Tower Fire Ecosystem Analysis
Umatilla National Forest
North Fork John Day Ranger District

FOREST VEGETATION REPORT

David C. Powell
Forest Silviculturist
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INTRODUCTION

The Tower fire was first reported at 5:55 PM on Tuesday, August 13, 1996. It and numerous other fire starts resulted from a lightning storm passing over the Blue Mountains during most of the day. At first, the Tower fire was difficult to find and it was unmanned until the morning of the 15th, when smokejumpers were flown to the area. By late that afternoon, the fire incident log included the following statements: “blowing up, abandon the area, go out, travel to the road, get helicopter to get them” [the smokejumpers]. On August 16th, the fire was reported as moving northeast and 80 acres in size; the Tower Mountain fire lookout was evacuated at 3:30 that afternoon (Rother 1996).

The Tower fire progressed somewhat normally until late in the afternoon on August 25th, when severe fire behavior began and continued throughout the night. The fire increased approximately 20,000 acres in size in the 24-hour period ending at 5:00 PM on August 26th. This major ‘blow-up’ event was associated with a combination of weather factors particularly conducive to extreme burning conditions: strong northeast winds, high temperatures, and low humidity (Rother 1996).

The goal of this analysis was to examine the effects of the Tower wildfire on forest ecosystems. It also provides recommendations for both short-term restoration and long-term recovery treatments designed to address the wildfire impacts. The analysis was guided by these key questions:

1. How has fire affected roads, trails, and plantations?
2. What restoration opportunities exist?
3. How should partially burned areas be managed?
4. What resource values need to be retained/protected?
5. How should vegetation conditions and patterns be restored to be more ecologically sustainable?

Pre-Fire Forest Cover Types

Pre-fire forest types were very diverse, largely in response to a relatively steep elevational gradient ranging from 3,000 feet near the North Fork of the John Day River at the southwestern corner of the fire perimeter to 6,850 feet at Tower Mountain lookout on the extreme eastern edge of the analysis area.

Predominant forest cover types in the analysis area were combined into four major groups – dry forests, mesic forests, lodgepole pine forests, and cold forests. Selected characteristics of the forest cover type groups are provided in Table 1. The 'coarse vegetation map' (fig. 1) shows the geographical distribution of the forest cover type groups.

Table 1: Characterization of pre-fire forest types for the Tower analysis area.

FOREST COVER TYPE GROUP	PREDOMINANT COVER TYPES	ECOLOGICAL SETTINGS	PERCENT OF FIRE AREA
Dry Forest	**PP, DF**	**PP, WD**	**23%**
Mesic Forest	**GF, Mixed, WL, WP**	**WD, CM**	**44%**
Lodgepole Pine	**LP**	**CM, LP, CD**	**27%**
Cold Forest	**AF, ES**	**CD**	**6%**

Source/Notes: Predominant cover type species codes are: PP: ponderosa pine; DF: Douglas-fir; GF: grand fir; Mixed: mixed species; WL: western larch; WP: western white pine; LP: lodgepole pine; AF: subalpine fir; and ES: Engelmann spruce. See Table 2 for a description of the ecological settings. The 'percent of fire area' figures were derived from figure 1.

Potential Natural Vegetation

The wide diversity of site conditions found in the Tower fire is derived from changes in physiography (landform), topography, climate, soils, aspect, geology and other biophysical factors. Each combination of site factors results in slightly different temperature and moisture conditions. In the Tower analysis area and in other mountainous terrain, temperature and moisture tends to vary predictably with changes in elevation and slope exposure (fig. 2).

Since plant distributions are controlled largely by environmental factors, sites with equivalent temperature and moisture conditions will eventually support similar plant communities. Sites with the potential to support similar plant communities (associations) are called ecological settings. The plant associations in each setting are ecologically similar – they evolved in response to similar climatic and disturbance regimes, they have similar productivities, and they respond to management practices in a similar manner. Table 2 shows the plant associations present in each forested setting; table 3 summarizes selected characteristics for the settings. Figure 3 shows the geographical distribution of the ecological settings.

Why do we care about the potential natural vegetation (PNV) of the Tower analysis area? The main reason is that PNV is valuable as an ecological template for developing treatment recommendations, since a particular management activity can have widely varying results when applied in different environments. For example, consider a prescribed burn with flame lengths of 2 feet and an intensity of 25 BTU/ft/sec – that practice would have nonlethal results when used on dry sites dominated by thick-barked ponderosa pines, Douglas-firs, and western larches, but would cause significant tree mortality on cold sites supporting subalpine fir and other thin-barked species.

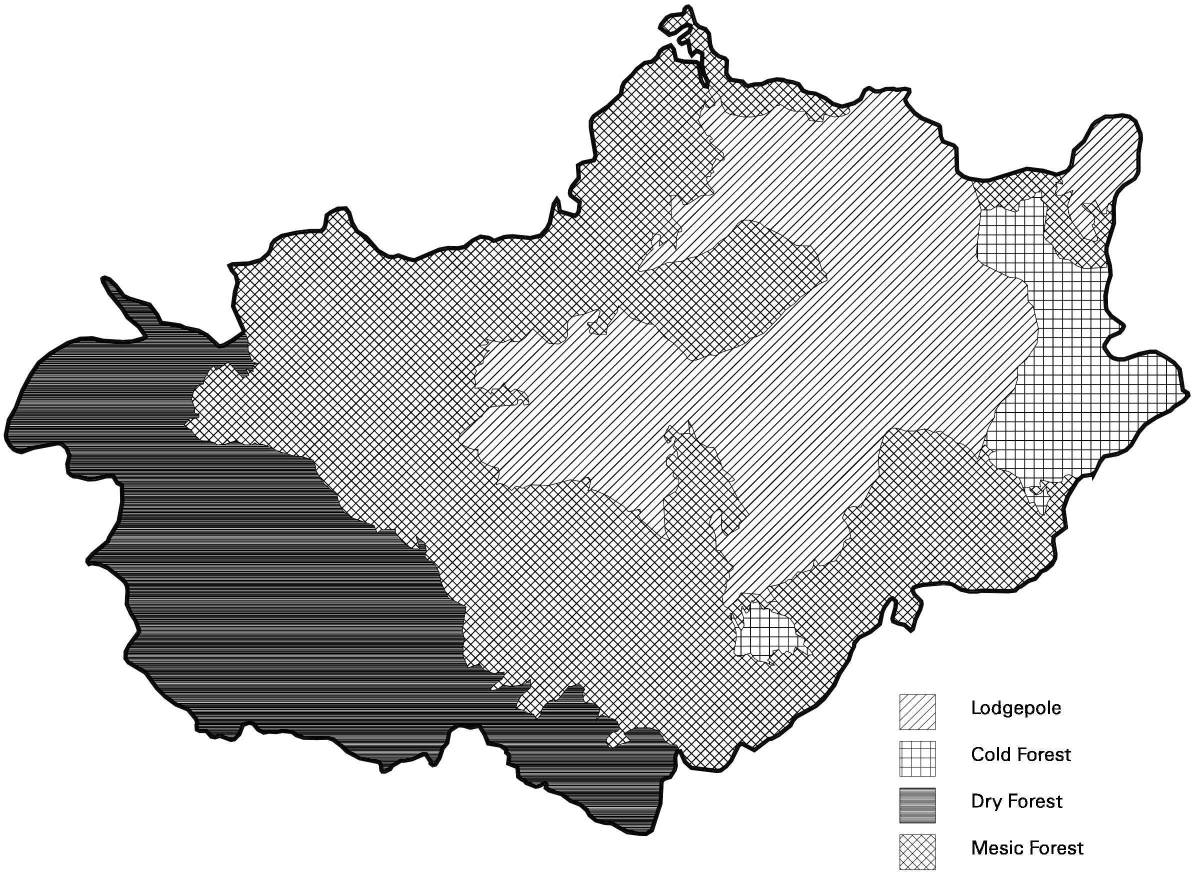

Figure 1 – Pre-existing forest vegetation types for the Tower analysis area. See Table 1 for information about the forest cover types that were combined to form the four groups shown above. This map portrays the geographical distribution of 'generalized' groups of existing vegetation as they existed just before the fire in 1996. It is considered to be a 'coarse' map because small inclusions of one group that occur within a larger one were ignored. It is not intended to depict the absolute acreage and location of the pre-fire forest cover types; rather, it was designed to show the relative abundance and distribution of the four groups using a 'zonal' approach.

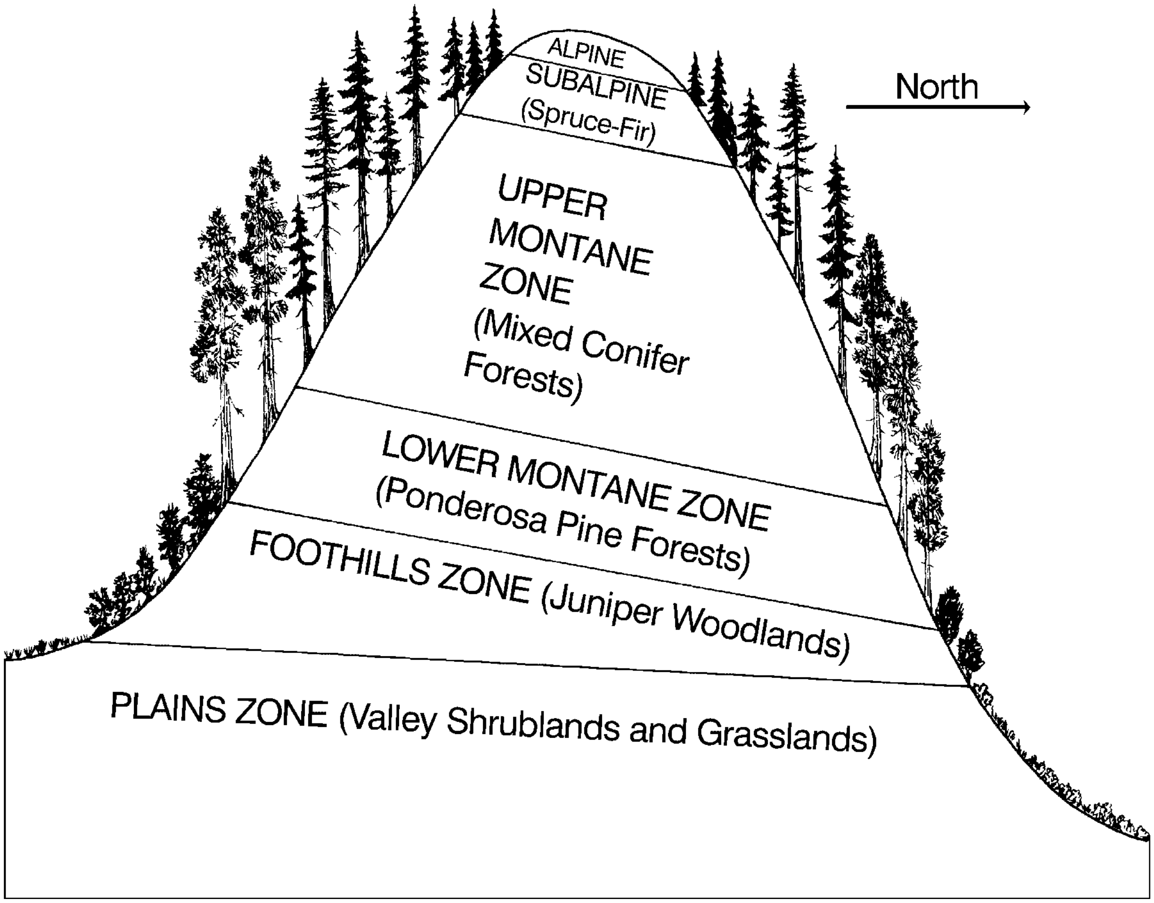

Figure 2 – Vegetation zones of the central Blue Mountains. Vegetation types tend to occur in well-defined zones as one moves up or down in elevation. In the Northern Hemisphere, a south-facing slope receives more insolation (incoming solar radiation) than a flat surface, and a north-facing slope receives less. Thus the same temperature conditions found on a plateau or bench may occur higher on an adjacent south-facing slope, and at a lower altitude on a north slope. Because of this, a particular vegetation type will be found above its ordinary elevational range on south slopes and below it on north slopes (Bailey 1996). The end result is shown above: vegetation zones arranged vertically in response to elevation (moisture), and sloping downward from south to north in response to aspect or exposure (temperature). Note that these effects can be modified by the direction of moisture-bearing winds, by variations in fog or cloud cover, and by latitude since the Pacific coastal influence gradually deteriorates from north to south in the Blues. The **plains zone** occurs at low elevations; it contains grasslands and shrublands because moisture is too low to support forests except along waterways. The **foothills zone** may be dominated by western juniper, although shrublands occupy this zone in the northern Blues where a maritime climatic regime prevails. Located above the foothills zone is the **lower montane zone**, which contains warm, dry forests of ponderosa pine and Douglas-fir. Lower montane sites are usually too dry to support grand fir forests except in riparian zones. The **upper montane zone** is widespread in the Blue Mountains. It includes cool, moist forests of Douglas-fir, grand fir, western larch, lodgepole pine and, occasionally, western white pine. Cold sites at high elevations support a **subalpine zone** with forests of Engelmann spruce and subalpine fir, or a treeless **alpine zone** near mountain summits. Alpine environments are uncommon in the relatively low-elevation Blue Mountains.

Table 2: Forested plant associations of the Tower analysis area.

PLANT ASSOCIATION	PLANT ASSOCIATION NAME	CODE
	Cold, Dry *Forested Setting* (7% of Analysis Area)	
ABGR/VASC	Grand Fir/Grouse Huckleberry	CWS811
ABGR/VASC-LIBO2	Grand Fir/Grouse Huckleberry-Twinflower	CWS812
ABLA2/VASC	Subalpine Fir/Grouse Huckleberry	CES411
	Cool, Moist *Forested Setting* (21% of Analysis Area)	
ABGR/CLUN	Grand Fir/Queencup Beadlily	CWF421
ABGR/LIBO2	Grand Fir/Twinflower	CWF311, CWF312
ABGR/VAME	Grand Fir/Big Huckleberry	CWS211, CWS212
ABLA2/LIBO2	Subalpine Fir/Twinflower	CES414
ABLA2/VAME	Subalpine Fir/Big Huckleberry	CES311, CES315
	Warm, Dry *Forested Setting* (33% of Analysis Area)	
ABGR/CAGE	Grand Fir/Elk Sedge	CWG111
ABGR/CARU	Grand Fir/Pinegrass	CWG112, CWG113
PSME/CAGE	Douglas-fir/Elk Sedge	CDG111
PSME/CARU	Douglas-fir/Pinegrass	CDG112, CDG121
PSME/HODI	Douglas-fir/Creambush Oceanspray	CDS611
PSME/PHMA	Douglas-fir/Mallow Ninebark	CDS711
PSME/SYAL	Douglas-fir/Common Snowberry	CDS622, CDS624
PSME/VAME	Douglas-fir/Big Huckleberry	CDS821
	Ponderosa Pine *Forested Setting* (14% of Analysis Area)	
PIPO/AGSP	Ponderosa Pine/Bluebunch Wheatgrass	CPG111
PIPO/CAGE	Ponderosa Pine/Elk Sedge	CPG222
PIPO/CARU	Ponderosa Pine/Pinegrass	CPG221
PIPO/ELGL	Ponderosa Pine/Blue Wildrye	CPM111
PIPO/FEID	Ponderosa Pine/Idaho Fescue	CPG112
PIPO/SYAL	Ponderosa Pine/Snowberry	CPS522
	Lodgepole Pine *Forested Setting* (18% of Analysis Area)	
PICO(ABGR)/ARNE*	Lodgepole Pine/Pinemat Manzanita	CLS5
PICO(ABGR)/CARU*	Lodgepole Pine/Pinegrass	CLG2
PICO(ABGR)/VAME*	Lodgepole Pine/Big Huckleberry	CLS511
PICO(ABLA2)/VASC*	Lodgepole Pine/Grouse Huckleberry	CLS411
PICO/CARU/VASC*	Lodgepole Pine/Pinegrass/Grouse Huckleberry	CLG211

***** These are successional (seral) plant communities rather than plant associations.

Sources/Notes: Includes plant associations recorded on stand examinations and current vegetation survey (CVS) plots for the Tower analysis area. The percentage values do not sum to 100% because this table does not include nonforest ecological settings.

Table 3: Selected characteristics for forested ecological settings.

Ecological Setting	Disturbance Agents	Fire Interval	Fire Mortality	Patch Sizes	Primary Landform	Elevation Zone	Typical Aspects
Cold, Dry (CD)	Wind Insects Fire Diseases	> 100 years	> 70% of large trees	5-1,000 acres	Gentle Tablelands	High (> 5800′)	North East Flat
Cool, Moist (CM)	Wind Fire Insects Diseases	26-100 years	20-70% of large trees	300-10,000 acres	Dissected Sideslopes	Moderate (4800-5800′)	North East West
Warm, Dry (WD)	Fire Insects Diseases	1-25 years	0-20% of large trees	150-2,000 acres	Dissected Sideslopes	Low (< 4800′)	South West
Ponderosa Pine (PP)	Fire Insects Diseases	1-25 years	0-20% of large trees	10-200 acres	Dissected Sideslopes	Low (< 4500′)	South East
Lodgepole Pine (LP)	Insects Fire Diseases	> 100 years	> 70% of large trees	40-1,000 acres	Gentle Tablelands	Moderate (> 5000′)	East North Flat

Sources/Notes: Fire interval and fire mortality ratings are from Agee (1993); disturbance agents, patch sizes, landforms, elevation zones, and aspects were adapted from Powell and Erickson (1996).

CURRENT CONDITIONS

Much of the Tower fire area is a good example of the damage caused by a crown fire. A crown fire is one that spreads through the forest canopy. Crowning is one of the most spectacular fire behavior phenomena that wildland fires exhibit. Crown fires are fast spreading and release a tremendous amount of heat energy in a relatively short period of time. Spread rates exceeding 7 miles per hour and flame lengths over 150 feet have been recorded (Pyne and others 1996).

A running crown fire may spread for several hours, burning out entire drainages and crossing mountain ridges that would normally serve as topographic barriers. Fully developed crown fires are of two types: wind driven or convection (also called plume-dominated fires). Tower was an instance in which a strong convection column (the plume) built vertically above the fire.

The velocity of air rushing upward in a convection crown fire causes air near the ground to be sucked into the column, which promotes rapid fuel combustion. The resulting in-drafts increase fire intensity, thus accelerating fire spread. This process results in a towering smoke column and spread rates that are exceptionally fast for the prevailing winds – the fire expands at a speed much greater than would be expected from the ambient wind conditions (Pyne and others 1996).

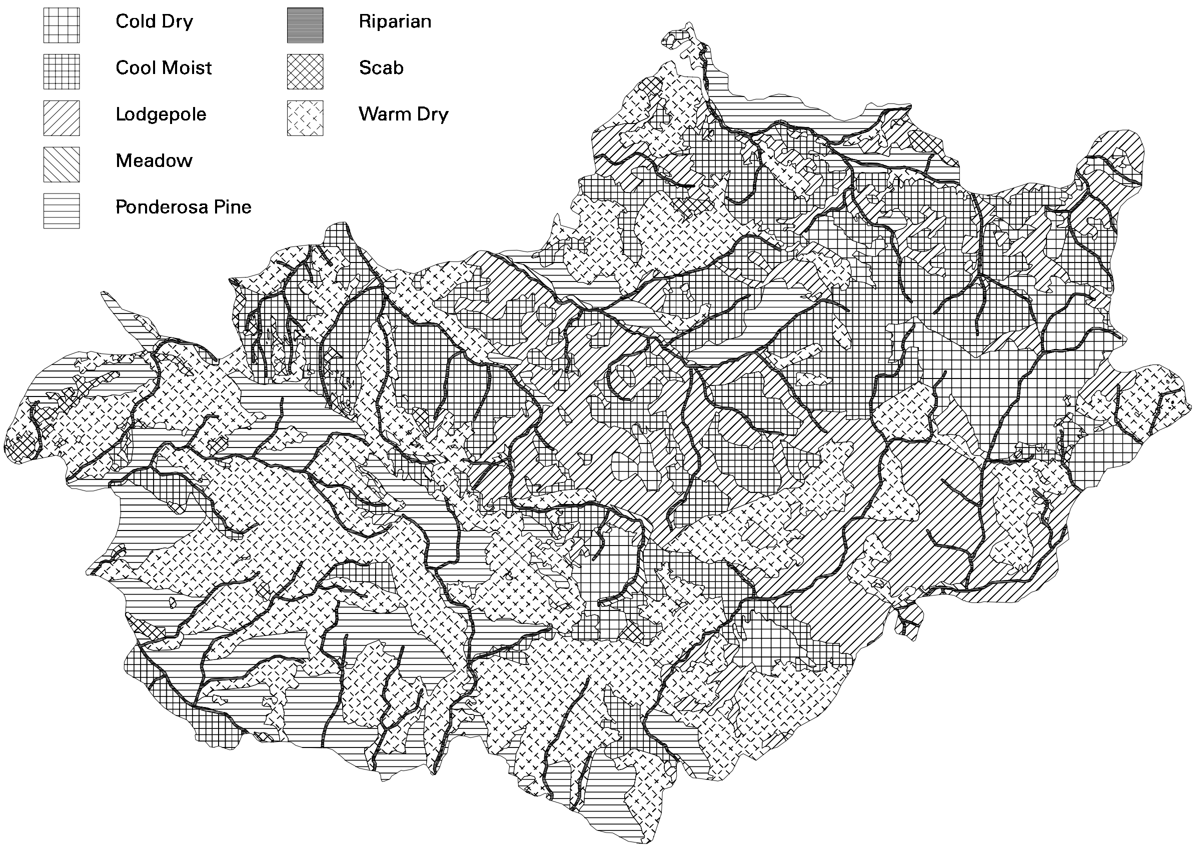

Figure 3 – Potential natural vegetation (PNV) of the Tower analysis area. This map shows the geographical distribution of the eight ecological settings found in the analysis area (it was prepared by Karl Urban, Forest Botanist for the Umatilla National Forest). PNV was used when developing management recommendations, such as the tree planting specifications provided in Table 23.

It is also believed that the Tower fire exhibited a dangerous condition called a downburst or microburst, where winds blow outward near the ground as the convection column collapses. These winds can be very strong and can greatly accelerate a fire. Downburst conditions are initiated by evaporative cooling that cools surrounding air, causing it to descend rapidly and spread horizontally at the ground surface (Pyne and others 1996).

A convection crown fire is one of the most intense disturbance events that wildland forests ever experience. They cause enduring changes to stand structure, species composition, and other ecosystem components. Occasionally, even the forest floor is consumed by a very intense fire, which can then affect nutrient cycling (Tiedemann and Klock 1973), soil wettability (Dyrness 1976), and other ecological processes with a direct influence on site productivity.

What were the results of a convection crown fire in the Tower analysis area? Figure 4 shows that 45% of the forests in the analysis area experienced complete, or near-complete, mortality. The balance of the area (55%) sustained partial mortality – seldom were all of the trees killed in those stands. Partial-mortality areas with a high proportion of thin-barked trees may experience significant mortality because a small amount of bole scorch can be lethal for those species. Figure 5 shows the geographical distribution of two categories of stand mortality: partial (labeled 'under') and complete (labeled 'heavy').

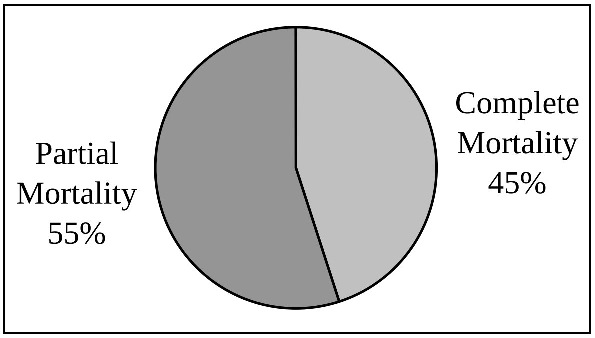

Figure 4 – Stand mortality caused by the fire.

