Umatilla National Forest
North Fork John Day Ranger District
Desolation Watershed Ecosystem Analysis

UPLAND FOREST VEGETATION ANALYSIS

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[Looking into a portion of the Desolation watershed from Desolation Butte Lookout; October 10, 1935.]

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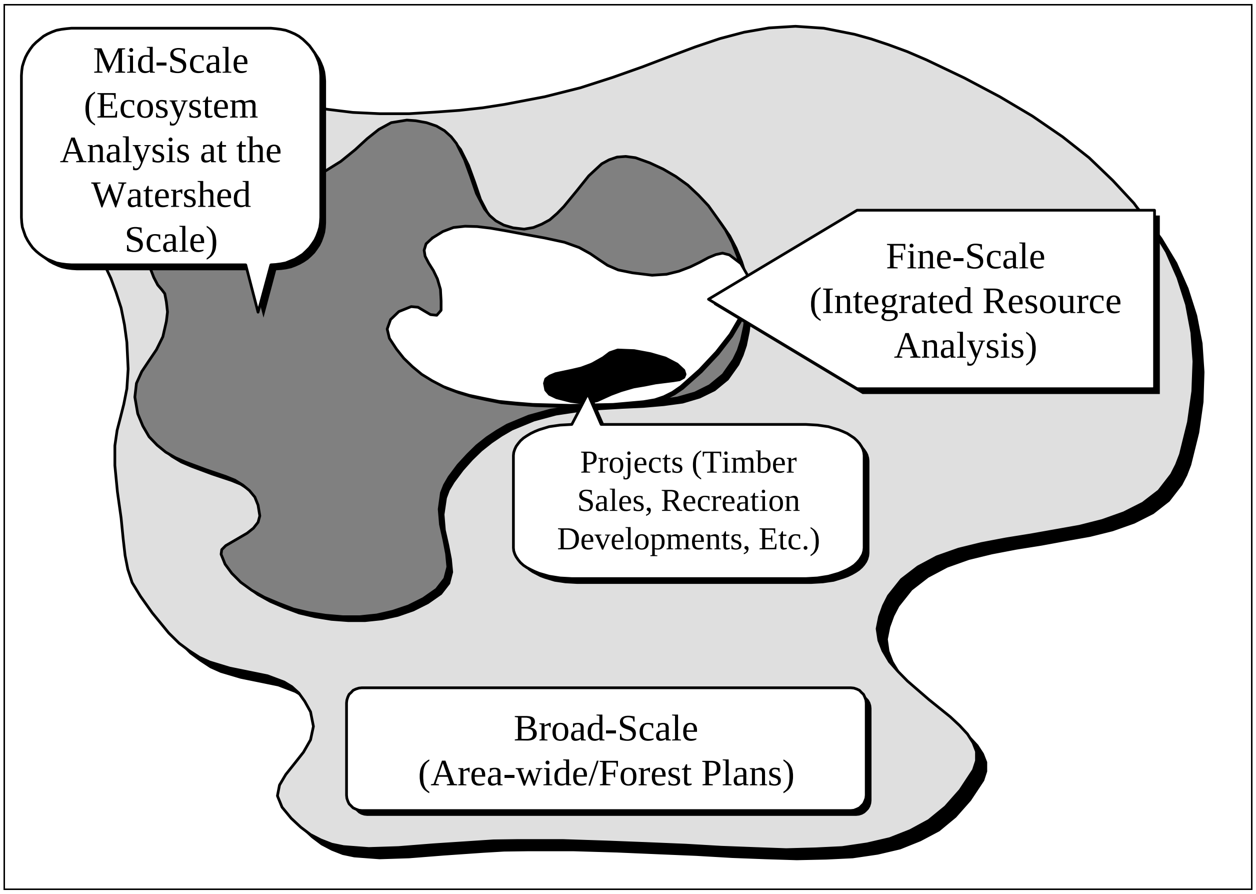
INTRODUCTION

Ecosystem analysis at the watershed scale is used to characterize the human, aquatic, riparian, and terrestrial conditions and processes within a watershed. It provides a systematic way to understand and organize ecosystem information. In so doing, watershed analysis enhances our ability to estimate the effects of management activities and disturbance agents in a drainage. The understanding gained through such an analysis is critical to sustaining the health and productivity of the natural resources that have been entrusted to our care (Regional Ecosystem Office 1995).

Federal agencies are conducting watershed analyses as a way to shift their focus from individual species and sites to the ecosystems that support them. Hopefully, that change in attitude will result in a better understanding of the consequences of management actions before they are implemented. The watershed scale was selected because a watershed is a well-defined land area with a relatively homogenous set of features and processes, at least from a hydrologic perspective (Regional Ecosystem Office 1995).

Watershed analysis is driven by issues. Rather than attempting to address everything in the ecosystem, analysis teams focus on seven core topics along with watershed-specific issues and concerns. The issues and concerns may be known or suspected before embarking on the process, or may be discovered during the analysis itself. The analysis identifies ecological processes of greatest concern, establishes how well those processes are functioning, and then determines the conditions or circumstances under which restoration and other management activities could occur in the watershed (Regional Ecosystem Office 1995).

Watershed analysis is not a decision-making process. It is an incremental endeavor, with new information derived from surveys or monitoring incorporated whenever it becomes available. An important function of watershed analysis is to set the stage for subsequent decision-making processes by providing context for fine-scale integrated resource analysis and project planning (Regional Ecosystem Office 1995; Veg Figure 1).



Veg Figure 1 – Analysis scales, showing that "ecosystem analysis at the watershed scale" is considered to be a mid-scale process.

This report provides the results of an upland-forest vegetation analysis for the Desolation watershed. It describes the potential natural vegetation, cover types, landscape patches, size classes, structural stages, canopy cover, canopy layers, and disturbances for upland forests of the Desolation ecosystem analysis area. In addition, several other factors pertaining to upland forests were also examined, including the historical range of variation for forest structural stages, an analysis of stand density, an assessment of forest sustainability, and consideration of limited vegetation components. At the end of this report, one appendix describes the vegetation databases that were used to support the analyses; a second appendix provides suggested stocking levels for tree species that occur in the analysis area.

CHARACTERIZATION

Characterization is the first step in a six-step process for ecosystem analysis at the watershed scale (EAWS). It is designed to identify the ecosystem elements (components, structures, and processes) that influence vegetation conditions in the watershed (Regional Ecosystem Office 1995). For this report, the scope of characterization and other ecosystem analyses was limited to upland forest vegetation only.

Forest vegetation reflects the interaction of ecosystem components, structures, and processes. *Components* are the kinds and numbers of organisms that make up an ecosystem (Manley and others 1995). Forest vegetation components include tree species, aggregations of tree species called cover types, or combinations of cover types called life-forms, depending on the scale being considered (Veg Table 1). The existing situation with respect to forest vegetation components of the Desolation watershed is described in the *Current Conditions* section (page 13); the historical situation is described in the *Reference Conditions* section (page 26).

Structures are the arrangement or distribution of ecosystem components (Manley and others 1995). Structures can occur both horizontally (the spatial distribution of structural stages across a landscape) and vertically (trees of varying height growing together in a multi-layered structure). Forest structures consist of size classes, structural stages, or physiognomic types, depending on the scale being considered (Veg Table 1). The existing situation with respect to forest vegetation structures of the Desolation watershed is described in the *Current Conditions* section (page 13); the historical situation is described in the *Reference Conditions* section (page 26).

Processes are the flow or cycling or energy, materials, and nutrients through space and time (Manley and others 1995). Forest processes can include everything from photosynthesis and nutrient cycling to stand-replacing wildfires and insect outbreaks (Veg Table 1). In the Desolation watershed and the Interior Northwest in general, disturbances have influenced vegetation conditions to a greater degree than other ecosystem processes (Clark and Sampson 1995; Oliver and Larson 1996). The existing and historical situation with respect to forest disturbances is discussed in both the *Current Conditions* and *Reference Conditions* sections (pages 13 and 26, respectively).

Veg Table 1: Selected examples of forest ecosystem elements.

ECOSYSTEM ELEMENTS	ECOSYSTEM SCALE (HIERARCHICAL LEVEL) FINE	MID	BROAD
Components	Tree Species	Cover Types	Life-form (forest; shrubland, etc.)
Structures	Tree Size Classes	Structural Stages	Physiognomic Types
Processes	Wind; Senescence	Bark Beetles; Pathogens	Fire; Defoliators

Sources/Notes: Although they are shown individually in this table, it is important to note that forest components, structures, and processes are interrelated – from an ecosystem perspective, they do not operate independently.

Veg Table 1 demonstrates that ecological analysis is highly influenced by scale because ecosystem elements occur in hierarchies (Haynes and others 1996). Some elements are easily identified at one scale but not at another. That doesn't mean an element ceased to exist – it is just not apparent at the resolution of a different hierarchical level. For example, at the fine scale represented by the interior of a forest stand, individual tree species can be readily distinguished. After moving back to the mid-scale, individual species are imperceptible but species groups (cover types) become apparent. At a broad scale, discrete cover types can no longer be discerned although life-forms (forest versus non-forest) are obvious.

Potential Natural Vegetation

Why do some forest components occur only in certain portions of the Desolation watershed (subalpine fir cover type at high elevations, for example)? Why are some forest structures associated more often with one component than another (the *old forest single stratum* structural stage with warm dry sites)? And why do certain disturbance agents act differently depending on which cover type they occur in? Those and other questions are best addressed using a concept called potential natural vegetation (PNV), which is defined and described below.

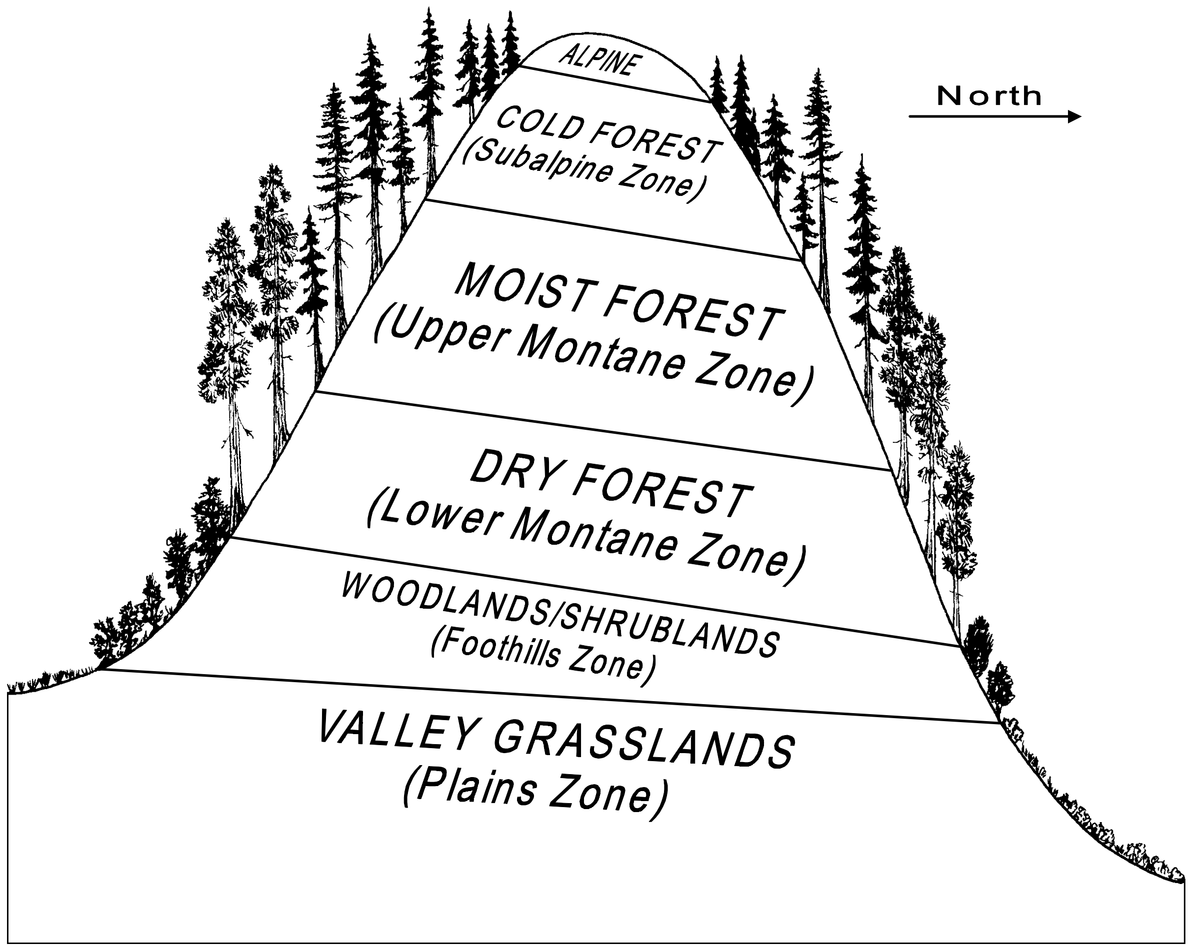
Mountainous areas such as the Desolation watershed have steep environmental gradients, which means that site conditions vary in response to changes in landform, elevation, climate, soils, slope exposure, geology, and a variety of other abiotic factors. Any unique combination of abiotic factors results in a slightly different environment, usually expressed as a change in temperature and moisture conditions. In the Desolation analysis area, temperature and moisture varies somewhat predictably with changes in elevation and aspect (Veg Figure 2).

The climax plant community (e.g., the PNV) associated with a particular set of environmental conditions (temperature and moisture) is called a *plant association*. Sites that can support similar plant associations are grouped together as a *plant association group* (PAG). In a similar way, closely related plant association groups can be aggregated into *potential vegetation groups* (PVG). The ultimate result is a taxonomy or hierarchy of potential natural vegetation, ranging from plant associations at the lowest level to potential vegetation groups at the highest level (Veg Table 2). Veg Figure 3 shows the location and distribution of upland forest PVGs in the Desolation watershed; Veg Figure 4 provides the same information for PAGs. Veg Table 3 summarizes selected characteristics of the PVGs.

PNV has an important influence on forest components, structures, and processes for the Desolation watershed. It is the "engine" that powers vegetation change – it controls the speed at which shade-tolerant species get established beneath shade-intolerant trees, the rate at which forests produce and accumulate biomass, and the influence that fire, insects, pathogens, and other disturbance agents exert on forest structure. Those processes are predictable, at least to some extent, for a reason – they can be related to PNV, and research has consistently shown that sites with the same PNV behave in a similar way.

Because of its predictive power, PNV is valuable for developing management implications. Disturbances and management activities can have widely varying results in different environments. For example, a prescribed fire with a flame length of 2 feet and an intensity of 25 BTU/ft/sec would have relatively benign, nonlethal results when used on warm dry sites where the overstory trees are thick-barked ponderosa pines, Douglas-firs, and western larches. That same treatment could have dramatic results (total tree mortality) on cold dry sites dominated by thin-barked subalpine firs and lodgepole pines.

Recent EAWS efforts have reported management recommendations by subwatershed – a delineation within a hydrologic coding system that represents a group of streams flowing into a watershed (Quigley and Arbelbide 1997). Using subwatersheds during analysis is reasonable in terms of understanding spatial patterns of aquatic ecosystem quality and for addressing aquatic risk (Omernik 1995). However, subwatersheds have limited influence on upland forest processes at a landscape scale. Since ecosystem processes are strongly influenced by PNV, all recommendations pertaining to upland forests are summarized and reported using PNV (either by PAG or by PVG).

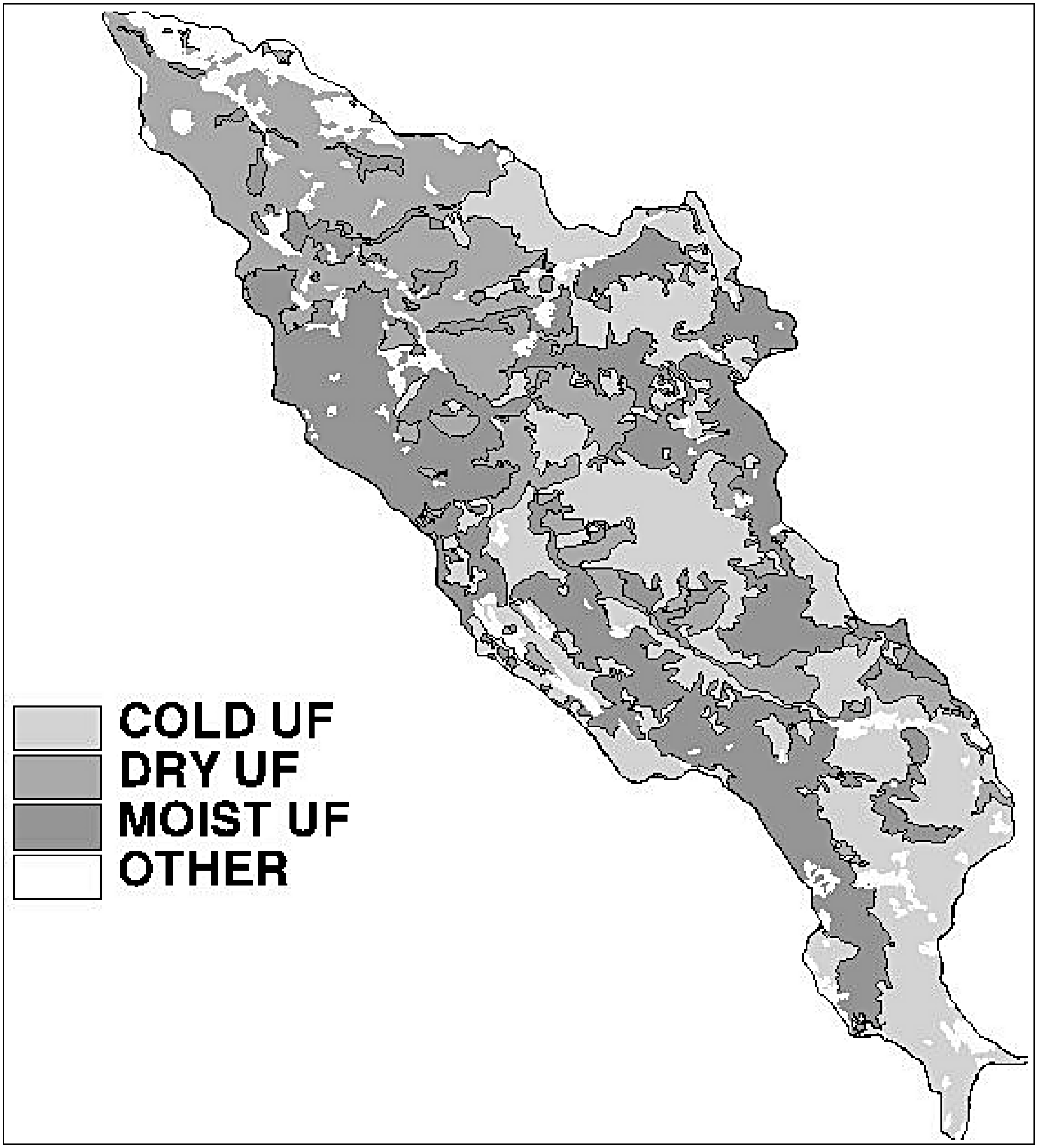


Veg Figure 2 – Vegetation zones of the Blue Mountains (Powell 1998). Vegetation types tend to occur in zones as one moves up or down in elevation. In the Northern Hemisphere, a south-facing slope receives more solar radiation than a flat surface, and a north-facing slope receives less. Thus the same temperature conditions found on a plateau or bench may occur higher on an adjacent south-facing slope, and lower on a north aspect. 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 slope exposure (temperature). Each of the three forest zones typically occupies about 2,000 feet of elevation, with the upper edge of a zone controlled by tolerance to low temperature and the lower edge by tolerance to low moisture. 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 maritime climatic influence gradually deteriorates from north to south in the Blue Mountains. Also, fire suppression has blurred the historical zonation of forest vegetation; Douglas-fir, grand fir, and Engelmann spruce have expanded their range to lower elevations over the last 90 years. **Valley grasslands** occur at low elevations where moisture is too limiting to support trees except along waterways. The **foothills zone** tends to be dominated by western juniper in the central and southern Blue Mountains, although shrublands (serviceberry, hawthorne, chokecherry, etc.) occupy this zone in the northern Blues where a marine climate prevails. **Dry forests** occur on warm dry sites where ponderosa pine, Douglas-fir or grand fir are the climax species. These sites were historically dominated by ponderosa pine because it is well adapted to survive the natural disturbance regime – low-intensity wildfires that occurred every 8 to 20 years. The **moist forest** zone is relatively common, especially in the northern Blue Mountains. It includes cool moist sites where Douglas-fir, grand fir or subalpine fir are the climax species. Lodgepole pine and western larch are common seral species. Western white pine occurs in this forest zone. **Cold forests** occur on harsh sites at high elevations in the subalpine zone. This zone features forests of subalpine fir and Engelmann spruce. Lodgepole pine often forms persistent plant communities there. Above the cold-forest zone is a treeless **alpine zone**, although alpine environments are uncommon in the relatively low-elevation Blue Mountains.

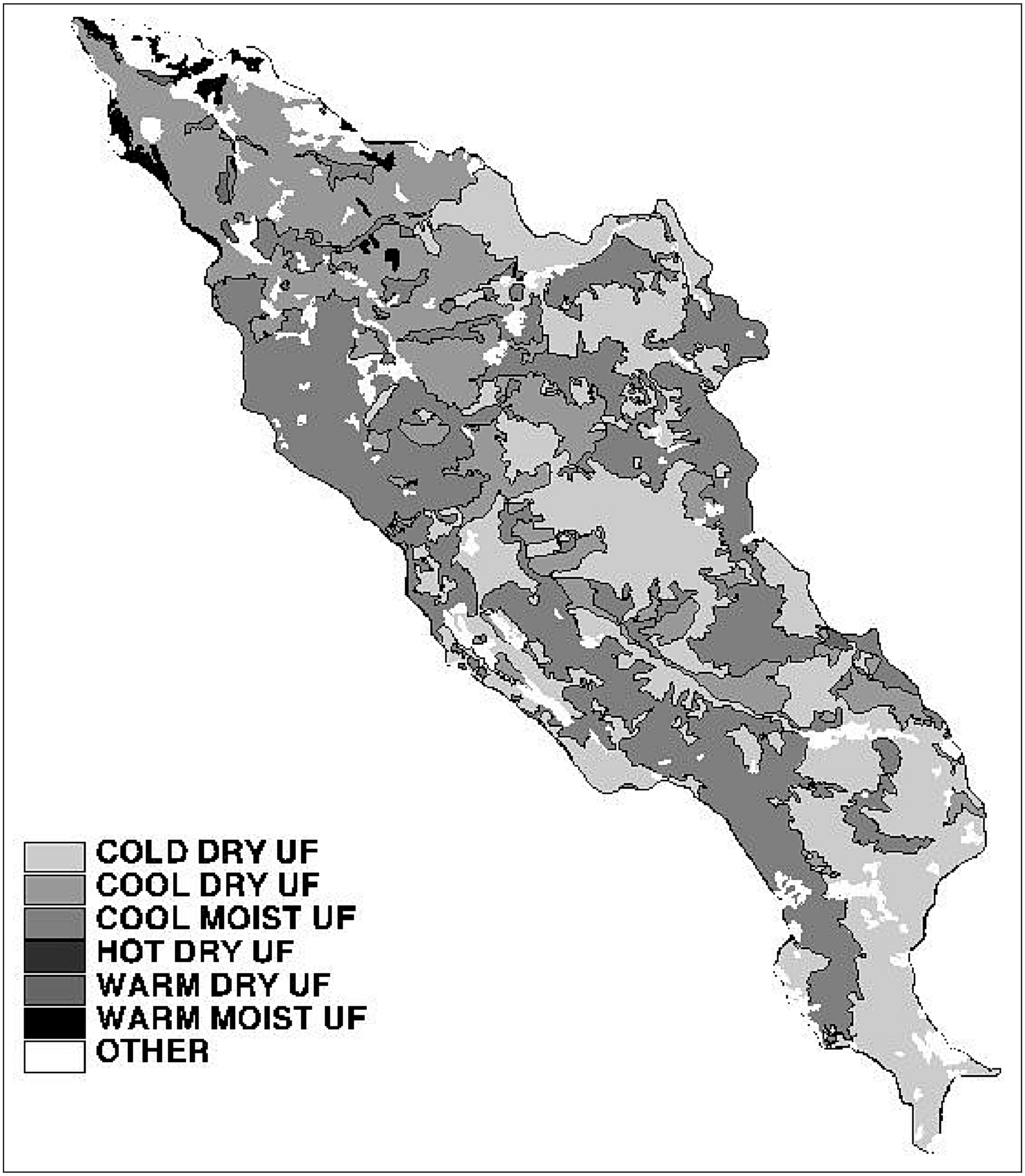
Veg Table 2: PVGs, PAGs, and vegetation types for upland forests/woodlands of the Desolation area.

