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CHAPTER ONE

WATERSHED ANALYSIS OBJECTIVES

Watershed analysis is ecosystem analysis at the watershed scale. Federal agencies are directed to use an ecosystem management approach to manage public lands. The Record of Decision for Amendments to Forest Service and Bureau of Land Management Planning Documents Within the Range of the Northern Spotted Owl (1994 NWFP) recommends that watershed analysis be conducted within watersheds where timber management activities are being proposed, in order to understand the consequences of management actions *before* implementation. This is the reason for conducting the Lemolo Lake and Diamond Lake Watershed analysis.

The objectives of the Lemolo-Diamond Lake Watershed analysis are to:

☐ Develop a scientifically based understanding of the dominant physical, biological, and human processes and features and their interactions within the watershed.

☐ Use this understanding to sustain the productivity of natural resources in order to meet human needs and desires.

☐ Use this understanding to develop the basis to estimate direct, indirect, and cumulative effects of management activities.

☐ Relate these features and processes to those occurring in the river basin or province.

☐ Guide the general type, location, and timing of management activities within the watershed.

☐ Identify restoration and rehabilitation opportunities within the watershed.

☐ Establish a watershed context for evaluating project consistency with NWFP standards and guidelines for matrix lands.

☐ Establish a watershed context for evaluating project consistency with the Aquatic Conservation Strategy objectives.

☐ Establish a consistent, watershed-wide context for implementing the Endangered Species Act, including conferencing and consulting under Section 7.

☐ Establish a consistent, watershed-wide context for the protection of beneficial uses identified by the states and tribes in their water quality standards under the Federal Clean Water Act.

Watershed analysis is not a detailed study of everything in the watershed. Instead, it is built upon the most important issues which are discussed and prioritized in Chapter Three of this document. Watershed analysis is not a decision making process. It is not intended to take the place of detailed, site specific project planning and analysis under the National Environmental Policy Act (NEPA).

This watershed analysis report is a dynamic document. Additions or changes to this document may occur as new information becomes available. This is the first iteration of the Lemolo-Diamond Lake Watershed analysis.

CHAPTER TWO

CHARACTERIZATION

--

INTRODUCTION

The purpose of this chapter is to:

☐ Identify the dominant physical, biological, and human processes and features of the watershed that affect ecosystem function or condition.

☐ Relate these features and processes with those occurring in the river basin or province.

☐ Provide the watershed context for identifying elements that need to be addressed in the analysis.

☐ Identify, map, and describe the most important land allocations, plan objectives, and regulatory constraints that influence resource management in the watershed.

GEOGRAPHICAL LOCATION

The Lemolo Lake and Diamond Lake Watershed analysis area encompasses about 119,800 acres, of which 103,000 acres (170 square miles) falls within the Umpqua National Forest. The remaining acres are within the Crater Lake National Park. The watershed encompasses the eastern portion of the Diamond Lake Ranger District, including Lemolo and Diamond Lakes (see Figure 1, Vicinity Map). On the Diamond Lake District, the watersheds are located in all or portions of sections 22, 23, 25,26,27, 28, 29, 32, 33, 34, 35, 36, T25S, R6E; sec 31, T25S R7E; Sec 32, 33, 34, 35, 36 of T25.5S, R6E; Sec 31, 32, 33 of T25.5S R7E; Sec 9, 10, 11, 12, 13, 14, 15, 22, 23, 24, 25, 26 of T26S R5E; all sections of T26S R6E; Sec 4, 5, 6, 7, 8, 9, 16, 17, 18, 19, 20, 21, 27, 28, 29, 30, 31, 32, 33, 34, 35 of T26S R7E; Sec 6, 12, 27, 24, 25, 26, 34, 35, 36 of T27S R5E; all of T27S R6E;, sec 3, 4, 5, 6, 7, 8, 9, 17, 18, 19, 30 of T27S R7E; Sec 1, 2, 3, 10, 11, 12, 13, 14, 15, 16, 21, 22, 23, 24, 25, 26, 36 of T28S R5E; sec 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15, 16, 17, 18, 19, 20, 21, 22, 23, 24, 25, 26, 27, 28, 29, 30, 31, 32, 33, 34, 35 of T28S R6E; sec 2, 3, 4, 5, 6 of T29S R6E. Willamette Meridian, Douglas County, Oregon.

Figure 1. Vicinity Map of the Lemolo-Diamond lake Watershed Analysis Area.

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Figure 2. Land Allocations

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LANDSCAPE OWNERSHIP, ALLOCATIONS, AND MANAGEMENT OBJECTIVES

The entire watershed is public land administered by the USDA Forest Service or by the USDI National Park Service. All adjacent land is also administered by the USDA Forest Service. PacifiCorp has part of a hydroelectric project in the Lemolo Lake area.

The 1990 Umpqua National Forest Land and Resource Management Plan (LRMP) and the Northwest Forest Plan (NWFP) designate the watershed (Figure 2) as 22,100 acres of wilderness, 36,370 acres of Oregon Cascade Recreation Area, and 15,300 acres of riparian reserve. There are about 21,000 acres of matrix available for timber harvest, plus additional acres of matrix which are in riparian reserve and other designations which do not allow regular timber harvest. Matrix lands are to be managed primarily for timber production consistent with NWFP standards and guidelines and Aquatic Conservation Strategy objectives. The LRMP allocates the watershed by Management Areas. Management Area 2 is the area around Diamond and Lemolo Lakes dedicated to developed recreation, Management Area 3 is dedicated to future winter sports on Mt. Bailey, Management Area 4 is wilderness, Management Area 5 is the Oregon Cascades Recreation Area. Management Area 6 provides for the protection and enjoyment of remarkable designated special interest areas such as Crystal Springs. Management Area 10 objectives focus upon producing timber on a cost efficient, sustainable basis consistent with other resource objectives. Management Area 11 has the dual objectives of timber production and wildlife habitat. There are about 3700 acres in the watershed which were formerly included in the Mt. Bailey roadless area and are in matrix. There are about 2300 acres of the former Thirsty appendage in the watershed. These areas were not considered to be roadless in character, and were not designated as roadless area in the 1990 LRMP.

Table 1. Land Allocations

Concentrated Developed Recreation	8,400 acres
Oregon Cascades Recreation Area	36,400 acres
Special Interest Area	177 acres
Semi-Primitive Unroaded Recreation	6,600 acres
Mt. Thielsen Wilderness	22,700 acres
Matrix (Sustained Harvest)	29,300 acres
Riparian (overlain in all above)	15,300 acres

CORE TOPICS

GEOLOGIC FEATURES/GEOMORPHIC PROCESSES

The Geology of the Upper Lemolo/Diamond Lake Analysis Area (LDLWA) was included in the detailed geologic mapping by David Sherrod as part of his dissertation (Sherrod 1986). This information was incorporated into the Umpqua Revised Geology Layer as part of the corporate GIS system. While it is recognized that some resolution was affected as a result of the manuscript process, the analysis team felt that the level of information available was adequate.

Regional Geology and Tectonic Setting

Plate tectonic processes which have occurred within the Cascadia province have resulted in the highly diverse landscapes seen today. The deeply eroded and weathered Western Cascades, and the striking peaks and highlands of the High Cascades physiographic sub-provinces are both represented within the analysis area.

The volcanic deposition of the Western Cascades began about 40 million years ago and underwent numerous periods of deposition and erosion which resulted in a series of peaks, ridges, and valleys. It is assumed that the ancestral North Umpqua valley was developed during this period. About 5 million years ago, the rock assemblage presently known as the Western Cascades was subjected to accelerated and differential uplift throughout the province. As a result, drainage systems became deeply entrenched, creating a highly dissected mountainous landscape.

The volcanic activity about 1 million years ago is typically considered the beginning of the High Cascades rock assemblage. These rocks are believed to be in contact with the older Western Cascades along a predominantly north-south orientation. The Rogue Fault, discussed in the Upper Clearwater Watershed Analysis, is the identifiable boundary just west of the analysis area. The construction of a number of composite volcanoes such as Mt. Thielsen and Mt. Bailey predominated the landscape during this period.

The glacial events of the past 1-2 million years affected topographic features in both erosional and depositional environments. The Western Cascades in the Upper North Umpqua show evidence of glacial erosion, however the more predominant feature are glacial deposits, typically as till on the mid-upper slopes of the ridges. About 7000 years ago, the formation of the caldera associated with the eruption of another composite volcano, Mt. Mazama, resulted in the deposition of unconsolidated tephra (pumiceaous material) over a widespread area.

Localized Geology

The following map (Figure 3) portrays the relative distribution of geologic units throughout the planning area.

Geologic Units of the Upper Lemolo, Diamond Lake Watershed Analysis Area

The watershed analysis area has several map units of Western Cascade rock units along the western perimeter. These rock units are all part of the Mid-Miocene Volcanics (TWB) and are basalts that have been aged between 10-15 million years (Sherrod 1986). The predominant locations include Elephant Mountain and the area known as Bunker Hill. Although these areas are relatively small features in the larger landscape, they do represent the oldest rock types in the area.

Figure 3. Geoterrain

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The most predominant rock type found in the southern High Cascades is identified as Qyba, which is a mix of Andesites and Basaltic Andesite, that were extruded as relatively thin flow events from numerous vents which developed during the construction of the High Cascade Composite Volcanoes. Although this rock unit is exposed in only about 10 percent of the analysis area, Sherrod (1986) suggests that this rock unit underlies most of the area that is currently covered by the various surficial deposits. In addition to the Qyba unit, there are a number of other andesitic and basaltic units that are indistinguishable in casual observation. Laboratory analysis and age dating are the predominant means of discerning the mineralogy of lava flows.

Several significant features in the Lemolo/Diamond Lake area are associated with the basaltic andesite terrain. Most noticeable of these is the east flank of Mt. Bailey, as well as Rodley Butte and Hemlock Butte which are all located on the western side of the analysis area. These lava deposits are thought to be some of the younger rocks in the High Cascades based on limited glacial erosion and scattered age dating.

The andesitic and basaltic flow rocks that underlie the analysis area were deposited under relatively mild tectonic conditions, which are reflected in the gentle to moderate slopes and low relief topography. The role of these units associated with groundwater storage and transport is not well understood, other than the general acceptance that these units have high permeability and porosity which lends itself to rapid infiltration and low release. The enormous contribution of these rocks to the North Umpqua River has been suggested for a number of years, however little research has occurred to quantify the assumptions. Sherrod, in his dissertation, suggested that the thickness of these deposits may exceed 1200 meters in the vicinity of Mt. Thielsen. Even with half this thickness, the amount of available storage for groundwater would be substantial.

Along the eastern flank of the watershed, a number of topographic features predominate the landscape. The most prominent and photogenic is Mt. Thielsen, often typified as “the Lightning Rod of the Cascades”, due to the orographic influence and predilection for lightening strikes. The geologic map unit Qtmv corresponds with a number of peaks and promontories throughout the eastern slope of the basin and includes other landmarks such as Howlock Mountain, Cinnamon Butte and Tipsoo Peak. This rock unit underlies less than 1 percent of the area but the local influence on the ecological as well as social conditions is significant.

This rock unit is predominantly a near vent deposit of pyroclastics, cinders, scoria and lava flows that suggest the core of volcanic activity. The amount of erosion and weathering processes have corroborated to develop the skyline exhibited today. When viewed from a distance, it appears that these peaks are the source of the large volcanic deposits which surround them. Upon closer evaluation however, these are relatively small volcanoes that developed on much larger and gentler volcanic deposits over short periods of geologic time (Sherrod, 1986).

Surficial Deposits

Much of the watershed analysis area is covered by unconsolidated or slightly indurated deposits of various origin. Some of these deposits are characteristic of the modern climatic conditions and include, landslide, stream and colluvial deposits. Other material such as glacial drift and outwash correspond to distinct climatic episodes. The most significant surficial deposit in the Southern High Cascades is the Holocene tephra erupted during caldera formation associated with Mt. Mazama. An additional surficial deposit identifiable in the vicinity of Diamond Lake is a lacustrine (lake) deposit that partially surrounds Diamond Lake. Due to the nature of deposition and unique landscape features, these three types of deposits will be discussed separately.

The glacial till, drift and outwash was grouped into the map unit Qgd for this effort, based on Sherrod's (1986) information. This material is typically poorly sorted clastic sediments, consisting of a grayish sand and clay matrix, and sub-rounded pebbles, cobbles and occasional boulder deposits. The weathering characteristics of these large deposits result in a landscape littered with stones of various sizes reflecting the volcanic sources of the area. Approximately 25 percent of the analysis area is covered with some type of glacial deposit.

There is a large variation in the ages of the glacial deposits evident in the geologic record. In the vicinity of the Lemolo Dam, the glacial tills are covered by the Pleistocene lava flows, which appear to have an age between 250,000 and 730,000 years. In the vicinity of Cinnamon Butte, the glacial deposits are covered by lava flows estimated to be 10-15,000 years in age. Based on these types of observations, Sherrod (1986) suggests that several distinct episodes of glacial advance and retreat sculpted the landscape of the area.

There are two large and distinct glacial deposits evident in the Lemolo/Diamond Lake Analysis Area, that appear to be similar. The highlands north of Crystal Springs and east of White Mule Creek are dominated by a large glacial deposit characterized by low relief and a very low stream density.

The other significant glacial deposit is found on either side of Diamond Lake and is roughly parallel with the present channel of Lake Creek. The glacial striations present on basalt outcrops on the northwest side of the lake, coincide with the presumed direction of the glacial advance. Based on the widths of the glacial deposit, there is speculation that a much larger valley feature was created during the glacial period and subsequently filled with glacial outwash and debris during the later episodes. The topographic feature that divides the Upper Clearwater watershed and the west side of Diamond Lake is a glacial deposit which resembles a lateral moraine. Discussions with David Sherrod and limited field investigations suggest that there may be some connection of the groundwater regimes between these hydrologic basins at depth.

The development of the present channel that is known as Lake Creek reflects a strong influence by glacial deposits. These can be seen as the topographic high points in monotonous ash terrain. It is probable that the present drainage of Diamond Lake is controlled by the underlying glacial features beneath the ash-flow deposits.

A large area to the north and east of Diamond Lake is overlain by an air-fall tephra deposit identified as map unit Qpf. These tephra deposits (Pumice) are associated with volcanic events which led to the formation of the Crater Lake Caldera. This deposit thickens rapidly to the south-east and buried much of the underlying rock units to depths in excess of 20 meters (Sherrod 1986, Bacon 1983). These air fall deposits are typically pale gray in color and weather to a pale orange color when exposed. The largest fragments exceed 15 cm, however the average is 2-4 mm and is often termed popcorn pumice. Although this Surficial Deposit covers less than 25 percent of the analysis area, its importance in the groundwater hydrology is believed to be substantial.

Immediately after the air-fall events, the eruption of ash-flow deposits occurred. These deposits identified as map unit Qaf were pyroclastic flow deposits consisting of unsorted ash with up to 30 percent of the deposit as pumice lapilli bombs up to 40 cm across. Typically, the upper 2-3 meters of the deposits are grayish pink in color. Evaluation of modern ash-flow deposits around the Pacific rim indicate temperatures in excess of 2,000° C as these ash-flows are traveling down the slopes. Charred organic material can be observed throughout the area.

These pyroclastic flow deposits form the floors of the valleys and the sharp contact of the deposits along the valley walls suggest that they were controlled by topography during the depositional period. The deposits in the vicinity of Diamond Lake ponded to depths of 12 meters (Purdom, 1963), however its unclear how much of this is related to reworking and secondary deposition.

A minor component of the geologic record are a number of localized ash-cloud deposits scattered through out the High Cascades. These are explained as isolated deposits, often as deep as 3 meters that are separated by large topographic features from the ash-flow deposits. They are similar in composition, however they contain much smaller particle sizes. Examples of these deposits are found on the northwest slope of Hemlock Butte, along the lower reaches of Thielsen Creek and near the west side of the analysis area adjacent to White Mule Creek.

The map unit Qal is a lake shore and lake bed deposit of unconsolidated, thinly bedded, sand sized material of Mazama tephra composition. The best exposure of these sands is on the northwest shore of Diamond Lake, where 2 meters of it overlie the pyroclastic ash-flow features. These deposits can be found as high as 8 meters above the present elevation of Diamond Lake. The sand also is present above the glacial deposits on the southern shore of the lake, which serves as riparian habitat and presently is an active riparian marsh.

Sherrod (1986) suggests that these sand deposits formed in a lake environment after the Mazama eruptions, with a much larger lake shore than is evident today. Based on this hypothesis, additional field work was completed, which appears to support the evidence. A number of drill logs were reviewed as part of this process and the information appears to substantiate the idea that the deposits are reworked sands and up to 100 feet in depth.

The interpretation that the present lake feature was created with the eruptive events is supported by the shallow depth of the lake and the greater thickness of ash-flow deposits on the western shore. The outlet of present day Diamond Lake is a bedrock spillway associated with a basalt feature. Immediately west of the outlet, an ash-flow deposit 0.5 km across can be found on the north shore. Sherrod (1986) suggested that the pyroclastic flows may have choked the stream that drained “Diamond Valley”, damming the original effluent and creating a closed basin with a much higher lake level than exist today. As this dam was breached, the bedded lacustrine sands were deposited. Although additional work is necessary to substantiate the hypothesis of the origination of Diamond Lake, an obvious correlation can be seen in the composition of the current shoreline.

Although Sherrod (1986) defined the area overlain by the Qal sands, he was unable to determine the extent of this deposit. In evaluating the adjacent slopes below Mt. Bailey in light of glacial erosion, there was speculation that the lake deposits were quite deep and thickened to the west. A review of over 20 water well logs along the west shore as well as a minimal amount of subsurface exploration suggest that the these sands extend well below the present elevation of the lake (50-100 feet) and prior to the Mazama event Diamond Valley exhibited much more topographic relief.

Geomorphic Processes

Several significant geomorphic processes are evident in the watershed upstream from Lemolo Dam. As discussed in the Watershed Analysis for the Upper Clearwater River, the importance of the contribution of groundwater to the North Umpqua River from this area has been recognized for years. The importance of erosional processes in this analysis area is proportional to the age of the material and the transport mechanism. Based on field review and aerial photographic analysis, it appears that the potential for mass wasting is limited and very localized in nature. Based on these observations as well as consultation with the Watershed Analysis Team preparing the North Umpqua Relicensing Watershed Analysis, the discussion of erosional processes will focus on surficial erosion.

The high volume and water storage capacity of volcanic rocks in the High Cascades is well documented in the literature (Ingebritsen et al. 1994) however, the relationship of surface to subsurface flow is not well understood. There are several geologic features that contribute to this phenomenon. The porosity and permeability of the relatively young rock units does not appear to be altered by weathering or metosomatic processes to any great extent. The uniform mineralogy of the andesites and basaltic rocks allow for a large volume of material with relatively uniform storage capacity. In addition, the common occurrence of joints and fracture patterns associated with these rock types provide the opportunity for rapid infiltration and migration of surface water vertically as well horizontally over wide areas. Another factor that appears to be affecting the groundwater is the lack of drainage development in these extremely resistant and youthful rock units. Low drainage densities in these rock units correlate well and support the concept identified in other areas that the water regime is predominantly controlled by groundwater.

Although the ability to store and release the large volume of water for extended time periods is dominated by the underlying volcanic rock units, the overlying surficial deposits play an important role in the evolution of riparian and riverine features.

The glacial deposits discussed in the earlier section were evaluated in terms of spring development as well as channel conditions. In general, these features have very few perennial streams that have developed, although on the upper slopes, streams are observable near the glacial/bedrock contacts. Although the total stream miles on these landscapes is low the extensive springs that emerge along the margins of these glacial deposits are a significant source of the total flow of the North Umpqua River. The Spring River emanates from a contact of Ash Flow deposits and Glacial Outwash near the mouth of Lake Creek and provides a large contribution, particularly during the summer and fall. On the upstream side of Lemolo Lake, a number of large springs coalesce and are know as Crystal Springs. These are unique in that the flow appears to be influenced by the abutment of the Mazama Ash Flow and are forced to flow east to join the North Umpqua River above Lemolo Lake.

The LRMP addresses the concept of the North Umpqua River aquifer and its importance for high quality and quantity of water. Standards and Guidelines number Five under Watershed Cumulative Effects and Water Quality discusses and identifies a number of soil units that have the potential to be affected by certain management scenarios. Upon additional review and discussion, it appears that the role of the soil types is less certain, and research suggest that the underlying volcanic rocks are the controlling factor in the development of the aquifer. Under this assumption, there would be a significant increase in the lands associated with aquifer development based on available geologic mapping (Sherrod 1984). Under the inventory system developed in the LRMP, about 33 percent of the analysis area is underlain by aquifer terrain. From a geomorphic perspective its estimated that upwards of 75 percent would be included.

The erosional processes in the analysis area can be viewed in four distinct categories, lake shore erosion, channel erosion, hill slope erosion and road related erosion. Although the effects of the various erosional processes are substantially different, each is important to address.

SOIL

Watershed Soil Development and Parent Material

Soil development is based on five factors, Geology/Parent Material, Geologic Time, Climate, Topography, and an Organic component (i.e. vegetation, microbes, insects and animals). Most of the soils within this watershed are relatively young and poorly developed, with an approximated age of 7000 years; the exception being older glacially derived soils. The soil parent material of the watershed is derived from a mix of glacial activity and volcanic eruptions, most notably from Mount Mazama. The surface of almost all of the soils is covered by either air-fall ash or pyroclastic flow from Mazama.

Identifying the soils of the Watershed

To create soil delineations in the watershed, the Soil Resource Inventory (SRI), Geologic mapping (Sherrod 1986), Environmental Unit Inventory (D.Morrison, personal communication) and data from 28 soil pit descriptions were used.

Within the watershed 32 soil-types are identified in the SRI; 13 are separate soil types (consocations), and 19 are combinations (complexes) of individual soils. The consocations include, talus slopes, cinder cones, two types of rock outcrops, a wet non-forest soil, and eight other developed volcanic soils of various texture, drainage and depth. Rather than creating a separate text on the numerous soils within the watershed, the following three generalizations were made to provide a practical means of describing the soil present. Each group is intimately related to the geology and vegetation patterns present.

The first group is designated as 4e-1. The soils within this group are moderately deep (three to six feet) and deep (six to eight feet) on gentle slopes ($\leq$35 percent) and are generally shallow (≤ three feet) on steeper slopes (≥ 60 percent). The textures in this land unit ranges from sandy pumice to loamy sand and sandy loams, derived from ash flow, ash fall and glacial activity. Aggregate structure is weak, fine and medium granular aggregates to structureless fine, medium and coarse single grain sands of pumice and ash. Typically associated with mountain hemlock *(Tsuga mertensiana)* this soil type is found throughout the watershed and covers the largest area, from high elevations to flat surfaces along the eastern half of the watershed. Associated geology is dominated by Qaf, Qpf and Qgd geologic units.

The second group is designated as 4e-2. Depth of this soil group is also deep on gentle slopes (≤35 percent) to shallow on steeper slopes (≥ 60 percent). Texture of these soils is loamy sand and gravely loamy sand to sandy loam. Structure is weak, very fine and fine granular aggregates to moderate medium subangular blocky peds or clods. The improved soil structure and moisture potential of this soil group are in direct proportion to the glacially derived material and buried glacial till present. Typically associated with white fir *(Abies concolor)* this soil group is found in relatively flat portions of the watershed like White Mule Creek, Crystal Springs and north of Diamond Lake along Lake Creek. Associated geology are mostly Qaf and Qgd geologic units

The third group is designated as 4e-3. This soil group is deep to very deep (≥12 feet), typically found on broad flat expanses and terraces with gentle slopes (≤35 percent). The texture of these soils are loamy fine sands to coarse sandy pumice. Soil structure is typically structureless single grains to coarse sands. This group is typically associated with lodgepole pine *(Pinus contorta)* which grows in cold air drainage and wet areas of the watershed. This soil is found typically near Diamond and Lemolo Lakes. In some locations this soil group has reddish accumulations on soil ped surfaces that appear to be oxidized iron. The presence of the iron coated peds may indicate a fluctuating water table. The presence of a fluctuating water-table has yet to be confirmed beyond visual indications of oxidized iron. Associated geology are dominated by the Qaf and Ql geologic units.

The primary reason for the vegetation differences in this watershed are drainage changes and plant available water. These factors are driven by textural variance in the soil and their overall permeability. With an increase in soil structure derived from humus and finer textures, such as is found in the glacially derived soils, plant available water is buffered from loss. In the excessively well drained soils only the most tolerant vegetation species are present. For example in the ash flow soils near Diamond Lake only lodgepole pine *(Pinus contorta)* is present. The available water present in these soils is mostly held at the contact of particles in the soil, as shown in Figure 4. The plant available water in sands found in the watershed is quickly used by plants or turned to vapor, drying the soil with the onset of summer. Plants that are not drought tolerant tend to grow near streams or in soil that has glacial influences.

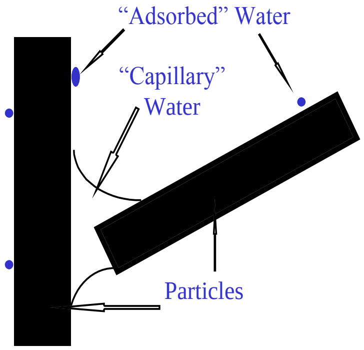


Figure 4. Diagram of Adsorption and Capillary Effect in Sandy Soils (Depiction adapted from Hillel 1980.)

Soil desiccation is not the only problem in this watershed. In the soil group associated with lodgepole pine *(Pinus contorta)* there are reddish accumulations at a depth of 40 to 60 inches that may be evidence of a fluctuating water-table. It is theorized that large pores associated with these soils provide easy access for a rising water-table during snow melt or heavy rains. The combination of the droughty or excessively drained soil and a fluctuating water table in areas near Diamond and Lemolo Lakes may have resulted in the dominance of lodgepole pine *(Pinus contorta)*. The presence of a fluctuating water-table has yet to be confirmed beyond the visual indications of reddish accumulations.

The soils of this watershed are weak, fine aggregates and fine to coarse sands. The sandy texture of the watersheds soils allow for a high rate of infiltration in their natural state. The natural bulk densities of these soils range from 0.55 g/cm^3 to 0.75 g/cm^3. The high rate of infiltration prevents surface flow that could cause erosion of these non-cohesiveness soils. Unfortunately, some past practices may have decreased the high rates of infiltration through compacting the soil of harvest units. Compaction of the soil occurred with ground-based harvesting that provided no designated skid roads and multiple passes over the soil, most noticeable in the units harvested before the 1970s.

Certain harvest sites show signs of excessive alteration. A good example is a harvest area near Lake Charline in the north portion of the watershed. Harvested in 1960s, these units show compaction that has remained after 30 years. The disturbance begins four inches below the mineral surface of the soil and extends down into the profile 12 inches. To determine if this was a natural occurrence a description pit was dug outside the unit and no compacted layer was present.

The level of compaction can be controlled with the use of designated skid roads, fewer passes from equipment, and recognition that volcanic soils do compact.

HYDROLOGY

The North Umpqua River above the Lemolo Lake drains approximately 187 square miles of the North Umpqua River Watershed. The North and South Umpqua Rivers flow from the crest of the Oregon Cascades to the Pacific Ocean. They drain roughly a quarter and a third, respectively, of the 4,560 square-mile Umpqua River basin, but the North Umpqua River summer flow is ten times that of the South. Flow of 750 cubic feet per second (cfs) of the North Umpqua joins 80 cfs from the South Umpqua below Roseburg, and 970 cfs flow past Elkton through the Coast Range to the ocean (1-day, 2-year low flows).

The North Umpqua River is famous for its summer steelhead and spring chinook, and the high summer flow that attracts them. Just below the Lemolo Lake the North Umpqua River flows over 400 cubic feet per second during the summer of most years, about two-thirds of the flow where it joins the Clearwater River at Toketee Lake. People recognized long ago that most of the North Umpqua River flowed from the High Cascades above Soda Springs, and stream gages were installed in the 1920s. Constant flow provided hydroelectric power, and Pacific Power's Clearwater, Upper North Umpqua, and Fish Creek diversions were built in the early 1950s. Since then, 90 percent of the Upper North Umpqua has flowed through a canal beginning at Lemolo Lake diversion to Lemolo I powerhouse at the mouth of Warm Springs Creek. From Lemolo Lake, about 33 cfs remains in the North Umpqua, with more than 365 cfs diverted into the open canal.

The Upper North Umpqua River flow depends on both snowmelt and rain falling on the entire watershed above Lemolo Lake. Measured annual precipitation in the watershed ranges from 50.3 inches at Diamond Lake (within Mt. Bailey's rain shadow) to 64.1 inches at Lemolo Lake. Figure 5 and Figure 6 show that maximum precipitation occurs in November and December predominantly as snow, but with rain intermittently falling on low elevation portions of the watershed (generally less than 5,000 feet). Precipitation minimums occur during July and August.

