A SILVICULTURAL PRESCRIPTION TO PROMOTE LONG-TERM FOREST HEALTH, FIRE RESILIENCY, AND WILDLIFE HABITAT IN A CENTRAL OREGON PONDEROSA PINE STAND

by

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Except where reference is made to the work of others, the work described in this Master of Forestry Paper is my own or was done in collaboration with my advisory committee.

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STAND DESCRIPTION SUMMARY

The Tenino stand, located on the Warm Springs Indian Reservation (WSIR) near Warm Springs, Oregon, is being considered for treatment that will promote long-term forest health, fire resiliency, and wildlife habitat. The management direction for this area is outlined in two WSIR documents: 1) Integrated Resources Management Plan for the Forested Area (CTWSIR 2001), and 2) Forest Management Implementation Plan (CTWSIR 2003). The stand is part of the wildlife land management zone and is allocated to the management of vegetation for the benefit of deer and elk. Timber harvesting is permitted with management practices directed toward the production of quality habitat for deer and elk. The stand is listed as part of management group 1 – ponderosa pine plant associations. This management group is one of the least productive on the WSIR with an estimated managed stand production potential of 200 board feet per acre per year (CTWSIR 2003).

The Tenino stand is comprised of four smaller stands with the following identification numbers: 9050016, 9050086, 9050165, and 9050185. Presently the combined 83.2-acre stand is primarily ponderosa pine (*Pinus ponderosa*) (30-120 years old) with excessive understory regeneration of pine. There are a few Douglas-fir (*Pseudotsuga menziesii*), western juniper (*Juniperus occidentalis*), and incense-cedar (*Calocedrus decurrens*) scattered throughout. Some ponderosa pine is naturally regenerating in the openings. Areas of older regeneration are in clumps up to 2 acres in size. The other two components of the stand are sapling/pole and small saw-log groups. The stand has been harvested over several years (1923, 1942, 1960, 1986, and 1999) that removed most of the overstory ponderosa pine and left a dense

understory of young, clumpy ponderosa pine. Damage caused by the western pine beetle (*Dendroctonus brevicomis*), mountain pine beetle (*D. ponderosae*), and the pine engraver (*Ips pini*), as well as injuries incurred during harvesting have affected many of the residual trees. Western dwarf mistletoe *(Arceuthobium campylopodum)* has also infected about 2% of the ponderosa pine. The stand has a relatively dense, young understory in clumps that are beginning to feel the effects of competition. The vertical structure is such that ladder fuels may cause a non-lethal fire to become catastrophic and stand replacing. The dense understory will continue to stagnate and create a major fire hazard if this stand is not treated.

ABIOTIC ENVIRONMENT

Location and Land Ownership

The stand is located on the Confederated Tribes of the Warm Springs Indian Reservation approximately 20 miles west of Warm Springs, OR. The legal description is T 19, R 11, S 20, 21. Access is from US highway 26 and WSIR forest roads P-200 and P-320. The WSIR covers over 1,000 square miles in the Deschutes River Drainage of Oregon (Figure 1). The west boundary lies near the summit ridge of the Cascade Mountains. The Metolius and the Deschutes Rivers make up the southern and eastern boundaries. The northern boundary trends slightly north of west, beginning near latitude 45 North on the Deschutes River and meeting the western boundary in the Cascades. The WSIR lies mostly in Jefferson and Wasco counties and includes small portions of Linn, Clackamas, and Marion counties. There are 440,781 acres of forested lands on the WSIR. The forest changes in species composition moving from east to west. The dry, open ponderosa pine stands, which include the Tenino stand, are found on the far eastern portion of the forestland adjacent to the range and sagebrush steppe areas (Figure 2). The WSIR is located in a region that is subject to frequent natural disturbances. Fire, flooding, windstorms, and insect attacks regularly cause mortality in the forest.

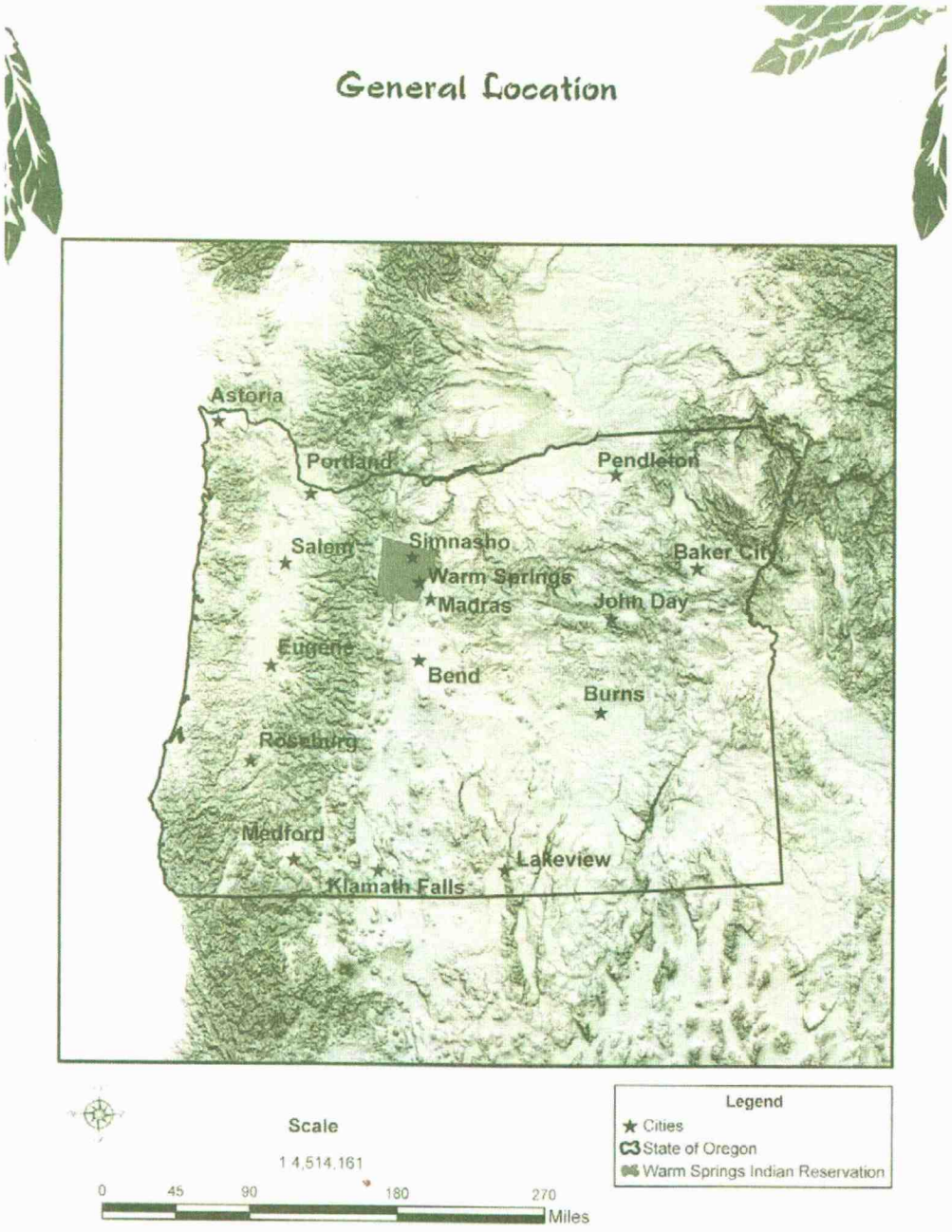

Figure 1: *General location of the Warm Springs Indian Reservation within the state of Oregon (graphic from CTWSIR 2003).*

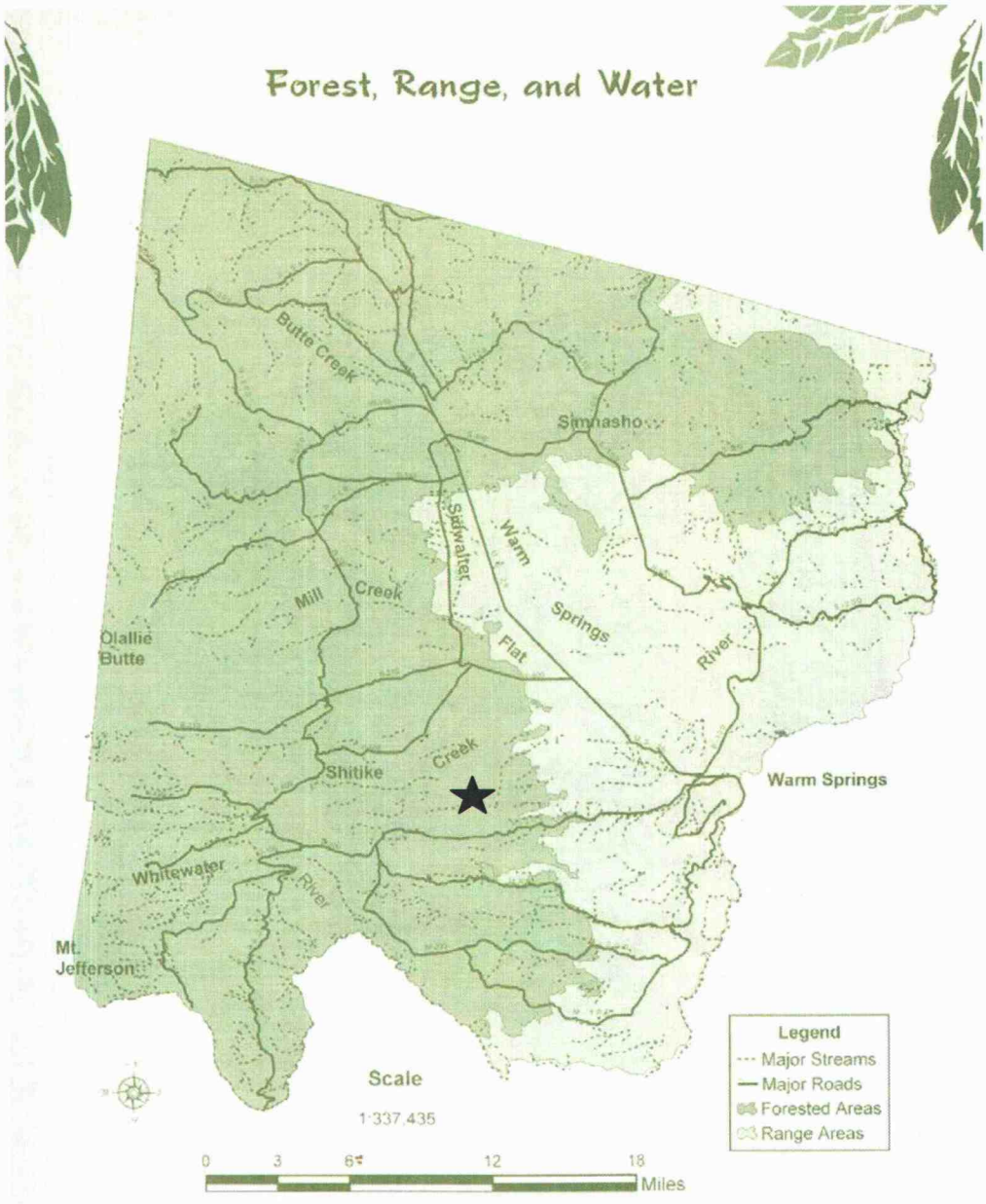

Figure 2: *Forest, range, and water classifications within the Warm Springs Indian Reservation (graphic from CTWSIR 2003). Note: star indicates approximate location of the Tenino stand.*

Climate

The climate is primarily continental with some moderating effect due to the relative proximity of the Pacific Ocean. The annual precipitation in the Cascade Range averages 120 inches, whereas the eastern two-thirds of the WSIR are in the rain shadow where precipitation averages less than 20 inches annually. Annual snowfall is about 200 inches at the crest of the Cascades but diminishes rapidly to about 15 inches at the lower elevations. The frost free period within the Tenino stand is approximately 80-110 days (NRCS 1993). Tables 1 and 2 contain a summary of the environmental conditions found in the Tenino stand. Precipitation and temperature measurements were made at Warm Springs, OR, elevation 1,500 feet, which is approximately 1,400 feet lower in elevation than the Tenino stand. In summer, the climate is generally arid, with little rainfall between May and September. The maximum temperatures can reach 100° F for many weeks in a row.