PVG	PAG	Abbreviation & Common Name of Vegetation Type (Association/Community Type)		Area
Cold Forest	Cold Dry	ABGR/VASC	Grand Fir/Grouse Huckleberry	6,657
		ABLA2/CAGE	Subalpine Fir/Elk Sedge	1,675
		ABLA2 subalpine parks	Subalpine Fir subalpine parklands	641
		ABLA2/VASC	Subalpine Fir/Grouse Huckleberry	10,091
		PICO(ABGR)/VASC/CARU	Lodgepole Pine (Grand Fir)/Grouse Huck./Pinegrass	1,990
		PICO(ABLA2)/VASC	Lodgepole Pine (Subalpine Fir)/Grouse Huckleberry	2,322
		PICO subalpine parks	Lodgepole Pine subalpine parklands	61
	Cool Dry	ABLA2/CARU	Subalpine Fir/Pinegrass	12
Moist Forest	Cool Moist	ABGR/CLUN	Grand Fir/Queen's Cup Beadlily	357
		ABGR/LIBO2	Grand Fir/Twinflower	2,261
		ABGR/VAME	Grand Fir/Big Huckleberry	9,119
		ABGR/VASC-LIBO2	Grand Fir/Grouse Huckleberry-Twinflower	2,168
		ABLA2/CLUN	Subalpine Fir/Queen's Cup Beadlily	102
		ABLA2/LIBO2	Subalpine Fir/Twinflower	1,699
		ABLA2/VAME	Subalpine Fir/Big Huckleberry	7,783
		PICO(ABGR)/VAME	Lodgepole Pine (Grand Fir)/Big Huckleberry	746
		PICO(ABGR)/VAME-LIBO2	Lodgepole Pine (Grand Fir)/Big Huck.-Twinflower	42
		PICO(ABLA2)/VAME	Lodgepole Pine (Subalpine Fir)/Big Huckleberry	216
	Warm Moist	ABGR/BRVU	Grand Fir/Columbia Brome	212
Dry Forest	Warm Dry	ABGR/CAGE	Grand Fir/Elk Sedge	1,669
		ABGR/CARU	Grand Fir/Pinegrass	2,867
		PIPO/CAGE	Ponderosa Pine/Elk Sedge	2,011
		PIPO/CARU	Ponderosa Pine/Pinegrass	1,950
		PIPO/CELE/CAGE	Ponderosa Pine/Mountain-mahogany/Elk Sedge	416
		PIPO/PUTR/CAGE	Ponderosa Pine/Bitterbrush/Elk Sedge	61
		PIPO/SPBE	Ponderosa Pine/Birchleaf Spirea	128
		PIPO/SYAL	Ponderosa Pine/Common Snowberry	1,235
		PSME/CAGE	Douglas-fir/Elk Sedge	1,448
		PSME/CARU	Douglas-fir/Pinegrass	2,769
		PSME/SPBE	Douglas-fir/Birchleaf Spirea	97
		PSME/SYAL	Douglas-fir/Common Snowberry	842
		PSME/VAME	Douglas-fir/Big Huckleberry	413
	Hot Dry	PIPO/AGSP	Ponderosa Pine/Bluebunch Wheatgrass	537
		PIPO/PUTR/FEID-AGSP	Ponderosa Pine/Bitterbrush/Idaho Fescue-Bluebunch Wheatgrass	276
Moist Wood-land	Hot Moist	JUOC/CELE/CAGE	Western Juniper/Mountain-mahogany/Elk Sedge	48
		JUOC/FEID-AGSP	Western Juniper/Idaho Fescue-Bluebunch Wheatgrass	172

Sources/Notes: Adapted from Powell (1998). The "Area" column is the total acreage for the vegetation type in the Desolation area (summarized from the DesoPNV database). Area values will not sum to the analysis area total because non-forest types (grassland, herbland, shrubland) and riparian forests are not included in this summary.



Veg Figure 3 – Potential vegetation groups (PVGs) for upland forests of the Desolation analysis area. Codes are as follows: Cold UF is cold upland forest; Dry UF is dry upland forest; Moist UF is moist upland forest; and Other includes non-forest and riparian forest PVGs. See Veg Table 2 for additional information about the upland-forest PAGs that were aggregated to form these potential vegetation groups.



Veg Figure 4 – Plant association groups (PAGs) for upland forests of the Desolation analysis area. Codes are as follows: Cold Dry UF is cold dry upland forest; Cool Dry UF is cool dry upland forest; Cool Moist UF is cool moist upland forest; Hot Dry UF is hot dry upland forest; Warm Dry UF is warm dry upland forest; Warm Moist UF is warm moist upland forest; and Other includes non-forest and riparian forest PAGs. See Veg Table 2 for additional information about the plant associations that were aggregated to form these plant association groups.

Veg Table 3: Selected characteristics of potential vegetation groups (PVGs) for upland forests.

PVG	AREA (ACRES)	DISTURBANCES	FIRE REGIME	PATCH SIZE	ELEVATION (FEET)	SLOPE (PERCENT)	TYPICAL ASPECTS
Dry Upland Forest	16,719	Harvest Fire Insects	Low	433 (4-12809)	4508 (2971-6792)	15 (1-57)	Southwest West South
Moist Upland Forest	24,705	Harvest Fire Insects Diseases	Moderate	473 (1-7216)	5424 (2984-7278)	15 (0-52)	North Northeast Northwest Level
Cold Upland Forest	23,449	Wind Insects Fire Diseases	High	655 (1-7888)	6125 (4395-7632)	17 (1-58)	Northeast North Southwest West

Sources/Notes: Areas, elevations, slope percents, and aspects were summarized from the vegetation databases (see appendix 1). Patch size (acres) was calculated using the UTOOLS computer program (Ager 1997). Disturbances, which show the primary agents affecting upland-forest ecosystems, were based on the author's judgment. For patch sizes, elevations, and slope gradients, values are portrayed in the following format: average (minimum-maximum). Fire regime ratings (Agee 1993) have the following interpretation:

Low: 1-25 year fire return interval; 0-20 percent mortality of large trees; a non-lethal fire regime.

Moderate: 26-100 year fire return interval; 20-70 percent large-tree mortality; a mixed fire regime.

High: greater than 100 year fire return interval; greater than 70% large-tree mortality; a lethal fire regime.

ISSUES AND KEY QUESTIONS

Identification of issues and key questions is the second step in a six-step process for ecosystem analysis at the watershed scale. The purpose of step 2 is to focus the analysis on key elements of the ecosystem that are most relevant to the management questions and objectives, human values, or resource conditions within the watershed. Key questions are formulated from indicators commonly used to measure or interpret the key ecosystem elements (Regional Ecosystem Office 1995).

Over the last 10 to 20 years, Blue Mountains forests have experienced increasing levels of damage from wildfire, insects, and diseases. Scientific assessments and studies have documented the high damage levels and speculated about their underlying causes (Caraher and others 1992, Gast and others 1991, Lehmkuhl and others 1994, Powell 1994, Shlisky 1994). Partly in response to the scientific assessments, the Blue Mountains area attained national notoriety for its forest health problems (Boise Cascade Corporation 1992, Joseph and others 1991, Lucas 1992, McLean 1992, Petersen 1992, Phillips 1995).

A recent survey conducted by Oregon State University found that residents of the Blue Mountains perceive their forests to be unhealthy (Shindler and Reed 1996). In response to high levels of concern about forest health, both from the scientific community and the general public, the primary issue used in this analysis was **forest sustainability**.

Forest sustainability was assumed to be somewhat analogous to forest health – sustainable forest ecosystems maintain their complexity while providing for human needs (O'Laughlin and others 1994). This means that sustainable forests contain insects, diseases and other tree-killing agents, but not to the extent that they jeopardize the long-term integrity, resiliency and productive capacity of the forest.

The upland-forest vegetation analysis was designed to respond to these key questions:
1. How do current forest conditions compare to those that existed historically?
2. Are current forest conditions considered to be ecologically sustainable over the long term?
3. If current forest conditions are considered to be unsustainable, how could they be changed in order to create a more sustainable situation?
4. How have disturbance processes shaped existing forest conditions, and what role might we expect them to play in the future?

The key questions were addressed during an analysis of the ecosystem elements. Specific analysis indicators were selected for each ecosystem element and are shown in Veg Table 4. A variety of databases were used for the analysis and are described in appendix 1.

Veg Table 4: Key elements and analysis indicators for forest vegetation.

ECOSYSTEM ELEMENTS	ANALYSIS INDICATORS
Forest Components	Cover Types Forest Density Landscape Patches
Forest Structures	Size Classes Structural Stages Canopy Layers
Forest Processes	Disturbances Insect and Disease Risk Overstory Mortality

Sources/Notes: Ecosystem elements exert a strong influence on forest conditions in the analysis area. Analysis indicators are items commonly used to measure or interpret the ecosystem elements. Also, see Veg Table 1 for more information.

CURRENT CONDITIONS

Description of current conditions is the third step in a six-step process for ecosystem analysis at the watershed scale. The purpose of this step is to develop information (more detailed than was done for characterization in step 1) that is relevant to the issues and key questions identified in step 2. The current range, distribution, and condition of key ecosystem elements are documented in this step (Regional Ecosystem Office 1995).

Forest Cover Types. The *Characterization* section of this report described the potential natural vegetation of the Desolation analysis area, e.g., the plant composition that would be expected to occur if disturbances were prevented from interrupting plant succession. This *Current Conditions* section describes forest cover types as they actually *exist right now*, regardless of whether they represent the potential natural ("climax") community or a seral stage resulting from wildfire, timber harvest, windstorms, or another disturbance.

Veg Table 5 summarizes forest cover types for the Desolation ecosystem analysis area (the data is current as of 1997 and reflects post-fire conditions for the Bull and Summit wildfire areas). It shows that the predominant forest cover type is grand fir (38% of the analysis area), followed by lodgepole pine (21%), Douglas-fir (12%), and subalpine fir (8%). Forests dominated by whitebark pine, western larch or western juniper are rare, occupying less than three percent of the analysis area in aggregate.

Veg Table 5: Forest cover types of the Desolation ecosystem analysis area (1997).

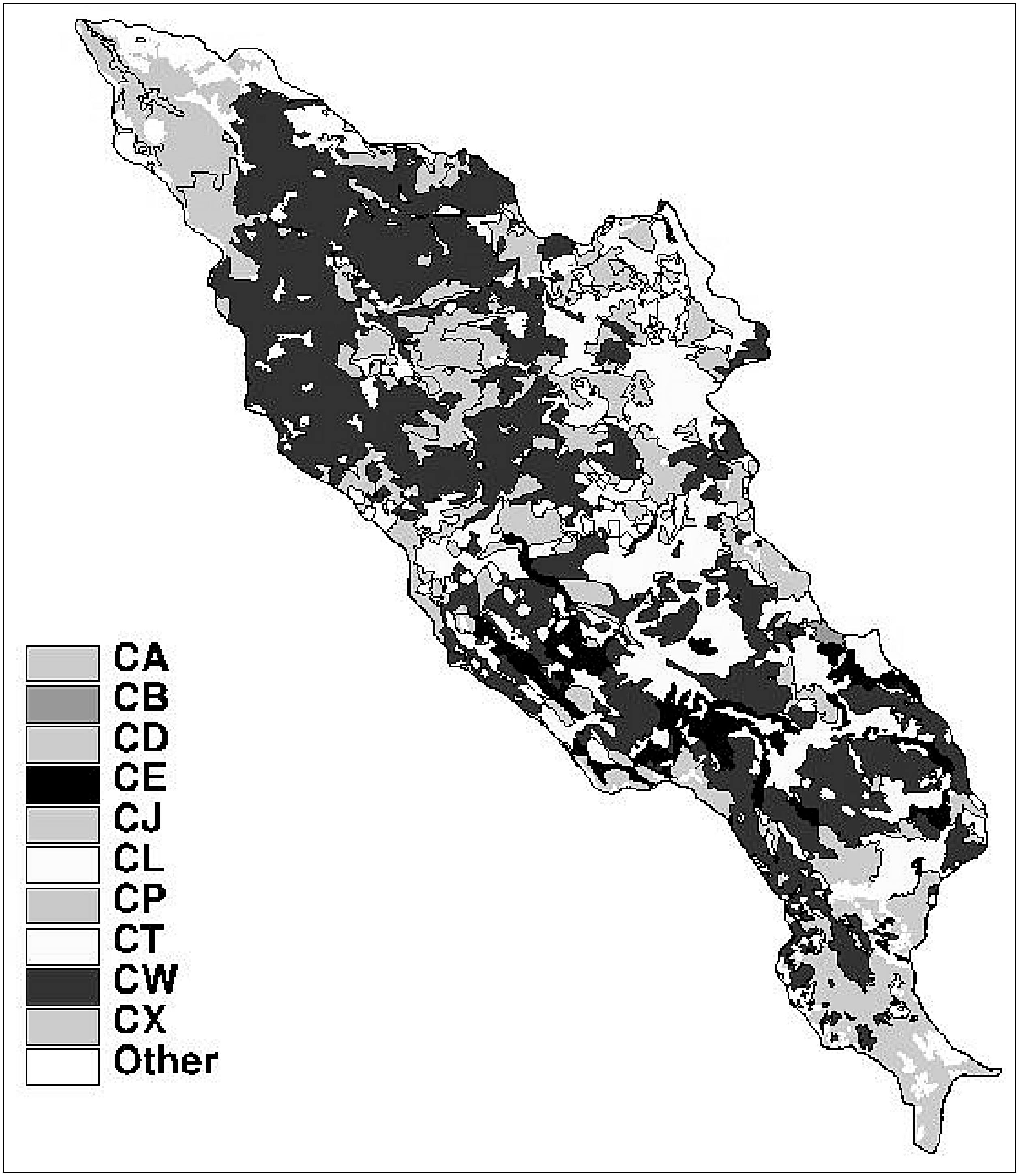
CODE	COVER TYPE DESCRIPTION	ACRES	PERCENT
CA	Forests with a predominance of subalpine fir trees	5,667	8
CB	Forests with a predominance of whitebark pine trees	116	<1
CD	Forests with a predominance of Douglas-fir trees	8,203	12
CE	Forests with a predominance of Engelmann spruce trees	2,916	4
CJ	Forests with a predominance of western juniper trees	21	<1
CL	Forests with a predominance of lodgepole pine trees	14,598	21
CP	Forests with a predominance of ponderosa pine trees	3,902	6
CT	Forests with a predominance of western larch trees	1,501	2
CW	Forests with a predominance of grand fir trees	26,459	38
CX	Forests with a mixed composition; less than 50% of one species	1,921	3
Other	Non-vegetated and non-forested cover types (see appendix 1)	4,232	6

Sources/Notes: Summarized from the 97veg database (see appendix 1). Acreage figures include private land located within the analysis area. Forest cover types are based on a plurality of stocking and are seldom pure – the grand fir type (CW), for example, has a predominance of grand fir trees (50% or more) but can also contain minor proportions of ponderosa pine, Douglas-fir and other species.

The Desolation watershed contains a relatively high proportion of forests dominated by Engelmann spruce and subalpine fir, which is unusual for the Umatilla National Forest. A large acreage of spruce-fir forest reflects the fact that about 20% of the Desolation area occurs above 6,000 feet, and those elevations typically support Engelmann spruce, subalpine fir, whitebark pine, and other species indicative of the subalpine vegetation zone (see Veg Fig. 1). Veg Figure 5 shows forest cover types as of 1997.

Landscape Patches. Ecologists refer to landscapes as large areas comprised of interconnected or repeated patterns of habitats or ecosystems (Forman 1997, Turner and Gardner 1991). The science of landscape ecology studies the biological functions and interactions of vegetation patterns across large areas. A single drainage basin may be considered a landscape if it is large enough to contain a variety of repeating patterns, but often a landscape will include more than one watershed. To be considered a “landscape” an area must contain a variety of components that interact over time and space to perform ecological functions and processes (Forman and Godron 1986, Turner 1998).

The most common element in a landscape is referred to as the “matrix.” The matrix in many landscapes of the Pacific Northwest would be a continuous forest cover of conifers. In some landscapes of the northern Blue Mountains, the matrix would consist of grassland. The most important quality of the matrix is that it is the most connected element in the landscape; there are no inherent barriers to movement from one portion of the matrix to another. Like the open space in a pinball machine, energy, animals, or objects can move freely within the matrix area (Diaz and Apostol 1992).



Veg Figure 5 – Forest cover types of the Desolation watershed (1997). Refer to Veg Table 5 for a description of the forest cover type codes.

An area within the landscape that differs from the matrix and is isolated from other similar areas is called a "patch." Like the pins in a pinball machine, patches lack the connectivity of the matrix. A patch may consist of a single opening in a forest, or it could be a remnant stand of mature forest in a landscape dominated by young trees or openings.

Landscape patterns affect how organisms use large land areas. Characteristics of landscape patterns, such as connectivity or the quality and quantity of edges between different landscape elements, can be measured and analyzed to reveal how well different plant and animal species may survive or move through an area. FRAGSTATS, UTOOLS and other computer programs have been developed to aid in the analysis of landscape characteristics (Ager 1997, McGarigal and Marks 1995).

Due to time and computer processing constraints, it was not possible to complete a robust analysis of landscape patterns for the Desolation watershed. However, a rudimentary analysis was completed using the UTOOLS program (Ager 1997), although no attempt was made to differentiate the matrix from patches or to analyze edge characteristics. This means that all landscape elements were treated as patches and analyzed accordingly. For the Desolation analysis, two categories of forest vegetation were included in the landscape analysis: cover types, which represent plant composition at a mid scale, and structural stages, which reflect how that composition is arranged from a vertical perspective.

Veg Table 6 summarizes patch characteristics for forest cover types and structural stages for the Desolation analysis area (the data is current as of 1997 and reflects post-fire conditions for the Bull and Summit wildfires). It shows that lodgepole pine has the most cover type patches in the Desolation landscape, followed by grand fir and then Douglas-fir. The largest patches are those comprised of grand fir, however, since they average 401 acres in size and range up to 15,475 acres. In terms of landscape characterization, grand fir forest would be considered the matrix from a plant composition standpoint.

Veg Table 6 shows that the *stem exclusion open canopy* structural stage has the most patches in the Desolation watershed (excluding the non-forest patches (NF) that were ignored for the structural stage analysis), followed by *stand initiation* and then *young forest multi strata*. The largest patches are those comprised of young, single-layer forest (*stand initiation*), since they average 476 acres in size and range up to 21,544 acres. In terms of landscape characterization, *stand initiation* would be considered the matrix from a structural stage viewpoint.

Forest Size Classes. Historically, forest size classes were defined using economically important criteria that emphasized product or utilization standards (small sawtimber and large sawtimber size classes, for example). Recently, size class definitions have been evolving to incorporate a biological approach based on tree size or physiological maturity. This Desolation analysis used size class definitions that reflect tree size (size was based on tree diameter rather than height).

Veg Table 7 summarizes forest size classes for the Desolation ecosystem analysis area (the data is current as of 1997 and reflects post-fire conditions for the Bull and Summit wildfire areas). It shows that the predominant overstory size class is small trees ranging from 9 to 15 inches in diameter (49% of the analysis area), followed by poles and small trees mixed (21%), and small trees ranging from 15 to 21 inches in diameter (10%). Forest overstories dominated by large or medium trees (those with diameters of 21 inches or more), or saplings (trees from 1 to 5 inches in diameter) are rare; each of those size classes occupies one percent or less of the Desolation area.

Forest Structural Stages. As a forest matures, it passes through successive and predictable stages with regard to its structural development. It usually begins as a young, single-layer stand, but does not stay in that stage forever and eventually occupies other stages as part of a normal maturation (successional) process (see Veg Table 8). In some classification systems, structural entities have been referred to as "classes" rather than "stages" because it is not always appropriate to assume a sequential progression from one stage to another (O'Hara and others 1996).

Veg Table 6: Patch analysis for the Desolation analysis area (1997 conditions).

	PATCH TYPE	NUMBER OF PATCHES	MINIMUM PATCH SIZE	AVERAGE PATCH SIZE	MAXIMUM PATCH SIZE
Cover Types	CA	28	1	192	3,119
	CB	1	21	21	21
	CD	63	3	130	997
	CE	15	21	194	1,015
	CJ	1	117	117	117
	CL	77	1	189	3,792
	CP	24	7	162	2,096
	CT	41	4	36	246
	CW	66	3	401	15,475
	CX	15	23	128	453
	Total	331			
Structural Stages	NF	148	1	29	674
	OFMS	14	1	56	252
	OFSS	22	2	36	129
	SECC	49	1	106	796
	SEOC	100	1	70	1,305
	SI	75	1	476	21,544
	UR	35	2	193	2,344
	YFMS	60	2	146	1,728
	Total	503			

Sources/Notes: Based on information contained in the 97veg database (see appendix 1), including private land located within the analysis area. Refer to Veg Table 5 for a description of the cover type codes; refer to Veg Table 9 for a description of the structural stage codes. Patches were calculated using the UTOOLS program (Ager 1997).

One of the first efforts to characterize vertical forest structure in the Interior Northwest was Thomas's (1979) description of structural development for forest stands in the Blue Mountains of northeastern Oregon and southeastern Washington. Those stages described the sequential development of stands following clearcutting and, barring additional disturbance, involved a six-step progression: seedlings and saplings, saplings and poles, poles, small sawtimber, large sawtimber, and old growth. Although Thomas's stages were designed to represent vertical stand structure, their quantification was actually based on tree size classes rather than canopy stratification (layering).

Since publication of Thomas's classification, other structural approaches have been developed. Recently, a series of four process-based stand development stages were published by Oliver and Larson (1996). Their stages were defined primarily by the availability of, and competition for, growing space, especially by single-cohort (even-aged) stands originating after a stand-replacement disturbance event.

Veg Table 7: Forest size classes of the Desolation ecosystem analysis area (1997).

CODE	SIZE CLASS DESCRIPTION	ACRES	PERCENT

1	Seedlings; trees less than 1 inch in diameter	1,559	2
2	Seedlings and saplings mixed	1,403	2
3	Saplings; trees from 1 to 4.9 inches in diameter	228	<1
4	Saplings and poles mixed	439	<1
5	Poles; trees from 5 to 8.9 inches in diameter	1,853	3
6	Poles and small trees mixed	14,625	21
77	Small trees; trees from 9 to 14.9 inches in diameter	34,317	49
88	Small trees; trees from 15 to 20.9 inches in diameter	7,035	10
8	Small trees and medium trees mixed	2,805	4
9	Medium trees from 21 to 31.9 inches in diameter	344	<1
10	Medium and large trees mixed	689	1
11	Large trees from 32 to 47.9 inches in diameter	7	<1
Other	Non-vegetated and non-forested cover types (see appendix 1)	4,232	6

Sources/Notes: Summarized from the 97veg database (see appendix 1). Acreage figures include private land located within the analysis area. Forest size classes are based on the predominant situation and are seldom pure – the pole size class (5), for example, has a predominance of pole-sized trees (50% or more) but may also contain minor proportions of other size classes. For multi-layered stands, this information pertains to the overstory layer (tallest stratum) only.