Annual river flow of the North Umpqua below Lemolo Lake (306,500 acre-ft/yr) equates to 30 inches of runoff, or 47 percent of the precipitation assumed to be falling on the drainage. Lake Creek's annual flow (at Diamond Lake, 41,510 acre-ft/yr) equates to 12 inches of runoff, or 24 percent of the precipitation. These annual flow values are much lower than those found in other gaged drainages in the North Umpqua River basin above Copeland Creek. For example, the Clearwater River (a mix of both High Cascades and Western Cascades geology) and Fish Creek (predominantly Western Cascades) have annual flows which equate to 56 and 47 inches of runoff, or 87 and 73 percent (both respectively) of the precipitation at Lemolo Lake. The lower values found in the North Umpqua River and Lake Creek are likely a result of the watershed predominantly being within the High Cascades geology, which stores large volumes of water, releasing less than 50 percent to surface runoff on an average year. Additionally, Diamond Lake and Lemolo Lake likely increase water infiltration and percolation into the permeable surficial and underlying bed rock material due to the increase in time that water is in contact with this material when groundwater levels are low.

Figure 5. Climatological data at Lemolo Lake (mean monthly precipitation data from 1978-96 and mean monthly temperature data from 1978-95, from U.S.D.A. Forest Service 1997b).

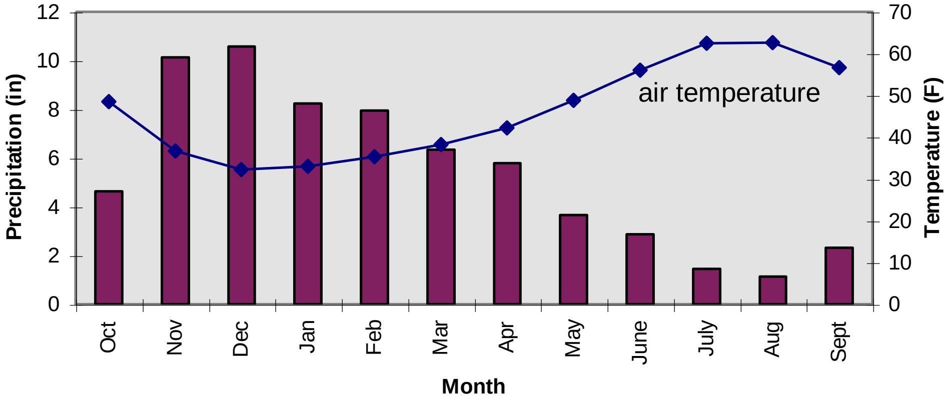
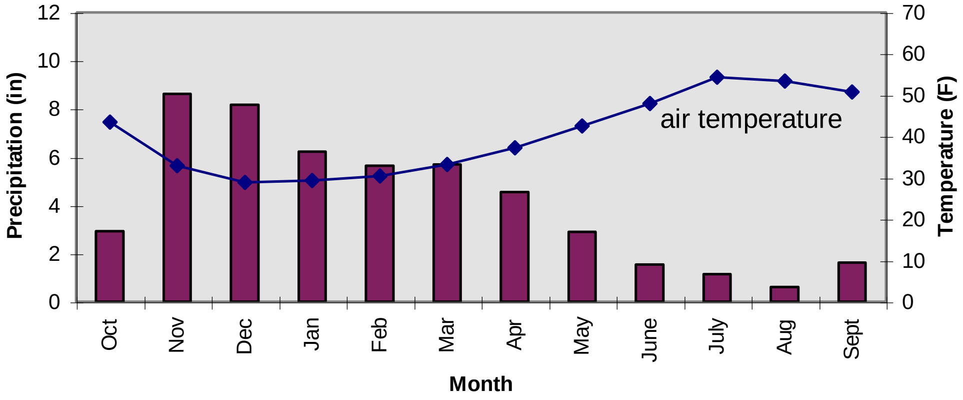


Figure 6. Climatological Data at Diamond Lake (mean monthly precipitation data from 1980-96 and mean monthly temperature data from 1987-96, from U.S.D.A. Forest Service 1997b).



In most years, it appears that spring snowmelt provides the highest flow of the year which occurs typically in May and June (Figure 7). However, the largest floods have been caused by storms that bring rain and melt snow in mid-winter. The North Umpqua River and its tributaries are largely spring-dominated channels draining relatively young, deeply fractured basalt in the High Cascade geology. The resulting flow regime is gentle and constant from watershed streams with little change from summer to winter, keeping the river cool in summer and greatly diminishing winter floods. Still, the record flood flow of December 1964 (4,680 cfs) was twelve times the usual summer low flow.

Lake Creek typically experiences peak monthly flows during the winter months of December through February and a secondary peak in June (Figure 8). Since most of the precipitation, in the Diamond Lake drainage, occurs in the form of snow, groundwater is supplied by spring snowmelt. This annual input of water is assumed to recharge an unconfined aquifer and feed spring-dominated channels. Thus the height of the water table will increase following spring snowmelt, and variations in the level of this free surface will cause flow (Manga 1996).

Whiting and Stamm (1995) determined that groundwater-dominated channels typically have a long lag between precipitation and snowmelt, and streamflow response. This study found peak discharge, occurring during late summer and fall, to be delayed from spring snowmelt by at least four months, and potentially greater than a year, in a southern Oregon stream. It appears that Lake Creek may experience a similar lag time of about seven months. The secondary peak in June corresponds with a rise in air temperature and subsequent snowmelt and rain-on-snow melt events. These events may occur when the water table is at a level at which direct runoff results. Whether the North Umpqua River is responding to direct runoff due to spring snowmelt or is experiencing a lag time of about one year is difficult to determine. Recent studies by Whiting and Stamm (1995) and Manga (1996) suggest that the latter theory is most likely the prevailing process of these groundwater-dominated systems.

Figure 7. Comparison of mean monthly adjusted flow of the North Umpqua River below Lemolo Lake (1968-1996) and mean monthly precipitation at Lemolo (1978-1996) (U.S.D.A. Forest Service 1997b).

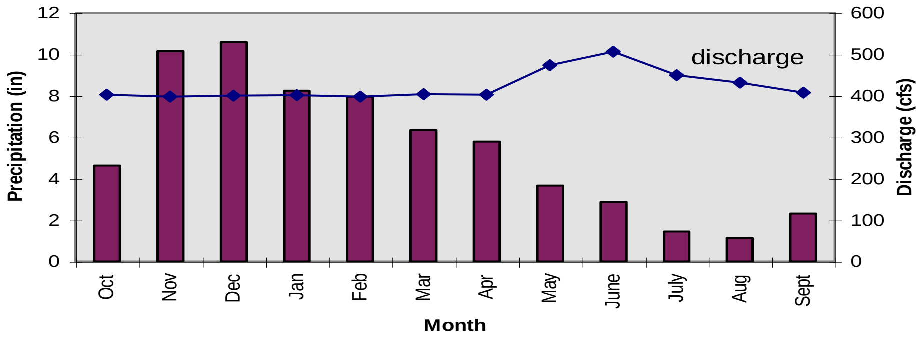
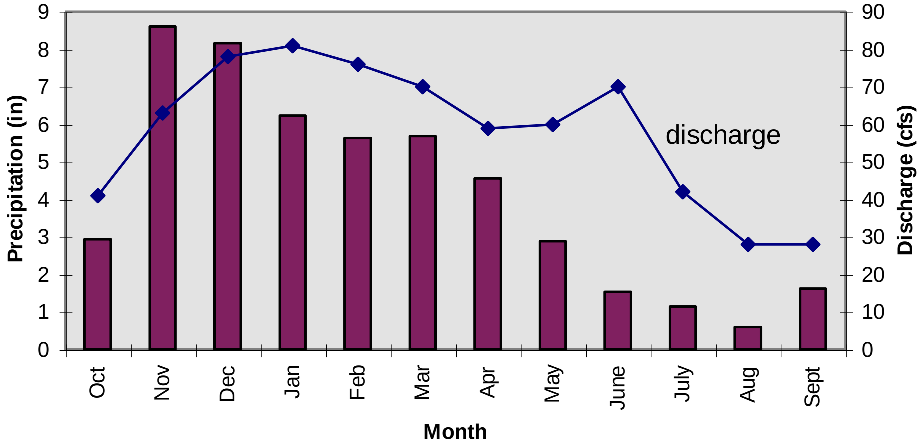


Figure 8. Comparison of mean monthly flow of Lake Cr. at Diamond Lake (1923-1984) and precipitation at Diamond Lake (1980-1996).



Water Quality

Beneficial Uses

Beneficial uses designated by Oregon's Department of Environmental Quality (ODEQ) for the North Umpqua River drainage above Lemolo Lake (including Diamond Lake) are inclusive of the following: water contact recreation, domestic water supply, aesthetics, and aquatic life. Lake Creek (from Diamond Lake to Lemolo Lake) has been identified by ODEQ's 303(d) list as water quality limited due to high summer stream temperatures. Oregon's Water Quality Status Assessment Report 305(b) (1994) estimated that the beneficial uses of aesthetic and aquatic life, in both Diamond Lake and Lemolo Lake, are being only partially supported since both water bodies were determined to exceed State standards for both pH (6.5 to 8.5) and algae (chlorophyll α: 15µg/L). Furthermore, both Diamond Lake and Lemolo Lake have been identified as water quality limited on ODEQ's 303(d) list due to algae and pH.

Water Quality Criteria Necessary to Protect Beneficial Uses

The Environmental Protection Agency (EPA) regulations require each state to adopt an antidegradation policy as a component of its water quality standards. The objective of the antidegradation policy is that as a minimum, existing water uses and level of water quality necessary to protect the existing uses, shall be maintained and protected. The following standards found in ODEQ's 1994/1996 303(d) List of Water Quality Limited Water Bodies & Oregon's Criteria Used for Listing Water Bodies, need to be applied to all water bodies within the project area to maintain beneficial uses:

Sedimentation: The formation of appreciable bottom or sludge deposits or the formation of organic or inorganic deposits deleterious to fish or other aquatic life or injurious to public health, recreation, or industry shall not be allowed.

Dissolved Oxygen: Dissolved Oxygen concentrations shall meet the following during times and in waters that support salmonid spawning until fry emergence from the gravels:

- Dissolved oxygen (DO) shall not be less than 11 mg/l; unless
    - intergravel dissolved oxygen is greater than 8.0 mg/l (as a spatial median minimum), then DO criteria is 9.0; or
    - where conditions of barometric pressure, altitude and naturally occurring temperatures preclude attainment of the 11 or 9 mg/l standard, then DO levels shall not be less than 95 percent saturation.
- Spatial median minimum intergravel dissolved oxygen concentrations shall not fall below 6.0 mg/l.

Aquatic Weeds or Algae: The development of fungi or other growths having a detrimental effect on stream bottoms, fish or other aquatic life, or which are injurious to health, recreation, or industry shall not be allowed.

Flow and Habitat Modification: Waters of the State shall be of sufficient quality to support aquatic species without detrimental changes in the resident biological communities.

Biological Criteria: Waters of the State shall be of sufficient quality to support aquatic species without detrimental changes in the resident biological communities.

Water quality standards needed to protect beneficial uses found in the Umpqua National Forest Plan are as follows:

Water Quality and Riparian Areas Standards and Guidelines

Standard 12: The application of the Best Management Practices for the protection of water quality and beneficial uses (fish habitat or potable water, for example) will be monitored on ground disturbing activities.

Watershed Cumulative Effects and Water Quality Standards and Guidelines

Standard 2: Beneficial uses of water and aquatic habitats will not be degraded by turbidity, sediment, or scoured stream channels caused by timber harvest, road construction, and related activities...

Standard 4: Beneficial uses of water and aquatic habitats will not be degraded by increased peak flows and resulting channel scour, caused by timber harvest, road construction, and related activities...

Standard 5: Infiltration of snowmelt and rain should not be decreased on deep pumic soils common to the North Umpqua River aquifer...

Critical Water Quality Parameters

Stream temperatures in the watershed are within State standards (as indicated by numerous "grab" samples and district monitoring) with the exception of Lake Creek. However, since Lake Creek drains from the warm epilimnion (upper) layer of Diamond Lake, stream temperatures warmer than the typical system stream are expected. The current stream temperature regime is not likely to have been altered from natural conditions. Overall, perennial streams in the watershed are characterized by cool groundwater discharge flow which diminishes little through the summer. With the addition of largely undisturbed riparian zones, stream temperatures are generally cold through the summer. For instance, maximum summer water temperatures in the North Umpqua River get to about 50 degrees Fahrenheit (50°F) at the outlet of Lemolo Lake.

Nitrogen and phosphorous concentrations in the North Umpqua River are highest in summer and fall, when flow is lowest. These nutrients are used by floating and attached algae, which can cause high and low daily swings of pH and dissolved oxygen downstream. The North Umpqua River sometimes exceeds water quality standards for pH, both above Toketee Lake and downstream in the Wild and Scenic River Reach. Approximately 200 feet downstream from the Lemolo Lake, pH did not exceed the Oregon Department of Environmental Quality (ODEQ) standard of 8.5 in 1993 when monitored by PacifiCorp (1995b). In Lake Creek, pH was found to approach the ODEQ standard, with a value of 8.4 in 1994 (PacifiCorp, 1995b). Dissolved Oxygen (DO) in both the North Umpqua River (1993) and Lake Creek (1994) exceeded the ODEQ lower limit of six milligrams per liter (mg/l) for DO concentrations taken within channel substrate.

Although groundwater has high concentrations of phosphorus in the High Cascades, nitrogen apparently limits growth of algae in the North Umpqua River. While the North Umpqua River dissolved nitrogen is low, small increases from erosion, fire, timber harvest, fertilizer, or Lake storage and hydropower operations might cause increased algae growth and water quality changes downstream.

LAKES

LEMOLO LAKE

Physical Habitat

Climate

The climate of the Lemolo Lake area is moist maritime with wet, mild winters and dry summers. Average annual precipitation in the North Umpqua Basin ranges from 33 inches (86 cm) at lower elevations to 74 inches (188 cm) at higher elevations (Radtke and Edwards 1976 cited in Bonoff 1996). Annual precipitation at Lemolo Lake is 64.1 inches (163 cm) (Abbott 1997). Approximately 80 percent of annual precipitation occurs from October through March. A snow pack generally persists through the winter above 3,000 ft elevation.

Most of the data used in this analysis were collected during the period 1992 through 1994. With the exception of 1993, extremely dry conditions prevailed in the project area during this period. Precipitation near Lemolo Lake was 15 inches below average in 1992, but 23 inches above average in 1993 (PacificCorp 1995a).

Morphometry

Lemolo Lake, located in the Umpqua National Forest 75 miles east of Roseburg, Oregon, and 16 miles north of Crater Lake National Park, is the largest reservoir in the North Umpqua Power Development Project (Johnson et al. 1985, Bonoff et al. 1996). The watershed above the lake is variously described as 185 sq. mi. (Abbot 1997) or 170 sq. mi. (Johnson et al. 1985, PacifiCorp 1995a).

The reservoir was formed in 1954 behind a 120 ft (37 m) rock fill dam. At full pool (elevation 4,148 ft) the reservoir covers 435 acres (170 ha) with a maximum depth of approximately 98 feet (30 m). Although the lake is approximately 30 m deep near the dam, the average depth is only 9 m at full pool (Johnson et al. 1985). Drawdown in the winter reduces the area and volume to about 51 acres (20.7 ha) and 670 ac-ft respectively (PacifiCorp 1995a).

Hydrology

The inlets to Lemolo Lake include the North Umpqua River, Lake Creek (which drains Diamond Lake), and Poole Creek. Outlets from the lake include the intake to the Lemolo No. 1 waterway, the intake to the North Umpqua River, spillway valves at the base of the dam, and a surface spillway at the dam (Bonoff et al. 1996). Because of the porous pumice soil of the region, it is possible that groundwater flow is important in the hydrology of the lake, but no data are available to quantify this element. Water originating in Diamond Lake, Lake Creek and the sewage stabilization ponds serving the Diamond Lake resort and campgrounds may travel as groundwater, emerging in the Spring River upstream of Lemolo Lake (PacifiCorp 1997b).

The flow in the North Umpqua River measured during the base flow period (June-September) in 1993 was about 270 cfs of which 90 percent was contributed by the Spring River. Together the Spring River and the North Umpqua River usually provide in excess of 290 cfs to Lemolo Lake during the summer months (PacifiCorp 1995b). Because of the heavy contribution of springs, flow in the North Umpqua tends to be relatively stable throughout the year.

Lake Creek originates as outflow from Diamond Lake, and flows approximately 10 mi. north to Lemolo Lake. During the base flow period of the summer in 1993 (June-September) Lake Creek contributed less than 10 percent of the total inflow to Lemolo Lake (15-30 cfs). Flow in Lake Creek varies considerably with precipitation and runoff. Flows during October and November 1992 were estimated to vary between 10 and 100 cfs (PacifiCorp 1995, Vol. 3).

Operation of the project changes the elevation of the lake on a seasonal basis. Typically the lake is held at approximately full pool during the summer. The reservoir is drawn down during the fall and operates at a lower level until spring. The reservoir fills during April, May, and June. Typical water surface fluctuations are between 0.1 and 1 ft per day, but may be as great as 2 ft per day. The extremes of record are 14,000 ac-ft at elevation 4,149.5 ft on December 24, 1964 and 11 ac-ft at elevation 4,055.4 ft on March 5, 1955. In 1996 (water year) the maximum pool was 13,410 ac-ft at elevation 4,148.5 on May 16, and the minimum pool was 5,910 ac-ft at elevation 4,126 ft on November 22 (Hubbard et al. 1997).

Discharge from Lemolo Lake is distributed to the North Fork Umpqua River channel and the Lemolo 1 power canal. The power canal has a capacity of 565 cfs. The amount discharged to the North Umpqua River for in-stream use is specified in the existing FERC permit at 25 cfs or greater. Actual flow in the North Umpqua River downstream from Lemolo dam is typically about 35 cfs (PacifiCorp 1995, Vol. 22). Flow varies throughout the year. The maximum flow of record (river plus bypass) was 4,680 cfs on December 24, 1964. The minimum flow of record was 9.7 cfs, May 13, 1955. Extremes of 1996 water year (river only) were a maximum of 791 cfs on August 25, and a minimum of 34 cfs on several days in October and November.

For water years 1968-1996 the highest annual mean flow (not including diversion to power canal) was 125 cfs in 1996 and the lowest annual mean flow was 24.1 cfs in 1973. The highest daily mean flow was 1070 cfs on June 4, 1975. The lowest daily mean flow was 15 cfs on October 15, 1970 (Hubbard et al. 1997).

Temperature

The temperature of the inflow to Lemolo Lake varies according to the source. In 1993, temperatures in Lake Creek during the summer (June-September) ranged from 4^{o} to 18^{o} C. Temperatures in the North Umpqua River at the inlet to Lemolo Lake during the same period ranged from 4^{o} to 9^{o} C. For the summers of 1993 and 1994, the 50 percent exceedence values show Lake Creek to be 6^{o} to 7^{o} C warmer than the North Umpqua River (PacifiCorp 1995, Vol. 21).

In 1995, the warmest water temperatures measured in Lake Creek were recorded near the outflow from Diamond Lake. The 80 percent exceedence value at the outlet near Diamond Lake for temperatures recorded during the summer (16^{o} C) was higher than the 20 percent exceedence value at monitoring sites closer to Lemolo Lake (Harza 1996). Measurements taken in 1995 confirm earlier results showing the North Umpqua River to have a more constant temperature than Lake Creek when entering Lemolo Lake.

Profiles of temperature with depth taken in Lemolo Lake in 1992 showed strong vertical stratification during the summer, especially in August. Stratification decreased in the fall, and was non-existent in December (PacifiCorp 1993). Temperatures at the surface in August were between 20^{o} and 22^{o} C and decreased to approximately 11^{o} C near the bottom of the reservoir (15 to 18 m). In 1993, profiles measured on August 11 and 12 showed similar stratification. Temperature at the surface was 18^{o} C and at depth (15 m) was 9^{o} C (Bonoff et al. 1996). During both years, the region of greatest change in temperature with depth was between 3 and 5 m.

During the 1993 study, continuous measurements were made for 24 hours on August 11 and 12 at depths of 2 m and 15 m. Temperature at 2 m ranged from 17.0^{o} to 17.8^{o} C. Temperature at 15 m ranged from 8.5^{o} to 8.8^{o} C (Bonoff et al. 1996).

Temperature of the outflow from Lemolo Lake is intermediate between the two major sources. The Spring River and North Umpqua River join just upstream of Lemolo Lake, and account for most of the inflow, which is generally about 3^{o} C colder in the summer than the water released from Lemolo Lake. Lake Creek is typically 4^{o} C warmer than the Lemolo release (PacifiCorp 1997a). Mid-July mean maximum daily temperatures at the release from Lemolo Lake are about 10^o C.

Water Quality

Nutrients

Phosphorus

The volcanic soils and bedrock in the North Umpqua basin are relatively high in phosphorus and consequently most streams in the area have high phosphorus concentrations. In addition, high phosphorus concentrations in Lake Creek from the outflow of Diamond Lake enter directly into the surface waters of Lemolo Lake. This results in relatively high total phosphorus concentrations in Lemolo Lake (Table 2). The median value for total phosphorus in Lemolo Lake was 17 μg/L. On two occasions in 1994, total phosphorus was measured in both the epilimnion and hypolimnion on the same date. Total phosphorus concentration in the hypolimnion was three to five times greater than in the epilimnion, but orthophosphate concentrations were similar.

Orthophosphate comprises 50 percent of the total phosphorus in Lemolo Lake (based on median values). This is unusually high. A more typical value would be near 5 percent (Wetzel [1985] cited in PacifiCorp [1995], Vol. 21).

Phosphorus concentration differs between the two main tributary streams to Lemolo Lake. The median value for the North Fork Umpqua River at the inlet to Lemolo Lake (June 1992 through September 1994) was 80 μg/L total phosphorous. The median value for Lake Creek for the same period was about 30 μg/L (PacifiCorp 1995, Vol. 21.)

Nitrogen

Inorganic nitrogen is generally not present in detectable amounts in waters of the North Umpqua basin. Grab samples taken from Lemolo Lake near the surface have shown detectable (> 5 μg/L) concentrations of nitrate nitrogen on only two occasions. Nitrate-nitrogen has been detected in the streams entering Lemolo Lake. In samples taken from Lake Creek in May, July and September 1994, nitrate nitrogen ranged between 7 and 9 μg/L. In the North Umpqua River, nitrate nitrogen was measured at 6 μg/L in July and 15 μg/L in September (PacifiCorp 1995 vol. 21).

Total Kjeldahl nitrogen (organic nitrogen plus ammonia nitrogen) measured in Lemolo Lake in 1993 ranged from 160 to 370 μg/L. Of 16 TKN measurements taken between December 1992 and September 1994, ten had concentrations greater than the method detection limit (10 μg/L). The mean of these ten values equaled 240 μg/L (Bonoff et al. 1996). In measurements made in the inlet streams in 1994, TKN was not detected in the North Umpqua River in May, July, or September, or in Lake Creek in July, but was present in Lake Creek at 28 μg/L in May and 26 μg/L in September (PacifiCorp 1995 vol. 21).

Dissolved Oxygen

Vertical profiles of dissolved oxygen measured in Lemolo Lake on several occasions in 1992 showed the lake to be strongly stratified by June with surface temperature about 19^o C above 3 m, a rapid decrease in temperature to about 14^o C at 5 m, and a more gradual decline to about 9^o C at the deepest point (18 m)(

Table ***3***). This condition persisted through August. By late September, the lake was still stratified, but the top 3 m had cooled to approximately 15^o C while the deepest point (15 m) had cooled to about 7^o C. By December, the lake was a uniform 3^o C throughout (PacifiCorp 1995b).

This temperature stratification was accompanied by a corresponding vertical gradation in dissolved oxygen (DO). DO tended to be constant in the upper 3 m, increase rapidly between 3 and 5 m, and then decrease gradually to the bottom. Surface values ranged from about 9 to 11 mg/L in June through August. Values in the metalimnion (about 4 m) ranged from 10 mg/L in June to 17 mg/L in August. DO concentrations at maximum depth remained near 10 mg/L through the period of stratification.

In a study of diel changes in water quality constituents in 1993, dissolved oxygen concentration varied with depth with a maximum near the thermocline (about 4 m). Hypolimnetic dissolved oxygen minimum was 9.7 mg/L (Bonoff et al. 1996). Oxygen showed a strong diel variation on August 11 - 12, 1993. Measurements at 2 m ranged from 9.3 to 12.1 mg/L and from 8.8 to 11.1 mg/L at 15 m. Oxygen saturation ranged from 127 percent to 96 percent at 2 m and from 76 to 96 percent at 15 m.

pH

In vertical profiles taken in 1992 and 1993, pH varied with depth during the summer months when Lemolo Lake was thermally stratified (Table 4). The highest pH values were usually seen at intermediate depth near the thermocline (3 to 5 m), with lower values near the surface, and the lowest values at depth in the hypolimnion. The highest pH value recorded was 9.7 in the metalimnion in August 1992. The lowest value recorded was pH 6.8 in April 1993 during spring snowmelt.

During a 24 hour diel study in August, 1993, pH varied with depth. pH exceeded 8.5 from the surface to 5 m with a maximum of 9.1 at 2 m. The minimum pH value of 7.4 was recorded at 5 m. Continuous measurement at 2 m and 15 m showed notable differences (Bonoff et al. 1996).

Based on an alkalinity measurement made in August 1982, when conditions were similar to those seen in the 1993 diel study, the expected pH in Lemolo Lake would be around 7.5 assuming a CO_2 concentration in equilibrium with the atmosphere (Snoeyink and Jenkins 1980). This indicates that the high pH values obtained from Lemolo Lake are caused by CO_2 depletion as the result of photosynthetic activity.

BIOTA

Chlorophyll

Chlorophyll *a* ranged from 1 to 33 μg/L throughout the monitoring period of 1992 and 1994

(Table 5). Concentrations were generally low with the exception of samples taken during phytoplankton blooms in August 1992 and August and September 1993 (PacifiCorp 1995b, vol. 21).

Chlorophyll *a* was measured in the streams entering Lemolo Lake in 1994. The concentrations seen in the tributary streams were comparable to the minimum values observed in Lemolo Lake.

Secchi Disc Transparency

Secchi depth was measured in Lemolo Lake in 1982 (Johnson et al. 1985) and in 1992 through 1994 (PacifiCorp 1995, Vol. 21). Secchi depth ranged from 2.0 m to 8.7 m with a mean value of 5.2 m. The lowest Secchi depth measurements were obtained during periods of high phytoplankton abundance in the summer.

Phytoplankton

Phytoplankton samples were analyzed from Lemolo Lake in August, 1982 (Sweet 1986) and in May, August, and October 1993 (PacifiCorp 1995, Vol. 21). In August 1982, the phytoplankton biovolume was 1211 cubic micrometers per liter and the dominant species were *Anabaena affinis*, *Ankistrodesmis falcatus*, and *Anabaena flos-aquae*, indicators of a eutrophic, nitrogen-limited system. In August 1993, the biovolume was 4,705 cubic micrometers per liter and the phytoplankton assemblage was 95 percent *Anabaena* species. In May and October 1993, the community was dominated by diatoms, primarily *Stephanodiscus* species and *Asterionella formosa*. The biovolume in May was 58 cubic micrometers per liter and in October 402 cubic micrometers per liter.

Fish

Historically, native fish may not have been present in the North Umpqua River or its tributaries upstream of Toketee Falls (PacifiCorp 1997a)(Table 6).

Trout harvests in the larger impoundments of the North Umpqua Hydropower Development, including Lemolo Lake, meet or exceed expectations based on harvest from other reservoirs. Trout growth in project impoundments does not appear to be limited by food availability because observed growth rates fall within, or exceed, the range expected under current temperature regimes (PacifiCorp 1997a).

Two species of trout ,brown (*Salmo trutta*) and rainbow (*Oncorhyncus mykiss*), and a small population of kokanee salmon (*Oncorhynchus nerka kennerlyi*) exist in Lemolo Lake. Tui chub (*Gila bicolor*) are found in large numbers in Lemolo Lake (PacifiCorp 1997a). Stocking of hatchery rainbow trout using out-of-basin stocks occurred in Lemolo Lake from 1955 through 1972 (ODFW 1980 cited in PacifiCorp 1997a). Fish populations in Lemolo Lake are now self-sustaining. Brook trout (*Salvelinus fontinalis*), brown trout, and kokanee redds have been observed in the streams draining into Lemolo Lake (PacifiCorp 1997a).

Trophic Status

Trophic state index (TSI) values were calculated for Lemolo Lake using the chlorophyll α based index (Carlson 1977). Summer time average TSI values (June through October) were 44 in 1992 and 47 in 1993. TSI values for August were 55 in 1992 and 64 in 1993 (PacifiCorp 1995, Vol. 21). These values would place Lemolo Lake in the category of mesotrophic to eutrophic. Johnson et al. (1985) described Lemolo Lake as mesotrophic.