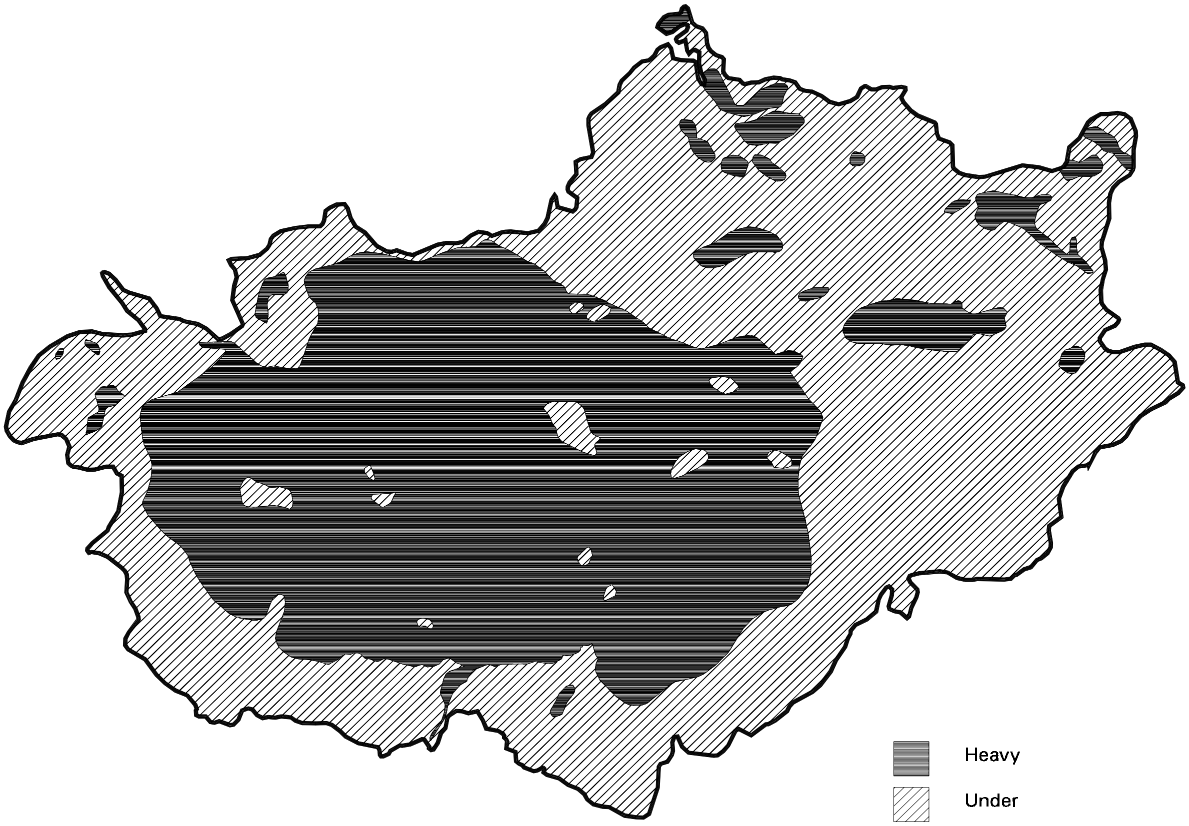

Figure 5 – Distribution of stand mortality in the analysis area. A convection crown fire resulted in stands with complete, or near-complete, tree mortality in the Tower analysis area. Those areas are shown as 'heavy' fire damage in this figure. The 'under' areas were underburned and sustained partial tree mortality; seldom were entire stands killed in those areas. The large area of complete mortality in the western half of the analysis area was the result of a 'blow up' wildfire event that occurred from the afternoon of August 25th to about 5 PM on August 26th, 1996. The fire consumed approximately 20,000 acres during that 24-hour period.

Figure 6 – An example of a ‘partial mortality’ burn area. Fifty-five percent of the Tower analysis area was affected by a fire intensity that did not kill all of the trees. This view, which was taken in the North Fork John Day Wilderness Area near Upper Winom Creek (north of the 52 road), shows a mosaic burn in which the fire crept around and caused intermittent consumption of the forest floor. The center of this photo shows a small, unburned area in which small lodgepole pine seedlings about one foot tall were not damaged by the fire. If not reburned in the near future, these small ‘escape’ areas will form the basis of a future forest on these sites.

Figure 7 – Examples of ‘complete mortality’ burn areas. Forty-five percent of the Tower analysis area was burned intensely enough to kill all, or nearly all, of the trees. These views show examples of dead stands (left, near lower Winom Creek south of the 52 road) and the forest floor (right) in areas that sustained complete mortality.

Effects of the Fire on Western White Pine (Powell and Erickson 1996)

The Tower fire adversely affected a number of natural stands of western white pine on the North Fork John Day District (NFJD), including those occurring in Hidaway Meadows, Winom Butte, Pearson Ridge, and the Texas Bar drainage (fig. 8). Fire intensity was moderate to high in those areas and, as a consequence, an estimated 60-70 percent of the natural white pine populations on the District have been extirpated. This is of particular concern because the Blue Mountains have a restricted, outlier population of white pine anyway (fig. 9).

In addition to their intrinsic biotic value, the burned stands would have served as a major source of reforestation seed for the District. Most of the remaining western white pine on NFJD is inaccessible or has high levels of blister rust. The loss of the 20-acre Texas Bar stand is especially significant since plans were underway to thin and culture it for use as a seed production area. In addition, a number of the burned white pines were select parent trees being screened for resistance to western white pine blister rust at the Dorena Genetic Resource Center.

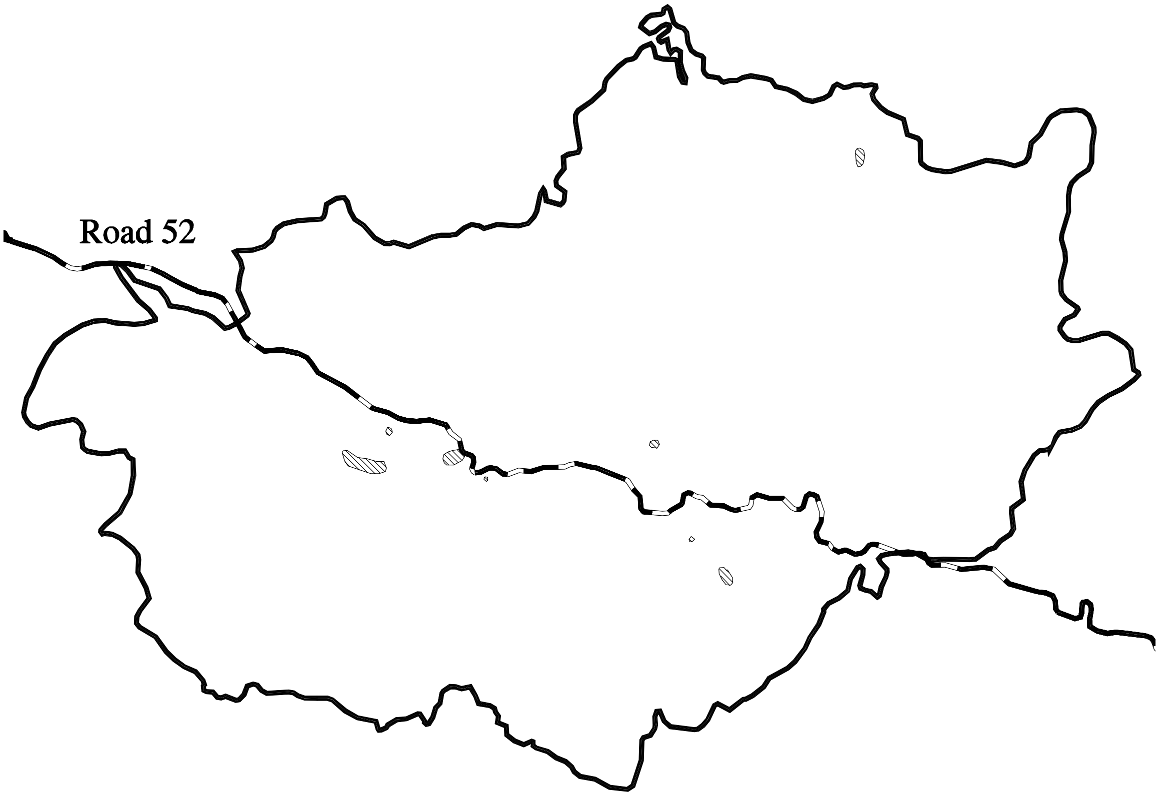

Figure 8 – Location of western white pine stands affected by the Tower fire. In the Tower analysis area, fire intensity was moderate to high in most of the areas where western white pine occurred. As a consequence of the high fire intensity, and because white pine has relatively low fire resistance (see Table 6), an estimated 60-70 percent of the natural white pine populations on North Fork John Day Ranger District were extirpated by the fire.

Over the last 15 years, western white pine has increasingly been used in District reforestation plantings due to its high survival and juvenile growth rates when established on ecologically suitable sites. An estimated 25-50 percent of those plantings (approximately 300-400 acres) were destroyed by the Tower Fire. The majority of the plantations occurred in the Texas Bar and Oriental Creek areas.

The Role of Wildfire in Blue Mountains Forests

Dry forests evolved with fire as a frequent visitor. Historically, many low-elevation sites in the Tower analysis area supported open, park-like forests of ponderosa pine, often with a dense undergrowth of tall grasses. Those conditions had been created and maintained by low-intensity surface fires occurring every 8-20 years (Hall 1977). Although lightning started many fires in mid or late summer (Plummer 1912), a surprising number were ignited by American Indians (Cooper 1961, Johnston 1970, Robbins and Wolf 1994).

Fire has traditionally been viewed as an undesirable event, but in presettlement pine forests it was a critically important ecological process. In dry forests, natural decomposition of needles, twigs, and other forest litter occurs slowly. Low-intensity fire was important for periodically cycling the litter's rich supply of nutrients (fig. 10).

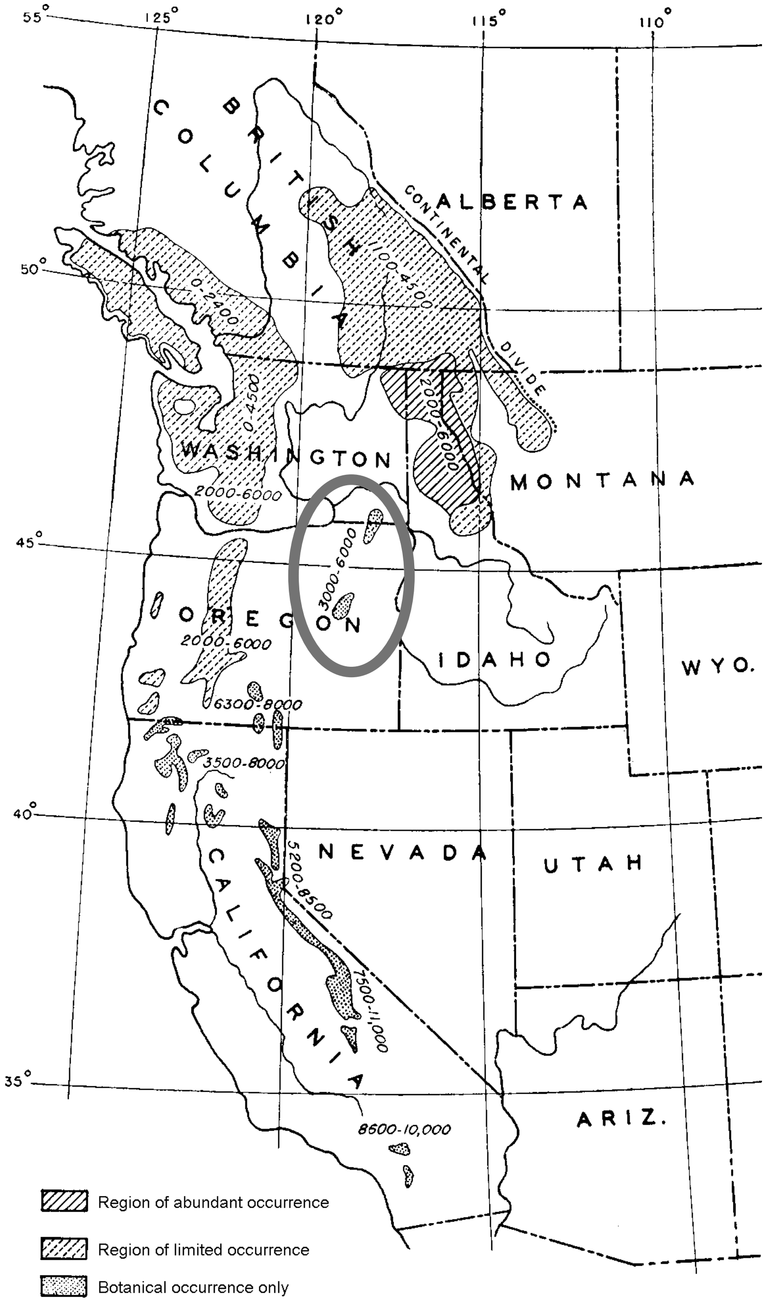

Figure 9 – Geographic distribution of western white pine. This map shows the range of western white pine in North America as it was known in the late 1930s. The area enclosed in the gray ellipse (center of figure) shows the restricted distribution of white pine in the Blue Mountains. Unfortunately, the Tower fire killed many white pine stands, further limiting its distribution on the Umatilla National Forest (Figure adapted from Haig and others 1941.)

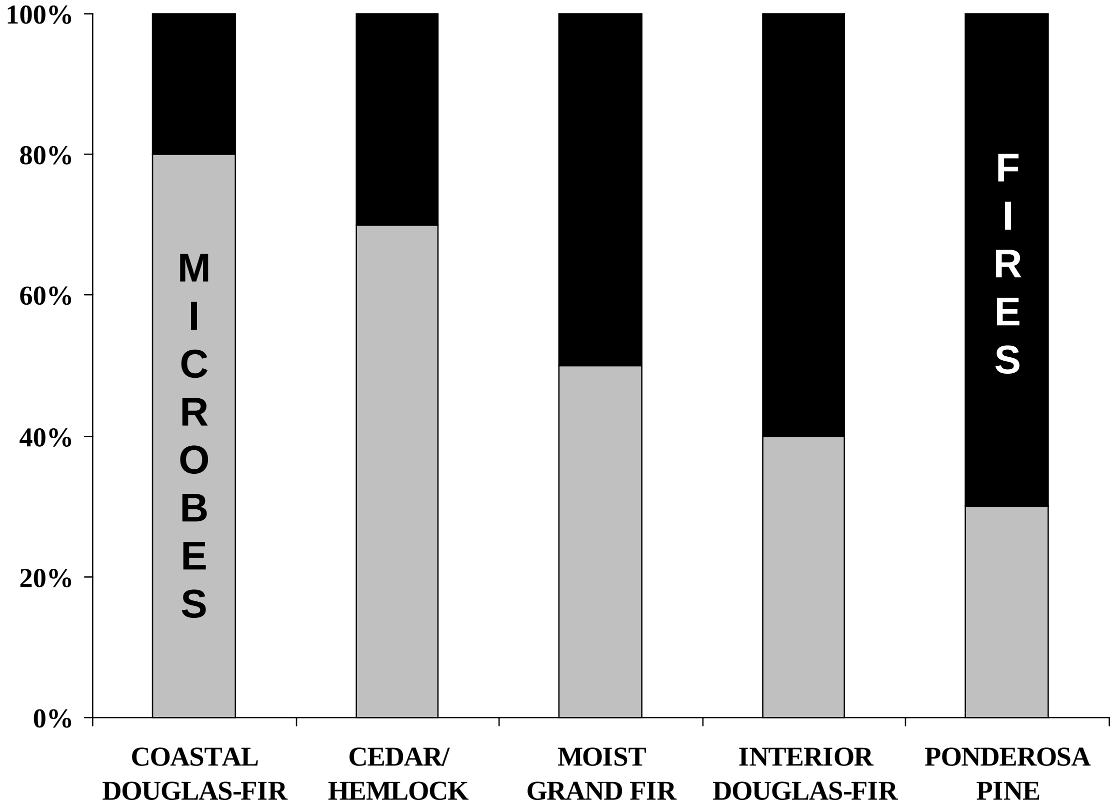

Figure 10 – Fire as a decomposer. In dry forests of the interior Pacific Northwest, fire was an important ecological process for nutrient cycling. Coastal Douglas-fir forests and other areas with a humid, temperate climate can recycle nutrients using microbial decomposition, but microbes are relatively ineffective in dry ecosystems. After frequent, low-intensity fires were suppressed following Euro-American settlement of the Blue Mountains, microbial decomposition has been unable to recycle all of the organic debris (needles, twigs, branches, etc.) that accumulates beneath forests as they grow and develop. In such situations, a disturbance event eventually 'resets' the system by converting the accumulated biomass back to its elemental constituents. A conflagration-type wildfire served as the 'reset' event for the Tower analysis area. (Figure adapted from Harvey and others 1994.)

Low-intensity fire was also important for thinning (Weaver 1947, 1957), which was needed because ponderosa pine stagnates when growing in dense, crowded stands. If crowded pine stands were not thinned by fire, bark beetles or pathogens eventually reduced their density. Since fire's influence was so pervasive, underburned pine stands were stable, ecologically sustainable systems (fire-dependent plant communities).

Mixed-conifer (mesic) and lodgepole pine forests are similar in that a physical deterioration over time eventually induces high flammability. Most often, the physical deterioration is caused by defoliators (spruce budworm or tussock moth), bark beetles, root diseases, and other factors associated with dense, overstocked stand conditions. Once highly flammable conditions exist, a stand-replacement fire is the ultimate result (Habeck and Mutch 1973).

In the cold-forest zone, a short growing season and low temperatures slow plant succession and other ecological processes. Consequently, the effects of stand-replacement fire can be extremely persistent, often enduring for many decades. Unlike low elevations where frequent fires were important for maintaining biotic diversity (Hall 1991), the impacts from infrequent subalpine burns are long-lasting (Habeck and Mutch 1973).

Effects of Fire Suppression

After low-elevation fires were suppressed, the effects were eventually dramatic. Multi-storied stands of shade-tolerant conifers got established, often at high densities. Thick layers of organic matter accumulated beneath the invading fir trees, tying up nitrogen and other nutrients that are cycled slowly without fire (fig. 10). Little natural mortality occurred, and the trees that died were usually the small pines and larches that succumb to suppression before the firs. Fuels accumulated at an alarming rate. Herbage production declined substantially, affecting both native and introduced ungulates. A study from dry forests in the southwestern United States found that stream flows were reduced by a third or more because dense tree stands use more water than open ones (Covington and Moore 1994).

Many land managers would agree that wildfire suppression was a policy with good intentions, but that policy failed to account for the ecological implications of a major shift in species composition. Grand firs and Douglas-firs can get established under ponderosa pines in the absence of underburning, but they may not have enough resiliency to persist over the long run, let alone survive the next drought. Perhaps the recent deterioration of forest health in the Blue Mountains is not surprising when considering the changes in vegetation composition and structure that occurred after fire was prevented from fulfilling its ecological role (Powell 1994).

Recent spruce budworm damage is just one legacy of fire suppression; perhaps a more dramatic consequence was the catastrophic wildfires affecting much of the Blue Mountains during the late 1980s and 1990s (Glacier, Snowshoe, Sheep Mountain, Buck Springs, Canal, Tepee Butte, Bull, Tower, Summit, etc.). Catastrophic fires occurred after fire suppression allowed fuel loads to reach unnatural levels, and because dense forests provide a stand structure that promotes destructive crown fires. Even though current technology allows low-intensity fires to be controlled, it is almost impossible to extinguish high-intensity wildfires in heavy fuels – they burn until the fuel is gone or until the weather changes.

REFERENCE CONDITIONS

Table 4 compares historical forest types (1937) with those that existed before the fire occurred in 1996. It shows that dry forests have declined 47% between 1937 and 1996, with a corresponding increase in mesic forest types. Although Table 4 also shows a high percentage increase in cold forest types, that change may not be real because the 1937 map did not distinguish cold-forest types to the same level of detail as current mapping. Figure 11 shows the geographical distribution of the 1937 forest type groups.

A substantial decline in dry forest types between 1937 and 1996 is a good example of an impact resulting from fire suppression over the last 75 years (see “Effects of Fire Suppression” above). *Perhaps the most important management strategy that could be adopted for the Tower analysis* *area is one that would attempt to restore dry forests (those occurring on the ponderosa pine and warm dry ecological settings) to a level that approximates their historical abundance.*

Table 4: Comparison of historical and pre-fire forest cover type groups.

FOREST COVER TYPE GROUP	PERCENT OF AREA IN 1937	PERCENT OF AREA IN 1996	PERCENT CHANGE
Dry Forest	**43%**	**23%**	**– 47%**
Mesic Forest	**30%**	**44%**	**+ 47%**
Lodgepole Pine	**27%**	**27%**	**0**
Cold Forest	**< 1%**	**6%**	**+ 500%**

Source/Notes: The ‘percent of area in 1937’ figures were derived from a 1937 forest type map prepared by the Pacific Northwest Forest Experiment Station (Andrews and Cowlin 1937). Although the 1937 map varies somewhat from current standards, the 1937 types were grouped in a similar way as the 1996 types. The 1937 figures probably underestimate the true percentage of cold forest since some of that group was apparently included in a type that included higher elevation mixed-conifer forest (type code 19). See comments for Table 1 for derivation of the 1996 percentages.

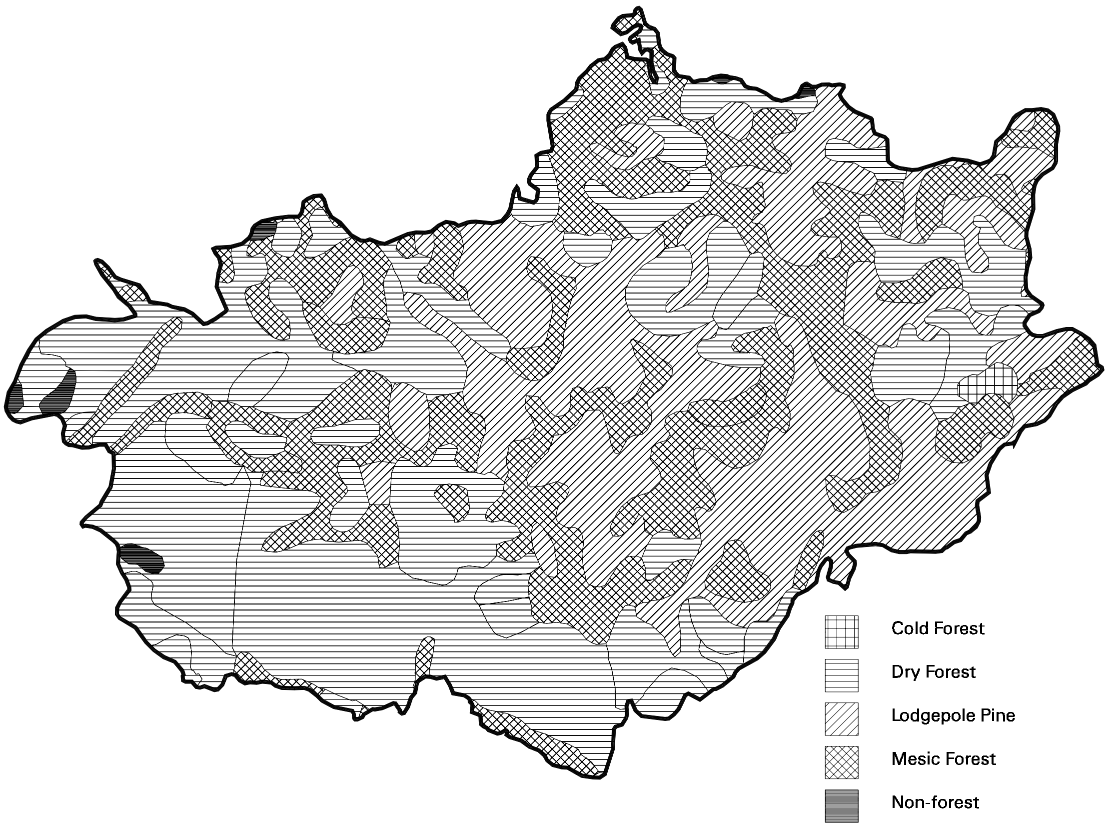

Figure 11 – Historical forest types (Andrews and Cowlin 1937). Cold forest was map symbol 03 on the 1937 map; dry forest was a combination of map symbols 06, 07, 08, 13, 14, 15, and 17 (ponderosa pine and Douglas-fir cover types); lodgepole pine was map symbol 04; mesic forest was map symbols 19 and 20 (true fir types); nonforest was map symbol 01.