Table 1: *Environmental conditions found in the Tenino stand of the Warm Springs Indian Reservation.*

Elevation (ft)	2,800 – 3,000
Aspect (°)	40
Slope (%)	0 – 7, average 3.5
Precipitation (in)[1]	11 annually

Table 2: *Local temperature ranges (F°), recorded at Warm Springs, OR.*

Month	Minimum	Avg. Min.	Average	Avg. Max.	Maximum
January	-12	26	36	46	71
July	36	51	73	95	114

[1] Only 2.6 inches or 24% of the annual precipitation occurs May through September.

Soil Conditions

Soils within the Tenino stand are moderately deep (20-40 inches), rocky, and well drained. The soil type is characterized as Hehe-Teewee complex. The parent material is residuum and colluvium derived from andesite or basalt with an influence of volcanic ash. The soil profile consists of: 0-11 inches -- dark brown very stony loam; 11-19 inches -- dark brown very bouldery loam; 19-38 inches -- dark brown very bouldery clay loam; and >38 inches -- weathered andesite. Available water capacity is 2-6 inches with a potential rooting depth from 20-40 inches. Runoff is slow or medium with a slight to moderate hazard of erosion (NRCS 1993).

A visual soil disturbance survey was conducted to determine the existing soil conditions and the amount of area currently in skid trails. Initial observations indicated areas of significant compaction from previous ground-based harvesting operations. Table 3 lists the disturbance types and codes used during the survey.

Table 3: *Visual soil disturbance codes used during data collection. Adapted from McMahon (1995).*

DISTURBANCE TYPE	CODE
Undisturbed	
No evidence of machine or log passage, litter and understory intact	1
Shallow Disturbance	
Litter still in place, evidence of minor disruption	2
Litter removed, topsoil exposed	3
Litter and topsoil mixed	4
Evidence of tire, track, or log passage (imprint < 4 inches deep)	5
Deep Disturbance	
Topsoil removed, mineral soil exposed	6
Erosion feature (rill, gully, etc.)	7
Rutted, evidence of tire, track, or log passage	
4-8 inches deep	8
> 8 inches deep	9
Clarifiers	
Skid trail	10
Haul road	11
Non-soil (stumps, rocks)	12

The 83.2-acre stand was systematically divided into 16, approximately 5-acre subunits. Eight of the subunits were randomly selected for the visual disturbance survey. Within each subunit, 6 plot centers were identified from a systematic grid of the area, yielding 48 plot centers for the survey. This approach was used to establish a representative sample of each subunit. At each of the 48 plot centers, 2 random transect directions were established using a random number generator. Possible azimuths ranged from 20-360° in 20° intervals, yielding 18 possible directions. On each transect, using the point transect method (McMahon 1995), one visual disturbance observation was recorded at a point 10, 20, and 30-ft from plot center along the two transects. The study yielded 288 visual soil disturbance observations or approximately 7 per acre. Percentages of the observations in each disturbance category are shown in Figure 3. Only undisturbed (code 1) and skid trail (code 10) categories were observed during the survey. These results confirm the initial observation that the stand has been impacted by several previous mechanized entries resulting in 26% of the area containing skid trails.

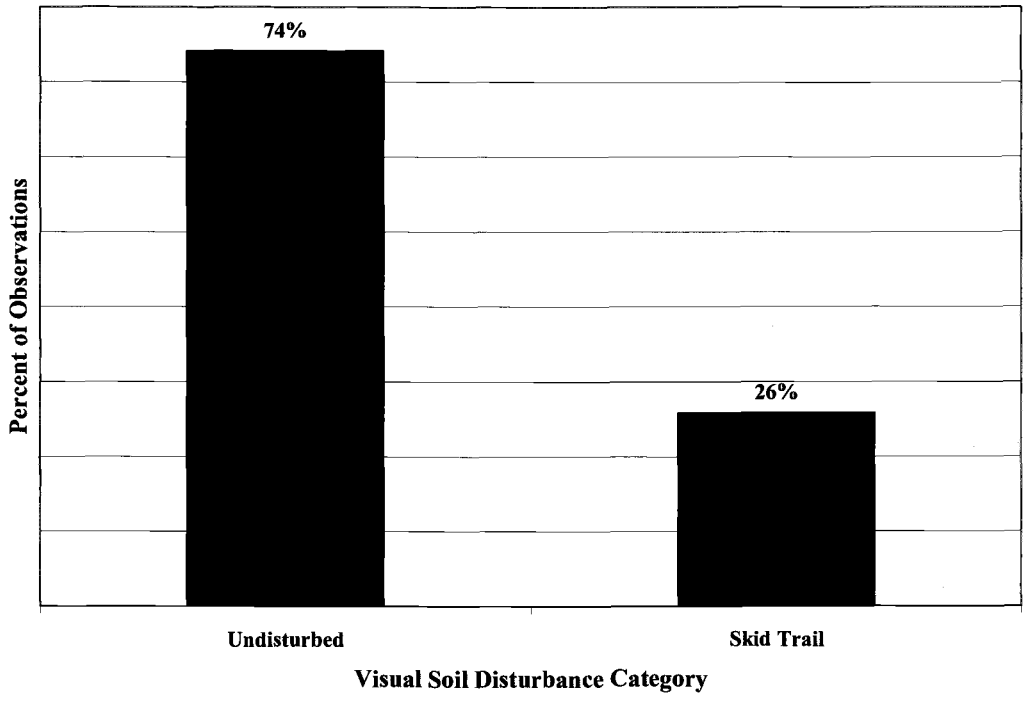

Figure 3: *Percent of observations recorded during the visual soil disturbance survey.*

Watershed

The Warm Springs River, Shitike Creek, Whitewater River, and Beaver Creek are the major drainages located within the WSIR boundaries. The mean annual streamflow from the WSIR averages 740 cubic feet per second (cfs) which is approximately 17% of the total flow of the Deschutes River. The Metolius River receives 180 cfs or 12% of its mean annual flow from the WSIR.

The Tenino stand is located in the Lower Shitike Creek watershed (Figure 4). There are no streams, ponds, or springs located in or near the stand. No significant increase in sedimentation is expected as a result of harvesting this stand.

WATERSHEDS

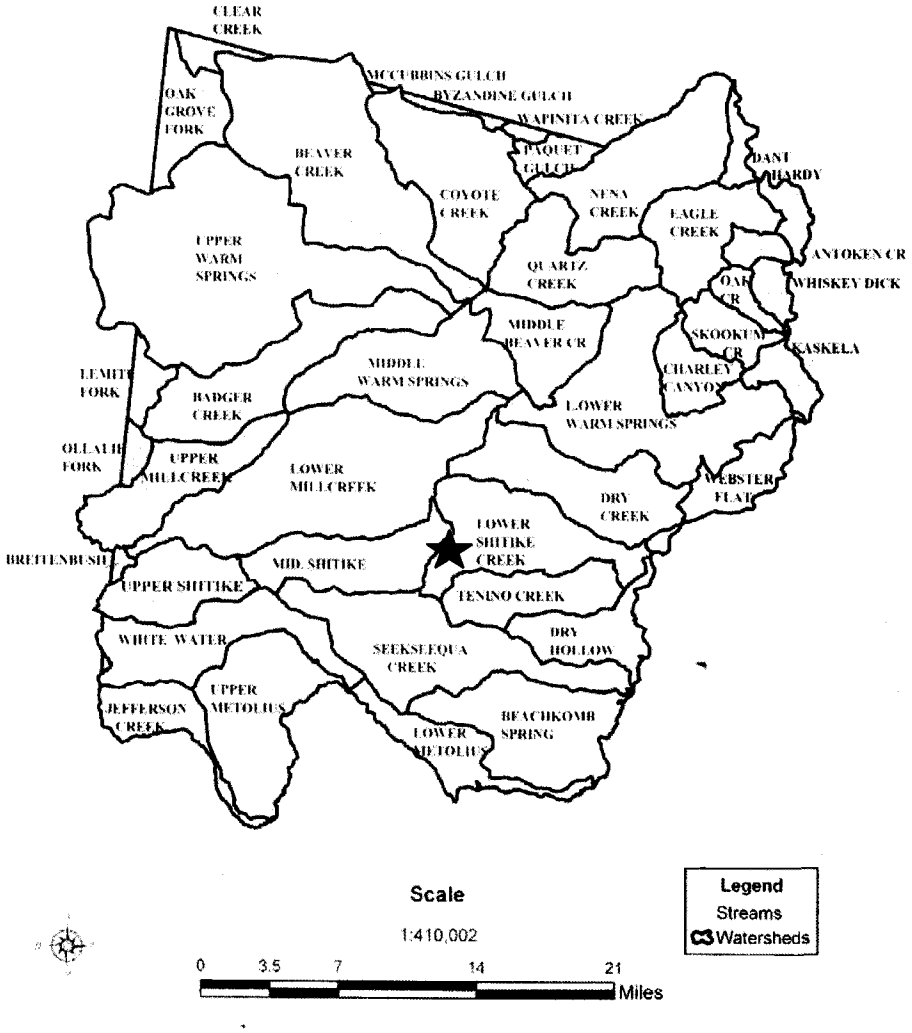

Figure 4: *Watersheds of the Warm Springs Indian Reservation. The Tenino stand is located in Lower Shitike Creek (graphic from CTWSIR 2001). Note: star indicates approximate location of the Tenino stand.*

BIOTIC ENVIRONMENT

Stand Treatment History

Logging history in the Tenino stand indicates several previous mechanized entries based on Keen's classification for selection and sanitation harvesting as well as individual tree marking (Keen 1936, 1943, 1946). Harvesting has been conducted over several years (1923, 1942, 1960, 1986, and 1999) that removed most of the overstory ponderosa pine and left the dense understory of young, clumpy ponderosa pine. The most recent harvesting in 1999, Big Wind Salvage, occurred after a wind event that blew down several overstory trees.

Historically this stand was composed of uneven-aged groups of large diameter trees (150-500 years old). The groups of large trees were mostly in clumps of ¼ to 2 acres in size. Past harvesting opened the stand, creating the present day three-age, three-size class structure. However, some areas are two-aged with poles and old growth. The Tenino stand was created primarily through harvesting and fire exclusion rather than insects and wildfire. Fire, which maintained ponderosa pine as a climax species, was excluded from the area in the early twentieth century. The fire suppression policy has prevented periodic surface fires from preparing necessary seed beds for regeneration. The exclusion of fire has also left the pole-sized and seedling/sampling-sized clumps overstocked and stagnated.

Plant Community

The plant community within the Tenino stand is classified as PIPO/PUTR-ARPA (ponderosa pine (*Pinus ponderosa*), bitterbrush (*Purshia tridentata*), and green-leaf manzanita (*Arctostaphylos patula*) (Marsh et al. 1987). The overstory is

almost purely ponderosa pine (99.4%) with a few other species scattered throughout. Western juniper (0.5%), Douglas-fir (0.08%), and incense-cedar (0.02%) make up a very small portion of the stand. Understory shrubs consist primarily of dense bitterbrush and green-leaf manzanita, ranging in age from 30-40 years old and height up to 5 feet.

Description of Existing Stand

Stand Exam

A stand exam was performed during the summer of 2004 to determine tree species, diameter, stems per acre, basal area, height to live crown, total height, and mortality status. Due to the patchiness of the stand, a strip cruise was used with 2, 33-feet wide strips placed systematically in each of the 16, 5-acre subunits. When appropriate, the strips were placed perpendicular to periodic variation to more accurately represent the characteristics of the entire subunit. Within each strip, all trees $\geq$ 5 feet in height (trees with a DBH) were measured and recorded. The total area cruised was 11.3 acres or 13.6% of the stand area. Descriptive statistics from the stand exam are listed in Table 4.

Table 4: *Stand exam statistics report per 5-acre subunit*[2].