Table 2. Water Quality Collected from Lemolo Lake, June 1992 Through September 1994

Date	Time	Turbidity (NTU)	Total Phosphorus (mg/L)	Ortho-phosphorus (mg/L)	Total Kjeldahl Nitrogen (mg/L)	NO_2+ NO_3	Fecal Coliform (MPN)	Chlorophyll *a* (mg/m^3)	Secchi Depth (m)
6/25/92	1120	0.7	0.029		<0.10		<2	2.67	5.0
7/21/92	1348	0.5	0.045		<0.10		<2	2.70	6.1
8/17/92	1407	4.2	0.021		0.72				2.1
8/29/02	1016						<2	11.50	2.7
9/22/92	1700	0.4	0.130		<0.10				7.8
10/22/92	1320	0.2	0.051		<0.10		<2	3.17	6.6
12/2/92	835	0.5	0.056	0.050	0.15	0.11	<2	3.75	5.7
4/8/93	1240	<0.1	0.037	0.036	<0.10	<0.0	<2	2.39	6.2
5/5/93	1030	0.1	0.047	0.029	0.14	<0.0	<2	1.97	6.2
6/9/93	1215	1.4	0.025	0.013	0.23	<0.0	<2	5.84	2.6
7/12/93	1200	0.4	0.024	0.010	0.16	<0.0	<2	1.00	6.2
8/11/93	1300	3.4	0.036	0.012	0.37	<0.0	<2	28.40	2.1
8/12/93	1530	4.0	0.025	<0.01	0.21	<0.0		33.40	2.0
9/12/93	1230	0.3	0.021	<0.01	0.17	<0.0	<2	6.37	8.7
10/25/93	1500	0.1	0.049	0.019	<0.10	<0.0	<2	2.97	6.2
7/28/94	910	0.4	0.025	0.017	0.11	<0.0		3.41	5.5
7/28/94	910	0.5	0.049	0.048	<0.10	<0.0			
9/25/94	1600	0.6	0.023	0.011	0.15	0.01		4.34	4.9
9/25/94	1600	1.8	0.070	0.057	0.10	0.01			
Minimum		<0.1	0.021	<0.01	<0.10	<0.0	<2	1.00	2.0
Maximum		4.2	0.130	0.050	0.72	0.11	2	33.40	8.7
Median		0.4	0.036	0.017	0.16	<0.0	2.0	3.58	5.9
Average		1.0	0.036	0.025	0.19	0.06	2.0	8.08	5.2
# Samples		13	13	12	13	12	9	12	12

Table 3. Dissolved Oxygen in Lemolo Lake

August 1993		
Value	2m depth	5m depth
Maximum mg/L	12.1	11.1
Minimum mg/L	9.3	8.8
Maximum saturation	127%	96%
Minimum saturation	96%	76%

Table 4. pH in Lemolo Lake

August 1993		
Value	2m	5m
Maximum	9.1	7.9
Minimum	8.9	7.3
Mean	9.0	7.8

Table 5. Chlorophyll α concentration (μg/L) in streams near Lemolo Lake

Site	May 1994	July 1994	September 1994
N. Umpqua	1.36	1.66	1.17
Lake Creek	2.25	1.33	1.34
Below Lemolo Lake	nd	nd	1.34

Table 6. Fishery Characteristics in Lemolo Lake

Angler Use	158.5 hrs./ha/yr
Catch rate	0.47 fish > 6"/hr
1992 angler harvest	2493.7 kg
Entrainment	36.8 kg/yr
Species composition	brown trout, 78%, max. size = 860 g tui chub, 20% rainbow trout, < 1%, max. size = 720 g kokanee, < 1%
Based on ODFW data 1975-1991. Recent species composition in Lemolo Lake is available in PacifiCorp 1995, V25, P5-43. and PacifiCorp 1997a, Table 7.4-1.	

DIAMOND LAKE

Physical Habitat

Morphometry

Diamond Lake is a large, relatively shallow lake (Table 7) bounded by Mt. Thielsen to the east and Mt. Bailey to the west. The lake bathymetry is highly regular, reaching a maximum depth of 15.8 m (52 ft) in the north central portion of the lake with a mean depth of 7.3 m (24 ft). The watershed-to-lake-area ratio is 10.5 and the estimated hydraulic residence time is 1.6 yr (Johnson et al. 1985). Because of its relatively shallow depth, a considerable portion of the lake is less than 6.7 m (22 ft), the mean Secchi disk transparency (Salinas and Larson 1995) recorded from 1992 to 1994. This extensive littoral zone provides considerable potential habitat for aquatic macrophytes and the species associated with this habitat.

Stratification

Diamond Lake has been classified as a dimictic lake (Salinas and Larson 1995, Lauer et al. 1979) based on its isothermal conditions in spring and fall and its thermal stratification in summer and winter. Some degree of thermal stratification is generally established by late June or early July and is almost always present in August. However, the stratification is generally not intense and mixing has been observed throughout the open-water period. Although Diamond Lake does stratify, the low stability of the stratification suggests that the lake behaves more as a polymictic system in which the duration of open-water stratification is less than typical for a temperate lake. The consequence of limited stratification is that dissolved oxygen depletion in the hypolimnion seldom becomes severe, although in July and

August 1992 and August 1993, DO concentrations approached 0 mg/L below ~12 m (Salinas and Larson 1995).

Table 7. Morphometry of Diamond Lake

Morphometry of Diamond Lake and its Watershed-1 [a].

	Metric	English
Lake Surface Area (ha/ac)	1300.7	3214
Depth (m/ft)- max.	15.8	52
-mean	7.3	24
Volume (hm^3/ac-ft)	95.11	77,100
Length (km/mi.)	5.5	3.4
Width (km/mi.)	2.5	1.6
Elevation (m/ft)	1580	5183
Watershed Area (km^2/mi^2)	136	55
Precipitation (cm/in)	140-165	55-65
Residence Time (yr.)	1.6[a,b,c]	

[a] Johnson et al. (1985)

[b] Calculating τ based on watershed area precipitation (less evaporation of 30 cm/yr. [cf Nelson 1991]), and lake volume $\left(\tau_w = \frac{V}{Q}\right)0$ yields

$$\frac{9.511\ x\ 10^7\, m^3}{1.36\ x\ 10^8\, m^2\ x\ (1.5m - 0.3m)/\ yr} = 0.58yr$$

[c] Lauer et al. (1979) estimated τ = 1.5 yr.

Substrate

The substrate throughout the pelagic zone is characterized by a light tan, highly oxidized sediment (Dean and Bradbury 1993). The sediment in the littoral zone is also flocculent, light brown, and often contains macrophytes (Lauer et al. 1979). The sediment profile is relatively uniform, has a high water content, and a high organic component (Eilers et al. 1997). Concentrations of N, P, and Si are high in these sediments. The flocculent organic-rich sediments provide a highly-suitable habitat for macroinvertebrates, primarily comprised of chironomidae and oligocheata (Lauer et al. 1979). Amphipods, gastropods, and hirudinea (leeches) also form important components of the macrobenthos, especially in the littoral zone.

Hydrology

The hydrologic flow paths are difficult to establish with confidence in highly permeable volcanic terrain. Measurements of surface discharge entering and exiting Diamond Lake when used to compute a hydrologic residence time yield a value of 1.6 yr (Johnson et al. 1985). However, the hydrologic budget is subject to considerable uncertainty because of the problematic nature of the groundwater component. Lauer et al. (1979) using the difference between surface inflow and surface outflow estimated that groundwater inflow averaged 21 percent of the outflow. They assumed groundwater losses from the lake were zero. However, data collected in 1997 by the Umpqua National Forest (unpublished data) showed a strong groundwater gradient leading from the lake westward. The slope of the difference in potentiometric surface was steep, indicating that the volume of discharge from the lake to the groundwater could be substantial (refer to the geotechnical information). The extent of shoreline with flow paths to the groundwater is unknown at this time, but the fact that it exists indicates that the surface flows underestimate the total discharge to and from the lake. The hydraulic residence time calculated based on surface flows was 1.5 (Lauer et al. 1979) to 1.6 yr (Johnson et al. 1985). If we assume that all precipitation falling in the watershed eventually reaches the lake, the hydraulic residence time decreases to 0.6 yr (Eilers et al. 1997). The actual hydraulic residence time is probably intermediate between these two values. Unfortunately, the uncertainty in the hydrologic budget and the magnitude of the components of the budget greatly adds to the uncertainty in other analyses such as nutrients budgets.

Water Quality

The water quality in any lake varies spatially and temporally. Nearly all the available water quality data collected from Diamond Lake was collected in the open-water period from May through October, although winter samples were collected through the ice in 1972 and 1975 (Lauer et al. 1979). Spatial variability in the surface waters of Diamond Lake appears to be low (cf. Lauer et al. 1979; Salinas and Larson 1995). The lake shape is not complex and surface discharges are relatively small with respect to lake volume. The lake is moderately exposed to wind and consequently, there do not appear to be any persistent spatial patterns in surface water quality. Most of the variation in water quality is associated with typical changes associated with seasonal changes in productivity and periodic stratification. Unless stated otherwise, the characterizations of water quality for Diamond Lake described in the following section are based largely on epilimnion samples (surface water) collected during the open-water period.

Nutrients

Phosphorus

Phosphorus (P) is considered to be the nutrient that typically limits primary production in most lakes (cf. Wetzel 1983, Thompson and Rhee 1994). Sources of P include atmospheric precipitation, geologic sources from watershed weathering, recycled P from mineralization of detrital material in the water column and sediments, and input from anthropogenic sources.

Phosphorus concentrations in Diamond Lake (Table 8) are high relative to other lakes in the Cascades (Table 9). A probability sample of lakes in the western United States showed that lakes in the Cascades had total phosphorus (TP) concentrations ranging from <1 to 60 µg/L with a median value of 3.5 µg/L (Eilers et al. 1987). Diamond Lake would fall above the 90th percentile for the TP distribution for this population of lakes. Of the 66 Oregon Cascade lakes summarized by the Oregon Department of Environmental Quality (DEQ)[1], they classified 11 (17 percent) as ultra-oligotrophic (average TP=5 µg/L), 26 (39 percent) as oligotrophic (average TP=9 µg/L), 26 as mesotrophic (average TP=15 µg/L), and 3 (5 percent) as eutrophic (average TP=46 µg/L). Elevation and lake depth were not factors in distinguishing between the ultra-oligotrophic and eutrophic lakes.

Annual (open water) mean concentrations of TP ranged from 17 µg/L in 1995 to highs of 62 µg/L reported in both 1971 and 1992 (Table 8). The large variability in TP concentrations for Diamond Lake is typical of the greater variability expected for more productive lakes. The fluctuations in TP concentrations for Diamond Lake may reflect the large variations in phytoplankton abundance which will be captured in these unfiltered samples. Concentrations of dissolved P are generally about 50 percent of TP values, although in some cases (e.g., Sanville and Powers 1973, and Salinas 1996) measured ortho-phosphorus (OP) values were = 1 µg/L.

The only P budget for Diamond Lake was prepared by Lauer et al. (1979). They reported that the majority of TP loading occurs from the surface water inputs and that on average 33 percent of the TP is retained in the lake sediments (Table 10). Despite the extensive data set developed by Lauer et al., the table illustrates some of the difficulties in preparing a P budget for Diamond Lake. First, the groundwater term was generated as the difference between measured surface inflows and surface outflows. The residual term was assumed to represent groundwater input and groundwater outflow was assumed to be zero. We now suspect that groundwater inputs could be much greater than the surface residual terms based on confirmation that substantial groundwater input occurs on the west side of the lake and may occur on the northern end of the lake (unconfirmed). The amount of groundwater input would need to be increased proportional to any additional amount of the groundwater outflow that might be added to the hydrologic budget.

The role of internal cycling of P was acknowledged by Lauer et al. (1979) and a net retention of 33 percent was calculated based on the measured inputs and outputs of P. This net P retention apparently did not include the calculated export in P from fish harvesting, nutrient fluxes associated with macrophytes, or changes in P retention associated with top-down effects on primary productivity caused by fisheries management. These factors would generally tend to increase the rate of P throughput which would increase primary productivity. Some information that can be gleaned from the TP budget of Lauer et al. (1979) is that P inputs from precipitation are a small proportion of the total P load. Surface inputs constitute a major portion of the P load as currently formulated, although groundwater inputs could be a much greater portion of the inputs than previously believed. Biological controls on in-lake P concentrations are poorly understood on a quantitative basis at this

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[1] using median summer values from Johnson et al. (1985)

time, although we know that productive lakes generally became more productive with the introduction of planktivorous fish such as tui chub (Proulx et al. 1996, Nicholls et al. 1996, Drenner et al. 1996, Harris 1996, Sarnell 1996).

Table 8. Concentrations of Phosphorus (µg/L) in Diamond Lake

Year	Total Phosphorus		Ortho-Phosphorus		Source
	Concentration	N	Concentration	N	
1967	52[a]	5	-		DEQ
1969	20	3	-		DEQ
1970	58	1	38	1	Maloney et al. (1975)
1971	62 53	15 61	- 13	 67	Lauer et al. (1979) Sanville and Powers (1973)
1973	28	6	-	-	Lauer et. al. (1979)
1974	29	6	-	-	Lauer et. al. (1979)
1975	37	5	-	-	Lauer et. al. (1979)
1976	38 140	6 1	- 50	- 1	Lauer et. al. (1979) DEQ
1977	51	8	-	-	Lauer et. al. (1979)
1982	61	1	-	-	Sweet (1986)
1988	54	2	28	2	Sweet (1990)
1989	36	2	9	2	Sweet (1990)
1992	62	23	27	21	Salinas and Larson (1995)
1993	45	13	27	12	Salinas and Larson (1995)
1994	22	8	6	8	Salinas and Larson (1995)
1995	17[b]	9	2	9	Salinas (1996)
Median	45		27		

[a] 4 samples < 10 µg/L; 1 sample 220 µg/L

[b] Excluding 1 sample at a depth of 13 m with TP=113 µg/L

Table 9. Selected Characteristics of 66 Cascade Lakes

Trophic State	No. of Lakes	Land Use	Lake Type	Elev. (ft)	Precip. (in)	Lake Size (ac)	Aver. Depth (ft)	% Shoal (% <10 ft)	Ret. Time (mo.)	Secchi Depth (m)	pH (su)	Chlor. *a* (g/L)	Total Phosp. (mg/L)	Comments
Ultra-oligotrophic	11	88% Forested	Natural	5077	78	148	23	29	12	15.8	6.8	0.2	0.005	Sensitive lakes in High Cascades/USFS land; recreation concerns
Oligotrophic	26	91% Forested	Natural	4455	75	78	17	18	9	7.2	7.0	0.3	0.009	Sensitive lakes in High Cascades/USFS land; recreation concerns
Mesotrophic	26	96% Forested	Reservoir	1714	62	980	28	12	2	4.5	7.4	1.5	0.015	Power/irrigation/flood control reservoirs at lower elevations on large rivers
Eutrophic	3	88% Forested	Lake With Dam	5016	60	957	24	18	-	1.7	8.4	15.7	0.046	Interest to Clean Lakes Program

Table 10. Phosphorous Loading to Diamond Lake in kg/yr.

Year	Precipitation	Groundwater	Surface Water	Fish[a]	Sediment	Input	Output
1972	125	353	2619	-324	b	3097	2619
1973	129	201	2119	-554	b	2449	1499
1974	126	341	1834	-547	b	2301	858
1975	137	341	2076	-378	b	2554	1256
1976	71	218	2107	-314	b	2396	1510
1977	96	143	2227	-403	b	2466	2514
Ave.	114	266	2164	-420	-2043	2544	1709

[a] Assuming TP removed by fish harvest at 1.7% P; 15 kg P added from fish stocking; and 70 kg P added from bait (Lauer et al. 1979).

[b] Sediment release calculated for non-uniform periods; negative value indicates net loss of P to sediments.

Nitrogen

Most of the nitrogen in Diamond Lake is present as organic (TKN) nitrogen (Table 11), which is about four times more abundant than total inorganic N (TIN, Table 11). Most of the TIN has been measured as ammonia (NH_3) which is typically greater than nitrate (NO_3) by a factor of 4 (Table 11). Ammonia is generally much more abundant in the hypolimnion, particularly when dissolved oxygen concentrations become depleted. Using standard stoichiometric ratios of nutrients in biomass (Redfield et al. 1963), the water quality data for Diamond Lake (Table 12) indicate that nitrogen would be expected to be a common limiting nutrient (N:P molar ratio is 16:1).

Table 11. Ammonia (NH_3-N), Nitrate (NO_3-N) and total inorganic nitrogen (TIN) concentrations in Diamond Lake (μg/L).

	NH_3-N	n	NO_3-N	n	TIN	n	Source
1967	358	5	27	5	385	5	DEQ
1969	100	3	63	3	163	3	DEQ
1970	290	1	32	1	322	1	Maloney et al. (1975)
1971	15	55	3	69	18	-	Sanville & Powers (1973)
1971	-	-	-	-	19	5	Lauer et al. (1979)
1972	-	-	-	-	43	5	Lauer et al. (1979)
1973	-	-	-	-	117	6	Lauer et al. (1979)
1974	-	-	-	-	-	0	Lauer et al. (1979)
1975	-	-	-	-	23	6	Lauer et al. (1979)
1976	-	-	-	-	64	6	Lauer et al. (1979)
1977	-	-	-	-	36	8	Lauer et al. (1979)
1982	30	1	20	1	50	1	Sweet (1986)
1988	<110	2	28	2	<138	2	Sweet (1990a)
1989	60	2	<40	2	<100	2	Sweet (1990a)
1992	56	22	14	24	70	a	Salinas & Larson (1995)
1993	86	11	2	11	88	11	Salinas & Larson (1995)
1994	18	10	2	10	28	10	Salinas & Larson (1995)
1995	15	11	<1	11	<16	11	Salinas (1996)
Median	60		14		64		

[a] TIN (NO_3 + NH_3) values are based on unequal numbers of samples

The N budget in Diamond Lake is only partially understood. Work by Lauer et al. (1979) indicates that groundwater is a major source of the N input, although the budget does not include any term for N-fixation by blue-green algae which could be a significant contribution to the lake (Table 13). Also, no terms were developed for N inputs associated with fisheries management or for loss terms to the sediment, atmosphere, and lake outlet.

Table 12. Total Inorganic Nitrogen/Total Phosphorous (Mass Ratio)

Year	Ratio	Reference
1971	0.31	Lauer et al. (1979)
1972	1.05	Lauer et al. (1979)
1973	4.18	Lauer et al. (1979)
1974	No data	
1975	0.62	Lauer et al. (1979)
1976	1.68	Lauer et al. (1979)
1977	0.71	Lauer et al. (1979)

Table 13. Inorganic Nitrogen Budget (kg/yr) for Diamond Lake

after Lauer et al. 1979

Year	Precipitation	Groundwater	Surface Water	Fish	Sediment	Input	Output
1972	515	6271	581	NC	NC	7367	NC
1973	529	3564	979	NC	NC	5072	NC
1974	516	6055	655	NC	NC	7226	NC
1975	565	6046	649	NC	NC	7260	NC
1976	291	3871	559	NC	NC	4721	NC
1977	395	2531	451	NC	NC	3377	NC
Ave.	469	4723	647			5837	

NC = Not computed/measured

Silica

Silica concentrations in Diamond Lake are below average for lakes in the Cascade Range and lower than would be expected given the relatively high productivity of Diamond Lake.

The median silica concentration was 3.8 mg/L (Table 14), compared to an average of 4.2 mg/L reported by Eilers et al. (1987) for the Cascades and 7.0 mg/L reported by Nelson and Delwiche (1983) for the Oregon Cascades. The modest concentrations of silica in the lake are in strong contrast to the much higher concentrations of 18.0 for Silent Creek and 21.9 mg/L for Short Creek in 1992-1995. The loss of over 80 percent of the silica entering the lake in the surface waters occurs most likely because of uptake of silicon by diatoms and eventual loss to the sediments. The sediments are comprised of over 30 percent Si which is high considering that input of allochthonous Si from erosional inputs is probably minimal. Thus, it appears that accumulation of detrital material from phytoplankton, especially from diatoms, forms a major component of the lake sediments.

Table 14. Silica in Diamond Lake

Year	SiO_2 (mg/L)	n	References
1963	3.8	1	USGS, file data
1968	4.7	1	FWPCA, file data
1971	5.5	64	Sanville and Powers (1973)
1988	6.5	2	Sweet (1990a)
1989	6.2	2	Sweet (1990a)
1992	2.4	22	Salinas and Larson (1995)
1993	1.9	11	Salinas and Larson (1995)
1994	3.7	10	Salinas and Larson (1995)
1995	3.2	11	Salinas (1996)
Median	3.8		

Micronutrients

There are a variety of elements that can become limiting or co-limiting in addition to N, P, and Si. These elements include Fe, Zn, Mo, Co, Mn, B, Cl, Cu, Na, and V (Hutchinson 1967). Chloride and sodium are unlikely to be limiting in Diamond Lake, but it is possible that one or more of the remaining elements could be limiting. Miller et al. (1974) determined that some unidentified element(s) could be limiting algal productivity in Diamond Lake based on algal bioassay analyses. No additional studies have been completed to resolve this issue in Diamond Lake.

Dissolved Oxygen

Dissolved oxygen (DO) is a critical component affecting both the fisheries habitat in a lake and the recycling of nutrients from the sediment. In addition, it is an important indicator of the productivity of a stratified lake. Dissolved oxygen concentrations in Diamond Lake in the surface waters are typically at or greater than saturation levels with the atmosphere (Salinas and Larson 1995). Super saturation is commonly encountered in lakes with high primary productivity as oxygen is produced by plants at a rate greater than the rate through which equilibrium with the atmosphere can occur through diffusion. Supersaturated values for surface waters of 126 percent were reported by Sanville and Powers (1973) and 128 percent by Salinas and Larson (1995). Both observations occurred in June. Maximum supersaturation was measured in August 1994 when a metalimnetic maximum saturation of 161 percent was observed at 8 m (Salinas and Larson 1995). The metalimnetic DO super saturation was attributed to high phytoplankton production.

Depletion of dissolved oxygen in Diamond Lake occurs in the hypolimnion during summer and winter stratification. Salinas and Larson (1995) observed anoxia in July, 1992 and August 1992, 1993, and 1994. Anoxia was generally limited to the bottom 2 to 3 m and was relatively short-lived. Destratification occurred in either late August or early September resulting in recirculation and re-oxygenation of bottom waters. A similar pattern was reported by Lauer et al. (1979). The ODFW also reported low DO (0.3 mg/L) at 15.2 m in August 1946 (Locke 1947).

Dissolved oxygen during winter was measured by Lauer et al. (1979) who observed a minimum value of 0.5 mg/L in February 1972 just above the bottom. A second observation in March 1975 showed a bottom DO concentration of 1.5 mg/L.

In summary, the high uptake rate of dissolved oxygen in Diamond Lake is indicative of a highly productive lake in which mineralization of organic matter creates a considerable demand for oxygen. Oxygen is usually replaced rapidly in Diamond Lake because the low thermal stability provides for adequate mixing under most conditions. However, during July and August a sufficient thermal gradient is often established that limits circulation resulting in short-term anoxia in the bottom portion of the hypolimnion. Although winter oxygen depletion was observed, it apparently was not as profound as anoxia measured during the summer. Even though the duration of winter stratification was much greater than the summer stratification, winter oxygen depletion is apparently not as severe as the summer because of the lower rates of degradation, a temperature-dependent process.

Major Ion Chemistry

Diamond Lake is an alkaline lake with moderate concentrations of major ions (Table 15). Compared to other lakes in the Cascades, (cf. Eilers et al. 1987), Diamond Lake is a relative hard water system. The major cation (on an equivalent basis) in Diamond Lake is sodium, followed by calcium and magnesium. The low chloride concentrations in the lake indicate that contamination by anthropogenic salts is low and that weathering of volcanic andesites is the logical source for sodium. The ratios of the major ions to one another and to silica indicate that silicate weathering and ion exchange are the likely sources of major ions. Sulfate concentrations are low indicating that geothermal inputs and weathering of sulfur deposits from ancient geothermal vents are not occurring to any measurable degree in the watershed. Fluoride was not detected indicating that weathering of fluorapatite, common to many lakes in Idaho (Vertucci and Eilers 1993), is not occurring here.

Table 15. Ion Chemistry of Diamond Lake

J.M. Eilers, unpublished data	
Parameter (units)	October 1, 1996[a]
pH (su)	7.15
Conductivity (µS/cm)	35.2
Cations	
Ca (µeq/L)	137
Mg (µeq/L)	95
Na (µeq/L)	167
K (µeq/L)	25
NH_4 (µeq/L)	33
TOTAL	457
Anions	
HCO_3 (µeq/L)	381
SO_4 (µeq/L)	3
NO_3 (µeq/L)	0
Cl (µeq/L)	8
F (µeq/L)	0
TOTAL	392
C_B-C_A (µeq/L)	412
Cal. Cond. (µS/cm)	43.6
Sample collected from mid-lake at 0.5 m depth	

The high concentrations of major ions and silica relative to other Cascade lakes indicates that Diamond Lake is receiving water with considerable weathering products. Because the proportion of ions is typical of Cascade lakes (e.g., Na ³ Ca > Mg > K) and the ratio of Si to base cations is also typical of this region, the weathering inputs do not differ qualitatively, but rather exhibit quantitative differences in weathering inputs. This suggests that the input water to Diamond Lake has a relatively long contact time with the watershed minerals. A long contact time can only be achieved if the source water is dominated by groundwater or surface input comprised largely of groundwater discharge. The short length of the major inlets, the relatively constant discharge of the inlet streams, and the poorly developed stream network all support the concept that Diamond Lake is a groundwater-dominated lake. Using a simple mixing model (Hounslow 1995) of major ion chemistry of snow (from Eilers et al. 1996), lake chemistry (from Eilers et al. 1997), and data from Short Creek (Salinas and Larson 1995; ion chemistry estimated based on conductivity and ion ratios in lake water) to represent groundwater inputs indicates that the lake chemistry can be reconstructed with a mixture of 25 percent precipitation on the lake surface and 75 percent groundwater inputs. Undoubtedly, the actual weathering processes are heterogeneous and the distribution of source waters could be substantially different. However, results from this simple model indicate the potential importance of groundwater sources to Diamond Lake.

Trophic Status

There are a variety of techniques for assessing the trophic status of lakes. It is generally accepted that any single approach can be problematic because of the complexity of lake processes and the non-uniform response of lakes to various inputs. Therefore, the following section examines the trophic status of Diamond Lake from multiple lines of evidence.

Nutrients

The nutrient status in Diamond Lake indicates that this is a highly productive lake. Using the median total phosphorus concentration (45 µg/L, Table) as an indicator of lake productivity (temporarily ignoring the issue of whether P is limiting primary production), it shows that Diamond Lake is an eutrophic system. The trophic state index (TSI, Carlson 1977) value based on TP is 59 where:

$$TSI_{TP} = 14.42 (\ln TP) + 4.15$$

Values greater than 50 are typically associated with eutrophic lakes. This index assumes that P is the limiting nutrient. Also, the average TP concentration in Diamond Lake is highly variable and the TSI for the last two years of available data (1994, 1995; Salinas and Larson 1995, Salinas 1996) would yield TSI values of 48 and 45, respectively. These TSI values are in the mesotrophic range.

Other classifications of lake trophic status based on TP also place Diamond Lake in the mesotrophic to eutrophic range(Table 16). Although the productivity of most lakes is assessed on the basis of phosphorus concentrations, nitrogen and other elements also can be critical in assessing trophic status. If P is no longer limiting, then N often becomes the limiting nutrient. The degree to which P is no longer limiting can be an indication of the potential for problems associated with blue-green algae production because of the capability of some blue-green algae to fix nitrogen. Ratios of TN:TP indicate that Diamond Lake is N-deficient, which in the presence of high TP concentrations allows primary production to achieve high rates.

Table 16. Trophic State Classification of Diamond Lake

Based on OECD probability distributions (after Ryding and Rast 1989).				
Parameter	Probability of Being Classified			
	Oligotrophic	Mesotrophic	Eutrophic	Hyper-Eutrophic
Mean TP (45 µg/L) median (34 g/L) 1992-1995	0 0	**50** **63**	45 35	5 2
Mean Chlorophyll (6.8 µg/L)	0	**57**	38	5
Peak Chlorophyll (39.9 µg/L) 1977 (26.8 µg/L) 1993	0 1	19 42	**56** **45**	25 12
Mean Secchi Disk (5.6 m)	31	**53**	16	0

Although silica has not been explicitly used as an indicator of trophic status, it provides some insight into the productivity of Diamond Lake. Approximately 80 percent of the surface inputs of SiO_2 are lost to the sediments. The high rate of SiO_2 uptake is a strong indicator of the degree to which diatom utilization of Si in frustule production occurs.