RECOMMENDATIONS

This section provides management recommendations that could facilitate either short-term recovery, or long-term restoration, of forest vegetation in the Tower analysis area. The recommendations did not explicitly consider project feasibility (logging operability, etc.), so they basically represent management opportunities. Whether those opportunities can be realized or not will depend on the detailed project planning that will follow this ecosystem analysis.

Tree Salvage (pertains to forested uplands only)

Salvage cutting is "the removal of dead trees or trees being damaged or dying due to injurious agents other than competition, to recover value that would otherwise be lost" (Society of American Foresters 1994). For the Tower area, salvage cutting could be considered for three categories of trees:
- dead trees that were killed by the fire;
- live trees that are likely to die in the near future as a result of fire-caused damage;
- live trees that are likely to be killed by insects which attack fire-stressed trees.

Salvage logging can have both positive and negative impacts. Some important benefits of salvage are to harvest and utilize wood fiber while it is still merchantable, to remove enough dead trees to promote regeneration of sun-loving seral species, and to reduce fuel loadings to the point where wildfire risk is acceptable and a prescribed burning program could be initiated (Powell 1994). Table 5 shows the management areas in which the Umatilla NF Forest Plan allows salvage cutting to occur.

Whether a tree was killed or damaged by the fire depends on a variety of factors, such as fire resistance characteristics that vary by species (Table 6), fire intensity, fire duration, when the fire occurred during the growing season, and the amount of tree damage caused by the burn. An important concern is the increased susceptibility of fire-damaged trees to insect attack. For ponderosa pine, the risk of western pine beetle attack varies in direct proportion to the amount of crown lost from fire scorch (Table 7).

The response of ponderosa pine and many other conifers to crown scorch varies depending on when the fire occurred during the growing season – early summer fires cause more damage than late summer burns. Less damage occurs in late summer because tree growth has slowed, terminal buds have formed, and root (food) reserves have been accumulated. Crown scorching in early spring, before or immediately after bud burst, often results in minimal damage to the tree (Crane and Fischer 1986).

Bark thickness has an important influence on tree survival; thin-barked species have a greater probability of dying within a year of being fire damaged than thick-barked species (Tables 8-15).

Insect Considerations. A recent study of fire-injured trees after the Yellowstone fires of 1988 (Ryan and Amman 1994) found that insects would attack a variety of conifers:

1. Douglas-firs with more than 50% crown scorch, or more than 75% basal girdling, suffered high mortality from Douglas-fir beetle and wood borers.

2. A large proportion of burned lodgepole pines were killed by beetles (mostly pine engravers) within 3 years of the fire, even though most trees had received less than 25% crown scorch. Although mountain pine beetle was not a major problem following the Yellowstone fires, it has infested large-diameter lodgepole pine in eastern Oregon following root injury or minor basal girdling caused by fire.
3. Engelmann spruce can experience very high levels of spruce beetle infestation following fire injury, either in standing trees or in windthrown stems whose shallow roots were damaged by surface fires that smoldered in accumulations of litter and duff at the tree bases.
4. For subalpine firs, virtually any fire vigorous enough to scorch the bark will cause cambial injury, followed by sloughing of the dead bark. Wood borers quickly and aggressively colonize the fire-damaged trees and thereby contribute to extremely high mortality rates.

Table 5: Management direction summary for the Tower analysis area.

Management Area Allocation	Salvage Permitted?	Suitable Lands?	Plant Using NFFV Funds?	Percent Of Area
A3: Viewshed 1	Yes	Yes	Yes	5
A6: Developed Recreation	Yes	No	No♦	< 1
A7: Wild and Scenic Rivers	Yes	Yes	Yes	2
A9: Special Interest Area	Yes	No	No♦	< 1
B1: Wilderness	No	No	No♦	25
B7: Wilderness (Wild/Scenic River)	No	No	No♦	< 1
C1: Dedicated Old Growth	Yes*	No	No♦	2
C2: Managed Old Growth	Yes	Yes	Yes	< 1
C3: Big Game Winter Range	Yes	Yes	Yes	< 1
C4: Wildlife Habitat	Yes	Yes	Yes	8
C5: Riparian (Fish and Wildlife)	Yes	Yes	Yes	< 1
C7: Special Fish Management Area	Yes	Yes	Yes	56
E2: Timber and Big Game	Yes	Yes	Yes	< 1
PACFISH (Riparian Mgmt. Areas)	Yes	No	No♦	N.A.

Sources/Notes: Management area allocations are from the Umatilla NF Forest Plan (USDA Forest Service 1990). The 'salvage permitted?' item shows whether salvage timber harvests are allowed by the management direction (standards and guidelines) for each land allocation; the 'suitable lands?' item shows whether capable forested lands in the management area are designated as suitable by the Forest Plan; the 'plant using NFFV funds' shows whether denuded or understocked lands could be planted using appropriated timber management funds (NFFV); and the 'percent of area' item shows the percentage of National Forest lands in the analysis area allocated to the management emphasis.

* Salvage harvest allowed ONLY if an old-growth tree stand is killed by a catastrophic disturbance.

♦ Although appropriated NFFV funds cannot be used for planting because these lands are unsuitable, planting could occur if appropriated funds were provided by the benefiting resource (wildlife, fish, etc.) OR if a salvage harvest occurred and K–V funds were collected to finance the planting.

Table 6: Fire resistance characteristics for major conifer species of the Tower analysis area.

Tree Species	Bark Thickness	Rooting Habit	Bark Resin (Old Bark)	Branching Habit	Stand Density	Foliage Flammability	Fire Resistance
Western Larch	Very thick	Deep	Very little	High and very open	Open	Low	Most resistant
Ponderosa Pine	Very thick	Deep	Abundant	Moderately high & open	Open	Medium	Very resistant
Douglas-fir	Very thick	Deep	Moderate	Moderately low & dense	Moderate to dense	High	Very resistant
Grand Fir	Thick	Shallow	Very little	Low and dense	Dense	High	Medium
Western White Pine	Medium	Medium	Abundant	High and dense	Dense	Medium	Medium
Lodgepole Pine	Very thin	Medium	Abundant	Moderately high & open	Dense	Medium	Low
Engelmann Spruce	Thin	Shallow	Moderate	Low and dense	Dense	Medium	Low
Subalpine Fir	Very thin	Shallow	Moderate	Very low and dense	Moderate to dense	High	Very low

Sources/Notes: Adapted from Flint (1925) and Starker (1934). Species rankings are based on the predominant situation for each trait. A species trait is not absolute – it can vary during the lifespan of an individual tree, and from one individual to another in a population. For example, grand fir's bark is thin when young, but relatively thick when mature.

Table 7: Relationship between crown scorch and mortality caused by western pine beetle for ponderosa pine.

Percent Scorch (Defoliation)	Percent of Trees Killed by Beetles
0-25	0-15
25-50	13-14
50-75	19-42
75-100	45-87

Sources/Notes: Adapted from Crane and Fischer (1986). [**Note**: although the original chart that this table was based on came from Crane and Fischer (1986), the data that they used to prepare it came from: Stevens, R. D.; Hall, R. C. 1960. Beetles and burned timber. Miscellaneous Paper 49. Berkeley, CA: U.S. Department of Agriculture, Forest Service, Pacific Southwest Forest and Range Experiment Station. 2 p.]

Table 8: Probability of fire-induced mortality for ponderosa pine.

	CROWN SCORCH VOLUME (PERCENT)									
DBH	**10**	**20**	**30**	**40**	**50**	**60**	**70**	**80**	**90**	**100**
5	49.0%	53.0%	59.6%	68.2%	77.6%	86.2%	92.6%	96.5%	98.6%	99.5%
6	42.1%	46.1%	52.7%	61.9%	72.4%	82.5%	90.5%	95.5%	98.1%	99.3%
7	35.8%	39.5%	46.1%	55.4%	66.8%	78.4%	87.9%	94.2%	97.6%	99.1%
8	30.1%	33.6%	39.8%	49.0%	60.9%	73.7%	84.9%	92.6%	96.9%	98.9%
9	25.3%	28.4%	34.1%	43.0%	55.0%	68.7%	81.5%	90.8%	96.1%	98.5%
10	21.1%	23.9%	29.1%	37.4%	49.2%	63.5%	77.7%	88.6%	95.1%	98.2%
12	14.8%	17.0%	21.1%	28.0%	38.6%	53.1%	69.4%	83.5%	92.6%	97.2%
14	10.6%	12.2%	10.1%	20.9%	29.9%	43.5%	60.7%	77.5%	89.5%	95.9%
16	7.8%	9.0%	7.4%	15.8%	23.3%	35.4%	52.3%	71.0%	85.9%	94.4%
18	5.9%	6.8%	5.6%	12.3%	18.4%	28.9%	44.9%	64.5%	81.9%	92.6%
20	4.6%	5.4%	4.4%	9.8%	15.0%	24.1%	38.9%	58.6%	77.9%	90.7%
22	3.8%	4.5%	3.6%	8.1%	12.5%	20.5%	34.1%	53.6%	74.1%	88.8%
24	3.3%	3.8%	3.1%	7.0%	10.9%	18.0%	30.6%	49.6%	71.0%	87.1%
26	2.9%	3.4%	2.8%	6.3%	9.8%	16.4%	28.2%	46.8%	68.6%	85.8%
28	2.7%	3.2%	2.6%	5.9%	9.2%	15.5%	26.9%	45.1%	67.1%	84.9%
30	2.7%	3.1%	2.5%	5.8%	9.0%	15.2%	26.4%	44.5%	66.5%	84.6%

Sources/Notes: These values are the probabilities, expressed as a percent, of ponderosa pines of various diameters being killed by fire. They are based on an equation and bark thickness factor from Steele and others (1996). Values above and to the right of the heavy black line show those combinations of crown scorch and tree size that result in a mortality probability that is greater than, or equal to, 50 percent.

Table 9: Probability of fire-induced mortality for Douglas-fir.

	CROWN SCORCH VOLUME (PERCENT)									
DBH	**10**	**20**	**30**	**40**	**50**	**60**	**70**	**80**	**90**	**100**
5	51.5%	55.5%	62.0%	70.3%	79.3%	87.4%	93.3%	96.9%	98.7%	99.5%
6	45.0%	49.0%	55.7%	64.6%	74.7%	84.2%	91.4%	96.0%	98.3%	99.4%
7	38.9%	42.7%	49.4%	58.6%	69.6%	80.5%	89.2%	94.9%	97.9%	99.2%
8	33.3%	36.9%	43.3%	52.7%	64.3%	76.4%	86.7%	93.5%	97.3%	99.0%
9	28.3%	31.7%	37.7%	46.8%	58.8%	72.0%	83.7%	92.0%	96.6%	98.7%
10	24.0%	27.1%	32.6%	41.3%	53.3%	67.3%	80.5%	90.2%	95.8%	98.4%
12	17.2%	19.6%	24.2%	31.7%	42.9%	57.5%	73.1%	85.8%	93.8%	97.6%
14	12.5%	14.3%	18.0%	24.1%	34.0%	48.1%	65.0%	80.6%	91.2%	96.6%
16	9.2%	10.7%	13.5%	18.5%	26.8%	39.8%	57.0%	74.7%	88.0%	95.3%
18	7.0%	8.1%	10.4%	14.4%	21.4%	32.9%	49.5%	68.7%	84.5%	93.8%
20	5.5%	6.4%	8.2%	11.5%	17.3%	27.4%	43.1%	62.8%	80.7%	92.0%
22	4.4%	5.2%	6.7%	9.4%	14.4%	23.2%	37.7%	57.5%	77.0%	90.3%
24	3.7%	4.3%	5.6%	7.9%	12.3%	20.1%	33.5%	53.0%	73.7%	88.5%
26	3.2%	3.8%	4.9%	7.0%	10.8%	17.9%	30.4%	49.4%	70.8%	87.0%
28	2.9%	3.4%	4.4%	6.3%	9.8%	16.4%	28.2%	46.8%	68.6%	85.8%
30	2.7%	3.2%	4.2%	5.9%	9.3%	15.5%	26.9%	45.1%	67.1%	85.0%

Sources/Notes: See comments for Table 8.

Table 10: Probability of fire-induced mortality for western larch.

	CROWN SCORCH VOLUME (PERCENT)									
DBH	**10**	**20**	**30**	**40**	**50**	**60**	**70**	**80**	**90**	**100**
5	49.5%	53.5%	60.1%	68.6%	78.0%	86.4%	92.7%	96.6%	98.6%	99.5%
6	42.7%	46.6%	53.3%	62.4%	72.9%	82.9%	90.7%	95.6%	98.2%	99.3%
7	36.4%	40.2%	46.7%	56.1%	67.4%	78.8%	88.2%	94.3%	97.6%	99.1%
8	30.7%	34.3%	40.5%	49.8%	61.6%	74.3%	85.3%	92.8%	97.0%	98.9%
9	25.8%	29.0%	34.8%	43.7%	55.7%	69.4%	82.0%	91.0%	96.2%	98.6%
10	21.7%	24.5%	29.8%	38.2%	50.0%	64.3%	78.3%	88.9%	95.2%	98.2%
12	15.3%	17.5%	21.7%	28.7%	39.4%	54.0%	70.1%	84.0%	92.9%	97.3%
14	10.9%	12.6%	15.8%	21.5%	30.7%	44.4%	61.5%	78.1%	89.9%	96.1%
16	8.0%	9.3%	11.8%	16.3%	24.0%	36.2%	53.2%	71.7%	86.3%	94.6%
18	6.1%	7.1%	9.0%	12.6%	19.0%	29.7%	45.8%	65.4%	82.4%	92.8%
20	4.8%	5.6%	7.2%	10.1%	15.4%	24.7%	39.6%	59.4%	78.4%	91.0%
22	3.9%	4.6%	5.9%	8.4%	12.9%	21.0%	34.8%	54.3%	74.7%	89.1%
24	3.4%	3.9%	5.1%	7.2%	11.1%	18.4%	31.1%	50.2%	71.5%	87.4%
26	3.0%	3.5%	4.5%	6.4%	10.0%	16.7%	28.6%	47.2%	68.9%	86.0%
28	2.8%	3.2%	4.2%	6.0%	9.3%	15.6%	27.1%	45.3%	67.3%	85.0%
30	2.7%	3.1%	4.1%	5.8%	9.1%	15.2%	26.4%	44.5%	66.6%	84.6%

Sources/Notes: See comments for Table 8.

Table 11: Probability of fire-induced mortality for grand fir.

	CROWN SCORCH VOLUME (PERCENT)									
DBH	**10**	**20**	**30**	**40**	**50**	**60**	**70**	**80**	**90**	**100**
5	67.9%	71.3%	76.4%	82.5%	88.4%	93.2%	96.5%	98.4%	99.3%	99.8%
6	64.6%	68.2%	73.7%	80.3%	86.8%	92.2%	96.0%	98.2%	99.2%	99.7%
7	61.3%	65.0%	70.8%	77.9%	85.1%	91.1%	95.4%	97.9%	99.1%	99.7%
8	57.8%	61.7%	67.8%	75.4%	83.2%	89.9%	94.7%	97.6%	99.0%	99.6%
9	54.4%	58.4%	64.7%	72.7%	81.2%	88.6%	94.0%	97.2%	98.9%	99.6%
10	51.0%	55.0%	61.5%	69.9%	79.0%	87.1%	93.1%	96.8%	98.7%	99.5%
12	44.4%	48.4%	55.1%	64.1%	74.3%	83.9%	91.2%	95.9%	98.3%	99.4%
14	38.2%	42.1%	48.7%	58.0%	69.1%	80.1%	89.0%	94.7%	97.8%	99.2%
16	32.6%	36.2%	42.6%	51.9%	63.6%	75.9%	86.3%	93.4%	97.2%	99.0%
18	27.7%	31.0%	37.0%	46.1%	58.0%	71.3%	83.3%	91.8%	96.5%	98.7%
20	23.4%	26.4%	31.9%	40.5%	52.5%	66.5%	79.9%	89.9%	95.7%	98.4%
22	19.8%	22.4%	27.4%	35.5%	47.1%	61.6%	76.3%	87.8%	94.7%	98.0%
24	16.7%	19.1%	23.5%	30.9%	42.0%	56.6%	72.4%	85.4%	93.5%	97.6%
26	14.2%	16.2%	20.2%	26.9%	37.4%	51.8%	68.3%	82.8%	92.3%	97.1%
28	12.1%	13.9%	17.4%	23.4%	33.1%	47.2%	64.2%	80.0%	90.8%	96.5%
30	10.3%	11.9%	15.0%	20.5%	29.4%	42.8%	60.0%	77.0%	89.3%	95.8%

Sources/Notes: See comments for Table 8.

Table 12: Probability of fire-induced mortality for lodgepole pine.

CROWN SCORCH VOLUME (PERCENT)

DBH	10	20	30	40	50	60	70	80	90	100
5	76.6%	79.3%	83.4%	87.9%	92.2%	95.5%	97.7%	99.0%	99.6%	99.8%
6	75.4%	78.2%	82.5%	87.2%	91.7%	95.2%	97.6%	98.9%	99.6%	99.8%
7	74.2%	77.1%	81.5%	86.5%	91.2%	94.9%	97.4%	98.8%	99.5%	99.8%
8	72.9%	76.0%	80.5%	85.7%	90.7%	94.6%	97.2%	98.7%	99.5%	99.8%
9	71.6%	74.8%	79.5%	84.9%	90.1%	94.3%	97.0%	98.7%	99.5%	99.8%
10	70.3%	73.5%	78.4%	84.1%	89.5%	93.9%	96.9%	98.6%	99.4%	99.8%
12	67.6%	71.0%	76.2%	82.3%	88.3%	93.1%	96.5%	98.4%	99.3%	99.8%
14	64.8%	68.4%	73.9%	80.4%	86.9%	92.3%	96.0%	98.2%	99.3%	99.7%
16	62.0%	65.7%	71.4%	78.4%	85.5%	91.4%	95.5%	97.9%	99.2%	99.7%
18	59.1%	62.9%	68.9%	76.3%	83.9%	90.4%	95.0%	97.7%	99.1%	99.7%
20	56.2%	60.1%	66.3%	74.1%	82.2%	89.3%	94.4%	97.4%	98.9%	99.6%
22	53.3%	57.3%	63.6%	71.8%	80.5%	88.1%	93.7%	97.1%	98.8%	99.6%
24	50.4%	54.4%	60.9%	69.4%	78.6%	86.9%	93.0%	96.7%	98.7%	99.5%
26	47.6%	51.6%	58.2%	66.9%	76.6%	85.5%	92.2%	96.4%	98.5%	99.5%
28	44.8%	48.8%	55.5%	64.4%	74.6%	84.1%	91.4%	95.9%	98.3%	99.4%
30	42.1%	46.1%	52.7%	61.9%	72.4%	82.5%	90.5%	95.5%	98.1%	99.3%

Sources/Notes: See comments for Table 8.

Table 13: Probability of fire-induced mortality for Engelmann spruce.

	CROWN SCORCH VOLUME (PERCENT)									
DBH	**10**	**20**	**30**	**40**	**50**	**60**	**70**	**80**	**90**	**100**
5	73.1%	76.1%	80.6%	85.8%	90.7%	94.6%	97.3%	98.7%	99.5%	99.8%
6	71.1%	74.2%	79.0%	84.6%	89.9%	94.1%	97.0%	98.6%	99.4%	99.8%
7	69.0%	72.3%	77.3%	83.2%	88.9%	93.5%	96.7%	98.5%	99.4%	99.8%
8	66.8%	70.3%	75.5%	81.8%	87.9%	92.9%	96.3%	98.3%	99.3%	99.8%
9	64.6%	68.2%	73.7%	80.3%	86.8%	92.2%	96.0%	98.2%	99.2%	99.7%
10	62.4%	66.1%	71.8%	78.7%	85.7%	91.5%	95.6%	98.0%	99.2%	99.7%
12	57.8%	61.7%	67.8%	75.4%	83.2%	89.9%	94.7%	97.6%	99.0%	99.6%
14	53.3%	57.3%	63.6%	71.8%	80.5%	88.1%	93.7%	97.1%	98.8%	99.6%
16	48.8%	52.8%	59.4%	68.0%	77.5%	86.1%	92.5%	96.5%	98.6%	99.5%
18	44.4%	48.4%	55.1%	64.1%	74.3%	83.9%	91.2%	95.9%	98.3%	99.4%
20	40.2%	44.1%	50.8%	60.0%	70.8%	81.4%	89.8%	95.1%	98.0%	99.3%
22	36.3%	40.1%	46.6%	56.0%	67.3%	78.7%	88.1%	94.3%	97.6%	99.1%
24	32.6%	36.2%	42.6%	51.9%	63.6%	75.9%	86.3%	93.4%	97.2%	99.0%
26	29.2%	32.7%	38.8%	48.0%	59.9%	72.9%	84.4%	92.3%	96.8%	98.8%
28	26.2%	29.4%	35.2%	44.2%	56.1%	69.8%	82.2%	91.2%	96.2%	98.6%
30	23.4%	26.4%	31.9%	40.5%	52.5%	66.5%	79.9%	89.9%	95.7%	98.4%

Sources/Notes: See comments for Table 8.

Table 14: Probability of fire-induced mortality for subalpine fir.

CROWN SCORCH VOLUME (PERCENT)

DBH	10	20	30	40	50	60	70	80	90	100
5	76.2%	78.9%	83.1%	87.7%	92.0%	95.4%	97.7%	98.9%	99.6%	99.8%
6	74.9%	77.8%	82.0%	86.9%	91.5%	95.1%	97.5%	98.9%	99.5%	99.8%
7	73.5%	76.5%	81.0%	86.1%	90.9%	94.8%	97.3%	98.8%	99.5%	99.8%
8	72.2%	75.3%	79.9%	85.3%	90.3%	94.4%	97.1%	98.7%	99.5%	99.8%
9	70.8%	74.0%	78.8%	84.4%	89.7%	94.0%	96.9%	98.6%	99.4%	99.8%
10	69.3%	72.6%	77.6%	83.5%	89.1%	93.6%	96.7%	98.5%	99.4%	99.8%
12	66.4%	69.9%	75.2%	81.5%	87.7%	92.8%	96.3%	98.3%	99.3%	99.7%
14	63.4%	67.0%	72.7%	79.4%	86.2%	91.8%	95.8%	98.1%	99.2%	99.7%
16	60.3%	64.1%	70.0%	77.2%	84.6%	90.8%	95.2%	97.8%	99.1%	99.7%
18	57.2%	61.1%	67.2%	74.9%	82.8%	89.7%	94.6%	97.5%	99.0%	99.6%
20	54.1%	58.1%	64.4%	72.5%	81.0%	88.5%	93.9%	97.2%	98.8%	99.6%
22	51.0%	55.0%	61.5%	69.9%	79.0%	87.1%	93.1%	96.8%	98.7%	99.5%
24	48.0%	52.0%	58.6%	67.3%	76.9%	85.7%	92.3%	96.4%	98.5%	99.5%
26	45.0%	49.0%	55.7%	64.6%	74.7%	84.2%	91.4%	96.0%	98.3%	99.4%
28	42.1%	46.1%	52.7%	61.9%	72.4%	82.5%	90.5%	95.5%	98.1%	99.3%
30	39.3%	43.2%	49.8%	59.1%	70.1%	80.8%	89.4%	95.0%	97.9%	99.2%

Sources/Notes: See comments for Table 8.

Table 15: Probability of fire-induced mortality for western white pine.