Although Oliver and Larson's (1996) classification works well for the geographical area in which it was developed (coniferous forests located west of the Cascade crest in Oregon and Washington), several forest structures of the Interior Northwest do not fit their four-stage approach. Consequently, their system was expanded to seven stages to include a greater variety of structural conditions and was recently used for the Interior Columbia Basin Ecosystem Management Project (O'Hara and others 1996).

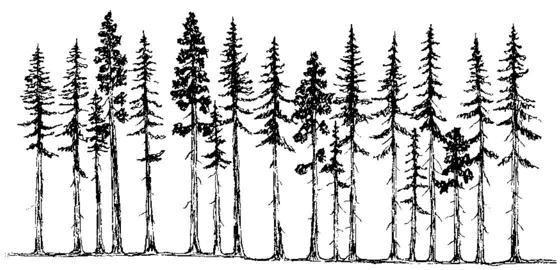
Veg Table 9 summarizes forest structural stages for the Desolation ecosystem analysis area (the data is current as of 1997 and reflects post-fire conditions for the Bull and Summit wildfire areas). It shows that the predominant structural stage is *stand initiation* (52% of the analysis area), followed by *young forest multi strata* (13%), *stem exclusion open canopy* (10%) and *understory reinitiation* (10%). Old forest structures (*old forest multi strata* or *old forest single stratum*) are rare, occupying one percent or less of the analysis area. Veg Figure 6 shows forest structural stages in the Desolation watershed as of 1997.

Forest Canopy Cover. Very little of the Desolation analysis area has been recently examined using field surveys such as stand examinations. For that reason, quantified data suitable for characterizing stand density (such as trees per acre or basal area per acre) was unavailable for this analysis effort. Consequently, canopy cover values resulting from interpretation of aerial photography were used for any analyses that required information about stand density.

Veg Table 10 summarizes existing canopy cover for forests of the Desolation ecosystem analysis area (the data is current as of 1997 and reflects post-fire conditions for the Bull and Summit wildfire areas). It shows that the predominant situation is low-density forest (≤40% canopy cover; 48% of the analysis area), followed by moderate density (41-55% cover; 23%) and high density (56-70%; 19%). Very high density forest (>70% canopy cover) is rare, occupying only three percent of the analysis area.

Veg Table 8: Description of forest structural stages.

Stand Initiation (SI). Following a stand replacing disturbance such as wildfire or timber harvest, growing space is occupied rapidly by vegetation that either survives the disturbance or colonizes the area. Survivors literally survive the disturbance above ground, or initiate growth from their underground roots or seeds on the site. Colonizers disperse seed into disturbed areas, the seed germinates, and the new seedlings establish and develop. A single canopy stratum of tree seedlings and saplings is present in this stage.



Stem Exclusion (SECC or **SEOC)**. In this stage of development, growing space is occupied by vigorous, fast-growing trees that compete strongly for available light and moisture. Because trees are tall and reduce light, understory plants (including smaller trees) are shaded and grow more slowly. Species that need sunlight usually die; shrubs and herbs may become dormant. In this stage, establishment of new trees is precluded by a lack of sunlight (**stem exclusion closed canopy**) or of moisture (**stem exclusion open canopy**).

Understory Reinitiation (UR). As a forest develops, new age classes of trees (cohorts) establish as the overstory trees die or are thinned and no longer fully occupy growing space. Regrowth of understory vegetation then occurs, and trees begin to develop in vertical layers (canopy stratification). This stage consists of a sparse to moderately dense overstory with small trees underneath.

Young Forest Multi Strata (YFMS). In this stage of forest development, three or more tree layers have become established as a result of continued canopy stratification. This stage consists of a broken overstory layer with a mix of sizes present (large trees are absent or scarce); it provides high vertical and horizontal diversity.

Old Forest (OFSS or **OFMS)**. This developmental stage is marked by many age classes and vegetation layers and usually contains large old trees. Decaying fallen trees may also be present that leave a discontinuous overstory canopy. The illustration shows a single-layer, old-forest stand of ponderosa pine that evolved from low-intensity underburning (**old forest single stratum**). On cool moist sites without recurring underburns, multi-layer stands with large trees in the uppermost stratum may be present (**old forest multi strata**).

Sources/Notes: Based on O'Hara and others (1996) and Oliver and Larson (1996).

Veg Table 9: Forest structural stages of the Desolation ecosystem analysis area (1997).

CODE	STRUCTURAL STAGE DESCRIPTION	ACRES	PERCENT

OFMS	Old Forest Multi Strata structural stage	781	1
OFSS	Old Forest Single Stratum structural stage	800	1
SECC	Stem Exclusion Closed Canopy structural stage	5,195	7
SEOC	Stem Exclusion Open Canopy structural stage	7,021	10
SI	Stand Initiation structural stage	35,944	52
UR	Understory Reinitiation structural stage	6,761	10
YFMS	Young Forest Multi Strata structural stage	8,802	13
Other	Non-vegetated and non-forested cover types (see appendix 1)	4,232	6

Sources/Notes: Summarized from the 97veg database (see appendix 1). Acreage figures include private land located within the analysis area. Veg Table 8 describes the forest structural stages.

Veg Table 10: Forest canopy cover classes of the Desolation ecosystem analysis area (1997).

CODE	CANOPY COVER DESCRIPTION	ACRES	PERCENT
≤40	Live canopy (crown) cover of trees is 40 percent or less	33,668	48
41-55	Live canopy cover of trees is between 41 and 55 percent	16,190	23
56-70	Live canopy cover of trees is between 56 and 70 percent	13,142	19
>70	Live canopy cover of trees is greater than 70 percent	2,304	3
Other	Non-vegetated and non-forested cover types (see appendix 1)	4,232	6

Sources/Notes: Summarized from the 97veg database (see appendix 1). Acreage figures include private land located within the analysis area.

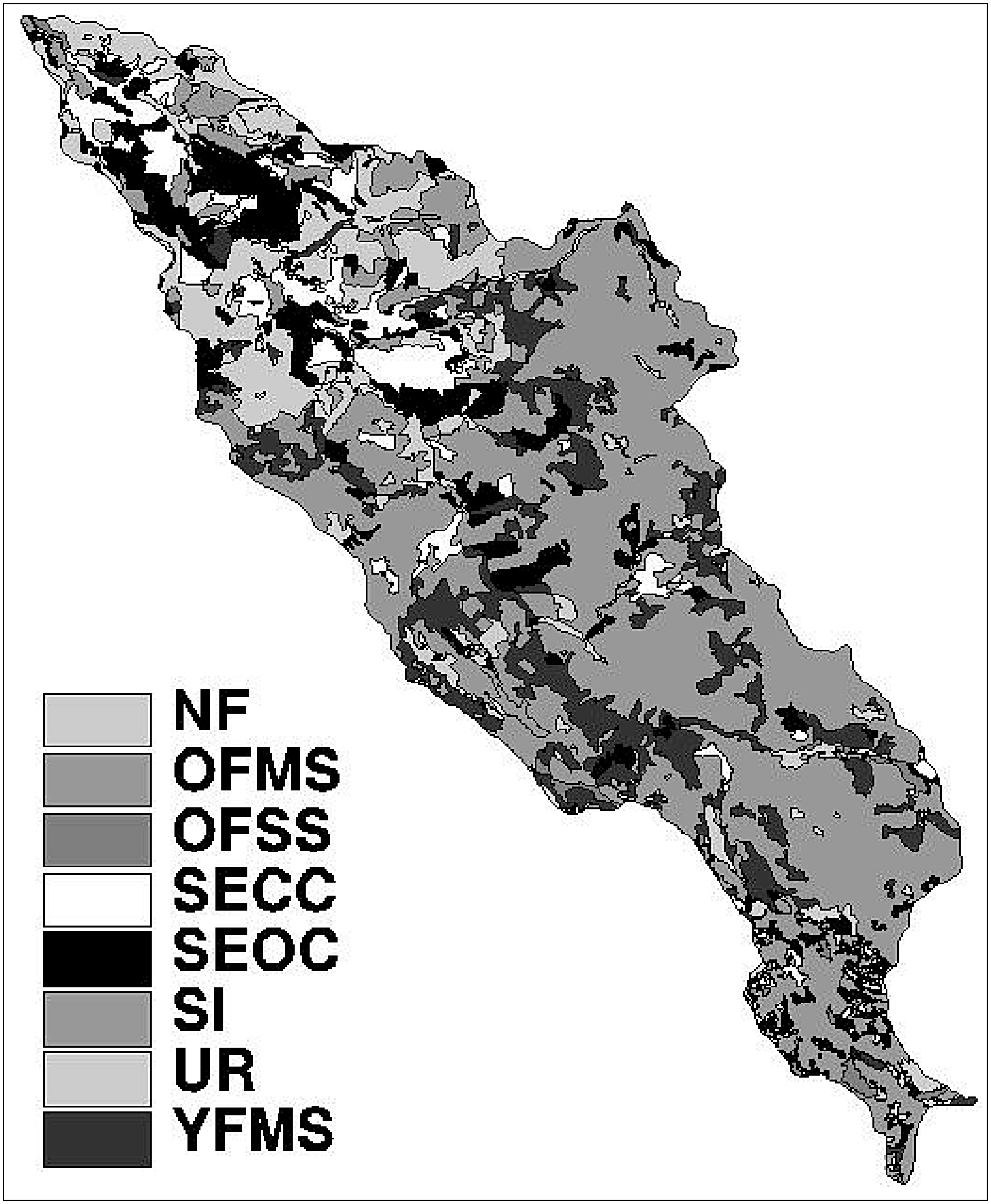
Forest Canopy Layers. The vertical arrangement of tree canopy can affect management objectives in several ways. For example, multi-layered stands with "old-growth" characteristics (e.g., a predominance of grand fir trees, high canopy closure, and the absence of logging) are extensively used by pileated woodpeckers in the Blue Mountains (Bull and Holthausen 1993). Open, single-layered structures may have limited value for water quality, but high desirability for water yields (O'Hara and Oliver 1992).

Veg Table 11 summarizes existing forest canopy layers for the Desolation ecosystem analysis area (the data is current as of 1997 and reflects post-fire conditions for the Bull and Summit wildfire areas). It shows that the predominant situation is a two-layer stand structure (48% of the analysis area), followed by single-layer forest (19%) and a highly-complex layer structure (3 or more layers; 4%).

Veg Table 11: Forest canopy layers of the Desolation ecosystem analysis area (1997).

CODE	CANOPY LAYER DESCRIPTION	ACRES	PERCENT
1	Live canopy (crown) cover of trees occurs in l layer (stratum)	13,467	19
2	Live canopy cover of trees occurs in 2 layers or strata	49,194	71
3	Live canopy cover of trees occurs in 3 or more layers or strata	2,643	4
Other	Non-vegetated and non-forested cover types (see appendix 1)	4,232	6

Sources/Notes: Summarized from the 97veg database (see appendix 1). Acreage figures include private land located within the analysis area.



Veg Figure 6 – Forest structural stages of the Desolation watershed (1997). Refer to Veg Table 9 for a description of the structural stage codes.

Forest Disturbances. The last twenty years saw a period of rapid change for thousands of forested acres in the Desolation area. Some of that change was related to normal forest growth and maturation, but much of it resulted from disturbance processes. Substantial portions of the project area were affected by a mountain pine beetle *(Dendroctonus ponderosae)* outbreak in the late 1970s and early 1980s, western spruce budworm *(Choristoneura occidentalis)* outbreaks in 1944-1958 and 1980-1992, and outbreaks of Douglas-fir beetle *(Dendroctonus pseudotsugae)* and fir engraver *(Scolytus ventralis)* during the late 1980s and early 1990s (Gast and others 1991). A prolonged drought in the late 1980s and early 1990s exacerbated those problems by reducing tree vigor and lowering stand resistance to insect damage.

Veg Table 12 summarizes forest disturbances for the Desolation ecosystem analysis area (the data is current as of 1997 and reflects post-fire conditions for the Bull and Summit wildfire areas). It shows that the predominant disturbances have been associated with multiple-use activities such as timber harvest (Veg Figure 7) – clearcuts (15% of the analysis area), partial cuts (16%, including sanitation/salvage), and thinnings (11%) could all be distinguished on recent aerial photography for the analysis area. Wildfire was also a common disturbance (13% of the analysis area).

Seral vegetation refers to the plant communities that establish after disturbance. In seral communities, the populations of some species are replaced by others as a result of plant succession. On many forest sites in the Desolation analysis area, a seral stage resulting from fire, timber harvest, or another disturbance agent is currently occupying the area. In some areas, the seral stage is a non-forest type such as grassland or shrubland; in others, it is lodgepole pine or another forest type that colonizes disturbed sites.

What impact did disturbances have on tree mortality in the analysis area? Veg Table 13 summarizes overstory mortality for the Desolation area (the data is current as of 1997 and reflects post-fire conditions for the Bull and Summit wildfire areas). It shows that disturbances have resulted in 25% of the analysis area supporting forests with moderate, high, or very high overstory mortality. Sixty-nine percent of the analysis area has forests with low overstory mortality (10 or fewer dead trees per acre).

Although insects and diseases were not specifically noted as a disturbance agent in Veg Table 12, they have been important disturbance agents in the past (Veg Table 14). Often, the timber harvest program was designed to respond to insect or disease problems by removing dead or dying trees (sanitation/salvage harvests).

A computerized model was used to estimate current risk (susceptibility) for 14 insects and diseases present in the analysis area (Ager 1998). Risk ratings were calculated for both the 1939 and 1997 vegetation conditions, thereby facilitating a side-by-side comparison of risk trends. The results of that analysis are provided in Veg Table 15. When comparing high risk only, it shows that susceptibility to Douglas-fir beetle, Douglas-fir dwarf mistletoe, Indian paint fungus, ponderosa pine dwarf mistletoe, Schweinitzii root and butt rot, western spruce budworm, and western larch dwarf mistletoe have all increased between 1939 and 1997.

Veg Table 15 shows that high susceptibility to fir engraver, mountain pine beetle, and mixed-conifer root diseases (laminated root rot, annosus root disease, and armillaria root disease) decreased between 1939 and 1997. It is interesting that Douglas-fir tussock moth susceptibility increased substantially between 1939 and 1997. Each spring, pheromone traps are placed in mixed-conifer stands throughout the Umatilla National Forest as an early-warning system for Douglas-fir tussock moth. Some traps had very high moth counts when they were collected in the fall of 1998, indicating that a tussock-moth outbreak could be imminent for some portions of the Forest.

Veg Table 12: Forest disturbances of the Desolation ecosystem analysis area (1997).

CODE	DISTURBANCE DESCRIPTION	ACRES	PERCENT
CC	Recent clearcut timber harvest	1,943	3
CR	Old clearcut, now regenerated	8,256	12
FI	Evidence of recent fire	8,850	13
PC	Recent partial cutting timber harvest (selection, seed-tree, etc.)	2,283	3
PR	Old partial cut, now regenerated	8,187	12
SS	Evidence of sanitation/salvage timber harvest	848	1
TH	Evidence of a thinning silvicultural treatment	7,442	11
Blank	No discernable evidence of disturbance (on air photos)	27,495	40
Other	Non-vegetated and non-forested cover types (see appendix 1)	4,232	6

Sources/Notes: Summarized from the 97veg database (see appendix 1). Acreage figures include private land located within the analysis area.

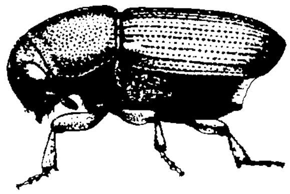
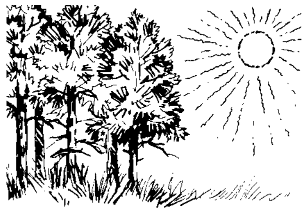
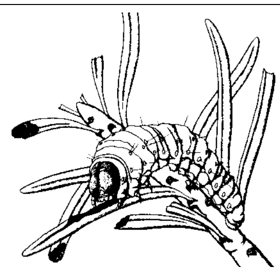
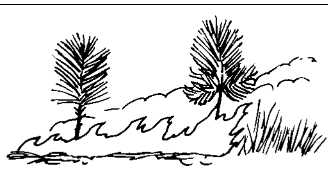
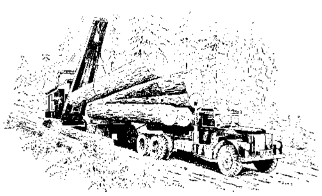
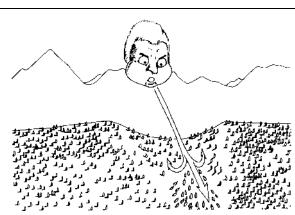
Veg Figure 7 – Multiple use management in Desolation watershed, 1960.

Veg Table 13: Forest overstory mortality of the Desolation ecosystem analysis area (1997).

CODE	OVERSTORY MORTALITY DESCRIPTION	ACRES	PERCENT
L	Low overstory mortality; 10 or fewer dead trees per acre	47,653	69
M	Moderate overstory mortality; 11-20 dead trees per acre	12,356	18
H	High overstory mortality; 21-60 dead trees per acre	2,315	3
V	Very high overstory mortality; greater than 60 dead trees/acre	2,980	4
Other	Non-vegetated and non-forested cover types (see appendix 1)	4,232	6

Sources/Notes: Summarized from the 97veg database (see appendix 1). Acreage figures include private land located within the analysis area.

Veg Table 14: Selected disturbance agents for the Desolation analysis area.

DISTURBANCE AGENT	DESCRIPTION
	**Bark Beetles**. Douglas-fir beetle and fir engraver are the main bark beetles affecting mid-elevation mixed-conifer forests in the analysis area. Their populations were highest in the late 1980s and early 1990s. Mountain pine beetle has affected both ponderosa and lodgepole pines, with large outbreaks first appearing in the mid 1940s (Buckhorn 1948) and then again in the 1970s.
	**Drought**. Droughts are cyclic events of varying magnitude. The last drought was assumed to be 1985–1992, although reduced precipitation was not universal throughout the Blue Mountains. Subalpine firs died at high rates during the drought, and are continuing to die at an accelerated pace throughout the central and northern Blue Mountains (although more causes than just drought may be responsible for the mortality).
	**Diseases and Pathogens**. Root diseases tend to be localized, but can cause significant tree mortality in affected areas. Armillaria root disease is found in mixed-conifer stands, whereas Annosus root disease is associated with areas that have been selectively cut in the past, especially if fir stumps were created by the harvest. Dwarf mistletoes, a tree parasite, affect ponderosa pine, lodgepole pine, western larch, and Douglas-fir in the Desolation watershed.
	**Defoliating Insects**. The analysis area has experienced 2 spruce budworm outbreaks over the last 50 years: one in 1944–1958, and another from 1980–1992. In the first outbreak, the entire analysis area was defoliated to some degree by 1949; portions of it were sprayed with DDT in 1950, 1953 and 1958 (Dolph 1980). In the second outbreak, defoliation peaked by the late 1980s (Sheehan 1996). Douglas-fir tussock moth has periodically defoliated mixed conifer stands in the analysis area.
	**Wildfires**. A very large fire occurred in the analysis area about 1893; portions of the area also burned in 1910, a "bad" fire year throughout the Interior West. More recent fires included Junkens (100 acres), Jumpoff (2,000 acres), Lost Lake (3,200 acres), Saddle Camp (100 acres) and South Fork (350 acres), all in 1986; and the Summit and Bull fires of late summer and fall in 1996.
	**Timber Harvest**. Timber harvesting and other management practices designed to meet some of the needs of a human society have occurred in the lower and middle portions of the analysis area. Timber removals in the Blue Mountains began over a century ago, when small mills cut a few thousand board feet a day to meet the lumber demands of local farmers and settlers (Weidman 1936).
	**Windstorms**. Windstorms are common throughout the Blue Mountains and elsewhere in the Interior Columbia River Basin (Ferguson no date). The infamous 1962 Columbus Day windstorm, which caused damage throughout the Pacific Northwest, had little impact in the analysis area. Windstorms were often mentioned in historical accounts of the Blue Mountains (Smith and Weitknecht 1915).

Sources/Notes: Based on Gast and others (1991); annual, aerial insect detection surveys; and unpublished records available at the North Fork John Day Ranger District and the Umatilla National Forest Supervisor's Office.

Veg Table 15: Insect and disease risk ratings for Desolation watershed.

INSECT OR DISEASE	RISK RATING	1997 (ACRES)	1939 (ACRES)	CHANGE (ACRES)
Douglas-fir Beetle	High	27,812	10,296	17,516
	Moderate	1,505	18,494	-16,989
	Low	37,022	34,569	2,453
Douglas-fir Dwarf Mistletoe	High	15,727	9,030	6,697
	Moderate	7,088	17,733	-10,645
	Low	43,524	36,524	7,000
Fir Engraver	High	19,220	41,680	-22,460
	Moderate	1,100	317	783
	Low	46,019	21,362	24,657
Indian Paint Fungus	High	8,937	1,774	7,163
	Moderate	32,727	22,909	9,818
	Low	24,657	38,359	-13,684
Mountain Pine Beetle (Lodgepole Pine)	High	2,892	3,845	-953
	Moderate	1,736	16,232	-14,496
	Low	61,711	43,282	18,429
Mountain Pine Beetle (Ponderosa Pine)	High	736	532	204
	Moderate	691	1,302	-611
	Low	64,912	61,525	3,387
Ponderosa Pine Dwarf Mistletoe	High	7,811	3,679	4,132
	Moderate	4,400	3,718	682
	Low	54,128	55,645	-1,517
Mixed Conifer Root Diseases	High	28,614	30,980	-2,366
	Moderate	37,359	31,191	6,168
	Low	366	747	-381
Schweinitzii Root and Butt Rot	High	38,836	22,179	16,657
	Moderate	26,779	38,483	-11,704
	Low	724	2,380	-1,656
Spruce Beetle	High	0	0	0
	Moderate	0	0	0
	Low	56,499	61,370	-4,871
Western Spruce Budworm	High	49,206	40,569	8,637
	Moderate	12,768	17,988	-5,220
	Low	2,828	3,941	-1,113
Tomentosus Root and Butt Rot	High	3,109	2,387	722
	Moderate	143	546	-403
	Low	63,087	60,109	2,978
Douglas-fir Tussock Moth	High	0	0	0
	Moderate	52,176	20,218	31,958
	Low	14,163	43,141	-28,978
Western Larch Dwarf Mistletoe	High	16,226	7,996	8,230
	Moderate	14,005	15,971	-1,966
	Low	36,108	39,075	-2,967

Sources/Notes: From the UPEST risk calculator (Ager 1998). “Change” column uses 1939 as the base year.

REFERENCE CONDITIONS

Description of reference conditions is the fourth step in a six-step process for ecosystem analysis at the watershed scale. The purpose of step 4 is to explain how ecological conditions have changed over time as a result of human influence and disturbance processes. Reference conditions serve as a benchmark for later comparison with current conditions and with key management plan objectives (Regional Ecosystem Office 1995). Reference conditions help us understand what an ecosystem is capable of, how disturbance processes operate, and how ecosystems recover after a perturbation.

Forest Cover Types. Previous EAWS efforts used historical cover-type maps to characterize reference conditions (USDA Forest Service 1937). Historically, forest cover types were generally named for an economically important species (such as ponderosa pine) that might be present at a fairly low level of abundance, thus ignoring a more abundant but less valuable species. For that reason, aerial photography from the late 1930s and early 1940s was interpreted to derive unbiased information about historical cover types for the Desolation watershed.