	Mean	SD	CV (%)	SE	95% CI	%SE
Trees/acre	443.70	231.05	52	57.76	320.58-566.82	13
Basal area/acre (ft^2)	66.27	17.03	26	4.26	57.20-75.35	6
SDI	126.73	31.86	25	7.96	109.75-143.71	6
QMD (inches)	5.74	1.56	27	0.39	4.90-6.57	7

Shrub Component

Bitterbrush and green-leaf manzanita are the primary understory ground cover species in the Tenino stand. Although light competition is not a significant factor,

[2] The summation method for calculating SDI was used (Shaw 2000, Stage 1968).

these species, along with various grasses, effectively compete with crop trees for available water and soil nutrients. This competition can have an effect on pine regeneration, establishment, and growth.

To quantify the amount of area covered in shrubs, a line-intersect survey was conducted during the summer of 2004. In each of the 16, 5-acre subunits, 6 plot centers were equally spaced along the centerlines of each strip cruise location, yielding 96 plot centers. At each plot center, 2 random transect directions were established using a random number generator. Each transect was 50 feet long. The length of shrubs intersecting the plane above each transect was recorded by species. The total length of shrubs encountered divided by 50 feet determined the percent shrub cover. One-hundred ninety-two transects were recorded during the survey totaling 9600 feet in length. Descriptive statistics for the shrub survey are listed in Table 5.

Table 5: *Shrub survey statistics (% cover per 5 acre subunit).*

	Mean	**SD**	**CV (%)**	**SE**	**95% CI**	**%SE**
Bitterbrush	13.82	3.25	24	0.81	12.09-15.56	6
Manzanita	7.72	3.37	44	0.84	5.93-9.52	11
Total	21.54	4.56	21	1.14	19.11-23.97	5

Insects and Diseases

Presently the area has scattered dead trees from western pine beetle (*Dendroctonus brevicomis)* attacks in the small DBH classes. Both the pine engraver (*Ips pini)* and the mountain pine beetle (*Dendroctonus ponderosae*) have attacked young stressed ponderosa pine as well as the tops of some overstory trees. Western dwarf mistletoe *(Arceuthobium campylopodum)* has infected about 2% of the ponderosa pine. Thinning the understory clumps will reduce overall stand stress and

likely reduce the risk of insect or disease attack. Sapling and pole-size trees 5-8 inches in DBH are most commonly attacked by the pine engraver (Kegley et al. 1997). Thinning these size classes should curtail future attacks and prevent the insect from top-killing larger crop trees. Removal of the smaller diameter classes should limit detrimental effects of insect and disease attacks and induce conditions that favor vigorous growth. Such conditions can also be a deterrent to the western pine beetle and other insects (Owen 2003, DeMars and Roettgering 1982).

Down Woody Fuel

To quantify the down woody fuel composition (dead surface fuels) within the Tenino stand, a line intersect survey (Van Wagner 1968) was conducted during the summer of 2004. In each of the 16, 5-acre subunits, 6 plot centers were equally spaced along the centerlines of each strip cruise location, yielding 96 plot centers. At each plot center, 2 random transect directions were established using a random number generator. Each transect was 50 feet in length. Pieces of down woody fuel were classified using time lag fuel classes (Brown 1974). Specifically, fuel classes were: 1000-hr (>3 inches), 100-hr (1-3 inches), 10-hr (0.25-1 inches), and 1-hr (<0.25 inches). The number of pieces intersecting each transect were recorded and classified. One-thousand-hour fuels were recorded over the entire 50-ft transect length. One-hundred-hour, 10-hr, and 1-hr fuels were recorded only at the last 6 feet of each transect. This approach, adapted from Brown (1974), was used to ensure that the sampling area had not been disturbed as opposed to recording near the plot center where foot traffic was likely. One-hundred ninety-two transects were recorded during the survey totaling 9600 feet in length for the 1000-hr fuels and 1152 feet for the

other fuel classes. Descriptive statistics for the down fuel survey are expressed in terms of pieces of fuel per 1-ft of transect (Table 6) and tons per acre (Table 7) within each subunit. The tons per acre calculations were derived from equations by Van Wagner (1968) and specific gravity estimates from Brown (1974).

Table 6: *Down woody fuel distribution (number of pieces per 1-foot of transect).*

	Mean	SD	CV (%)	SE	95% CI	%SE
1000 hr	0.02	0.011	52	0.0026	0.015-0.026	13
100 hr	0.16	0.082	50	0.0205	0.121-0.208	13
10 hr	0.48	0.180	37	0.0450	0.385-0.577	9
1 hr	2.35	1.281	54	0.3203	1.665-3.031	14
Total	3.01	1.335	44	0.3338	2.302-3.725	11

Table 7: *Down woody fuel distribution (tons per acre).*

	Mean	SD	CV (%)	SE	95% CI	%SE
1000 hr	6.29	4.373	69	1.0933	3.962-8.623	17
100 hr	3.07	1.519	49	0.3798	2.265-3.884	12
10 hr	1.68	0.629	37	0.1572	1.342-2.013	9
1 hr	1.64	0.894	54	0.2235	1.165-2.118	14
Total	12.68	5.073	40	1.2682	9.981-15.387	10

Stand Structure and Composition

The current structure of the Tenino stand is a product of past harvesting and fire exclusion. Overstory removal has allowed groups of small diameter trees to restock group selection areas and become stagnated. The stand is uneven-aged with an inverse J-shaped diameter distribution (Figure 5). Ninety-five percent or 423 of the total trees per acre are in DBH classes $\leq$ 10 inches. The remaining overstory consists of a few large-diameter trees greater than 10-inches DBH, approximately 20 per acre. Suppressed and co-dominant crown classes contribute the greatest number of trees. The 10-inch DBH class contains 9.3 ft^2 of basal area per acre, which is more than any other class (Figure 6). Large-diameter trees greater than 20-inches DBH contain only 12.1 ft^2 of the total stand basal area per acre or 17%.

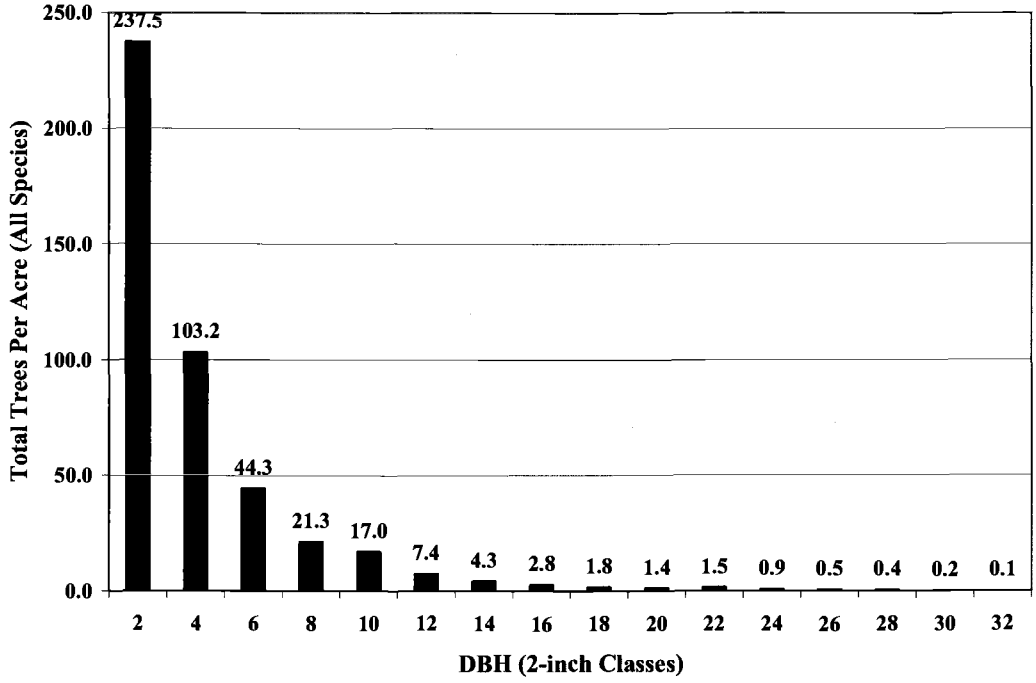

Figure 5: *Total trees per acre for all species within the Tenino stand by 2-inch DBH classes. Total = 445 TPA.*

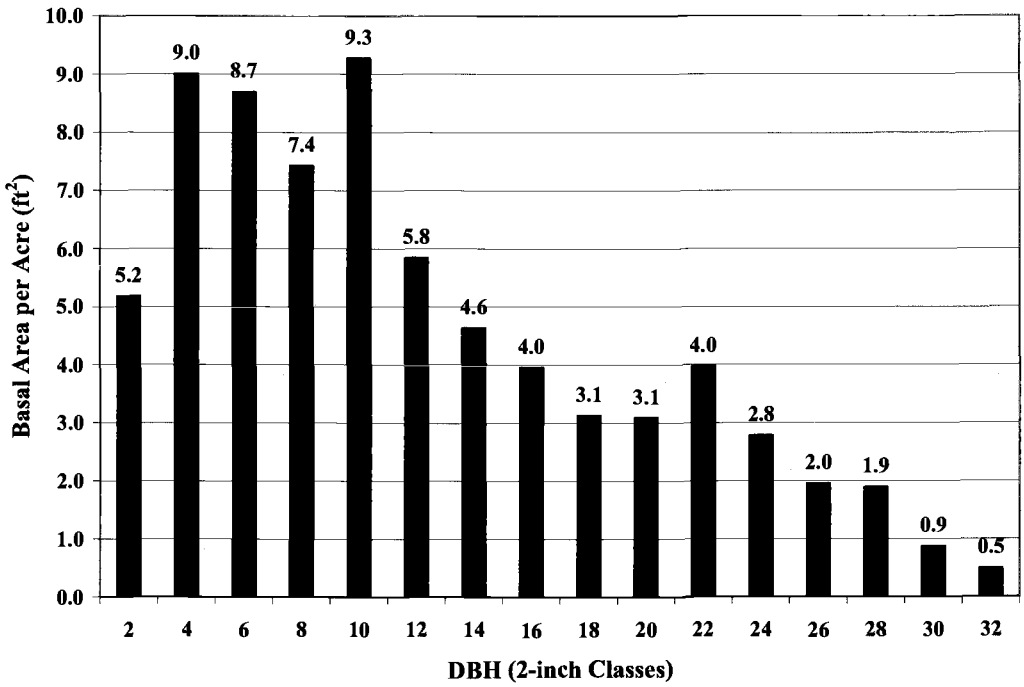

Figure 6: *Basal area per acre (ft^2) for the Tenino stand by 2-inch DBH classes. Total = 72.2 ft^2 per acre.*

Tree height increases with diameter as expected (Figure 7). Height to live crown (HLC), especially for the larger diameter trees, does not vary greatly. For the 8-22 inch DBH classes HLC ranges from 12-16 feet. Although, for the 24-30 inch DBH classes, HLC increases considerably, ranging from 20-23 feet. These trees represent the dominant crown class and are experiencing no competition for light from the dense understory. Mean live crown ratios are sufficiently large and increase from 53-84% for DBH classes 2-22 (Figure 8). The trend is less distinct for the larger DBH classes, ranging from 75-79%. This is likely due to the low frequency of observations recorded in these DBH classes. Had more large diameter trees been present, the increasing trend would have possibly continued. The relatively large crown ratios may indicate an opportunity for increased height and diameter growth after release.