Carbon-14 Production

Primary production was measured using Carbon-14 (^{14}C) techniques from 1992-1995 by Salinas and Larson (1995) and Salinas (1996). Most of the primary production occurs in the upper 4 m, although maximum productivity was measured at 6 m on August 30, 1995 (Salinas 1996). The median annual[2] primary productivity for the four years was 88 mg $C/m^3/hr$, with five of 12 observations exceeding 100 mg $C/m^3/hr$. The ^{14}C uptake rates for three other Cascade lakes are provided in Table 17. The ^{14}C values for Diamond Lake are generally greater than those reported for the ultra-oligotrophic lakes, Crater and Waldo, and less than those reported for Odell Lake. Note that the productivity measurements recorded for Odell Lake were collected prior to the full recovery of the lake associated with nutrient-reduction measures. Productivity in Odell Lake is perceived to have declined in recent decades (Johnson et al. 1985).

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[2] Data collected between June and October

Table 17. Carbon 14 Primary Productivity Rates for Selected Cascade Lakes

Lake	Trophic Status	Productivity		n	Source
		Range	Mean		
Crater	Ultra-oligotrophic	18.2-32.7	-	7	Larson 1972
Odell	Mesotrophic	10.4-396.8	-	13	D.W. Larson, unpub. data (cited in Salinas and Larson 1995)
Waldo	Ultra-oligotrophic	6.8-69.9	-	25	D.W. Larson and J.T. Salinas, unpub. data (cited in Salinas and Larson 1995)

Chlorophyll *a*

The chlorophyll *a* values in Diamond Lake generally indicate a lake with moderate productivity (Table 18). The trophic state index (TSI, Carlson 1977) based on the median chlorophyll concentration of 6.8 µg/L shows a value of 49.4 where:

$$TSI_C = 9.81 (\ln \text{Chlorophyll } a) + 30.6$$

This would classify the lake as a mesotrophic system, although the high excursions of chlorophyll *a* (e.g. > 30 µg/L; Sanville and Powers 1973, Lauer et al. 1979, Sweet 1990b) are more indicative of eutrophic lakes.

Secchi Disk Transparency

Secchi disk transparency is a common measure of lake trophic status (Table 19). The concept is relatively simple: phytoplankton populations are inversely related to lake transparency. In practice, the physics of how phytoplankton and other dissolved and particulate substances interact to affect transparency is complex (Verschuur 1997). Consequently, the observed relationship between Secchi disk transparency and phytoplankton biomass is comparatively weak (Figure 9;Table 20).

The median transparency in Diamond Lake is 5.6 m, with a range of 1.8 to 12.0 m (Salinas and Larson 1995). The trophic state index based on median Secchi disk transparency (Carlson 1977) is 35.2 where:

$$TSI_{SD} = 60 - 14.41 (\ln SD_{(m)})$$

The TSI value based on Secchi disk transparency is much lower than the TSI values computed on the basis of chlorophyll *a* (49) and total phosphorus (59). The TSI_{SD} value indicates that Diamond Lake is mesotrophic. However, the Secchi disk transparency can yield disproportionately high values if the algal cells are comparatively large (or colonial, filamentous).

Table 18. Chlorophyll α in Diamond Lake

Year	Chlorophyll *a* (µg/L_)	n	Source
1971	1.0-32	10	Sanville and Powers (1973)
1972	2-17	5	Lauer et al. (1979)
1973	1.5-9 (4.8)	6	Lauer et al. (1979)
1974	1.5-10	6	Lauer et al. (1979)
1975	3-10	5	Lauer et al. (1979)
1976	4-15	6	Lauer et al. (1979)
1977	3-39.8 (14)	7	Lauer et al. (1979)
1982	3.0	1	Sweet (1986)
1988	26.7	2	Sweet (1990a)
1989	11.4	2	Sweet (1990a)
1992	6.8	8	Salinas and Larson (1995)
1993	8.3	6	Salinas and Larson (1995)
1994	2.6	2	Salinas and Larson (1995)
1995	6.0	6	Salinas (1996)
Median	6.8		

Figure 9. Secchi Disk Transparency in Diamond Lake

Table 19. Secchi Disk Transparency in Diamond Lake

Date	Secchi Disk Transparency (m)	n	Source
1961	6.55	2	ODFW
1963	6.0	7	ODFW
1971	4.3	23	Sanville and Powers (1973)
1971	4.1	5	Lauer et al. (1979)
1972	6.2	5	Lauer et al. (1979)
1973	5.7	6	Lauer et al. (1979)
1974	7.4	6	Lauer et al. (1979)
1975	5.5	5	Lauer et al. (1979)
1976	6.65	6	Lauer et al. (1979)
1977	6.3	7	Lauer et al. (1979)
1978	3.8	1	Rinella (1979)
1982	3.8	1	Johnson et al. (1985)
1988	5.4	2	Sweet (1990a)
1989	5.1	2	Sweet (1990a)
1992	6.1	4	Salinas and Larson (1995)
1993	5.4	6	Salinas and Larson (1995)
1994	9.2	3	Salinas and Larson (1995)
1995	3.9	3	Salinas (1996)
Median	5.6		

Table 20. Secchi Disk Transparency versus Phytoplankton Density and Biovolume in Diamond Lake

Source: Salinas and Larson 1995, Salinas 1996.

Station D	Secchi Disk Transparency (m)	Phytoplankton Density (units/ml)	Phytoplankton Biovolume (cu.µM/ml) x 10^3
1992			
June 26	8.65 (mean)	1,613	2,282
July 26	4.0	4,294	131
August 22	5.0	5,032	331
September 19	6.65 (mean)	1,474	345
1993			
June 16	3.8	3,445	1,218
July 6	3.9	4,920	902
August 10	9.0	3,157	134
August 23	6.25 (mean)	3,143	1,351
September 7	4.8 (mean)	2,002	1,022
September 24	4.6	1,400	1,760
1994			
August 8	8.34 (mean)	947	135
August 21	7.35 (mean)	1,317	153
September 24	11.85 (mean)	1,284	87
1995			
August 30	4.3	2,332	1,886
September 13	4.1	3,552	2,042
October 8	3.2	1,890	2,000

Dissolved Oxygen Regimes

Dissolved oxygen concentrations, particularly in the hypolimnion, provide information on lake productivity. Oxygen depletion in the hypolimnion occurs as bacteria decompose detritus settling through the water column and organic material already deposited in the sediments. During the relatively brief periods of lake stratification in the summer, oxygen depletion occurs at a sufficient rate to cause periodic anoxia. This was particularly apparent in 1992 and 1993 when DO concentrations in June were near saturation throughout the water column, but by July significant loss of DO had occurred in the hypolimnion. If more frequent temperature and DO profiles were available for this period, it would be possible to compute hypolimnetic oxygen deficits (HOD).

Anoxia was reported by Salinas and Larson (1995) in July 1992 and August 1992, 1993, and 1994. Anoxia usually was present only in the bottom 1 to 2 m. The HOD rates are probably quite high, but because the stratification stability is low, the duration of stratification is usually insufficient to cause extensive oxygen depletion. However, even these brief periods of anoxia may be important in contributing to recycling of N, P, and Si from the sediments to the surface waters.

Dissolved oxygen concentrations have seldom been measured in Diamond Lake. Lauer et al. (1979) measured minimum DO concentrations at the lake bottom of 0.5 mg/L in February 1972 and 1.5 mg/L in March 1975. Both measurements suggest considerable DO depletion in the winter, although the low temperatures under the ice apparently slow the rate of decomposition sufficient to prevent serious anoxia and winter kill.

pH

The predicted pH in Diamond Lake based on equilibrium with CO_2 concentrations in the atmosphere and the bicarbonate concentrations indicate that the expected pH is about 7.5 (Butler 1964). Measured pH values in Diamond Lake range from 6.5 in anoxic bottom waters to values of 9.3 measured at the surface (Salinas and Larson 1995; Sanville and Powers 1973). The low pH values are caused by supersaturation of bottom waters with CO_2. The CO_2 is generated by decomposition reactions in the sediments which in this case cause P_{CO_2} (P_{CO2} = partial pressure in atmospheres of CO_2) 0values to change from $10^{-3.5}$ atm to $10^{-2.1}$ atm. In the surface waters, the opposite reaction occurs in which dissolved CO_2 (and HCO_3) is removed from the water by phytoplankton during photosynthesis. The P_{CO_2} 0associated with the maximum pH values measured in the lake equal $10^{-4.9}$ atm which indicates a considerable undersaturation with CO_2 caused by the relatively slow equilibrium of atmospheric CO_2 in the surface waters. Even typical summer values for pH which generally equal or exceed 8.2 (Salinas and Larson 1995; Sanville and Powers 1973) indicate a moderate undersaturation of CO_2 ($10^{-3.8}$ atm).

Summertime surface water pH values in Diamond Lake exceed state standards for surface waters causing Diamond Lake to be identified in the DEQ 305b report for impaired water bodies (DEQ 1994). However, the degree to which current pH values represent a response to increased development and recreational use of the lake is uncertain. Lauer et al. (1979) indicate that anthropogenic contributions of nutrients are relatively small (~ 14 percent of total). However, previous discussions cast doubt on the accuracy of these nutrient budgets and it is likely that anthropogenic contributions of nutrients are greater than indicated in this study (Salinas and Larson 1995; Eilers et al. 1997). Paleolimnological analyses indicate that Diamond Lake has increased in productivity (Meyerhoff et al. 1977; Eilers et al. 1997), which would result in an increase in summertime surface water pH. A diatom-inferred pH reconstruction of Diamond Lake showed that the average summertime pH increased, albeit the increase was not statistically significant (Eilers et al. 1997).

Phytoplankton Community

Salinas and Larson (1995) reported 55 phytoplankton taxa during 1992-1994. The most dominant taxon in the 1992-1995 samples based on numerical abundance of individuals was *Chromulina* sp. (Table 21). This is in contrast to the three samples in the 1980s which were dominated by *Rhodomonas minutus* and *Asterionella formosa* (Sweet 1986, 1990a, 1990b). In the 1970s, *Chromulina* was dominant in 1974, 1976 and 1977 whereas *Anabaena flos-aquae* and *Asterionella formosa* were dominant from 1971-1973 and 1975 (Lauer et al. 1979). Part of these apparent differences among years may be an artifact of when the samples were collected. A presentation of the dominant taxa by season (where data were presented by sample date) shows that *A. formosa* was the dominant taxon in the spring for 6 of 8 years (Table 22). *Anabaena flos-aquae* was the dominant taxon for most summer and fall samples with the exceptions of *Chromulina* during one summer and two fall samples, and *Rhodomonas minutus* for the three non-spring samples in the 1980s.

Table 21. Dominant Phytoplankton Genera in Diamond Lake Based on Numerical Abundance (cells/ml)

Date	Most Abundant to Least Abundant				
1971	*Asterionella*	*Anabaena*			
1972	*Anabaena*	*Asterionella*			
1973	*Anabaena*	*Asterionella*			
1974	*Chromulina*	*Anabaena*			
1975	*Asterionella*	*Anabaena*			
1976	*Chromulina*	*Asterionella*	*Anabaena*	*Stephanodiscum*	
1977	*Chromulina*	*Anabaena*	*Asterionella*	*Stephanodiscum*	
1982	*Rhodomonas*	*Ankistrodesmus*	*Chromulina*	*Anabaena*	
1988	*Asterionella*				
1989	*Rhodomonas*	*Cryptomonas*	*Chromulina*	*Anabaena*	*Cocconeis*
1992	*Chromulina*	*Rhodomonas*	*Cryptomonas*	*Chrysochromulina*	
1993	*Chromulina*	*Asterionella*	*Rhodomonas*	*Chrysochromulina*	
1994	*Chromulina*	*Chrysochromulina*	*Cryptomonas*	*Asterionella*	
1995	*Chromulina*	*Nitzschia*	*Anabaena*	*Fragilaria*	

Table 22. Seasonal Dominance of Phytoplankton Taxa for Diamond Lake Based on Numerical Abundance (cells/ml)

Seasonal dominants in phytoplankton taxa for Diamond Lake based on numerical abundance (cells/ml).

Date	Spring (April-June)	Summer (July, August)	Fall (September, October)
1971	*Asterionella**	*Anabaena*	*Anabaena*
1972	*Asterionella**	*Anabaena*	*Anabaena*
1973	*Asterionella**	*Anabaena*	*Anabaena*
1974	Unidentified Flagellates	*Chromulina**	*Anabaena*
1975	*Asterionella, Cyclotella*	*Asterionella**	*Anabaena, Chromulina*
1976	*Asterionella, Chromulina*	*Anabaena, Chromulina, Asterionella*	*Anabaena, Chromulina*
1977	*Chromulina*, Asterionella, Stephanodiscus*	*Anabaena, Chromulina, Asterionella*	*Chromulina, Anabaena, Chlamydomonas*
1982		*Rhodomonas*, Ankistrodesmus, Chromulina, Anabaena*	
1988	*Asterionella**		*Rhodomonas, Cryptomonas, Chromulina, Anabaena*
1989			*Rhodomonas, Cryptomonas, Chromulina, Anabaena*

* Most abundant for the year

However, numerical abundance can provide a misleading viewpoint of phytoplankton dominance because small individuals such as *Chromulina* are weighted equally with large blue-green algae. When phytoplankton abundance is presented based on biovolume (cell volume x cells/ml) it indicates that blue-green algae and chrysophytes were equally abundant in 1992 (Table 23). Chrysophytes and diatoms were most abundant in 1993, and the diatom *Fragilaria crotonensis*, and to a lesser extent *Anabaena flos-aquae*, were most abundant in 1995. Biovolume data were not available for 1994.

The dominant role of A. formosa in the spring is consistent with its known ecological preferences. This diatom is present in a wide range of mesotrophic to eutrophic lakes. A. formosa is usually found in systems with high Si:P ratios (Hecky and Kilham 1988) and where TP is greater than 20 µg/L. Nitrogen limitation is not expected to be severe immediately following ice-out because of accumulation of inorganic N under the ice. *A. formosa* is able to reproduce quickly in the cold spring conditions before competition with other algal divisions become limiting. *A. flos-aquae* (also reported was *A. circinales* and *A. planktonica*) is a nitrogen-fixing blue-green alga that requires warm waters, high light, and high concentrations of phosphorus. The ability to fix nitrogen means that it can thrive in low N:P environments so long as P is abundant. The dominance by *Chromulina* sp. is more difficult to explain. *Chromulina* is a flagellate chrysophyte and several species of *Chromulina* are reported from Lake Lucerne and other Swiss and German lakes (Hutchinson 1967). Lake Lucerne is a mesotrophic to eutrophic subalpine lake that has received considerable nutrient enrichment from anthropogenic sources. *Chromulina* is fairly widespread in Oregon Cascade lakes ranging from ultra-oligotrophic to eutrophic systems (James Sweet, personal comm.)

Macrophytes

Diamond Lake has an abundant macrophyte population generally present in depths of 2 m to 8 m (Lauer et al. 1979). Lauer et al. (1979) reported that the community occurred as three distinct bands in which *Elodea canadensis* was dominant from 2 to 4 m, *Potamogeton praelongis* and *E. canadensis* were co-dominant from 4 to 6 m, and *Nitella* was dominant from 6 to 8 m. *Elodea* and *Potamogeton* are aquatic vascular plants, whereas *Nitella* is actually a macroalgae related to *Chara*. The presence of *Nitella* at the deepest portion of the macrophyte community is consistent with other observations which indicate that in lakes with macrophytes comprised of both aquatic vascular plants and *Charophyceae*, the *Charophyceae* will be dominant in low light conditions (Hutchinson 1975). The fragility of some species of *Nitella* also restrict their growth to deeper quiescent waters.

Macroinvertebrates

The macroinvertebrates in Diamond Lake are an important component of the biological community because of their role in decomposition of the detritus and as a food source for fish. The relationship between the abundance of macrobenthic fauna and fish production was recognized early (Bauer 1976) when the expanding tui chub populations reduced the benthic biomass from 292 lbs. /acre in 1947 to 2.3 lbs. /acre in 1952. The macrobenthos is represented by two distinct communities, a mid-lake community dominated by *Chironomus* spp. and oligocheates and a more diverse littoral community comprised of *Tanytarsus* spp., amphipods, leeches, and gastropods. Macroinvertebrate densities were generally greatest in the mid-lake site, but densities fluctuated at all sites among years (Lauer et al. 1979).

Table 23. Plankton Abundance in Diamond Lake (Station D, center) based on biovolume.

Date	Depth (m)	Bio-volume x 10^6	Percentage of Algal Biovolume											
			Blue-Green			Chrysophytes			Diatoms					
			Anabaena flos-aquae	Anabaena planktonica	Ankistrodesmus falcatus	Cryptomonas erosa	Chromulina sp.	Sphaerocystis schroeteri	Stephanodiscus astraea	Melosira granulosa	Nitzschia	Asterionella formosa	Fragilaria crotonensis	Synedra ulna
1992 6-26	0	2.3	21.7	**75.2**										
	4	3.1	7.5	90.9										
7-26	0	0.06				25.7	**53.8**							
	4	0.07					47.7							
8-22	0	0.3	**57.3**			7.4	17.2							
	5	0.7	38.4		45.3	31.9	10.4			12.7				
9-19	0	0.3	23.4	39.1		6.2	20.2	8.7						
	6	0.2	25.8			**58.0**	14.2							
1993 8-08[a]	0	0.1		28.1		14.6		12.5			11.1			
	9	0.07	15.0			31.3	9.9							
8-21[b]	0	0.2					8.5		**62.5**					
	8	0.07			8.2	35.8	22.4							
9-24	0	0.09	11.2			35.0	18.6					19.8		
	8	0.2				30.2								**57.7**
1995 8-30	0	1.9								7.9	11.1		**75.5**	
	4	2.7								6.4			**85.5**	
9-13	0	2.0	20.7									9.0	**56.8**	
	13	2.1	6.7			6.8			24.0				**53.6**	
10-8	0	2.0	16.4										**72.7**	
	3	2.2	10.0										**81.9**	

a *Chrysochromulina* 12.8

b *Fragilaria construens* - 11.1; *Nephrocytium* - 13.1

Fish

The fisheries in Diamond Lake is comprised of two introduced species, the rainbow trout and the tui-chub. Prior to 1910, Diamond Lake was fishless. The rainbow trout are stocked annually (formerly as fingerlings and currently as adults) to maintain a sport fishery and formerly to provide surplus trout eggs for fish stocking needs elsewhere in Oregon. The tui chub were most likely introduced by discarding the chub from a live-bait bucket. They currently outnumber trout by ~ 25:1 (Dave Loomis, personal comm.).

The growth rates of the trout prior to introduction of the tui chub were very high and provided an abundant fishery. Trout catch during the 1960s and 1970s exceeded 100 kg/ha/yr on several occasions (ODFW 1996). The biomass of tui chub in 1954 when the lake was treated with rotenone also exceeded 100 kg/ha. Thus, by most standards, the fisheries production in Diamond Lake is high.

Because of the high value of the fisheries to the local economy, plans are being prepared to proceed with a second rotenone application to eliminate the tui chub and restock the lake with rainbow trout.

Subalpine Lakes

Physical Habitat

Morphometry

Three small subalpine lakes, Calamut, Lucille, and Maidu, are also located in the Diamond/Lemolo Lakes watershed. The three lakes are located near the topographic divide and are classified as headwater systems. All three lakes are at elevations near 1800 m, are less than 10 ha in surface area, and are less than 7 m deep (Table 24). Lucille and Maidu Lakes are located in pumice deposits near the Pacific Crest trail; the Calamut Lake watershed is situated in pumice deposits and older basaltic andesite (Sherrod 1986). Lakes such as these were probably formed as ice contact deposits during the Pleistocene. The comparatively simple morphometry of the lake basins provides little habitat for fish. These lakes were fishless prior to stocking by the Forest Service and the Oregon Department of Fish and Wildlife.

Stratification

Calamut, Lucille, and Maidu Lakes are all quite shallow (less than or equal to 7 m). Temperature profiles by Rinella (1979) and Eilers and Bernert (1990) show the lakes are well mixed and probably only stratify under the ice.

Substrate

The substrates of Calamut, Lucille, and Maidu Lakes were all visible from the lake surface which was evident from the Secchi disk transparency measurements which extended to the lake bottom (Eilers and Bernert 1990). The substrates of these shallow lakes in pumice terrain is generally highly organic with much of the sediment derived from benthic diatoms growing in these highly transparent waters. A description of the substrate composition in a comparable clear water, shallow seepage lake in the Cascade Range can be found in Eilers et al. (1996).

Hydrology

Lucille and Calamut are seepage lakes with no permanent surface water inlets or outlets. Although the topographic watersheds are comparatively large for these small lakes (A_W:A_L = 12.3 and 16.2, respectively), the hydraulic residence times for these lakes are likely to be relative long judging from the water chemistry (Table 24). In contrast, Maidu Lake has a permanent outlet which discharges to the headwaters of the Umpqua River. The discharge from Maidu Lake is apparently sustained with groundwater inputs from the watershed. As a consequence of the different hydrologic settings, the chemistry of Maidu Lake is considerably different than that of Lucille and Calamut Lakes.

Water Quality

Nutrients

Phosphorus

Phosphorus concentrations were ≤ 1 µg/L in Calamut, Lucille, and Maidu Lakes (Eilers and Bernert 1990; Table 25). The low phosphorus content was consistent with high transparency and other indicators of low lake productivity.

Nitrogen

Eilers and Bernert (1990) measured inorganic N (NH_4^+ and NO_3^-) in Calamut, Lucille, and Maidu Lakes. Nitrate was below the detection limit (≤ 0.3 µeq/L) and ammonium was measurable in Calamut (0.6 µeq/L) and Maidu Lakes (0.8 µeq/L; Table 25).

Silica

Silica concentrations were very low for Lucille (0.5 mg/l) and Calamut (1.3 mg/L) Lakes, but was quite high for Maidu Lake (18.7 mg/L; Table 25). The disparity in silica concentrations is a reflection of the hydrologic flow paths to the lakes whereby Lucille and Calamut are groundwater recharge systems and Maidu Lake is a groundwater discharge system. Silicate weathering is the dominant weathering reaction in these pumice terrains.

Dissolved Oxygen

Because Calamut, Lucille, and Maidu Lakes were well-mixed, dissolved oxygen profiles were uniform and near saturation (Eilers and Bernert 1990). There was no evidence of supersaturation commonly associated with high levels of primary productivity.

Major Ion Chemistry

Calamut and Lucille Lakes are remarkably dilute lakes, having major ion chemistry that differs little from precipitation chemistry in total ionic strength (Table 25). Forty percent of the sodium in Calamut and Lucille is derived from marine aerosols (assuming no chlorine from watershed inputs), yet sodium is still the primary cation weathering product. The small amount of weathering and reduction of nitrate and sulfate is sufficient to generate 7 to 10 µeq/L of bicarbonate in the two dilute lakes. As a result, pH is slightly greater in these two lakes than would be expected if no ANC generation occurred. The extremely low rates of weathering in Calamut and Lucille are also evident in the low SiO_2 concentrations.

Maidu Lake is far more concentrated than either Calamut or Lucille, but relative to most lakes, Maidu is still not high in major ions. Maidu Lake shows much higher weathering rates with C concentrations nearly 20-fold greater than Calamut and Lucille and silica concentrations from 14- to 37-fold greater than Calamut and Lucille. As a result, the pH in Maidu Lake is 7.4 compared to only 5.9 in Calamut and Lucille.

Trophic Status

Nutrients

Concentrations of inorganic N and P are very low in Calamut, Lucille, and Maidu Lakes, generally at or below most of the detection limits (Table 25). Silica is also low in Calamut and Lucille, but is abundant in Maidu. Both N and P are probably limiting in all three subalpine lakes. A TSI_P for these lakes would classify these lakes as ultra-oligotrophic ($TSI_{TP} \leq 11$). It is not possible to evaluate which nutrient(s) would be limiting with the available data because the analytes were generally not detectable.

Secchi Disk Transparency

Secchi disk transparency is greater than the lake depth in Calamut, Lucille, and Maidu Lakes. Therefore, it is not possible to fully utilize transparency in assessing the trophic status of these lakes.

Dissolved Oxygen Regimes

Calamut, Lucille, and Maidu Lakes were well-mixed throughout the water column and near saturation during the open water period. No winter-time dissolved oxygen data are available for these lakes. Casali and Diness (1988) indicate trout fish stocking in Lucille Lake was discontinued because of consistent winter kill, however we are unaware of data to support this conclusion.

pH

Measured summertime pH values for Calamut, Lucille, and Maidu Lakes are all within 0.05 pH units of expected pH based on measured ANC, assuming a P_{CO_2} 0of $10^{-3.2}$ atm. This indicates that primary productivity is low because no CO_2 deficit exists in the water column associated with uptake of carbon by phytoplankton.

Table 24. Physical Characteristics of the Sub-Alpine Lakes in the Lemolo Lake Watershed

Lake	Latitude[a] DMS	Longitude[a] DMS	Elevation[a] (m (ft)	Lake Area[b] (ha (acres)	Watershed Area[b] ha (acres)	Maximum Depth[a] m (ft)	Hydraulic Residence Time[c] (yr)	Hydrologic[d] Type	Geology
Calamut	43 21 50	122 06 24	1790 (5870)	6.5 (16)	105.3 (260)	7.0 (23)	0.16	Seepage	Qoba, Qpf(2)[e]
Lucille	43 15 14	122 00 53	1810 (5950)	3.3 (8)	40.5 (100)	4.9 (16)	0.16	Seepage	Qpf(5)[e]
Maidu	43 15 25	121 59 59	1820 (5980)	7.8 (19)	361.2 (892)	3.7 (12)	0.04	Drainage	Qpf(5), Qoba[e]

[a] Source: Rinella (1979)

[b] Source: Eilers and Bernert (1990); electronically planimetered on 1:24,000-scale USGS topographic maps

[c] Calculated residence time (inflow-based) as shown in Landers et al. (1987) where precipitation was assumed to be 1.8 m/yr and runoff was 1.3 m/yr. Runoff is based on topographic watershed area and residence times for most of these lakes, particularly the seepage lakes, are likely to be much greater.

[d] Seepage - no permanent surface inlets or outlets; Drainage - permanent surface inlets or outlets

[e] Source: Sherrod (1986), Ramp (1972); Qoba - older basaltic andesite, Qpf = pumice deposits (# is depth in meters).

Table 25. Chemistry of the Sub-Alpine Lakes in the Umpqua National Forest

Lake Name	pH	Conduct (µS/cm)	Ca^{2+}	Mg^{2+}	Na^+	K^+	NH_4^+	SCations	Cl^-	NO_3^-	SO_4^{2-}	HCI_3^- [a]	SAnions[b]	C_B-C_A [c]	SiO_2 (mg/L)
			µeq/L												
Calamut	5.90	2.9	1.8	0	7.5	1.9	0.6	11.7	4.1	0	0	9.7	13.8	7.1	1.3
Lucille	5.91	3.1	2.9	1.7	7.2	1.8	0	13.6	4.2	0	4.9	7.3	16.4	4.5	0.5
Maidu	7.43	28.7	81.3	33.9	62.6	28.8	0.8	207.5	6.6	0	0.5	248.1	255.2	199.6	18.7

[a] Gran alkalinity

[b] PO_4^{2-} is not shown. All values were less than t he detection limit with the exception of Maidu Lake (0.05 µeq/L).

[c] Calculated alkalinity

Macrophytes

Macrophyte populations were low in Calamut, Lucille, and Maidu Lakes (Rinella 1979). Emergent vegetation covered less than 1 percent of the lake area in Calamut Lake, although some submerged aquatic growth was observed in the shoal area. In Lake Lucille, only sparse submerged macrophytes were observed. Macrophytes were more abundant in Maidu Lake with emergent rushes, in about 5 percent of the lake and 2 percent of the bottom covered by submerged macrophytes.

STREAM CHANNEL

Stream channels within the Lemolo/Diamond Lake watershed analysis area are nearly all formed in young High Cascades geologic formations. This geology is characterized by deeply fractured basalt rock overlain by surficial deposits of glacier derived material and/or volcanics with high vesicularity. These surficial deposits have high infiltration rates and soil permeability. As a result, watersheds draining the analysis area typically have low stream densities with flows which are typically larger than expected for their drainage areas as represented by surface topography. Stream channels are typically spring-dominated and appear to have a relatively narrow range of flows. Fluctuations in discharge are depressed in these streams compared to flashy characteristics of surface runoff-dominated channels (Whiting and Stamm 1995). Figure 10 shows the flow duration curves (the graph's x-axis is modified slightly since a Gumbel probability is not available) for Lake Creek (at Diamond Lake), the Clearwater River (above Trap Creek), and Fish Creek, where discharge has been normalized by bank-full discharge. The Lake Creek and Clearwater River systems are spring-dominated, and are characterized by dampened discharge fluctuation when compared to the runoff-dominated channel of Fish Creek. Additionally, the average annual peak flow to bank-full ratio for both Lake Creek and the Clearwater River is 1.3, and 1.9 for Fish Creek.

