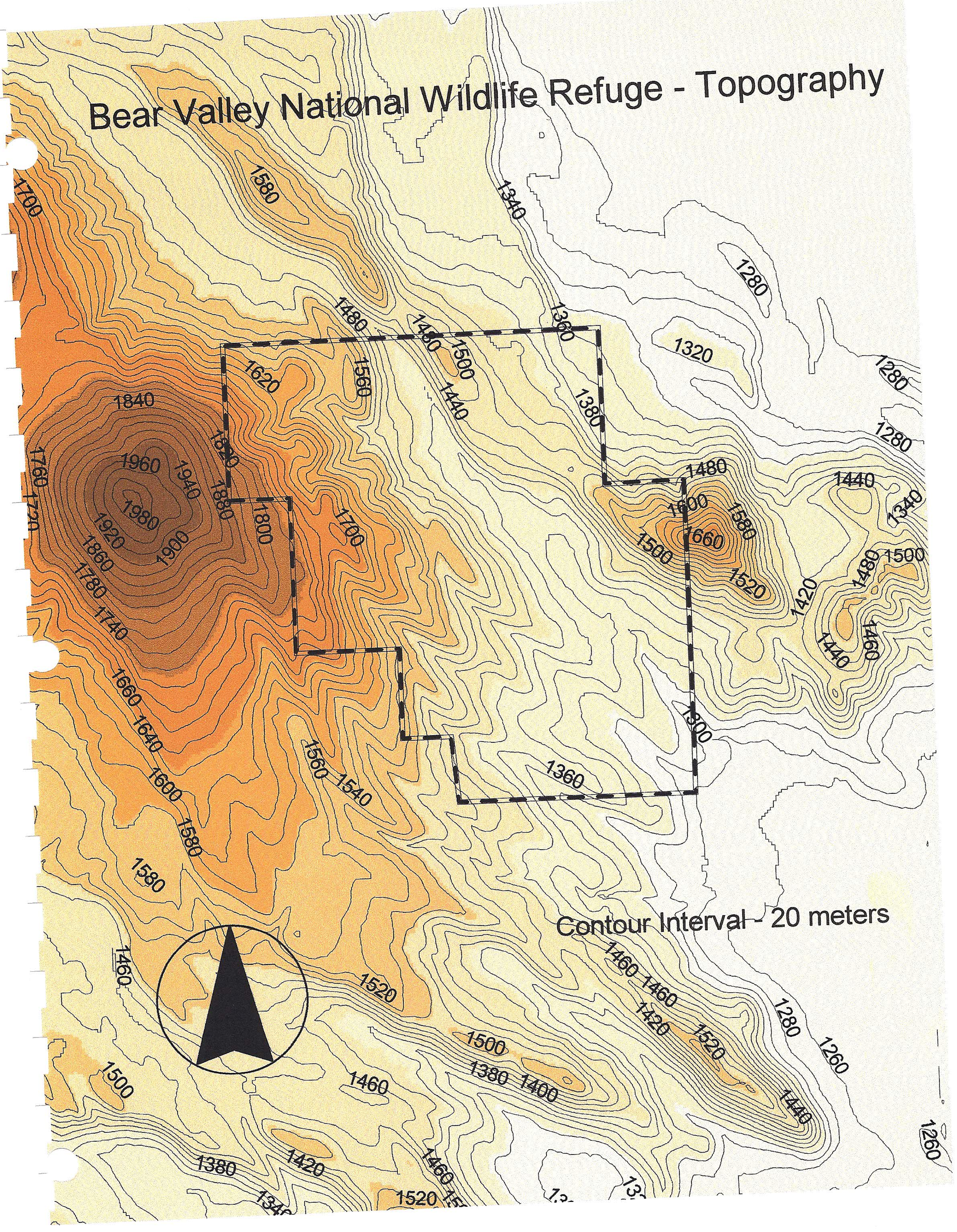
An interdisciplinary team has determined that the existing eagle roost habitat within the refuge is endangered by several agents including wildfire. This study examines a proposed habitat improvement project to determine if the project will effectively protect bald eagle roost trees from fire. The original environmental assessment for this project recognized the potential negative impact that a stand replacement fire would have on habitat, but did not adequately analyze the natural role of fire or estimate fire effects so that an adequate fire management strategy could be implemented.

Tools learned while attending Technical Fire Management were utilized to perform the analysis. Fuels inventory was completed to determine the current fuel loading. Photo series were used to estimate fuel conditions after treatment. Weather data extracted from KCWIMS (Kansas City Weather Information Management System) database was analyzed using PCSEASON and PCFIRDAT software to determine the average (50^{th} percentile) and average severe (90^{th} percentile) weather conditions. BEHAVE Fire Prediction System was used to model fire behavior for current and post treatment timber stands. FOFEM (First Order Fire Effects Model) was used to determine potential fire effects. POBACRE software was used to predict the probability of a fire event occurring over time. Concepts for maintaining a fire safe forest were used to analyze crown fire potential. GIS (Geographical Information System) was used to produce maps.

The alternatives of maintaining the current condition versus treating the area were evaluated using the criteria of maintenance of eagle habitat, economics, and fire hazard reduction. This data suggests a fire management strategy to reduce fire hazard within the core roosting areas of Bear Valley. Through implementation of this strategy, future fires will burn with lower intensities and severities. Roost trees will be more likely to withstand fires which may occur after the treatment has been implemented.