	CROWN SCORCH VOLUME (PERCENT)									
DBH	10	20	30	40	50	60	70	80	90	100
5	76.6%	79.3%	83.4%	87.9%	92.2%	95.5%	97.7%	99.0%	99.6%	99.8%
6	75.4%	78.2%	82.5%	87.2%	91.7%	95.2%	97.6%	98.9%	99.6%	99.8%
7	74.2%	77.1%	81.5%	86.5%	91.2%	94.9%	97.4%	98.8%	99.5%	99.8%
8	72.9%	76.0%	80.5%	85.7%	90.7%	94.6%	97.2%	98.7%	99.5%	99.8%
9	71.6%	74.8%	79.5%	84.9%	90.1%	94.3%	97.0%	98.7%	99.5%	99.8%
10	70.3%	73.5%	78.4%	84.1%	89.5%	93.9%	96.9%	98.6%	99.4%	99.8%
12	67.6%	71.0%	76.2%	82.3%	88.3%	93.1%	96.5%	98.4%	99.3%	99.8%
14	64.8%	68.4%	73.9%	80.4%	86.9%	92.3%	96.0%	98.2%	99.3%	99.7%
16	62.0%	65.7%	71.4%	78.4%	85.5%	91.4%	95.5%	97.9%	99.2%	99.7%
18	59.1%	62.9%	68.9%	76.3%	83.9%	90.4%	95.0%	97.7%	99.1%	99.7%
20	56.2%	60.1%	66.3%	74.1%	82.2%	89.3%	94.4%	97.4%	98.9%	99.6%
22	53.3%	57.3%	63.6%	71.8%	80.5%	88.1%	93.7%	97.1%	98.8%	99.6%
24	50.4%	54.4%	60.9%	69.4%	78.6%	86.9%	93.0%	96.7%	98.7%	99.5%
26	47.6%	51.6%	58.2%	66.9%	76.6%	85.5%	92.2%	96.4%	98.5%	99.5%
28	44.8%	48.8%	55.5%	64.4%	74.6%	84.1%	91.4%	95.9%	98.3%	99.4%
30	42.1%	46.1%	52.7%	61.9%	72.4%	82.5%	90.5%	95.5%	98.1%	99.3%

Sources/Notes: These values are the probabilities, expressed as a percent, of white pines of various diameters being killed by fire. They are based on an equation from Steele and others (1996), and a bark thickness factor from Keane and others (1996). Values above and to the right of the heavy black line show those combinations of crown scorch and tree size that result in a mortality probability that is greater than, or equal to, 50 percent.

I recommend that salvage cutting occur in the Tower wildfire area. It should be done carefully. Enough dead trees should be left to provide adequate habitat for cavity-dependent birds. Retaining dead trees also provides habitat for ants and other invertebrates that prey on the larvae of defoliating insects. And standing dead trees eventually fall to the ground, where they contribute to nutrient cycling, long-term site productivity, and mycorrhizal habitat.

A salvage program should be designed to address the following vegetation concerns:

1. Emphasize salvage in dry-forest areas (fig. 1) where fir encroachment and overstocking were present before the fire. [Sites meeting this criterion have ecologically inappropriate conditions, regardless of whether the trees are currently alive or dead.]
2. Emphasize salvage in mesic-forest areas (fig. 1) that have the capability to support a high proportion of ponderosa pine (Douglas-fir and warm grand fir plant associations). [Sites meeting this criterion would address the loss of dry forest from 1937 to 1996 (see Table 4).]
3. Consider salvage where timber volume, tree size, and species characteristics would generate sufficient revenue to fund tree planting and other restoration treatments. [This concern addresses the fact that tree planting is expensive, and that Congress may not fund all of it.]
4. Consider salvage for sites where the existing density of dead trees is great enough that a future reburn will probably destroy newly-established tree regeneration, especially if a reburn occurs shortly after the dead trees have fallen over and increased fuel continuity.
5. Consider salvage of live, damaged trees that are unlikely to survive more than a year or two:
   a. Ponderosa pines and western larches that have less than 20 percent green, healthy-appearing crown (by crown volume), regardless of bole scorch, scorch height, or duff consumption.
   b. Douglas-firs having less than 40 percent green, healthy-appearing crown (by volume) AND scorch height greater than 16 feet AND the fire consumed more than 50% of the preburn duff around the base of the tree.
   c. Subalpine firs, lodgepole pines, and Engelmann spruces with less than 60 percent green, healthy-appearing crowns (by volume) AND bole scorch on greater than 50% of the tree's circumference AND scorch height greater than 4 feet AND more than 25% of the preburn duff around the base of the tree was consumed by the fire.

Natural Regeneration (pertains to forested uplands only)

The Tower fire affected a very large area supporting a wide diversity of plant species. Plants have varying degrees of fire resistance. A plant's response to fire depends on factors such as the moisture content of soil and duff at the time of burning, the physiological stage of the plant (immature, mature, etc.), and the fire's severity, particularly regarding the amount of heat that permeates the litter, duff, and upper soil layers (Crane and Fischer 1986). An important factor affecting a plant's fire resistance is whether it regenerates vegetatively (survivor plants) or from off-site or buried seed (colonizer plants). Table 16 (at end of document) provides fire effects information for common plants of mixed-conifer forests in the Blue Mountains (Powell 1994).

The fire created conditions conducive to regeneration of early seral conifers. Unfortunately, it also killed most of the mature trees required for seed production. The probability of obtaining natural regeneration in the fire area will depend on several factors:

- the availability of surviving trees to serve as a seed source,
- the spatial distribution of seed trees, especially their proximity to severely-burned areas,
- whether the survivors are physiologically capable of producing seed in any abundance,
- whether cone (seed) crops are actually produced, and when.

We can expect forest recovery to be slow in many portions of the fire, especially areas that burned at a moderate or high intensity and whose pre-fire composition was dominated by species with low fire resistance (Table 6). Initially, severely burned areas will support herbaceous vegetation (forbs and grasses) and shrubs, with trees beginning to predominate by the end of the third decade (fig. 12).

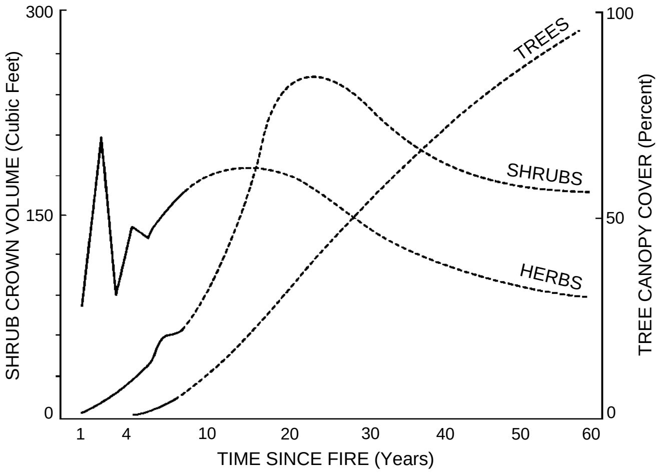

Figure 12 – Post-fire vegetation response. Herbaceous plants such as forbs and graminoids (grasses and sedges) will initially dominate the fire area. As succession progresses, woody plants eventually predominate, with shrubs peaking by the second decade and trees assuming dominance about 30 years after the fire. Figure taken from Koch (1996a).

Table 17 summarizes the area burned by ecological setting and stand mortality category. It shows that stands on ponderosa pine and warm dry ecological settings had a higher percentage of complete mortality than would be expected from the historical fire regime. Conversely, stands on the cold dry and lodgepole pine settings had a lower percentage of complete mortality than would have been expected. The cool moist ecological setting had a balanced mix of partial and complete mortality, which is close to the expected values. Figure 5 shows the geographical distribution of stand mortality categories.

Table 17: Burn summary by ecological setting and mortality category.

	ACRES (PERCENT) BY STAND MORTALITY CATEGORY				
Ecological Setting	**Partial Mortality**	**Expected**	**Complete Mortality**	**Expected**	**Total**
Cold Dry Forest	2,315 (69%)	20%	1,036 (31%)	80%	3,351
Lodgepole Pine	5,409 (58%)	20%	3,977 (42%)	80%	9,386
Cool Moist Forest	5,464 (50%)	40%	5,364 (50%)	60%	10,828
Warm Dry Forest	8,538 (50%)	80%	8,402 (50%)	20%	16,940
Ponderosa Pine	4,317 (61%)	90%	2,798 (39%)	10%	7,115
Meadows	99 (41%)		143 (59%)		242
Riparian	1,212 (57%)		921 (43%)		2,133
Scabland	608 (74%)		213 (26%)		821
Total	27,962 (55%)		22,854 (45%)		50,816

Sources/Notes: Based on the potential natural vegetation and stand mortality maps (figures 3 and 5). Percentage values are percentages of the total by ecological setting. The ‘expected’ values are the percentages that would have been expected based on the historical fire regimes (Agee no date).

In the case of lodgepole pine, some natural regeneration may be produced by cones present in the canopy of dead stands, assuming of course that any canopy remained after the fire. In many areas that burned with a moderate intensity, the fire killed all of the lodgepole pines, although some of their crowns still persist and will serve as a seed source if cones were present before the burn. Although lodgepole pine has a low percentage of closed cones (serotiny) in the Blue Mountains (fig. 13), it is a prolific seed producer and good seed crops occur frequently (Trappe and Harris 1958). If 1996 was a good seed year for lodgepole pine stands in the Tower fire area, we can expect adequate to overly abundant lodgepole pine regeneration in the future.

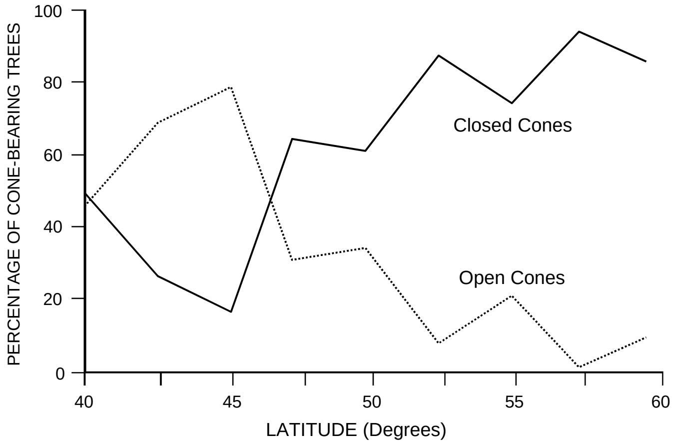

Figure 13 – Lodgepole pine serotiny varies with latitude. Note that the Tower analysis area (latitudinal zone within the gray rectangle centered on 45°) coincides with the lowest serotiny percentage for lodgepole pine in the western United States. (Figure from Koch 1996b.)

Table 18 summarizes seed production information for many different tree species. Table 19 provides effective seed dispersal distances for common conifers affected by the Tower fire.

Table 18: Seed production information for common tree species of the Blue Mountains.

TREE SPECIES	MINIMUM AGE (YEARS)	PERIOD WHEN ABUNDANT SEED CROPS PRODUCED	PERIODICITY OF GOOD SEED CROPS
Ponderosa Pine	**20**	**Late (40-60 years)**	**3-10 years**
Douglas-fir	**20**	**Intermediate (20-40 years)**	**3-10 years**
Western Larch	**15**	**Early (10-20 years)**	**3-5 years**
Black Cottonwood	**Not Provided**	**Early (10-20 years)**	**1-2 years**
Thinleaf Alder	**Not Provided**	**Early (10-20 years)**	**3-5 years**
Water Birch	**Not Provided**	**Early (10-20 years)**	**1-2 years**
Quaking Aspen	**Not Provided**	**Early (10-20 years)**	**3-5 years**
Grand Fir	**15**	**Late (40-60 years)**	**3-5 years**
Western White Pine	**15**	**Late (40-60 years)**	**3-5 years**
Lodgepole Pine	**15**	**Early (10-20 years)**	**1-2 years**
Engelmann Spruce	**25**	**Late (40-60 years)**	**2-6 years**
Subalpine Fir	**25**	**Late (40-60 years)**	**2-3 years**
Whitebark Pine	**60**	**Late (40-60 years)**	**Not Provided**

Sources/Notes: 'Minimum age' (Keane and others 1996) is when seed crops start to be produced; 'period when abundant seed crops produced' and 'periodicity of good seed crops' (Daniel and others 1979) shows when good crops are produced, and the average time interval between good crops.

Table 19: Effective seed dispersal distances for common conifers of

the Umatilla National Forest.

SPECIES	EFFECTIVE SEED DISPERSAL
Ponderosa Pine	**Up to 100-120 feet**
Western Larch	**Up to 120-150 feet**
Douglas-fir	**Up to 300-330 feet**
Grand Fir	**Up to 200 feet**
Western White Pine	**Up to 400 feet**
Engelmann Spruce	**Up to 100-120 feet**
Subalpine Fir	**Up to 50-100 feet**
Lodgepole Pine	**Up to 200 feet**

Source/Notes: Barrett (1966), Dahms (1963), and Nyland (1996). These distances are maximums for most of the seed; for example, at least 50% of Engelmann spruce seed will fall within 120 feet of the windward edge of an opening, although up to 10% of the seed will be dispersed as far as 300 feet. Figure 14 illustrates this concept for Engelmann spruce.

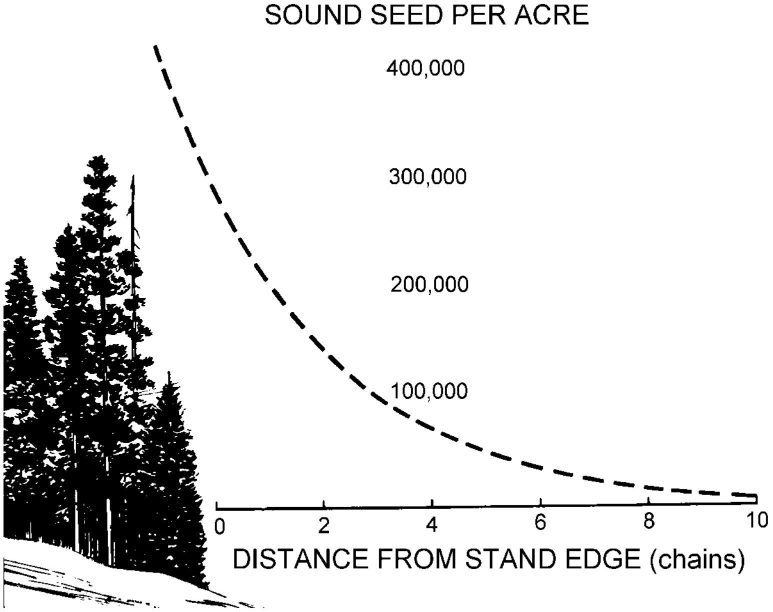

Figure 14 – Seed quantities decline rapidly with increasing distance from a seed source. This diagram shows that Engelmann spruce is a prolific seed producer, but that seed amounts decline rapidly as the distance from a seed source increases (from Roe and others 1970).

After considering the information contained in tables 18 and 19, along with local experience gained by following recovery after other fires, it was possible to estimate lag times to obtain natural regeneration in the Tower fire area. Those estimates are provided in Table 20. It is difficult to estimate lag times precisely due to variations in fire intensity, burn patterns, and stand mortality, all of which affect seed availability and establishment of natural regeneration.

Figure 15 shows the areas where natural regeneration is expected to occur. When it was prepared, I assumed that a live seed source would be present in the 'partial mortality' areas (see fig. 5), and that the seed source would be sufficient to result in natural regeneration for at least 60 meters (197 feet) into the complete-mortality areas. The 60-meter width was determined using seed dispersal information contained in Table 19. The acres of natural regeneration portrayed in figure 15 are summarized in Table 21.

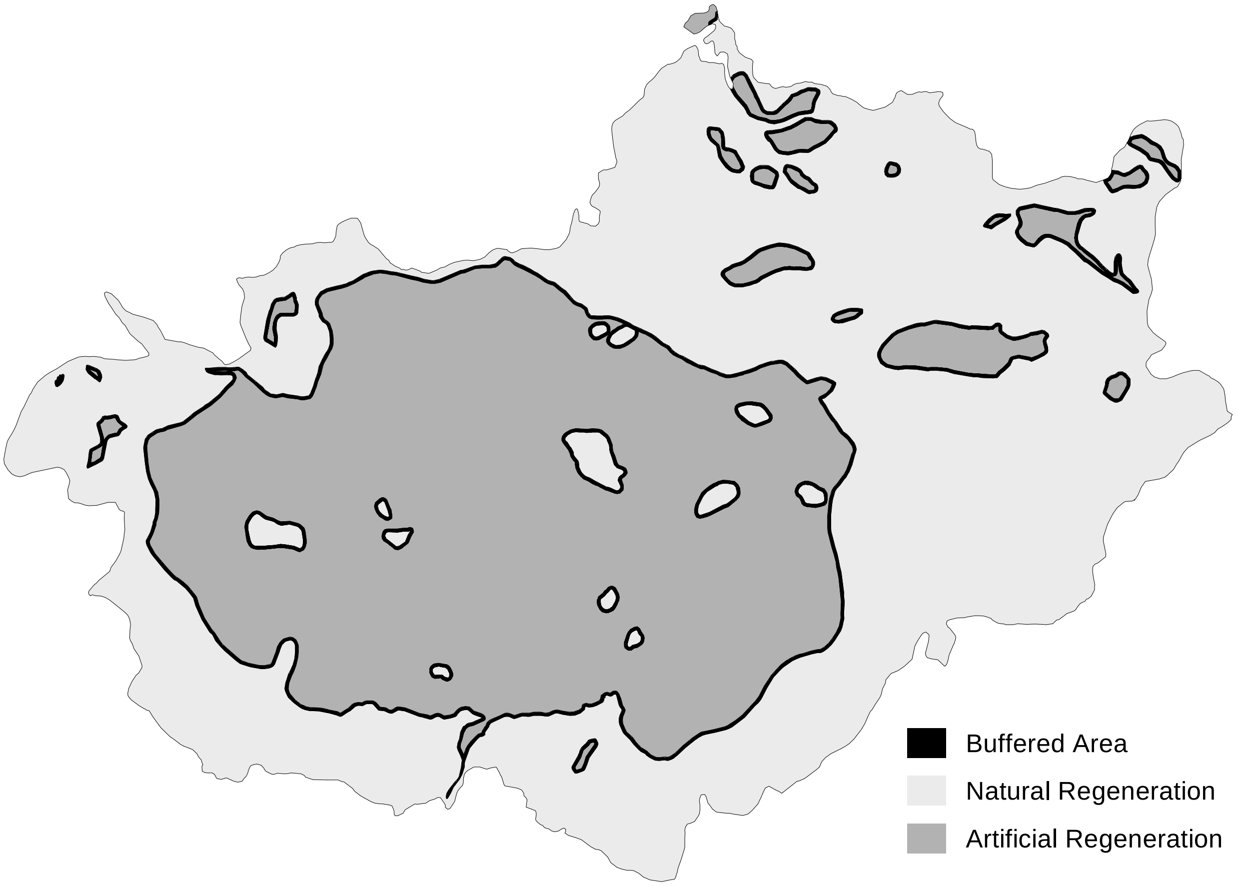

Figure 15 – Regeneration estimates for the Tower fire area. It was assumed that a live seed source would be present in the 'partial mortality' areas (see fig. 5 for a description of the stand mortality categories) and that it would allow natural regeneration to get established in those portions of the burn (shown as 'natural regeneration' in this figure). It was also assumed that the seed source present near the edges of the partial-mortality areas would be sufficient to result in natural regeneration for at least 60 meters (197 feet) into the 'complete mortality' portions of the burn. The 60-meter width (shown as 'buffered area' above) was based on the seed dispersal information contained in Table 19. Refer to table 21 for an acreage summary of the information portrayed in this figure; the 'NR' columns in table 21 are a combination of the 'natural regeneration' and 'buffered area' categories shown above. It is recommended that tree planting (shown as 'artificial regeneration' above) occur on 15,851 acres of the severely burned area; if that occurs, it is estimated that the cost could total $8,585,247.78 (see Table 25).

Table 20: Estimates of natural regeneration lag times for the Tower fire area.

FOREST	EARLY SERAL	NATURAL REGENERATION LAG PERIOD

COVER TYPE	TREE SPECIES	Partial Mortality	Complete Mortality
Dry Forest	**PP**	**< 10 years**	**10-15 years**
Mesic Forest	**WL, PP, LP**	**< 5 years**	**5-10 years**
Lodgepole Pine	**LP, WL**	**< 5 years**	**5-10 years**
Cold Forest	**LP, WL**	**< 10 years**	**15-25 years**

Source/Notes: ‘Early seral tree species’ are ecologically adapted to site conditions created by a stand-replacing disturbance event such as wildfire. Estimates of natural regeneration lag times are based on the author’s judgment, and assume that living trees of seed-bearing age are present within a reasonable distance of the site to be colonized. Table 1 describes the cover type and tree species codes; figure 5 describes the mortality classes.

Table 21: Estimated tree regeneration status by ecological setting and management area allocation.

	Cold Dry		Cool Moist		Lodgepole		Ponderosa		Warm Dry		Riparian		Grand Total	
MA	**NR**	**PL**	**NR**	**PL**	**NR**	**PL**	**NR**	**PL**	**NR**	**PL**	**NR**	**PL**	**NR**	**PL**
A3	0	1	62	174	409	418	264	104	225	681	39	**72**	960	1378
A6	0	**0**	0	**50**	0	**0**	0	**1**	0	**9**	0	**10**	0	**60**
A7	0	0	239	0	0	0	427	0	67	0	59	**0**	733	0
A9	0	**0**	0	**0**	23	**0**	0	**0**	0	**0**	12	**0**	23	**0**
B1	1902	**334**	652	**637**	2729	**215**	468	**15**	3225	**944**	318	**58**	8976	**2145**
B7	0	**0**	0	**0**	0	**0**	101	**0**	39	**0**	7	**0**	140	**0**
C1	0	**7**	431	**301**	22	**43**	1	**9**	77	**32**	27	**38**	531	**392**
C2	25	0	57	5	84	14	0	0	0	0	8	**0**	166	19
C3	0	0	0	0	0	0	1	0	130	0	12	**0**	131	0
C4	0	0	49	161	23	6	428	668	646	1432	35	**109**	1146	2267
C5	0	0	10	1	0	0	4	11	2	42	13	**34**	16	54
C7	494	552	4332	3531	2388	2916	1676	1389	3315	3745	642	**444**	12205	12133
E2	0	0	0	0	12	0	0	0	0	0	0	**0**	12	0
Pvt	0	**0**	54	**24**	0	**0**	1137	**411**	1248	**1082**	114	**72**	2439	**1517**
Total	2421	894	5886	4884	5690	3612	4507	2608	8974	7967	1286	**837**	27478	19965
NFFV		553		3872		3354		2172		5900		0		15851

Source/Notes: Derived from the potential natural vegetation (fig. 3) and regeneration (fig. 15) maps, in combination with the management area allocations. Management area (MA) ‘Pvt’ refers to private land within the analysis area. The ‘NR’ column shows the acres that are expected to naturally regenerate; ‘PL’ summarizes the acres where planting is believed to be necessary to obtain prompt tree regeneration. *Shaded cells indicate the acres where forest vegetation funds (NFFV) cannot be used to finance tree planting operations* (assuming they were appropriated by Congress). The NFFV total (bottom row) shows the acres that could qualify for planting using that funding source, if funds were available. Note that this table does not include all acres in the analysis area because nonforest ecological settings (meadows and scablands) were excluded.

Artificial Reforestation (pertains to forested uplands only)

According to field reconnaissance and a GIS analysis, it appears that 19,965 forested acres were burned severely enough to warrant artificial reforestation. After removing severely burned areas that are likely to regenerate naturally, and burned acreage that cannot be planted due to legal or administrative constraints (see Table 5), *I recommend that the remainder of the severely burned area (15,851 acres) be artificially reforested as soon as possible* (see Table 21). Figure 15 shows the geographical distribution of areas where artificial reforestation should be considered.

Planting is an effective way to influence the future composition of a forest. *If forest health is an objective, then planting should attempt to establish a future composition with at least 60 percent of the trees being early- and mid-seral species*. The successional (seral) status of 9 major conifer species found in the Tower analysis area is provided in Table 22.

I recommend that all plantings emphasize establishment of early-seral conifers on upland sites, and other appropriate species in riparian zones (see Karl Urban's floristic biodiversity report for riparian species recommendations). Table 22 shows the early seral conifers that could be considered for each of the forested plant associations. Since lodgepole pine is expected to regenerate naturally on all but the highest intensity burns, *I recommend that upland plantings emphasize other early-seral species (western larch and ponderosa pine) to a greater degree than lodgepole pine. My planting recommendations (species mixes and densities) are provided in Table 23.*

Planting recommendations (species mix, and seedlings per acre) were based on a variety of considerations. Since each tree species can tolerate a particular mix of environmental conditions (Table 24), it should not be included in a planting mix unless it is well adapted to the sites being planted. As an example, consider ponderosa pine – on hot, dry sites at low elevations, it is typically the only tree species; on warm, dry sites where Douglas-fir or grand fir are climax, it is a dominant seral species; on cool, moist sites where grand fir or subalpine fir are climax, it is a minor or accidental species; and on cold, dry sites at high elevations, ponderosa pine doesn't occur because it cannot survive in those ecological environments.

It must be emphasized that the planting recommendations in Table 23 involve a mixture of species. Even if a mixture were not being planted, a mixed stand would eventually exist after natural regeneration got established. A common misconception is that plantations are monocultures, 'corn-row' forests devoid of plant diversity. Nothing could be further from the truth, although a monoculture is certainly possible for closely spaced plantations comprised of a single species, especially if that species is susceptible to stagnation such as lodgepole pine or ponderosa pine.