The hydrology of spring-dominated streams results in a distinctive geomorphology. These systems typically have moist, nearly flat benches adjacent to the channel, where water-tolerant plants are common (grasses, sedges, alder, willow, etc.). Conifers and less water-tolerant plants generally grow above the flood plain where soils are drier. Channels are typically much wider than they are deep and rectangular in cross section. Depositional features are weakly developed in these channels and the channel is diverted by logs in the channel. Logs in the channel commonly lay across, either spanning or partly spanning the channel and have not been moved to a more stable alignment with stream flow. Woody material in the channel is persistent as evidenced by thick grass and moss growth on the wood. Channel substrate in these systems is variable in size, having sand, gravel, and few cobble size particles. Much of the bed material is derived of volcanics, which typically have low densities due to the vesicular structure. These particles are easily made mobile at a relatively low boundary shear stress. Similar to what was found by Whiting and Stamm (1995) in spring-dominated streams, stream channels within the analysis area experience shear stress often high enough to move channel substrate, but not sufficiently high to develop depositional features or to remove or adjust woody material.

Figure 10. Flow duration curves

Flow duration curves comparing spring-dominated streams (Lake Creek and the Clearwater River) to runoff-dominated streams (Fish Creek) as scaled by bank full discharge. Spring-dominated streams have less discharge fluctuation than runoff-dominated channels.

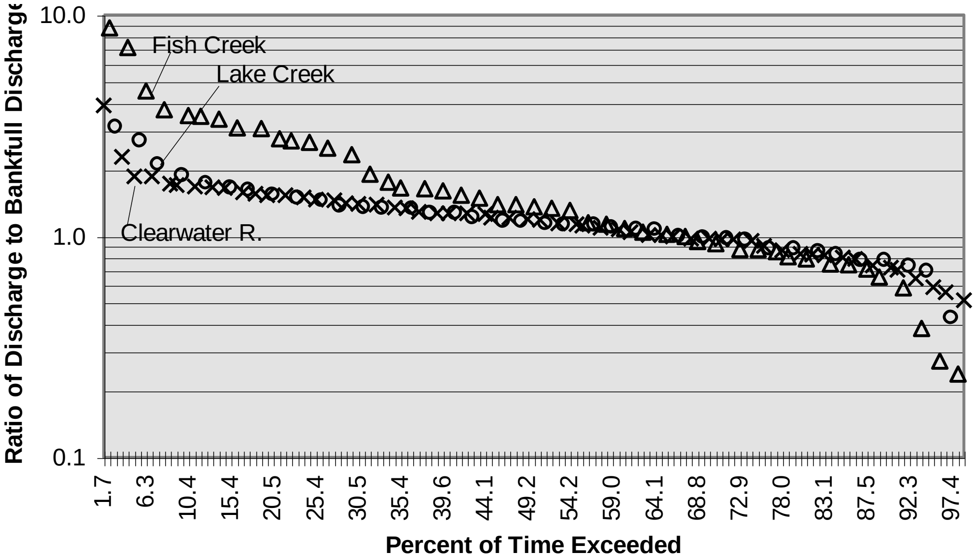

Table 26 shows about 209.7 miles of stream in the Lemolo/Diamond Lake watershed (Figure 11). Class I and II streams are perennial (flow year-round) and support resident fish habitat and supply public water systems downstream. Class III streams are perennial, and Class IV streams are intermittent and ephemeral (seasonal) stream channels. Class III and IV channels are considered headwater streams, which do not directly provide habitat for fish. In the High Cascades, where high infiltration of rain and snowmelt carves fewer streams, as much as 56 percent of streams are intermittent and there are typically less than two miles of stream per square mile of drainage area, with the exception of the Lakeview subwatershed. These stream densities are relatively low when compared to stream networks formed in Western Cascade geology (Abbott 1996).

Stream channels and their lengths identified in Table 26 are from the U.S. Geological Survey maps and have not been modified to fit actual locations and stream class. Therefore, the actual stream length is assumed to be shorter than shown in Table 26 due to the nature of the landscape, high permeability of soils, and as determined from field verification. As streams are walked during road restoration, timber sale analysis, and other specific projects, planners will verify and record actual stream locations. Table 27 shows the estimated acres of riparian reserves within 200 feet of all streams in the sub-watersheds of the analysis area. Actual riparian reserves will be wider on streams with fish habitat, and the acreage estimate will change as actual stream locations are mapped.

Table 26. Estimated Miles of stream by stream class and sub-watershed for the Lemolo/Diamond Lake watershed

Subwatershed	**No.**	**Area Mi^2**	**Stream Mi/Mi^2**	**Total Miles**	**Class I**	**Class II**	**Class III**	**Class IV**
Whisper	0101	48.3	0.44	21.35	0	1.63	9.51	10.21
Bailey	0102	8.0	0.22	1.76	0	0	0	1.76
Diamond Lake Composite	0103	10.7	1.52	16.27	6.68	2.86	0.33	6.40
Lake Creek	0201	7.9	1.03	8.16	3.37	0	4.77	0.03
Sheep	0202	25.5	0.94	24.01	3.96	5.66	8.64	5.76
Thirsty 03	0203	23.4	1.08	25.28	5.02	0.22	4.15	15.89
Thirsty 04	0204	25.7	1.86	47.82	0	9.24	7.58	31.00
Grits	0205	25.1	1.85	46.47	0.81	0.73	6.11	38.82
Natural	0206	7.1	0.87	6.15	3.30	0	0.16	2.69
Lakeview	0207	5.4	2.30	12.42	4.87	0	2.71	4.84
Total *or* [a] Mean		187.1	1.21[a]	209.7	28.01	20.34	43.96	117.40

Figure 11. Lemolo/Diamond Lake 5th and 6th field watersheds above Lemolo dam.

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Table 27. Estimated riparian reserve acres by sub-watershed for the Lemolo/Diamond Lake watershed.

Subwatershed	No.	Area (Acres)	Riparian Reserve (Acres)
Whisper	0101	30,891	1,113
Bailey	0102	5,118	86
Diamond Lake Composite	0103	6,831	3,833
Lake Creek	0201	5,089	544
Sheep	0202	16,312	1,611
Thirsty 03	0203	15,014	1,417
Thirsty 04	0204	16,465	2,794
Grits	0205	16,060	2,357
Natural	0206	4,528	580
Lakeview	0207	3,458	979
Total		119,766	15,317

There are approximately 50 miles of usable fish habitat within the analysis area. Analysis area streams can be divided into ten stream systems supporting resident fish populations. These include the North Umpqua River, Poole Creek, Spring Creek, Bradley Creek, Warrior Creek, Tolo Creek, Lake Creek, Thielsen Creek, Sheep Creek, and Silent Creek. The main stream channels for all of these systems were surveyed using the 1996 USFS Region 6 Stream Survey Methodology. Stream channels were classified according to the Rosgen (1996) methodology. Selected perennial non-fish bearing and intermittent streams were also surveyed using the Umpqua National Forest modification of the Pfankuch stream stability survey methodology.

Poole Creek

Poole Creek drains a watershed area of 1,500 acres, has a mainstem length of approximately 1.2 miles, and originates on Elephant Mountain in western Cascades geology at an elevation of approximately 4,440 feet. It flows directly into Lemolo Lake at an elevation of approximately 4,142 feet. Brook trout are present in approximately the lower 0.5 miles of the stream. Brown trout may enter the lower few hundred feet of the stream from Lemolo Lake to spawn and/or rear. Streamflow measured at the upper end of fish distribution (FR 2610 crossing) was 2.1 cfs on August 8, 1997. The headwaters (Class III) section of the channel is in the steeper gradient basalt (Twb) geologic unit, while Class II (fish bearing) reaches are in two geologic units. These two geologic units are basically split by Forest Service Road (FSR) 2610. Upstream from the road is the glacial drift (Qgd) and below the road is the pyroclastic ash flows (Qaf).

The lower half of the stream is a low gradient (≈1.5 percent), high sinuosity system classified as an "E" type channel. Channel gradient increases to over 10 percent and sinuosity decreases markedly in the upper half of the channel mainstem, and transitions to a "B", and subsequently an "A" channel type. The stream channel is dominated by riffle type habitats, with only about ¼ of the stream classified as pool habitat. However, much of the channel is narrow and deep, with poorly defined hydraulic controls making clear delineation of pool and riffle areas difficult. Riparian timber harvest has occurred along the lower portion of the creek mainstem.

North Umpqua River

The North Umpqua River upstream from Lemolo Lake drains a watershed area of 47,000 acres and has a mainstem length of approximately 9.8 miles. The North Umpqua River originates as the outflow from Maidu Lake, near the Cascade divide in the Mt. Thielsen Wilderness Area. Brook trout are present throughout the system, and brown trout are probably present in the lower nine miles of stream. Streamflow was measured at 406 cfs on August 10, 1997, near the stream mouth. Summer water temperatures are cold throughout most of the channel mainstem, typically ranging from 6-14^{o}C, with temperatures above 15.0^{o}C probably being rare to very rare. Summer water temperatures can be very warm in the upper mile of the stream, measured at up to 24^{o}C in August, 1997. The warm temperatures in the upper reach are most likely due to the stream origin as an epilimnetic outflow from Maidu Lake.

Stream channel types ranged from a low gradient "E" channel type in the lower 3.2 miles of stream, transitioning to a "C" channel in the mid reaches, and finally to "B" and "A" channel types in the upper third of the channel mainstem. Brown trout distribution probably extends to the upper limit of "C" channel types. Brook trout enter the system from Maidu Lake, and are thus distributed to the headwaters. The occurrence of instream large woody material is at fully functional levels throughout the low to mid reaches of the stream, with somewhat high levels present in the upper half of the stream channel. Pool frequency ranges from low in the lower reaches to very low in the upper reaches, inversely proportional to woody material frequency. The low pool frequencies may be due to high stream velocity and poorly defined hydraulic controls making pool/riffle delineation difficult in the lower reaches, and pool filling due to high sand content in some areas.

Spring River

Spring River originates from a large spring complex that produces the vast majority of the streamflow. Water emerging from the spring source is cold, approximately 5^{o}C. Most likely due to a very high width/depth ratio, the water is able to warm considerably (to 10.6^{o}C on August 8, 1997) in the short 1.0 mile channel length during the summer. The Spring River stream channel is classified as a "B" channel type.

The watershed area ultimately draining into the 1.1 mile long Spring River is not accurately known. The immediate watershed area of approximately 500 acres is far too small to produce the streamflow that occurs (measured at 210 cfs on August 10, 1997). Thirsty Creek, a perennial, fishless stream, located in what appears to the same watershed basin, is lost to groundwater approximately ½ mile from the Spring River origin. If the watershed for Thirsty Creek is included, the watershed area for Spring River becomes approximately 16,000 acres. However, this still does not appear to fully account for the high streamflow of Spring River, and subsurface piping from other watersheds may be occurring (see Chapter IV Hydrology section for more detail).

Spring River is believed to be an important spawning area for brown trout and kokanee. Both species are known to enter the Spring River to spawn, and juvenile rearing is also likely to occur. Brown trout most likely enter both directly from a fluvial population in the North Umpqua River and from an adfluvial population in Lemolo Lake via the North Umpqua River. Kokanee migrate to Spring River from Lemolo Lake via the North Umpqua River. The preference for spawning in Spring River is likely due to a combination of stable flow, extensive area of spawning sized gravel, appropriate water temperature, and other factors.

Bradley Creek

Bradley Creek drains a watershed area of approximately 2,200 acres, with a mainstem approximately four miles in length. Bradley Creek originates southeast of Sawtooth Mountain and flows southwest, emptying into the North Umpqua River. Brook trout are present in the lower 2.7 miles of stream. Brown trout are known to be present in the North Umpqua River at the Bradley Creek confluence, and are likely to be present in the lower reach of Bradley Creek. Streamflow was measured at 20.5 cfs in late September, 1996. Summer water temperatures are cold, and ranged from 4-9^{o}C in late August/early September, 1996.

The lower three miles of stream are classified as an “E” channel. Pool frequency throughout the stream is moderate, with moderate to extensive amounts of glide habitat also present in some, particularly the lower, portions of the stream. Large woody material levels are high throughout the stream, and combined with extensive undercut banks, creates good habitat complexity.

Warrior Creek

Warrior Creek drains a watershed area of approximately 4,500 acres and has a mainstem length of over three miles. The stream channel originates near Windigo Butte and the Cascade crest in the Oregon Cascades Recreation Area. Warrior Creek terminates as a tributary to Bradley Creek. Brook trout are the only fish species known to be present, and distribution is limited to the lower 0.7 miles of the stream. Streamflow was measured at 9.7 cfs on August 12, 1997 near the stream mouth. Summer water temperatures are cold throughout the stream length, measured at 8-9^{o}C during August, 1997. Pool frequency is low in the lower reach of the stream, increasing to a moderate level in the upper reach. The stream channel is predominately a “B” type in the lower reach with inclusions of lower gradient channel types, likely “E” and/or “C”, and an “E” type channel, in the upper reach. Headwater streams have formed in the air fall tephra (Qpf) geologic unit, and are composed of “B”, “E”, and “A” stream types with stable channel conditions.

Tolo Creek

Tolo Creek drains a watershed area of approximately 2,800 acres and has a mainstem length of approximately two miles. Tolo Creek originates on mountain slopes located between Tolo Mountain and Tenas Peak, and terminates as a tributary to the North Umpqua River. The upper reaches of headwater channels are assumed to be in the andesite (Qta) geologic unit where streams generally have stable perennial flow, with tributaries and seeps being common. The lower reaches of the headwaters flow through air fall tephra (Qpf) deposits which inherently yield poorer channel stability conditions due to an increased sensitivity to bank scour. Brook trout are present throughout the channel mainstem. A tributary to Tolo Creek, originating on the slopes of Tolo Mountain, with a channel length of approximately two miles, also contains brook trout throughout most of it’s channel length. Streamflow of the Tolo Creek mainstem was measured at 6.5 cfs on August 12, 1997, and a flow of 3.4 cfs was measured in the fish bearing tributary on August 10, 1997. Summer water temperatures are cold, with temperatures measured at 8-10^{o}C in August, 1997.

Stream channel morphology was quite variable in both Tolo Creek and the fish bearing tributary, overall falling into the “C” and “B” channel classification. Much of the channel profile was stair stepped, with steep channel sections followed by lower gradient sections. Channel sinuosity increased in lower gradient sections, and decreased in steeper sections. Pool frequency was somewhat low, with large woody material and boulders being the principal pool causing features.

Lake Creek

Lake Creek drains a watershed area of approximately 65,000 acres, and has a creek mainstem length of approximately 11.6 miles. Lake Creek begins at the north end of Diamond Lake as the outflow of the lake, and ends when the creek empties into Lemolo Lake. Due to the origin of Lake Creek as an epilimnetic outflow of Diamond Lake, Lake Creek naturally contains warmer water than is typical of streams in the area. Stream habitat is fairly consistent as the stream passes primarily through low gradient topography. Channel types are typically “E” and “C”, with some “B” channel present in a canyon dominated reach near Diamond Lake.

Brown trout, rainbow trout, brook trout, and tui chub are all present in part or all of the creek mainstem. Brown trout enter Lake Creek from Lemolo Lake and are present throughout the system. However, an old gradient control structure apparently blocks access to the upper few hundred yards of habitat. This is apparently what prevents brown trout from invading Diamond Lake. Rainbow trout and tui chub enter Lake Creek from Diamond Lake and are distributed throughout most of the mainstem length. In areas where they are absent, it is most likely due to a lack of preferred habitat. Brook trout are present in the mid-reaches of Lake Creek, between the Sheep Creek tributary confluence and the canyon reach approximately two miles upstream.

Thielsen Creek

Thielsen Creek drains an area of approximately 14,250 acres, and has a mainstem length of approximately 11.9 miles. Thielsen Creek originates at the base of Lathrop Glacier and flows into Lake Creek approximately 0.8 mile north of Highway 138. Sections of headwater channels are covered by ice fields in the valley bottom which are assumed to contribute cold stream flow year round. After about ½ mile from the channel's origin, the dominant source of flow is that originating from springs in the valley bottom. The upper reaches of Thielsen Creek were characterized by Sherrod (1986) as being basaltic andesite talus and wash on the west slope and pumice-fall deposits on the east. Further down the draw pumice fall deposits predominate. Brook trout are present in the lower three miles of stream, and a very low density of brook trout may be present up to a 15 foot waterfall located approximately five miles from the creek mouth. Streamflow was measured near the creek mouth at 6.6 cfs on August 10, 1997. Summer stream temperatures are generally cold (5-9^{o}C), with temperatures above 10^{o}C measured rarely, during an August, 1997 survey.

The stream channel in the lower 7-8 miles of stream is predominantly an "E" channel type, with inclusions of "B" channel. The upper 2-3 miles of stream is dominated by "B" type channel, with some inclusions of "E" channel near the headwaters. Stream types above the upper extent of fisheries habitat consist of "A" and "B" channels, with a range in channel condition from "Good" to "Poor". The "Poor" channel conditions are a result of the inherent nature of the drainage in which these reaches have formed and are not a result of management activities. Some riparian timber harvest and low standard road crossings are present in the lower 4.5 miles of stream. However, extensive channel effects do not appear to have occurred. Woody material is the primary pool creating feature throughout most of the channel length.

Sheep Creek

Sheep Creek drains an area less than 1,000 acres in size, and has a mainstem length of less than ½ mile. Sheep Creek originates from a small spring complex approximately two miles north of Diamond Lake, and flows northwest until emptying into Lake Creek. Summer water temperatures are cold, with temperatures in the vicinity of 7^{o}C measured during early August, 1996. Streamflow was measured at 1.1 cfs in August, 1996.

The entire length of the perennial channel is classified as an "E" type channel. High sinuosity, high pool frequency, and large amounts of large woody material create highly complex fish habitat. However, the bed substrate is highly dominated by sand. It is not known whether fish are present in the stream.

Silent Creek

Silent Creek drains an area of approximately 7,250 acres, and has a mainstem length of approximately two miles. Silent Creek originates in pumice flats southwest of Diamond Lake, flowing north and emptying into the southwest corner of Diamond Lake. A short distance downstream from the stream origin, a spring complex provides the majority of flow for the lower 1.6 miles of the stream. Headwater reaches are predominantly in the pyroclastic ash flow (Qaf) geologic unit with small sections in the young basalt andesite

(Qyba) and glacial drift (Qgd). Fish bearing reaches are in the Qaf and lacustrine deposits (Q1). Soils are moderately deep to deep, with an average depth greater than 32 inches. Average surface rock cover is 1 percent, with 32 percent gravel. Both soil surface and subsurface texture is sandy loam with 15 percent, and 15 to 20 percent cobbles, respectively (U.S. Forest Service 1976). Small numbers of tui chub and rainbow trout enter lower Silent Creek from Diamond Lake. Summer water temperatures in Silent Creek are cold, with temperatures of 4.5-7^{o}C measured during August, 1997. Streamflow was measured in August, 1997 near the creek mouth at 30cfs.

The stream channel is classified as a “C” type for the entire channel length. While pool/riffle ratio and large woody material numbers are low, structural habitat requirements such as pool depth and cover appear to provide fair quality fish habitat. The very low number of fish using Silent Creek may best be explained by the cold summer water temperatures. Headwater reaches are predominantly intermittent through the ash flow geologic unit, represented by “A”, “B”, and “E” stream types. Where these reaches become perennial (near the Highway 230 crossing), water seepage from lower side slopes is common. Below the Highway 230 crossing, the channel is predominantly a swale (wide, grassy, stable stream without scoured bed or banks) with inclusions of “E” stream type.

VEGETATION

The high diversity of landscape pattern of plant communities and seral stages of those communities in the watershed have been shaped by natural disturbance, climate, soils, and human activities.

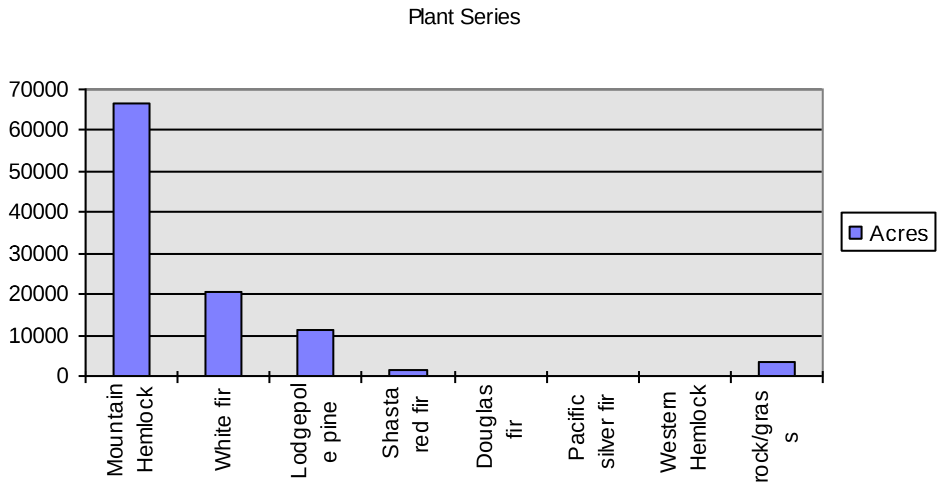
Seven plant series are present within the watershed (Figure 12,Figure 13), including mountain hemlock (*Tsuga mertensiana*), White fir (*Abies concolor*), Lodgepole pine (*Pinus contorta*), Shasta red fir (*Abies magnifica var. shastensis*), Douglas-fir (*Pseudotsuga menziezii*), Pacific silver fir (*Abies amabilis*), western hemlock (*Tsuga heterophylla*), plus grass/shrub/rock (Figure 12 and Figure 13). Elevations range from about 4200 feet to about 9200 feet.

Coarse Woody Material

Large snags and logs are integral components of all stages of forested stands. Both of these structural features persist into young stands that originate after natural disturbances such as wildfire, wind, or competition-related mortality that kill the overstory trees (Bartels et al. 1985). For the watershed analysis we defined coarse woody material (CWM) as logs with at least a 16 inch diameter at the small end and a minimum length of 10 feet; snags at least 10 inches diameter breast high (4.5 feet, dbh) and with a minimum height of 6 feet. These are based on the standards and guidelines of the LRMP as amended by the NWFP, and from other references (Neitro et al 1985). The volume and biomass of CWM in unmanged natural stands are highest in transitional and sifting gap stages (old growth), intermediate in young stands (establishment and thinning) and lowest in mature stands (maturation) (Spies et al 1988). CWM comprises 10 percent to 20 percent of the above ground biomass of the average old-growth Douglas-fir stand (Perry 1991). Size of CWM is an important consideration for both habitat values and the influence of logs on ecosystem processes.

Large logs are more stable and provide better habitat for wildlife. Compared to young and mature stands, late successional stand contain a higher proportion of logs in the larger size classes. Immediately after a stand replacement fire there may be large quantities of logs corresponding to the size of the stand, which may leave large logs in the subsequent young stand.

Figure 12. Plant Series



Factors that affect site productivity in turn affect the recruitment of CWM into a stand. Moist north-facing, lower-elevation sites have higher amounts of CWM than drier south-facing upper slopes because they generally produce more biomass and larger tree boles, are less subject to surface fires that consume CWM, and tend to have a concave topography which collects CWM (Spies et al 1988). As CWM decomposes it enriches the soil, which increases the site productivity. Decaying logs are sponge-like, thus providing an important source of moisture for the forest stand during the dry summer months. Logs are an important barrier to erosion and provide important structural components in aquatic systems. Past forest practices have reduced the levels of CWM in most managed stands to well below natural levels. It had been common practice to remove as much down material as possible to provide wood products. During some timber operations contractors were required to remove CWM from streams, and from harvested stands to reduce fire risks. Both the 1994 NWFP and LRMP have established minimum interim requirements for CWM retention in harvested stands.

Figure 13. Plant Series/Ecoclass

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Fire Disturbance

Wild fires are relatively common in the watershed. The amount of disturbance as a result of these fires has been limited with the advent of modern fire suppression. Fire suppression was very limited with little effect prior to 1910. In Perkins (1938), a personal interview with George Arthur Bonebrake is recorded, in which Mr. Bonebrake tells of a number of fires spread over the district started by an electrical storm on July 5,1910; many of which were not extinguished until fall rains in September. Since 1910, fire suppression technology and road access have improved, and fire suppression has been very successful. As a result of this the watershed is characterized by artificially small fires that cause very little disturbance to the area.

Endangered, Threatened, and Sensitive Plant Species

There are no known occurrences of Endangered or Threatened plant species in the Lemolo-Diamond Lake Watershed. There are six Sensitive plant species documented to occur within or immediately adjacent to the Lemolo-Diamond Lake Watershed. These are *Allium campanulatum, Arnica viscosum, Asarum wagneri, Haplopappus whitneyi, Mimulus jepsonii,* and *Utricularia minor.* In addition, the following Sensitive plant species may also occur within this watershed: *Arabis suffrutescens, Asplenium septentrionale, Astragalus umbraticus, Botrychium pumicula, Calamagrostis breweri, Campanula scabrella, Collomia mazama, Cimifuga elata, Cypripedium fasciculatum, Frasera umpquensis, Fritillaria glauca, Gentiana newberryi, Haplopappus whitneyi, Hieracium bolanderi, Iliamna latibracteata, Lewisia columbiana, Lewisia leana, Oxypolis occidentalis,* and *Romanzoffia thompsonii.*

Noxious Weeds

There are documented occurrences of Scotch broom (*Cytisus scoparius*), St. Johnswort (*Hypericum perforatum*), bull thistle (*Cirsium vulgare*), Canadian thistle (*Cirsium arvense*), and spotted knapweed (*Centaurea maculosa*) found within the Lemolo-Diamond Lake Watershed. In addition, several noxious weeds have become established on the district and have the potential to spread to this watershed. These include yellow starthistle (*Centaurea solstitialis*), rush skeletonweed (*Chondrilla juncea*), yellow toadflax (*Linaria vulgaris*), and tansy ragwort (*Senecio jacobaea*).

SPECIES AND HABITATS

Wildlife And Human Interactions

Wildlife species react in many ways to interactions with humans and even react differently depending on the time on year. The species of greatest concern that may be affected by direct disturbance from human in the LDLWA are elk, wolverines, bald eagles, and spotted owls. The effects on species such as spotted frogs are related more to habitat destruction and the release of non-native fish species that act as predators on spotted frogs.

Resident Terrestrial Species

Elk (*Cervus elaphus*)

Elk are considered generalists, using a variety of habitat types. In the watershed, they move between newly harvested logging units to late successional forests, depending on food availability, weather conditions, time of year, and disturbance factors. They may consume grasses, forbs, or browse. They generally favor forest openings, such as harvested timber units, to feed in when the area is not covered by snow. Forested areas are favored for protection against summer heat and the cold, snowy conditions during the winter. Logging activities in the last four decades have provided a mosaic of habitat types, which has probably enhanced elk herd productivity. For more information about elk habitat needs consult Thomas and Toweill (1982), Witmer et al. (1985), and Lehmkuhl and Ruggiero (1991).

Elk are found throughout the watershed. They generally move through and out of this watershed in the winter to lower elevations in the Upper North Umpqua Watershed. Elk also move down from the higher elevations, along the eastern edge of the watershed, when winter conditions occur. As the southern logged slopes and meadows are exposed when deep snow melts, elk move into these areas.

Wolverine (*Gulo gulo luteus*)

The wolverine is the largest bodied terrestrial mustelid. It’s distribution is circumpolar (Wilson 1982). It is characterized as one of North America's rarest mammals and least known large carnivores. Within its geographic range, the wolverine occupies a variety of habitats. However, the areas it inhabits are remote from human developments and any human contact. The characteristics of the wilderness it depends upon are unknown. The wolverine is a carrion feeder, depending on wolves and other predators to provide carrion (Bianci 1994). It is listed by the USDA Forest Service as a sensitive species in Region 6. Aerial surveys conducted in early 1997 in the Mt. Thielsen Wilderness, produced a possible wolverine den location. Follow-up surveys have been inconclusive.

Northern Spotted Owl (*Strix occidentalis caurina*)

Spotted owls are federally listed as threatened. They are generally considered habitat specialists. They inhabit closed-canopy, multi-layered forest sites, usually found in late seral forest stands (mature, transitional, and shifting gap) within the white fir, western hemlock, Shasta red fir, and Douglas-fir Plant Series. They use broken topped trees and cavities, and natural platforms such as abandoned raptor nests and mistletoe brooms in which to nest. Roost sites are typically in forest stands with high canopy closure dominated by large trees. Foraging habitat is characterized by high canopy closure and complex structure, including coarse woody material that serves as habitat for the owl's prey (U.S. Department of Interior 1992).