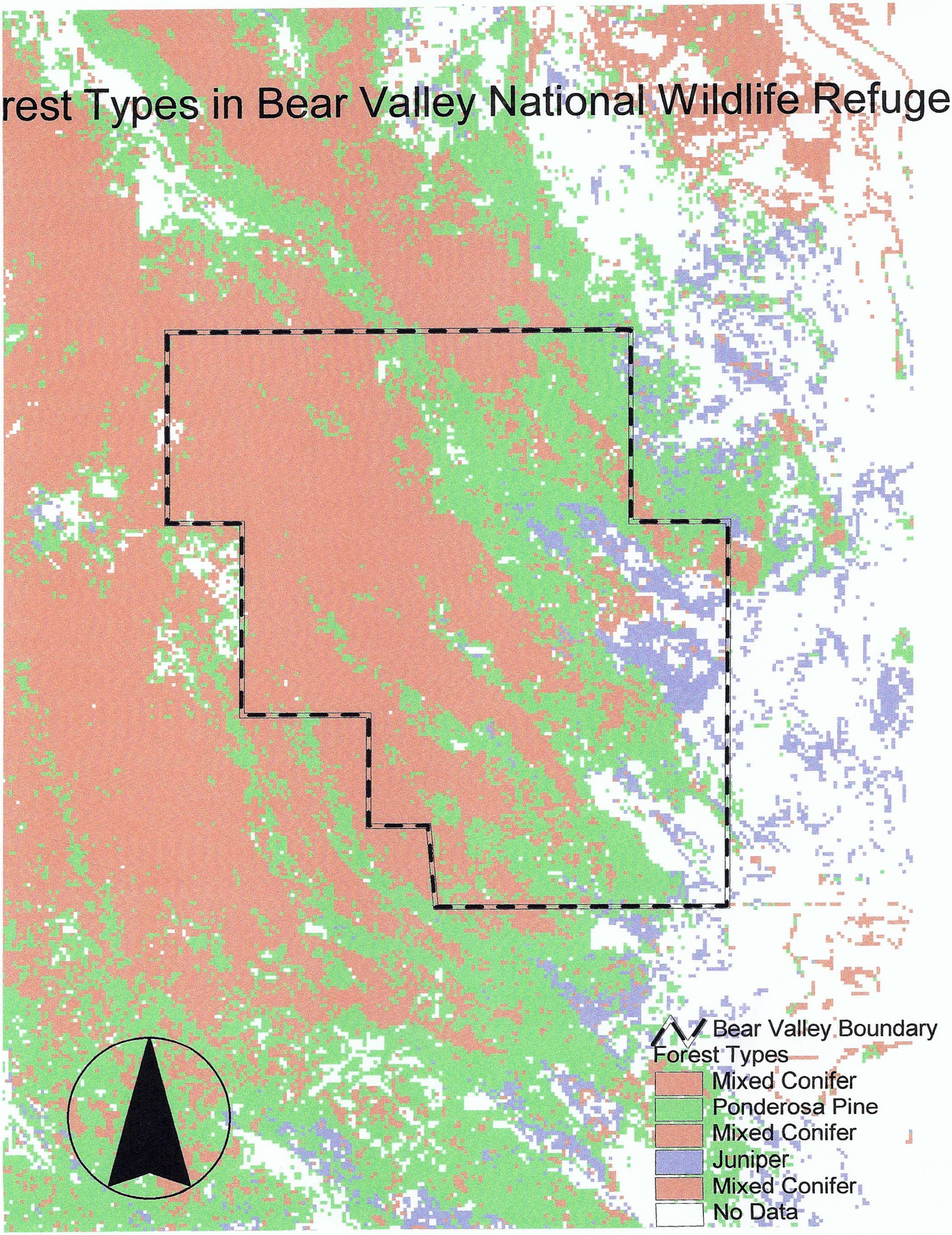


Location of the Bear Valley National Wildlife Refuge (NWR) in Klamath County, Oregon, and general location of 4 subroosts within the Refuge.



Bear Valley National Wildlife Refuge - Topography

Forest Types in Bear Valley National Wildlife Refuge



Introduction:

The Bear Valley National Wildlife Refuge is located 13 miles southwest of Klamath Falls, in south-central Oregon. The 4,200 acre refuge was established in 1978 to preserve an important bald eagle, *Haliaeetus leucocephalis*, winter roosting site. The roost has one of the highest concentrations of eagle use in the continental United States. Up to 1,000 bald eagles utilize the Bear Valley refuge between October and April.

Elevations in the refuge range from 4,200 to 5,800 feet (1,280 - 1,830 meters). Topography in the refuge is dominated by deep, narrow valleys and a series of north-south running ridges. Slopes range from 0% to over 40%, with most of the refuge situated on 20-30% slopes. Forests in the low to mid elevations are primarily pure ponderosa pine, *Pinus ponderosa*, stands. Higher elevation stands are mixed conifer, with white fir, *Abies concolor*, ponderosa pine, Douglas-fir, *Pseudotsuga menziesii*, incense-cedar, *Calocedrus decurrens* and sugar pine, *Pinus lambertiana* present. Western juniper, *Juniperus occidentalis*, is found in the lowest elevations.

Historic timber stands were composed of large, widely spaced trees. Ponderosa pine was the predominant tree species, with a minor presence of other species. Periodic light severity fires kept undergrowth to a minimum (Eglitis, 1996).

Some of the earliest logging operations in Klamath County were in the Bear Valley area. The first mill in the county was located three miles northwest of the refuge in 1868 (Bourdeau, 1995). Logging activities prior to 1978 resulted in the removal of many of the largest diameter trees. Ponderosa pine was the most sought after tree species during logging. A major reason for establishing the refuge was to prevent further high grade logging from occurring within known eagle roost areas.

Current timber stands are composed of dense clumps of small diameter stems. These dense clumps serve as ladder fuel for fire to travel into the crowns of the larger diameter trees. The height of crown base found in the current stands is on average below 6 feet.

An extensive study of castings found under roost trees helped to determine the habitat preferred by eagles. The study identified that roost trees were typically the larger, older, taller trees in the stands and were almost always the dominant or codominant trees with open-branching (Dellasala, et al. 1987). Sources indicate that eagles prefer large diameter ponderosa pine and Douglas-fir for roosting (Dellasala, et al. 1987 ; Arnett and Kelton, 1996). Trees greater than 14" are considered to be potential roost trees.

There are four main roost areas on the refuge. The roost areas comprise 1,800 acres of the refuge. The remaining 2,400 acres serve as a buffer around these roost areas.

A habitat management plan for the refuge recognized the potential for roost tree mortality from a stand replacing wildfire (greater than 80% mortality). This plan initiated a habitat improvement project. The preferred alternative of the habitat improvement project is a selective thinning of trees followed by prescribed fire in the main roost areas.

Problem:

Historically, stands in the Bear Valley area were composed of large and widely spaced trees. The open nature of the stands was maintained by periodic low severity fires. In the lower elevations of the refuge, ponderosa pine was the dominant species. In the higher elevations, stands were composed of ponderosa pine and sugar pine, with lesser amounts of incense cedar and Douglas-fir. White fir was a minor component. (Eglitis, 1996).

After years of fire suppression and logging operations that concentrated on harvesting the largest trees, the current stands are composed of densely stocked clumps of smaller diameter trees. White fir is now a major component of the area. Large diameter ponderosa pine, which is preferred as roosting habitat is scarce. Logging combined with mortality from insect attack and disease has produced an excessive amount of dead and down material on the ground.

Several assessments have identified a high risk and hazard to the refuge from wildfire (Dellasala et al.; Eglitis). Numerous structures and roads located in timber and brush fuel types have led to a high number of human-caused fires in the area. The area is also one that receives a high number of lightning strikes during fire season (Arnett and Kelton, 1996). Densely stocked stands with multiple stories serving as ladder fuels, coupled with large amounts of dead and down material on steep slopes indicate a high fire hazard.

The Bear Valley Refuge was established to preserve bald eagle roosting habitat (Arnett and Kelton, 1996). It is thought that eagles prefer older, larger-diameter ponderosa pine and Douglas-fir over other trees for roosting. There is concern that the remaining large diameter ponderosa pine and Douglas-fir in the refuge are at risk, particularly from wildfire.

Goal Statement:

The goal of this project is to protect bald eagle roosting habitat from potentially catastrophic wildfire. This will be done by changing fuel characteristics.

Objectives:

1: Determine fuel loadings.
2: Determine the fire return interval that favored the perpetuation of large ponderosa pine and Douglas-fir trees.
3: Determine potential fire behavior/effects (average and severe).
4: Analyze two alternatives.

BEAR VALLEY PHOTOGRAPHS

Photo 1: View of high fuel load in ponderosa pine stand.

Photo 2: Encroaching fir and cedar.

Methodology:

Current Stocking:

The number of trees per acre within a timber stand is an important factor needed to determine fire hazard within a stand. Crown bulk densities, a factor determined by stocking levels, is an indicator of how resistant a stand is to a crown fire establishing in the event of a fire. The current stocking levels in Bear Valley were obtained from an intensive stand exam centered on the four core roost areas in the refuge.