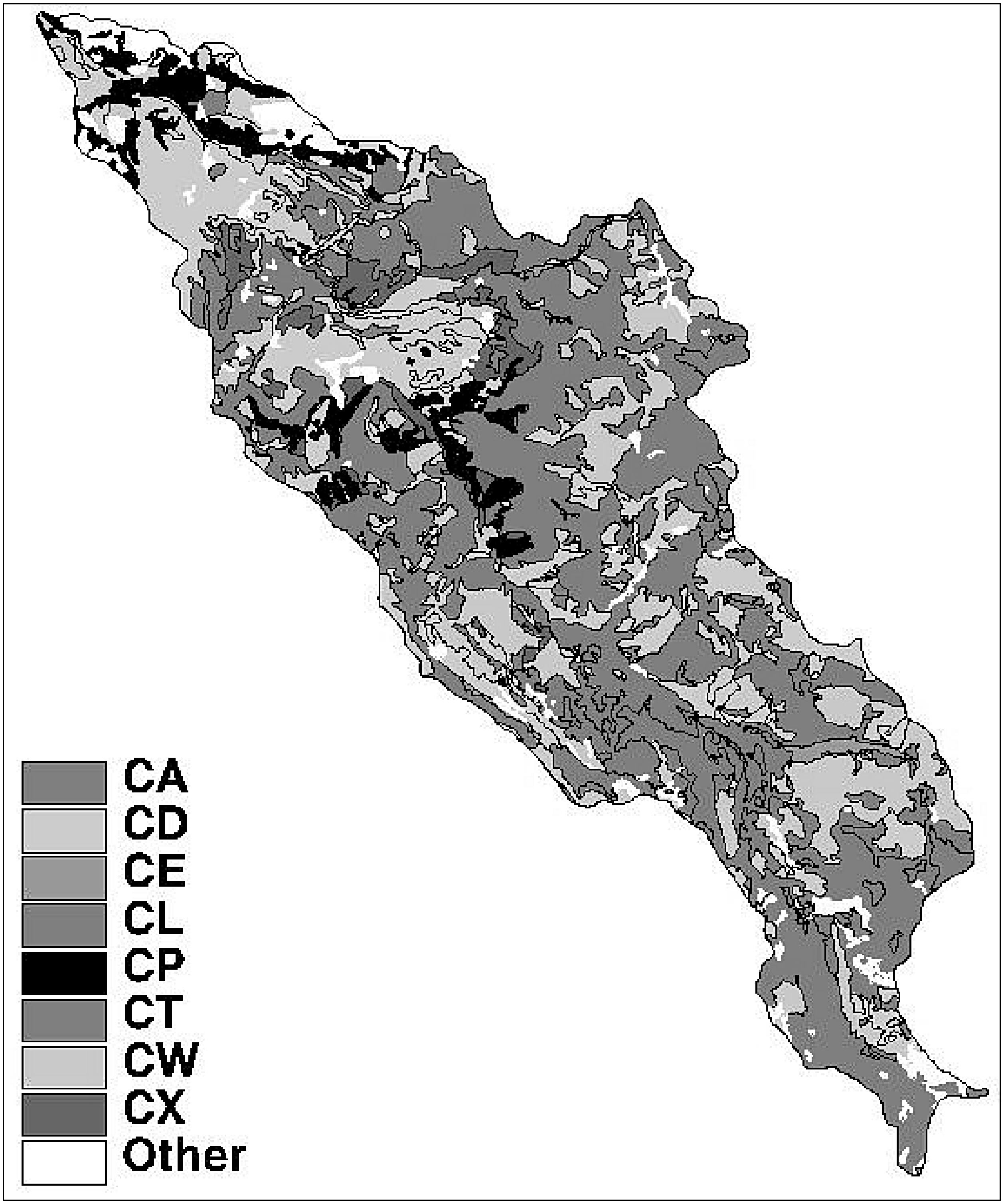
Veg Table 16 summarizes historical forest cover types for the Desolation ecosystem analysis area. It shows that the predominant forest cover type in 1939 was lodgepole pine (37% of the analysis area), followed by Douglas-fir (19%), grand fir (17%) and subalpine fir (11%). Forests dominated by whitebark pine or western juniper were apparently less common in 1939 than in 1997, since neither forest type was identified on the historical aerial photography. Veg Figure 8 shows forest cover types as of 1939.

Veg Table 16: Forest cover types of the Desolation ecosystem analysis area (1939).

CODE	COVER TYPE DESCRIPTION	ACRES	PERCENT
CA	Forests with a predominance of subalpine fir trees	8,003	11
CB	Forests with a predominance of whitebark pine trees	0	0
CD	Forests with a predominance of Douglas-fir trees	12,916	19
CE	Forests with a predominance of Engelmann spruce trees	485	1
CJ	Forests with a predominance of western juniper trees	0	0
CL	Forests with a predominance of lodgepole pine trees	25,624	37
CP	Forests with a predominance of ponderosa pine trees	3,620	5
CT	Forests with a predominance of western larch trees	1,509	2
CW	Forests with a predominance of grand fir trees	12,021	17
CX	Forests with a mixed composition; less than 50% of one species	2,391	3
Other	Non-vegetated and non-forested cover types (see appendix 1)	3,084	4

Sources/Notes: Summarized from the 39veg database (see appendix 1). Acreage figures include private land located within the analysis area. Forest cover types are based on a plurality of stocking and are seldom pure – the grand fir type (CW), for example, has a predominance of grand fir trees (50% or more) but also contains minor proportions of ponderosa pine, Douglas-fir and other species.

Analysis of lake sediments from Lost Lake, which is located in the upper (southeastern) portion of the Desolation watershed, showed that forest composition has been remarkably stable. Fossil and pollen evidence showed that lodgepole pine, western larch, Douglas-fir, grand fir, subalpine fir, and Engelmann spruce were common conifers after the Mount Mazama volcano erupted about 7,600 years ago. White pines, however, were not common in the fossil/pollen record. About 4,000 years ago, a moist climatic regime apparently prevailed and lodgepole pine, spruce, and firs were abundant. Dwarf mistletoe pollen was also present in the Lost Lake sediments; dwarf mistletoe was probably parasitizing lodgepole pines (Mehringer 1997).



Veg Figure 8 – Forest cover types of the Desolation watershed (1939). Refer to Veg Table 16 for a description of the cover type codes.

Landscape Patches. Veg Table 17 summarizes patch characteristics for historical cover types and structural stages for the Desolation analysis area. It shows that Douglas-fir had the most cover type patches in the Desolation landscape, followed by grand fir and then lodgepole pine. The largest patches were those comprised of lodgepole pine, however, since they averaged 434 acres in size and ranged up to 18,126 acres. In terms of landscape characterization, lodgepole pine forest would be considered the matrix from a plant composition standpoint.

Veg Table 17 shows that the *stand initiation* structural stage had the most patches in the Desolation watershed in 1939 (excluding the non-forest patches (NF) that were ignored for the structural stage analysis), followed by *old forest single stratum* and then *young forest multi strata*. The largest patches were those comprised of old forest (*old forest multi strata* and *old forest single stratum*), since they averaged 214-223 acres in size and ranged up to 4,840-6,271 acres. In terms of landscape characterization, *old forest* would be considered the matrix from a structural stage viewpoint.

Veg Table 17: Patch analysis for the Desolation analysis area (1939 conditions).

	PATCH TYPE	NUMBER OF PATCHES	MINIMUM PATCH SIZE	AVERAGE PATCH SIZE	MAXIMUM PATCH SIZE
Cover Types	CA	23	1	348	6,400
	CB	0	0	0	0
	CD	85	3	152	3,087
	CE	10	3	48	273
	CJ	0	0	0	0
	CL	59	1	434	18,126
	CP	35	4	103	1,421
	CT	22	5	68	502
	CW	80	6	150	2,027
	CX	20	12	119	471
	Total	334			
Structural Stages	NF	85	1	36	589
	OFMS	72	9	214	6,271
	OFSS	85	3	223	4,840
	SECC	69	1	183	2,815
	SEOC	3	19	24	31
	SI	117	1	63	838
	UR	12	11	98	423
	YFMS	73	1	149	2,009
	Total	516			

Sources/Notes: Based on information contained in the 39veg database (see appendix 1), including private land located within the analysis area. Refer to Veg Table 16 for a description of the cover type codes; refer to Veg Table 19 for a description of the structural stage codes. Patches were calculated using the UTOOLS program (Ager 1997).

Forest Size Classes. Veg Table 18 summarizes historical forest size classes for the Desolation ecosystem analysis area. It shows that the predominant overstory size class in 1939 was a mixture of small and medium trees ranging from 9 to 32 inches in diameter (50% of the analysis area), followed by medium trees (21 to 32 inches DBH; 20%) and then small trees ranging from 9 to 21 inches in diameter (15%). Forest overstories dominated by seedlings (trees less than 1 inch DBH), saplings (trees from 1 to 5 inches in diameter) or poles (5 to 9 inches in diameter) were rare, occupying less than eight percent of the analysis area in aggregate.

Veg Table 18: Forest size classes of the Desolation ecosystem analysis area (1939).

CODE	SIZE CLASS DESCRIPTION	ACRES	PERCENT
1	Seedlings; trees less than 1 inch in diameter	0	0
2	Seedlings and saplings mixed	30	<1
3	Saplings; trees from 1 to 4.9 inches in diameter	1,722	2
4	Saplings and poles mixed	1,746	2
5	Poles; trees from 5 to 8.9 inches in diameter	2,272	3
6	Poles and small trees mixed	1,356	2
77	Small trees; trees from 9 to 14.9 inches in diameter	5,355	8
88	Small trees; trees from 15 to 20.9 inches in diameter	4,897	7
8	Small trees and medium trees mixed	35,029	50
9	Medium trees from 21 to 31.9 inches in diameter	13,856	20
10	Medium and large trees mixed	307	<1
11	Large trees from 32 to 47.9 inches in diameter	0	0
Other	Non-vegetated and non-forested cover types (see appendix 1)	3,085	4

Sources/Notes: Summarized from the 39veg database (see appendix 1). Acreage figures include private land located within the analysis area. Forest size classes are based on the predominant situation and are seldom pure – the pole size class (5), for example, has a predominance of pole-sized trees (50% or more) but may also contain minor proportions of other size classes. For multi-layered stands, this information pertains to the overstory layer (tallest stratum) only.

Forest Structural Stages. Veg Table 19 summarizes historical forest structural stages for the Desolation watershed. It shows that the predominant structural stage in 1939 was old forest (49% of the analysis area consisted of either of the two old forest structural stages), followed by *stem exclusion closed canopy* (18%), *young forest multi strata* (16%) and then *stand initiation* (16%). The *understory reinitiation* and *stem exclusion open canopy* structural stages were rare, occupying two percent or less of the area. Veg Figure 9 shows forest structural stages for the Desolation watershed as of 1939.

Forest Canopy Cover. Veg Table 20 summarizes historical canopy cover classes for forests of the Desolation watershed. It shows that the predominant situation in 1939 was very high-density forest (>70% canopy cover; 59% of the analysis area), followed by high density (56-70% cover; 23%) and then low-density (≤40% cover; 8%). Moderate-density forest (41-55% canopy cover) was relatively uncommon in 1939, occupying only six percent of the analysis area.

Veg Table 19: Forest structural stages of the Desolation ecosystem analysis area (1939).

CODE	STRUCTURAL STAGE DESCRIPTION	ACRES	PERCENT
OFMS	Old Forest Multi Strata structural stage	15,390	22
OFSS	Old Forest Single Stratum structural stage	18,946	27

SECC	Stem Exclusion Closed Canopy structural stage	12,641	18
SEOC	Stem Exclusion Open Canopy structural stage	72	<1
SI	Stand Initiation structural stage	7,427	11
UR	Understory Reinitiation structural stage	1,184	2
YFMS	Young Forest Multi Strata structural stage	10,909	16
Other	Non-vegetated and non-forested cover types (see appendix 1)	3,085	4

Sources/Notes: Summarized from the 39veg database (see appendix 1). Acreage figures include private land located within the analysis area. See Veg Table 8 for information about structural stages.

Veg Table 20: Forest canopy cover classes of the Desolation ecosystem analysis area (1939).

CODE	CANOPY COVER DESCRIPTION	ACRES	PERCENT
≤40	Live canopy (crown) cover of trees is 40 percent or less	5,284	8
41-55	Live canopy cover of trees is between 41 and 55 percent	4,108	6
56-70	Live canopy cover of trees is between 56 and 70 percent	16,329	23
>70	Live canopy cover of trees is greater than 70 percent	40,848	59
Other	Non-vegetated and non-forested cover types (see appendix 1)	3,085	4

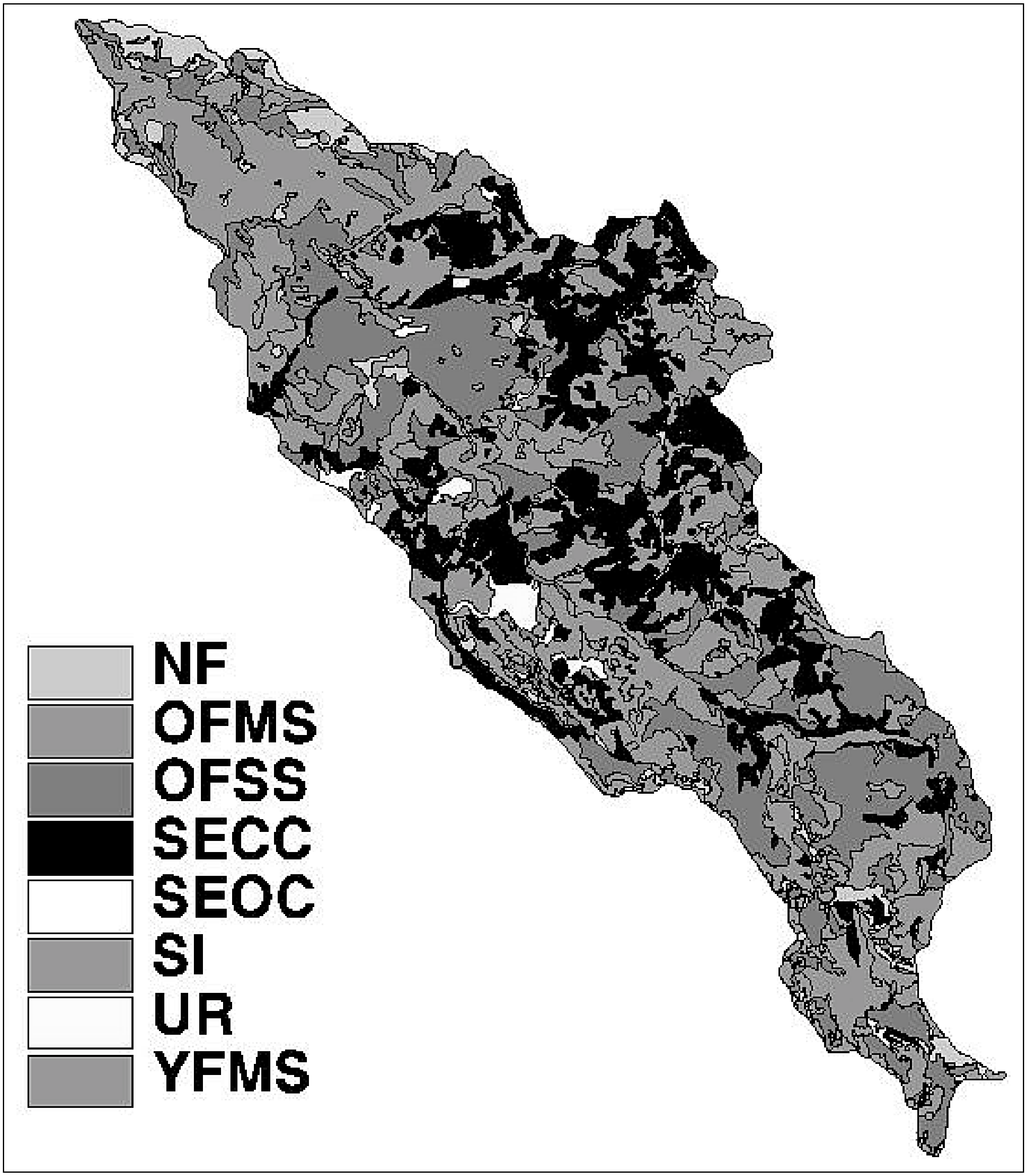
Sources/Notes: Summarized from the 39veg database (see appendix 1). Acreage figures include private land located within the analysis area.

Forest Canopy Layers. Veg Table 21 summarizes historical forest canopy layers for the Desolation watershed. It shows that the predominant situation in 1939 was a two-layer stand structure (64% of the analysis area), followed by single-layer forest (25%). A highly-complex layer structure (3 or more canopy layers) was relatively uncommon, occupying only six percent of the analysis area.

Veg Table 21: Forest canopy layers of the Desolation ecosystem analysis area (1939).

CODE	CANOPY LAYER DESCRIPTION	ACRES	PERCENT
1	Live canopy (crown) cover of trees occurs in l layer (stratum)	17,531	25
2	Live canopy cover of trees occurs in 2 layers or strata	44,830	64
3	Live canopy cover of trees occurs in 3 or more layers or strata	4,208	6
Other	Non-vegetated and non-forested cover types (see appendix 1)	3,085	4

Sources/Notes: Summarized from the 39veg database (see appendix 1). Acreage figures include private land located within the analysis area.



Veg Figure 9 – Forest structural stages of the Desolation watershed (1939). Refer to Veg Table 19 for a description of the structural stage codes.

Forest Disturbances. Veg Table 22 summarizes historical forest disturbances for the Desolation watershed. It shows that the analysis area had little or no evidence of recent disturbance in 1939, or at least none that could be distinguished on the historical aerial photography. Although the effects of long-past wildfire was apparent in the landscape pattern of the watershed (the distribution and configuration of lodgepole pine patches, for instance), there was no recent disturbance other than a minor amount of timber harvest (<1% of the analysis area had been affected by partial cutting). Even though insects and diseases were not specifically noted, they were important disturbance agents historically (Veg Table 14).

Veg Table 22: Forest disturbances of the Desolation ecosystem analysis area (1939).

CODE	DISTURBANCE DESCRIPTION	ACRES	PERCENT
CC	Recent clearcut timber harvest	0	0
CR	Old clearcut, now regenerated	0	0
FI	Evidence of recent fire	0	0
PC	Recent partial cutting timber harvest (selection, seed-tree, etc.)	182	<1
PR	Old partial cut, now regenerated	0	0
SS	Evidence of sanitation/salvage timber harvest	0	0
TH	Evidence of a thinning silvicultural treatment	0	0
Blank	No discernable evidence of disturbance (on aerial photographs)	66,387	95
Other	Non-vegetated and non-forested cover types (see appendix 1)	3,085	4

Sources/Notes: Summarized from the 39veg database (see appendix 1). Acreage figures include private land located within the analysis area.

What impact did disturbances have on tree mortality in the Desolation watershed? Veg Table 23 summarizes overstory mortality for the Desolation area. Not unexpectedly, it shows that disturbances had little or no impact on forest conditions, as least when using overstory tree mortality as a criterion of impact. Ninety-six percent of the analysis area had forests with low overstory mortality (10 or fewer dead trees per acre) in 1936 – which includes all of the forested area since the remaining 4 percent of the Desolation watershed was not forested.

Veg Table 23: Forest overstory mortality of the Desolation ecosystem analysis area (1939).

CODE	OVERSTORY MORTALITY DESCRIPTION	ACRES	PERCENT
L	Low overstory mortality; 10 or fewer dead trees per acre	66,569	96
M	Moderate overstory mortality; 11-20 dead trees per acre	0	0
H	High overstory mortality; 21-60 dead trees per acre	0	0
V	Very high overstory mortality; greater than 60 dead trees/acre	0	0
Other	Non-vegetated and non-forested cover types (see appendix 1)	3,085	4

Sources/Notes: Summarized from the 39veg database (see appendix 1). Acreage figures include private land located within the analysis area.

SYNTHESIS AND INTERPRETATION

Synthesis and interpretation of information is the fifth step in a six-step process for ecosystem analysis at the watershed scale. The purpose of step 5 is to compare current (step 3) and reference (step 4) conditions for key ecosystem elements, to explain significant differences, similarities, or trends, and to examine their causes. The capability of the ecosystem to achieve key management plan objectives is also evaluated in this step (Regional Ecosystem Office 1995).

Forest Cover Types. Stands dominated by lodgepole pine were much more abundant in 1939 than in 1997 (see Veg Tables 5 and 16). The most likely reason for a reduction in the lodgepole pine cover type was a mountain pine beetle outbreak during the late 1970s and early 1980s that killed most of the mature lodgepole pine, not just in the Desolation analysis area but throughout the central Blue Mountains (Gast and others 1991). After bark beetles killed the overstory trees, the new stands were often dominated by shade-tolerant, late-seral species that had regenerated beneath the shade-intolerant, early-seral lodgepole pines. Since grand fir is a shade-tolerant, late-seral species, this scenario could help explain why the grand fir cover type doubled in area between 1939 and 1997.

Although a 43% reduction in the lodgepole pine cover type and a 120% increase in the grand fir cover type represents a substantial amount of change, it is probably within the historical range of variation for species composition. Fluctuations in cover types have always occurred in response to forest disturbances, and is occurring now in response to the Bull and Summit wildfires and other recent disturbance events. For example, one expected consequence of those wildfires in the Desolation watershed is a future reduction in the subalpine fir, Engelmann spruce and grand fir cover types, and an increase in the lodgepole pine, western larch, and subalpine grassland cover types.

A comparison of Veg Tables 5 and 16 would indicate that two new forest cover types became established sometime between 1939 and 1997 – western juniper (CJ) and whitebark pine (CB). Actually, it's possible that one of them (western juniper) did get established during that period, but likely that the other one (whitebark pine) was already present in 1939 and could not be distinguished, or was misidentified, on the historical aerial photography, which was small-scale (1:20,000) and of lower resolution than modern film.

Western juniper trees are not uncommon on hot dry sites at low elevations in the analysis area. Historically, juniper abundance and distribution was largely controlled by fire, since it has low fire resistance (Agee 1993) and seldom survives any but the lowest-intensity burns. One of the consequences of 90 years of fire suppression in the Inland West has been a substantial increase in western juniper, both on grassland sites and in dry ponderosa pine forests (Quigley and Arbelbide 1997). It is possible that the small amount of western juniper cover type identified in 1997 is a direct result of fire suppression.

It is also interesting that the acreage of non-forested cover types (grassland, shrubland, forbland/meadows, etc.) increased between 1939 and 1997 (see Veg Tables 5 and 16). The reasons for that change are many and varied – in some cases, the effect of timber harvest or wildfire resulted in areas with less than 10 percent canopy cover of trees, which caused them to be coded as a non-forest cover type. Eventually, those areas will support trees once again as plant succession progresses. In other instances, the better resolution and larger scale of the 1995-1997 aerial photography allowed more of the "patchy" non-forest vegetation to be delineated as separate polygons (typically ranging from 1 to 3 acres). That level of detail or refinement was seldom possible on the coarser photography used for the 1939 characterization.

Landscape Patches. In some respects, patch characteristics have changed substantially between 1939 and 1997. Lodgepole pine had a significantly larger mean patch size in 1939 (434 acres) than in 1997

(189 acres) (see Veg Tables 6 and 17). Subalpine fir, Douglas-fir, and western larch are other cover types whose mean patch size decreased between 1939 and 1997. Engelmann spruce, ponderosa pine, grand fir, and mixed conifer are the forest cover types whose mean patch size increased between 1939 and 1997. For structural stages, the OFMS, OFSS, SECC, and YFMS stages had a larger mean patch size in 1939 than in 1997. For the SEOC, SI, and UR stages, mean patch sizes in 1997 were greater than in 1939.

Fragmentation of primary natural forest has been a recent concern (Noss and Cooperrider 1994). When considering the Desolation watershed in its entirety, it appears that fragmentation did not occur between 1939 and 1997. In 1939, there were 334 cover type patches and 516 structural stage patches; by 1997, there were 331 cover type patches and 503 structural stage patches. Since there were fewer patches in 1997 than in 1939, it appears that patches became more connected and more contiguous between 1939 and 1997.