Seedling density recommendations in Table 23 will seem too low to some readers. Relatively low seedling densities were selected for these reasons:

- Silviculturists tend to be conservative and often plant more trees than are really necessary in order to 'hedge their bets' for the future (Oliver and Larson 1996).
- Stands with close spacings (high densities) often have poor tree-height differentiation, which could lead to stagnation and arrested or improper development from that point onward.
- High-density stands develop tall, spindly trees often called 'wet noodles' because they can't support themselves and fall over if adjacent support trees are removed or die.

- Open stands have low levels of inter-tree competition and are highly vigorous. High-vigor stands are healthier than dense ones and generally experience few insect or disease problems.
- Open stands yield high volumes of usable timber (Sassaman and others 1977). If wood continues to be valuable, then higher yields of usable timber will be a future benefit.
- Wide spacings allow ample opportunity for establishment of natural regeneration, while also minimizing the amount of precommercial thinning that may need to occur in the future.

Table 22: Successional status of tree species by plant association.

PLANT ASSOCIATION	WJ	PP	WL	LP	DF	WP	GF	ES	AF
ABGR/VASC		ES	ES	ES	MS		PNC	LS	
ABGR/VASC-LIBO2			ES	ES	MS		PNC	LS	
ABLA2/VASC			ES	ES	MS			LS	PNC
ABGR/CLUN		ES	ES	ES	MS	MS	PNC	LS	
ABGR/LIBO2		ES	ES	ES	MS	MS	PNC	LS	
ABGR/VAME		ES	ES	ES	MS		PNC	LS	
ABLA2/LIBO2			ES	ES				LS	PNC
ABLA2/VAME			ES	ES				LS	PNC
ABGR/CAGE		ES	ES		MS		PNC		
ABGR/CARU		ES	ES	ES	MS		PNC		
PSME/CAGE		ES			PNC		A		
PSME/CARU		ES			PNC		A		
PSME/HODI		ES			PNC				
PSME/PHMA		ES	ES		PNC				
PSME/SYAL	A	ES	ES		PNC				
PSME/VAME		ES	ES		PNC				
PIPO/AGSP	A	PNC							
PIPO/CAGE	A	PNC			A				
PIPO/CARU	A	PNC			A				
PIPO/ELGL		PNC			A				
PIPO/FEID	LS	PNC							
PIPO/SYAL	A	PNC			A				
PICO(ABGR)/ARNE*		ES	ES	ES	MS		PNC	LS	
PICO(ABGR)/CARU*		ES	ES	ES	MS		PNC		
PICO(ABGR)/VAME*		ES	ES	ES	MS		PNC	LS	
PICO(ABLA2)/VASC*				ES			LS	LS	PNC
PICO/CARU/VASC*			ES	ES	MS		PNC		

Sources/Notes: From Clausnitzer (1993) for grand fir plant associations, and Johnson and Clausnitzer (1992) and Hall (1973) for other vegetation types. Codes (Hall and others 1995) are: PNC = species dominates the potential natural community; LS = late seral species; MS = mid seral species; ES = early seral species; A = accidental occurrence. See Table 1 for a description of the species codes that are used as the column headings in this table. The horizontal lines delineate the ecological settings (see Table 2).

Table 23: Planting recommendations for Tower analysis area.

	Seedling Density		**SPECIES COMPOSITION OF PLANTING MIX**							
ECOLOGICAL SETTING	**TPA**	**Spacing**	**PP**	**WL**	**LP**	**DF**	**WP**	**GF**	**ES**	**AF**
Cold Dry	222	14 feet		40%	NR	20%		NR	40%	NR
Lodgepole Pine – Cool♦	194	15 feet		30%	NR	30%		NR	40%	NR
Lodgepole Pine – Cold♦	194	15 feet			NR	40%		NR	60%	NR
Cool Moist – Moist♠	222	14 feet		30%	NR	20%	20%	NR	30%	NR
Cool Moist – Mesic•	222	14 feet	NR	40%	NR	40%		NR	20%	
Warm Dry – Mesic♣	151	17 feet	60%	20%		20%		NR		
Warm Dry – Dry♣	151	17 feet	80%			20%				
Ponderosa Pine	151	17 feet	100%							

Sources/Notes: Refer to Table 2 and Table 21 for information about the plant associations and tree species, respectively, that occur in each of the ecological settings. Trees per acre (TPA) and spacing recommendations are based on the author's judgment and Powell (1992). The species composition recommendations are based on the author's judgment, Cole (1993), Kaiser (1992), and Wallowa-Whitman NF (1996). See Table 1 for a description of the species codes used as column headings in the species composition section of this table.

NR = Natural Regeneration. I anticipate these species will occur as natural regeneration. They were not included in the planting mix, but could be used if more desirable species are in short supply.

♦ Cool types are PICO(ABGR)/ARNE, PICO(ABGR)/CARU, and PICO(ABGR)/VAME; cold types are PICO(ABLA2)/VASC and PICO/CARU/VASC.

♠ White pine is adapted to these plant associations on the North Fork District, not all of which occur in the Tower area: ABGR/TABR/LIBO2, ABGR/LIBO2, ABGR/CLUN, and ABGR/ACGL (Urban 1996).

• Includes all cool moist plant associations except ABGR/LIBO2 and ABGR/CLUN.

♣ Mesic plant associations are ABGR/CAGE, ABGR/CARU, PSME/SYAL, and PSME/VAME; all others in the warm dry forest setting are considered to be dry.

Table 24: Frost tolerance, drought tolerance, and snow damage resistance ratings for common conifers of the Tower analysis area.

TREE SPECIES	**FROST TOLERANCE**	**DROUGHT TOLERANCE**	**SNOW DAMAGE RESISTANCE**
Ponderosa Pine	**Low**	**High**	**Low**
Douglas-fir	**Low**	**Moderate**	**Low**
Western Larch	**Low**	**Moderate**	**Moderate**
Grand Fir	**Moderate**	**Moderate**	**Moderate**
Western White Pine	**High**	**Moderate**	**Moderate**
Lodgepole Pine	**High**	**Moderate**	**Moderate**
Engelmann Spruce	**High**	**Low**	**High**
Subalpine Fir	**Moderate**	**Low**	**High**

Sources/Notes: Adapted from Williams and others (1995) and Cole (1993). Species rankings are based on the predominant situation for each trait. A species trait can vary during the lifespan of an individual tree, and from one individual to another in a population.

Mixed-species, single-cohort (even-aged) stands in the Blue Mountains contain various combinations of western larches, ponderosa pines, Douglas-firs, grand firs, Engelmann spruces, and lodgepole pines. Although such stands contain trees of the same age, each species develops at a different rate so that a stratified or 'layered' structure is the ultimate result (fig. 16). Those who observe these stands sometimes assume that their height variations reflect a range of ages (i.e., the stands are uneven-aged). Figure 16 shows those assumptions to be incorrect because a mixed-species stand in which every tree is the same age does not develop into a single-storied, biologically-simple structure, regardless of its origin (from planting or natural regeneration).

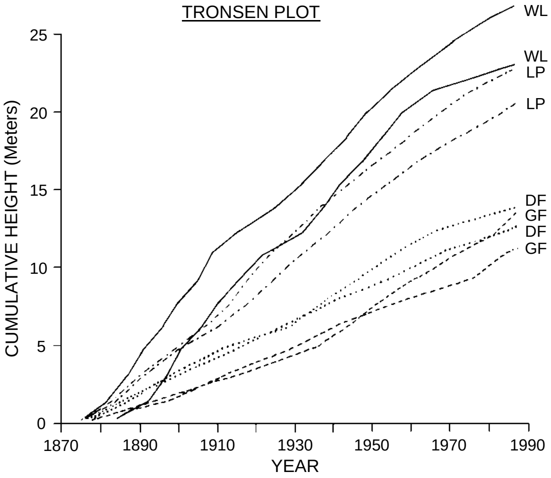

Figure 16 – Development of mixed-species, single-cohort stands (from Cobb and others 1993). Different tree species grow and develop at different rates. This figure shows how early-seral species (western larch and lodgepole pine) grow faster than their late-seral associates (grand fir and Douglas-fir) when both are present in an even-aged (single cohort) stand. The end result is a multi-storied structure sometimes mistaken for an uneven-aged condition (even by silviculturists who don't use an increment borer).

Previously Established Plantations. According to field reconnaissance and a GIS analysis, it appears that 2,240 acres of well-established (certified) and recently completed plantation were burned by the fire (fig. 17). If that assessment is accurate, then an investment of well over $1,000,000 was lost in plantations alone, not counting additional losses for other cultural treatments. Since the plantations represent a serious loss of timber productivity, and are areas where we have legal responsibilities to quickly reestablish tree cover in harvested areas (as required by the National Forest Management Act), *I recommend that the burned plantations be replanted as quickly as possible*. Table 25 shows the cost implications associated with the planting recommendations in this section.

Western White Pine Situation (from Powell and Erickson 1996). At present, the District has less than 20 pounds of western white pine seed on inventory, enough to yield approximately 153,000 shippable seedlings. Another 9,000 seedlings are at Stone Nursery for 1997 delivery. Together these inventories are sufficient for planting approximately 1,860 acres (20% WWP in mix, 10′ x 10′ spacing), roughly the acreage in the Tower fire area suitable for planting white pine. Once these sources have been depleted, the District will face a serious dilemma as to where to obtain additional western white pine seed for reforestation.

Fortunately, western white pine exhibits little differentiation over geographic, ecologic, or elevational gradients, and non-local seed sources can thus be transferred widely with little risk of maladaptation (Rehfeldt and others 1984, Steinhoff 1979, Townsend and others 1972, Rehfeldt and Steinhoff 1970). In the future (approximately 20-25 years from now), reforestation seed may also be obtained from the Paddy Flat Seed Orchard (Pine RD, Wallowa-Whitman National Forest), which is being established to supply seed for the Umatilla, Wallowa-Whitman, and Malheur national forests.

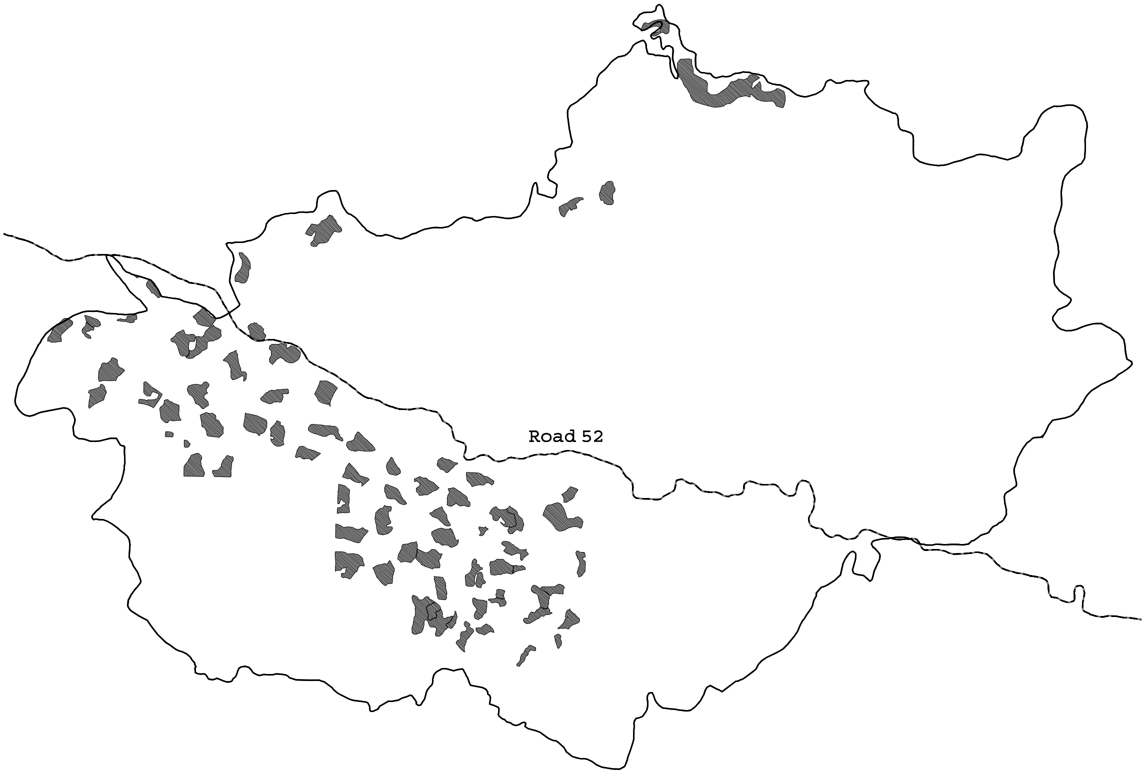

Figure 17 – Tower fire's impact on established plantations. The Tower fire burned about 2,240 acres of long-established and recently completed plantation. When considering the investment to establish those plantations, the burned plantations represent a loss of more than $1,000,000.

Table 25: Economic consequences of the planting recommendations for the Tower analysis area.

ECOLOGICAL SETTING	PLANTING NEEDED (Acres)	PLANTING COST (Dollars/Acre)	TOTAL COST (Dollars)
Cold Dry	553	556.60	307,799.80
Lodgepole Pine	3,354	546.63	1,833,397.02
Cool Moist	3,872	556.60	2,155,155.20
Warm Dry	5,900	531.33	3,134,847.00
Ponderosa Pine	2,172	531.33	1,154,048.76
Total	15,851		$8,585,247.78

Sources/Notes: Planting acres came from Table 21; planting cost was based on recent empirical costs for the North Fork John Day Ranger District; and the total cost is the product of column 2 (planting needed) multiplied by column 3 (planting cost). Planting cost includes the following activities: animal damage control ('vexar' tubing for big-game damage), pre- and post-plant surveys, program management (traversing, contract administration, etc.), tree cooler maintenance, seed procurement, planting, and seedling procurement.

White Pine Seed Availability. Several sources of non-local western white pine seed would be suitable for use in District planting mixes. Seed origin should be documented in planting records, and survival and growth performance monitored closely over time so that transfer guidelines can be modified as needed. In order of preference, seed sources considered appropriate for District use include the following:

a) Other Blue Mountain sources: The Malheur NF has the greatest abundance of western white pine in the Blue Mountains, as well as an active seed collection program. At present, however, no surplus seed is available. The Wildcat and Summit fires (1996) have generated unplanned reforestation needs on the Malheur NF, and it's highly unlikely that surplus white pine seed from this source will be available for years to come.

b) Couer d'Alene Nursery Seed Orchard: Established in late 1970s with tested materials from Northern Idaho (Nez Perce, Clearwater, Panhandle NFs), as well as a few sources from Northeast Washington and Northwest Montana. Blister rust resistance rating is approximately 60%. Harvested seed crops are allocated on an annual basis to R–1 National Forests. The Umatilla has made a request for surplus seed, but supplies are very limited and demands are high.

   Surplus seedlings are currently available from this source for outplanting in 1997 (100M, 2-0 stock) and 1998 (100M, 3-0 stock?). If stock quality is acceptable, we highly recommend the acquisition of these seedlings for District use.

c) Moscow Arboretum: Established in the 1950s/1960s, this orchard now supplies seed for cooperators in the Inland Empire Tree Improvement Cooperative (IETIC). Resistance level is approximately 60%. All surplus seed in storage was sold earlier this summer; future offerings are unknown.

d) Sandpoint Seed Orchard: Estimated resistance is 35%, so plant materials originating from this orchard are not recommended for use on high risk sites. *Coeur d'Alene Nursery currently has 28M surplus seedlings (3-0 stock) available for outplanting in 1997.*

e) Dorena Seed Orchard: Surplus seed and seedlings originating from Zone 3 (Willamette and Deschutes NF) and Zone 4 (Umpqua/Rogue River NFs and a portion of Winema NF) are frequently available to the Forest. Dorena tested seed is assigned a Hazard Use Class (HUC). These values range from 91 to 99, with 99 being the safest seed to use in a high infection risk area. HUC value of Dorena orchard seed is 97, which is fairly high quality seed. *Plant materials from R-1 are preferable to those from this source, however.*

Competing Vegetation. As described previously, one of the potential benefits of the Tower wildfire is that it provided a 'site preparation' treatment in terms of tree regeneration. Rhizomatous grasses, shrubs, and other plants that compete with trees for moisture, sunlight, and nutrients have been temporarily 'knocked back' by the fire. If planting occurs quickly, trees could get established before allelopathic plants and other competitors have fully recovered from the fire (fig. 18, table 26).

Of particular concern is the potential for pinegrass, smooth brome, red top, Kentucky bluegrass, and other rhizomatous grasses to compete with planted or naturally regenerated tree seedlings. Grasses produce an abundance of surficial roots that rapidly absorb moisture before it can percolate to the deeper roots of woody species. Their rooting habit gives grasses a competitive advantage over trees, particularly on droughty sites (Oliver and Larson 1996).

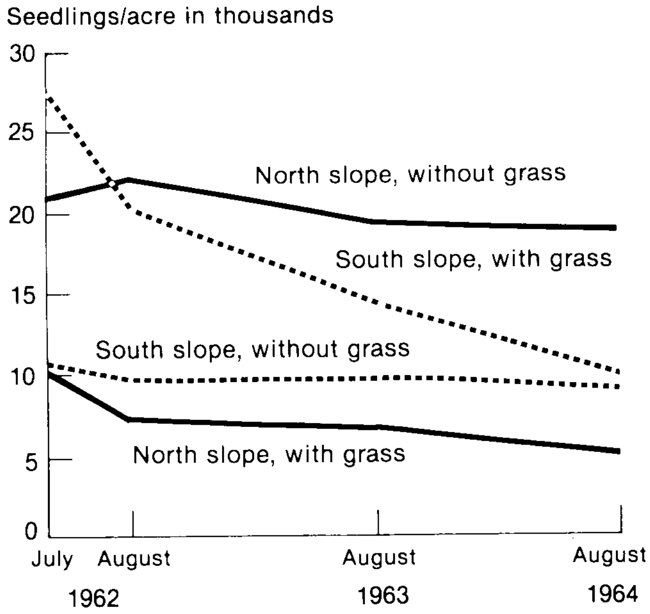

Figure 18 – Effect of grass competition on lodgepole pine regeneration (from Lotan and Perry 1983). This figure illustrates two situations with regard to grass competition. In one instance (north-facing slopes), the presence of grass resulted in a significant reduction (50% or more) in tree establishment. In the other situation (south-facing slopes), grass did not prevent trees from getting established, but it did cause a precipitous drop in their survival over time.

Thinning (pertains to forested uplands only)

A common silvicultural treatment is thinning, where some trees are removed so that those that remain have access to more growing space, nutrients, and sunlight. Thinning from below (small trees are removed; large trees are retained) is often beneficial because it creates an open, single-storied stand structure amenable to natural underburning or prescribed burning (Powell 1994).

Recent concerns about forest health in the Blue Mountains (McLean 1992) have recognized the value of maintaining stand densities that promote high tree vigor and minimize damage from insects and pathogens (fig. 19). Thinning is effective at preventing or minimizing serious mortality from mountain pine beetle and, perhaps, western pine beetle. It can also prevent dwarf mistletoe from becoming a serious problem in even-aged stands of ponderosa pine (Cochran and others 1994). Density management can be used to shift a site's growth potential to fewer stems so that trees with 'old-growth' size characteristics could be produced more quickly.

Even though much of the Tower analysis area was affected by a convection crown fire, which means that stand densities and structures, fuel characteristics, and other factors had a limited influence on fire behavior, *I recommend that future stand densities be maintained at levels which minimize the potential for crown fires.* Those recommendations are provided in Table 27.

Table 26: Allelopathic plant species.

Plants With Known or Suspected Allelopathy
Bearberry (*Arctostaphylos nevadensis; A. uva-ursi*)
Bottlebrush Squirreltail (*Sitanion hystrix*)
Bracken Fern (*Pteridium aquilinum*)
Cheatgrass (*Bromus tectorum*)
Columbian Brome (*Bromus vulgaris*)
Elderberry (*Sambucus* spp.)
Foxtail Fescue (*Festuca myuros*)
Japanese Brome (*Bromus japonicus*)
Meadow Brome (*Bromus commutatus*)
Mountain Brome (*Bromus carinatus*)
Rattlesnake Brome (*Bromus briziformis*)
Smooth Brome (*Bromus inermis*)
Timothy (*Phleum pratense*)
Western Coneflower (*Rudbeckia occidentalis*)
Western Wheatgrass (*Agropyron smithii*)

Source/Notes: From Ferguson (1991), Ferguson and Boyd (1988), Fisher (1980), McDonald (1986) and Urban (1996). Allelopathy is defined as "a competitive strategy of plants in which there is the production of chemical compounds (allelochemicals) by such plants that interfere with the germination, growth, or development of another plant" (Dunster and Dunster 1996). Other allelopathic species occur on the Umatilla NF, but these are the ones that definitely occur within the Tower analysis area.

Table 27: Maximum stand densities as related to crown fire susceptibility.

AVERAGE STAND DIAMETER (Inches)	MAXIMUM STAND DENSITY (Trees/Acre) Ponderosa Pine	Douglas-fir	Grand Fir
3.0	584	574	344
7.5	390	238	245
12.5	197	162	157
17.5	170	104	83

Source/Notes: From Agee (1996). These figures refer to single-sized, non-stratified stands that are predominately of a single species. They do not pertain to stands in which differentiation into crown strata has occurred such that ladder fuels from the understory to the overstory are present. To limit future crown fire risk, any stand density treatment (thinnings, weedings, release, etc.) should leave no more than the trees per acre given above. For example, if a pole-size Douglas-fir stand is thinned from below, and the average stand diameter after thinning is about 7.5″, then the residual stocking should be no more than 238 trees per acre (13.5′ spacing) to limit the risk of future crown fire. [Note: the ponderosa pine figures appear to be too high and should be used with caution.]

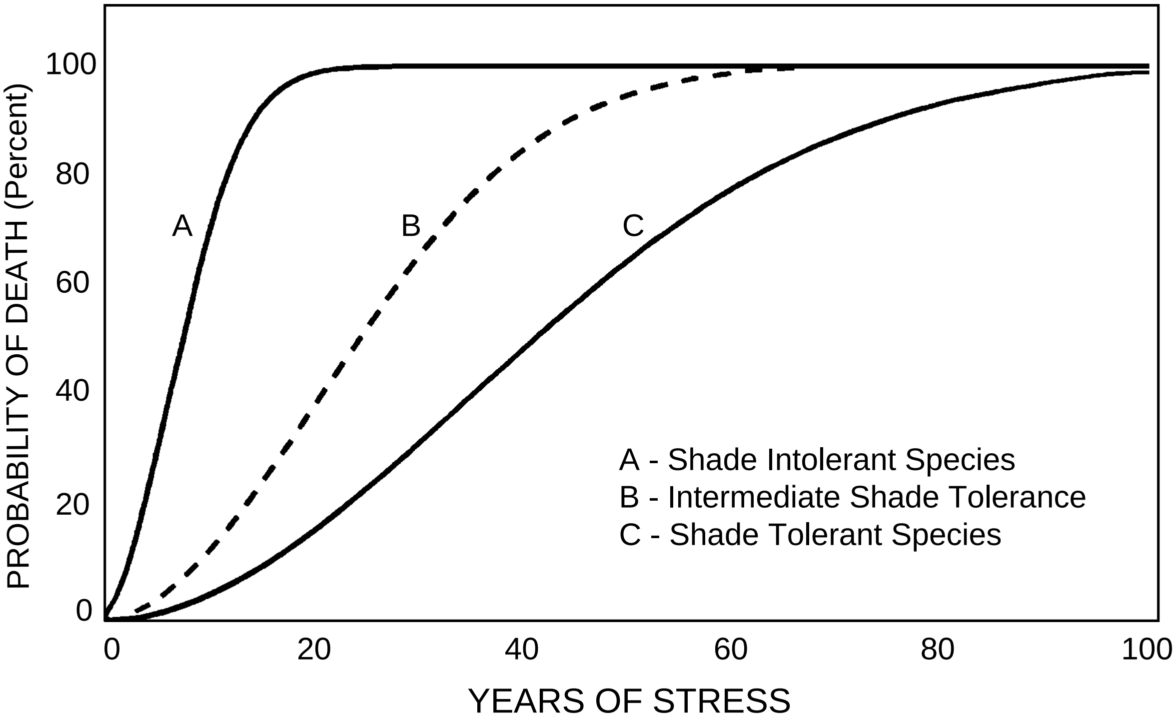

Figure 19 – Tree resistance to stress varies with shade tolerance. Intolerant tree species (ponderosa and lodgepole pines, and western larch) will die relatively quickly when exposed to stress (overcrowding, etc.). Trees with intermediate shade tolerance (western white pine and Douglas-fir) can withstand a longer period of stress without dying. Shade tolerant species (grand fir, Engelmann spruce, and subalpine fir) can withstand long periods of stress without dying. (Figure adapted from Keane and others 1996.)