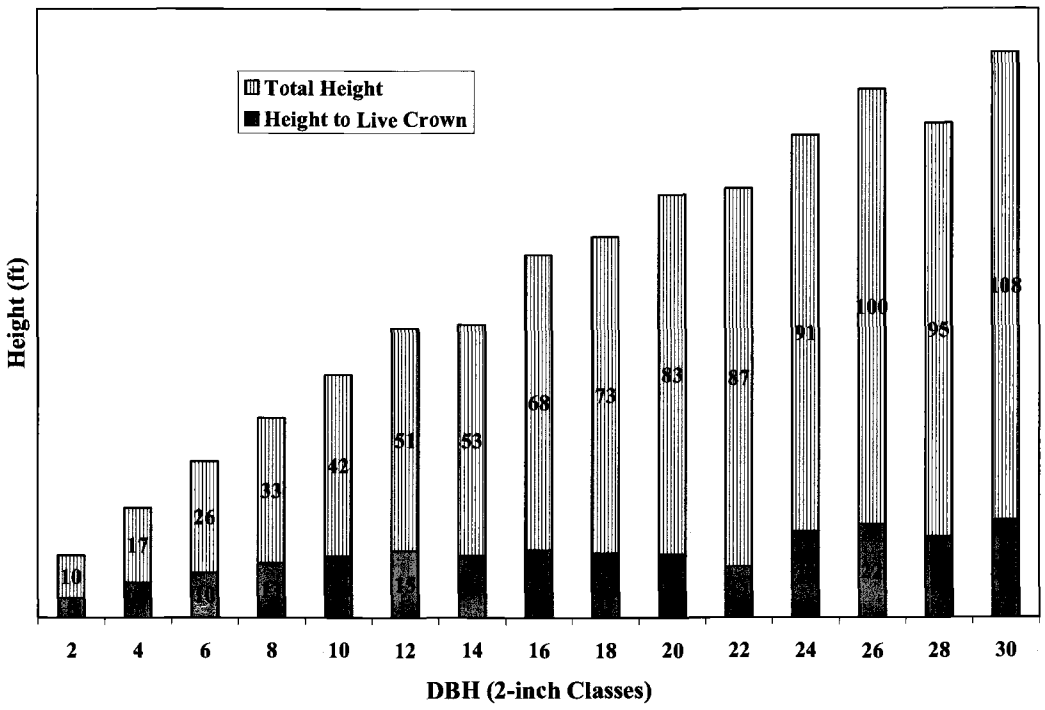

Figure 7: *Total height and height to live crown for all trees within the Tenino stand by 2-inch DBH classes.*

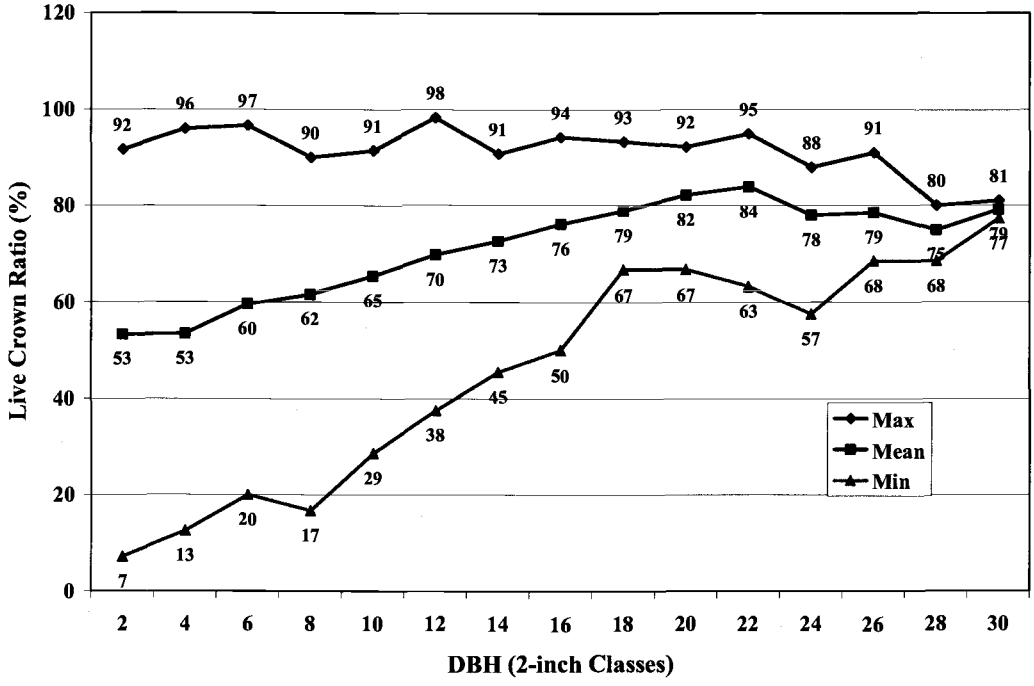

Figure 8: *Minimum, mean, and maximum crown ratios of all live trees within the Tenino stand by 2-inch DBH classes.*

Mortality status within the Tenino stand follows an inverse J-shaped distribution (Figure 9) similar to that observed for the diameter/trees per acre relationship (Figure 5). The 2- and 4-inch DBH classes contain the most mortality with each class containing more older dead trees than ones experiencing recent mortality. Older dead trees were defined as those containing no foliage and often showed signs of bark slippage. Trees characterized as experiencing recent mortality were ones with all brown foliage. If trees contained any green needles, they were classified as live. The 2- and 4-inch DBH classes are experiencing self-thinning and stagnation in the small patches of advanced regeneration throughout the stand. The small DBH classes are competing for limited resources and being overtopped by the co-dominant crown class. Little insect or disease caused mortality was observed for any diameter class.

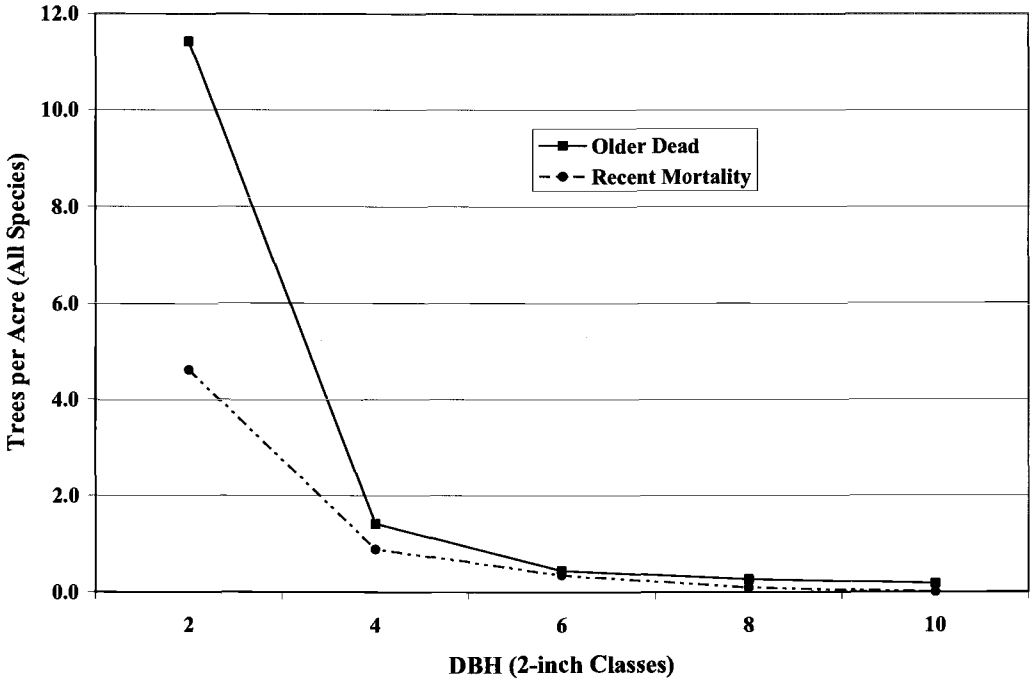

Figure 9: *Trees per acre by mortality status for 5 DBH classes.*

Stand density index (SDI) (Reineke 1933) was calculated for the Tenino stand (Figure 10) using the summation method (Shaw 2000, Stage 1968). The SDI distribution is similar to that found for basal area per acre (Figure 6). An SDI of 79.8 or 63% of the total stand SDI (126.4) is contained in DBH classes less than 12 inches. SDI is a good measure of site occupancy and indicates that the majority of the stand is occupied by small diameter trees. In particular, the 4-inch DBH class has an SDI of 19.9 which is 16% of the total stand SDI. Larger trees, 12-inches DBH and greater, decrease in SDI contribution as DBH increases. This is due to the same decreasing relationship with trees per acre. Larger trees contain more SDI, but low numbers per acre keep the overall SDI contribution small.

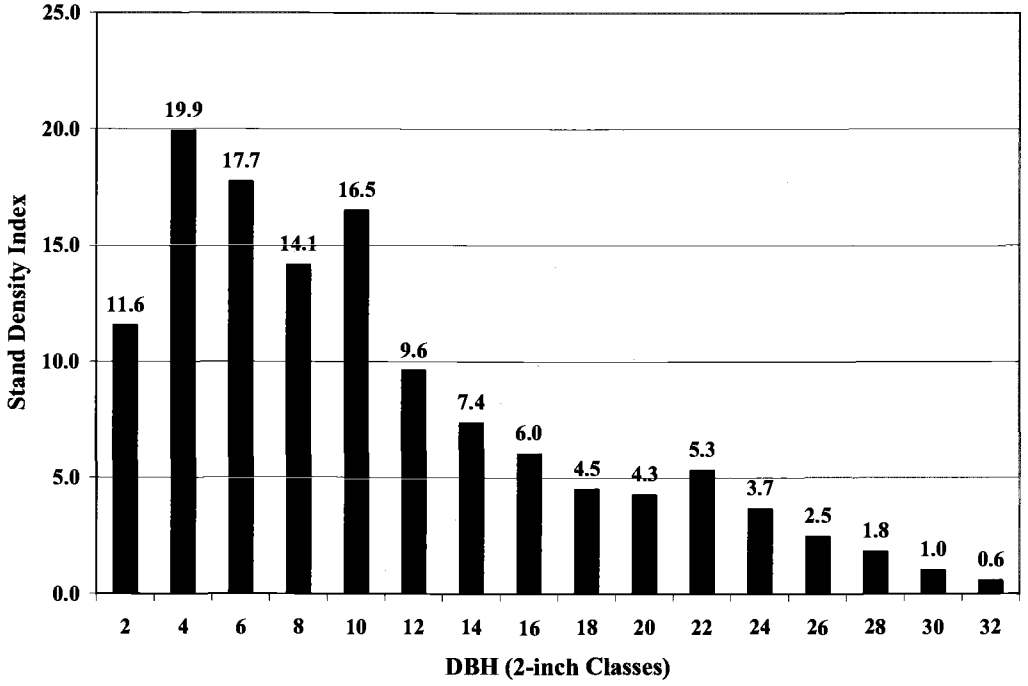

Figure 10: *Stand Density Index (SDI), calculated using the summation method (Shaw 2000, Stage 1968) for the Tenino stand by 2-inch DBH classes. Total SDI = 126.4.*

Fuel Management

Historically, this area burned approximately every 11 years creating park-like conditions (Weaver 1959). CTWSIR (2003) reports historic fire return intervals from 3-20 years. Since the inception of fire suppression, in the early 1900s, fire return intervals have lengthened and caused stands with histories of low-severity fire to experience uncharacteristic catastrophic wildfire. The Tenino stand is an example of such conditions. The absence of fire has caused the understory to become dense and stagnated. These standing small trees provide ladder fuels for fire to encroach into the crowns of larger crop trees. Ladder fuels are the greatest concern in this stand.

Past timber harvesting has not produced a significant amount of activity fuels (logging slash) throughout the stand. The gentle terrain allows for typical ground-

based harvesting systems that most often transport whole trees to a central landing for processing. Future entries should consider harvesting systems that distribute activity fuels throughout the stand and avoid concentration in large landing piles. During dry summer conditions, these piles contribute to a significant fire hazard. Current dead surface fuels are light and discontinuous (Tables 6 and 7). The largest concentration is near past group selection cuts.

Live surface fuels consist mainly of shrubs (Table 5). If left untreated, the shrub component will continue to increase and aid the intensity of future surface fires. Both manzanita and bitterbrush contain volatile chemicals that allow each to burn intensely. The increasing height of the present shrubs is also a concern and could potentially promote the spread of surface fires into ladder fuels and subsequently overstory tree crowns. Given the large live crown ratios (Figure 8) and low height to live crown (Figure 7) of most DBH classes, even the smallest aid to surface fire could prove catastrophic to the overstory. Abundant understory shrubs and clumps of dense regeneration contribute significantly to the overall stand fuel loading and the probability that a surface fire could spread to tree crowns.