When examining individual patch types, however, it does appear that fragmentation may have occurred, at least for certain forest cover types or structural stages (see Veg Tables 6 and 17). A good example is the old forest structural stages – in 1939, their maximum patch sizes were 4,840 and 6,271 acres (for the *old forest single stratum* and the *old forest multi strata* stages, respectively); by 1997, their maximums had declined to only 129 and 252 acres, respectively.

Forest Size Classes. Stands comprised of large-diameter trees were more common in 1939 than in 1997 (see Veg Tables 7 and 18). In 1939, 85% of the analysis area had stands with trees in the small or medium size classes; by 1997, the percentage had declined to only 65% (based on size class 77 and greater). However, the distribution of size classes was more balanced in 1997 since there was a better representation of the small-tree classes (seedlings, saplings, and poles).

The primary reasons for size-class changes were that selective timber harvest removed many of the economically-valuable, large-diameter trees (Powell 1994); that certain bark beetles specifically seeked out and attacked large-diameter trees because the phloem of smaller trees is unsuitable habitat for their broods (Gast and others 1991); and that recent, stand-replacing wildfires initiated new stands that are now dominated by small, seedling-size trees.

Forest Structural Stages. Since structural stages represent different points in the development of a forest, they can serve as a valuable framework for assessing wildlife habitat (Thomas 1979). When analyzing current conditions with respect to structural stages, it is often helpful to put them in an historical context. A technique was recently developed that facilitates a comparison of current and reference conditions – the historical range of variation (HRV).

Historical range of variation for forest structural stages. HRV can serve as a framework for comparing reference and current conditions (Morgan and others 1994). Managers often consider HRV to be an indicator of ecological sustainability – historical conditions are believed to represent sustainable conditions, at least to whatever extent Nature emphasized sustainability. After identifying historical ranges for a particular variable, managers can then infer which ecological processes may have been important for creating and sustaining those conditions. HRV is especially valuable as a reference point or benchmark (Swanson and others 1994).

HRV was recently proposed as one alternative for assessing ecosystem health and integrity. Although "ecosystem health" may not be an appropriate term (Wicklum and Davies 1995), it is valuable for communication – people identify with the concept by drawing an analogy to human health. A key premise of HRV is that native species are adapted to, and have evolved with, the native disturbance regime of an area. For that reason, ecosystem elements occurring within their historical range are believed to represent diverse, resilient, productive, and healthy situations (Swanson and others 1994).

Although HRV can be applied to a wide variety of ecosystem elements, it was decided to use it with structural stages. Structural stages are inclusive – any particular point on a stand's developmental pathway can be assigned to a structural stage. They are also universal – every forest stand eventually passes through a series of structural stages, although not every stand passes through all of the stages or spends an equal amount of time in any particular stage. For those reasons – inclusiveness and universality – structural stages are an ideal framework for comparing current and reference conditions.

An HRV analysis was completed for the Desolation watershed. It was based on two primary factors – forest structural stages and potential natural vegetation (as represented by PVGs). Potential natural vegetation was important for explicitly recognizing that all forest stands will not occupy every structural stage, and that forests with differing ecological potential will not spend an equal amount of time in any particular structural stage.

Results of the HRV analysis are provided in Veg Table 24. It summarizes the current percentage of each structural stage, by PVG, for two groupings of subwatersheds in the Desolation analysis area. Results are also provided for the watershed in its entirety. Subwatershed groupings were developed because it was recommended that an HRV analysis be conducted on land areas of 15,000 to 35,000 acres (USDA Forest Service 1994).

The Desolation watershed has a pronounced elevational gradient spanning almost 5,000 feet (2,971 to 7,632 feet), resulting in a well-balanced mix of upland forest PVGs. Unfortunately, partitioning the watershed into two smaller groups essentially disrupted the good balance. For that reason, the HRV analysis pertaining to the whole watershed (the "Total" section in Veg Tables 24 and 25) is considered to be the most accurate, even though it pertains to an area that exceeds 35,000 acres.

Veg Table 24 also shows the historical range for each of the structural stages. It must be emphasized that the historical ranges vary by PVG, which demonstrates why potential natural vegetation is an integral component of an HRV analysis. The historical ranges were derived from a variety of sources that are described in the "Sources" section of the table.

When considering the entire Desolation watershed, the HRV analysis for current structural stages (Veg Table 24) shows that *old forest* structure is deficient for all PVGs. *Young forest multi strata* is also deficient for the dry forest PVG. The *stand initiation* structural stage exceeds the historical range, often by a considerable amount, for all three of the PVGs. *Stem exclusion* and *understory reinitiation* also exceed the historical range, but only for the dry forest PVG.

In the interest of consistency and also to provide a sensitivity analysis for the historical ranges, an HRV analysis was completed for the reference (1939) structural stages. Results of that analysis are provided in Veg Table 25. It shows that *old forest* structure exceeded the historical range, but only for the dry forest PVG. The *young forest multi strata* structural stage was deficient for the dry forest PVG. The percentage of all other stages occurred within their historical ranges.

If one assumes that the 1939 conditions represent an unmanaged or unmodified situation, at least with respect to anthropogenic changes other than fire suppression, then the reference condition HRV analysis (Veg Table 25) indicates that the historical ranges used in Veg Tables 24 and 25 are reasonably accurate. If that wasn't the case, then one would have expected more deviations in Veg Table 25 than actually occurred (current percentages above or below the historical ranges). Since few human-caused changes had affected forest conditions by the late 1930s, the apparent accuracy of the historical ranges would indicate that they adequately reflect the natural disturbance regime of the analysis area.

Veg Table 24: HRV analysis for structural stages; 1997 forest conditions.

GROUP	PVG		SI	SE	UR	YFMS	OF	ACRES
Lower	Cold UF	H%	5-20	5-35	1-25	10-40	5-40	
		C%	**74**	3	8	13	2	5,062
	Moist UF	H%	1-10	5-25	1-20	20-50	10-60	
		C%	**50**	10	**27**	13	0	10,185
	Dry UF	H%	5-15	5-30	1-10	5-25	5-70	
		C%	16	**60**	**22**	0	3	13,613
Upper	Cold UF	H%	5-20	5-35	1-25	10-40	5-40	
		C%	**75**	8	1	12	4	18,367
	Moist UF	H%	1-10	5-25	1-20	20-50	10-60	
		C%	**61**	3	3	32	2	14,733
	Dry UF	H%	5-15	5-30	1-10	5-25	5-70	
		C%	**65**	31	4	0	0	3,323
Total	Cold UF	H%	5-20	5-35	1-25	10-40	5-40	
		C%	**75**	7	2	12	4	23,429
	Moist UF	H%	1-10	5-25	1-20	20-50	10-60	
		C%	**56**	6	13	24	1	24,918
	Dry UF	H%	5-15	5-30	1-10	5-25	5-70	
		C%	**26**	**54**	**18**	0	2	16,936

Sources/Notes: Summarized from the 97veg database (see appendix 1). Current percentages include private land located within the analysis area. Historical percentages (H%) were derived from Hall (1993), Johnson (1993), and USDA Forest Service (1995a). Potential vegetation group (PVG) is described in Powell (1998) and in Veg Table 2. "Group" is a subwatershed grouping developed specifically for the HRV analyses; see appendix 1 for a description of the subwatersheds in each grouping. The "total" section of the table shows the HRV situation for the Desolation analysis area in its entirety. Structural stage codes are described in appendix 1, with these exceptions: SE is stem exclusion (SEOC and SECC combined); OF is old forest (OFMS and OFSS combined). Shaded cells indicate those instances where the current percentage (C%) is above the historical range for that structural stage. Cells enclosed in a box indicate those instances where the current percentage is below the historical range. Since an HRV analysis is somewhat imprecise, deviations (whether above or below the H% range) were only noted when the current percentage differed by 2 percent or more. Acreage figures (the "Acres" column) include private land located within the analysis area.

Veg Table 25: HRV analysis for structural stages; 1939 forest conditions.

GROUP	PVG		SI	SE	UR	YFMS	OF	ACRES
Lower	Cold UF	H%	5-20	5-35	1-25	10-40	5-40	

		C%	6	**46**	1	7	41	4,019
	Moist UF	H%	1-10	5-25	1-20	20-50	10-60	
		C%	7	10	3	21	59	10,064
	Dry UF	H%	5-15	5-30	1-10	5-25	5-70	
		C%	6	9	1	0	**85**	14,592
Upper	Cold UF	H%	5-20	5-35	1-25	10-40	5-40	
		C%	20	31	1	23	26	18,378
	Moist UF	H%	1-10	5-25	1-20	20-50	10-60	
		C%	9	18	4	26	43	15,742
	Dry UF	H%	5-15	5-30	1-10	5-25	5-70	
		C%	**17**	3	0	4	**77**	3,772
Total	Cold UF	H%	5-20	5-35	1-25	10-40	5-40	
		C%	17	33	1	20	28	22,397
	Moist UF	H%	1-10	5-25	1-20	20-50	10-60	
		C%	8	15	3	24	49	25,806
	Dry UF	H%	5-15	5-30	1-10	5-25	5-70	
		C%	8	7	1	1	**83**	18,364

Sources/Notes: Summarized from the 39veg database (see appendix 1). Current percentages include private land located within the analysis area. Historical percentages (H%) were derived from Hall (1993), Johnson (1993), and USDA Forest Service (1995a). Potential vegetation group (PVG) is described in Powell (1998) and in Veg Table 2. "Group" is a subwatershed grouping developed specifically for the HRV analyses; see appendix 1 for a description of the subwatersheds in each grouping. The "total" section of the table shows the HRV situation for the Desolation analysis area in its entirety. Structural stage codes are described in appendix 1, with these exceptions: SE is stem exclusion (SEOC and SECC combined); OF is old forest (OFMS and OFSS combined). Shaded cells indicate those instances where the current percentage (C%) is above the historical range for that structural stage. Cells enclosed in a box indicate those instances where the current percentage is below the historical range. Since an HRV analysis is somewhat imprecise, deviations (whether above or below the H% range) were only noted when the current percentage differed by 2 percent or more. Acreage figures (the "Acres" column) include private land located within the analysis area.

Forest Canopy Cover. High-density forest (canopy cover greater than 70%) was much more common in 1939 than in 1997 (see Veg Tables 10 and 20). Conversely, low-density forest (canopy cover of 40% or less) is much more abundant currently than it was historically. The primary reason for these changes is that forest disturbances have caused substantial reductions in stand density through time. In some instances, clearcutting, lethal wildfire, or another major disturbance killed an entire stand, with the newly-regenerated, post-disturbance forest often having a lower density (canopy cover) than the original one. In other cases, partial-cutting timber harvests, spruce budworm defoliation, or a similar disturbance killed some trees but not the entire stand, thereby reducing the stand density (canopy cover).

Analysis of stand density. Recently-developed stocking guidelines (Cochran and others 1994) were used to analyze stand density levels and infer whether they were ecologically sustainable. By using the stocking guidelines in conjunction with potential natural vegetation (PAGs) and information about the seral status of forest vegetation, it was possible to determine the acres that would be considered overstocked. The stand density analysis, which was used to help formulate treatment recommendations and opportunities, was completed using the following process.

a. Since canopy cover was the only data item that could serve as a surrogate for stand density, equations were used to convert the SDI information from Cochran and others (1994) into basal areas, and then from basal area into canopy cover (see the tables in appendix 2).

b. Moist sites are capable of supporting higher stand densities than dry sites, so potential natural vegetation (as represented by the PAGs) was used to stratify the watershed into classes with similar ecological capability to support tree stocking.

c. An analysis of stand density is species dependent, but it would be cumbersome to evaluate stocking for every tree species that could occur in each PAG. Therefore, it was decided to assign each of the forest cover types to a seral status (this strategy assumed that a cover type code reflects the predominant tree species for each forested polygon). Since the seral status of a tree species varies depending upon which PAG it occurs in (Hall and others 1995), the assignment of forest cover types to a seral-status category also varied by PAG (Veg Table 26).

d. It was then possible to compare the stand density (canopy cover) information from the vegetation databases with the stocking guidelines that had been converted to canopy cover values. A tree species was first selected to represent each seral-status category (early, mid, late) for each PAG, and the stocking guidelines for that species from appendix 2 were used to determine how many acres of each seral status/PAG combination would be considered overstocked (see Veg Table 27 for the 1997 results, and Veg Table 28 for the 1939 results).

Veg Table 26: Seral status of forest cover types by plant association group.

PLANT ASSOCIATION GROUP	SERAL STATUS EARLY	MID	LATE
Cold Dry Upland Forest	CB, CL, CT	CD, CX	CA, CE, CW
Cool Dry Upland Forest		CD	
Cool Moist Upland Forest	CL, CP, CT	CD, CX	CA, CE, CW
Hot Dry Upland Forest			CP
Warm Dry Upland Forest	CL, CP, CT	CX	CD, CW
Warm Moist Upland Forest	CP	CD	

Sources/Notes: The 39veg and 97veg databases were queried to determine which forest cover types were associated with each of the PAGs. The forest vegetation analyst then assigned each cover type to a seral status category, based on his knowledge of the ecological role that the predominant tree species in a cover type would fill in a particular PAG. The cover type/PAG relationships shown in this table were then used to assign a seral status code (ES, MS, or LS) to each forested polygon in both the 39veg and 97veg databases. Refer to Hall and others (1995) for a description of seral status. Note that these are not the only possible combinations of cover type and PAG because some cover types that exist elsewhere on the Forest were not present in the Desolation watershed. However, this table does include every combination that occurred in either of the Desolation databases.

Veg Table 27: Stand density analysis; 1997 forest conditions.

PAG	SS	TREE SPECIES	LMZ COVER	UMZ COVER	TOTAL AREA	OVER-STOCKED
					(Acres)	

Cold Dry Upland Forest	ES	LP	59	66	9,677	1,484
	MS	DF	72	78	2,426	0
	LS	SF	76	83	11,315	63
Cool Dry Upland Forest	MS	DF	72	78	11	0
Cool Moist Upland Forest	ES	LP	58	65	6,304	325
	MS	DF	74	80	4,052	0
	LS	SF	74	81	14,424	366
Hot Dry Upland Forest	LS	PP	26	33	690	308
Warm Dry Upland Forest	ES	PP	43	51	3,402	358
	LS	DF	68	75	12,844	0
Warm Moist Upland Forest	ES	PP	55	62	44	44
	MS	DF	68	75	94	0
TOTAL					65,283	2,948

Sources/Notes: Summarized from the 97veg database (see appendix 1). Acreage figures include private land located within the analysis area. For seral stage (SS), ES refers to early seral; MS refers to mid seral; LS refers to late seral (see Hall and others 1995). Tree species codes, lower management zone (LMZ) values, and upper management zone (UMZ) values are described in appendix 2. The LMZ and UMZ figures are canopy cover values and refer to a "management zone" in which stand densities are considered to be ecologically sustainable (Cochran and others 1994). The "total area" figure shows the acreage of each PVG/SS combination in the analysis area; the "overstocked" value is the acreage with a canopy cover value that exceeds the "UMZ cover" figure and would therefore be considered overstocked.

It is interesting that approximately 57% of the Desolation watershed would be considered overstocked in 1939, as compared to only 4.5% in 1997, and yet the historical overstocking was apparently not reflected in high levels of insect or disease damage (see Veg Tables 22 and 23). The high stocking levels, however, may have been a portent of widespread bark-beetle outbreaks that occurred across the southern Umatilla National Forest in the mid to late 1940s (Buckhorn 1948), and an intense spruce budworm outbreak that began in 1944 and continued until 1958 (Dolph 1980).

Forest Canopy Layers. Stands with two canopy layers were slightly more common in 1997 than in 1939 (see Veg Tables 11 and 21). Single-layer stands were more abundant in 1939 than in 1997, possibly reflecting the influence of a recurring disturbance process called natural underburning. Underburns, which were low-intensity wildfires occurring on a cycle of 8-20 years, resulted in a condition referred to as "park-like ponderosa pine" – large, widely-spaced trees growing above a dense undergrowth of tall grasses (Powell 1998a). Stands with three or more canopy layers have been relatively stable through time, occupying 4 percent of the watershed in 1997 and 6 percent in 1939.

Veg Table 28: Stand density analysis; 1939 forest conditions.

PAG	SS	TREE SPECIES	LMZ COVER	UMZ COVER	TOTAL AREA	OVER-STOCKED
					(Acres)	

Cold Dry Upland Forest	ES	LP	59	66	12,709	11,736
	MS	DF	72	78	2,357	216
	LS	SF	76	83	7,333	1,292
Cool Moist Upland Forest	ES	LP	58	65	11,129	10,565
	MS	DF	74	80	3,636	982
	LS	SF	74	81	11,042	2,556
Hot Dry Upland Forest	LS	PP	26	33	1,059	394
Warm Dry Upland Forest	ES	PP	43	51	5,855	5,242
	MS	DF	68	75	1,072	1,012
	LS	DF	68	75	10,376	3,075
TOTAL					66,568	37,070

Sources/Notes: Summarized from the 39veg database (see appendix 1). Acreage figures include private land located within the analysis area. For seral stage (SS), ES refers to early seral; MS refers to mid seral; LS refers to late seral (see Hall and others 1995). Tree species codes, lower management zone (LMZ) values, and upper management zone (UMZ) values are described in appendix 2. The LMZ and UMZ figures are canopy cover values and refer to a "management zone" in which stand densities are considered to be ecologically sustainable (Cochran and others 1994). The "total area" figure shows the acreage of each PVG/SS combination in the analysis area; the "overstocked" value is the acreage with a canopy cover value that exceeds the "UMZ cover" figure and would therefore be considered overstocked.

Forest Disturbances. The effects of forest disturbances were more apparent in 1997 than in 1939 (see Veg Tables 12 and 22). In particular, the effects of anthropogenic disturbances (primarily timber harvest) were more obvious in 1997 than in 1939. The impacts of recent wildfire were readily observed on the 1995-1997 aerial photography but not on the historical photographs. In fact, it is believed that the lack of obvious disturbance indicates that the late 1930s and early 1940s were a particularly quiescent period in the Desolation watershed, although significant changes were on the way in the form of bark-beetle and spruce budworm outbreaks that would begin in 1944 or 1945 (Buckhorn 1948).

Healthy forests can tolerate periodic disturbances and may even depend on them for renewal. Healthy forests maintain their integrity, resiliency and productive capacity. Forest integrity involves sustaining a wide range of ecological processes whereby plants, animals, microorganisms, soil, water and air are constantly interacting. These processes form soils, recycle nutrients, store carbon, clean water, and fulfill other functions essential to life. Significant changes in the extent or pattern of natural disturbances may be an indicator of impaired forest health. Forest health and sustainability are discussed next.

Assessment of Forest Sustainability. The health and sustainability of forest ecosystems has been a recent issue, not just in the United States but around the World (Heissenbuttel and others No date). As a result of that concern, a protocol was recently established for evaluating forest sustainability at a national or international scale, including a set of criteria and indicators (Montreal Process 1995). In an effort to develop an assessment protocol that could be applied at smaller scales, a landscape-level methodology was recently developed (Amaranthus 1997). It was based on four criteria originally proposed in 1994 (Kolb and others 1994). The four criteria, and an assessment of how the Desolation watershed rates with respect to each of them, are provided below.

1. **The physical environment, biotic resources, and trophic networks to support productive forests**. Over most of the Desolation watershed, the physical, biotic, and trophic networks are intact to support the forest ecosystem. There are some exceptions at the stand level, particularly in the lower or middle thirds of the drainage where there are highly-eroded or steep, raveling hillsides, and recent clearcuts that have not yet regenerated and are out of scale with respect to the natural disturbance regime. Based on this criterion, the forests of the Desolation watershed are probably in a sustainable condition.
2. **Resistance to catastrophic change and the ability to recover on the landscape level**. The major agents of "catastrophic" change include stand-replacing wildfire, defoliating insects, and bark-beetle outbreaks. The watershed has experienced two major budworm outbreaks in the last 50 years (1944-1958 and 1980-1992) but, in general, stands comprised of the late-seral, shade-tolerant species that served as a budworm food source are still largely intact. Although wildfires have recently been active in the drainage, they burned in a mosaic pattern and at a variety of burn intensities, which is what would have been expected for the natural disturbance regime on cold and moist forest sites. Natural rates of fire frequency indicate that much of the lower third of the analysis area has missed two to five fire cycles, but the effects on biomass accumulation and forest sustainability may have been minimal since those areas are generally in private ownership and have been intensively managed (e.g., timber harvest removed the biomass instead of fire). Based on the second criterion, the forests of the Desolation watershed are probably in a sustainable condition, although unsustainable stand densities or species compositions are sometimes present at the stand level.
3. **A functional equilibrium between supply and demand of essential resources.** In some areas dominated by overstocked stands, nutrient cycling and the availability of water and growing space is undoubtedly impaired. In specific areas that sustained high burn intensities, the wildfires may have contributed to future forest health problems because nitrogen, potassium, sulfur and other important nutrients were volatized (lost to the atmosphere) or oxidized. However, the fires burned with a variety of intensities and affected a relatively small percentage of the drainage (13%), so the impacts are not considered to be outside the historical range of variation for that disturbance process. Based on this criterion, the forests of the Desolation watershed are probably in a sustainable condition.
4. **A diversity of seral stages and stand structures that provide habitat for any native species and all essential ecosystem processes**. The Desolation watershed contains a diversity of seral stages and stand structures. Logging and recent wildfires, however, have resulted in an abundance of stands with smaller, younger trees and a simplification of stand structure from what apparently existed in the pre-settlement era. In particular, the representation of old forest structures in the landscape mosaic is substantially reduced from what existed historically. Patch sizes are also reduced from their historical levels for many vegetative elements. Based on this fourth criterion, the forests of the Desolation watershed are either not in a sustainable condition, or are only marginally sustainable. If field reconnaissance verifies that the structural stage information is correct, then thinnings, prescribed burning, fertilization or other management practices should be considered for restoration of old-forest conditions as quickly as possible.

RECOMMENDATIONS

Formulation of recommendations is the sixth step in a six-step process for ecosystem analysis at the watershed scale. The purpose of step six is to bring the results of the previous five steps to conclusion, focusing on management recommendations that are responsive to ecosystem processes identified by the analysis. Monitoring activities are also identified in this step. Data gaps and analysis limitations are documented at this point in the process (Regional Ecosystem Office 1995).

This section provides management recommendations that could facilitate either short-term recovery, or long-term restoration, of upland forest vegetation in the Desolation 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. *It must be emphasized that these recommendations pertain to upland forest sites only (not to Riparian Habitat Conservation Areas).*

Tree Salvage. 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" (Helms 1998). For the wildfire areas in the Desolation watershed, salvage 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). Veg Table 29 shows the management areas in which the Umatilla NF Forest Plan allows salvage cutting to occur.

Salvage logging after wildfire has been controversial. Some scientists advocate a passive, custodial approach to post-fire management, maintaining that removal of fire-killed trees makes an unfortunate situation even worse (Beschta and others 1995). Other scientists believe that active management (including salvage logging), in combination with natural processes, is appropriate for restoration of post-fire sustainability. Regardless of which philosophy is considered correct, it is generally accepted that limiting post-fire management to just a single approach (whether passive or active) is inappropriate because each situation is different and should be handled on a case-by-case basis (Everett 1995).

For the Desolation watershed, it may be appropriate to adopt an active management approach with respect to salvage logging of fire-killed trees in the Bull wildfire area. Tree stands in that area often experienced complete mortality as a result of the wildfire (Scott and Schmitt 1996). Even large-diameter western larches – the most fire resistant tree species on the Umatilla National Forest (Agee 1993) – were killed by the fire. Without using salvage logging to remove the heavy fuel loads created by the fire, it will not be possible to reestablish western larch because it requires an open, sunny environment in which to germinate and grow – conditions that are not present in the shade of a dense, dead stand.