Suitable nesting/roosting/foraging (NRF) habitat is found primarily in the western portion of the watershed. Currently known owl nest sites are also concentrated in the western portion of the watershed. Fifty-one, one hundred acre spotted owl core areas (unmapped late successional reserves) have been identified on the district. There are five of these core areas within the watershed and 3 other home ranges which extend into the watershed. Generally the majority of this watershed is not considered suitable habitat, even though much of the forested land is in a late seral state. The vegetative structure and plant composition is not preferred by spotted owls. No spotted owl critical habitat (CHU) has been designated in this watershed.

Bald Eagle (*Haliaeetus leucocephalus*)

Bald eagles are federally listed as threatened. They are primarily fish-eating birds, although they will feed opportunistically on any available carrion. During the breeding season they are closely associated with lakes, ponds, or large rivers which provide readily available food sources. Their large stick nests are usually located in large trees in the upper reaches of the forest canopy.

Non-breeding individuals may be seen in many habitats, but feed primarily near wetland areas. During the winter they are generally found near water bodies with ice-free water, or near frozen water bodies where carrion is common. The only active nest observed in the past year (where breeding activity occurred) was on the north side of Lemolo Lake. Nesting attempts have been made on the Silent Creek nest on Diamond Lake in the past 5 years.

Spotted Frog (*Rana pretiosa*)

The western populations of the spotted frog are listed as sensitive by the Forest Service in Region 6. It is being petitioned for inclusion on the Endangered Species List. This medium-sized frog is one of our most aquatic native frogs. It is usually found in or near a perennial water body such as a spring, pond, lake, or sluggish stream. It is often associated with non-woody wetland plant communities. It is found at higher elevations than most other native frog species, up to 8000 feet (Corkran and Thoms 1996). Breeding occurs from February to June, depending on the elevation. This species has had precipitous population declines, especially at lower elevations. The destruction of wetlands and the introduction of bullfrogs (*Rana catesbeiana*) and non-native fish species into spotted frog habitats are believed to be at least partly to cause for this frog's decline (Leonard et al. 1993).

Resident Fish

The streams and lakes within the analysis area contain simple fish communities as compared to the North Umpqua River system downstream from Soda Springs dam. This is primarily due to the lack of connectivity to the lower North Umpqua River mainstem, caused by both natural and anthropogenic upstream migration barriers, and the resultant lack of access by fluvial and anadromous species. Six species of fish, rainbow trout (*Oncorhynchus mykiss*), brook trout (*Salvelinus fontinalis*), brown trout (*Salmo trutta*), kokanee (*Oncorhynchus nerka kennerlyi),* golden shiner (*Notemigonus crysoleucas),* and tui chub (*Gila bicolor*) are currently known to inhabit the North Umpqua River system within the analysis area. Of the six species, brown trout, brook trout, kokanee, golden shiners, and tui chub originate exclusively from introductions. Rainbow trout have been introduced, but a native strain may have also been present.

The earliest recorded stocking of brook trout occurred in 1939, when fish were stocked in Maidu Lake. The date that brown trout were first stocked in the upper North Umpqua River system is unknown, but historical records indicate that a population was well established by 1940 (Diamond Lake R.D. Stocking Plan 1940). The first stocking of rainbow trout in Diamond Lake is believed to have occurred in 1910. The lake apparently does not support rainbow trout reproduction well, as several attempts were required before a stable, hatchery maintained fishery was established. In 1913, a Forest Service employee and a game warden reportedly caught 3-4 dozen fish below Toketee Falls and transported them in 5 gallon cans to Diamond Lake (Darling 1963). A 1916 article in the Oregon Sportsman magazine (Skelton 1916) states that 6,000 to 8,000 rainbow trout were stocked "...several years ago..." in Diamond Lake, and 35,000 more in 1915, but that the lake was still fishless. At the time, the belief was that the fish were leaving the lake via the Lake Creek outlet soon after they were stocked. By the early 1920s, an egg taking station was established at the Lake Creek outlet and several weirs were in place to capture adults at tributary inlets. Additional introductions of rainbow trout directly into the North Umpqua River system occurred by 1927 (Diamond Lake R.D. Stocking Plan 1940). Kokanee were stocked in Lemolo Lake sometime after the reservoir creation in 1954. Golden shiners and tui chub were introduced into Diamond Lake by bait fishermen by the 1940s. Diamond Lake was treated with rotenone in 1954 to rid the lake of bait fish. Both tui chub and golden shiners reappeared in the lake by the early 1990s.

Brown trout inhabit the North Umpqua River and some tributaries above Lemolo Lake, Lemolo Lake, and most of the Lake Creek mainstem. Brook trout are present in most fish bearing streams in the analysis area, Maidu Lake, with a few individuals present in Lemolo Lake. Rainbow trout are present in Diamond Lake, Lake Creek, and Lemolo Lake. Lemolo Lake contains a kokanee population that enters the North Umpqua River and Lake Creek inlets to spawn. Tui Chub are present in Diamond Lake, Lake Creek, and Lemolo Lake. Golden shiners are only known to be present in Diamond Lake.

Fish habitat in the analysis area can be divided into four primary units, consisting of two large lakes and two stream systems; Lemolo Lake, Diamond Lake, the North Umpqua River and tributaries upstream from Lemolo Lake, and Lake Creek and tributaries. Lemolo Lake is a reservoir created in the early 1950s by construction of the North Umpqua Hydroelectric Project. Diamond lake is a naturally occurring water body. The North Umpqua River originates at the outflow of Maidu Lake, near the Cascade crest in the Mt. Thielsen Wilderness area, and flows west to Lemolo Lake. Lake Creek originates as the natural outflow at the northern end of Diamond Lake and flows northward, emptying into Lemolo Lake. Both Lemolo Lake and Diamond Lake have other small fish bearing tributaries. Current fish habitat condition for salmonids in the analysis area ranges from fair to high quality.

General life histories of the species known to currently exist in the upper North Umpqua River analysis area are discussed below.

Brook Trout

Brook trout are native to northeastern North America. Brook trout have a short life span, rarely reaching four years of age. They spawn in the fall, usually in October, with declining water temperature and day length. Redds are usually built in gravel, but if ground water upwelling is present, spawning may occur on sandy substrate. Brook trout generally do not migrate far, but some anadromy has been reported. In streams, movement is generally minimal. Young migrate from the redd to shallow water and establish territories, moving into deeper water as they grow. Dominant foods include plankton, terrestrial and aquatic insects, and fish.

Rainbow Trout

Rainbow trout are native to most Pacific northwest rivers and streams, but were not historically as widely distributed as cutthroat trout. Kamloops rainbows are relatively long lived, are piscivorous, grow to a large size, and generally live in lakes. Other non-anadromous strains generally live in streams and feed primarily on terrestrial and aquatic insects their entire lives, and do not grow to a large size. Spawning occurs in the spring, with the timing generally consistent in a given stream, but can vary by a month or more among streams in the same region. Life histories vary from resident, fluvial, adfluvial, to anadromous. Survival in redds is generally inversely proportional to the amount of fine sediments present in the gravels.

Kokanee

Kokanee are a landlocked form of sockeye salmon. Kokanee naturally occur in lakes with and without anadromous sockeye. When found living sympatrically, kokanee populations generally exist independently from anadromous forms, and spawn earlier in the fall. Kokanee typically have a three year life cycle. The secondary sexual characteristics of kokanee are the same as those for sockeye, with bright red coloration at maturity. Spawning may occur along lake shores or in tributary streams. Distinct sub-populations may develop within a single lake. Diet is principally pelagic zooplankton and insects. Average adult length among populations varies from 7-12 inches.

Brown Trout

Brown trout are native to western Europe and have been widely introduced in the United States. Life histories vary from resident, fluvial, adfluvial, to anadromous. In Europe, both anadromous and non-anadromous populations are present. Most populations in North America are non-anadromous. Brown trout are primarily insectivores, but larger fish can become highly piscivorous. Spawning occurs in the fall or early winter, with offspring emerging from the redd in late winter or spring. Adfluvial fish may live as long as 10 years.

Golden Shiner

The golden shiner is a member of the minnow family, is native to the eastern United States, and has been introduced west of the Rocky Mountains. Golden shiners prefer clear, weedy ponds. When found in large lakes, such as Diamond Lake, they tend to remain close to weed beds. Benthic broadcast spawning adhesive eggs over weed beds occurs over an extended period during mid-summer. Diet consists primarily of planktonic crustaceans, but insects, mollusks, and algae may also be consumed. Adult length is generally 3-7 inches.

Tui Chub

Tui chub are members of the minnow family and are native to the Owens and Mojave rivers, and several interior basins in Oregon and Nevada. Tui chub typically become sexually mature at three years of age. When in lacustrine systems, tui chub begin entering shallow shoreline areas to spawn beginning in late May to early June. Spawning activity generally peaks in July and concludes in August. Nearly the entire population of tui chub may be present in shallow shoreline areas during July. From September through April, adults return to deeper water. In some systems, tui chub are an integral part of the food chain and are heavily preyed upon by piscivorous fish.

HUMAN USES

The Diamond Lake/Lemolo watershed is situated at the highest elevation of the North Umpqua River basin. Elevation ranges from 9800 feet on top of Mt. Thielsen to 4100 feet at Lemolo Lake. The location of the watershed on the west side of the Cascade crest, combines with water storage features of the High Cascade geology allow the Diamond Lake/Lemolo watershed to supply a cold, clean, dependable supply of water to the lower reaches of the North Umpqua river. Above the Soda Springs/Slide Creek dam a significant lake and stream fishery exists, while below the dam the anadromous habitat of the famous North Umpqua River begins.

The Diamond Lake/Lemolo Watershed Area encompasses 170 square miles, with 18 dispersed recreation sites. Two large lakes with 7 developed campgrounds two major destination recreation areas, dispersed recreation, wilderness, and extensive summer and winter trail systems attract a large number of visitors. The watershed is responsible for over 90 percent of the DLRD recreation program and over 70 percent of the available People At One Time (PAOT) capacity and over 65 percent of the Developed Recreation overnight lodging and camping use on the Umpqua National Forest (UNF). Human uses range from highly organized commercial activities such as logging, gathering of forest products, hydroelectric power generation, and summer and winter resort area operations to non-commercial individualized activities such as hunting, fishing, camping, hiking, snowmobiling, cross country skiing, ATV use, mountain biking, touring, firewood gathering and many other uses. Within the analysis area there are 210 miles of stream, 199 miles of road, 110 miles of hiking trail, and 146 miles of winter trail.

Recreation

Recreation opportunities and use within the watershed follow the goal outlined in the 1990 Land and Resource Management Plan (LMRP) for the UNF:

> *"...provide a broad spectrum of dispersed and developed recreation opportunities to all segments of society."*

Approximately 70 percent of the watershed is managed primarily for recreation. It contains the Diamond Lake Recreation Area, Lemolo Lake Recreation Composite, dispersed recreation, the Mt. Thielsen Wilderness and Oregon Cascades Recreation Area (OCRA), extensive summer and winter trail systems and portions of the Rogue Umpqua Scenic Byway.

Diamond Lake Recreation Area

The most concentrated developed recreation within this watershed is in the Diamond Lake Recreation Area. The recreation area lies predominately in the Diamond Lake Composite (03) sub-watershed and partly in the Lake Creek (01) and Bailey (02) sub-watersheds. The Diamond Lake Recreation Area is approximately 8,100 acres and is centered around Diamond Lake with Mt. Bailey on the western side(8,363 feet in elevation), Mt. Thielsen to the east (9182 feet in elevation), and Crater Lake National Park to the south. Diamond Lake is at an elevation of 5,182 feet, over 3,000 acres in size, and is approximately 3.5 miles long and 1.5 miles wide. FSR 4795 surrounds the lake and is the main access route to recreation facilities (See Figure 14). The lake is managed as a fishing lake by the Oregon Department of Fish and Wildlife (ODF&W) with a maximum speed limit on the lake of 10 mph.

Diamond Lake is a high use destination recreation area (approximately 700,000 Recreation Visitor Days [RVD's] per year). Diamond Lake has traditionally been recognized as a regionally and nationally renowned trout fishery with an average of over 100,000 angler days annually. The area is easily accessible via Oregon State Highways 138, 230 and 97 and fairly equidistant (82 to 92 miles) from the major communities of Bend, Klamath Falls, Medford and Roseburg in central and southern Oregon. Diamond Lake is identified in the LMRP as a special management area (MA2) and is to be administered for concentrated developed recreation and has a Recreation Opportunity Spectrum (ROS) class of Rural. To meet the recreational demand, the Diamond Lake Recreation Area contains extensive USFS and private permitee developments.

The USFS operates and maintains:

- 3 developed campgrounds (Diamond Lake, Broken Arrow and Thielsen View) with a capacity of 446 sites
- Two Day Use areas (South Shore and Noble Fir),
- Hiker biker camp (six sites)
- Three group reservation areas
- Five boat ramps and docks
- Overflow camping area
- Visitor Information Center
- Administrative work center
- Sewer and water systems
- Paved bike path around the lake.

Figure 14. Diamond Lake Recreation Area

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Major use activities are fishing, camping, sightseeing, and biking. Normal operating season for the USFS facilities is mid-April through October coinciding with the fishing season. During the winter months the campgrounds are closed and used for cross-country skiing and other winter sport activities. Diamond Lake Campground (238 sites) is located along the eastern shore of Diamond Lake between the lake and FSR 4795. Broken Arrow Campground (148 sites) is located south of FSR 4795 approximately ¼ to ½ mile from Diamond Lake. The South Shore Picnic Area is located along the southern end of Diamond Lake. Thielsen View Campground (60 sites) is located along the northwest shoreline of Diamond Lake between the lake shore and FSR 4795. All of the campgrounds and the South Shore Picnic Area have paved roads and spurs with hardened sites. They can accommodate RV, vehicle, or tent camping. Diamond Lake and Broken Arrow Campgrounds and the South Shore Picnic Area have water flush toilets, shower facilities, trailer dump stations, and are connected to a sewer collection and treatment system. Thielsen View Campground has water and vault toilets while Noble Fir Day Use Area has no water and a vault toilet. A list of facilities can be found in the Recreation Appendix D.

Other developments in the area are the Diamond Lake Resort (Diamond Lake Improvement Company), Diamond Lake RV Park, Summer Home Recreation Residences, and ODF&W. These developments operate under special use permits, and, with the exception of ODF&W, are privately owned facilities.

The Diamond Lake Resort, located primarily at the northeast corner of Diamond Lake, is a full service resort with 92 lodging units with a pillow count of 500. There are four restaurants with a combined seating capacity of 665, two grocery stores, 2 marinas with a capacity for 186 boats, a gas station, 46 employee-housing units and miscellaneous support buildings. The resort has a water system and is connected to the USFS central sewer system. The resort has a total permit area of 75 acres. Diamond Lake Resort operates year round. Major summer activities and services, in addition to lodging and fishing, are convention and reunion facilities, swimming, horse and bicycle rentals, charter boat service, boat and canoe rentals, and special events such as a square dance festival and a 4th of July Celebration. Major winter activities and services include snowmobile tours and rentals, inner tube sledding hill, ice skating, cross-country skiing and equipment rentals, and snow cat skiing on the west slope of Mt. Bailey. Special winter events are the annual sled dog and cross-country ski races and numerous senior oriented activity weekends.

Diamond Lake RV Park is located at the southeast end of Diamond Lake on the east side of FSR 4795. The park has 140 spaces with full hook-ups (water, sewer, and electric), shower and laundry facilities and living quarters and maintenance building. It has a water system and is also connected to the Forest Service central sewer system. The permit area is 22.9 acres and is operated seasonally from mid-May through mid-October and closed during the winter months.

Diamond Lake summer home recreation residences are located along the west side of Diamond Lake between the lake shore and FSR 4795. There are 102 privately owned residences in the tract with 81 residences possessing separate special use permits for boat docks along the west shoreline of Diamond Lake. Home lot sizes average approximately ½ acre with total permit acreage in the tract of 52 acres. Many of the summer homes have water and septic systems while others have no water and pit toilets. The residences are accessed by a series of unimproved roads off of FSR 4795. Full time occupancy of the residences is not allowed and many are used only occasionally while others are used off and on year-round. Major uses are relaxation, fishing, biking, and winter sports (primarily snowmobiling). Access to the tract is closed by snow during the winter months with access by snowmobile or skiing.

ODF&W owns and manages a cabin, out building, and lake level control structure on the northwest corner of Diamond Lake at the outflow of Diamond Lake into Lake Creek. The cabin has a well and septic holding tank. Permit acreage is 3 acres. Use is primarily during the fishing season by Oregon State employees engaged in the management of the Diamond Lake fisheries.

The Lemolo Lake Recreation Area

The Lemolo Lake Recreation Area lies within the Lakeview (07) sub-watershed. Its area is approximately 1,290 acres and is centered around Lemolo Lake. Lemolo Lake is a man-made reservoir operated by PacificCorp as a hydroelectric facility. The lake is approximately 419 acres in size at an elevation of 4,230 feet. The recreation area is primarily accessed via Oregon State Highway 138 and FSRs 60, 2612, and 2614 (Figure 15). ODF&W is responsible for the fisheries management of Lemolo Lake and the lake has a maximum speed limit of 40 mph. The Lemolo Lake Recreation Area is identified in the LMRP as a special management area (MA2) and is to be administered for concentrated developed recreation prescription A4-1. The ROS class is natural (RN). There are also two special interest areas: Crystal Spring and Spring River, identified in the LMRP as special management area MA6 to be managed for recreation with an ROS class of RN. Though PacifiCorp created Lemolo Lake for hydroelectric purposes, it has become a popular destination recreation area attracting both summer and winter recreationists. Similar to Diamond Lake, Lemolo Lake has both Forest Service and private permitee facilities to meet the recreational demand.

The USFS operates and maintains five campgrounds in the area with a combined capacity of 95 sites. Major activities during the summer include camping, boating, fishing, biking, ATV use, swimming, and sightseeing. The main winter activities are cross-country skiing and snowmobiling. The campgrounds usually operate from mid-May (once snow-free) until the end of October or November. Because of the high popularity of the area for fall elk hunting, the campgrounds will often remain open until the end of November, weather permitting.

The largest and most developed of the campgrounds is Poole Creek (60 sites). It is located in the southwest corner of Lemolo Lake and is accessed from FSR 2610. The campground has paved FSRs and spurs, water, vault toilets, group reservation camping areas, boat ramp and dock, and swimming area. The remaining 4 campgrounds are less developed and have gravel or unimproved FSRs and spurs, vault toilets, and no water. East Lemolo Campground (15 sites) is located in the southeastern sector of Lemolo Lake along the North Umpqua River. It is accessed from FSR 2614. Crystal Springs Campground (1 site) is located farther east of Inlet Campground (14 sites). Both campgrounds are accessed from

Figure 15. Lemolo Lake Recreation Area

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FSRs 2612 or 2614. Bunker Hill Campground (5 sites) is located along the northern shore of Lemolo Lake and is accessed from FSR 2612. There are also approximately 20 dispersed unimproved campsites throughout the area.

Lemolo Lake Resort is a privately owned facility operating under a USFS special use permit. It is located along the north shore of Lemolo Lake. It is a full service facility having 10 lodging units with a pillow count of 32, and a restaurant and bar with seating capacity of 48. It has a trailer park with 36 spaces with full hook-ups and shower and laundry facilities, gas station, grocery store, boat ramp and docks, employee housing, and shop buildings. The resort has its own water supply and has septic tanks with drainfields. Major summer activities and services include fishing, boat rentals, water skiing, swimming, sightseeing, bicycling, ATV riding, and hiking. During the fall, the primary activities are fishing and hunting. During the winter, snowmobiling and cross-country skiing dominate the activities in the area.

Wilderness/OCRA

The Mt. Thielsen Wilderness and the Oregon Cascade Recreation Area (OCRA) lie along the eastern border of the watershed. 22,700 acres of the Mt. Thielsen Wilderness lie within the watershed (Figure 2). The Wilderness is identified in the LMRP as management area 4 (MA4) and is to be managed as part of the National System of Wilderness. The management prescriptions are Wilderness Primitive (22,000 acres) and Wilderness Semi-Primitive (500 acres). The semi-primitive prescription is primarily for the Mt. Thielsen (1456) and North Umpqua/Maidu Lake (1414 and 1459) trails. Portions of the Pacific Crest Trail pass through the wilderness. The Visual Quality Objective (VSQ) is preservation. Primary activities are hiking, climbing, fishing, camping, and horseback riding. The most concentrated use occurs around Mt. Thielsen and the Mt. Thielsen trail with climbing as the main objective. Primary access to the Mt. Thielsen trail is from the trailhead parking area located off Oregon State Highway 138 in the Diamond Lake area. Diamond Lake Resort also operates guided horse rides into the wilderness using the Howlock (1448) and Thielsen Creek (1449) trails. The OCRA , created along with the Mt. Thielsen Wilderness, is along the eastern boundary of the watershed. It is divided into seven management zones of which four (Zones 3,5,6, and 7) are within the watershed. They are defined within the LMRP as special management area 5 (MA5) with the objective to

> *“…manage the area so as to maintain a near natural state while providing*
>
> *for a wide range of recreation activities.”*

The ROS class varies from zone to zone while the VSQ is retention. Use also varies throughout the zones. Primary activities are camping, fishing, hiking, hunting, horse riding, and cross-country skiing.

Dispersed/Other

Within the watershed there are also other smaller developed campsites, dispersed recreation sites, a communications site, and Oregon Department of Transportation (ODOT) maintenance facility. Other developed sites include Calamut Lake Campground, Linda Lake Campground, Kelsay Valley Campground and trailhead, Thielsen Forest Camp, Millsite

Camp, and Sheep Creek Camp. With the exception of Kelsay Valley Campground, these are mainly small campsites near streams and lakes. Improvements are limited to vault toilets, tables, and fire rings. The combined capacity is approximately 39 sites. In addition, there are numerous dispersed sites within the watershed, primarily located along streams and rivers with numerous hunting camps in the Lakeview, Natural, and Lake Creek sub-watersheds. The major use activities for these areas are camping, hunting, hiking, and fishing. There are also seven snow parks located along Oregon State Highways 138 and 230 with a visitor capacity of 287 PAOT. Other uses include a communications site and Forest Service Lookout on Cinnamon Butte, power transmission line corridor along FSR 2610 and Oregon State Highway 138 from Lemolo Lake to Diamond Lake, and an ODOT maintenance building and sand shed located at the junction of FSR 2610 and Oregon State Highway 138.

Trails

Trails within this watershed comprise approximately 70 percent of the total number of trail miles within in DLRD. Trail development varies from wilderness to paved handicap-accessible trails. The trails system accesses lakes, creeks, mountains, and points of interest. There are both motorized and non-motorized trails throughout the watershed, used both summer and winter by hikers, bicyclists, ATVs, motorcyclists, cross-country skiers, and snowmobilers. Approximately 60 of these trails are part of the Winter Trails System. Many of the winter trails are groomed for motorized and non-motorized users by Diamond Lake Resort and snowmobile associations in cooperation with the Oregon State Snowmobile Association (OSSA).

Visuals

Visuals within the watershed are predominately designated in the LMRP with VQO ranging from retention to preservation. The area contains many predominant visual features such as Diamond and Lemolo Lakes, Mt. Bailey and Thielsen, and views of Diamond Peak and the Crater Lake Rim. Oregon State Highways 138 and 230 are part of the Rogue Umpqua Scenic Byway which is included in the USFS National Scenic Byway Program. To improve opportunities along the Byway, management plans have been developed between the USFS, other agencies, and governments to develop recreational opportunities and facilities, maintain and improve scenic quality, and develop opportunities to interpret natural and cultural resources.

Forest Products

Commercial forest products that are harvested from the area include timber, firewood, beargrass, hardwood shrubs, Christmas trees and boughs, mushrooms, prince’s pine, and yew wood. Timber harvest and it’s associated FSR construction began in the 1950s, peaked in the decades of the 1970s and 1980s, and has declined in the 1990s. Approximately **** percent of the watershed has been harvested under even aged management. Non-commercial forest products that are harvested include mushrooms, huckleberries, and blackberries.

CHAPTER THREE

ISSUES AND KEY QUESTIONS

INTRODUCTION

The purpose of this chapter is to:

☐ Focus the analysis on the key issues that are most relevant to the management questions, human values, or resource conditions within the watershed.

☐ Prioritize issues to identify those needing investigation in this iteration of ecosystem analysis.

☐ Formulate key questions based on the issues that will result in recommendations that will guide future management.

PUBLIC INVOLVEMENT

Public involvement focused on asking for information about past and current human uses and conditions within the watershed. Press releases were published in Douglas County newspapers. Letters were sent to approximately 30 individuals, businesses, officials, and organizations encompassing timber and environmental interests, tribal representatives, and recreation groups

ISSUES

The issues were based on relevancy to the management questions, human values, or resource conditions within the watershed. They were based on the assumptions that:

☐ Natural disturbance regimes were affected by years of fire suppression and past management practices.

☐ The aquatic system, resident fish stocks, water quality, and water flow may have been affected by past management practices.

☐ Timber harvest is programmed within the matrix allocation.

☐ PacifiCorp's facilities and operations dramatically affect the aquatic system within the watershed.

☐ There are many recreation facilities located within riparian reserves that may be affecting the aquatic system.

ISSUES AND KEY QUESTIONS

Timber Harvest/Sustained Yield/Site Productivity

1. What is the available land base for timber production?
2. What is the timber productivity of the available land base? What is the probable sale quantity based on the recommendations of this watershed analysis?
3. How and where have past management practices affected timber productivity?
4. How can timber harvest approximate natural disturbance processes at the stand and landscape scales?
5. What should be the harvest priorities? Where should they occur and why?
6. Should any harvest activities take place within riparian reserves? If so, under what set of circumstances and to meet what objectives?
7. Should the Lodgepole plant series be include in the timber base? How would this affect public fire wood cutting?
8. What miscellaneous forest products are harvested? What is the sustainability?
9. What should be done to reduce the incidence of insects and diseases?

Transportation System/Forest Service Road Management

1. What are the existing Forest Service Road densities and stream crossings by sub-watershed and erosion risk? Is there an upper limit to Forest Service Road density or stream crossings by sub-watershed and if so, why?
2. Where will we avoid building new Forest Service Roads and why?
3. What specific Forest Service Road systems pose the highest risk of mass-failure (landslides) or significantly influence chronic stream erosion as a result of fill failures, failed culverts at stream crossings, stream diversion, or stream network extension?
4. Where should we look for restoration/rehabilitation opportunities and to meet what objectives?
5. What types of Forest Service Road maintenance practices are needed and why? What are their priorities?
6. What type of work needs to be done to bring the existing road system up the current standards? How should it be prioritized?
7. What types of roads should be obliterated and why?
8. What types of roads should be blocked and why?

9. What geomorphic terrain's pose the highest erosion risk for road construction? Where are the consequences to beneficial uses the greatest?
10. Should new roads cross streams and riparian reserves? If so, where and how? If not, why?

Water Quality and Fisheries

1. What is the trophic status and history of Diamond Lake?
2. How is the trophic status of Diamond Lake affected by recreation in the Diamond Lake area?
3. How does the presence of tui chub influence the recreational rainbow trout fishery at Diamond Lake.?
4. What is the effect of the introduction of non-native species?
5. What are the erosion processes that affect Lemolo Lake?

Recreation

Diamond Lake

1. How is recreation use influencing lake shore erosion?
2. What is the recreation use and what are the trends?
3. What are the impacts of recreation use on riparian function?
4. Are the current recreation facilities adequate for future use? If not, what should be done, where should new facilities be located?
5. What is the carrying capacity for boating and other recreation uses?

Lemolo Lake

1. What are the impacts of recreation use on riparian function?
2. What is the recreation use and what are the trends?
3. What is the carrying capacity for boating and other recreation uses?
4. What is the relationship between recreation and FERC relicensing?
5. Are current recreation facilities adequate? If not, what should be done, where should new facilities be located?
6. Are regulations concerning dispersed recreation needed around the lake?

Other Areas

1. What are the appropriate recreational uses around high elevation lakes?
2. Are the current recreation uses in the OCRA appropriate?
3. Are the current winter trails adequate?

4. What are the current and potential winter recreation activities on Mt. Bailey?

Wilderness

1. What is the desired future condition for recreation in wilderness?
2. Are there any valid mineral claims in the wilderness?
3. Are there any valid mineral claims in the OCRA?
4. Are we meeting our wilderness management guidelines?

Wildlife

1. What are the important elk movement corridors?
2. What is the relationship between recreation use and wildlife disturbance?
3. What is the distribution of spotted frogs?

Vegetation Management

1. Are appropriate measures being taken to protect Sensitive plants and their habitats?
2. Are restoration/landscaping projects using appropriate native plant species?
3. Are noxious weeds being managed effectively?