Species	0-6" DBH	7-10"	11-14"	>14"	**Totals**
Douglas-Fir	75	28	14	9	**126**
Incense Cedar	24	4	1	1	**30**
Ponderosa Pine	49	25	8	4	**86**
Sugar Pine	3	0	0*	0*	**3**
White Fir	76	22	8	7	**113**
Totals	**227**	**79**	**31**	**21**	***358***

Table 1. Trees per acre. *Data converted from trees/hectare to trees per acre (Delllasla, et al. 1987)*
* = Less than one half of one percent.

Fuels:

Fuel loadings were estimated to be between 6.8 and 56.3 tons per acre in the habitat management plan (Arnett and Kelton, 1996). These numbers were a gross estimate obtained from photo series. Fuels inventory was conducted to better determine the actual fuel load.

Fuels inventory was conducted in the main roost areas. The planar intersect technique (Brown, 1974) was used. Twenty plots were completed in the predominantly ponderosa pine stands, and another twenty plots were completed in the mixed conifer stands. The tons per acre were calculated using Carlton's Dead and Down Woody Biomass Inventory Chart and Fuels Inventory-Data Reduction-For Fuel Loading spreadsheets.

PONDEROSA PINE - 20 plots					
	0-3" FUEL LOAD	3"+ FUEL LOAD	TOTAL FUEL LOAD	DUFF DEPTH	PARTICLE DEPTH
MEAN	5.7 t/a	9.3 t/a	15.2 t/a	0.8"	4.3"
STND DEVIATION	6.6	11.8	14.9	0.6	6.7
STND ERROR	1.5	2.6	3.3	0.1	1.5
% ERROR	26%	28%	22%	16%	35%

Table 2. Results of fuel inventory - ponderosa pine.

MIXED CONIFER - 20 plots					
	0-3" FUEL LOAD	3"+ FUEL LOAD	TOTAL FUEL LOAD	DUFF DEPTH	PARTICLE DEPTH
MEAN	3.8 t/a	7.3 t/a	17.8 t/a	1.1"	1.1"
STND DEVIATION	3.9	9.8	18.5	0.8	1.1
STND ERROR	0.9	2.2	4.1	0.2	0.2
% ERROR	23%	30%	23%	16%	23%

Table 3. Results of fuel inventory - mixed conifer.

Based on the results obtained, the data suggests that the current average total dead fuel load for the roost areas in the Bear Valley Refuge is 17 tons per acre. A fire behavior fuel model 10 (timber - litter and under story) is used as the most representative model for the current fuel condition. 2 tons per acre are added to the dead fuel load to account for the live fuel component of a fuel model10 (Anderson, 1982). Total fuel load is estimated at 19 tons per acre.

Fuel loadings in Bear Valley for the 0-3" category are higher than the 3.01 tons per acre used for the actual fuel model 10. This is especially true in the ponderosa pine, where 0-3" material equals 5.7 tons per acre. As fire spread is largely driven by the 0-3" fuel load, a fuel model 10 will actually under predict the fire behavior expected for the current condition.

Proposed commercial thinning will utilize whole tree yarding. While an increase in the 0-3" fuel load will occur, an overall reduction in fuel load will occur due to the fact that much of the downed material greater than 3" will be removed. It is estimated from a photo series (2-MC-3-PC) that the fuel load after thinning will be reduced from 19 tons to 12 tons per acre, a 37% reduction (Maxwell and Ward, 1979).

Burning could further reduce the fuel load. FOFEM (First Order Fire Effects Model) suggests that a moderate intensity fall prescribed fire could reduce the total fuel load to 3 tons per acre. A fuel model 9 will be used to estimate the fire behavior after treatment. A fuel model 9 will over predict the expected fire behavior. FOFEM predicts a 0-3" fuel load of 0.2 tons per acre. The model uses 2.92 tons per acre for the critical 0-3" material.

Fire History

Eglitis describes two possible fire regimes for the Bear Valley area. In the lower ponderosa pine dominated forests, fires were very frequent, occurring at 8-15 year intervals and were of low intensity. In the higher elevation mixed conifer forests, fires were less frequent than in the ponderosa pine forests. Intervals between fires ranged from 20 to 40 years in the mixed conifer forests.

In order to verify these figures a fire history study was conducted in order to determine the natural fire regime on the refuge. Wedges from fire scarred stumps were cut with a chainsaw. After the wedges were sanded, tree rings were counted using a handheld lens and binocular microscope to determine the years that fires occurred. A total of seven trees with 39 fire intervals were sampled. These samples were gathered within the higher elevation mixed conifer forest. Samples taken from this area can be expected to show the less frequent fire return interval. It was planned to take more samples not only in the higher elevation mixed conifer stands, but also in the ponderosa pine dominated stands. Seasonal access restrictions prohibited further entry into the refuge and further sampling will need to occur at a time when eagles are not nesting or roosting.

Sample	1	2	3	4	5	6	7
Dates of fire scars	1772 1777 1800 1809 1836 1840 1845 1862 1875 1897 1913 1929	1886 1929	1845 1855 1871 1875 1897	1797 1800 1809 1819 1822 1825 1843	1766 1777 1788 1797 1809 1822	1786 1800 1809 1825 1833 1843 1849 1865 1897 1905 1913 1929	1886 1929

Table 4. - Dates of fires from sampled trees.

The mean fire return interval for the refuge was determined to be about 14 years with the range between fires ranging from 3 years to 43 years and a standard deviation of 9.7. Agee recommends a minimum of 20 samples. The initial sample size needed for a specified level of precision can be calculated by using the following formula:

$$n = \frac{(Z\alpha)^2 (S)^2}{(B)^2}$$

Where:

n = The uncorrected sample size estimate.

Z_α= The standard normal coefficient from Table of standard normal deviates for various confidence levels (P. 346, Elzinga, et al, 1998)

S = The standard deviation.

B = The desired precision level expressed as half of the maximum acceptable confidence interval width.

Given the results from the study of fire scars in Bear Valley, an estimate of the mean return interval and population size with 95% confidence intervals that are within 20% of the estimated true value can be calculated.

Results of sampling:
Mean ($\bar{x}$) = 14 years/interval.
Standard deviation (S) = 9.7

Given:
The desired confidence level is 95% so the appropriate Z_α from the table (P.346, Elzinga, Et. al, 1998) = 1.96. The desired confidence interval width is 20% (0.20) of the estimated true value. Since the estimated true value is 14 years/interval, the desired confidence interval (B) = 14 x 0.20 = 2.8

$$n = \frac{(1.96)^2 (9.7)^2}{(2.8)^2} = 46.1$$

This gives an uncorrected sample size value. Sample size correction tables (Pp 349-350, Elzinga, Et al, 1998) were used to estimate that the corrected sample size necessary to meet the desired confidence levels would be 60 samples.

Since only 39 fire intervals were counted in the fire history study, 21 more samples would be needed to meet the 95% confidence level. With more samples, it is probable that the mean fire return interval would actually decrease. Not every fire scars every tree and the probability of missing fires is high with the small sample size used.