Understory Removals (pertains to forested uplands only)

This silvicultural practice is used in multi-storied stands, typically those with an overstory of early-seral trees and an understory of shade-tolerant species. The objective is to remove a high proportion of the understory trees. Their removal improves overstory vigor by reducing competition and, when the overstory trees are overmature ponderosa pines and western larches, this treatment is particularly effective at ensuring their continued survival.

‘Encroachment by fir’ is a management issue where Douglas-firs and grand firs are growing on sites that historically supported pure, or nearly pure, stands of ponderosa pine. In those instances, the firs should be viewed as ‘ecologically offsite’ species. Although fir seedlings can obviously get established on many ponderosa pine sites, they would not have survived without human suppression of low-intensity fire. Reestablishing ponderosa pine and western larch on sites that are suitable for their survival and growth, and a thinning or prescribed fire program to keep those stands open and vigorous, would undoubtedly contribute much toward ensuring future vegetation sustainability.

Understory removals are particularly appropriate for removing firs that have encroached on warm dry sites. They may also be effective on other sites with a remnant pine/larch component, especially if thinnings reduce stand densities to more sustainable levels and improve the vigor and survivability of pine and larch. *I recommend that understory removals be considered for partial-burn areas where multi-storied, mixed-species stands have survived the fire, especially if they occur on ponderosa pine or warm dry ecological settings.*

Prescribed Burning (pertains to forested uplands only)

After completing salvage harvests, understory removals, thinnings and other treatments described in this section, managers should strongly consider implementing a prescribed burning program. Once ponderosa pines and larches are 10 to 12 feet tall, a prescribed burn could be completed, although a low-intensity fire would leave most of the 6- to 8-foot trees undamaged as well (Wright 1978). From that point on, surface fires could be used regularly, usually at intervals of 15 to 25 years. Fall burns, which are desirable from an ecological standpoint because they replicate the natural fire regime, result in fewer losses of overmature ponderosa pines to fire damage or western pine beetle attack (Swezy and Agee 1991).

Periodic burning can also be used to increase the nutrient capital of a site by maintaining sparse stands of snowbrush ceanothus, lupines, peavines, vetch, buffaloberry, and other nitrogen-fixing plants. Numerous studies have documented the slow decomposition rates associated with large, woody material in the interior West (Gruell 1980, Gruell 1983, Gruell and others 1982). Forests of the interior West may have depended more on nitrogen-fixing plants to replenish soil nutrients than on the decomposition of woody debris. Providing adequate levels of site nutrition is important for maintaining tree resistance to insects and pathogens (Mandzak and Moore 1994).

Cautions About the Use of Fire. Fire may not be beneficial on all mixed-conifer sites; on moist areas, burns could favor bracken fern, western coneflower, and other allelopathic plants that inhibit conifer regeneration (Ferguson 1991, Ferguson and Boyd 1988; see Table 24).

On droughty sites in eastern Washington, residual trees increased growth following surface fires that killed intermediate and suppressed trees, but growth increases were greater when manual cutting thinned the forest. Unlike fire, manual thinning does not damage roots, so residual trees can reoccupy the growing space quickly. Once overstory trees claim the growing space provided by a thinning, grasses do not readily invade (Oliver and Larson 1996).

On poor to moderate forest sites (generally dry areas with coarse or shallow soils and thin forest floors), broadcast burning can be detrimental from a nutritional standpoint. The short-term benefits of prescribed burns, such as improved planter access, fuel reduction, site preparation, and increased soil temperature regimes, may be achieved at a cost of high soil pH, nitrogen and sulfur deficiencies, and other nutritional problems later in a stand’s life (Brockley and others 1992).

I recommend that prescribed burning be used in existing dry-forest types (ponderosa pine and Douglas-fir) that have received an understory removal treatment, and that it be considered as a future treatment for plantations established on ponderosa pine and warm dry ecological settings. Future prescribed burns will probably not occur until at least 30 years after plantations have been established, and could then be coordinated with pruning treatments to lower the risk of pole-sized trees being killed by a fire (torching).

Fertilization (pertains to forested uplands only)

The fire may contribute to future forest health problems by its impact on nutrients that were present in vegetation, litter, and the upper soil layers. Nutrients can be lost to the atmosphere during combustion (volatilized) or converted by heat to their mineralized or elemental form (oxidized). Oxidized nutrients are retained in the ash and remain on site unless ash is redistributed by wind or water. Mineralized nutrients are eventually returned to the ecosystem as water (snowmelt, rain) leaches them into the soil, where they are available for plant growth unless leaching moves them deeper than roots can reach.

From a forest health perspective, the primary concern is focused on volatilization losses of nitrogen, potassium, and sulfur. Nitrogen is a critical element needed for plant growth, and it is likely that a high proportion of the available nitrogen is now gone in areas that sustained complete stand mortality (i.e., the areas of moderate and high fire intensity). For example, measurements completed after the Entiat fire in 1970 showed that 97% of the nitrogen in the forest floor (litter and duff) was lost, and that 33% of nitrogen in the upper layer of mineral soil (A1 horizon) was also volatilized (Grier 1975).

On the dry sites burned by the Entiat fire, those were significant losses – replacement of lost nitrogen from the atmosphere (via precipitation) would require 907 years. Obviously, nitrogen will need to accumulate from other sources – primarily weathering of soil parent material and symbiotic nitrogen fixation associated with the root systems of certain plant species (Grier 1975).

The loss of potassium and sulfur is also important since on-going studies indicate that those nutrients play an important role in forest health. Apparently, forests growing on soils derived from geological parent materials with low potassium concentrations are prone to poor health such as chronic outbreaks of insects and diseases (Moore and others 1993). Fortunately, it appears that mineralized potassium is retained in the upper soil profile (0-8″ depth) as ash is leached, thereby making it available for uptake by trees and other plants (Grier 1975).

Fertilization may provide other benefits that are related to insect and disease susceptibility. It provides opportunities to modify foliar chemistry and thereby improve a tree’s resistance to budworm defoliation (Clancy and others 1993). It may help reduce stem decay for grand firs that have been wounded during logging or by other agents (Filip and others 1992). By changing root chemistry, fertilization with nitrogen and potassium apparently has beneficial effects on a tree’s resistance to Armillaria root disease (Moore and others 1993).

I recommend that fertilization be considered as a future treatment for young stands growing on ponderosa pine or warm dry ecological settings. Fertilization would probably not be needed until 20 to 30 years after plantations have been established, and could then be coordinated with other cultural treatments such as precommercial thinning.

Pruning (pertains to forested uplands only)

Pruning is typically used to produce clear, knot-free wood, but it could also play a role in the future management of budworm-susceptible forests. In areas where budworm-host trees will continue to be a stand component, pruning could provide several benefits. The first and most obvious benefit is that by removing the lower crown portion of host trees, pruning results in less food for the survival and growth of budworm larvae.

After pruning trees that are large enough to have developed a fire-resistant bark, it would be possible to underburn mixed-species stands without ‘torching’ the leave trees. Trees with short, pruned crowns would be less likely to serve as ladder fuels, thereby minimizing the risk of an underburn turning into a crown fire. Pruning must be carefully coordinated with the onset of an underburning program – if trees were pruned too soon, epicormic ‘water’ sprouts could occur on the stem and increase a tree’s risk of torching in an underburn (Oliver and Larson 1996).

Mechanical pruning would produce a stand that can be underburned much more quickly than waiting for natural pruning. For example, Table 28 shows that ponderosa pine can self-prune quickly, but that dead branches often persist and that mechanical pruning would be advisable if a perfectly clean, branch-free bole is desired to minimize the risk of crown scorch or torching.

I recommend that pruning be considered as a future treatment for young stands on ponderosa pine and warm dry ecological settings. Pruning may not be needed until at least 30 years after plantations have been established, when it could then be coordinated with prescribed burning treatments as a way to lower the risk of pole-sized trees being killed by a fire (torching).

Table 28: Natural pruning in ponderosa pine.

Age	Height to Base of the Live Crown (Feet)	Bole Length Without Any Dead Branches (Feet)
20	3	1
30	18	2
40	28	3
50	36	4
60	45	7
70	50	11
80	56	19
90	61	27
100	65	29

Sources/Notes: From Kotok (1951). This data shows that ponderosa pine ‘lifts’ its live crown very quickly (2nd column) when growing in a dense stand, but that dead branches are somewhat persistent and a ‘clean’ branch-free bole requires a long time to develop (3rd column). Note that these figures were derived from dense, wild stands; open, thinned stands would lift their crowns much more slowly than is shown above.

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Table 16 – Fire effects information for common plants of mixed-conifer forests in the central Blue Mountains.

CODE	PLANT NAME	FIRE RESISTANCE	FIRE RESPONSE	SITE TYPE	COMMENTS ABOUT REGENERATION METHODS
			TREES		
ABLA2	Subalpine fir (*Abies lasiocarpa)*	Low	Low	Cold, Mesic	Entire stands of this high-elevation species are easily killed by fire; colonizes burned areas very slowly.
JUOC	Western juniper (*Juniperus occidentalis)*	Medium	Low	Warm, Dry	Post-fire establishment occurs from seed, much of which is dispersed by animals (rabbits, squirrels, etc.).
LAOC	Western larch (*Larix occidentalis)*	High	High	Cool, Mesic	Our most fire-resistant conifer because of its thick bark, short crown length, and high tolerance to foliage loss.
PIEN	Engelmann spruce (*Picea engelmannii)*	Low	Low	Cold, Moist	Easily killed by fire because of its long, full crown, thin bark, and a shallow root system.
PICO	Lodgepole pine (*Pinus contorta)*	Medium	High	Cool, Mesic	Often regenerates after stand-replacing wildfires, when it forms dense, even-aged thickets.
PIPO	Ponderosa pine (*Pinus ponderosa)*	High	High	Warm, Mesic	Very high fire resistance; experiences reduced diameter growth after high levels of crown scorch.
PSME	Douglas-fir (*Pseudotsuga menziesii)*	High	Medium	Warm, Mesic	Mature trees are fire resistant due to thick bark, but thin-barked poles and saplings are easily damaged by burning.
			SHRUBS		
AMAL	Serviceberry (*Amelanchier alnifolia)*	Medium	High	Cool, Mesic	Sprouts immediately after fire and also reproduces from bird- and mammal-dispersed seed; germinates on bare soil in partial shade.
ARNE	Manzanita (*Arctostaphylos nevadensis)*	Low	Medium	Cool, Dry	Regenerates from the root crown, runners (stolons) or from seed; survives cool fires if the litter/duff was not completely consumed.
BERE	Creeping hollygrape (*Berberis repens)*	Medium	Medium	Cool, Dry	Sprouts from surviving rhizomes after fire; survives all but severe burns that cause high soil heating.
CEVE	Snowbrush ceanothus (*Ceanothus velutinus)*	High	High	Warm, Mesic	Often regenerates prolifically from seeds buried in the soil; seeds can remain viable for hundreds of years.
CELE	Mountain mahogany (*Cercocarpus ledifolius)*	Low	Low	Warm, Dry	Sprouts weakly after low-intensity fires; reproduces from wind- and mammal-dispersed seed (some soil storage); germinates in full sun.
HODI	Oceanspray (*Holodiscus discolor)*	Medium	High	Warm, Dry	Regenerates from the surviving root crown, and from seed stored in the soil; its seedlings establish easily on fresh mineral soil.
PAMY	Myrtle pachistima (*Pachistima myrsinites)*	Medium	Medium	Cool, Mesic	Regenerates from the crown of a deep taproot, or from stem bud sprouts or stored seed; may increase after cool or moderate burns.
PRVI	Common chokecherry (*Prunus virginiana)*	Medium	High	Warm, Mesic	Sprouts prolifically from its root crown; reproduces from bird- and mammal-dispersed seed; germinates in full sun after disturbances.
RICE	Wax currant (*Ribes cereum)*	Medium	High	Warm, Dry	Regenerates from seed stored in the litter/duff, and from basal stem sprouts; susceptible to fire-induced mortality after severe burns.

Table 16 – Fire effects information for common plants of mixed-conifer forests in the central Blue Mountains (CONTINUED).

Code	Plant Name	Fire Resistance	Fire Response	Site Type	Comments About Regeneration Methods
RILA	Prickly currant (*Ribes lacustre*)	High	High	Cool, Moist	Usually increases after burning, even severe fires. Cool or moderate-intensity fires favor establishment of prickly currant seedlings.
ROGY	Baldhip rose (*Rosa gymnocarpa)*	Medium	Medium	Cool, Mesic	Regenerates from the root crown, stem bases, and from seed; it responds vigorously to cool or moderate fires.
SASC	Scouler willow (*Salix scouleriana)*	High	High	Cool, Mesic	Regenerates from the root crown, or by using small, windborne seed; may increase dramatically after fire, especially on moist sites.
SPBE	White spiraea (*Spiraea betulifolia)*	High	High	Cool, Mesic	Regenerates from the root crown, and by use of rhizomes located 2-5 inches beneath the soil surface; usually increases after burning.
SYAL	Common snowberry (*Symphoricarpos albus)*	Medium	High	Cool, Mesic	Regenerates from deep rhizomes, basal stem buds, and seed; favored by cool or moderate fires, but often survives severe ones too.
SYOR	Mountain snowberry (*Symphoricarpos oreophilus)*	Low	Medium	Cool, Dry	Sprouts weakly from the root crown, and from rhizomes; usually maintains prefire cover and abundance after cool or moderate fires.
VAME	Big huckleberry (*Vaccinium membranaceum)*	High	Medium	Cool, Mesic	Regenerates from rhizomes and seed, but post-fire recovery may be slow; fire used by native Americans to maintain huckleberry fields.
VASC	Grouse huckleberry (*Vaccinium scoparium)*	Medium	Medium	Cold, Mesic	Regenerates from shallow rhizomes and seed; usually survives cool or moderate fires that don't consume all of the litter and duff layers.
GRASSES AND GRASS-LIKE PLANTS					
BRCA	California brome (*Bromus carinatus)*	Medium	Medium	Warm, Dry	Regenerates from the root crown and from wind-disseminated seed; nonrhizomatous; germinates on bare soil in full sun.
BRVU	Columbia brome (*Bromus vulgaris)*	Medium	Medium	Cool, Moist	Regenerates from seed, some of which may be stored in the soil; generally declines following severe fires.
CARU	Pinegrass (*Calamagrostis rubescens)*	Medium	Medium	Warm, Mesic	Regenerates from rhizomes and wind-disseminated seed; survives all but severe fires; germinates on bare soil.
CACO	Northwestern sedge (*Carex concinnoides)*	Medium	Medium	Cool, Moist	Sprouts from rhizomes located in the duff; fires which consume most of the litter and duff will have an adverse impact on this plant.
CAGE	Elk sedge (*Carex geyeri)*	High	High	Warm, Mesic	Sprouts from surviving rhizomes and reproduces from seed stored in the soil; germinates on bare soil after burning or scarification.
CARO	Ross sedge (*Carex rossii)*	High	Medium	Cool, Dry	Regenerates from short rhizomes and from seed stored in the duff and upper soil; germinates on bare soil mainly after scarification.
ELGL	Blue wildrye (*Elymus glaucus)*	Medium	Medium	Warm, Mesic	Regenerates from the root crown, rootstock sprouts, and seed; seed can survive temperatures associated with a moderate-intensity burn.
FEID	Idaho fescue (*Festuca idahoensis)*	Low	Medium	Warm, Dry	Regenerates from the root crown, and from wind-disseminated seed; nonrhizomatous; germinates on bare soil.
FEOC	Western fescue (*Festuca occidentalis)*	Low	Low	Cool, Mesic	Regenerates from the root crown, and from off-site seed; generally declines after fire, although it germinates well on bare, shaded soil.

Table 16 – Fire effects information for common plants of mixed-conifer forests in the central Blue Mountains (CONTINUED).

CODE	PLANT NAME	FIRE RESISTANCE	FIRE RESPONSE	SITE TYPE	COMMENTS ABOUT REGENERATION METHODS
KOCR	Prairie junegrass (*Koeleria cristata)*	Medium	Medium	Warm, Dry	Regenerates from seed – susceptible to mortality from late-spring burns, although this is one of our more fire-resistant bunchgrasses.
PHPR	Common timothy (*Phleum pratense)*	Medium	Medium	Disturbances	Regenerates from the surviving root crown or, more commonly, from seed blowing in from adjacent roadsides and forest openings.
PONE	Wheeler bluegrass (*Poa nervosa)*	Medium	High	Warm, Mesic	Regenerates from surviving rhizomes and seed; seldom damaged by fire unless the litter and duff layers are consumed.
POPR	Kentucky bluegrass (*Poa pratensis)*	High	High	Warm, Mesic	Regenerates from basal stem buds, slender rhizomes, and seed; seldom damaged by fire except for hot, spring burns.
SIHY	Bottlebrush squirreltail (*Sitanion hystrix)*	Medium	High	Warm, Dry	Regenerates from the root crown and seed; since it 'cures' early, this grass survives summer fires better than spring ones.
STOC	Western needlegrass (*Stipa occidentalis)*	Low	Low	Warm, Dry	Regenerates from surviving root crowns and wind-disseminated seed; non-rhizomatous; germinates on bare soil in full sun.
FORBS					
ACMI	Western yarrow (*Achillea millefolium)*	Medium	High	Disturbances	Regenerates from short, shallow rhizomes and seed; declines after severe fires, but invasion from off-site seed usually occurs rapidly.
ADBI	Trailplant (*Adenocaulon bicolor)*	Low	Low	Cool, Moist	Regenerates from short surface rhizomes and seed; generally survives cool fires although post-fire recovery is usually slow.
ANRO	Rose pussytoes (*Antennaria rosea)*	Low	Medium	Cool, Dry	Regenerates from trailing stolons and wind-blown seed; is apt to increase slightly or remain unchanged after cool or moderate burns.
AQFO	Red columbine (*Aquilegia formosa)*	Medium	Medium	Cool, Moist	Regenerates mostly from seed; likely that moderate or hot fires will have a detrimental effect on this species.
ARMA3	Bigleaf sandwort (*Arenaria macrophylla)*	Low	Medium	Cool, Mesic	Regenerates from shallow rhizomes and seed; decreases slightly or remains unchanged after fire depending on duff consumption.
ARCO	Heartleaf arnica (*Arnica cordifolia)*	Low	High	Cool, Mesic	Sprouts from surviving rhizomes; readily invades burned areas using windborne seed; germinates on bare soil in partial shade.
ASCO	Showy aster (*Aster conspicuus)*	Medium	High	Cool, Mesic	Regenerates from surviving rhizomes and wind-disseminated seed; germinates on bare soil in partial shade.
BASA	Balsamroot (*Balsamorhiza sagittata)*	High	High	Warm, Dry	Regenerates from a root crown and animal-disseminated seed; plant densities are often greater than pre-burn levels by the second year.
CAMI2	Scarlet paintbrush (*Castilleja miniata)*	Medium	Medium	Warm, Mesic	Regenerates from the crown of a deep taproot, and from off-site seed; reestablishment in the post-fire community is somewhat slow.
CHUM	Pipsissewa (*Chimaphila umbellata)*	Low	Medium	Cool, Mesic	Sprouts from shallow rhizomes; usually survives cool or moderate burns that don't consume all of the litter and duff layers.
CIVU	Bull thistle (*Cirsium vulgare)*	Medium	Medium	Disturbances	Regenerates from root sprouts and seed; often increases dramatically after burning and may compete moderately with tree seedlings.

Table 16 – Fire effects information for common plants of mixed-conifer forests in the central Blue Mountains (CONTINUED).

		FIRE	FIRE		

CODE	PLANT NAME	RESISTANCE	RESPONSE	SITE TYPE	COMMENTS ABOUT REGENERATION METHODS
CLUN	Queencup beadlily (*Clintonia uniflora)*	Low	Low	Cool, Moist	Regenerates from widely spreading rhizomes, and from seed; generally declines after fire.
ERCO3	Longleaf fleabane (*Erigeron corymbosus)*	Low	Medium	Cool, Dry	Regenerates from off-site seed or a moderately well-developed rootcrown; apt to decrease slightly or remain unchanged after fire.
FRVE	Woods strawberry (*Fragaria vesca)*	Medium	Medium	Cool, Mesic	Regenerates from root crown sprouts, runners (stolons), and seed stored in upper soil; survives cool fires.
FRVI	Blueleaf strawberry (*Fragaria virginiana)*	Medium	High	Cool, Mesic	Regenerates from root crown sprouts and runners (stolons); survives cool fires that don't consume all of the litter and duff layers.
GABO	Northern bedstraw (*Galium boreale)*	Medium	Medium	Cool, Mesic	Regenerates from creeping, underground rhizomes, and from sticky seed; is fairly resistant to light burns but declines after severe fires.
GATR	Sweetscented bedstraw (*Galium triflorum)*	Low	Medium	Cool, Moist	Regenerates using rhizomes and seed; decreases dramatically after severe fires, but can increase following cool burns.
GOOB	Rattlesnake plantain (*Goodyera oblongifolia)*	Low	Low	Cool, Mesic	Regenerates using rhizomes and seed; easily killed by fire because its shallow rhizomes are very sensitive to heat.
HIAL2	Western hawkweed (*Hieracium albertinum)*	Low	Medium	Cool, Dry	Lacks rhizomes or another means of vegetative reproduction, but readily invades burned areas using windborne seed.
HIAL	White hawkweed (*Hieracium albiflorum)*	Low	Medium	Cool, Mesic	Lacks rhizomes or another means of vegetative reproduction, but readily invades burned areas using windborne seed.
LALA2	Thickleaf peavine (*Lathyrus lanzwertii)*	Medium	High	Warm, Dry	Regenerates from rhizome sprouts and seed; similar to other legumes in that this plant is a nitrogen fixer.
LANE	Cusick's peavine (*Lathyrus nevadensis)*	Medium	High	Warm, Mesic	Reproduces from surviving rhizomes and from seed stored in the soil; also a nitrogen fixer.
LIBO2	American twinflower (*Linnaea borealis)*	Low	Medium	Cool, Moist	Regenerates from root crowns, stolons, and seed; survives cool fires if the duff and litter layers were damp and not totally consumed.
LUCA	Tailcup lupine (*Lupinus caudatus)*	High	Medium	Cool, Mesic	Regenerates from a deep taproot and heavy seed; its seed can survive for long periods in the lower duff and upper soil layers.
MITR	False agoseris (*Microseris troximoides)*	Medium	High	Warm, Dry	Regenerates from a deep taproot; increases or remains unchanged after fires which don't consume all of the litter and duff layers.
MIST2	Sideflowered mitella (*Mitella stauropetala)*	Medium	High	Cool, Mesic	Regenerates from the root crown and seed; fires which consume most of the litter and duff are apt to have a detrimental impact.
OSCH	Mountain sweetroot (*Osmorhiza chilensis)*	Medium	Medium	Cool, Moist	Regenerates from a taproot or root crown, and from seeds; flowering usually increases after the tree canopy has been opened by fire.
POPU	Polemonium (*Polemonium pulcherrimum)*	Low	Medium	Cold, Moist	Regenerates from the semi-woody crown of a large taproot, and from seed; usually declines following fire.
PTAQ	Bracken fern (*Pteridium aquilinum)*	High	High	Cool, Moist	Sprouts from surviving rhizomes and spreads vigorously after fire; inhibits conifer regeneration by producing chemicals (allelopathy).

Table 16 – Fire effects information for common plants of mixed-conifer forests in the central Blue Mountains (CONTINUED).