Fire Disturbance

1. Under what circumstances should prescribed fire not be allowed in riparian reserves?
2. What areas would benefit the most from prescribed fire?
3. What is the natural fire disturbance process?
4. How prone is this watershed to high intensity fire?
5. Are there areas within the watershed where management could reduce the risk of high intensity fire and its adverse effects on soils, water, and other resources?
6. Should prescribed natural fire be allowed to play its historic role in the Mt. Thielsen Wilderness area. In the Oregon Cascades Recreation Area?
7. Should management ignited fire be used to meet resource management objectives in the Mt. Thielsen wilderness? In the Oregon Cascades Recreation Area?

Heritage Resources

1. Do we have sufficient information about heritage resources in the Lemolo Lake and Diamond Lake Watershed Analysis Area?
2. What could be done to increase public understanding of history in the Lemolo Lake and Diamond Lake Watershed Analysis Area?

CHAPTER FOUR

REFERENCE AND CURRENT CONDITION, SYNTHESIS, AND INTERPRETATION

INTRODUCTION

The purpose of this chapter is to:

☐ Outline analysis procedures, assumptions, and data gaps.

☐ Develop a reference for comparison with current conditions and with key management plan objectives.

☐ Explain how ecological conditions have changed over time as the result of human influence and natural disturbances.

☐ Develop information relevant to the issues and key questions that is more detailed than information outlined in Chapter Two (Characterization).

☐ Document the current range, distribution, and condition of the core topics.

☐ Compare current and reference conditions and explain significant differences, similarities, or trends and their causes.

☐ Explain influences and relationships to other ecosystem processes.

CORE TOPICS

GEOLOGIC FEATURES/GEOMORPHIC PROCESSES/SOIL

Reference Conditions

The reference condition with respect to Lemolo Lake has been determined to be prior to 1953 when Copco, now PacifiCorp, began the development of Lemolo 1, which converted a riverine environment and adjacent meadows to a reservoir. Previous to that time, its assumed that the erosional processes that were occurring were similar to other reaches of the upper North Umpqua River. Based on field observations as well as stream inventory information there is little evidence that large scale erosion was occurring in this area. Although some timber harvest and road construction had occurred prior to 1953, it was limited in nature and the lack of stream power limited the ability to provide a significant mechanism for transport and delivery.

As discussed in Chapter 2, the reference condition for Diamond Lake is assumed to be prior to the 1880s. At that time, the primary erosional processes that were affected the lake were associated with shoreline erosion from wind waves, surficial erosion associated with natural disturbances (fires) and input from Silent Creek and other streams that flow into Diamond Lake. As evidenced by the extensive lake sediments along the west shore (numerous well logs indicate over `100 feet of sand), the record of erosion and deposition in the lake area is substantial over the past 7000 years. The paleolimnological studies recently completed suggest that there was organic as well as inorganic sedimentation occurring.

There are dramatic differences in the stream channels that are dependent on geomorphic terrain, particularly between the surficial deposits and the volcanic rocks of the high cascades. In general, the low stream densities, stable flows and resistant substrate associated with basaltic rocks result in very low sediment rates. Another feature of a substantial number of these streams is a typically intermittent or ephemeral condition associated with spring runoff conditions or summer thunderstorms. Under reference conditions, these stream channels would likely be subjected to only minor channel erosion.

The stream channel erosion on the surficial deposits is perceived to be dramatically different in terms of both rates and particle size. Streams developed in glacial deposits are typically steeper gradient with a much higher coarse fraction in both the banks and bed. The diverse assemblage of glacial tills and outwash provides for a wide range of erosional rates that are very site specific to each reach. In general, however under the reference condition, as characterized by some reaches in the OCRA and Thielsen Wilderness, these streams may have contributed substantial amounts of channel related sediments to the system.

The more typical channel identified in the watershed is associated with the pumiceaous deposits of Mount Mazama. Although the air fall and ash flow deposits are distinctly different in their depositional environment, its difficult to see in the channels. Typically these streams are incised into the surrounding ash deposits and are characterized by fine grained beds and banks. The inherent stable flows in these systems limits stream erosion in all but the most extreme discharges.

The surficial erosion process that had the potential to contribute sediment and affect site productivity during the reference period were predominantly associated with severe disturbances that affected vegetation and soil cover. With the exception of such cataclysmic events like volcanic eruptions, stand replacing fires were the dominant process on the landscape, although numerous studies suggest the high potential for surface erosion of tephra deposits (Umpqua National Forest 1990).

Field inventory identified several reaches of Lake Creek downstream of Diamond Lake and above Highway 138 as unique in terms of geomorphic development and sedimentary processes. The reach above Sheep Creek is characterized by steeper gradients (4-8 percent) and very confined channels that meet the traditional definition of inner gorge, with side slopes in excess of 70 percent and a large number of stream side landslides. A unique geologic unit was identified along this reach that appears to be laminated silts and sands interpreted to be associated with ancient glacial lake deposits prior to the Mazama eruptions. Although only a small portion of the geologic section was observable, there appears to be a large lake bed deposit underlying the tephra which Lake Creek has incised through. It appears that this reach of stream is producing a large volume of sediment and large woody material through the mass wasting process on an annual basis. Due to the gradient and sustained flows through out the year, this reach does not appear to be accumulating large volumes of sediment, however the wood loading was pronounced.

The reach immediately below Sheep Creek has much lower gradients and extends well below Highway 138. This reach is highly adjustable with meanders, side channels and well developed bars. Observations, as well recent inventory data suggest this reach may be sensitive to flow changes, particularly with regards to bed and bank mobility. A number of bars were examined and recent accumulations of sands and gravels were observed as well as filling of side channels. Based on the limited upslope land management activities that have occurred, it appears that this section of Lake Creek from the highway to Lemolo Lake is responding to processes similar to the reference condition.

Current Condition

The erosion of the Lemolo Lake shoreline is well documented in the PacifiCorp License Application for the North Umpqua Hydropower Project and identifies wave erosion along 17,000 feet of shoreline. This is concentrated on over steepened pumice slopes associated with the ash-flow deposits. Studies in the license application suggest wave erosion has resulted in the retreat of headlands by 0.5-2 feet / year. The erosion of the shoreline appears to be directly related to the drawdown of the reservoir during the course of the year and the inability of the over-steepened pumice slopes to revegetate.

Since the development of the lake in 1955, there have been over 2 million cubic yards deposited in the impoundment. Watershed Analysis studies conducted for PacifiCorp suggest that this deposit does not correlate with sediment budgets using current techniques for these terrain types. Several explanations may be offered for this additional material. The amount of exposed surface area during drawdown periods and prior to the development of a snowpack may be contributing to the sediment deposit. Based on channel types identified in lower Lake Creek, there may be a substantial amount of sediment contribution to Lemolo Lake from in channel sources. Additional work is needed to quantify the role of Lake Creek to the sedimentation of Lemolo Lake.

Diamond Lake Erosion

The erosion issues that exist under the recent time period have been largely influenced by a variety of management and anthropogenic processes. Eilers et al. (1997) suggest that several changes in sediment deposition have occurred in the last century, that appear to be associated with a sequence of events. These are described in detail in the Hydrology Appendix E. The erosion of the lake shore can be characterized between the Glacial Tills on the east shore and the Lake Bed deposits on the west shore.

At least two variables have been overlain on the natural erosion processes of the lake shore since introduction of fish. The most obvious are the impacts to over 70 percent of the shoreline associated with recreational activity, including foot trails, boat launches and dock facilities, and removal of native vegetation for access and firewood. A survey of the western shore by the Diamond Lake Ranger District in 1996 identified a large number of slips that have been developed since boats were introduced to the lake and in some cases appear to be expanding the surface area of the lake.

The other variable that may be less noticeable is the artificial control of lake elevation on a seasonal basis. By modifying the pool elevation, the probability of increasing wind and ice related erosion exist, however, it has not been quantified.

Hillslope Erosion

The role of hill slope erosion in the analysis area appears to be very limited in nature and associated with vegetation disturbance where it does occur. The disturbance mechanisms that affect hill slope erosion typically affect water, affect surface cover and require slope. This area is typical of High Cascade terrain and occupies relatively gentle slopes with very few perennial streams. With these limitations, hill slope erosion is predominantly associated with surficial processes, sheet, rill and gully erosion. Although the fragile nature of many of the soils in the area suggest high erosion ratings, there was little indication that this was a widespread concern. Some specific sites had been identified in association with high use recreational sites and a strategy was implemented in the 1980s to address many of these by hardening a number of developed recreation sites and permitted areas.

Road Related Erosion

Although the effects of roads on erosional processes are well documented, this analysis area shows little evidence of road related erosion that is affecting water quality and aquatic habitat at a landscape level. The watershed analysis inventories identified two areas where road related erosion was occurring and have a negative effect on soil productivity and water quality.

The roads located on the lacustrine deposits along the west shore of Diamond Lake, particularly the summer home tract, are extremely sensitive to surficial erosion. Virtually every road observed, even on slopes as gentle as five percent, showed signs of rill and gully erosion. The exact road locations and densities are unknown, however, the historical pattern of development was not consistent with current transportation development standards.

The consequences of the erosion associated with roads is twofold. The most noticeable is the amount of soil loss throughout the development, and the second are the impacts to site productivity. As these roads and tracks continue to deepen, they are typically abandoned and another route is developed. The number of acres of land in this area that have been utilized for vehicular traffic is unknown.

Although the impacts of the roads in this area are observable by following the routing of the erosion to the lake shore, there is little information available to quantify the effects. Eilers et al. (1997) suggests that there have been several surges in inorganic sediments that they attribute to development in the basin; however, the types and timing of these events are unknown.

SOIL

The young soils of the watershed have been impacted primarily through the use of ground based harvesting of timber. In the past, this method involved using heavy ground based equipment that would either drive to a fallen tree or drag it into position. As a result, some older harvest units have diminished potential for revegetation, as a result of decreased availability of air, water, and nutrients to roots (Adams and Froehlich 1984). A good example is Windigo Pass Sale Unit 16 near Lake Charline north part of the watershed.

Harvested in the 1960s, the harvest unit shows compaction still remaining after 30 years. To evaluate the extent of soil disturbance, two pits were exhumed; one within a harvest unit, the other approximately 100 feet outside the unit. Comparison showed an estimated four inches of soil lost from the surface of the harvest unit; of which two inches were a total loss of the organic horizon and another two inches were from a six inch A horizon (the upper mineral soil). Most of the soil appears to have remained within the unit and accumulated at the down slope portion of the unit. Within the harvest unit compaction begins four inches below the mineral surface of the soil and extends 12 inches down into the profile for. Vegetation has returned to the unit, however it is sparse in some areas and evidence of J-rooting was found among trees.

Infiltration of moisture was reduced within the harvest unit. Soil in the compacted zone was found to have a strong platy structure as opposed to the moderate, blocky structure found at the same depth outside the unit. To regenerate vegetation in such areas it may be necessary to decompact the soil. Decompation, or sub-soiling, is done with a tined implement pulled by heavy equipment usually a Caterpillar Tractor. The sub-soiler breaks up the platy structure and allows for greater root growth and moisture infiltration and flow within the soil.

An example of how current harvest practices reduce soil disturbance can be seen at Lakeview Timber Sale 4, west of Lemolo Lake. Harvesting was done from designated skid roads placed an estimated 100 to 150 feet apart. Equipment used in the harvest was allowed only to travel on skid trails that had slash covering the trail; and the movement of equipment was restricted to designated skid roads

Due to the preventative measures in place, only five percent of the soil was adversely impacted; this level is well below the Standard and Guidelines for unacceptable soil disturbance. For some areas, ground based harvesting is often the most practical and economical means of harvest and Lakeview 4 provides an excellent example of how to continue that harvesting without adversely affecting the soil.

HYDROLOGY

The North Umpqua River floods annually during spring snowmelt, and less often during winter rains (Figure 5, Chapter Two). Peak flows from the High Cascades above Lemolo Lake are about one-tenth the size of floods in the Western Cascades downstream. Fall low flow is sustained by young, volcanics in the High Cascades. This sustained flow varies from about 300 cubic feet per second (cfs) in late fall to 750 cfs during winter and spring floods. Until July 1955, these flows from the North Umpqua River and Lake Creek flowed through a wide valley bottom then constricting to a narrow canyon which is now occupied by Lemolo Lake and a dam. Inflow from the North Umpqua River above Lemolo Lake and Lake Creek was about 394 cfs, a relatively high flow year, since average low flows before regulation were 315 cfs. Spring River contributed more than 50 percent of the North

Umpqua flow and six percent was from Bradley Creek. Other sources of perennial flow in the North Umpqua valley bottom occurring as springs are common. Springs typically occur at geologic contacts where more porous material overlays more resistant material. Few tributaries (approximately nineteen) which connect to the North Umpqua River above the Bradley Creek confluence are present because of high soil permeability and minimal surface runoff. However, springs occur on steep side slopes where ash fall deposits are relatively thin. Typically this flow goes subsurface and stream channels disappear lower on the slope where gradient decreases and ash fall deposit depths increase.

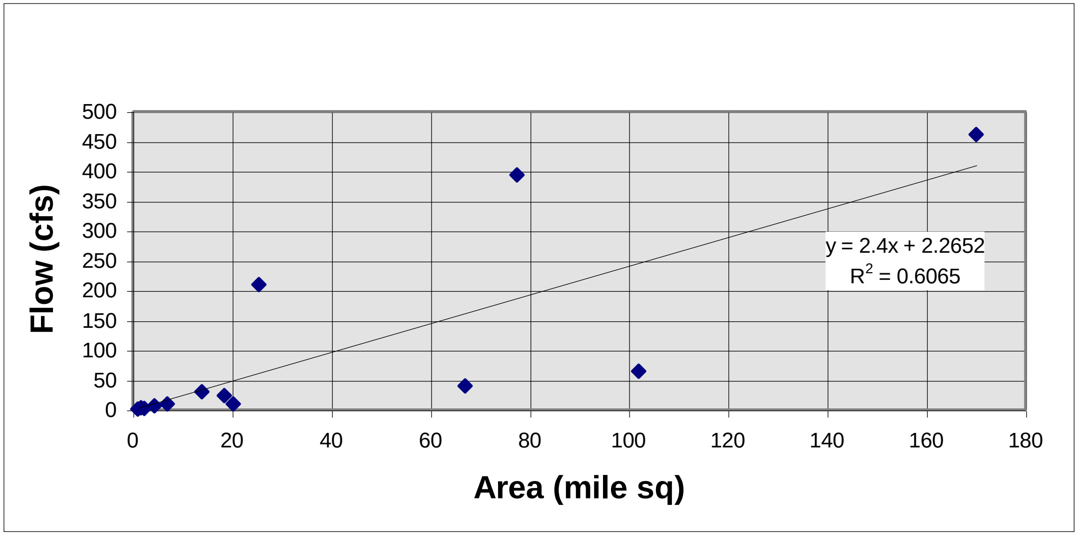
Lake Creek at the Diamond Lake outlet had a discharge of about 40 cfs in late July, a value similar to measured mean flows for that month for the period of record from 1923 through 1984 (USGS 1990), and equal to about six percent of the annual runoff. Lake Creek was flowing at about 65 cfs at its outlet to Lemolo Lake during the 1997 summer survey. The increase in flow of about 25 cfs is attributed to inputs from several tributaries, including Thielsen Creek (the main tributary to Lake Creek with a low flow discharge of about 10 cfs), and Sheep Creek (1.0 cfs), several unnamed tributaries, and numerous springs in the valley bottom.

Table 28. Summary of summer 1997 low flow discharge to drainage area..

Stream Channel	Low Flow Discharge (cfs)	Drainage Area (miles^2)	Flow / Area
North Umpqua River blw Lemolo Dam	461	187	2.5
Poole Creek	2.1	2.3	0.9
North Umpqua River abv Lemolo Lake	394.0	77.5	5.1
Spring River	210.1	25.5 (includes Thirsty Cr. Drainage)	8.2
Bradley Creek	23.8	18.5	1.3
Warrior Creek	9.7	7.0	1.4
Tolo Creek	6.5	4.4	1.5
Tolo Cr. Tributary	3.4	1.7	2.0
Lake Creek at mouth	64.9	102.0	0.6
Lake Creek just blw Diamond Lake	39.5	67.0	0.6
Thielsen Creek	10.1	20.3	0.5
Sheep Creek	1.1	1.0	1.1

Silent Creek	29.9	13.9	2.2

Figure 16. Comparison of 1997 summer flow discharge to drainage area for selected streams in the Lemolo/Diamond Lake watershed.Liner regression and r^2 included to show a linear relationship, where y is equal to low flow in cfs and x is drainage are in square miles.



A comparison of 1997 summer stream flow to drainage area is presented in Table 28 and Figure 16. Figure 16 shows a linear relationship between area and square miles and flow in cfs. Generally, as drainage area increases in the High Cascade geology, summer flow also increases with a linear relationship which has moderate scatter (represented numerically by an r^2 equal to 0.61). Summer flow to area ratios of tributaries to the North Umpqua River above the Bradley Creek confluence range from 1.3 to 2.0 cfs/sq. mi. Below the confluence ratios increase to 5.1 to 8.2 cfs/sq. mi. for the North Umpqua River and Spring River, respectively. These high ratios can be attributed to the large number of springs in the lower portion of the North Umpqua River below the Bradley Creek confluence, and the large volume of water which comes from them. Water which is not commonly expressed as surface flow elsewhere in the drainage emerges mainly within this reach, apparently where more resistant, less fractured bed rock is close to the surface.

Several of the drainages, including the Spring River and Lake Creek drainages, have poorly defined watershed boundaries and therefore unknown drainage areas since surficial deposits of highly permeable material may not give a true indication of actual contributing groundwater flow. The drainage basin for the Spring River is assumed to include the Thirsty Creek drainage where flow is expressed as both perennial and intermittent until it goes subsurface into deep surficial deposits of ash. Groundwater flow and that which is not expressed as surface runoff in the Thirsty Creek drainage is assumed to emerge as perennial flow in the Spring River. Subsurface flow from the North Umpqua River drainage, as represented on the surface, may also emerge at this point.

Summer flow to drainage area ratios (flow/area) for the Lake Creek subwatershed are typically less than those of the North Umpqua subwatershed, ranging from 0.5 to 2.2 cfs/sq. mi. A notable relationship is the difference between the ratio for the area draining into Diamond Lake and that at the outlet of the lake. Silent Creek (assumed representative of surface inflow to Diamond Lake) had a ratio of 2.2 cfs/sq. mi., while at the outlet of Diamond Lake the ratio was 0.6, or a flow/area 73 percent less than the inflow. Therefore, it is likely that water, which would be streamflow in Lake Creek, is lost within Diamond Lake. It is also likely that the drainage area designated for Silent Creek is smaller than actual contributing area. The dominant loss of surficial flow from Diamond Lake is assumed to be from groundwater recharge. The occurrence of groundwater input during the summer has been explored and is presented in the Geology section (the first topic in Chapter Four). A hypothesis not fully explored is the further loss of stream flow from Lake Creek to the adjacent Clearwater River watershed. This small set of data does not support that hypothesis since there is not a difference between the flow/area ratio for Lake Creek at Diamond Lake and Lake Creek at its mouth.

Floods

The Upper North Umpqua has a stream gage below Lemolo Lake with records beginning in 1928. Floods in 1861 and 1890 affected rivers throughout the basin, although records on the Umpqua near Elkton indicate that these did not match the record flood of 1964. The North Umpqua stream gage measures flow from about 187 square miles (or 170 square miles as determined by USGS) of the North Umpqua and Lake Creek, including the watershed of Diamond Lake. All gage flows were corrected to include the canal diversion for hydropower, until 1983. Flows since that time have not been corrected, and are not shown in the figure or in the Hydrology Appendix E. Since the gage was installed, the North Umpqua has experienced “10-year” floods in 1956, 1972, 1974, and 1983. The record flood of December 25, 1964 (water year 1965) was 4680 cfs, larger than a 100-year event (USGS 1996).

Floods on the Upper North Umpqua, Lake Creek, and the tributaries cause little channel adjustment, because waters rise slowly and have low flood peaks. Existing High Cascade equations for ungaged streams estimate much higher flow than actually occurs (USGS 1979). See the Hydrology Appendix E for an alternative way to estimate peak flows for culverts or other crossings on ungaged streams in the High Cascades.

The North Umpqua has higher summer flows and lower flood flows because the watershed is located within the High Cascades geologic subprovince. The river is famous for the water quality associated with these sustained flows. If annual rain and snowmelt did not percolate through ash and glacial soils, seeping into the volcanics of the High Cascades much less water would remain in summer to sustain the North Umpqua River and the Wild and Scenic River downstream. An important question concerning floods is if there has been an impact from logging with tractors (soil compaction), and if constructing roads has caused less recharge to infiltrate hill slopes or stream channels. Also, removal of forest canopy may have increased snow pack accumulation or accelerated melt. If so, the result may be higher floods or lower summer flows.

Plotting the sum of annual floods of the North Umpqua River shows no obvious change in the average annual flood over time (Hydrology Appendix E). This visual look at average annual floods covers the High Cascades above Lemolo Lake. Streamflow recorded in the period from 1928 to 1950 (before most hydropower facilities and logging activities began), represents the reference condition. Annual floods from 1950 to 1983 represent the period which led to the current condition. A similar look at peak flows in the Lake Creek subwatershed at the Diamond Lake outlet shows no obvious increase in annual floods between 1927 (assumed to be near reference condition) and 1984. Major development within this drainage and around Diamond Lake was completed before the end of the discharge record, with the exception of road and trail paving after that period. Surface runoff and water yield to Diamond Lake may have increased with the paving of roads in the drainage. However, these increases are assumed to be small and diminished by Diamond Lake, thus modifying them to a point where they are not noticeable in Lake Creek.

Peak flow data is also available for Thielsen Creek and Silent Creek (Hydrology Appendix E). For the period of record, these systems appear to have annual peak flows which mimic the pattern of those occurring both in Lake Creek at Diamond Lake and the North Umpqua River. However, the months at which these peaks occur varies throughout the year with the North Umpqua River below Lemolo Lake peaking during May and June, Lake Creek during November through February with a secondary peak in June, Thielsen Creek during May, and Silent Creek peaking in June, September, or December. Only two of the six annual peak flows recorded for Silent Creek occurred on or around the time of those of Lake Creek, while none of six peaks in Thielsen Creek match Lake Creek. Therefore, it appears that these systems respond to annual runoff events with a similar pattern of fluctuating annual peaks, but the timing of the event often differs within the year. These differences may be the result of varying climatic conditions among the drainages, and differences in groundwater recharge and storage, determined by type of surficial deposit (glacial, ash fall/pumic, or a combination of the two) and aquifer thickness. The velocity of groundwater movement depends on the horizontal gradient of the free water surface (water table) and is independent of aquifer thickness (Manga 1996).

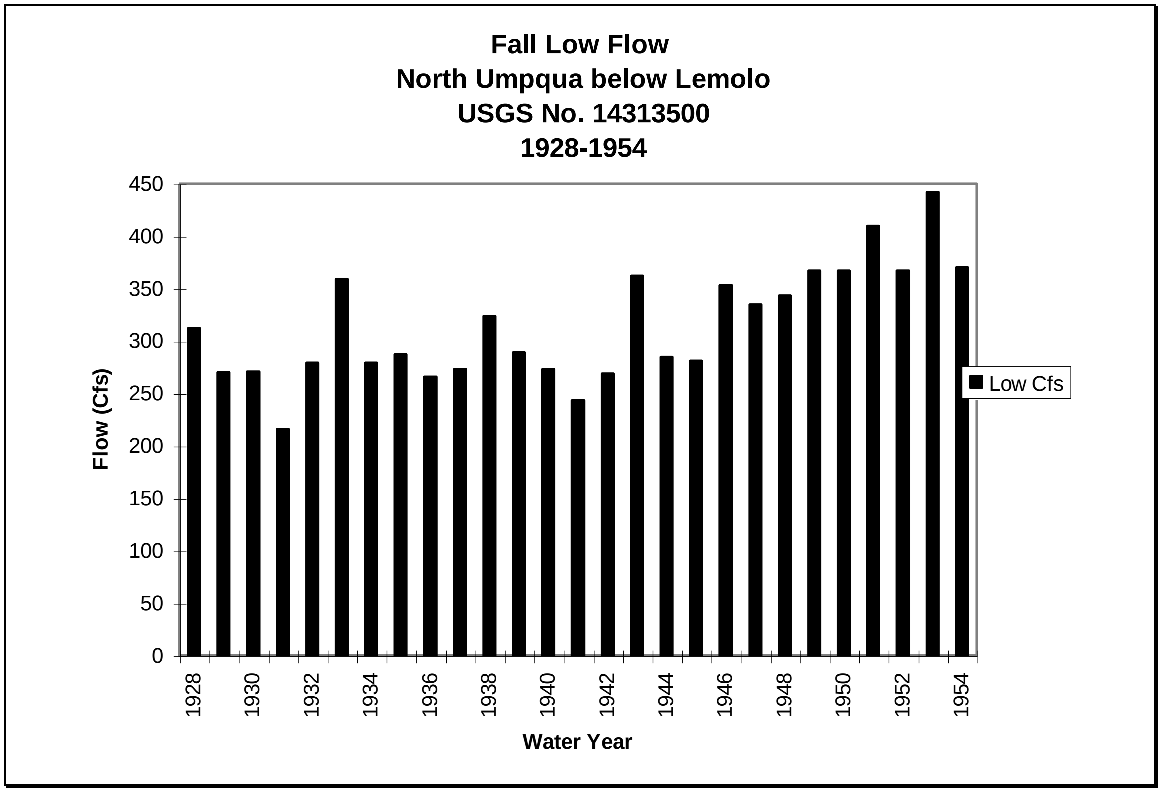
Since the streamflow record of the North Umpqua River below Lemolo Lake and Lake Creek below Diamond Lake, show no obvious increase in average annual floods since measurements began around 1930, it is assumed that impact of management has been minimal. Furthermore, management that has occurred has not been sufficient to affect annual flood peaks at the scale analyzed. Avoiding further soil compaction, canopy removal, and road ditch runoff to streams is still a prudent measure to reduce surface erosion, but it is unlikely that prevention or mitigation (like soil ripping) will be noticed in flows measured downstream due to the low impact in this analysis area.

Low Flows

The lowest fall flows on the North Umpqua River each year from 1928 to 1954 are shown in Figure 17. Notable low flows occurred in 1929, 1930, 1931, 1936, 1937, 1940, and 1941. The lowest late summer/fall natural flow from 1928-1954 was 216 cfs on November 11, 1931 The highest late summer flow recorded in the same period was 442 cfs. After 1955, storage and release of flows from Lemolo Lake alters the published flow record (river plus canal flow), usually increasing flows as the reservoir is drawn down in winter.

A cumulative plot of low flows until 1954 is in Appendix E which showed slightly higher average annual fall flow after about 1945, when annual precipitation appears to increase after a dry period. This entire period before logging activity began represents the reference period. This cumulative plot shows the effects of climate (higher rain, snow, or a difference between high rainfall or snowfall years) and watershed characteristics on low flow.

Figure 17. Annual Fall Low Flows, North Umpqua River, Below Lemolo Gage No. 14313500 (data from 1928-1954).



Water Quality

Water in the North Umpqua River below Lemolo Lake before human activity, was likely cold (less than 60°F) and clear, with the relatively high nutrients of groundwater common to the young, poorly weathered High Cascade bedrock and soils. The North Umpqua River inflow to Lemolo Lake has retained its cold high quality status, since there has been little human activity within the watershed. Monitoring conducted by PacifiCorp in 1995 recorded summer water temperatures which ranged from 35.6°F to about 49°F in the North Umpqua River. Data from 1994, 1993, and 1992 reveals a maximum daily temperature below 53°F for those years. The Lake Creek subwatershed has experienced a larger degree of human disturbance including timber harvest, road construction, and lake shore development. To characterize Lake Creek, one must first address the water quality of Diamond Lake.

Diamond Lake is a dimictic lake, mixing completely in fall and spring. Stratification during the summer is generally weak because of the shallow nature of the lake. Diamond Lake is generally ice-covered from December to April. The lake experiences partial dissolved oxygen depletion in winter and summer, although the hypolimnion never becomes completely anoxic (Salinas and Larson 1995). The lake is eutrophic, as indicated by high lake productivity and abundant algal growth, resulting in chlorophyll α concentrations ranging up to 48mg/L (Oregon DEQ 1994). High productivity causes summer pH to reach 9.3, with a maximum occurring at depths of 13 to 23 feet (Lauer et al. 1979). Both of these water quality parameters exceed State standards and impair beneficial uses, and are the primary cause of DEQ's designation of water quality limited status. For a more detailed description of water quality in Diamond Lake, refer to the section on "Diamond Lake" in Chapters two and four.