Although the data does not meet the set confidence level, it is fairly apparent from the mean fire return interval that the refuge would fall into the frequent light surface fire (1-25 year return intervals) as described by Agee (1993).

Fire Occurrence:

One way to determine fire risk is to determine annual fire occurrence. Fire occurrence was studied to determine the annual fire frequency by size class. This information was used to calculate long term fire risk.

The Fish and Wildlife Service did not assume fire suppression responsibilities for the Bear Valley NWR until the early 1990's. The Oregon Department of Forestry provided fire protection for the area prior to an active suppression program by the Fish and Wildlife Service. Oregon Department of Forestry fire records dating from 1970-1998 were used for fire occurrence information. An area larger than the actual refuge was used to study fire occurrence. Within this larger area of interest, it was assumed that fires could respond to fuels, weather and/or topography and burn onto the refuge.

Within the Bear Valley fire occurrence area, a total of 183 fires occurred between 1970 and 1998. Of this total, 76 (41.5%) fires were human caused and 107 (58.5%) fires were lightning caused. The community of Keno and several subdivisions outside of Keno are located in forested settings within this boundary. Undoubtedly this wildland-urban interface condition explains the high percentage of human-caused fires within the study area.

	Human Caused	Lightning Caused	Total
Class A Fires (0-0.25 acre)	54	93	147
Class B Fires (0.26-9.9 acres)	17	11	28
Class C Fires (10-99.9 acres)	3	2	5
Class D Fires (100-299.9 acres)	1	0	1
Class E Fires (300-999.9 acres)	1	1	1
Total	76	107	183

Table 5. - Fire occurrence for Bear Valley area 1970-1998

	Human Caused	Lightning Caused	Total Fires/Year
Class A Fires (0-0.25 acre) per year	1.93	3.32	5.25
Class B Fires (0.26-9.9 acres) per year	0.61	0.39	1.00
Class C Fires (10-99.9 acres) per year	0.11	0.07	0.18
Class D Fires (100-299.9 acres) per year	0.03	0	0.03
Class E Fires (300-999.9 acres) per year	0.03	0.03	0.06
Total	2.71	3.81	6.52

Table 6. - Fires per year in the Bear Valley area (1970-1998)

Fire Probability Assessment:

The computer program PROBACRE, which produces probability estimates based on the Poisson distribution, was used to assess the long term risk of fire. The equation for the Poisson probability distribution is:

$$P(N) = \frac{(\lambda)^N (e)^{-\lambda}}{N!}$$

Where:
P is the probability of (N) fires.
λ is the population mean number of occurrences per unit time or rate.
e is the exponential of the mean.
N is the specific number of occurrences over the period of time.
N! factorial.

Annual fire frequencies were obtained from fire occurrence records. Size classes used for the PROBACRE calculations were the midpoints for the fire size classes, A (0-.25) 0 acres; B (.26-9.9) 5 acres; C (10-99.9) 50 acres; D (100-299.9) 200 acres; and E (300-999.9) 700 acres. The time period for probability estimates was set at 20 years. PROBACRE outputs are shown in Table X.

SIZE	FIRE FREQUENCY		PROBABILITY OF NUMBER OF FIRES PER PERIOD					
CLASS	ANNUAL	PERIOD	NONE	1	2	3	4	>4
0	5.250	105.000	0.000000	0.000000	0.000000	0.000000	0.000000	1.0000
5	1.000	20.000	0.000000	0.000000	0.000000	0.000003	0.000014	1.0000
50	0.180	3.600	0.027324	0.098365	0.177058	0.212469	0.191222	0.2936
200	0.030	0.600	0.548812	0.329287	0.098786	0.019757	0.002964	0.0004
700	0.060	1.200	0.301194	0.361433	0.216860	0.086744	0.026023	0.0077
PROBABILITY OF EXCEEDING			50 ACRE THRESHOLD IN			20 YEARS IS 1.00000		
PROBABILITY OF EXCEEDING			100 ACRE THRESHOLD IN			20 YEARS IS 1.00000		
PROBABILITY OF EXCEEDING			500 ACRE THRESHOLD IN			20 YEARS IS 0.83523		
PROBABILITY OF EXCEEDING			1,000 ACRE THRESHOLD IN			20 YEARS IS 0.66289		

Table 7. - PROBACRE outputs

Weather Analysis:

Seldom Remote Automated Weather Station (RAWS), located on the Winema National Forest, was used as the representative weather station for the Bear Valley NWR. The elevation of the Seldom RAWS is 4,879 feet with similar vegetation to Bear Valley.

Weather records for the Seldom RAWS were extracted from the Kansas City Weather Information Management System (KCWIMS) database. The records used included data from 1985 through 1998. This data was input into the PCFIRDAT and PCSEASON software and used to identify the 50th percentile (average weather)and 90th percentile (average severe weather) parameters.

Parameter	50th Percentile	90th Percentile
1 Hour Fuel Moisture	7%	5%
10 Hour Fuel Moisture	10%	8%
100 Hour Fuel Moisture	14%	13%
Live Herb Fuel Moisture	90%	41%
Live Woody Fuel Moisture	112%	76%
Wind Speed	6 MPH	9 MPH
Dry Bulb Temperature	70	84

Table 8. - Seldom RAWS 50th and 90th percentile weather parameters.

Fire Behavior Modeling:

BEHAVE was used to predict fire behavior for both average (50th percentile) and severe (90th percentile) weather conditions. BEHAVE assumes a spreading surface fire in a continuous fuel bed. It does not consider crown fuels and will not model crown fires.

BEHAVE runs were completed for both fuel model 10 (current condition) and fuel model 9 (preferred condition). As determined in the fuels section, a fuel model 10 will actually under predict fire behavior expected from a fire burning in the current condition, and a fuel model 9 will over predict fire behavior for a fire burning in the preferred condition. For this study, it is assumed that the fuel models will accurately predict fire behavior for the conditions. A future need to fine tune fire behavior predictions would be to develop and test models using the FUEL subsystem of BEHAVE.

	FM 9 (50th %)	FM 9 (90th %)	FM 10 (50th %)	FM 10 (90th %)
Rate of Spread , CH/H	12	26	11	25
Heat per Unit Area, BTU/SQFT	354	390	1211	1354
Fireline Intensity, BTU/FT/S	77	186	236	613
Flame Length, FT	3.3	5.0	5.6	8.6
Reaction Intensity, BTU/SQFT/M	2292	2521	5565	6223
Effective Windspeed, MI/H	6.4	9.3	6.5	9.4

Table 9. - BEHAVE results for fuel models 9 and 10 under average and severe weather conditions (Andrews and Chase, 1997).

BEHAVE results for fuel model 10 at 90th percentile weather predict 9 foot flame lengths. Results for fuel model 9 at 90th percentile weather predict 5 foot flame lengths. Flame lengths will be reduced by almost one half if the fuel characteristics are changed from a fuel model 10 to a fuel model 9. With reduced flame lengths, fires could be controlled easier and damage to stands would likely be less. Reducing the current fuel loading would decrease flame lengths and fireline intensity. Damage to the stands would be less.