CODE	PLANT NAME	FIRE RESISTANCE	FIRE RESPONSE	SITE TYPE	COMMENTS ABOUT REGENERATION METHODS

PYSE	Sidebells pyrola (*Pyrola secunda)*	Low	Low	Cool, Mesic	Sprouts from rhizomes in the lower duff or at the soil surface; commonly decreases after fire unless duff moisture is high.
SEIN	Woolly groundsel (*Senecio integerrimus)*	Low	Medium	Cool, Dry	Regeneration occurs mainly from off-site seed; apt to decrease slightly or remain unchanged after low- or moderate-intensity fire.
SMRA	Feather solomonplume (*Smilacina racemosa)*	Medium	Medium	Cool, Mesic	Regenerates from creeping rhizomes and is fairly resistant to fire damage; usually maintains its prefire frequency after burning.
SMST	Starry solomonplume (*Smilacina stellata)*	Medium	Medium	Cool, Mesic	Sprouts from creeping rhizomes; often decreases after fire, especially severe burns that consume most of the litter and duff.
TAOF	Common dandelion (*Taraxacum officinale)*	Medium	Medium	Disturbances	Regenerates from a deep taproot and light, windborne seed; can quickly colonize burns located near an ample seed source.
VIAM	American vetch (*Vicia americana)*	Medium	High	Cool, Mesic	Regenerates from rhizomes in the upper soil; seldom damaged unless the litter/duff has been consumed; a nitrogen fixer.
VIOR2	Darkwoods violet (*Viola orbiculata)*	Medium	Medium	Cool, Mesic	Regenerates from short, slender rhizomes and seed stored in the upper soil or duff layers; usually declines following fire.

Source: Adapted from Table 5 in Powell (1994). **Notes**: Common and scientific plant names generally follow Hitchcock and Cronquist (1973). Codes were taken from Powell (1989). Fire resistance and fire response ratings, and comments about reproduction methods, were obtained from the following sources: Bradley and others (1992), Crane and Fischer (1986), Fischer and Bradley (1987), Fischer and Clayton (1983), Flinn and Wein (1977), Geier-Hayes (1989), Hopkins and Rawlings (1985), Leege and Godbolt (1985), McLean (1968), Noste and Bushey (1987), Sampson (1917), Steele and Geier-Hayes (1995), Stickney (1986), and Volland and Dell (1981). Valuable information was also obtained from the Fire Effects Information System (FEIS) developed by the Intermountain Fire Sciences Laboratory at Missoula, Montana (Fischer and others 1996). For some plants, no literature sources were found for one or both of the fire ratings, so an estimate was made using information for species with similar morphological or reproductive characteristics.

Fire resistance ratings have the following interpretation:

- High – Greater than 65 percent chance that 50 percent of the species population will survive or immediately reestablish after passage of a fire with an average flame length of 12 inches.
- Medium – 35 to 64 percent chance that 50 percent of the species population will survive or immediately reestablish after passage of a fire with an average flame length of 12 inches.
- Low – Less than 35 percent chance that 50 percent of the species population will survive or immediately reestablish after passage of a fire with an average flame length of 12 inches.

Fire response ratings estimate of how quickly a plant species will regain its prefire population level. They have the following interpretation:

- High – The species population will regain its preburn frequency or cover in 5 years or less.
- Medium – The species will regain its preburn frequency or cover in 5 to 10 years.
- Low – The species will regain its preburn frequency or cover in more than 10 years.

Site type ratings are an estimate of the temperature and moisture relationships for sites on which the species is abundant and widely distributed.

Tower Fire
FOREST VEGETATION BAER REPORT
September 1996

David C. Powell and Vicky Erickson

Introduction

The rehabilitation of areas burned by wildfires has three distinct steps. They are: rehabilitation of damage caused by fire suppression efforts, burned area emergency rehabilitation, and long-term fire recovery efforts.

Burned area emergency rehabilitation (BAER) is designed to alleviate emergency watershed conditions following wildfire to help stabilize soil, control water, sediment, and debris movement, and prevent threats to life, property, and other downstream values, both on-site and off-site. The goal of BAER is to respond quickly after a fire and provide emergency site protection before the first damaging precipitation or runoff event.

BAER may recommend a wide array of treatments for burned areas, such as:

- removal of debris that may clog drainage structures along roads
- seeding of grass to provide temporary ground cover while native plants become reestablished
- construction of temporary channel structures to slow water runoff and capture sediment
- improving drainage on trails to prevent excessive erosion
- felling of trees on the contour to capture sediment

Each fire is different and will require a separate BAER evaluation and individual treatment prescriptions designed specifically for that fire's conditions.

Generally, only the most seriously burned areas are treated as a result of the BAER process. It is often best to let a burned site recover naturally. BAER treatments are designed to speed recovery in specific areas where watershed emergencies threaten life and property.

Long-term fire recovery is designed to recover the burned area beyond the emergency measures implemented by the BAER process. Washed out roads and damaged bridges may be replaced during this phase. Trees may be planted to replace stands killed or seriously damaged by the fire. Fences on range allotments may be rebuilt. Recreation facilities may need to be reconstructed. Fisheries structures or wildlife habitat enhancements may need to be repaired or replaced. These long-term projects are funded by the responsible resource area, such as silviculture, wildlife, or range.

Since planting, fertilization, thinning, and other tree stand activities are considered long-term recovery practices, most of the recommendations in this report do not have a direct bearing on proposed BAER treatments.

Vegetation Types

Pre-fire vegetation types were very diverse, largely in response to a relatively steep elevational gradient ranging from 3,000 feet at the southwestern corner of the fire perimeter to 6,850 feet at Tower Mountain lookout on the extreme eastern edge of the fire.

Predominant forest cover types in the fire area, as arrayed on an elevational gradient from low to high, included dry forests, mesic forests, lodgepole pine forests, and cold forests. Selected characteristics of the forest cover types are provided in Table 1. See the "Coarse Vegetation Map" (map 2 in the appendix) for the geographical distribution of the forest types.

Table 1. Characteristics of forest cover types in the Tower fire area.

FOREST COVER TYPE	PREDOMINANT SPECIES	ECOLOGICAL SETTINGS	PERCENT OF FIRE AREA
Dry Forest	**PP, DF, WJ**	**Warm Dry (WD)**	**15%**
Mesic Forest	**GF, DF, WL, PP, LP, WP**	**Cool Moist (CM)**	**50%**
Lodgepole Pine	**LP, GF, SF, ES, WL**	**CM, CH, LP**	**30%**
Cold Forest	**SF, ES, LP, WL**	**Cold Harsh (CH)**	**5%**

Source/Notes: Predominant species codes are: PP: Ponderosa pine; DF: Douglas-fir; WJ: Western juniper; GF: Grand fir; WL: Western Larch; LP: Lodgepole pine; WP: Western white pine; SF: Subalpine fir; and ES: Engelmann spruce. See Table 2 for further information about the ecological settings on which the forest cover types occur. The "percent of fire area" estimates were derived from the "Coarse Vegetation Map" for the Tower fire area (see map 2 in appendix), and from field reconnaissance.

The wide diversity of site conditions found in the Tower fire is derived from changes in physiography (landform), topography, climate, soils, aspect, geology and other biophysical factors. Each unique combination of those factors results in a site with slightly different temperature and moisture conditions. In the Tower fire area and in other mountainous terrain, temperature and moisture tends to vary predictably with changes in two environmental factors – elevation and aspect (slope exposure).

Since plant distributions are controlled largely by environmental factors, sites with equivalent temperature and moisture conditions will eventually support similar plant communities. Sites with the potential to support similar plant communities (associations) are called *ecological settings*. Lands in the same setting are ecologically similar – they were exposed to similar climatic and disturbance regimes, they have similar productivities, and they respond to management practices in a similar manner. Table 2 summarizes selected characteristics for forested ecological settings of the Tower fire area.

TABLE 2: SELECTED CHARACTERISTICS FOR THE ECOLOGICAL SETTINGS.

Ecological Setting	Disturbance Agents	Fire Regime	Patch Sizes	Primary Landform	Elevation Zone	Typical Aspects
Cold, Harsh (CH)	Wind Insects/Fire Pathogens Avalanches Drought	High	5-1,000	Gentle Tablelands	High	North East Flat
Cool, Moist (CM)	Wind Pathogens Insects/Fire Drought	Moderate or High	300-10,000	Dissected Sideslopes	Moderate	North East West
Warm, Dry (WD)	Fire Insects Pathogens	Low or Moderate	150-2,000	Dissected Sideslopes	Low	South West
Lodgepole Pine (LP)	Insects Fire	High	40-1,000	Gentle Tablelands	Moderate	East North Flat

Sources/Notes: Fire regime ratings came from Agee (1993); disturbance agents, patch sizes, primary landforms, elevation zones, and typical aspects were adapted from Powell (1996). Patch sizes are given in acres.

Fire regime ratings are:

Low: 1-25 year return interval; 0 to 20% mortality of large trees; a nonlethal fire regime.

Moderate: 26-100 year return interval; 20-70% mortality of large trees; a mixed fire regime.

High: > 100 year return interval; > 70% mortality of large trees; a lethal fire regime.

Fire Behavior

Much of the Tower fire area is a good example of the damage caused by a crown fire. A crown fire is one that spreads through the forest canopy. Crowning is one of the most spectacular fire behavior phenomena that wildland fires exhibit. Crown fires are fast spreading and release a tremendous amount of heat energy in a relatively short period of time. Spread rates exceeding 7 miles per hour and flame lengths over 150 feet have been recorded (Pyne and others 1996).

When winds are strong and sustained, a running crown fire may spread for several hours, burning out entire drainages and crossing mountain ridges that would normally serve as topographic barriers. Fully-developed crown fires can be either wind driven or convective (also called plume-dominated fires). Tower was an instance in which a strong convection column (the plume) built vertically above the fire. It is hypothesized that momentum feedback from the vertical velocity within the column causes turbulent indrafts which promote rapid combustion. The resulting increase in turbulence and fire intensity increases both convective and radiant heat transfer, thus accelerating fire spread. This positive reinforcement process results in a towering convection column and spread rates that are exceptionally fast for the prevailing winds – in other words, the fire spreads at its own self-directed speed and that speed is much greater than would be expected from the ambient wind conditions (Pyne and others 1996).

It is also believed that the Tower fire exhibited a dangerous condition called a downburst or microburst, where winds blow outward near the ground from the bottom of the convection cell. These winds can be very strong and can greatly accelerate a fire. Downburst conditions are initiated by evaporative cooling that cools surrounding air, causing it to descend rapidly and spread horizontally at the ground surface (Pyne and others 1996).

Expected Response to the Fire

The Tower fire affected a very large area supporting a wide diversity of plant species, so a detailed table is provided in the appendix (Table 10) that summarizes fire effects information for many common plants of mixed-conifer forests in the central and southern Blue Mountains of northeastern Oregon (Powell 1994). Since table 10 provides information for more than 70 species, including common trees, shrubs, graminoids, and forbs, some characteristics affecting the fire resistance of eight major tree species is summarized separately in Table 3.

We can expect forest recovery to be slow in many portions of the fire, especially for sites that burned at a moderate or high intensity and supported stands with a high proportion of thin-barked species (subalpine fir, lodgepole pine, grand fir, Engelmann spruce, and western white pine). The fire actually created site conditions that are conducive to regeneration of early seral conifers. However, the fire intensity resulting in conducive conditions was also responsible for killing most of the seed trees that are required for establishment of new tree seedlings.

Table 4 summarizes the acreage burned by forest type and fire intensity. It shows that *42% of the Tower fire burned with an intensity that was severe enough to kill most of the trees in a stand*, particularly stands with thin-barked species. If subalpine fir or lodgepole pine were present, low-intensity areas will also experience some tree killing because a small amount of bole scorch can result in lethal cambial girdling for those species. See the “Fire Intensity Map” in the appendix for the geographical distribution of fire intensity classes for the Tower fire area.

Some of the moderate-intensity acreage in the dry forest cover type may not experience catastrophic mortality, depending on species composition, tree age and vigor, and stand structure. Ponderosa pine trees can withstand a relatively high amount of crown scorch (up to 80%), especially vigorous trees in the large-pole and small-sawtimber size classes. Western larch can also survive a very high amount of bole and crown scorch, resulting in it having the highest fire resistance of any conifer in the Tower fire area (Table 3).

Table 3. Bark thickness, crown length, and fire resistance rankings for common tree

species of the montane and subalpine vegetation zones in the Blue Mountains.

BARK THICKNESS	CROWN LENGTH	FIRE RESISTANCE
Ponderosa Pine (thickest)	**Western Larch (shortest)**	**Western Larch (highest)**
Western Larch	**Western White Pine**	**Ponderosa Pine**
Douglas-fir	**Lodgepole Pine**	**Douglas-fir**
Grand Fir	**Ponderosa Pine**	**Western White Pine**
Western White Pine	**Douglas-fir**	**Grand Fir**
Engelmann Spruce	**Grand Fir**	**Lodgepole Pine**
Subalpine Fir	**Engelmann Spruce**	**Engelmann Spruce**
Lodgepole Pine (thinnest)	**Subalpine Fir (longest)**	**Subalpine Fir (lowest)**

Sources: Powell (1994, Table 2). Species rankings are based on the predominant situation for each trait. A species trait is not absolute – it can vary during the lifespan of an individual tree, and from one individual to another in a population. For example, grand fir's bark is thin when young, but relatively thick when mature.

TABLE 4: AREA (ACRES) BURNED, BY FIRE INTENSITY AND FOREST TYPE.

	AREA (ACRES) BY FIRE INTENSITY				
Forest Type	**Low**	**Moderate**	**High**	**Severe**	**Total**
Dry	5,898	2,110	548	2,658 (31%)	8,556
Mesic	12,503	9,429	3,488	12,917 (51%)	25,420
Lodgepole	8,002	3,847	1,851	5,698 (42%)	13,700
Cold	2,840	246	56	302 (10%)	3,142
Total	29,243	15,632	5,943	21,575 (42%)	50,818

Sources: Fire intensity and coarse vegetation maps for the Tower fire area (see appendix). The "severe" column is the moderate and high acreages combined; the percentage shown after each severe value was computed by dividing the severe value by the total for the forest type.

Ponderosa Pine Response. The response of ponderosa pine to crown scorch varies with time of burning since early summer fires cause more damage than late summer burns. Less damage occurs in late summer because tree growth has slowed, terminal buds have formed, and root (food) reserves have been accumulated. Crown scorching in early spring, before or immediately after bud burst, often results in minimal damage to the tree (Crane and Fischer 1986). An important concern is the increased susceptibility of ponderosa pine to bark-beetle attack after crown scorch (defoliation). For ponderosa pine, the risk of western pine beetle attack varies in direct proportion to the amount of crown lost by scorching (Table 5).

TABLE 5: RELATIONSHIP BETWEEN CROWN SCORCH AND MORTALITY CAUSED BY WESTERN PINE BEETLE FOR PONDEROSA PINE (SOURCE: CRANE AND FISCHER 1986).

Percent Scorch (Defoliation)	Percent of Trees Killed by Beetles
0-25	0-15
25-50	13-14
50-75	19-42
75-100	45-87

Forest Insect Response. A recent study of fire-injured trees in the Yellowstone fires of 1988 (Ryan and Amman 1994) showed that insects can be expected to affect other species too:

1. Douglas-firs with more than 50% crown scorch, or more than 75% basal girdling, suffered high mortality from Douglas-fir beetle and wood borers.
2. A large proportion of burned lodgepole pines were killed by beetles (mostly pine engravers) within 3 years of the fire, even though most trees had received less than 25% crown scorch. Although mountain pine beetle was not a major problem following the Yellowstone fires, it has infested large-diameter lodgepole pine in eastern Oregon following root injury or minor basal girdling caused by fire.
3. Engelmann spruce can experience very high levels of spruce beetle infestation following fire injury, either in standing trees or in windthrown stems whose shallow roots were consumed by smoldering fires in accumulations of litter and duff at the tree bases.
4. For subalpine firs, virtually any fire vigorous enough to scorch the bark will cause cambial injury, followed by sloughing of the dead bark. Wood borers quickly and aggressively colonize the fire-damaged trees and thereby contribute to extremely high mortality rates.

Natural Regeneration. The probability of obtaining natural regeneration in the fire area will depend on several factors:

- the availability of surviving trees to serve as a seed source,
- the spatial arrangement of seed trees (their proximity to severely-burned areas),
- whether the survivors are physiologically capable of producing seed in any abundance,
- whether cone (seed) crops are actually produced, and when.

In the case of lodgepole pine, some regeneration may be produced by cones present in the canopy of dead stands, assuming of course that any canopy remained after the fire. In many moderate-intensity areas, all lodgepole pines were killed by the fire, although foliage still persists and will provide some seed if cones were present before the burn. Although lodgepole pine has low serotiny (closed cones) in the Blue Mountains, it is a prolific seed producer and good seed crops occur frequently. If 1996 was a good seed year for lodgepole pine stands in the Tower fire area, we can expect adequate to overly-abundant lodgepole pine regeneration in the future.

Table 6 summarizes silvical characteristics related to seed production. Table 7 provides effective seed dispersal distances that can be expected for important conifers affected by the Tower fire.

Table 6. Minimum reproductive age (years), period when abundant seed crops begin to be produced, and periodicity of good seed crops for common tree species of the montane and subalpine vegetation zones in the Blue Mountains.

TREE SPECIES	MINIMUM AGE (YEARS)	PERIOD WHEN ABUNDANT SEED CROPS PRODUCED	PERIODICITY OF GOOD SEED CROPS
Ponderosa Pine	**20**	**Late (40-60 years)**	**3-10 years**
Douglas-fir	**20**	**Intermediate (20-40 years)**	**3-10 years**
Western Larch	**15**	**Early (10-20 years)**	**3-5 years**
Black Cottonwood		**Early (10-20 years)**	**1-2 years**
Thinleaf Alder		**Early (10-20 years)**	**3-5 years**
Water Birch		**Early (10-20 years)**	**1-2 years**
Quaking Aspen		**Early (10-20 years)**	**3-5 years**
Grand Fir	**15**	**Late (40-60 years)**	**3-5 years**
Western White Pine	**15**	**Late (40-60 years)**	**3-5 years**
Lodgepole Pine	**15**	**Early (10-20 years)**	**1-2 years**
Engelmann Spruce	**25**	**Late (40-60 years)**	**2-6 years**
Subalpine Fir	**25**	**Late (40-60 years)**	**2-3 years**
Whitebark Pine	**60**	**Late (40-60 years)**	

Sources/Notes: "Minimum age," from Keane and others (1996), refers to the age at which the species starts producing seed crops; "period when abundant seed crops produced" and "periodicity of good seed crops," from Daniel and others (1979), refers to the period when the species begins to produce abundant seed crops, and the average time interval between good seed crops.

Table 7. Effective seed dispersal distances for common coniferous trees of the montane and subalpine vegetation zones on the Umatilla National Forest.

SPECIES	EFFECTIVE SEED DISPERSAL
Ponderosa Pine	**Up to 100-120 feet**
Western Larch	**Up to 120-150 feet**
Douglas-fir	**Up to 300-330 feet**
Grand Fir	**Up to 200 feet**
Western White Pine	**Up to 400 feet**
Engelmann Spruce	**Up to 100-120 feet**
Subalpine Fir	**Up to 50-100 feet**
Lodgepole Pine	**Up to 200 feet**

Source/Notes: Nyland (1996). These distances are maximums for the majority of seed; for example, at least 50% of Engelmann spruce seed will fall within 120 feet of the windward edge of an opening, although up to 10% of the seed will be dispersed as far as 300 feet.

After considering the information contained in tables 6 and 7, along with local experience gained by following recovery after other fires (although none of the recent historical fires approached the size of Tower), it was possible to estimate lag times to obtain natural regeneration in the Tower fire area. Those estimates are provided in Table 8. It is difficult to estimate lag times precisely due to variations in fire intensity, burn patterns, and stand mortality, all of which have a bearing on seed availability and the probability of obtaining natural regeneration.

Table 8. Estimates of natural regeneration lag times for the Tower fire area.

FOREST COVER TYPE	EARLY SERAL TREE SPECIES	Natural Regen Period By Fire Intensity LOW	Natural Regen Period By Fire Intensity SEVERE
Dry Forest	**PP**	**< 10 years**	**10-15 years**
Mesic Forest	**WL, PP, LP**	**< 5 years**	**5-10 years**
Lodgepole Pine	**LP, WL**	**< 5 years**	**5-10 years**
Cold Forest	**LP, WL**	**< 10 years**	**15-25 years**

Source/Notes: "Early Seral Tree Species" are those species that are ecologically adapted to the site conditions created by a stand-replacing disturbance event such as wildfire. Estimates of natural regeneration (regen) lag times are based on the authors' judgment, and assume that a seed source (living trees of seed-bearing age and vigor) is present within a reasonable distance of the site to be colonized. See Table 1 for tree species codes, and Table 4 for a description of the fire intensity classes.

Fire Effects on Western White Pine Natural Stands and Plantations

The Tower fire adversely affected a number of natural stands of western white pine on the North Fork John Day District (NFJD), including those occurring in Hidaway Meadows, Winom Butte, Pearson Ridge, and the Texas Bar drainage (Map 3, in appendix). Fire intensity was moderate to high in those areas and, as a consequence, an estimated 60-70 percent of the natural white pine populations on the District, and also a high proportion for the Forest, have been extirpated.

In addition to their intrinsic biotic value, these stands represented a major source of reforestation seed for the District. Most of the remaining western white pine on NFJD is inaccessible or has high levels of blister rust. The loss of the 20-acre Texas Bar stand is especially significant since plans were underway to thin and culture it for use as a seed production area. In addition, a number of the white pine trees lost were select parent trees and were being screened for resistance to western white pine blister rust at the Dorena Genetic Resource Center.

Over the last 15 years, western white pine has increasingly been used in District reforestation plantings due to its high survival and juvenile growth rates when established on ecologically suitable sites. An estimated 25-50 percent of these plantings (approximately 300-400 acres) were destroyed by the Tower Fire. The majority of the plantations occurred in the Texas Bar and Oriental Creek areas.

At present, the District has less than 20 pounds of western white pine seed on inventory, enough to yield approximately 153,000 shippable seedlings. Another 9,000 seedlings are at Stone Nursery for 1997 delivery. Together these inventories are sufficient for planting approximately 1,860 acres (20% WWP in mix, 10′x10′ spacing), roughly the acreage in the Tower fire area suitable for planting white pine. Once these sources have been depleted, the District will face a serious dilemma as to where to obtain additional western white pine seed for reforestation.

Fortunately, western white pine exhibits little differentiation over geographic, ecologic, or elevational gradients, and nonlocal seed sources can thus be transferred widely with little risk of maladaptation (Rehfeldt et al. 1984, Steinhoff 1979, Townsend et al. 1972, Rehfeldt and Steinhoff 1970). Recommendations regarding the use of nonlocal western white pine seed are provided in the following section (item #6). In the future (approximately 20-25 years from now), reforestation seed may also be obtained from the Paddy Flat Seed Orchard (Pine RD, Wallowa-Whitman National Forest), which is being established to supply seed for the Umatilla, Wallowa-Whitman, and Malheur National Forests.

Conclusions and Recommendations

1. In areas where the mesic forest, lodgepole pine, and cold forest cover types burned with a low intensity, and in areas where the dry forest cover type burned with a low or moderate intensity, it is unclear how many trees will ultimately survive the fire. Since the abundance, distribution, and species composition of the survivor component will have important implications for artificial reforestation, *we recommend that the District acquire high-resolution (2-meter), color infrared (CIR) photography for the fire area*. CIR photography is ideal for assessing vegetation stress, and would probably be the best remote sensing product for estimating tree mortality (or survival). Acquiring CIR photography at a high resolution would allow it to do double duty – not only could it help identify living and damaged trees, but it would serve as an ideal GIS “base layer” for salvage planning, reforestation, and other post-fire project work.
2. According to field reconnaissance completed by the BAER team and Scott McDonald, it appears that a large acreage of established (certified) and recently-completed plantation was burned in the fire (perhaps 1,200 acres). If that assessment turns out to be accurate, then a silvicultural investment of well over $1,000,000 was lost in plantations alone, with unknown additional losses for thinnings and other cultural treatments. Since the plantations represent a serious loss of timber productivity, and are areas where we have entered into a de facto “contract” with the public, timber purchasers, and other stakeholders to quickly reestablish tree cover in harvested areas (as directed by the National Forest Management Act), *we recommend that the burned plantations be replanted as quickly as possible*.
3. According to reconnaissance completed by the BAER team, and by Vince Novotny, Scott McDonald and other District employees, it appears that large areas were burned with an intensity that warrants consideration for artificial reforestation (perhaps 16,000 acres or more, including the Cable Creek roadless areas). After identifying areas that are likely to regenerate naturally, as discussed in the “Response to the Fire” section above, and after locating areas where planting would need to be postponed until salvage treatments are completed, *we*

recommend that the remaining areas with a high amount of stand mortality (outside of the North Fork John Day Wilderness) be scheduled for planting.