Wildlife

The Tenino stand is part of the WSIR wildlife land management zone and is allocated to the management of vegetation for the benefit of deer and elk. Timber harvesting is permitted with management practices directed toward the production of quality habitat for these species. The area serves as a primary elk winter range and both summer and winter range for deer. To promote this habitat the WSIR maximizes opportunities to increase the amount of nutritious bitterbrush available for

browse as well as thermal cover. However, ponderosa pine typically does not provide optimum thermal cover (70% canopy cover). Adjacent stands in higher elevation draws should provide additional cover not available in the Tenino stand (CTWSIR 2003).

At present, no threatened or endangered species have been identified in the area. Some species of existing wildlife can damage trees and cause growth loss and mortality. Pocket gophers and livestock can cause damage to young seedlings. Gophers snip the seedling roots and livestock cause damage by trampling and browsing. Some open range horses were observed browsing the tops of seedlings near landings during the stand exam. However, these animals were sparse, and no effect on reforestation operations or stand dynamics is expected. Porcupines are also present and tend to girdle young ponderosa pine. The girdling damage can cause tree tops to fork or eventually die (CTWSIR 2003).

There are very few snags present. Most of the mortality is in the small diameter classes that do not provide the necessary habitat for most species of cavity-nesting birds. In areas where snags are deficient, green replacement trees should be retained. Large green trees could be girdled to produce additional snags suitable for cavity-nesting birds.

SOCIAL ENVIRONMENT

There are no specified cultural resource sites or threatened or endangered plants identified within the Tenino stand. There are no special use permits, mining claims, or developed recreational opportunities. The area is occasionally used to collect ponderosa pine cones for wreath and potpourri making. The stand is approximately 20 miles from the city of Warm Springs, OR, and a considerable distance from frequently traveled highways; therefore, no significant aesthetic concerns are expected to constrain treatment options. In compliance with WSIR policies, the Tribal Protection Code will be followed in any future management activities (CTWSIR 2003).

FUTURE STAND WITHOUT TREATMENT

Without treatment, the Tenino stand will continue to decrease in stand growth, productivity, vigor, and overall health. Small trees that are tightly spaced in clumps will continue to experience competition, stagnate, and become susceptible to insect and disease attack. The continuing encroachment of understory shrubs, promoted by the absence of fire, will further compete with pine regeneration success and leave open, unstocked areas to remain. Co-dominant crown classes will also be slow to gain dominance and will become more susceptible to insect attack promoted by the dense and low-vigor nature of the understory. As individual mortality occurs, growth of surviving co-dominant trees may increase, but in general, decreased stand growth is expected. Regeneration throughout the stand is concentrated in small clumps. In open canopy areas, shrub competition has significantly impacted seedling success. If left untreated, this stand will continue to experience patchiness and a reduction in vigorous seedlings that are free to grow. Given the surprisingly large live crown ratios of most small trees (Figure 8), a thinning treatment may provide release and allow trees to overcome stagnation and increase in size. Due to the low productivity of the site, any positive effect will be slow to emerge. Without treatment, little effect on wildlife populations is expected in the short term. As the shrub component ages, however, it will become less nutritious and desirable for browsing. As shrub percent cover increases, ground-dwelling birds and other mammals may benefit from the additional hiding cover. Snags and down woody fuel will increase over time as tree mortality occurs. However, new snags are not expected to be from the large diameter

classes, which are most important for some species of wildlife, especially cavity-nesting birds.

Wildfire threat in this stand will continue to become more prominent over time. Surviving trees in clumps, underneath dominant overstory trees, will increase in height, although very slowly. Shrubs will continue to increase in height as well, which increases the chance of low-intensity surface fire encroaching into the ladder fuels and possibly overstory crowns. If left untreated, I predict that this stand will experience a wildfire of stand replacement nature within the next 20 years.

MANAGEMENT DIRECTION AND CONSTRAINTS

As noted earlier, the management direction for the Tenino stand is predominantly enhancement of wildlife habitat, particularly deer and elk. Specific requirements for the wildlife zone from CTWSIR (2003) include:

- Maintain adequate thermal cover for large game with a goal of 70% crown closure.
- Maintain 2 to 3 layers of tree crown canopy.
- Maintain a high tree density to provide adequate hiding cover.
- Maintain or attain four snags per acre.
- After meeting wildlife objectives, strive to attain the objectives for the timber zone.

An example prescription commonly used for the timber zone is listed in Table 8. Specific requirements for the timber zone from CTWSIR (2003) include:

- Attain the maximum potential tree growth of the site.
- Maintain or improve forest health by decreasing amount of disease, stem decays, and insect damage.
- Maintain or increase tree species diversity.
- Maintain or attain prescribed tree density as measured by basal area (50 ft^2 per acre) or number of trees per acre.
- Decrease the amount of mortality within the stand.
- Maintain large woody material, as specified in the BMPs and standards.
- Maintain or attain four large snags per acre.

Table 8: *An example silvicultural prescription for the ponderosa pine timber zone (from CTWSIR (2003)).*

Action	Year	Specifications
Group Selection – Natural Regeneration	0-10	Openings of ¼ to 2 acres during harvest should regenerate with approximately 400 seedlings per acre of ponderosa pine. Some Douglas-fir and incense-cedar will seed in.
Walkthrough Exam	12	Perform walkthrough exam to insure that there is regeneration in the openings.
Pre-commercial Thin	20	Thin saplings to a density of 170 trees per acre leaving mostly ponderosa pine with a minor percentage of Douglas-fir.
Stand Exam	60	Perform stand exams to insure healthy development and check for insects and diseases.
Intermediate Thin of Group	80	Thin from below in each group to a residual BA/AC of 50 ft^2.
Intermediate Thin of Group	100	Thin from below in each group to a residual BA/AC of 50 ft^2.
Intermediate Thin of Group	120	Thin from below in each group to a residual BA/AC of 50 ft^2.
Intermediate Thin of Group	140	Thin from below in each group to a residual BA/AC of 50 ft^2.
Final Harvest of Group	160	Group select; residual trees may be left as a seed source if there is an inadequate seed source outside the group.

SILVICULTURAL OBJECTIVES

Given the before mentioned management direction and constraints, the following three objectives emerge as overarching goals to promote long-term forest health, fire resiliency, and wildlife habitat within the Tenino stand. Treatment alternatives will be proposed that address each goal separately. Relative scores from evaluation criterion performance will determine the applicability of each alternative when compared to other management directions.

1. Maintain stand characteristics through time that will maximize wildlife winter range and thermal cover with a goal of 70% crown closure.
2. Return the stand to pre-settlement, historical fire regime conditions with an aggressive fuel management program that promotes long-term fire resiliency and minimizes the possibility of catastrophic wildfire.
3. Promote long-term forest health and productivity by attaining maximum potential volume growth and minimizing mortality.

EVALUATION CRITERIA

To assess the relative applicability of each treatment alternative, evaluation criteria were established from the management direction and constraints of the Tenino stand. Each criterion is weighted according to importance for meeting management objectives, currently and in the future. Importance followed the direction outlined in CTWSIR (2001 and 2003). Criteria with higher weights are considered to be more important in order of priority than ones with lower weights. Each of the treatment alternatives were scored in relation to their predicted probability of satisfying each criteria. This score was multiplied by the criteria's weight and the resulting metrics were summed. The summed score indicates the relative effectiveness of each alternative as a stand treatment currently and in the future.

Criterion 1: Maximize crown closure with a goal of 70%. [Weight = 10]

This criterion evaluates the potential of each alternative to maintain a diversified uneven-aged stand structure that contains the necessary crown closure to promote hiding and thermal cover for deer and elk. The criterion is considered most important as it corresponds with the overarching objectives for the stand, to promote big game wildlife habitat. The alternative that most closely meets the criteria will be assigned a rank of 10 with the other alternatives ranked proportionally lower.

Criterion 2: Reduce the potential for catastrophic stand-replacement wildfire, improve fire resiliency, and return the stand to a structure produced by historic fire regimes with frequent low-intensity surface fires. [Weight = 9]

This criterion assesses the potential of each alternative for reducing the probability of catastrophic wildfire. The alternative producing the highest crowning index will be given a rank of 10 with other alternatives ranked lower in proportion to their predicted index. The crowning index is a measure for assessing the potential for severe fire and is recorded as the wind speed (miles per hour) 20 feet above the canopy that is required to cause an active crown fire. The alternative producing the highest wind speed will be considered the best approach for minimizing catastrophic fire.

Criterion 3: Maintain a target prescribed tree density of 50 ft^2 of basal area per acre as outlined in the timber zone requirements. [Weight = 8]

The alternative that most closely meets the tree density requirement in each management period will be ranked highest. This criterion is important as it maintains open conditions and provides growing space for regeneration. It also assesses the potential of each alternative to maintain uneven-aged conditions that are integral to the ecology of the Tenino stand.

Criterion 4: Improve forest health by decreasing the amount of overall stand mortality, particularly from disease and insect attack. [Weight = 7]

This criterion assesses the alternatives' ability to reduce stand mortality from disease, insect attack, and self thinning. Potential wildfire-induced mortality will not be considered while evaluating this criterion. A score of 10 implies the best possible conditions are met for reducing mortality.

Criterion 5: Attain maximum potential volume growth to promote the production of useable wood products. [Weight = 6]

The estimated merchantable timber volume produced by each alternative will be compared on a cubic-foot per acre basis. The alternative with the greatest mean merchantable cubic-foot prediction will be ranked with the highest score of 10, with others ranked proportionately lower. This criterion is considered moderately important in relation to the other four criteria. This is a result of the management direction prescribed to the stand with timber production being a secondary objective after other goals are met.

TREATMENT ALTERNATIVES

Alternative treatment approaches to meet the objectives specified for the Tenino stand were formulated to correspond with the three specific silvicultural objectives as listed earlier. In addition, a fourth alternative, "do nothing", was evaluated that served as a control for comparison. Each alternative was simulated using the Forest Vegetation Simulator (FVS) (Dixon 2002) and evaluated on a 100-year planning horizon with 20-year assessment intervals. Wildfire potential was evaluated using the Fire and Fuels Extension to the FVS (FFE-FVS) (Reinhardt and Crookston 2003). All alternatives were based on the modeling assumptions used in the South Central Oregon / Northeastern California (SO) variant of the FVS (USFS 2005) (Figure 11). This is the variant used by WSIR personnel for other modeling projects south of Shitike Creek (Figure 2), where the Tenino stand is located. Plant association PIPO/PUTR-ARPA, SDI_{MAX} of 307, and site index 74 (base age 100) were used in the projections. The biological SDI_{MAX} for the Tenino area is 409 (Arena 2005). However, 75% of SDI_{MAX}, or 307, was used during modeling to account for insect damage and other stress factors (Arena 2005). In addition, all thinning treatments will occur during the months from June to December to reduce the chance of the pine engraver infesting green logging slash.

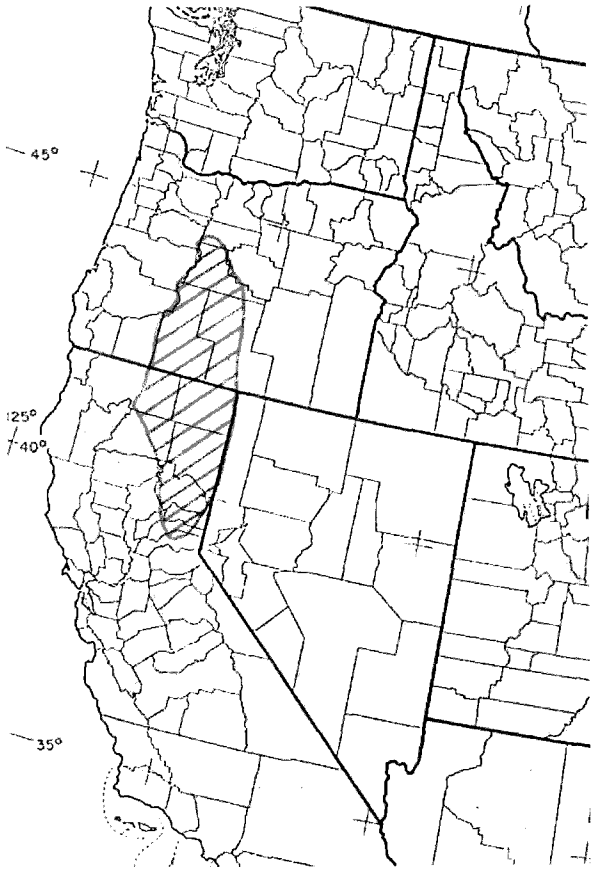

Figure 11: *Shaded area indicates the approximate geographic range covered by the SO variant of the Forest Vegetation Simulator (graphic from USFS 2005).*

Alternative 1: Maintain stand characteristics through time that will maximize wildlife winter range thermal cover with a goal of 70% crown closure.