Crown Fire Assessment:

Since BEHAVE does not consider crown fuels, fire behavior will be under predicted in situations where fire may reach the crowns of the trees. Rothermel developed nomograms for predicting crown fire behavior as a response to this limitation (Rothermel, 1991). By adding the crown fuel loading to the fuel loading for fuel model 10 the actual fuel loading (23.48 tons/acre) may be better represented by a fuel model 12. Crown fuel loading was determined from Rothermel by using stand exam data and interpolating.

Fuel Model 12	50th % Weather	90th % Weather
Rate of Spread, CH/H	17	28
Heat per Unit Area, BTU/SQFT	2112	2226
Fireline Intensity, BTU/FT/S	645	1131
Flame Length, FT	8.8	11.4
Reaction Intensity, BTU/SQFT/M	6294	6634
Effective Windspeed, MI/H	6.7	9.7

Table 10. - BEHAVE results for fuel model 12 under average and severe weather conditions (Andrews and Chase, 1997).

Using a fuel model 10 and adding 1.1 tons per acre for 4-inch crown fuel loading, Rothermel's nomograms predict 35-foot flame lengths when using a 10 mi/h 20-foot wind and a 30% slope.

Fire Effects:

Fire effects are largely determined by fire intensity and fire severity. Fire intensity is the rate of heat release, per unit time per unit length or fire front (Btu/sec/ft). Fire intensity depends on the rate of spread, heat of combustion, and the total amount of fuel consumed. Fire intensity accounts for the convective heat that goes up. Fire effects on the overstory are largely determined by intensity. Fire severity is the amount of conductive and radiant heat that goes down. Fire effects on the understory are largely determined by severity. (Saveland and Bunting, 1987) Fire severity is often associated with fuels directly on the surface of the ground and organic soil layers.

Both intensity and severity will affect a timber stand. Higher intensities can result in scorch to the crown, which can reduce photosynthesis. Damage to the bole or roots of a tree can impair water and nutrient transport. Fire may also result in reduced competition and increased nutrient availability. High severity fires may cause excessive soil heating which can destroy organic layers and damage root systems. Mineral soil exposed by a high severity fire may provide a favorable seedbed for the establishment of Douglas-fir and ponderosa pine seedlings. (Walstad et al. 1990; Miller and Findley, 1994) There may be both negative and positive effects on tree growth from fire.

Ponderosa pine and Douglas-fir have evolved in a fire environment and have developed mechanisms which protect them from the heat of a fire. Thick bark, deep roots, and high crowns help make these trees fairly fire resistant. Ponderosa pine boast high foliar moisture content and large protected buds. These adaptations allow Douglas-fir and ponderosa pine to be classified as resistors (Agee, 1993) and are able to survive low intensity fires.

White fir and incense cedar are less fire resistant. They have thinner bark, shallow roots and low, dense crowns. White fir and incense cedar are less likely to survive low intensity fires.

Direct mortality caused by fireline intensity is the most important fire effect for this study. The goal of this project is to protect roost trees from catastrophic wildfire. Mortality in timber stands can be easily predicted and measured. Other fire effects are harder to predict. The effects fire severity may have on factors that influence tree growth, such as nutrient cycling and root system development are fairly nebulous.

The First Order Fire Effects Model (Keane, et. al, 1995) was utilized to calculate the probability of stand mortality for the stands in Bear Valley. FOFEM can calculate mortality probabilities for specific tree species by diameter size classes. The inputs required by FOFEM to calculate mortality are stand information and flame length which is an indication of fireline intensity. Stand exam data from the habitat management plan was used . Flame lengths from BEHAVE outputs were used. FOFEM runs were completed for both fuel model 10 (current stand condition) and fuel model 9 (desired condition). It is particularly important to predict mortality for trees over 14" in diameter at breast height (DBH), as these are the trees most likely utilized as roost trees.

		0-6"DBH		7-10" DBH		11-14" DBH		>14" DBH		Total	
		50 %	90%	50%	90%	50%	90%	50%	90%	50%	90%
Douglas-fir	**Pre-fire**	75	75	28	28	14	14	9	9	126	126
	Post-fire	1	1	3	0	8	0	6	0	18	1
Ponderosa pine	**Pre-fire**	49	49	25	25	8	8	4	4	86	86
	Post-fire	11	3	19	4	7	4	4	2	41	13
Incense cedar	**Pre-fire**	24	24	4	4	1	1	1	1	30	30
	Post-fire	0	0	1	0	1	0	1	0	3	0
Sugar pine	**Pre-fire**	3	3	0	0	0	0	0	0	3	3
	Post-fire	0	0	0	0	0	0	0	0	0	0
White fir	**Pre-fire**	76	76	22	22	8	8	7	7	113	113
	Post-fire	1	0	5	0	5	0	5	0	16	0
Total	**Pre-fire**	227	227	79	79	31	31	21	21	358	358
	Post-fire	13	4	28	4	21	4	16	2	78	14

Table 11. - Comparison of pre and post fire trees per acre by diameter class for 50th and 90th weather parameters - Fuel Model 10 - current condition.

Table 11 represents the current fuel model 10 condition. Only 4% of the trees could be expected to survive a fire occurring under 90th percentile weather conditions in these stands. 22% of the trees would survive a fire during 50th percentile weather conditions. While 76% of the large diameter trees would survive a 50th percentile fire, only 9% of these large trees would survive a 90th percentile fire. No large diameter Douglas-fir trees would survive a fire under 90th percentile weather.

		0-6"DBH		7-10" DBH		11-14" DBH		>14 " DBH		Total	
		50 %	90%	50%	90%	50%	90%	50%	90%	50%	90%
Douglas-fir	**Pre-fire**	75	75	28	28	14	14	9	9	126	126
	Post-fire	25	1	22	8	13	10	8	7	68	26
Ponderosa pine	**Pre-fire**	49	49	25	25	8	8	4	4	86	86
	Post-fire	32	22	20	20	7	7	4	4	63	53
Incense cedar	**Pre-fire**	24	24	4	4	1	1	1	1	30	30
	Post-fire	8	0	2	1	1	1	1	1	12	3
Sugar pine	**Pre-fire**	3	3	0	0	0	0	0	0	3	3
	Post-fire	1	0	0	0	0	0	0	0	1	0
White fir	**Pre-fire**	76	76	22	22	8	8	7	7	113	113
	Post-fire	24	2	13	8	6	6	5	5	48	21
Total	**Pre-fire**	227	227	79	79	31	31	21	21	358	358
	Post-fire	90	25	57	37	27	24	18	17	192	103

Table 12. - Comparison of pre and post fire trees per acre by diameter class for 50th and 90th weather parameters - Fuel Model 9.

Table 12 represents the fuel model 9 condition. This table is for comparison purposes only. This table shows the same number of pre-fire trees as the fuel model ten table (Table 11). Actually, the fuel model 9 condition would have far fewer pre-fire trees. Percent mortality is a better way to describe the results. 29% of the trees would survive a fire occurring under severe weather conditions. 54% of the trees in a fuel model 9 can be expected to survive a fire during average weather conditions. 81-85% of the large diameter trees (>14" DBH) that are potential roost trees would survive depending on the weather condition.

Fires occurring in fuel model 9 conditions will result in less mortality of large diameter trees preferred by roosting eagles than fires occurring in fuel model 10 conditions under both average and severe conditions.