Using salvage to remove fuel accumulations would reduce the risk of newly-established plantations being reburned in a subsequent wildfire. In 1986, a major wildfire episode affected the North Fork John Day Ranger District. One of the 14 areas that burned in 1986 was the Long Meadows fire (200 acres), which occurs in the Tower wildfire area just north of the junction of the 52 and 5507 roads. None of the Long Meadows fire was salvage logged, which means that dead trees (mostly lodgepole pines) had fallen over and were lying on and above the ground when the area reburned in 1996.

When the Tower wildfire burned through the 1986 Long Meadows fire, intense combustion of the accumulated fuels resulted in substantial on-site impacts. For example, most of the lodgepole pine seedlings (they averaged 3-4 feet in height) that had regenerated after the 1986 fire were not only killed during the reburn, but were consumed completely down to the ground line. Impacts from the reburn were certainly severe enough that artificially-regenerated plantations, even with seedlings planted at a relatively wide spacing, would not have fared any better than the naturally-regenerated seedlings, *assuming that the same fuel loading was present in both instances*.

Veg Table 29: Management direction summary for the Desolation analysis area.

Management Area Allocation	Salvage Permitted?	Suitable Lands?	Plant Using NFFV Funds?	Percent of Area
A3: Viewshed 1	Yes	Yes	Yes	<1
A4: Viewshed 2	Yes	Yes	Yes	4.5
A6: Developed Recreation	Yes	No	No♦	<1
A7: Wild and Scenic Rivers	Yes	Yes	Yes	<1
A8: Scenic Area	Yes	No	No♦	19.1
B1: Wilderness	No	No	No♦	1.1
C1: Dedicated Old Growth	Yes*	No	No♦	2.8
C2: Managed Old Growth	Yes	Yes	Yes	1.5
C3: Big Game Winter Range	Yes	Yes	Yes	5.6
C4: Wildlife Habitat	Yes	Yes	Yes	<1
C5: Riparian (Fish and Wildlife)	Yes	Yes	Yes	<1
C7: Special Fish Management Area	Yes	Yes	Yes	46.2
P: Private (non NF) Lands	N.A.	N.A.	N.A.	18.2
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 forest vegetation funds (NFFV); and the "percent of area" item shows the percentage of National Forest System lands in the analysis area allocated to the management emphasis. N.A. is not applicable.

* 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.

I recommend that salvage cutting be considered for approximately 1,000 acres in the Bull 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 (Veg fig. 3) 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 changes in species composition on warm dry sites.]
2. Consider salvage where timber volume, tree size, and species characteristics would generate sufficient revenue to fund tree planting and other restoration treatments. [This recommendation recognizes the fact that restoration treatments can be expensive, and that Congress may not fund all of it.]
3. Consider salvage for sites where the existing density of dead trees is great enough that a future reburn would probably destroy newly-established tree regeneration, such as the situation described previously (page 43) for the Long Meadows reburn in the Tower wildfire area.
4. 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 more than 50% of the preburn duff around the base of the tree was consumed by the fire.
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.

Even though many portions of the Bull fire were mapped as low burn intensity, they can still be expected to have high fire severity if the pre-fire forests were dominated by subalpine fir, Engelmann spruce, lodgepole pine, grand fir and other thin-barked species. Veg Table 30 shows the relationship between burn intensity and fire severity for all of the forest cover types that occur within the Desolation analysis area.

Veg Table 30: Tree mortality estimates, by fire intensity rating, for forest cover types.

	FIRE INTENSITY RATING		
FOREST COVER TYPE	**HIGH**	**MODERATE**	**LOW**
Douglas-fir (CD)	High Mortality	Moderate Mortality	Low Mortality
Engelmann Spruce (CE)	High Mortality	High Mortality	High/Moderate Mortality
Grand Fir (CW)	High Mortality	High Mortality	Moderate Mortality
Lodgepole Pine (CL)	High Mortality	High Mortality	High/Moderate Mortality
Mixed Conifer (CX)	High Mortality	High Mortality	Moderate Mortality
Ponderosa Pine (CP)	High Mortality	Moderate/Low Mortality	Low Mortality
Subalpine Fir (CA)	High Mortality	High Mortality	High/Moderate Mortality
Western Juniper (CJ)	High Mortality	High Mortality	Moderate Mortality
Western Larch (CT)	High Mortality	Moderate/Low Mortality	Low Mortality
Whitebark Pine (CB)	High Mortality	High Mortality	Moderate Mortality

Sources/Notes: Fire intensity refers to energy release rates; it is a physical descriptor of a fire. Tree mortality is based on fire severity, which refers to the ecological effects of a fire on the dominant organisms (Agee 1997). For the purposes of this table, the dominant organisms were assumed to be large trees. High tree mortality means that 70 percent or more of the large trees would be killed; moderate mortality – 20 to 70 percent; and low mortality – less than 20 percent.

Forest Regeneration. The Bull and Summit fires created conditions that are conducive to regeneration of early seral conifers. Unfortunately, the fires also killed many of the mature trees required for seed production. The probability of obtaining natural regeneration in the fire areas 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.

Forest recovery is expected to be slow in some portions of the Bull and Summit fires, especially for areas that experienced a moderate or high burn intensity and whose pre-fire composition was dominated by tree species with low fire resistance. 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 after the fire (Koch 1996a).

In the case of lodgepole pine, some natural regeneration will be produced by cones present in the canopy of dead stands, assuming of course that any canopy remained after the fire. In the areas that burned with a low or moderate intensity, most of the lodgepole pines were killed, even though some of their crowns persisted (the “red crown” condition) and served 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 (Koch 1996b), 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 Bull and Summit fire areas, we can expect adequate to overly-abundant lodgepole pine regeneration in the future.

Tree planting is an effective way to influence the future composition of a forest. *If forest health and resistance to insect defoliation 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* (Powell 1994).

Whenever possible, tree plantings should emphasize establishment of early-seral conifers on upland sites. Since lodgepole pine is expected to regenerate naturally on all but the highest intensity burns, it is recommended that upland plantings emphasize other early-seral species (western larch and ponderosa pine) to a greater degree than lodgepole pine. Tree planting recommendations (species mixes and densities) are provided in Veg Table 31.

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, 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 Veg Table 31 involve a mixture of species. Even if a mixture was not being planted, a mixed stand would eventually result after natural regeneration got established. A common misconception is that plantations are monocultures – “corn-row” forests devoid of floristic biodiversity. 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.

Veg Table 31: Planting recommendations for Desolation analysis area.

	Tree Density		**Species Composition of Planting Mix**							
PAG	**TPA**	**Spacing**	**PP**	**WL**	**LP**	**DF**	**WP**	**GF**	**ES**	**SF**
Cold Dry	222	14 feet		40%	NR	20%		NR	40%	NR
Lodgepole Sites – Cool♦	194	15 feet		30%	NR	30%		NR	40%	NR
Lodgepole Sites – 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%				
Hot Dry	151	17 feet	100%							

Sources/Notes: 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 appendix 2 for a description of the species codes used as column headings in the species composition section of this table (WP is western white pine).

NR = Natural Regeneration. It is expected that 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/CARU, 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 Desolation 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 PAG are considered to be dry.

The tree density recommendations in Veg Table 31 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 crown-class 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 (Oliver and Larson 1996).
- 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.

Competing Vegetation. One of the potential benefits of the Bull and Summit wildfires was that they 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.

Of particular concern is the potential for pinegrass, smooth brome, red top, Kentucky bluegrass, bracken fern, elk sedge, red fescue, snowbrush ceanothus and other competing vegetation to affect the survival of planted or naturally-regenerated tree seedlings. In particular, 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).

Stand Density Management. 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. 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 could also be used to shift a site's growth potential to fewer stems so that the large-diameter trees desired as wildlife habitat could be produced more quickly (Cochran and Barrett 1995).

Research conducted in the Blue Mountains of northeastern Oregon has consistently shown that substantial increases in individual tree growth will occur following a low thinning, a stocking-control treatment where small trees are removed to favor those in upper crown classes. This result was obtained in stands of western larch (Seidel 1987), ponderosa pine (Cochran and Barrett 1995) or lodgepole pine (Cochran and Dahms 1998). Research from central Oregon has shown a similar response for thinned stands of Douglas-fir, grand fir, western white pine or Engelmann spruce (Seidel and Cochran 1981).

Thinning treatments should address the overstocked areas shown in Veg Table 27 (approximately 3,000 acres). The tables in appendix 2 provide tree density recommendations by species and by plant association (plus an average for each PAG). They establish a "management zone" in which stand densities are presumed to be ecologically sustainable and resistant to insect and disease problems. In addition, understory thinnings in multi-cohort stands should be considered for warm dry sites that have 2 or more tree layers and a canopy cover of 40 percent or more, since they would be considered marginally overstocked and currently have a vertical structure that would inhibit reintroduction of landscape-scale fire.

Understory Thinnings in Multi-Cohort Stands. 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 mature ponderosa pines and western larches, this treatment is effective at ensuring their continued survival (Arno and others 1995).

"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 stand densities are reduced to more sustainable levels, thereby improving the vigor and resilience of pine and larch. It is recommended that understory removals be considered for warm dry sites supporting multi-storied, mixed-species stands with canopy cover of 40 percent or more (approximately 4,000 NFS acres).

Prescribed Burning. After completing salvage harvests, understory removals, thinnings and other treatments described in this section, managers should strongly consider implementing a prescribed burning program.

On the areas that have been planted with early-seral tree species, a prescribed burn could be completed once ponderosa pines and larches are 10 to 12 feet tall, 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 western pine beetle (Swezy and Agee 1991) and to Armillaria root disease (Filip and Yang-Erve 1997).

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). This means that forests of the interior West may have depended more on nitrogen-fixing plants and low-intensity fires to recycle soil nutrients than on microbial decomposition of woody debris (Veg Figure 10).

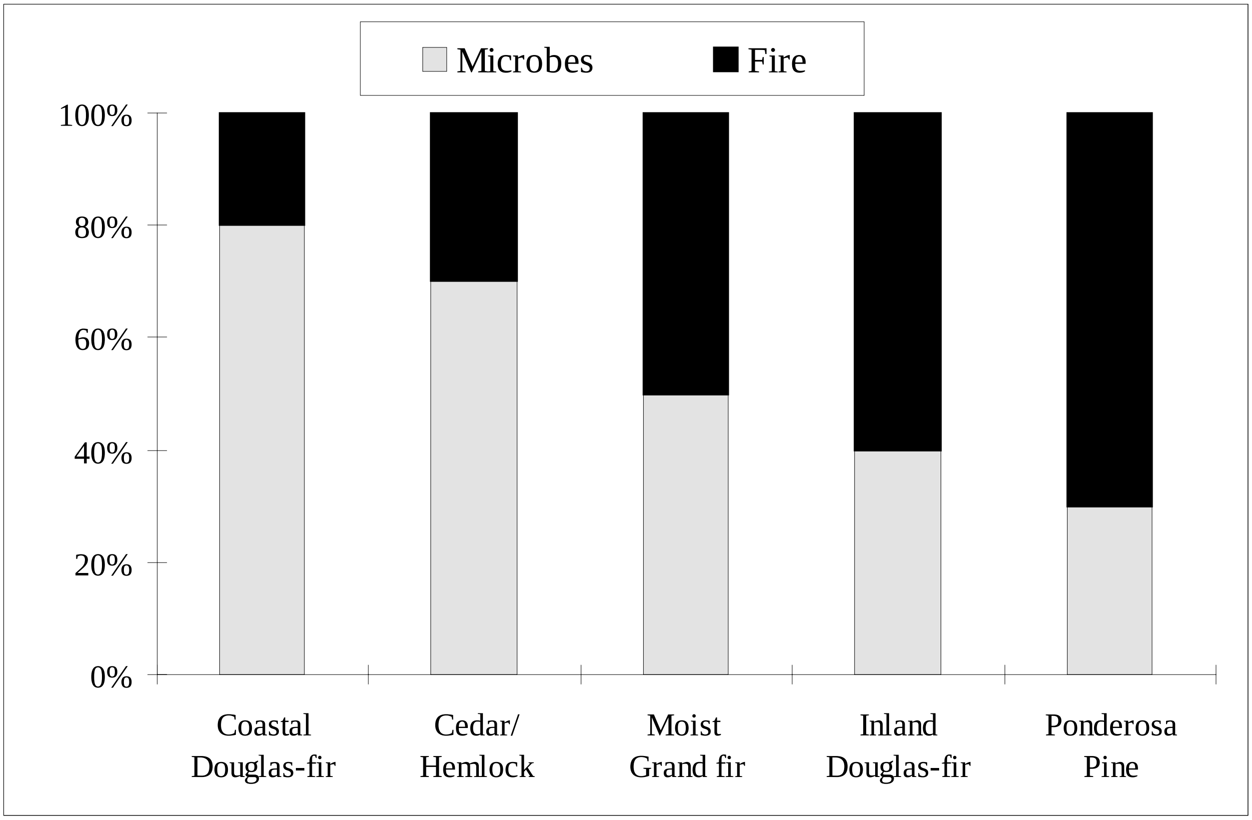
Providing adequate levels of site nutrition is important for maintaining tree resistance to insects and diseases (Mandzak and Moore 1994). In central Oregon, for example, Reaves and others (1984, 1990) found that ash leachates (chemical substances produced when water percolates through the ash remaining after a fire) from prescribed burns in ponderosa pine forests had a direct negative effect on the growth of *Armillaria ostoyae*, cause of Armillaria root disease. Much of the Armillaria suppression was due to a fungus called *Trichoderma*, which was strongly antagonistic to *Armillaria ostoyae* in burned soils.

It is recommend that prescribed burning be used in existing dry-forest types (ponderosa pine and Douglas-fir) that have received an understory thinning treatment, and that it be considered as a future treatment for plantations established on hot dry and warm dry PAGs. Future prescribed burns will probably not occur for at least 30 years after plantations have been established, and could then be coordinated with thinning and pruning treatments designed to create stand structures with a low risk of crown fire or other undesirable fire behavior (Agee 1996, Scott 1998).

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

Prescribed fire has recently been proposed as a possible replacement for mechanical thinning. On droughty sites in eastern Washington, residual trees increased growth following surface fires which killed intermediate and suppressed trees, but growth increases were greater when the forest was thinned by manual cutting. Unlike fire, manual thinning did not damage roots, so residual trees reoccupied the growing space quickly. After overstory trees appropriated the additional growing space provided by a thinning, grasses did 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 access for tree planters, 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 the stand's life (Brockley and others 1992). In central Oregon, prescribed burning was observed to cause a net decrease in nitrogen mineralization rates and a decline in long-term site productivity (Cochran and Hopkins 1991, Monleon and others 1997).



Veg Figure 10 – Fire as a decomposer. In dry forests of the Inland 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 keep pace with the organic debris that accumulates beneath forests as they grow and develop (needles, twigs, branches, etc.). Eventually, a disturbance event will "reset" the system by converting the accumulated biomass back to its elemental constituents (carbon, phosphorus, calcium, etc.). Wildfire often serves as the "reset" event in western forests. (Figure adapted from Harvey and others 1994.)

Fertilization. The recent wildfires may contribute to future forest health problems by their 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 burn 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 as 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).

It is recommended that fertilization be considered as a future treatment for young stands growing on the hot dry or warm dry plant association groups. 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. Pruning has historically been used to produce clear, knot-free wood for the lumber trade. But pruning can also play a role in achieving natural resource objectives. For example, the Desolation watershed has experienced two intense outbreaks of western spruce budworm over the last fifty years. 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, Veg Table 32 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.

It is recommended that pruning be considered as a future treatment for young stands on the hot dry and warm dry plant association groups. 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).

Consideration of Limited Vegetation Components. By its very nature, ecosystem analysis at the watershed scale (EAWS) encourages analysts to adopt a broad perspective that emphasizes looking beyond site-level conditions to focus on ecological processes at the landscape scale. One potential pitfall of a broad perspective, however, is the risk of overlooking limited vegetation components such as quaking aspen, whitebark pine, western white pine or black cottonwood – many of which have a restricted distribution and are indistinguishable at a landscape scale.

Veg Table 32: 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), 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.

For the Desolation watershed, quaking aspen, black cottonwood, and whitebark pine are three limited components of particular concern. In the case of whitebark pine, Desolation may well be the only watershed on the entire Umatilla National Forest in which it occurs. Unfortunately, it is found in remote situations (on isolated scree slopes, at upper treeline high in the subalpine zone, etc.) and very little is known about its current condition. In other portions of its range, there is high concern about the continued existence of whitebark pine because of mortality caused by an introduced disease – white pine blister rust (Keane and Arno 1993). In the Desolation watershed, it is unknown if whitebark pine is infected with blister rust because planned surveys of whitebark pine have not yet been completed.

It is recommended that whitebark pine surveys be completed as soon as possible, under the direction of the Forest's botany program.

Aspen is a good example of an ecosystem element that is valued for a wide variety of benefits. Its leaves and buds are a choice food for ruffed grouse, beaver, snowshoe hares, Rocky Mountain elk and many other species. And in winter, when foliage is no longer present, elk like to feed on its smooth white bark. After dying, aspen may be used by almost as many species as when alive, since dead trees are prized by woodpeckers, flickers and other birds that use cavities (DeByle 1985). When present in areas dominated by conifer forests, the golden yellows or tawny russets of fall aspen foliage provide a welcome splash of color.

Although it may be difficult to prove (or quantify), it is very likely that aspen used to be more common in the Blue Mountains than it is now – fire suppression activities over the last 90 years have undoubtedly reduced its distribution.

Veg Figure 11 – An aspen enclosure in the Desolation watershed.

Aspen is a clonal species that primarily regenerates by producing suckers from its root system (Schier and others 1985). Unfortunately, the suckers are highly palatable to elk, deer and domestic livestock. In order to allow the suckers to persist and eventually grow above the browse height of large ungulates, it is a common practice to fence aspen clones to prevent grazing damage (Veg Figure 11). Relict aspen clones exist sporadically in the Desolation watershed (Howard Creek, Sponge Creek, Park Creek, etc.). Some of them have already been fenced but others have not, so it is recommended that clones without enclosures be fenced as soon as possible (Veg Figure 11).

Black cottonwood has a wide geographical distribution but it is mainly a tree of the Pacific Northwest. Like other cottonwoods, its habitat consists of wet areas – along live streams, around seeps, and on floodplains. It can tolerate yearly spring flooding and in some respects almost requires it for survival (Lanner 1984). Its growth is enhanced by frequent depositions of nutrient-rich sediments, and the fine gravels or sand supplied by periodic flooding provide an ideal substrate for cottonwood regeneration. After humans intervened to curtail or control flooding, however, black cottonwood has declined or disappeared altogether (Peterson and others 1996).

Unlike aspen, black cottonwood does not reproduce from root suckers, but it does sprout from the root collar and occasionally from rhizomes located close to the parent tree (Kershaw and others 1998). It can also be propagated by sticking a branch cutting into moist soil and letting it form roots (Lanner 1984). Although long-term trend data is unavailable for the Umatilla National Forest, black cottonwood is another species whose distribution is thought to be substantially reduced from historical levels. Grazing by wildlife and livestock, curtailment of frequent spring flooding, and simplification of riverine floodplain areas have combined with other factors to limit cottonwood regeneration.

It is recommended that black cottonwood be planted on appropriate sites in both the upper portion of the dry forest PVG and in the moist forest PVG. Ecologically, black cottonwood is not considered an appropriate revegetation species for the cold forest PVG.

Restoration of Natural Vegetation Patterns. All landscapes have definable characteristics with respect to their scenic attractiveness. People value highly-scenic landscapes, which research has shown to be those with a natural appearance based on their landform, vegetation patterns, and water characteristics (Lucas 1991, Magill 1992, USDA Forest Service 1995b).

In the Desolation ecosystem analysis area, landscape patterns have been altered by previous timber harvest practices, particularly with respect to the effects of clearcutting. Often, the result of clearcutting was a visual pattern whose texture, form, line, and color were out of scale with "natural" landscapes. [Note that natural landscapes are defined as those whose elements – texture, form, line, color, etc. – were produced by a disturbance regime that did not include timber harvests, fire suppression, or other human-caused activities.] Recent, square-shaped clearcuts resulting from the Junkens timber sale are a good example of a human-induced pattern that is inconsistent with natural landscape patterns.

When considered from a landscape perspective, created openings ranging up to 40 acres in size are out of scale with the natural vegetation patterns associated with a fully functioning disturbance regime (Delong and Tanner 1996). Patch sizes created by anthropogenic disturbances such as clearcutting have been constrained to 40 acres because of limitations imposed by the National Forest Management Act of 1976 and its implementing regulations (36 CFR 219). Veg Table 17 shows that historical average patch sizes for forest cover types ranged from 48 to 434 acres, and from 24 to 223 acres for forest structural stages (see page 28). Clearcuts of 40 acres or less are inappropriately small when considering the historical patch size situation.

It is recommended that future management treatments attempt to rehabilitate the existing visual situation by restoring a natural vegetation pattern. For example, existing clearcut units could eventually be expanded and shaped in such a way as to approximate the pattern, juxtaposition and size of patches created by historical occurrences of stand-replacing wildfire, particularly for areas within the cold and moist forest PVGs. At a minimum, visual rehabilitation efforts should attempt to modify the unnatural, geometrically regular pattern associated with the existing square clearcuts.

Restoration of Old Forest Structure. An analysis of current and reference conditions for structural stages indicates that the existing amount of old forest structure is substantially reduced from historical levels (see Veg Tables 9 and 19). Information on historical amounts and distribution of old forests is scarce, but a recent assessment effort identified that old forest abundance has been significantly reduced in most of eastern Oregon and Washington since the pre-settlement era (Lehmkuhl and others 1994).

In the Desolation watershed, old forest structure occurs in two forms, and each form was developed and maintained by a different disturbance regime. In dry forest areas, vegetative succession toward a climatic climax was historically interrupted by low- and moderate-intensity fires that maintained forest stands in an early-seral condition. These seral communities were very stable because ecosystems with frequent disturbances exhibit only a narrow range of plant communities (Steele and Geier-Hayes 1995).

An example of a stable, early-seral community from the Blue Mountains is "park-like" ponderosa pine, a forest condition with large, widely-spaced trees growing above a dense undergrowth of tall grasses. In some situations, that same vegetative condition existed with western larch as the dominant species instead of ponderosa pine. Those attractive landscapes had been created and maintained by low-intensity, high-frequency wildfires occurring on a cycle of 8 to 20 years. In this report, the old forest structure associated with early-seral conditions is referred to as *old forest single stratum* (see Veg Tables 9 and 19).

Some moist or cold forest areas, by virtue of their topographic position, soil type, or a combination of environmental conditions and vegetation attributes, are less frequently affected by stand-replacing disturbances than the surrounding landscape. These areas may be thought of as semi-stable elements in a dynamic landscape because their environmental settings allowed them to function as old-forest fire refugia. Disturbance refugia are often associated with specific physiographic settings such as upper headwalls, the confluence of two stream channels, areas with perched water tables, and valley bottoms immediately adjacent to perennial streams (Camp and others 1997, Taylor and Skinner 1998).

Disturbance refugia typically differ from the surrounding landscape matrix in species composition or structural attributes, such as tree height, density, or diameter distribution. Refugia may harbor plant and animal species that would otherwise be absent if an entire landscape was subjected to the same disturbance regime. Whereas fire was the predominant disturbance agent for matrix areas in the landscape, disturbance refugia were more often affected by insects and diseases that created soft snags and other biotic components missing from the surrounding forest (Camp and others 1997).

Old forest structure associated with disturbance refugia typically consists of late-successional species occurring in multi-cohort, high density stands (e.g., stands of grand fir, Engelmann spruce, or subalpine fir with multiple canopy layers and a high canopy cover percentage). In this report, the old forest associated with disturbance refugia is referred to as *old forest multi strata* (see Veg Tables 9 and 19).