To facilitate maximum big game habitat, crown closure, for the stand as a whole, must increase. Currently, only the patches of small trees and a few groups of co-dominant size trees will meet crown closure requirements. Open areas with widely spaced dominant overstory trees do not meet the closure criteria. To exacerbate the problem, understory shrubs are thriving from the openness and resulting sunlight. Shrubs are competing with pine seedlings and make successful

pine regeneration difficult in already harsh growing conditions. This problem will only continue to grow without action.

Treatment alternative 1 (Table 9) begins with a mechanical treatment in 2005 that will masticate existing understory shrubs while maintaining the integrity of current natural regeneration. This treatment should occur in late spring after bitterbrush shrubs have produced new foliage and allocated most of their resources aboveground. Shrub removal, in the short term, will adversely affect wildlife habitat, particularly browse for big game and hiding cover for ground-dwelling birds and small mammals. However, this alternative attempts to produce maximum crown closure for big game thermal cover. As a result, scarification of the forest floor is necessary for successful pine regeneration. The intent is not to eradicate shrubs but to allow for improved seedling establishment. Shrubs will continue to be present in this system as pine regeneration will likely never fill all gaps due to low site productivity. Following shrub mastication, ponderosa pine will be planted at a rate of 600 per acre in the openings. The high number of trees per acre is necessary due to the probability of poor seedling survival. If seedling establishment is successful and overtops the new shrub layer, crown closure should increase greatly throughout time. Seven years after planting, the stand will be burned with a cool backfire to kill the new shrub layer and give seedlings an increased opportunity for overtopping the shrubs. Prescribed fire will be conducted in the winter or early spring when fuel conditions are moist and the relative humidity is high. This should give regeneration the best chance for survival while killing new shrub sprouts. Walkthrough exams will be performed periodically to assess regeneration success and determine the need for additional

planting. Once successful shrub overtopping has occurred, the need for additional burning will decrease.

To meet the objectives of this alternative, I see no reason for future commercial timber harvesting. However, pre-commercial thinning may be necessary if seedling establishment is successful. The stand should progress as an uneven-aged system with current open areas becoming stocked with ponderosa pine and nearing crown closure requirements. As self-thinning and mortality occur, successive natural and artificial regeneration should be adequate to fill canopy gaps and maximize thermal cover.

Table 9: *Silvicultural prescription for alternative 1 (maximizing crown closure and wildlife thermal cover).*

Action	Year	Specifications
Shrub Mastication and Planting	0 - 2005	Mechanically masticate understory shrubs throughout for scarification and plant ponderosa pine to a density of 600 per acre in the openings.
Prescribed Fire and Walkthrough Exam	7 - 2012	Perform a prescribed fire and walkthrough exam to examine regeneration success.
Stand Exam	35 - 2040	Perform stand exam to insure healthy development, check for insects and diseases, and assess crown closure.
Stand Exam	70 - 2075	Perform stand exam to insure healthy development, check for insects and diseases, and assess crown closure.
Stand Exam	100 - 2105	Perform stand exam to insure healthy development, check for insects and diseases, and assess crown closure.

Alternative 2: Return the stand to pre-settlement, historical fire regime conditions with an aggressive fuel management program that promotes long-term fire resiliency and minimizes the possibility of catastrophic wildfire.

Due to the absence of fire and effects of group selection, this stand is densely stocked with small trees tightly spaced in clumps. Small trees and encroaching understory shrubs have provided a ladder for surface fires to reach overstory crowns. To alleviate this situation and change the stand trajectory toward a structure maintained by historic fire regimes with low intensity surface fires, mechanical treatment of small, suppressed trees and shrubs is necessary.

Treatment alternative 2 (Table 10) begins with a mechanical treatment in 2005 that will masticate existing understory shrubs, surface fuel, small stagnated trees, and some co-dominants up to 12 inches DBH. The diameter limit constraint is a result of WSIR management direction for non-commercial fuel treatments. All patches sapling/pole size up to 8 inches DBH will be thinned to a density of 170 trees per acre (approximately 16 by 16 feet spacing). Eight to 12 inch DBH trees will be thinned using a spacing of approximately 22 by 22 feet. This will result in the removal of few trees in the 8-12 inch DBH classes since low numbers per acre exist currently. The goal of this action is to reduce crown closeness through spacing standards. Shrubs will be masticated throughout with this being the only treatment in open areas with dominant overstory trees. The existing advanced regeneration will be maintained when spacing guidelines allow. The thinning will be from below and by spacing standards. This treatment will reduce crown closeness, increase the height to live crown, remove ladder fuels, and allow less risk with future prescribed fires. With this initial treatment, the stand will continue to be multi-storied and uneven-aged with a minor component in the understory. Additional surface fuels generated by masticating will add to the overall fuel loading but will not significantly increase

surface fire intensity in the long-term since successive underburning will be prescribed. The masticated pieces will serve as an addition to the nutrient pool that may increase site productivity over time.

Following the initial mechanical treatment, an underburn will be prescribed in year 5 that will consume the additional surface fuels generated from masticating and keep the new shrub layer under control. Prescribed fires will then be conducted in 15-year intervals with a goal reducing continuous surface fuels and improving fire resiliency that was characteristic prior to the inception of widespread fire suppression. This treatment should provide release for remaining small trees that have been stagnated in prior, dense understory clumps. Co-dominant trees should continue to grow and progress in dominance to replace the older dominant trees that will be lost to mortality. Twenty-five years following treatment, a thinning from below will be required to ensure adequate spacing of sapling/pole size trees and reduce the density of co-dominants to 35 ft^2 of basal area per acre. All trees less than 12 inches DBH will be thinned. Along with underburning, this treatment will continue in 30-year intervals maintaining wide tree spacing and fire resiliency.

Table 10: Silvicultural prescription for alternative 2 (long-term fire resiliency).

Action	Year	Specifications
Shrub, Fuel, Small Tree, and Co-dominant Mastication	0 - 2005	Mechanically masticate understory shrubs, surface fuels, small trees, and some co-dominants.
Prescribed Fire	5 - 2010	Perform a prescribed fire that consumes masticated surface fuels and new shrubs.
Prescribed Fire	20 - 2025	Perform a prescribed fire that consumes surface fuels, shrubs, and mimics historical fire regime.
Intermediate Thin	25 - 2030	Perform an intermediate thin to maintain small tree spacing and limit crown closeness in the co-dominant class. Thin trees <12 in. DBH from below to 35 ft^2 of basal area per acre.
Prescribed Fire	35 - 2040	Perform a prescribed fire that consumes surface fuels, shrubs, and mimics historical fire regime.
Stand Exam	40 - 2045	Perform stand exam to insure adequate crown spacing, minimal ladder fuels, and check for insects and diseases.
Prescribed Fire	50 - 2055	Perform a prescribed fire that consumes surface fuels, shrubs, and mimics historical fire regime.
Commercial Thin	55 - 2060	Perform a commercial thin to limit crown closeness in the co-dominant class. Thin trees <12 in. DBH from below to 35 ft^2 of basal area per acre.
Prescribed Fire	65 - 2070	Perform a prescribed fire that consumes surface fuels, shrubs, and mimics historical fire regime.
Stand Exam	70 - 2075	Perform stand exam to insure adequate crown spacing, minimal ladder fuels, and check for insects and diseases.
Prescribed Fire	80 - 2085	Perform a prescribed fire that consumes surface fuels, shrubs, and mimics historical fire regime.
Commercial Thin	85 - 2090	Perform a commercial thin to limit crown closeness in the co-dominant class. Thin trees <12 in. DBH from below to 35 ft^2 of basal area per acre.
Prescribed Fire	95 - 2100	Perform a prescribed fire that consumes surface fuels, shrubs, and mimics historical fire regime.
Stand Exam	100 - 2105	Perform stand exam to insure adequate crown spacing, minimal ladder fuels, and check for insects and diseases.

Alternative 3: Promote long-term forest health and productivity by attaining maximum potential volume growth and minimizing mortality.

To ensure long-term stand productivity, the existing dense clumpy understory must be reduced to release the most vigorous trees with good crowns. This will be done (Table 11) by pre-commercially thinning trees less than 5 inches DBH to a residual density of 50 trees per acre. The treatment will reduce numbers in the 2-inch DBH class by 80% and remove approximately 50% in the 4-inch DBH class. This approach will reduce the existing ladder fuels and release stagnated small trees. Following pre-commercial thinning, a prescribed fire will be performed in late spring that consumes logging slash and kills understory shrubs. After underburning, 600 ponderosa pine trees per acre will be planted in the openings to promote an overall more fully stocked stand and ensure maximum volume growth potential. Thirty years following the initial treatments, the stand will be commercially thinned from below (DBH classes <20 in.) to a residual basal area of 50 ft^2 per acre. This treatment will be conducted in thirty-year intervals. Trees 20 inches DBH or greater will be retained on the site to ensure the presence of old growth trees throughout time. This approach adheres to the ecology of the ponderosa pine region within the WSIR. The stand will progress throughout time and continue to add volume in the co-dominant and dominant crown classes while eventually overtopping shrubs. The periodic commercial low thinnings will target the removal of low vigor trees and recent mortality. This approach should reduce the accumulation of mortality and maintain a productive, healthy stand with growth potential.

Table 11: *Silvicultural prescription for alternative 3 (merchantable volume production).*

Action	Year	Specifications
Pre-commercial Thin	0 - 2005	Pre-commercially thin trees less than 5 inches DBH to a residual density of 50 trees per acre.
Prescribed Fire	1 - 2006	Perform a prescribed fire that consumes logging slash and shrubs.
Plant	2 - 2007	Plant ponderosa pine to a density of 600 per acre in the openings.
Commercial Thin	32 - 2037	Commercially thin, from below, trees less than 20 inches DBH to 50 ft^2 of basal area per acre.
Stand Exam	40 - 2045	Perform stand exam to assess regeneration success and check for insects and diseases.
Commercial Thin	62 - 2067	Commercially thin, from below, trees less than 20 inches DBH to 50 ft^2 of basal area per acre.
Stand Exam	70 - 2075	Perform stand exam to assess regeneration success and check for insects and diseases.
Commercial Thin	92 - 2097	Commercially thin, from below, trees less than 20 inches DBH to 50 ft^2 of basal area per acre.
Stand Exam	100 - 2105	Perform stand exam to assess regeneration success and check for insects and diseases.

Alternative 4: Do nothing. This alternative allows the stand to progress naturally without active management. The analysis of this alternative will serve as a control in which to compare other alternatives.

EVALUATION OF ALTERNATIVES

To determine scores and rankings for each alternative, I evaluated each of the five criteria. Each alternative was evaluated over a 100-year planning horizon with 20-year assessment intervals. FVS and FFE-FVS were used to simulate each management action presented in Tables 9-11 as well as the do-nothing alternative 4. The following Figures and text describe the performance of each criterion within the treatment alternatives.

Criterion 1: Maintain stand characteristics through time that will maximize wildlife winter-range thermal cover with a goal of 70% crown closure. [Weight = 10]

Percent canopy cover was simulated for each treatment alternative using FVS (Crookston and Stage 1999). The variable is an output of the COVER and SHRUBS extension (Moeur 1985) and is displayed in Figure 12. Alternative 1 produced the most canopy cover in all assessment periods with an average of 41%. Alternative 4 produced similar results with average canopy cover estimated at 38% over the assessment periods. In contrast, alternative 2 (fire resiliency) resulted in decreased canopy cover, ranging from 20-30% after initial treatment. Scores for each alternative are listed in Table 12.