Fire Safe Forests:

As protecting roost trees is the goal of this paper, it is important to identify how forests containing roost trees can be made fire safe. The concept of a fire safe forest is one that will not carry crown fire (Agee, 1996). There are three steps to managing for a fire safe forests:

1) Keep the critical level of fireline intensity (Io) high relative to the actual fireline intensity (I)

2) Keep I (Actual fireline intensity) low by keeping surface fuels at low levels.

3) Manage mass flow rate of fuel (S) into fire below critical level (So).

Critical fireline intensity:

Critical fireline intensity can be calculated by the equation:

$$I_O = (Czh)^{2/3}$$

where

Io = critical surface intensity
C = empirical constant
z = height of crown base
h = heat of ignition (largely a function of crown moisture content)

Critical surface intensity can be calculated for a range of heights of crown base and foliar moisture contents. The values represent minimum levels of fireline intensity necessary to initiate a crown fire.

Foliar Moisture Content %	**Height of Crown Base (m)**						
	2	**4**	**6**	**8**	**12**	**16**	**20**
70	308	871	1600	2463	4526	6968	9737
80	362	1024	1881	2897	5321	8193	11449
90	419	1185	2178	3353	6159	9482	13252
100	479	1354	2488	3830	7036	10833	15140
120	606	1714	3148	4847	8904	13709	19159

Table 13. - Critical levels of fireline intensity associated with initiation of crown fire activity in coniferous stands (reprinted from: The Influence of Forest Structure on Fire Behavior, table 2, page 58, Agee, 1996).

Foliar Moisture Content %	**Height of Crown Base meters (nearest foot)**						
	2 (6)	**4 (13)**	**6 (20)**	**8 (26)**	**12 (40)**	**16 (53)**	**20 (66)**
70	1.1 (4)	1.8 (6)	2.3 (8)	2.8 (9)	3.7 (12)	4.6 (15)	5.3 (17)
80	1.2(4)	1.9 (6)	2.5 (8)	3.0 (10)	4.0 (13)	4.9 (16)	5.7 (19)
90	1.3(4)	2.0 (7)	2.7 (9)	3.3 (10)	4.3 (14)	5.3 (17)	6.1 (20)
100	1.3(4)	2.1 (7)	2.8 (9)	3.4 (11)	4.6 (15)	5.6 (18)	6.5 (21)
120	1.5(4)	2.4 (8)	3.2 (10)	3.9 (13)	5.1 (17)	6.2 (21)	7.3 (24)

Table 14. - Flame lengths associated with critical levels of fireline intensity from Table XX using Byrum's (1959) equation (reprinted from: The Influence of Forest Structure on Fire Behavior, table 2, page 58, Agee, 1996).

If the height of crown base for a stand and the foliar moisture content are known then critical levels of fireline intensity can be calculated. If one considers the most extreme conditions of 70% live foliar moisture content and a 6 foot height of crown base from Table 13 above, the critical flame length is 4 feet. From Agee 50th percentile live fuel moisture is 90% and 90th percentile live fuel moisture is 41%. If the height of crown base is only 6 feet, then the critical level of fireline intensity would easily be exceeded during severe conditions. By raising the height of crown base to 20 feet, the critical level of fireline intensity is doubled. Pruning trees and thinning under story trees would raise the height of crown base.

The average height of crown base is currently below 6 feet in the roost areas in Bear Valley. Proposed thinning would raise the height to crown base. Pruning is the best method to raise the height to crown base. Some pruning of leave trees will occur from falling operations and contact by mechanized logging equipment. Some hand pruning would be necessary to double the critical level of fireline intensity in Bear Valley.

Actual Fireline Intensity:

Actual fireline intensity is determined by surface fuels. If surface fuels are kept to a low level, then fireline intensity will remain low. Common methods of managing surface fuels include, removal by thinning trees, adjusting fuel arrangement to produce a less flammable fuel bed and encouraging live under story vegetation to raise the average moisture content of surface fuels.

Even though thinning in Bear Valley would require whole tree yarding, breakage of tops and branches would add some flammable fuels to the fuel bed. Pruning, either intentional or accidental, would add additional fuel. The fuel conditions would change to a slash fuel model. Burning would be effective in reducing the fuel added from thinning and pruning, as well as the natural fuel accumulation. Fuels could be re-arranged by pulling material away from the base of trees. By performing pull back, lower fireline intensities would occur directly under trees.

Mass Flow Rate of Fuel:

Mass flow rate is described by the equation:

$S=Rd=E/h$

Where:

- S = Mass flow rate (mass per unit cross section area of crown per unit time)
- R = Rate of spread
- d = crown bulk density
- E = net horizontal heat flux
- h = heat of ignition

Mass flow rate is described as a mass of fuel moving by a stationary flaming front. The mass flow rate below which crown fire will not occur is determined by combinations of the rate of spread and crown bulk density. Even with favorable crown fire conditions, a mass flow rate less than 0.05 will limit crown fire initiation.

Agee established three arbitrary rate of spread (R) thresholds. R1 was described as the maximum rate of spread for fires (1.35 m sec) from a study by Rothermel. R2, the middle range, was the maximum rate of spread (0.67 m sec) for a set of wind driven fires in the same study. R3 was the average maximum rate of spread (0.40 m sec) for the same set of fires used for R2. As the critical mass flow rate (So) is equal to 0.05, then crown bulk densities (d) will be as shown below:

R1(1.35) x d (0.037) = 0.05
R2(0.67) x d (0.074) = 0.05
R3(0.40) x d (0.125) = 0.05

Crown bulk densities (d)can be calculated from stand exam information. According to Agee, the critical crown bulk density is 0.10 km m3. Typically unthinned stands will exceed the critical level. Crown bulk densities (d) for unthinned stands in Bear Valley are estimated to be greater then 0.10 km m3. From critical crown bulk density tables, thinned stands of ponderosa pine equal 0.015 and thinned stands of Douglas-fir equal 0.037 km m3. Thinning would reduce the critical bulk density to below 0.10 km m3 in Bear Valley

Alternatives:

Two alternatives were considered. The first alternative would maintain the current condition. The other alternative would treat the roost areas with a combination of thinning, pruning and burning.

Current Condition:

Habitat improvement would not be implemented under this alternative. Natural succession would be allowed to occur.

Fuel loadings, currently at 17 tons per acre, would increase over time until consumed by a wildfire. Crown base heights would remain low due to increased incidence of shade tolerant white fir. Future wildfires will be increasingly difficult to control with suppression forces. Fire severity will increase with high fuel loadings. Crown fires are likely to occur as crown base heights will remain low.

Thin, Prune and Burn:

Under this condition, stands within roost areas (1,800 acres) would be commercially thinned to an average spacing of 20 feet between trees. Stands would be reduced from an average of 358 stems per acre to an average of 121 stems per acre. Douglas-fir and ponderosa pine would be selected as leave trees over other species of tree. Most trees over 14 " in diameter

would be left. Most of the dead and down material between 3 and 20 inches in diameter would be removed from the site. Whole tree yarding would occur. Fuel loadings would increase after logging in the less than three inch material, but would decrease in the larger diameter material. Average fuel loadings after thinning, but before burning are estimated from photo series to be 12 tons per acre.