Old forests can contribute significantly to local and regional biodiversity. For that and other reasons, there is strong interest in restoring old forest structure to a level that approximates its historical abundance. Any restoration approach should incorporate the following concepts relating to the landscape ecology of eastern Oregon (Camp and others 1997, Everett and others 1994):

- Current anomalous landscapes and disturbance regimes need to be restored to a more sustainable state if old-forest remnants are to be conserved and old-forest networks created and maintained;
- Today, many old-forest remnants are surrounded by a mosaic of young forest types with heightened fire and insect hazard;
- Given the limited contribution from any individual old-forest patch, additional old-forest stands need to be continually created to maintain a dynamic balance through time;
- Efforts to conserve old forest should not sacrifice contributions from other structures or components in the landscape;
- Conserving the disturbance processes that influence ecosystems is every bit as important as conserving individual plant and animal species or old forest structure – a lack of disturbance can be as threatening to biological diversity as excessive disturbance;
- Management of old forest patches must be integrated with the disturbance regimes characteristic of their associated landscape;
- Any plan to sustain old forests must first sustain the landscape of which they are a part;
- In managing old forests, a landscape perspective is needed that coordinates species requirements with the functional attributes of ecosystems;
- Forest ecosystems of the Interior Pacific Northwest are in a constant state of change, and it must be recognized that the successional pathway of a high proportion of the forest stands will be interrupted by fire, blow-down, insect attack, or disease before they can reach an old-forest condition.

A restoration strategy for old forests could include the following components (Camp and others 1997, Everett and others 1994):

- Conservation of the remaining old-forest patches is the cornerstone of any management scheme, if for no other reason than it best maintains future options;
- Sites that do not have a full complement of old forest characteristics can partially function as old forest for those attributes that are present;
- The potential for increasing the amounts and distribution of *old forest multi strata* stands is present on the landscape in the form of late-seral structural stages (specifically, the *understory reinitiation* and *young forest multi strata* stages);
- Although late-seral stands are "in the pipeline" to replace old forests lost to natural disturbances, we still do not know the appropriate ratio of late-seral to old forest to ensure that current or desired levels of old forests are maintained in perpetuity;
- In some parts of the landscape it may be necessary to designate areas of younger forest as old-growth management areas in order to meet desired future objectives with respect to a seral stage distribution;
- Evaluating historical amounts of old forest (as is often done when analyzing the historical range of variability or HRV) can provide a first approximation of old forest abundance that was sustainable and in which plant and animal species evolved;
- Ideally, historical evaluations should incorporate several reference points in time and at a sufficient spatial scale to ensure that major disturbance regimes have been accounted for;
- A successful old forest strategy would allow flexibility in specific on-the-ground locations over time. The "shifting mosaic" landscape concept suggests a dynamic framework in which old forest patches are lost and created in an equilibrium at appropriate spatial and temporal scales;
- Restoration of old forests carries with it long-term management costs with little expectation of substantial commodity production. Creation of an old-forest network explicitly assumes that biological diversity and other old-forest values are specifically desired by human society;
- A dynamic ecosystems philosophy should be the foundation of any old-forest strategy – an ecologically sustainable representation of old forest structure in the landscape is more important than preservation of individual old forest patches.

How could these concepts be applied in the Desolation watershed? I believe that the following process would contribute to development of an old forest network:

1. Identify any existing old-forest patches and recommend that they be protected (from anthropogenic disturbances such as timber harvest) as a cornerstone of a future network.
2. Identify late-seral patches (*understory reinitiation* and *young forest multi strata* stands) in close proximity to the existing old forest as potential replacements for them.
3. Examine the late-seral patches on the ground to determine which old forest attributes they currently have, and to determine if cultural activities (thinnings, etc.) could promote missing attributes more quickly than would occur by doing nothing.
4. Identify a desired future patch distribution and determine if young-seral stands (*stand initiation* and *stem exclusion*) located on a desirable spacing could be cultured (thinned, etc.) to produce old-forest attributes more quickly than would occur by doing nothing. When identifying candidates for future *old forest multi strata*, stands should be selected that have the highest potential to survive to the old forest stage – namely areas on north-facing aspects and at high elevations, particularly if they occur within valley bottoms and drainage headwalls (Camp and others 1997).

Data Gaps and Analysis Limitations. One product of the recommendations step in ecosystem analysis at the watershed scale is identification of data gaps and analysis limitations (Regional Ecosystem Office 1995). The following gaps and limitations were identified during analysis of upland forest vegetation for the Desolation watershed:

1. *Future conditions were not considered*. Most of this vegetation analysis focused on reference (historical) and current conditions. There was no explicit consideration of future conditions. Unfortunately, the inter-agency Federal process developed for watershed analysis (Regional Ecosystem Of-

fice 1995) does not require an assessment of future conditions. Perhaps future EAWS efforts would benefit from having the "third leg of the triangle" (i.e., future conditions) take its place alongside reference and current conditions. Analytical tools have recently been developed that would help evaluate future scenarios, such as the Vegetation Dynamics Development Tool (Beukema and Kurz 1996).

2. *A detailed landscape analysis was not completed*. As described previously, time and other constraints allowed nothing more than a cursory analysis of landscape characteristics (see page 16). Although its value could not be fairly judged in this Desolation analysis, it is believed that a robust landscape characterization could have improved our understanding of broad-scale ecosystem processes and their effect on vegetation patterns.
3. *Additional information about limited vegetation components was needed*. Insufficient information was available about the condition and trend of limited vegetation components such as quaking aspen, black cottonwood, whitebark pine and western white pine in the Desolation drainage. The North Fork John Day District has information about some of these components but, in several instances, the information is not readily available or has not yet been synthesized or interpreted. It is recommended that the District continue its on-going efforts to develop a "species of special concern" GIS layer (and associated databases) to monitor the location and status of limited vegetation components.
4. *High-resolution data sources may have improved analysis accuracy*. Inventory information is used to prepare assessments of watersheds, landscapes, entire National Forests, and other mid- or broad-scale land areas. Dating back to the early 1990s, inventory budgets have been steadily declining, quickly resulting in reduced availability of stand examinations and other high-resolution surveys. As high-resolution data sources became scarce, there was increasing reliance on interpretation of aerial photography, satellite imagery, and other remotely-sensed data.

   Ground-based surveys typically provide detailed information about stand density (trees per acre, basal area per acre, etc.), whereas remote-sensing sources do not. Remote-sensing sources, however, do provide canopy cover information that can serve as a surrogate for stand density. Therefore, mathematical formulas developed during an elk thermal cover study (Dealy 1985) were used to calculate canopy cover values for suggested stocking levels of the Blue Mountains (see appendix 2). Once the suggested stocking levels had been converted to their corresponding canopy cover values, a stand density analysis was then possible (see page 38).

   It is important to emphasize that canopy cover is only an approximation of absolute stand density (basal area or trees per acre), and the overstocked area shown in Veg Table 27 (page 39) should be evaluated in the field to determine its actual suitability for thinning or another density management treatment.

   A similar situation exists with regard to structural stage determinations. Previous vegetation analyses have shown that stand examination information could significantly improve the accuracy of structural stage determinations, particularly for old forest. Since stand exams are typically available for only a limited portion of any particular analysis area, it has often been necessary to use low-resolution information derived from satellite imagery or photo interpretation to calculate structural stages. One disadvantage of this situation is that structural stage determinations require detailed information about tree size, and photo interpretation may not provide enough resolution to accurately differentiate certain tree-size categories.

   If accurate information about old forest and other structural stages is important for ecosystem analysis at the watershed scale, then the Umatilla National Forest should evaluate alternative data sources that would provide more resolution than interpretation of aerial photography.

APPENDIX 1: DESCRIPTION OF VEGETATION DATABASES

Vegetation data for the Desolation ecosystem analysis was stored in three different databases. This document serves as a data dictionary for the existing vegetation, historical vegetation, and potential natural vegetation databases, as described below:

- Interpretation of aerial photography acquired in 1995, 1996, and 1997 was used to characterize existing (current) conditions. The 1996 and 1997 photography was obtained after cessation of the Bull and Summit wildfires in order to characterize post-fire conditions. The database name is: **97veg**.
- Interpretation of late-1930s and early-1940s photography was used to characterize historical conditions. The database name is: **39veg**.
- The potential natural vegetation was determined for each polygon in the analysis area (based on the pre-fire polygons). Plant associations were derived from a variety of sources, including field surveys completed by a professional ecologist under contract to the Forest Service (Ayn Shlisky), sensitive plant surveys and personal knowledge of the analysis area by the Forest Botanist (Karl Urban), and historical stand examinations. The database name is: **DesoPNV**.

<u>Note</u>: Although delineation of existing and historical conditions were not made by the same interpreters, both efforts used the same coding scheme and database structure.

Site Number (**Site** is the database field name**)**: Polygons were numbered consecutively, starting at the northwest corner of the analysis area (near Dale work center) and proceeding southerly to the southeast corner by Sunrise Butte. [<u>Note</u>: polygon numbering was not consecutive for the **97veg** database after new polygons for the Summit and Bull fires were merged with existing (pre-fire) polygons.]

Total Area (TotArea): Total acreage within the polygon boundary; calculated using Arc/Info.

Private Area (PvtArea): Acreage within the polygon that is not owned/administered by the Umatilla National Forest; calculated using Arc/Info.

Data Source (Sour): Provides the data source for each record, as described below. [<u>Note</u>: this field was not used with the historical database since all of its data was derived from one source.]

Code	**Description**
KU	Ecoclass codes assigned by Karl Urban (pertains to plant association database only)
PI	Photo Interpretation
SE	Stand Examination
WT	Walk Through/Field Reconnaissance

Subwatershed (SWS): Provides the predominant subwatershed for each polygon. Derived by overlaying the subwatershed layer with both the historical and existing vegetation polygon layers, and then determining which subwatershed occupies the majority of each polygon.

Subwatershed Group (Group): This derived field was based on data in the *Subwatershed* field. It was used for the HRV analyses. Each polygon in the **39veg** and **97veg** databases was assigned to one of two subwatershed groups, as described below:

Code	**Description**
Low	Subwatersheds occurring in the lower portion of the watershed (36A, 36B, 36C, 36D)
Upp	Subwatersheds occurring in the upper part of the watershed (36E, 36F, 36G, 36H, 36I)

Photo Number (Photo#): Number of the aerial photograph on which the polygon was delineated. Photo number consists of the roll number and the print number, separated by a dash (–) or a space.

Elevation (Elev): Mean elevation of the polygon; calculated by Arc/Info after gridding the polygon into 30-meter square pixels. Value is an average of the pixels within a polygon.

Slope Percent (SlpPct): Mean slope percent of the polygon; calculated by Arc/Info after gridding the polygon into 30-meter square pixels. Value is an average of the pixels within a polygon.

Aspect (Asp): Mean aspect of the polygon; calculated by Arc/Info after gridding the polygon into 30-meter square pixels. Value is an average of the azimuth calculations, in degrees, for the pixels within a polygon. The azimuth (degree) value was converted to a compass direction using this relationship:

Code	**Description**
LE	Level (sites with no aspect; slope percents <5%)
NO	North (azimuths >338° and ≤23°)
NE	Northeast (azimuths >23° and ≤68°)
EA	East (azimuths >68° and ≤113°)
SE	Southeast (azimuths >113° and ≤158°)
SO	South (azimuths >158° and ≤203°)
SW	Southwest (azimuths >203° and ≤248°)
WE	West (azimuths >248° and ≤293°)
NW	Northwest (azimuths >293° and ≤338°)

Seral Status (Seral): This derived field was based on data in the *plant association group* and *cover type* fields. It was used for the stand density analyses. Each polygon in the **39veg** and **97veg** databases was assigned to one of three seral status categories (see Hall and others 1995), as described below:

Code	**Description**
ES	Early Seral status
MS	Mid Seral status
LS	Late Seral status

Plant Association Group (PAG): Assigned by generating a new thematic map from the **DesoPNV** data-base, and then overlaying the resulting PAGs with the existing (**97veg**) and historical (**39veg**) polygon layers. Refer to Powell (1998) for a description of how plant associations were combined into PAGs.

Code	**Description**
Cold Dry UF	Cold Dry Upland Forest PAG
Cold Moist US	Cold Moist Upland Shrubland PAG
Cold Wet HSM RF	Cold Wet High Soil Moisture Riparian Forest PAG
Cold Wet HSM RH	Cold Wet High Soil Moisture Riparian Herbland PAG
Cold Wet MSM RF	Cold Wet Moderate Soil Moisture Riparian Forest PAG
Cold Wet MSM RH	Cold Wet Moderate Soil Moisture Riparian Herbland PAG
Cool Dry UF	Cool Dry Upland Forest PAG
Cool Moist UF	Cool Moist Upland Forest PAG
Hot Dry UF	Hot Dry Upland Forest PAG
Hot Dry UG	Hot Dry Upland Grassland PAG
Hot Dry US	Hot Dry Upland Shrubland PAG
Hot Moist UW	Hot Moist Upland Woodland PAG
Rock	Rock (talus, outcrop, etc.) PAG
Warm Dry UF	Warm Dry Upland Forest PAG
Code	**Description**
Warm Moist UF	Warm Moist Upland Forest PAG
Warm Moist UG	Warm Moist Upland Grassland PAG

Warm Wet MSM RH	Warm Wet Moderate Soil Moisture Riparian Herbland PAG
Water Lake	Water (lakes) PAG

Potential Vegetation Group (PVG): Assigned by generating a new thematic map from the **DesoPNV** database, and then overlaying the resulting PVGs with the existing (**97veg**) and historical (**39veg**) polygon layers. Refer to Powell (1998) for a description of how the PAGs were combined into PVGs.

Code	Description
Cold UF	Cold Upland Forest PVG
Cold US	Cold Upland Shrubland PVG
Dry UF	Dry Upland Forest PVG
Dry UG	Dry Upland Grassland PVG
Dry US	Dry Upland Shrubland PVG
High SM RH	High Soil Moisture Riparian Herbland PVG
Mod SM RH	Moderate Soil Moisture Riparian Herbland PVG
Moist UF	Moist Upland Forest PVG
Moist UG	Moist Upland Grassland PVG
Moist UW	Moist Upland Woodland PVG
Rock	Rock PVG
Water	Water PVG
Wet RF	Wet Riparian Forest PVG

Plant Association (Ecoclass1, Ecoclass2, Ecoclass3): Since a typical vegetation polygon (20-30 acres) commonly contains more than one plant association, up to three plant associations were recorded for each polygon. The **DesoPNV** database contains the 6-digit Ecoclass codes (Hall 1998) that were used to record the plant association information. There are too many Ecoclass codes to include here; see Powell (1998) or Hall (1998) for a list that relates each Ecoclass code to the plant association it represents.

Plant Community Types (PCT1, PCT2): Up to two plant community types were recorded for each polygon. The **DesoPNV** database contains the 6-digit Ecoclass codes (Hall 1998) that were used to record the plant community type information. There are too many Ecoclass codes to list here; see Powell (1998) or Hall (1998) for a list that relates each Ecoclass code to the plant community type it represents.

Structural Stage (SS): Structural stages were derived using database queries. The queries used combinations of the overstory cover *(OvCov)*, overstory size *(OvSiz)*, understory cover *(UnCov)*, and understory size *(UnSiz)* fields in the existing (**97veg**) and historical (**39veg**) databases. Queries differed slightly by PVG. Veg Table 33 shows the structural stage queries. Refer to Oliver and Larson (1996) or O'Hara and others (1996) for definitions and further information about structural stages.

Code	Description
NF	Non Forest (no structural stage determined for non-forest polygons)
OFMS	Old Forest Multi Strata structural stage
OFSS	Old Forest Single Stratum structural stage
SECC	Stem Exclusion Closed Canopy structural stage
SEOC	Stem Exclusion Open Canopy structural stage
SI	Stand Initiation structural stage
UR	Understory Reinitiation structural stage
YFMS	Young Forest Multi Strata structural stage

Cover Types (CovTyp): These codes describe the predominant cover type (whether vegetated or not) for each polygon. Polygons were considered nonforest when the total canopy cover of trees was less than 10 percent. For forested polygons, the cover type code represents an aggregation of similar stands based on floristics (tree species) and dominance (plurality of basal area or canopy cover; see Eyre 1980). Plurality was defined as 50% or more of the species composition – a polygon with 50% or more of the canopy cover in ponderosa pine was coded CP. Cover type codes are described below. [Note: Not all of the codes were actually used; however, they do reflect what was available to the interpreters.]

Code	**Description**
Non-vegetated Cover Types	
AX	Administrative/Agriculture
NR	Rock Outcrop
NT	Talus/Scree
NS	Sparse/Scabland
NX	Bare Ground/Burned/Other
WL	Water (Lakes)
WR	Water (Running)
Non-forest Cover Types	
FM	Forblands
GB	Bunchgrass Grassland
GS	Subalpine/Alpine Meadow/Grassland
GX	Other Grassland
MD	Dry Meadow
MM	Moist Meadow
MS	Subalpine/Alpine Meadow
MW	Wet Meadow
SD	Dry Shrubland (sagebrush, etc.)
SL	Low Shrubs < 6’
SS	Subalpine/Alpine Shrubland
ST	Tall Shrubs > 6’ (Mtn-Mahogany, etc.)
Forest Cover Types	
CA	Subalpine Fir
CB	Whitebark Pine
CD	Douglas-fir
CE	Engelmann Spruce
CJ	Western Juniper
CL	Lodgepole Pine
CP	Ponderosa Pine
CT	Western Larch/Tamarack
CW	Grand Fir
CX	Mixed; < 50% of any one tree species
HA	Quaking Aspen
HC	Black Cottonwood

Live Canopy Cover (LivCov): Total canopy cover was recorded for polygons with a nonforest or forest cover type code – total tree cover for forest cover types; total shrub cover for shrub types; total herb cover for meadow or grassland types. Total canopy cover refers to the percentage of the ground surface obscured by live plant foliage.

Cover Class (CovCls): This derived field was based on data in the *LivCov* field. It was used for the stand density analyses. Each polygon in the **39veg** and **97veg** databases was assigned to one of four cover classes, as described below:

Code	**Description**
<=40	Live canopy (crown) cover is 40 percent or less
41-55	Live canopy cover is between 41 and 55 percent

56-70	Live canopy cover is between 56 and 70 percent
>70	Live canopy cover is 71 percent or more

Canopy Layers (#Lay): The number of canopy layers was recorded for all polygons with a forest cover type code, as described below:

Code	**Description**
1	1 layer present
2	2 layers present
3	Three or more layers present

Overstory Cover (OvCov): For polygons with a forest cover type code, the canopy cover associated with the overstory layer was recorded in this field. When added to the understory cover value, the total should equal the canopy cover of the polygon as a whole (as coded in the *LivCov* field). [Note: the overstory is the tallest tree layer, whereas the understory is the shortest one.]

Overstory Size Class (OvSiz): For polygons with a forest cover type code, the predominant size class for the overstory layer was recorded using these codes:

Code	**Description**
1	Seedlings; trees less than 1 inch DBH
2	Seedlings and saplings mixed
3	Saplings; trees 1–4.9” DBH
4	Saplings and poles mixed
5	Poles; trees 5–8.9” DBH
6	Poles and small trees mixed
77	Small trees 9–14.9” DBH
88	Small trees 15–20.9” DBH (code not in EVG)
8	Small trees and medium trees mixed
9	Medium trees 21–31.9” DBH
10	Medium and large trees mixed
11	Large trees 32–47.9” DBH

Overstory Species (OvSp1, OvSp2): For polygons with a forest cover type code, one to three tree species were recorded for the overstory (only two species were included in the database). Species were recorded in decreasing order of predominance, using the following codes. [Note: additional species codes (western white pine, quaking aspen, etc.) were available to the interpreters, but were not used.]

Code	**Description**
BC	Black Cottonwood
DF	Douglas-fir
ES	Engelmann Spruce
GF	Grand Fir
LP	Lodgepole Pine
PP	Ponderosa Pine
SF	Subalpine Fir
Code	**Description**
WB	Whitebark Pine
WJ	Western Juniper
WL	Western Larch

Overstory Mortality (OvMor): For polygons with a forest cover type code, the abundance of dead trees (snags) was recorded for the overstory layer using these codes:

Code	Description
L	Low; <10 dead trees per acre
M	Moderate; 11-20 dead trees per acre
H	High; 21-60 dead trees per acre
V	Very High; >60 dead trees per acre

Understory Cover (UnCov): For polygons with a forest cover type code and two canopy layers, the canopy cover associated with the understory layer was recorded in this field. When added to the overstory cover value, the total should equal the canopy cover of the polygon as a whole (as coded in the *LivCov* field). [Note: the understory is the shortest tree layer, the overstory the tallest one.]

Understory Size Class (UnSiz): For polygons with a forest cover type code and two canopy layers, the predominant size class for the understory layer was recorded in this field. Codes were the same as those described above for the overstory.

Understory Species (UnSp1, UnSp2): For polygons with a forest cover type code and two canopy layers, one to three tree species were recorded for the understory (only two species were included in the database). Species are recorded in decreasing order of predominance, using the same species codes described above for the overstory.

Clumpy (Clmp): For polygons with a forest cover type code, the "horizontal patchiness" or intra-stand variation was recorded using the following codes.

Code	Description
Blank	Not rated (nonforest polygons)
N	Continuous, non-clumpy distribution
L	Low; widely-scattered clump distribution (<30% of polygon's area)
M	Moderate clump distribution (30–70% of polygon occupied by clumps)
H	High/dense clump distribution (>70% of polygon occupied by clumps)

Disturbance (Dist): For all polygons, evidence of disturbance was recorded using these codes:

Code	Description
Blank	No visible evidence of disturbance
CC	Recent clearcut timber harvest
CR	Old clearcut, now regenerating
FI	Evidence of recent fire
PC	Recent partial cutting timber harvest (selection, shelterwood, etc.)
PR	Old partial cut, now regenerating
SS	Evidence of sanitation/salvage timber harvest
TH	Evidence of thinning silvicultural treatment

Veg Table 33: Structural stage methodology used for the Desolation Ecosystem Analysis (for both the historical and existing databases)

Order	PVG	OvCov	OvSiz	UnCov	UnSiz	Stage	Comments
1	Nonforest					NF	All F.., G.., M.., N.., S.., W.. polygons
2	Cold UF	>=30	88, 8, 9, 10, 11	>20		OFMS	Includes smaller size class (88) than ICBEMP (for LP, SF)
3	Cold UF	>=30	88, 8, 9, 10, 11	<=20		OFSS	Includes smaller size class (88) than ICBEMP (for LP, SF)
4	Dry UF	>=15	8, 9, 10, 11	>10		OFMS	Cover values are half of what ICBEMP used
5	Dry UF	>=15	8, 9, 10, 11	<=10		OFSS	Cover values are half of what ICBEMP used
6		>=30	8, 9, 10, 11	>20		OFMS	
7		>=30	8, 9, 10, 11	<=20		OFSS	
8	Dry UF	>=35	4, 5, 6, 77, 88	<10		SECC	Cover values are half of what ICBEMP used
9	Dry UF	<35	4, 5, 6, 77, 88	<10		SEOC	Cover values are half of what ICBEMP used
10		>=70	4, 5, 6, 77, 88	<10		SECC	
11		<=20		>=70	2 – 4	SECC	Stem exclusion under remnant overstory
12		<=20		<70	2 – 4	SI	Seeds/saps under remnant overstory
13			1, 2, 3, 4			SI	Seeds and saps are the overstory layer
14		<30	>=5			SI	Sparse overstory, but no seeds/saps are established yet
15	Dry UF	>=30	>=5	>=10		UR	Cover values are half of what ICBEMP used
16		>=30	>=5	Blank		SEOC	Sparse overstory stocking
17		>=30	>=5	<10		UR	Sparse overstory over sparse understory stocking
18		>=60	>=5	>=10		UR	
19		<60	>=5	>=10		YFMS	
20	?	?	?	?	?	?	Classify remaining polygons by hand (and refine queries)

Sources/Notes: These queries were based on a draft paper entitled "Assessing change in vegetation structure and composition at mid-scale in the Interior Columbia River Basin assessment: analysis plan" by Hessburg and Smith (1996). Order is important because it is assumed that these calculations would occur using the following query statement: "blank, changeto OFMS" (or another structural stage code). Therefore, if a polygon could meet more than one query option, a structural stage code would be assigned by the option with the lowest order number.