Table 12: *Performance and scores for criterion 1 (canopy cover).*

	Alt 1	**Alt 2**	**Alt 3**	**Alt 4**
Average Canopy Cover (%)	41	26	30	38
Score	10	7	8	9
Total	100	70	80	90

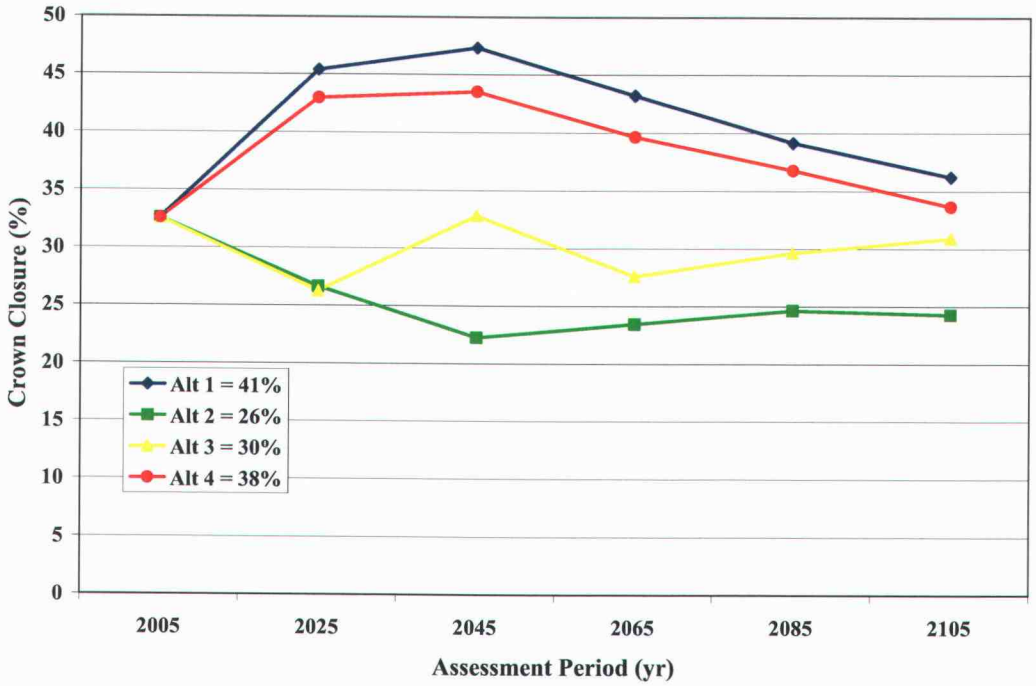

Figure 12: *Percent crown closure evaluated in six periods for each alternative. Note: numbers in the legend indicate averages over all periods.*

Criterion 2: Reduce the potential for catastrophic stand-replacement wildfire, improve fire resiliency, and return the stand to historic fire regime characteristics that experienced frequent low intensity surface fires. [Weight = 9]

This criterion assessed the potential of each alternative for reducing the potential of catastrophic wildfire based on crowning index. Crowning index has been used as a surrogate for fire hazard in past studies. Fiedler et al. (2001) rated crowning index values less than 25 miles per hour (mph) as high hazard, 25-50 mph as moderate hazard, and greater than 50 mph as low hazard.

Alternative 2 produced the highest average crowning index of 58 mph (Figure 13). This value places alternative 2 in the low hazard rating. The other alternatives fall into the moderate hazard category with values of 34, 47, and 36 mph,

respectively. Alternative 1, however, produced a crowning index slightly lower than the do nothing alternative, indicating that fire hazard may be increased using its set of management activities. Based on this evaluation, it is evident that alternative 2 with repeated underburning and thinning to reduce crown closeness will produce the most fire resilient stand. Alternative 3 also outperforms the other alternatives with crowning index values reaching low hazard criteria by 2065. The do nothing and canopy cover alternatives will result in higher densities and subsequent crown-fire potential. Scores for each alternative are listed in Table 13.

Table 13: *Performance and scores for criterion 2 (fire resiliency).*

	Alt 1	**Alt 2**	**Alt 3**	**Alt 4**
Average Crowning Index (mph)	34	58	47	36
Score	7	10	9	8
Total	63	90	81	72

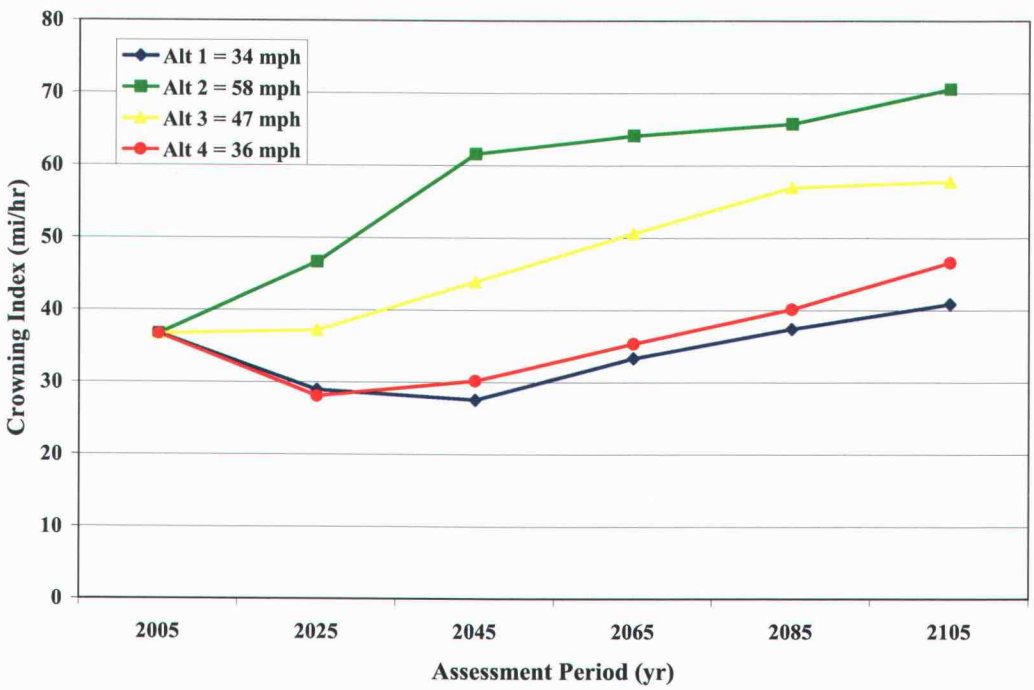

Figure 13: *Crowning index (miles per hour) evaluated in six periods for each alternative. Note: numbers in the legend indicate averages over all periods.*

Criterion 3: Maintain prescribed tree density of 50 ft^2 of basal area per acre as outlined in the timber zone requirements. [Weight = 8]

This criterion assessed the potential of each alternative for meeting the density target set by WSIR management direction. This criterion is also important as it maintains open conditions and provides growing space for regeneration. Figure 14 shows the results of simulation for each alternative. Alternative 2 produced the lowest average basal area per acre (84 ft^2) over the assessment periods. Therefore, it was ranked highest due to its potential to most closely meet the density target. Alternative 3 produced higher basal area numbers (average 99 ft^2 per acre) for periods beginning in 2045. Alternatives 1 and 4, canopy closure and do nothing, produced higher basal area figures due to increased density and the lack of thinning. Their values were 118 and 122 ft^2 per acre, respectively. As the stand ages, basal area will continue to increase in the co-dominant and dominant crown classes. The resulting scores for each alternative are listed in Table 14.

Table 14: *Performance and scores for criterion 3 (basal area).*

	Alt 1	**Alt 2**	**Alt 3**	**Alt 4**
Average Basal Area per Acre (ft^2)	118	84	99	122
Score	8	10	9	7
Total	64	80	72	56

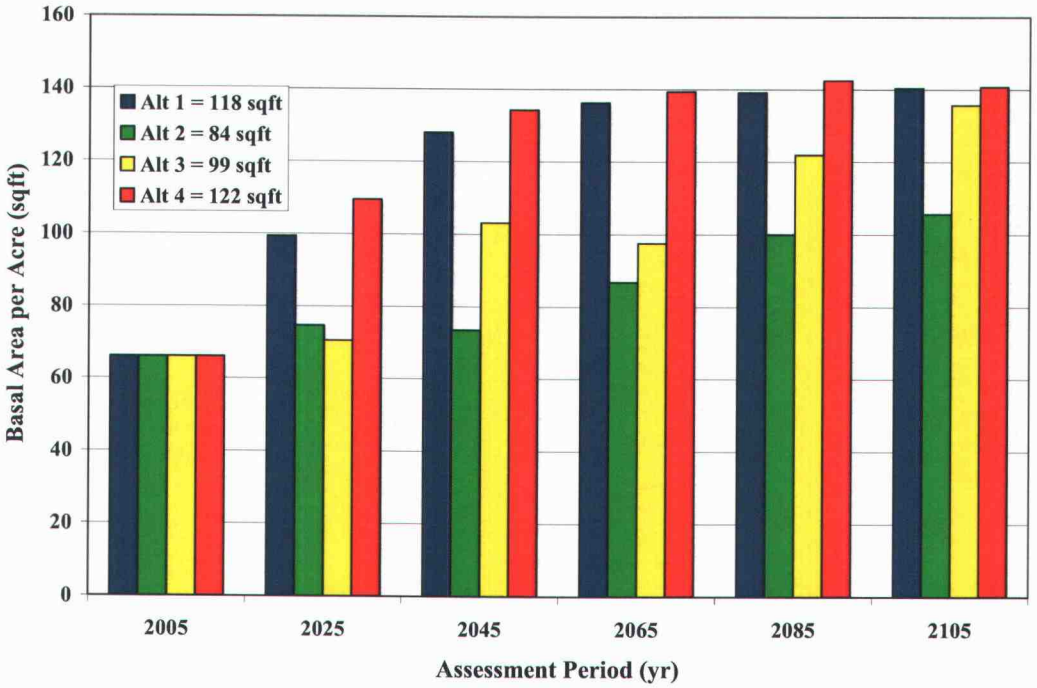

Figure 14: *Basal area per acre (ft^2) evaluated in six periods for each alternative. Note: numbers in the legend indicate averages over all periods.*

Criterion 4: Improve forest health by decreasing the amount of overall stand mortality, particularly from disease and insect attack. [Weight = 7]

This criterion assesses the alternatives' ability to reduce stand mortality from disease, insect attack, and self thinning. Potential wildfire-induced mortality was not considered during evaluation. Based on FVS projections, alternatives 2 and 3 produced low amounts of overall stand mortality, 11 and 9 ft^3 per acre (Figure 15). This result is due to repeated underburning and thinning included in prescriptions. Effectively thinning from below to basal area targets removed low vigor trees from the stand allowing for release and increased growth of residual trees. In contrast, alternatives 1 and 4 contained no thinning which in turn allowed the stand to accumulate more mortality and resulting downed woody debris. Average mortality

volume for these alternatives was nearly identical, 23.1 and 23.4 ft^3 per acre, respectively. Their values are substantially higher than the other alternatives, especially in assessment periods 2045-2085. This is due to their dense nature and the fact that the onset of self thinning occurred earlier. By 2105, alternative 3 showed comparable mortality volume as the impact of thinning became less apparent and more of the stand basal area moved into the larger diameter classes, not affected by thinning. Scores for each alternative are listed in Table 15.