Many of the leave trees would be pruned during harvest by mechanical equipment and falling trees. Follow-up pruning up to 18 feet on leave trees would occur where needed utilizing hand saws. A pull back of 10 feet for branches severed by pruning would also occur

Prescribed fire would be applied to all acres. It may be necessary to burn areas more than once to get to the desired lower fuel level. Fuel model 9 will best describe the desired fuel characteristics of this alternative.

Evaluation of Alternatives:

Alternatives will be evaluated using the following criteria:
1) Maintenance of bald eagle habitat.
2) Economics.
3) Fire hazard reduction.

Maintenance of Bald Eagle Habitat:

Current Condition:

Timber stand densities, which are already overstocked, will continue to increase with this alternative. White fir will encroach into more of the area that has historically been a ponderosa pine/Douglas-fir forest type. Existing roost trees will be more susceptible to stress from competition, insect infestations and disease. Opportunities for establishing replacement roost trees will decrease as canopy cover increases. Stand conditions will favor the establishment of shade tolerant white fir over ponderosa pine and Douglas-fir. Tightly spaced stands will not favor the open branching growth characteristic that eagles prefer.

Bald eagle habitat will decline in quantity and quality. Competition, disease, insect infestations and stand replacement fires will decrease the number of old, large diameter trees available for roosting. White fir, an unfavorable tree for roosting will become more dominant.

Thin, Prune and Burn:

Timber stand densities will be reduced from 358 trees per acre to 121 trees per acre. Existing roost trees, and ponderosa pine and Douglas-fir will be favored in a selective thinning process. There will be less competition for the existing roost trees, and they will be more resistant to insect infestations and disease. Seedling establishment of ponderosa pine and Douglas-fir will be more likely to occur in an open, widely spaced stand. Open stands are more likely to create trees with the open branches preferred by eagles.

Bald eagle habitat will be maintained. Large diameter ponderosa pine and Douglas-fir will be the dominant trees. With less competition, smaller diameter ponderosa pine and Douglas-fir will grow quicker to become roost trees.

Economic Comparison:

Current Condition:

Using the 90th percentile BEHAVE outputs for a fuel model 10, it was estimated that a crowning fire could burn at least 900 acres within the Bear Valley Refuge in the first burning period. Rothermel's crown fire nomograms predict 35 foot flame lengths which would make control efforts at the head of the fire ineffective. 900 acres will be the size of fire expected under severe conditions for the maintaining current condition alternative.

Thin, Prune and Burn:

BEHAVE indicates that a fire burning in a fuel model 9 under severe conditions could burn at least 800 acres in seven hours. With the 5 foot flame lengths predicted for a fuel model 9 and no crown fire, ground suppression forces would be much more likely to contain a fire at a smaller acreage. The production rate for the six engines and the one dozer that would be dispatched to a fire on the refuge is a combined 122 chains per hour (Schmidt and Rinehart, 1982). Forward spread of a fire under fuel model 9 severe conditions is predicted by BEHAVE to be 26 chains per hour. The size of a fire in one hour is predicted to be 17 acres with a 58 chain perimeter. As engines and dozers are both effective against 5 foot flame lengths, suppression forces could easily contain a fire within an hour with only a small acreage increase. Assuming that it will take all resources one hour to reach the fire, the expected fire size under severe conditions will be 20 acres.

Suppression Costs:

As the Fish and Wildlife Service does not utilize the National Fire Management Analysis System (NFMAS), estimates of suppression costs were very hard to obtain within the agency. The Bear Valley Refuge is surrounded by land protected by the Oregon Department of Forestry. While management priorities and suppression tactics and strategies may be different for the two agencies, it is assumed for this study that suppression costs are the same on Fish and Wildlife property as they are on adjoining Oregon Department of Forestry protected land. Average acre costs for commercial forest as estimated by the Oregon Department of Forestry were used for suppression costs.

Upper Acre Limit	Cost Per Acre
.25	$1848
10	$1366
100	$2474
300	$1730
1000	$1883
9999999	$85

Table 15. - Oregon Department of Forestry Average Acre Costs for Klamath Area - 1997

As the Oregon Department of Forestry costs per acre were from 1997, they need to be brought forward to 1999 costs. The following compounding formula for future values was used.

$$FC = P(1+i)^n$$

Where:

FC = Future cost (cost at time of treatment)
P = Present cost (1997 cost)
i = Interest rate
n = Number of years cost are being brought forward

	Current Condition	Thin, Prune and Burn
Present Cost (1997cost)	$1883/acre for a 900 acre fire	$2474/acre for a 20 acre fire
Interest Rate	4%	4%
Number of Years Costs Brought Forward	2	2
Future Cost (1999 cost)	$2037/acre x 900 = **$1,833,300**	2676/acre X 20 = **$53,520**

Table 16. - Suppression Costs for Alternatives

Net Value Change (NVC):

The benefits that will occur from protecting Bald Eagle habitat are very hard to quantify in dollar values. By examining the timber sale in progress on the Refuge, one can estimate the value of the commercial timber by dividing the acreage by the sale price. In the case of the current sale, the sale sold for $48,663 (1999 prices)and covers 246 acres. The value of the timber is $198 per acres. It would be difficult to place a value on the remaining trees and other resources, so the commercial timber value plus $1.00 ($199) was used to value the NVC for Bear Valley. Commercial timber in Bear Valley is considered all stems between 7 and 14 inches DBH. It is assumed that commercial timber values are uniform on every acre within the refuge. While timber killed by a fire will retain some salvage value, it is assumed that salvage logging would not occur within the refuge in the event of a fire.

Fofem mortality predictions for the current condition indicate that only a small percentage of the commercial ponderosa pine would survive a fire under severe conditions. If crown fire flame lengths of 35 feet are considered, complete mortality is certain under the current condition. Therefore 100% of the timber value is lost.

For the thin, prune and burn alternative, Fofem predicts a 62% mortality for the commercial timber size classes. 62% of $199 equals $123.

	Current Condition	Thin, Prune and Burn
Net Value Change (NVC)	$199 X 900 = **$179,100**	$123 X 20 = **$2,460**

Table 17. - Net Value Change for Alternatives

X-Loss (NVC + Suppression Costs):

	Current Condition	Thin, Prune and Burn
X-Loss (NVC + Suppression)	$1,833,300 + $179,100 = **$2,012,400**	$53,500 + $2,460 = **$55,960**

Table 18. - X-Loss For Alternatives

Treatment Costs:

At the present time, the cost of thinning is close to the value of the commercial timber being removed. Therefore it was assumed for this study that there is no cost to the Fish and Wildlife Service for any thinning done in Bear Valley. As much of the material that would be removed is of small diameter, it is possible that timber markets may dictate that the Fish and Wildlife Service will have to pay to have small material removed in the future.

Treatment costs for pruning, pull back and prescribed burning were calculated utilizing the Klamath Basin Interagency Prescribed Fire Cooperative Task Order Worksheet.

Cost for pruning was based on the fact that some of the branches will be knocked off during logging operations. Cost was based on 50 to 100 trees per acre which would need to be pruned, and was calculated to be $153 per acre.