APPENDIX 2: SUGGESTED STOCKING LEVELS

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. 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). Managing stand density is a good example of integrated pest management, a strategy that involves using silviculture and other measures to reduce susceptibility or vulnerability to common harmful agents (Nyland 1996).

The tables in this appendix provide tree density recommendations by species and by plant association (plus an average for each PAG). They establish a "management zone" in which stand densities are presumed to be ecologically sustainable. To preclude serious losses (tree mortality) from insects, diseases, parasites, drought, and certain other disturbance agents, stand densities should be maintained at a level below the upper management zone.

Veg Table 34: Suggested stocking levels for subalpine fir (SF).

	FULL STOCKING LEVEL				UPPER MGMT. ZONE				LOWER MGMT. ZONE			
PLANT ASSOCIATION	**TPA**	**BA**	**CC**	**ES**	**TPA**	**BA**	**CC**	**ES**	**TPA**	**BA**	**CC**	**ES**
ABLA2/MEFE	416	227	90	11.0	312	170	85	12.7	208	113	78	15.6
Mean: Cold Moist PAG	416	227	90	11.0	312	170	85	12.7	208	113	78	15.6
ABLA2/CAGE	372	203	88	11.6	279	152	83	13.4	186	101	76	16.4
ABLA2/VASC	365	199	88	11.7	274	149	83	13.6	183	100	76	16.6
ABLA2/VASC/POPU	365	199	88	11.7	274	149	83	13.6	183	100	76	16.6
Mean: Cold Dry PAG	367	200	88	11.7	276	150	83	13.5	184	100	76	16.5
ABGR/LIBO2	373	203	88	11.6	280	153	83	13.4	187	102	76	16.4
ABGR/VAME	412	225	90	11.0	309	169	85	12.8	206	112	78	15.6
ABGR/VASC-LIBO2	184	100	76	16.5	138	75	71	19.1	92	50	64	23.4
ABLA2/CLUN	416	227	90	11.0	312	170	85	12.7	208	113	78	15.6
ABLA2/LIBO2	335	183	87	12.3	251	137	82	14.1	168	91	75	17.3
ABLA2/TRCA3	382	208	89	11.5	287	156	84	13.3	191	104	77	16.2
ABLA2/VAME	265	145	83	13.8	199	108	77	15.9	133	72	70	19.5
Mean: Cool Moist PAG	338	184	86	12.5	254	138	81	14.5	169	92	74	17.7

Sources/Notes: All information in this table pertains to stands with a quadratic mean diameter (QMD) of 10 inches. The information would differ slightly for stands with other QMDs (Powell 1998). The full stocking level is equivalent to maximum stocking; the upper management zone is 75% of full stocking; the lower management zone is 67% of the upper management zone; TPA is trees per acre when the quadratic mean diameter is 10 inches; BA is basal area per acre; CC is canopy cover and was calculated using the "CE" equation from Dealy (1985); and ES is equilateral spacing – the spacing, in feet, that the trees per acre would have when spaced equilaterally apart (also referred to as triangular spacing). The TPA values were derived from Cochran and others (1994). The BA and ES values were calculated using equations and were based on the TPA values.

Veg Table 35: Suggested stocking levels for grand fir (GF).

	FULL STOCKING LEVEL				UPPER MGMT. ZONE				LOWER MGMT. ZONE			
PLANT ASSOCIATION	**TPA**	**BA**	**CC**	**ES**	**TPA**	**BA**	**CC**	**ES**	**TPA**	**BA**	**CC**	**ES**
ABGR/VASC	368	201	90	11.7	276	151	85	13.5	184	100	78	16.5
Mean: Cold Dry PAG	368	201	90	11.7	276	151	85	13.5	184	100	78	16.5
ABGR/TABR/CLUN	560	305	98	9.5	420	229	93	10.9	280	153	85	13.4
ABGR/TABR/LIBO2	560	305	98	9.5	420	229	93	10.9	280	153	85	13.4
Mean: Cool Wet PAG	560	305	98	9.5	420	229	93	10.9	280	153	85	13.4
ABGR/GYDR	553	302	98	9.5	415	226	92	11.0	277	151	85	13.5
ABGR/POMU-ASCA3	486	265	95	10.2	365	199	90	11.7	243	133	83	14.4
ABGR/TRCA3	554	302	98	9.5	416	227	92	11.0	277	151	85	13.5
Mean: Cool Very Moist PAG	531	290	97	9.7	398	217	92	11.3	266	145	84	13.8
ABGR/CLUN	560	305	98	9.5	420	229	93	10.9	280	153	85	13.4
ABGR/LIBO2	516	281	96	9.9	387	211	91	11.4	258	141	84	14.0
ABGR/VAME	455	248	94	10.5	341	186	89	12.1	228	124	82	14.9
ABGR/VASC-LIBO2	494	269	96	10.1	371	202	90	11.7	247	135	83	14.3
Mean: Cool Moist PAG	506	276	96	10.0	380	207	91	11.5	253	138	84	14.1
ABGR/ACGL	461	251	94	10.4	346	189	89	12.1	231	126	82	14.8
Mean: Warm Very Moist PAG	461	251	94	10.4	346	189	89	12.1	231	126	82	14.8
ABGR/BRVU	560	305	98	9.5	420	229	93	10.9	280	153	85	13.4
Mean: Warm Moist PAG	560	305	98	9.5	420	229	93	10.9	280	153	85	13.4
ABGR/CAGE	560	305	98	9.5	420	229	93	10.9	280	153	85	13.4
ABGR/CARU	444	242	94	10.6	333	182	89	12.3	222	121	81	15.1
ABGR/SPBE	354	193	90	11.9	266	145	84	13.8	177	97	77	16.9
Mean: Warm Dry PAG	453	247	94	10.7	340	185	89	12.3	226	123	81	15.1

Sources/Notes: All information in this table pertains to stands with a quadratic mean diameter (QMD) of 10 inches. The information would differ slightly for stands with other QMDs (Powell 1998). The full stocking level is equivalent to maximum stocking; the upper management zone is 75% of full stocking; the lower management zone is 67% of the upper management zone; TPA is trees per acre when the quadratic mean diameter is 10 inches; BA is basal area per acre; CC is canopy cover and was calculated using the "CW" equation from Dealy (1985); and ES is equilateral spacing – the spacing, in feet, that the trees per acre would have when spaced equilaterally apart (also referred to as triangular spacing). The TPA values were derived from Cochran and others (1994). The BA and ES values were calculated using equations and were based on the TPA values.

Veg Table 36: Suggested stocking levels for Engelmann spruce (ES).

PLANT ASSOCIATION	FULL STOCKING LEVEL				UPPER MGMT. ZONE				LOWER MGMT. ZONE			
	TPA	BA	CC	ES	TPA	BA	CC	ES	TPA	BA	CC	ES
ABLA2/VASC	366	200	88	11.7	275	150	83	13.5	183	100	76	16.6
ABLA2/VASC/POPU	366	200	88	11.7	275	150	83	13.5	183	100	76	16.6
Mean: Cold Dry PAG	366	200	88	11.7	275	150	83	13.5	183	100	76	16.6
ABGR/TABR/CLUN	426	232	91	10.9	320	174	86	12.5	213	116	79	15.4
ABGR/TABR/LIBO2	299	163	85	13.0	224	122	80	15.0	150	82	73	18.3
Mean: Cool Wet PAG	363	198	88	11.9	272	148	83	13.8	181	99	76	16.9
ABGR/POMU-ASCA3	469	256	92	10.4	352	192	87	12.0	235	128	80	14.6
ABGR/TRCA3	388	212	89	11.4	291	159	84	13.1	194	106	77	16.1
Mean: Cool Very Moist PAG	400	218	90	11.3	300	164	85	13.0	200	109	77	15.9
ABGR/CLUN	469	256	92	10.4	352	192	87	12.0	235	128	80	14.6
ABGR/LIBO2	399	218	90	11.2	299	163	85	13.0	200	109	78	15.9
ABGR/VAME	341	186	87	12.1	256	139	82	14.0	171	93	75	17.2
ABGR/VASC-LIBO2	349	190	87	12.0	262	143	82	13.9	175	95	75	17.0
ABLA2/CLUN	469	256	92	10.4	352	192	87	12.0	235	128	80	14.6
ABLA2/LIBO2	379	207	89	11.5	284	155	84	13.3	190	103	77	16.3
ABLA2/TRCA3	344	188	87	12.1	258	141	82	14.0	172	94	75	17.1
ABLA2/VAME	382	208	89	11.5	287	156	84	13.3	191	104	77	16.2
Mean: Cool Moist PAG	392	214	89	11.4	294	160	84	13.2	196	107	77	16.1
ABGR/ACGL	324	177	86	12.5	243	133	81	14.4	162	88	74	17.6
Mean: Warm Very Moist PAG	324	177	86	12.5	243	133	81	14.4	162	88	74	17.6
ABGR/BRVU	469	256	92	10.4	352	192	87	12.0	235	128	80	14.6
Mean: Warm Moist PAG	469	256	92	10.4	352	192	87	12.0	235	128	80	14.6

Sources/Notes: All information in this table pertains to stands with a quadratic mean diameter (QMD) of 10 inches. The information would differ slightly for stands with other QMDs (Powell 1998). The full stocking level is equivalent to maximum stocking; the upper management zone is 75% of full stocking; the lower management zone is 67% of the upper management zone; TPA is trees per acre when the quadratic mean diameter is 10 inches; BA is basal area per acre; CC is canopy cover and was calculated using the "CE" equation from Dealy (1985); and ES is equilateral spacing – the spacing, in feet, that the trees per acre would have when spaced equilaterally apart (also referred to as triangular spacing). The TPA values were derived from Cochran and others (1994). The BA and ES values were calculated using equations and were based on the TPA values.

Veg Table 37: Suggested stocking levels for lodgepole pine (LP).

PLANT ASSOCIATION	FULL STOCKING LEVEL				UPPER MGMT. ZONE				LOWER MGMT. ZONE			
	TPA	**BA**	**CC**	**ES**	**TPA**	**BA**	**CC**	**ES**	**TPA**	**BA**	**CC**	**ES**
ABGR/VASC	277	151	71	13.5	208	113	66	15.6	139	76	59	19.0
ABLA2/CAGE	277	151	71	13.5	208	113	66	15.6	139	76	59	19.0
ABLA2/VASC	277	151	71	13.5	208	113	66	15.6	139	76	59	19.0
ABLA2/VASC/POPU	277	151	71	13.5	208	113	66	15.6	139	76	59	19.0
Mean: Cold Dry PAG	277	151	71	13.5	208	113	66	15.6	139	76	59	19.0
PICO/CARU	223	122	67	15.0	167	91	62	17.3	112	61	55	21.2
Mean: Cool Dry PAG	223	122	67	15.0	167	91	62	17.3	112	61	55	21.2
ABGR/CLUN	277	151	71	13.5	208	113	66	15.6	139	76	59	19.0
ABGR/LIBO2	277	151	71	13.5	208	113	66	15.6	139	76	59	19.0
ABGR/VAME	238	130	68	14.5	179	97	63	16.8	120	65	56	20.5
ABGR/VASC-LIBO2	277	151	71	13.5	208	113	66	15.6	139	76	59	19.0
ABLA2/TRCA3	277	151	71	13.5	208	113	66	15.6	139	76	59	19.0
ABLA2/VAME	255	139	69	14.0	191	104	64	16.2	128	70	57	19.8
Mean: Cool Moist PAG	265	144	70	13.8	199	108	65	15.9	133	73	58	19.5
ABGR/CARU	277	151	71	13.5	208	113	66	15.6	139	76	59	19.0
Mean: Warm Dry PAG	277	151	71	13.5	208	113	66	15.6	139	76	59	19.0

Sources/Notes: All information in this table pertains to stands with a quadratic mean diameter (QMD) of 10 inches. The information would differ slightly for stands with other QMDs (Powell 1998). The full stocking level is equivalent to maximum stocking; the upper management zone is 75% of full stocking; the lower management zone is 67% of the upper management zone; TPA is trees per acre when the quadratic mean diameter is 10 inches; BA is basal area per acre; CC is canopy cover and was calculated using the "CL" equation from Dealy (1985); and ES is equilateral spacing – the spacing, in feet, that the trees per acre would have when spaced equilaterally apart (also referred to as triangular spacing). The TPA values were derived from Cochran and others (1994). The BA and ES values were calculated using equations and were based on the TPA values.

Veg Table 38: Suggested stocking levels for western larch (WL).

	FULL STOCKING LEVEL				UPPER MGMT. ZONE				LOWER MGMT. ZONE			
PLANT ASSOCIATION	**TPA**	**BA**	**CC**	**ES**	**TPA**	**BA**	**CC**	**ES**	**TPA**	**BA**	**CC**	**ES**
ABGR/VASC	304	166	73	12.9	228	124	67	14.9	152	83	60	18.2
ABLA2/VASC	380	207	77	11.5	285	155	71	13.3	190	104	64	16.3
ABLA2/VASC/POPU	380	207	77	11.5	285	155	71	13.3	190	104	64	16.3
Mean: Cold Dry PAG	355	193	75	12.0	266	145	70	13.8	177	97	63	16.9
ABGR/TABR/LIBO2	302	165	72	12.9	227	124	67	14.9	151	82	60	18.3
Mean: Cool Wet PAG	302	165	72	12.9	227	124	67	14.9	151	82	60	18.3
ABGR/POMU-ASCA3	350	191	75	12.0	263	143	70	13.8	175	95	63	17.0
ABGR/TRCA3	398	217	77	11.2	299	163	72	13.0	199	109	65	15.9
Mean: Cool Very Moist PAG	374	204	76	11.6	281	153	71	13.4	187	102	64	16.4
ABGR/CLUN	410	224	78	11.1	308	168	73	12.8	205	112	65	15.7
ABGR/LIBO2	370	202	76	11.7	278	151	71	13.5	185	101	64	16.5
ABGR/VAME	410	224	78	11.1	308	168	73	12.8	205	112	65	15.7
ABGR/VASC-LIBO2	253	138	69	14.1	190	103	64	16.3	127	69	57	19.9
ABLA2/CLUN	410	224	78	11.1	308	168	73	12.8	205	112	65	15.7
ABLA2/LIBO2	410	224	78	11.1	308	168	73	12.8	205	112	65	15.7
ABLA2/VAME	382	208	77	11.5	287	156	72	13.3	191	104	64	16.2
Mean: Cool Moist PAG	378	206	76	11.6	283	155	71	13.5	189	103	64	16.5
ABGR/ACGL	351	191	75	12.0	263	144	70	13.8	176	96	63	16.9
Mean: Warm Very Moist PAG	351	191	75	12.0	263	144	70	13.8	176	96	63	16.9
ABGR/BRVU	410	224	78	11.1	308	168	73	12.8	205	112	65	15.7
Mean: Warm Moist PAG	410	224	78	11.1	308	168	73	12.8	205	112	65	15.7
ABGR/CARU	307	167	73	12.8	230	126	68	14.8	154	84	60	18.1
PSME/PHMA	256	140	69	14.0	192	105	64	16.2	128	70	57	19.8
PSME/SYAL	205	112	65	15.7	154	84	60	18.1	103	56	53	22.2
Mean: Warm Dry PAG	256	140	69	14.2	192	105	64	16.4	128	70	57	20.0

Sources/Notes: All information in this table pertains to stands with a quadratic mean diameter (QMD) of 10 inches. The information would differ slightly for stands with other QMDs (Powell 1998). The full stocking level is equivalent to maximum stocking; the upper management zone is 75% of full stocking; the lower management zone is 67% of the upper management zone; TPA is trees per acre when the quadratic mean diameter is 10 inches; BA is basal area per acre; CC is canopy cover and was calculated using the "CL" equation from Dealy (1985); and ES is equilateral spacing – the spacing, in feet, that the trees per acre would have when spaced equilaterally apart (also referred to as triangular spacing). The TPA values were derived from Cochran and others (1994). The BA and ES values were calculated using equations and were based on the TPA values.

Veg Table 39: Suggested stocking levels for Douglas-fir (DF).

PLANT ASSOCIATION	FULL STOCKING LEVEL TPA	BA	CC	ES	UPPER MGMT. ZONE TPA	BA	CC	ES	LOWER MGMT. ZONE TPA	BA	CC	ES
ABGR/VASC	274	149	80	13.5	206	112	75	15.6	137	75	69	19.2
ABLA2/VASC	366	200	85	11.7	275	150	80	13.5	183	100	74	16.6
ABLA2/VASC/POPU	366	200	85	11.7	275	150	80	13.5	183	100	74	16.6
Mean: Cold Dry PAG	335	183	83	12.3	252	137	78	14.2	168	91	72	17.4
ABGR/TABR/LIBO2	380	207	85	11.5	285	155	81	13.3	190	104	74	16.3
Mean: Cool Wet PAG	380	207	85	11.5	285	155	81	13.3	190	104	74	16.3
ABGR/CLUN	380	207	85	11.5	285	155	81	13.3	190	104	74	16.3
ABGR/LIBO2	380	207	85	11.5	285	155	81	13.3	190	104	74	16.3
ABGR/VAME	380	207	85	11.5	285	155	81	13.3	190	104	74	16.3
ABGR/VASC-LIBO2	347	189	84	12.0	260	142	79	13.9	174	95	73	17.0
Mean: Cool Moist PAG	372	203	85	11.6	279	152	80	13.4	186	101	74	16.5
ABGR/ACGL	241	131	78	14.4	181	99	73	16.7	121	66	67	20.4
Mean: Warm Very Moist PAG	241	131	78	14.4	181	99	73	16.7	121	66	67	20.4
PSME/ACGL-PHMA	277	151	80	13.5	208	113	76	15.6	139	76	69	19.1
PSME/HODI	255	139	79	14.0	191	104	74	16.2	128	70	68	19.9
Mean: Warm Moist PAG	266	145	80	13.8	200	109	75	15.9	133	73	68	19.5
ABGR/CAGE	301	164	82	12.9	226	123	77	14.9	151	82	70	18.3
ABGR/CARU	357	195	84	11.9	268	146	80	13.7	179	97	73	16.8
ABGR/SPBE	198	108	75	15.9	149	81	70	18.4	99	54	64	22.5
PSME/CAGE	281	153	80	13.4	211	115	76	15.4	141	77	69	18.9
PSME/CARU	264	144	79	13.8	198	108	75	15.9	132	72	68	19.5
PSME/PHMA	225	123	77	15.0	169	92	72	17.3	113	61	66	21.1
PSME/SPBE	371	202	85	11.6	278	152	80	13.4	186	101	74	16.5
PSME/SYAL	247	135	78	14.3	185	101	74	16.5	124	67	67	20.2
PSME/VAME	183	100	74	16.6	137	75	69	19.1	92	50	62	23.4
Mean: Warm Dry PAG	270	147	79	13.9	202	110	75	16.1	135	74	68	19.7

Sources/Notes: All information in this table pertains to stands with a quadratic mean diameter (QMD) of 10 inches. The information would differ slightly for stands with other QMDs (Powell 1998). The full stocking level is equivalent to maximum stocking; the upper management zone is 75% of full stocking; the lower management zone is 67% of the upper management zone; TPA is trees per acre when the quadratic mean diameter is 10 inches; BA is basal area per acre; CC is canopy cover and was calculated using the "CD" equation from Dealy (1985); and ES is equilateral spacing – the spacing, in feet, that the trees per acre would have when spaced equilaterally apart (also referred to as triangular spacing). The TPA values were derived from Cochran and others (1994). The BA and ES values were calculated using equations and were based on the TPA values.

Veg Table 40: Suggested stocking levels for ponderosa pine (PP).

PLANT ASSOCIATION	FULL STOCKING LEVEL TPA	BA	CC	ES	UPPER MGMT. ZONE TPA	BA	CC	ES	LOWER MGMT. ZONE TPA	BA	CC	ES
ABGR/VASC	172	94	57	17.1	101	55	47	22.3	68	37	40	27.3
Mean: Cold Dry PAG	172	94	57	17.1	101	55	47	22.3	68	37	40	27.3
ABGR/LIBO2	686	374	83	8.6	162	88	56	17.6	109	59	48	21.5
ABGR/VAME	292	159	67	13.1	139	76	53	19.0	93	51	46	23.2
Mean: Cool Moist PAG	489	267	75	10.8	151	82	54	18.3	101	55	47	22.4
PSME/ACGL-PHMA	281	153	66	13.4	189	103	59	16.3	127	69	51	19.9
PSME/HODI	340	185	70	12.2	278	152	66	13.5	186	102	58	16.4
Mean: Warm Moist PAG	311	169	68	12.8	234	127	62	14.9	156	85	55	18.2
ABGR/CAGE	210	115	61	15.5	109	59	48	21.5	73	40	41	26.2
ABGR/CARU	316	172	68	12.6	154	84	55	18.1	103	56	47	22.1
ABGR/SPBE	255	139	64	14.0	147	80	54	18.5	98	54	47	22.6
PIPO/CAGE	201	110	60	15.8	83	45	43	24.6	56	30	36	30.1
PIPO/CARU	365	199	71	11.7	154	84	55	18.1	103	56	47	22.1
PIPO/CELE/CAGE	232	127	62	14.7	82	45	43	24.8	55	30	36	30.3
PIPO/ELGL	243	133	63	14.4	92	50	45	23.4	62	34	38	28.6
PIPO/PUTR/CAGE	204	111	60	15.7	70	38	40	26.8	47	26	33	32.7
PIPO/PUTR/CARO	243	133	63	14.4	92	50	45	23.4	62	34	38	28.6
PIPO/SYAL	318	173	68	12.6	218	119	61	15.2	146	80	54	18.6
PIPO/SYOR	260	142	65	13.9	135	74	52	19.3	90	49	45	23.6
PSME/CAGE	222	121	62	15.1	86	47	44	24.2	58	31	37	29.5
PSME/CARU	263	143	65	13.8	122	67	51	20.3	82	45	43	24.8
PSME/PHMA	274	149	66	13.5	167	91	56	17.4	112	61	49	21.2
PSME/SPBE	353	193	70	11.9	226	123	62	14.9	151	83	55	18.2
PSME/SYAL	273	149	65	13.6	151	82	54	18.3	101	55	47	22.3
PSME/SYOR	361	197	71	11.8	180	98	58	16.7	121	66	50	20.4
PSME/VAME	193	105	59	16.1	96	52	46	22.9	64	35	39	28.0
Mean: Warm Dry PAG	266	145	65	14.0	131	72	51	20.5	88	48	43	25.0
PIPO/AGSP	133	73	52	19.4	38	21	29	36.4	25	14	22	44.4
PIPO/CELE/FEID-AGSP	157	86	55	17.9	32	17	26	39.6	21	12	19	48.4
PIPO/FEID	194	106	59	16.1	63	34	38	28.3	42	23	31	34.5
PIPO/PUTR/FEID-AGSP	185	101	58	16.5	66	36	39	27.6	44	24	32	33.7
Mean: Hot Dry PAG	167	91	56	17.5	50	27	33	33.0	33	18	26	40.3

Sources/Notes: All information in this table pertains to stands with a quadratic mean diameter (QMD) of 10 inches. The information would differ slightly for stands with other QMDs (Powell 1998). The full stocking level is equivalent to maximum stocking; the upper management zone was determined using a process described in Cochran and others (1994); the lower management zone is 67% of the upper management zone; TPA is trees per acre when the quadratic mean diameter is 10 inches; BA is basal area per acre; CC is canopy cover and was calculated using the "CP" equation from Dealy (1985); and ES is equilateral spacing – the spacing, in feet, that the trees per acre would have when spaced equilaterally apart (also referred to as triangular spacing). The TPA values were derived from Cochran and others (1994). The BA and ES values were calculated using equations and were based on the TPA values.

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