Table 15: *Performance and scores for criterion 4 (overall mortality).*

	Alt 1	Alt 2	Alt 3	Alt 4
Average Mortality (ft^3/ac)	23.1	11	9	23.4
Score	8	9	10	7
Total	56	63	70	49

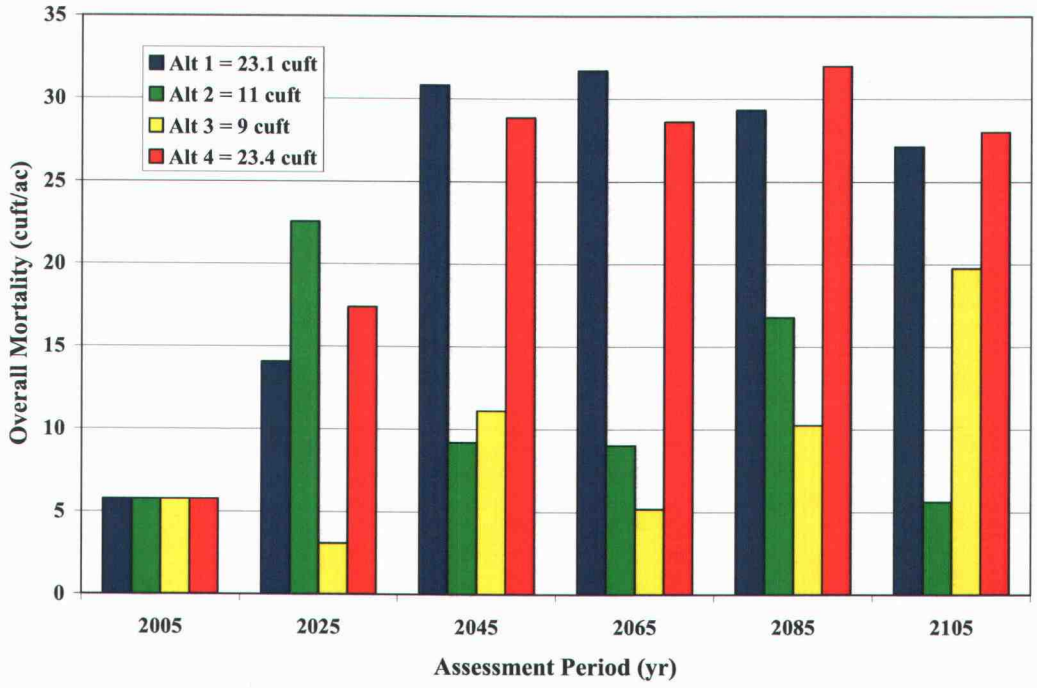

Figure 15: *Overall stand mortality (ft^3 per acre) evaluated in six periods for each alternative. Note: numbers in the legend indicate averages over all periods.*

Criterion 5: Attain maximum potential volume growth to promote the production of useable wood products. [Weight = 6]

To evaluate this criterion, the estimated merchantable volume produced by each alternative was compared on a cubic foot per acre basis (Figure 16). Volume projections do not include products removed during commercial thinnings in alternatives 2 and 3. Volume figures represent the amount of standing merchantable volume at each assessment interval. Due to the wildlife management direction, this criterion is considered least important in relation to the other criterion evaluated. Merchantable volume produced by alternative 2 was lower than the other alternatives beginning in 2045 (average 2,277 ft^3 per acre). With the exception of the do nothing alternative, alternative 2 is the only prescription that does not include planting. Its initial treatment considerably reduces trees per acre in the small diameter classes and therefore results in less merchantable volume production over the assessment periods. Alternatives 1 and 3 were comparable in average merchantable volume (2,496 and 2,641 ft^3 per acre). In addition, both included planting in their prescriptions which allowed for denser stands and subsequently more volume. The thinning from below prescribed for alternative 3 allowed for slightly more average volume than alternative 1. Alternative 4, do nothing, emerged as the largest producer of average volume (2,872 ft^3 per acre). Alternative 4, without active management consistently produced more volume in each assessment period, with the exception of 2105. Scores for each alternative are listed in Table 16.

Table 16: *Performance and scores for criterion 5 (merchantable volume production).*

	Alt 1	Alt 2	Alt 3	Alt 4
Average Merchantable Volume (ft^3/ac)	2496	2277	2641	2872
Score	8	7	9	10
Total	48	42	54	60

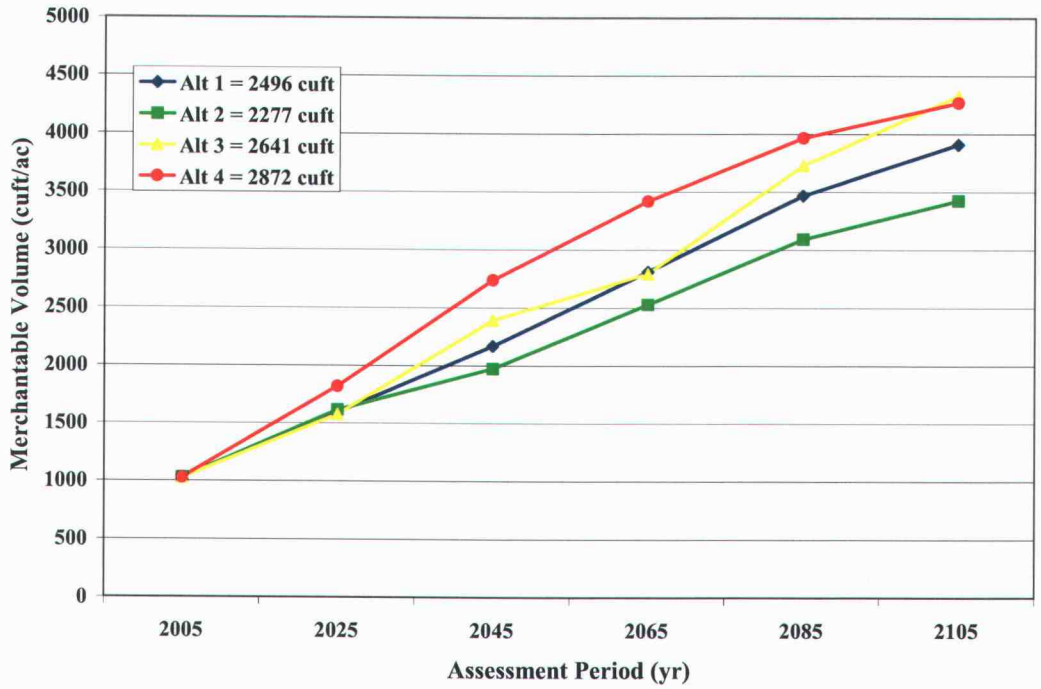

Figure 16: *Merchantable volume (ft^3 per acre) evaluated in six periods for each alternative. Note: numbers in the legend indicate averages over all periods and do not include thinning volume.*

SELECTION OF PREFERRED ALTERNATIVE

Based on the five rating criterion used in this analysis, I select alternative 3 as the preferred alternative for treating the Tenino stand. Outlined in Table 17, this alternative produced the highest performance for one criterion and second best for three criteria. The cumulative score of 357 is the highest of all alternatives evaluated. Alternative 2 performed similarly within each criterion but emerged as the second best management approach with a cumulative score of 345.

Table 17: *Treatment alternative ranking and evaluation. Note: alternative 3 produced the best cumulative score of 357.*

	Alternative 1 Crown	**Alternative 2 Fire**	**Alternative 3 Volume**	**Alternative 4 Nothing**
Crown Closure Weight = 10	Score = 10 Total = 100	Score = 7 Total = 70	Score = 8 Total = 80	Score = 9 Total = 90
Fire Resiliency Weight = 9	Score = 7 Total = 63	Score = 10 Total = 90	Score = 9 Total = 81	Score = 8 Total = 72
Basal Area Weight = 8	Score = 8 Total = 64	Score = 10 Total = 80	Score = 9 Total = 72	Score = 7 Total = 56
Mortality Weight = 7	Score = 8 Total = 56	Score = 9 Total = 63	Score = 10 Total = 70	Score = 7 Total = 49
Merch Volume Weight = 6	Score = 8 Total = 48	Score = 7 Total = 42	Score = 9 Total = 54	Score = 10 Total = 60
TOTAL SCORE	**331**	**345**	**357**	**327**

Alternative 3 (volume production) was most effective in meeting the criteria requirements of overall stand mortality and second best for fire resiliency, basal area, and merchantable volume. Over time, this alternative will produce a stand that is similar to pre-fire suppression conditions, which are characteristic of the ecology of the Tenino stand. However, the alternative performed third best with respect to canopy cover. This highlights the importance of tradeoffs within forest management. To promote merchantable volume production and overall forest health, canopy cover may have to be compromised. Assuming the assumptions made by Fielder et al.

(2001) regarding fire hazard and crowing index applies to the Tenino stand, there may be potential to modify the prescription outlined in Table 11. As shown in Figure 13, the crowning index reaches 50 mph (low hazard) by approximately 2065 and continues to increase throughout the assessment periods. Throughout time, managers may desire to lengthen the commercial thinning intervals that correspond to keeping the stand crowning index just above 50 mph. This modification may serve as a mechanism to increase canopy cover and merchantable volume production. However, these assumptions must be evaluated in the field after successful implementation of the initial management actions.

OPERATIONAL PRESCRIPTION

Stand Identification: Stand #s 9050016, 9050086, 9050165, and 9050185

Exam Type: Silvicultural Prescription Survey, Pre-treatment Stand Exam

Land Management Zone: Wildlife

Site Data:

Acres — 83.2

Slope — 3.5%

Aspect — 40°

Elevation — 2,800-3,000 feet

Plant Association — PIPO/PUTR-ARPA

Stand Data: (2004)

Structure — Multi-storied

Species Comp — Ponderosa pine (99.42%), Western juniper (0.5%), Douglas-fir (0.08%), and Incense-cedar (0.02%)

Average Age — 60/120

Quadratic Mean Diameter — 5.74 inches

Basal Area per Acre — 66.27 ft^2

Trees per Acre — 444

Stand Density Index — 127

Desired Future Condition:

This stand will be multi-storied with a species mixture of primarily ponderosa pine with scattered Douglas-fir, western juniper, and incense-cedar. The stand will have at least four age classes scattered in clumps. The open horizontal structure will insure less chance of a crown fire to the old growth and other older ponderosa pine. This will insure some structural diversity for the management group. The shrub layer will consist of healthy young plants for big game browse. The stand will also be resilient to lethal crown fire (low hazard rating) and develop along the historic structure of the pine areas. The treatment will reduce the closeness of crowns, promote merchantable volume production in the co-dominant class, and continue the stand as multi-storied with a minor component of dominant old-growth trees in the overstory.

Diagnosis:

This stand has a dense, young understory in clumps that are experiencing the effects of competition. The vertical structure or ladder fuels may cause a non-lethal fire to become lethal. The dense understory will continue to stagnate, lose growth potential, and become susceptible to insect and disease attack if left untreated.

Treatment:

2005 Year 0:

— Pre-commercially thin trees less than 5-inches DBH to a residual density of 50 trees per acre.

Reduce the risk of catastrophic wildfire and mortality losses by mechanically harvesting and extracting small trees less than 5-inches DBH. The thinning will be from below and by spacing standards (approximately 30-ft by 30-ft). Remove any tree with dwarf mistletoe infection. Do not leave the harvested tree stumps any lower than 2 inches or higher than 6 inches above the ground level, a boulder, or other unmovable object. Species in order of leave preference: 1) ponderosa pine, 2) Douglas-fir, 3) incense-cedar, and 4) western juniper. Tree characteristics in order of leave preference: 1) disease free, 2) dominant or co-dominant, 3) 30% crown ratio or greater, 4) dense crown, 5) good form with no forking, and 6) good terminal leader growth.

2006 Year 1:

— Perform a prescribed fire that consumes logging slash, surface fuels, and shrubs.

2007 Year 2:

— Plant ponderosa pine to a density of 600 per acre in the openings.

2037 Year 32:

— Commercially thin trees less than 20 inches DBH, from below, to a residual basal area of 50 ft^2 per acre.

2045 Year 40:

— Perform a stand exam to assess regeneration success and check for insects and diseases.

2067 Year 62:

— Commercially thin trees less than 20 inches DBH, from below, to a residual basal area of 50 ft^2 per acre.

2075 Year 70:

— Perform a stand exam to assess regeneration success and check for insects and diseases.

2097 Year 92:

— Commercially thin trees less than 20 inches DBH, from below, to a residual basal area of 50 ft^2 per acre.

2105 Year 100:

— Perform a stand exam to assess regeneration success and check for insects and diseases.

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