Cost for pull back of pruning slash was based on the same level of trees per acre as pruning. The cost was estimated at $90.50 per acre.
Costs for prescribed underburning and mop-up in the conditions found in Bear Valley were $190 per acre. Existing roads and skid trails can be used for firelines, so no cost of line construction was included.

A 20% planning and contract administration cost was added to the total treatment cost.

Pruning: $153/acre X 1,800 acres = $275,400
Pull Back: $90.50/acre X 1,800 acres = $162,900
Prescribed Burning: $190/acre X 1,800 acres = $342,000

Treatment Cost = $275,000 + $162,900 + $342,000 = $779,900

Planning/Admin Cost = $779,900 X 0.2 = $155,980

Total Treatment Cost = $779,900 + $155,980 = **$935,880**

Total Cost + Loss:

	Current Condition	Thin, Prune and Burn
Total Cost + Loss	$1,833,300 + $179,100 = **$2,012,400**	$53,500 + $2,460 + $935,880 = **$991,840**

Table 19. - Total Cost + Loss For Alternatives

Comparison of Current Condition vs Thin, Prune and Burn:

Table 20 shows the comparison of maintaining the current condition to the recommended prescribed burn and prune treatment. It summarizes the predicted acres burned, NVC, cost of suppression and cost of treatment to show the marginal net benefit of active versus inactive management.

	Current Condition	Thin, Prune and Burn
Fire Size (acres)	900	20
Suppression Cost	$1,833,300	$53,520
NVC	$179,100	$2,460
X-Loss (NVC+Supp Cost)	$2,012,400	$55,960
Treatment Cost	0	$935,880
Total Cost + Loss	$2,012,400	$991,840
Net Marginal Benefit	0	$2,012,400 - $991,840 = **$1,020,560**

Table 20. - Economic Comparison of Alternatives

The above calculations assume that treatment objectives could be met in one burn entry. Cost for another entry would increase the treatment cost and therefore reduce the net marginal benefit for the thin, prune and burn alternative.

Cost for second entry (three years in the future):

$$FC = \$342,000(1+.04)^3 = \$384,703$$

Planning/Admin Cost: = $384,703 X 0.2 = $76,941

Total Cost For Second Entry = $384,703 + $76,941 = $461,644

Total Cost + Loss(Including Second Entry): = $55,960 + $935,880 + $461,644 = **$1,453,484**

Net Marginal Benefit(Including Second Entry): = $2,012,400 - $1,453,484 = **$558,916**

Fire Hazard Reduction:

Current Condition:

Fuel loading, which is currently 17 tons per acre will continue to increase. Crown base heights, which are currently low in the multi-canopied stands, would continue to be low. Under a fuel model 10, with a low crown base height condition, a wildfire starting under severe weather conditions is likely to result in a crowning fire that would be resistant to direct attack. BEHAVE predicts that a fire could burn at least 900 acres in a burning period under severe conditions. Fofem predicts that a 97% mortality would occur to timber stands from a fire burning in these conditions. At least 90% of the roost trees would directly die in a fire. With an increased fuel load over time, it is certain that a future fire could be even larger and cause more mortality.

Forests in this alternative are not fire safe. Low height to crown base (often below 6 feet in Bear Valley) means that the flame lengths indicating critical fireline intensity are as low as 4 feet. Flame lengths are currently predicted to exceed 5 feet even during average conditions. Predicted actual fireline intensities are quite high for a fuel model 10. Crown bulk densities, which are important for determining mass flow rates, are higher in unthinned stands than in thinned stands. This forest is susceptible to crown fire.

Thin, Prune and Burn:

Thinning would remove material by whole tree yarding. Broken tops and branches would add to the fuel loading by increasing the 0-3" material. However total fuel loading would decrease as most of the downed material greater than 3" would be removed from the unit. Pruning would increase the fuel loading again, particularly in the 0-3" range. Fuel from the pruning would be rearranged by pull back so that fire intensity at the base of trees would be minimized. Prescribed fire would be used to reduce the loading, and would be particularly effective for reducing the 0-3" material. Fuel loading is predicted to be 12 tons per acre after thinning and pruning, but before burning. Fuel loading will be less than 12 tons per acre after burning.

By changing the fuels, the fuel condition would be a fuel model 9. BEHAVE predicts that a fire staring in a fuel model 9 would have 5 foot flame lengths which could be directly attacked by engine crews and dozers. Crews could contain a fire within an hour at 20 acres. Fofem predicts that 70% of the trees would die in a fire under severe weather conditions, however, nearly 80% of the large diameter trees preferred for roosting would survive.

Forests would be much more fire safe in this alternative. Pruning would raise the height to crown base to 20 feet. Higher height to crown base will increase the critical level of fireline intensity. A 20 foot height to crown base would not indicate a crown fire situation with expected 5 foot flame lengths. Surface fuels would be reduced which would reduce actual fireline intensities. By maintaining a thinned ponderosa pine/Douglas-fir forest, the crown bulk densities will be less than 0.10. This forest will resist crown fire.

Matrix of Alternatives:

Decision-Making Criteria	Current Condition	Thin, Prune and Burn
Maintenance of Bald Eagle Habitat	Will decline in quality and quantity. No replacement habitat will be established.	Will maintain current level. Replacement habitat will establish.
Economics (Net Marginal Benefit)	0	$1,020,560 or $558,916 if a second burn entry is required.
Fire Hazard Reduction:		
Fuel Model	10	9
Fuel Load	17 Tons per Acre	<12 Tons per Acre
Flame Lengths (90th % weather)	>8 ft	5 ft
Expected Fire Size (90th % weather)	900 acres	20 acres
Stand Mortality (90th % weather)	97%	70%
Roost Tree Mortality (90th % weather)	90%	19%
Height to Crown Base	<6 ft	20 ft
Fireline Intensity (90th % weather)	613 BTU/FT/S	186 BTU/FT/S
Crown Bulk Densities	>0.10 kg m3	<0.10 kg m3
Resistance to Crown Fire	low	high

Table 21. - Matrix of Alternatives

Recommendation:

The thin, prune and burn alternative will maintain bald eagle habitat, has a positive net marginal value, and will reduce the hazard of a high severity and intensity fire.

Conclusion:

The fuel loading in Bear Valley Wildlife Refuge is estimated to be 19 tons per acre. Historically fires burned frequently and with low severity. The fire return interval is estimated to be 21 years, but is probably actually lower than this. Fires maintained an open forest with large, widely spaced trees. Fire resistant ponderosa pine and Douglas-fir were the dominant tree species.

Logging operations removed many of the largest trees (particularly the ponderosa pine). Fire suppression activities have allowed less fire resistant trees to encroach into the under story. White fir, which was historically a minor component of the ecosystem, is now the most common tree. Lack of fire has allowed an accumulation of ground, surface and ladder fuels to develop. This accumulation will allow fires in the current condition to burn at a higher intensity and severity than fires which historically burned in the area. Crown fire is likely to initiate because of low height to crown base. Currently, a fire burning under average weather conditions could result in a 78% mortality.

An evaluation of maintaining the current condition versus treatment shows the advantages of treatment. By implementing a thin, prune and burn strategy, eagle roosting habitat is maintained by reducing the fire hazard. An economic comparison has shown that treatment will produce a net marginal value far greater than maintaining the current condition.

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