4. *We recommend that all plantings emphasize establishment of early-seral conifers on upland sites*, and appropriate hardwood species (black cottonwood, quaking aspen, thinleaf alder, water birch, etc.) in riparian zones. Table 8 shows the early seral conifers that could be considered for each of the forest cover types. Since lodgepole pine is expected to regenerate naturally on all but the highest intensity burns, we recommend that upland plantings emphasize western larch and ponderosa pine to a greater degree than lodgepole pine.
5. Even though Tower burned as a convection crown fire, which means that stand densities and structures, fuel characteristics, and other factors that typically influence fire behavior had little or no impact in this instance, *we recommend that future stand densities be maintained at levels which minimize the potential for crown fires*. Those recommended levels are provided in Table 9.

TABLE 9: MAXIMUM STAND DENSITIES TO LIMIT CROWN FIRE SUSCEPTIBILITY.

AVERAGE STAND DIAMETER (Inches)	**MAXIMUM STAND DENSITY (Trees/Acre)** Ponderosa Pine	Douglas-fir	Grand Fir
3.0	584	574	344
7.5	390	238	245
12.5	197	162	157
17.5	170	104	83

Source/Notes: From Agee (1996). These figures refer to single-sized, non-stratified stands that are predominately of a single species. They do not pertain to stands in which differentiation into crown strata has occurred such that ladder fuels from the understory to the overstory are present. To limit future crown fire risk, any stand density treatment (thinnings, weedings, release, etc.) should leave no more than the trees per acre given above. For example, if a pole-size Douglas-fir stand is thinned from below, and the average stand diameter after thinning is about 7.5″, then the residual stocking should be no more than 238 trees per acre (13.5′ spacing) to limit the risk of future crown fire.

6. Several sources of non-local western white pine seed exist which would be suitable for use in District planting mixes. Seed origin should be documented in planting records, and survival and growth performance monitored closely over time so that transfer guidelines can be modified as needed. In order of preference, seed sources considered appropriate for District use include the following:

   a) <u>Other Blue Mountain sources</u>: The Malheur NF has the greatest abundance of western white pine in the Blue Mountains, as well as an active seed collection program. At present, however, no surplus seed is available. The Wildcat and Summit fires (1996) have generated unplanned reforestation needs on the Malheur NF, and it's highly unlikely that surplus white pine seed from this source will be available for years to come.

b) Couer d'Alene Nursery Seed Orchard: Established in late 1970s with tested materials from Northern Idaho (Nez Perce, Clearwater, Panhandle NFs), as well as a few sources from Northeast Washington and Northwest Montana. Blister rust resistance rating is approximately 60%. Harvested seed crops are allocated on an annual basis to R-1 National Forests. The Umatilla has made a request for surplus seed, but supplies are very limited and demands are high.

   Surplus seedlings are currently available from this source for outplanting in 1997 (100M, 2-0 stock) and 1998 (100M, 3-0 stock?). If stock quality is acceptable, we highly recommend the acquisition of these seedlings for District use.

c) Moscow Arboretum: Established in the 1950s/1960s, this orchard now supplies seed for cooperators in the Inland Empire Tree Improvement Cooperative (IETIC). Resistance level is approximately 60%. All surplus seed in storage was sold earlier this summer; future offerings are unknown.

d) Sandpoint Seed Orchard: Estimated resistance is 35%; so plant materials originating from this orchard are not recommended for use on high risk sites. *Coeur d'Alene Nursery currently has 28M surplus seedlings (3-0 stock) available for outplanting in 1997.*

e) Dorena Seed Orchard: Surplus seed and seedlings originating from Zone 3 (Willamette and Deschutes NF) and Zone 4 (Umpqua/Rogue River NFs and a portion of Winema NF) are frequently available to the Forest. Dorena tested seed is assigned a Hazard Use Class (HUC). These values range from 91 to 99, with 99 being the safest seed to use in a high infection risk area. HUC value of Dorena orchard seed is 97, which is fairly high quality seed. *Plant materials from R-1 are preferable to those from this source, however.*

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Appendix

- Fire Effects Information for Plants of Mixed-Conifer Forests (Table 10)
- Map 1: Fire Intensity Map for the Tower fire area (not available in electronic format).
- Map 2: Coarse Vegetation Map for the Tower fire area (not available in electronic format).
- Map 3: White pine populations affected by the Tower fire (not available in electronic format).

Fire Effects Information for Mixed-Conifer Forests

The information in Table 10 provides fire effects information for more than 70 common plant species found on mixed-conifer sites in the central and southern Blue Mountains.

Plants have varying degrees of fire resistance. A plant's response to fire depends on many factors, including the moisture content of soil and duff at the time of burning, the physiological stage of the plant (immature, mature, etc.), and the fire's severity, particularly with regard to the amount of heat that permeates the litter, duff, and upper soil layers (Crane and Fischer 1986). An important factor affecting a plant's fire resistance is whether it regenerates vegetatively (survivor plants) or from off-site or buried seed (colonizer plants).

Fire resistance ratings ("Resistance" in Table 10) have the following interpretation:

- **High –** Greater than 65 percent chance that 50 percent of the species population will survive or immediately reestablish after passage of a fire with an average flame length of 12 inches.
- **Medium –** 35 to 64 percent chance that 50 percent of the species population will survive or immediately reestablish after passage of a fire with an average flame length of 12 inches.
- **Low –** Less than 35 percent chance that 50 percent of the species population will survive or immediately reestablish after passage of a fire with an average flame length of 12 inches.

Post-fire response ratings ("Response" in Table 10) are an estimate of how quickly a plant species will regain its prefire population level. They have the following interpretation:

- **High –** The species population will regain its preburn frequency or cover in 5 years or less.
- **Medium –** The species will regain its preburn frequency or cover in 5 to 10 years.
- **Low –** The species will regain its preburn frequency or cover in more than 10 years.

The site type ratings ("Site Type" in Table 10) describe the temperature and moisture relationships for sites on which the species is abundant and widely distributed.

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Table 10 – Fire effects information for common plants of mixed-conifer forests in the central Blue Mountains.

CODE	PLANT NAME	FIRE RESISTANCE	FIRE RESPONSE	SITE TYPE	COMMENTS ABOUT REGENERATION METHODS
			TREES		
ABLA2	Subalpine fir (*Abies lasiocarpa)*	Low	Low	Cold, Mesic	Entire stands of this high-elevation species are easily killed by fire; colonizes burned areas very slowly.
JUOC	Western juniper (*Juniperus occidentalis)*	Medium	Low	Warm, Dry	Post-fire establishment occurs from seed, much of which is dispersed by animals (rabbits, squirrels, etc.).
LAOC	Western larch (*Larix occidentalis)*	High	High	Cool, Mesic	Our most fire-resistant conifer because of its thick bark, short crown length, and high tolerance to foliage loss.
PIEN	Engelmann spruce (*Picea engelmannii)*	Low	Low	Cold, Moist	Easily killed by fire because of its long, full crown, thin bark, and a shallow root system.
PICO	Lodgepole pine (*Pinus contorta)*	Medium	High	Cool, Mesic	Often regenerates after stand-replacing wildfires, when it forms dense, even-aged thickets.
PIPO	Ponderosa pine (*Pinus ponderosa)*	High	High	Warm, Mesic	Very high fire resistance; experiences reduced diameter growth after high levels of crown scorch.
PSME	Douglas-fir (*Pseudotsuga menziesii)*	High	Medium	Warm, Mesic	Mature trees are fire resistant due to thick bark, but thin-barked poles and saplings are easily damaged by burning.
			SHRUBS		
AMAL	Serviceberry (*Amelanchier alnifolia)*	Medium	High	Cool, Mesic	Sprouts immediately after fire and also reproduces from bird- and mammal-dispersed seed; germinates on bare soil in partial shade.
ARNE	Manzanita (*Arctostaphylos nevadensis)*	Low	Medium	Cool, Dry	Regenerates from the root crown, runners (stolons) or from seed; survives cool fires if the litter/duff was not completely consumed.
BERE	Creeping hollygrape (*Berberis repens)*	Medium	Medium	Cool, Dry	Sprouts from surviving rhizomes after fire; survives all but severe burns that cause high soil heating.
CEVE	Snowbrush ceanothus (*Ceanothus velutinus)*	High	High	Warm, Mesic	Often regenerates prolifically from seeds buried in the soil; seeds can remain viable for hundreds of years.
CELE	Mountain mahogany (*Cercocarpus ledifolius)*	Low	Low	Warm, Dry	Sprouts weakly after low-intensity fires; reproduces from wind- and mammal-dispersed seed (some soil storage); germinates in full sun.
HODI	Oceanspray (*Holodiscus discolor)*	Medium	High	Warm, Dry	Regenerates from the surviving root crown, and from seed stored in the soil; its seedlings establish easily on fresh mineral soil.
PAMY	Myrtle pachistima (*Pachistima myrsinites)*	Medium	Medium	Cool, Mesic	Regenerates from the crown of a deep taproot, or from stem bud sprouts or stored seed; may increase after cool or moderate burns.
PRVI	Common chokecherry (*Prunus virginiana)*	Medium	High	Warm, Mesic	Sprouts prolifically from its root crown; reproduces from bird- and mammal-dispersed seed; germinates in full sun after disturbances.
RICE	Wax currant (*Ribes cereum)*	Medium	High	Warm, Dry	Regenerates from seed stored in the litter/duff, and from basal stem sprouts; susceptible to fire-induced mortality after severe burns.

Table 10 – Fire effects information for common plants of mixed-conifer forests in the central Blue Mountains (CONTINUED).

Code	Plant Name	Fire Resistance	Fire Response	Site Type	Comments About Regeneration Methods
RILA	Prickly currant (*Ribes lacustre)*	High	High	Cool, Moist	Usually increases after burning, even severe fires. Cool or moderate-intensity fires favor establishment of prickly currant seedlings.
ROGY	Baldhip rose (*Rosa gymnocarpa)*	Medium	Medium	Cool, Mesic	Regenerates from the root crown, stem bases, and from seed; it responds vigorously to cool or moderate fires.
SASC	Scouler willow (*Salix scouleriana)*	High	High	Cool, Mesic	Regenerates from the root crown, or by using small, windborne seed; may increase dramatically after fire, especially on moist sites.
SPBE	White spiraea (*Spiraea betulifolia)*	High	High	Cool, Mesic	Regenerates from the root crown, and by use of rhizomes located 2-5 inches beneath the soil surface; usually increases after burning.
SYAL	Common snowberry (*Symphoricarpos albus)*	Medium	High	Cool, Mesic	Regenerates from deep rhizomes, basal stem buds, and seed; favored by cool or moderate fires, but often survives severe ones too.
SYOR	Mountain snowberry (*Symphoricarpos oreophilus)*	Low	Medium	Cool, Dry	Sprouts weakly from the root crown, and from rhizomes; usually maintains prefire cover and abundance after cool or moderate fires.
VAME	Big huckleberry (*Vaccinium membranaceum)*	High	Medium	Cool, Mesic	Regenerates from rhizomes and seed, but post-fire recovery may be slow; fire used by native Americans to maintain huckleberry fields.
VASC	Grouse huckleberry (*Vaccinium scoparium)*	Medium	Medium	Cold, Mesic	Regenerates from shallow rhizomes and seed; usually survives cool or moderate fires that don’t consume all of the litter and duff layers.
GRASSES AND GRASS-LIKE PLANTS					
BRCA	California brome (*Bromus carinatus)*	Medium	Medium	Warm, Dry	Regenerates from the root crown and from wind-disseminated seed; nonrhizomatous; germinates on bare soil in full sun.
BRVU	Columbia brome (*Bromus vulgaris)*	Medium	Medium	Cool, Moist	Regenerates from seed, some of which may be stored in the soil; generally declines following severe fires.
CARU	Pinegrass (*Calamagrostis rubescens)*	Medium	Medium	Warm, Mesic	Regenerates from rhizomes and wind-disseminated seed; survives all but severe fires; germinates on bare soil.
CACO	Northwestern sedge (*Carex concinnoides)*	Medium	Medium	Cool, Moist	Sprouts from rhizomes located in the duff; fires which consume most of the litter and duff will have an adverse impact on this plant.
CAGE	Elk sedge (*Carex geyeri)*	High	High	Warm, Mesic	Sprouts from surviving rhizomes and reproduces from seed stored in the soil; germinates on bare soil after burning or scarification.
CARO	Ross sedge (*Carex rossii)*	High	Medium	Cool, Dry	Regenerates from short rhizomes and from seed stored in the duff and upper soil; germinates on bare soil mainly after scarification.
ELGL	Blue wildrye (*Elymus glaucus)*	Medium	Medium	Warm, Mesic	Regenerates from the root crown, rootstock sprouts, and seed; seed can survive temperatures associated with a moderate-intensity burn.
FEID	Idaho fescue (*Festuca idahoensis)*	Low	Medium	Warm, Dry	Regenerates from the root crown, and from wind-disseminated seed; nonrhizomatous; germinates on bare soil.
FEOC	Western fescue (*Festuca occidentalis)*	Low	Low	Cool, Mesic	Regenerates from the root crown, and from off-site seed; generally declines after fire, although it germinates well on bare, shaded soil.

Table 10 – Fire effects information for common plants of mixed-conifer forests in the central Blue Mountains (CONTINUED).

CODE	PLANT NAME	FIRE RESISTANCE	FIRE RESPONSE	SITE TYPE	COMMENTS ABOUT REGENERATION METHODS
KOCR	Prairie junegrass (*Koeleria cristata*)	Medium	Medium	Warm, Dry	Regenerates from seed – susceptible to mortality from late-spring burns, although this is one of our more fire-resistant bunchgrasses.
PHPR	Common timothy (*Phleum pratense*)	Medium	Medium	Disturbances	Regenerates from the surviving root crown or, more commonly, from seed blowing in from adjacent roadsides and forest openings.
PONE	Wheeler bluegrass (*Poa nervosa*)	Medium	High	Warm, Mesic	Regenerates from surviving rhizomes and seed; seldom damaged by fire unless the litter and duff layers are consumed.
POPR	Kentucky bluegrass (*Poa pratensis*)	High	High	Warm, Mesic	Regenerates from basal stem buds, slender rhizomes, and seed; seldom damaged by fire except for hot, spring burns.
SIHY	Bottlebrush squirreltail (*Sitanion hystrix*)	Medium	High	Warm, Dry	Regenerates from the root crown and seed; since it 'cures' early, this grass survives summer fires better than spring ones.
STOC	Western needlegrass (*Stipa occidentalis*)	Low	Low	Warm, Dry	Regenerates from surviving root crowns and wind-disseminated seed; non-rhizomatous; germinates on bare soil in full sun.
				FORBS	
ACMI	Western yarrow (*Achillea millefolium*)	Medium	High	Disturbances	Regenerates from short, shallow rhizomes and seed; declines after severe fires, but invasion from off-site seed usually occurs rapidly.
ADBI	Trailplant (*Adenocaulon bicolor*)	Low	Low	Cool, Moist	Regenerates from short surface rhizomes and seed; generally survives cool fires although post-fire recovery is usually slow.
ANRO	Rose pussytoes (*Antennaria rosea*)	Low	Medium	Cool, Dry	Regenerates from trailing stolons and wind-blown seed; is apt to increase slightly or remain unchanged after cool or moderate burns.
AQFO	Red columbine (*Aquilegia formosa*)	Medium	Medium	Cool, Moist	Regenerates mostly from seed; likely that moderate or hot fires will have a detrimental effect on this species.
ARMA3	Bigleaf sandwort (*Arenaria macrophylla*)	Low	Medium	Cool, Mesic	Regenerates from shallow rhizomes and seed; decreases slightly or remains unchanged after fire depending on duff consumption.
ARCO	Heartleaf arnica (*Arnica cordifolia*)	Low	High	Cool, Mesic	Sprouts from surviving rhizomes; readily invades burned areas using windborne seed; germinates on bare soil in partial shade.
ASCO	Showy aster (*Aster conspicuus*)	Medium	High	Cool, Mesic	Regenerates from surviving rhizomes and wind-disseminated seed; germinates on bare soil in partial shade.
BASA	Balsamroot (*Balsamorhiza sagittata*)	High	High	Warm, Dry	Regenerates from a root crown and animal-disseminated seed; plant densities are often greater than pre-burn levels by the second year.
CAMI2	Scarlet paintbrush (*Castilleja miniata*)	Medium	Medium	Warm, Mesic	Regenerates from the crown of a deep taproot, and from off-site seed; reestablishment in the post-fire community is somewhat slow.
CHUM	Pipsissewa (*Chimaphila umbellata*)	Low	Medium	Cool, Mesic	Sprouts from shallow rhizomes; usually survives cool or moderate burns that don't consume all of the litter and duff layers.
CIVU	Bull thistle (*Cirsium vulgare*)	Medium	Medium	Disturbances	Regenerates from root sprouts and seed; often increases dramatically after burning and may compete moderately with tree seedlings.

Table 10 – Fire effects information for common plants of mixed-conifer forests in the central Blue Mountains (CONTINUED).

		FIRE	FIRE		

CODE	PLANT NAME	RESISTANCE	RESPONSE	SITE TYPE	COMMENTS ABOUT REGENERATION METHODS
CLUN	Queencup beadlily (*Clintonia uniflora)*	Low	Low	Cool, Moist	Regenerates from widely spreading rhizomes, and from seed; generally declines after fire.
ERCO3	Longleaf fleabane (*Erigeron corymbosus)*	Low	Medium	Cool, Dry	Regenerates from off-site seed or a moderately well-developed rootcrown; apt to decrease slightly or remain unchanged after fire.
FRVE	Woods strawberry (*Fragaria vesca)*	Medium	Medium	Cool, Mesic	Regenerates from root crown sprouts, runners (stolons), and seed stored in upper soil; survives cool fires.
FRVI	Blueleaf strawberry (*Fragaria virginiana)*	Medium	High	Cool, Mesic	Regenerates from root crown sprouts and runners (stolons); survives cool fires that don't consume all of the litter and duff layers.
GABO	Northern bedstraw (*Galium boreale)*	Medium	Medium	Cool, Mesic	Regenerates from creeping, underground rhizomes, and from sticky seed; is fairly resistant to light burns but declines after severe fires.
GATR	Sweetscented bedstraw (*Galium triflorum)*	Low	Medium	Cool, Moist	Regenerates using rhizomes and seed; decreases dramatically after severe fires, but can increase following cool burns.
GOOB	Rattlesnake plantain (*Goodyera oblongifolia)*	Low	Low	Cool, Mesic	Regenerates using rhizomes and seed; easily killed by fire because its shallow rhizomes are very sensitive to heat.
HIAL2	Western hawkweed (*Hieracium albertinum)*	Low	Medium	Cool, Dry	Lacks rhizomes or another means of vegetative reproduction, but readily invades burned areas using windborne seed.
HIAL	White hawkweed (*Hieracium albiflorum)*	Low	Medium	Cool, Mesic	Lacks rhizomes or another means of vegetative reproduction, but readily invades burned areas using windborne seed.
LALA2	Thickleaf peavine (*Lathyrus lanzwertii)*	Medium	High	Warm, Dry	Regenerates from rhizome sprouts and seed; similar to other legumes in that this plant is a nitrogen fixer.
LANE	Cusick's peavine (*Lathyrus nevadensis)*	Medium	High	Warm, Mesic	Reproduces from surviving rhizomes and from seed stored in the soil; also a nitrogen fixer.
LIBO2	American twinflower (*Linnaea borealis)*	Low	Medium	Cool, Moist	Regenerates from root crowns, stolons, and seed; survives cool fires if the duff and litter layers were damp and not totally consumed.
LUCA	Tailcup lupine (*Lupinus caudatus)*	High	Medium	Cool, Mesic	Regenerates from a deep taproot and heavy seed; its seed can survive for long periods in the lower duff and upper soil layers.
MITR	False agoseris (*Microseris troximoides)*	Medium	High	Warm, Dry	Regenerates from a deep taproot; increases or remains unchanged after fires which don't consume all of the litter and duff layers.
MIST2	Sideflowered mitella (*Mitella stauropetala)*	Medium	High	Cool, Mesic	Regenerates from the root crown and seed; fires which consume most of the litter and duff are apt to have a detrimental impact.
OSCH	Mountain sweetroot (*Osmorhiza chilensis)*	Medium	Medium	Cool, Moist	Regenerates from a taproot or root crown, and from seeds; flowering usually increases after the tree canopy has been opened by fire.
POPU	Polemonium (*Polemonium pulcherrimum)*	Low	Medium	Cold, Moist	Regenerates from the semi-woody crown of a large taproot, and from seed; usually declines following fire.
PTAQ	Bracken fern (*Pteridium aquilinum)*	High	High	Cool, Moist	Sprouts from surviving rhizomes and spreads vigorously after fire; inhibits conifer regeneration by producing chemicals (allelopathy).

Table 10 – Fire effects information for common plants of mixed-conifer forests in the central Blue Mountains (CONTINUED).

		FIRE	FIRE		

CODE	PLANT NAME	RESISTANCE	RESPONSE	SITE TYPE	COMMENTS ABOUT REGENERATION METHODS
PYSE	Sidebells pyrola (*Pyrola secunda)*	Low	Low	Cool, Mesic	Sprouts from rhizomes in the lower duff or at the soil surface; commonly decreases after fire unless duff moisture is high.
SEIN	Woolly groundsel (*Senecio integerrimus)*	Low	Medium	Cool, Dry	Regeneration occurs mainly from off-site seed; apt to decrease slightly or remain unchanged after low- or moderate-intensity fire.
SMRA	Feather solomonplume (*Smilacina racemosa)*	Medium	Medium	Cool, Mesic	Regenerates from creeping rhizomes and is fairly resistant to fire damage; usually maintains its prefire frequency after burning.
SMST	Starry solomonplume (*Smilacina stellata)*	Medium	Medium	Cool, Mesic	Sprouts from creeping rhizomes; often decreases after fire, especially severe burns that consume most of the litter and duff.
TAOF	Common dandelion (*Taraxacum officinale)*	Medium	Medium	Disturbances	Regenerates from a deep taproot and light, windborne seed; can quickly colonize burns located near an ample seed source.
VIAM	American vetch (*Vicia americana)*	Medium	High	Cool, Mesic	Regenerates from rhizomes in the upper soil; seldom damaged unless the litter/duff has been consumed; a nitrogen fixer.
VIOR2	Darkwoods violet (*Viola orbiculata)*	Medium	Medium	Cool, Mesic	Regenerates from short, slender rhizomes and seed stored in the upper soil or duff layers; usually declines following fire.

Source: Adapted from Table 5 in Powell (1994). **Notes**: Common and scientific plant names generally follow Hitchcock and Cronquist (1973). Codes were taken from Powell (1989). Fire resistance and fire response ratings, and comments about reproduction methods, were obtained from the following sources: Bradley and others (1992), Crane and Fischer (1986), Fischer and Bradley (1987), Fischer and Clayton (1983), Flinn and Wein (1977), Geier-Hayes (1989), Hopkins and Rawlings (1985), Leege and Godbolt (1985), McLean (1968), Noste and Bushey (1987), Sampson (1917), Steele and Geier-Hayes (1995), Stickney (1986), and Volland and Dell (1981). Valuable information was also obtained from the Fire Effects Information System (FEIS) developed by the Intermountain Fire Sciences Laboratory at Missoula, Montana (Fischer and others 1996). For some plants, no literature sources were found for one or both of the fire ratings, so an estimate was made using information for species with similar morphological or reproductive characteristics.

Fire resistance ratings have the following interpretation:

- High – Greater than 65 percent chance that 50 percent of the species population will survive or immediately reestablish after passage of a fire with an average flame length of 12 inches.
- Medium – 35 to 64 percent chance that 50 percent of the species population will survive or immediately reestablish after passage of a fire with an average flame length of 12 inches.
- Low – Less than 35 percent chance that 50 percent of the species population will survive or immediately reestablish after passage of a fire with an average flame length of 12 inches.

Fire response ratings estimate of how quickly a plant species will regain its prefire population level. They have the following interpretation:

- High – The species population will regain its preburn frequency or cover in 5 years or less.
- Medium – The species will regain its preburn frequency or cover in 5 to 10 years.
- Low – The species will regain its preburn frequency or cover in more than 10 years.

Site type ratings are an estimate of the temperature and moisture relationships for sites on which the species is abundant.