Outflow from Diamond Lake to Lake Creek occurs from the lake surface, which is subject to relatively rapid warming due to air temperature and direct solar radiation energy inputs. The result is water temperatures which are similar to summer daytime air temperatures (60-70°F) and a stream warmer than typical High Cascade streams. For example, while Lake Creek was experiencing water temperatures greater than 72°F at the outlet of Diamond Lake, Silent Creek (the main tributary to Diamond Lake) had temperatures below 44°F, and Thielsen Creek was below 53°F. Data presented in Table 29 shows that water temperatures in Lake Creek were almost ten degrees Fahrenheit less at the mouth compared to the outlet of Diamond Lake. Lower stream temperatures at the mouth are the result of cold inflow from groundwater and tributaries, and from the influence of shading from both vegetation and topography. Water temperatures currently in the Lake Creek drainage are likely similar to temperatures before management began, since vegetation disturbance (including timber harvest, road construction, and campground development) in riparian areas of stream channels within the Lemolo/Diamond Lake watershed has been minimal within the past 60 years. Temperatures are likely to have improved since the 1940s when grazing disturbance was minimized.

Since construction of Lemolo dam and the Lemolo I diversion, 90 percent of the summer low flow is diverted to the hydropower canal. Most of the flow released to the North Umpqua River comes from the bottom of the reservoir, resulting in a cold water release. Occasionally, total phosphorous from the bottom of Lemolo Lake increases the fall phosphorous (and maybe nitrogen) in the river. In September 1992 total phosphorous was 0.20 mg/l below the dam, compared to usual values of 0.03-0.09 mg/l. Small changes in nutrients in Lemolo Lake, or even timber harvest or fertilizer use in the watershed, may increase algae and pH in the river downstream. In July 1995, pH in the North Umpqua River just above Toketee Lake exceeded the water quality standard of 8.5. Additional information on river water quality will result from a study conducted by the U.S. Geological Survey, currently in draft form.

Table 29. Water Temperatures (F) from monitored streams in the Lake Creek drainage.

Stream Channel / Year	**Seven-day mean of the daily maximum**	**Daily maximum**
Lake Creek below Diamond Lake		
1996	74.1	78.4
1997	73.4	76.2
Lake Creek below Sheep Creek		
1996	66.9	68.1
1997	67.4	68.7
Lake Creek below Hwy. 138		
1992	69.1	70.5
1993	62.8	64.6
1994	67.3	69.8
1995	66.0	67.8
1996	65.9	67.8
Lake Creek at mouth		
1997	65.0	66.4
Thielsen Creek one mile above mouth		
1997	50.8	52.3

State Standard: Seven (7) day moving average of the daily maximum shall not exceed 64°F (17.8°C).

Water Quality Standards

In 1996, the Oregon Department of Environmental Quality (ODEQ) published a greatly expanded list of “water quality limited” streams not meeting water quality standards under section 303 of the federal Clean Water Act. Water quality criteria require repeated violations of standards to place stream reaches on the list Even though water temperature, pH, total dissolved gases, habitat and flow are affected by hydropower and forestry activities in the North Umpqua River, below Lemolo Lake no stream reaches were listed as “water quality limited” by ODEQ in 1996. Upstream, Lemolo Lake and Diamond Lake do not meet standards for nuisance algae and pH. Lake Creek and the North Umpqua River below Steamboat Creek do not meet the temperature standard of 64 degrees Fahrenheit, and all four water bodies are on the Water Quality Limited list. Further analysis may show beneficial uses (like fish) are affected by water quality on the North Umpqua River below the reservoir, which will be considered by ODEQ in their review of PacifiCorps' application to re-license the North Umpqua Hydropower Project.

LAKES

LEMOLO LAKE

Water Quality And Species Habitat

Current Conditions in Lemolo Lake

Lemolo Lake is the second-largest water body in the area and the largest reservoir. The 120 foot-high Lemolo Lake No. 1 Dam creates the 435 acre lake whose main inflows are Lake Creek and the North Umpqua River. Spring River arises from the pumice fields of the pyroclastic rocks in the High Cascades and joins the North Umpqua River several miles upstream of Lemolo Lake.

Lemolo Lake is heavily used for recreation including boating, fishing, swimming and camping. The calculated hydraulic residence time, assuming complete mixing, for the lake is about two to three weeks depending on the season. The lake is generally classed as mesotrophic (Johnson et al. 1985), but can at times be considered eutrophic based on chlorophyll α concentration and pH. During algal blooms in the summer, pH occasionally exceeds the Oregon DEQ standard of 8.5 (PacifiCorp 1995, Vol. 21).

Lemolo Lake is thermally stratified during the summer. Stratification begins in April and becomes progressively more pronounced through the summer, reaching a maximum by mid August. Stratification weakens in the fall and the reservoir is usually isothermal by mid-November. The thermocline usually develops between three and six meters depth. The reservoir is frequently covered with ice and snow from January through March. (PacifiCorp 1995, Vol. 3)

This stratification, combined with the summertime phytoplankton bloom results in vertical variation in pH and dissolved oxygen. Photosynthetic activity results in a pH and dissolved oxygen maximum near the thermocline at approximately 3 m depth. Oxygen depletion in the hypolimnion has not been observed (Johnson et al. 1985, PacifiCorp 1995, Rinella 1979).

The influent streams to Lemolo Lake differ in average temperature and in nutrient content. Because the lake stratifies in the summer, cooler, phosphorus-rich water from the North Fork Umpqua will tend to flow deeper in the lake, contributing to the hypolimnion, while warmer water from Lake Creek will tend to stay nearer the surface and contribute to the epilimnion. Water is withdrawn from Lemolo Lake from the hypolimnion. Because the residence time is relatively short, on the order of 2 to 3 weeks, this sets up a flow-through condition in the hypolimnion that keeps it replenished with water from the North Fork Umpqua River while the epilimnetic water is retained in the lake during the period of stratification.

Reference Conditions

Because Lemolo Lake is an artificial impoundment built in 1954, there is no relevant historical condition. The natural historical condition would be the unimpounded river. There is no evidence to determine if the water quality of Lemolo Lake has changed since 1954.

Projected Future Conditions

Several actions are being considered that may affect conditions in Lemolo Lake. The North Umpqua Cooperative Watershed Analysis (PacifiCorp 1997) suggests several measures that would directly affect Lemolo Lake, including dredging the lake to remove sediment, installing a multi-level intake to facilitate temperature control of water leaving the reservoir, and reducing water level fluctuation in the reservoir. In addition, consideration is being given to treatment of Diamond Lake with rotenone to control the tui chub population in the lake (ODFW). Rotenone treatment of Diamond Lake may indirectly affect water quality in Lemolo Lake.

Key Assumptions

- Lemolo Lake will continue to be operated as a hydropower and flood control facility.
- Recreation at Lemolo Lake will remain the same or increase as proposed improvements to recreational facilities are completed.
- Diamond Lake, upstream, will be treated with rotenone to control tui chub.
- Nutrient inputs from the tributary streams to Lemolo Lake will remain the same as at present.

Forecasts

Nutrients

There is little evidence that sediments in Lemolo Lake are a significant source of nutrients to the lake or downstream. The hypolimnion appears to remain well oxygenated during the entire period of stratification, and does not exhibit conditions that would promote rapid release of nutrients from the sediment. Dredging the sediments would probably not reduce the amount of nutrients in Lemolo Lake.

The effects of a multi-level intake are difficult to forecast because they depend on the specific mode of operation. Operating the intake to selectively remove water from the epilimnion during stratification could produce a longer residence time for water in the hypolimnion which may increase the oxygen depletion in the hypolimnion to the point that nutrient release from the sediment is enhanced.

Treatment of Diamond Lake with rotenone will probably require lowering the level of Diamond Lake considerably as was done in 1954. This could have a short term adverse effect on nutrient conditions in Lemolo Lake, both because of the potential for significant input of solids from erosion in Lake Creek, and from the input of additional nutrients from

Diamond Lake.

Phytoplankton

Phytoplankton populations may not change appreciably. Much of the phosphorus reaching Lemolo Lake appears to be from natural groundwater sources. Nitrogen inputs are projected to decrease over the long term as a result of nutrient controls at Diamond Lake and changes in forest practices in the basin. Lemolo Lake currently exhibits phytoplankton assemblages characteristic of nitrogen limited systems. Proposed changes would tend to amplify the effects of nitrogen-limitation.

Transparency

There is little likelihood that transparency would change in the long-term. Short-term decreases in transparency might be expected as a result of increased flow in Lake Creek when Diamond Lake is drawn down, from temporarily increased nutrient input following rotenone treatment of Diamond Lake, or if dredging occurs in Lemolo Lake.

Hypolimnetic Oxygen Depletion

Hypolimnetic oxygen depletion could become more severe under certain conditions of operation with a multi-level intake tower.

Sediment Accumulation Rate

Sediment accumulation could increase markedly as a result of drawdown of Diamond Lake. In 1954, drawdown of Diamond Lake began on the same day that Lemolo Lake began to fill. Anecdotal reports (Paul Uncapher, personal comm.) suggest that considerable sediment was mobilized along Lake Creek and presumably was deposited in Lemolo Lake.

Macrophytes

Macrophyte populations could increase if the operation of Lemolo Lake is changed to reduce annual fluctuations in surface elevation.

Fisheries

Operation of a multi-level intake could adversely affect the fishing in Lemolo Lake by changing the temperature regime and annual stratification of the lake. Any management actions that resulted in significant increase in tui chub could adversely affect the trout fishing as a result of competitive interactions between the tui chub and trout.

DIAMOND LAKE

Water Quality And Species Habitat

Current Conditions in Diamond Lake

A considerable amount of information is available to assess the current conditions in Diamond Lake. An existing monitoring program initiated in 1992 (Salinas and Larson 1995, Salinas 1996) provides useful information on components of the lake chemistry and biota.

Based largely on these data we can characterize Diamond Lake from several perspectives. Relative to other Oregon Cascade lakes, Diamond Lake has high concentrations of nutrients, base cations, alkalinity, conductivity, and pH. The lake is productive in terms of nutrients, primary productivity, algal biomass, chlorophyll *a*, macrobenthos, macrophytes, and fish production. The trophic state of Diamond Lake generally falls between mesotrophic to eutrophic classifications for most metrics. As noted earlier, three of the five metrics used by the Organization for Economic Cooperation and Development (OECD) (1982) would classify Diamond Lake as mesotrophic and two metrics would be eutrophic (Table 30). Expressing the trophic state on a probability basis shows that on the basis of TP and maximum chlorophyll *a* one would classify Diamond Lake as most likely to be eutrophic. Using the other metrics, Diamond Lake would likely be mesotrophic (Table 31).

A similar conclusion is achieved using Carlson's (1977) trophic state index in which Diamond Lake would be eutrophic based on TP, mesotrophic based on Secchi disk transparency, and intermediate between mesotrophic and eutrophic based on chlorophyll *a* (Table 32). Lastly, if one expands the list of criteria for characterizing lake trophic state to include qualitative descriptions, the general assessment is that Diamond Lake shares a number of characteristics in common with eutrophic lakes, but few similarities with oligotrophic lakes (Table 33).

Reference Conditions

Reference Period

The question of what constitutes historical conditions requires definition of the historical period. With respect to Diamond Lake, the period prior to 1910 was selected as an appropriate basis for establishing historical conditions. Up until 1910, Diamond Lake was not used for recreation because of the absence of fish and the difficult access to the lake. The only documented visitors in the area were small numbers of Forest Service employees and occasional sheep herders passing through in the summer. Whatever effects they may have had on the lake were probably minimal.

The changes, if any, to Diamond Lake would have occurred after 1910 with the introduction of rainbow trout and the subsequent recreation-based development that occurred throughout the 20th century. Thus, the reference condition selected for Diamond Lake is the state of the lake near the beginning of the 20th century.

Data Available for Establishing Reference Conditions

No water quality data are available for Diamond Lake prior to 1910. In fact, relatively little water chemistry data exists prior to the EPA-funded study starting in 1971 (Lauer et al. 1979; cf. Salinas and Larson 1995, for a review of historical water quality data). Consequently, the only basis for establishing reference conditions in Diamond Lake are the paleolimnological investigations conducted by Meyerhoff (1977) and Eilers et al. (1997). The Meyerhoff study consisted of collecting a 50 cm sediment core and analyzing the sediments for water, LOI, SCDP, TP, TN, and dominant diatom taxa. The Meyerhoff core was not dated using radioisotopic methodology; dates were inferred in the sediments based on changes in sediment chemistry and diatom taxa. A sediment sample collected by Dean and Bradbury (1993) analyzed only the surface sediments and provides no basis for establishing reference conditions.

The Eilers et al. (1997) study was based on a 78-cm core also collected near the deepest location in the north-central portion of the lake. The sediments were analyzed for water, LOI, C, N, P, Fe, Ti, Si, Ca, Mg, Na, K, S, ^{210}Pb, ^{137}Cs, ^{14}C, and diatom species. Because of the additional length of the sediment core, the radioisotopic dating techniques, the more extensive sediment chemistry analyses, and the diatom taxonomy complete to species were possible, most of the historical analyses focus on the core by Eilers et al. (1972).

Reference Conditions Based on Paleolimnology

The sediment in Diamond Lake is somewhat unusual in that it is a very light tan/ochre color, with very high water content, and a composition derived largely from diatom (and presumably chrysophyte) remains. The relatively homogeneous sediment has a gelatinous consistency and appears to be highly oxidized (Dean and Bradbury 1993).

The age of the sediments based on ^{210}Pb, and generally corroborated with ^{137}Cs, indicate that the sample at 33 cm corresponds with a date of about 1900. The sediment accumulation rate (SAR) at this depth is about 0.009 g/cm^2/yr which is near the estimated long-term SAR calculated for the sediments below 40 cm using ^{14}C (Figure 18). This long-term SAR is approximately four-fold less than SAR values currently measured in the lake. Thus the first conclusion is that, under reference conditions, sediment was accumulating at a much lower rate than is presently occurring.

The nature of the sediments during reference conditions probably was similar to current sources of deposition in that historical sediments were probably also derived largely from autochthonous (in-lake) sources. This is based on examination of the titanium values which are only slightly less at the surface compared to the lower portion of the core and by the homogeneity of the sediments based on appearance and consistency. Although the primary source of sediment in Diamond Lake has not changed from the reference conditions, the species of diatoms (the major source of sediments) has changed. In the period circa 1900, the dominant taxa were *Fragilaria pinnata*, *Aulacoseira granulata*, and *Stephanodiscus minutulus* (Figure 18). *Fragilaria crotonensis, F. construens*, and *Asterionella formosa* were present only in relatively small numbers at the turn of the century. These last three taxa are found in fertile waters and their relative paucity in the reference period indicates that water quality in Diamond Lake at the turn of the century was quite good. The increase in these three taxa, particularly the large increase in *F. crotonensis* in the mid-century is a strong indication that pre development lake water quality was superior to present conditions.

Further indication that the nature of water quality during the reference period was better than current conditions is that the nature of the diatom community changed from one with relatively equal numbers of attached, planktonic, and tycoplanktonic taxa (Figure 20). As water quality deteriorated in the 20th century, the percentage of attached taxa decreased whereas the planktonic and tycoplanktonic taxa increased. Generally, a reduction in attached diatoms is indicative of reduced lake transparency. Because the phytoplankton increased, we can conclude that the reduction in transparency was caused by an increase in planktonic

Figure 18. Sediment accumulation rates (SAR) for Diamond Lake sediments computed using the CRS model of Appleby and Oldfield (1978) as modified by Binford (1990) for old age dates. the estimated long-term SAR range prior to development, based on 14C dating, is shown as a vertical bar

Figure 19. Percent abundance of the eight most abundant diatom taxa in Diamond lake sediments

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Figure 20. The proportion of diatom community classified in Diamond lake plotted against depth in sediment (cm). The groups of diatoms are epiphytes (•), attached (○), planktonic(Δ), and tycoplanktonic(□).

algae. The increase in planktonic algae and a decrease in transparency is most directly explained by an increase in nutrient concentrations in Diamond Lake.

Although the concentrations of C, N, and P are greater in surface sediments than bottom sediments, the nutrient concentrations cannot be used directly to infer an increase in nutrients in Diamond Lake because of the possibility of post-depositional mobility of the nutrients caused by diagenetic reactions in the sediments and physical transport associated with bioturbation. The sediments in Diamond Lake support abundant populations of chironomids (esp. *Chironomus* spp.; Lauer et al. 1979) which could be responsible for some distortion in the sediments. However, the ability to satisfactorily date the sediment core using ^{210}Pb suggests that sediment disturbance from bioturbation is not severe. However, the highly flocculent sediments in Diamond Lake provide pathways for diffusion of reduction/oxidation-sensitive species such as PO_4 and NH_3.

Both the Meyerhoff (1977) and Eilers et al. (1997) studies indicate that pre-development water quality in Diamond Lake was superior to conditions in the 1970s and 1990s, respectively. The degree to which water quality has changed in Diamond Lake is subject to considerable uncertainty, although several aspects of this issue can be addressed.

(1) *What was the historical trophic state of Diamond Lake?*

Judging from the historical diatom taxa, the apparent importance of internal cycling of nutrients in the lake, and the diatom-inferred changes in pH, Diamond Lake has always been productive compared to other Cascade lakes. However, the increase in productivity in the 20th century is also well documented. It is likely that Diamond Lake historically was a mid-mesotrophic system that is now characterized as an upper-mesotrophic to lower-eutrophic lake. Changes in water quality during the 20th century that would be consistent with this level of change in the trophic state *might* be represented by:

(a) a reduction in average Secchi-disk transparency of 1 to 2 m

(b) an increase in surface TP concentrations of 10 g/L

(c) an increase in surface TN concentrations of 100 g/L

(d) an increase in the hypolimnetic oxygen depletion rate

(e) an increase in epilimnetic summertime pH from 7.9 to 8.2

(2) *What basis is there for assuming that the trophic state of the lake changed given that other studies show the nutrient loading to the lake is largely natural?*

Lauer et al. (1979) concluded that the sewage collection and treatment system completed in 1973 had no positive impact on the lake because they estimated that this source represented only 14 percent of the total P inputs to the lake. The remainder of the sources were considered natural. This conclusion could be challenged from several aspects. First, the study extended only several years after completion of the project. Most studies show that lake response to nutrient reduction is much slower because of P-enrichment of the sediments (Chapra and Canale 1991). Furthermore, nutrient enrichment of the groundwater-contributing area would require a number of years to return to historical levels. Second, the Lauer et al. (1979) study largely focused on P as the limiting nutrient when nearly all studies have shown that maximum algal growth is achieved with addition of both N and P

(Thompson and Rhee 1994). Nitrogen loading from anthropogenic sources was probably greater than P-loading because of the greater mobility of N in groundwater. Lastly, Lauer et al. (1979) assumed that for nutrient enrichment to occur, additional nutrients were required from watershed loading. Alternative hypotheses were not considered. We now know that biomanipulation of fish populations can cause major changes in lake productivity and that introduction of planktivores, in particular, will commonly increase the trophic state of a lake (Sarnelle 1994).

The paleolimnological study by Eilers et al. (1997) indicates that the sediment accumulation rate (SAR) and diatom community composition have changed substantially and that the productivity of Diamond Lake has increased. Furthermore, the increases in trophic state are difficult to reconcile with the periods of rapid watershed development. The two most significant increases in SAR coincide with periods when tui-chub populations increased dramatically, suggesting that there is a strong biological component superimposed on the watershed loading of nutrients, that when combined, provide the most consistent explanation for the observed changes in Diamond Lake.

Projected Future Conditions

Forecasts for future conditions are necessarily based on a number of assumptions. It is these assumptions which are often times more useful than the actual predictions because the assumptions force us to describe our current understanding (or lack thereof) of the system. The forecasts are merely extensions of these assumptions.

Key Assumptions

a. Diamond Lake will continue to be managed for trout production (as per ODFW 1996).

b. Diamond Lake will be treated with rotenone in 1999 and re-stocked with rainbow trout (Dave Loomis, ODFW, personal comm.).

c. Recreational use at Diamond Lake will remain high at 800,000 visitor-days/year, although fishing may constitute a smaller percentage of user demand.

d. The level of sewage treatment will remain constant (i.e., continued operation of existing sewage system; no additional treatment associated with the Summer Home tract).

e. Nutrient inputs to the lake from former anthropogenic groundwater sources (campgrounds, resorts) have stabilized to levels approaching pre-development concentrations.

Forecasts

After completion of the rotenone treatment and return to a monoculture trout population, the following is likely to occur in Diamond Lake:

Nutrient Concentrations

Concentrations of TP and TN are expected to decrease slightly in Diamond Lake. The decreases are expected because of reduced predation of zooplankton and an increase in grazing pressure on the phytoplankton.

Algae Populations

Phytoplankton abundance is expected to decrease slightly as available nutrients decrease and zooplankton grazing pressure increases. The decrease in TP is expected to cause a reduction in the frequency and intensity of blue-green algae blooms. The proportion of green algae is expected to increase. The species composition and abundance of the diatoms will shift towards a community more similar to pre-development conditions (i.e., reduced *Fragilaria crotonensis, F. construens*, and *Asterionella formosa)*.

Transparency

Secchi disk transparency is expected to increase slightly as phytoplankton populations decrease. The magnitude of the increase in transparency is expected to be relatively small because of the non-linear relationship between chlorophyll *a* and transparency.

Hypolimnetic Oxygen Depletion (HOD)

HOD is expected to decrease slightly as a decrease in phytoplankton will cause a decrease in detritus to the hypolimnion. This in turn will reduce the magnitude of nutrient recycling from the sediment into the water column.

Sediment Accumulation Rate (SAR)

SAR will decrease somewhat as phytoplankton populations decline.

Macrophytes

The macrophyte population may expand slightly in the depth of its coverage as *Nitella* will be able to grow in slightly deeper water with an increase in transparency. The overall biomass of macrophytes is expected to exhibit little change.

Fisheries

The rainbow trout population is expected to return to pre-chub abundance levels observed in the 1970s, with catch levels near 100 kg/ha/yr. The health and vigor of the trout population will probably remain high until tui chub or other disruptive species are introduced into Diamond Lake. Given the level of recreational pressure and the inability to patrol the multiple access points to the lake, it is virtually a certainty that tui chub or similar opportunistic species will be re-introduced. Given that two introductions of tui chub have occurred, and that one introduction occurred approximately 30 years after the original trout stocking in 1910 and the other approximately 30 years after rotenone treatment in 1954, it seems reasonable to assume that this is an appropriate time-frame until the next reintroduction of a nuisance fish will once again require a major management intervention.

Table 30. Organization for Economic Cooperation and Development boundary values for fixed trophic classification system

(modified from OECD 1982). Values for Diamond Lake are shown at the bottom of the table. (Modified from Ryding and Rast [1989])

Trophic Category	TP (μg/L)	Mean Chlorophyll (μg/L)	Maximum Chlorophyll (μg/L)	Mean Secchi (m)	Minimum Secchi (m)
Ultra-oligotrophic	<4.0	<1.0	<2.5	>12.0	>6.0
Oligotrophic	<10.0	<2.5	<8.0	>6.0	>3.0
Mesotrophic	10-35	**2.5-8**	8-25	**6-3**	**3-1.5**
Eutrophic	**35-100**	8-25	**25-75**	3-1.5	1.5-0.7
Hyper-eutrophic	>100	>25	>75	<1.5	<0.7
Diamond Lake	45	6.8	39.8	5.6	1.8

TP = Mean annual in-lake total phosphorus concentration

Mean Chl = Mean annual chlorophyll *a* concentration in surface waters

Maximum Chl = peak annual chlorophyll *a* concentration in surface waters

Mean Secchi = Mean annual Secchi depth transparency

Minimum Secchi = Minimum annual Secchi depth transparency

Table 31. Organization for Economic Cooperation and Development boundary values for open trophic classification system

(annual mean values) (modified from OECD, 1982).

Parameter						Diamond Lake
Total Phosphorus (g P/L)		8.0	26.7	84.4		45
	± 1 SD	4.85-13.3	14.5-49	48-189		
	± 2 SD	2.9-22.1	7.9-90.8	16.8-424		
	Range	3.0-17.7	10.9-95.6	16.2-386	750-1200	
	n	21	19 (21)	71 (72)	2	
Chlorophyll *a* (Mean) (g/L)		1.7	4.7	14.3		6.8
	± 1 SD	0.8-3.4	3.0-7.4	6.7-31		
	± 2 SD	0.4-7.1	1.9-11.6	3.1-66		
	Range	0.3-4.5	3.0-11	2.7-78	100-150	
	n	22	16 (17)	70 (72)	2	
Chlorophyll *a* (Peak Value) (g/L)		4.2	16.1	42.6		39.8
	± 1 SD	2.6-7.6	8.9-29	16.9-107		
	± 2 SD	1.5-13	4.9-52.5	6.7-270		
	Range	1.3-10.6	4.9-49.5	9.5-275		
	n	16	12	46		
Secchi Depth (m)		9.9	4.2	2.45		5.6
	± 1 SD	5.9-16.5	2.4-7.4	1.5-4.0		
	± 2 SD	3.6-27.5	1.4-13	0.9-6.7		
	Range	5.4-28.3	1.5-8.1	0.8-7.0	0.4-0.5	
	n	13	20	70 (72)		

Table 32. Trophic State Index (TSI) and its Associated Parameters

(From Carlson 1977). Values for Diamond Lake are bolded.

	TSI	Secchi Disk (m)	Total Phosphorus (µg/L)	Chlorophyll (µg/L)
Ultra-oligotrophic	0	64	0.75	0.04
	10	32	1.5	0.12
Oligotrophic	20	16	3	0.12
Mesotrophic	30	8	6	0.94
	35	**5.6**		
	40	4	12	2.6
Eutrophic	**49**			**6.8**
	50	2	24	6.4
	59		**45**	
	60	1	48	20
Hyper-eutrophic	70	0.5	96	56
	80	0.25	192	154
	90	0.12	384	427
	100	0.062	768	1183

Table 33. General Characteristics Of Oligotrophic And Eutrophic Lakes And Reservoirs In The Temperate Zon

(compiled from Welch 1952, Sawyer 1966, Fruh et al. 1966, Lee 1977, Golterman 1975, OECD 1982 and adapted from Ryding and Rast 1989).

Parameter	Type of Water body		
	Oligotrophic	Diamond Lake Oligotrophic Eutrophic	Eutrophic
I. **Biological** Aquatic plant and animal production	low		high
Number of plant and animal species	many		many; can be substantially reduced in hyper-eutrophic waters
General levels of biomass in water body	low		high
Occurrence of algal blooms	rare		frequent
Relative quantity of green and blue-green algae	low		high
Vertical extent of algal distribution	into hypolimnion (bottom waters) in thermally stratified water bodies		usually only in surface waters
Aquatic plant growth in shallow shoreline area (littoral zone)	can be sparse or abundant; if present, usually consists of submerged and emergent vegetation		often abundant; usually an increase in the presence of filamentous algae and a decrease in macrophytes
Daily migration of algae	extensive		limited
Some characteristic algal groups	Green algae: Desmids *Staurastrum* Diatoms: *Tabellaria* *Cyclotella* Golden-brown algae *Dinobryon*		Blue-green algae: *Anabaena* *Aphanizomenon* *Microcystis* *Oscillatoria* Diatoms: *Melosira* *Fragilaria* *Stephanodiscus* *Asterionella*
Parameter	Type of Water body		
	Oligotrophic	Diamond Lake Oligotrophic Eutrophic	Eutrophic

Some characteristic zooplankton groups	*Bosmina obtusirostris* *B. coregoni* *Diaptomus gracillis*		*Bosmina longirostris* *Daphnia culcullata*
Characteristic bottom animals	Tanytarsus		Chironomids
Characteristic fish types	deep-dwelling, cold water fishes (salmon, trout, cisco)		surface-dwelling, warm water fishes (pike, perch, bass)
II. Chemical Oxygen content of bottom waters (hypolimnion)	high throughout year		can be low or absent during thermal stratification period
Total salt content of water (specific conductance)	usually low		sometimes very high
III. Physical Mean depth of water body	often deep		often shallow
Volume of hypolimnion	often large		can be small or large
Temperature of hypolimnion waters	usually cold		cold water usually minimal, except in deep eutrophic water bodies
IV. Water usage: Water quality for most domestic and industrial uses	good		often poor
Impairment of multi-purpose use	normally little impairment		often considerable impairment

SUBALPINE LAKES

Current Conditions in Calamut, Lucille, and Maidu Lakes

Calamut, Lucille, and Maidu Lakes are shallow, unproductive lakes. Calamut and Lucille Lakes are extraordinarily dilute groundwater recharge lakes that differ only slightly from precipitation chemistry. Maidu Lake is a groundwater discharge lake that receives modest inputs of groundwater. All three lakes have very low concentration of inorganic N and P and are considered ultra-oligotrophic lakes. The major resource management question associated with these lakes, especially Calamut and Maidu, is “To what extent, if any, does fish stocking impact the lakes?”

Reference Conditions

No historical data to evaluate change.

Projected Future Conditions

Calamut, Lucille, and Maidu Lakes are expected to remain similar to present conditions unless wilderness use increases dramatically or the effects of fish stocking on dilute subalpine lakes are found to be cumulative. Future impacts to Maidu Lake could be minimized by discouraging camping on the south side of the lake. This is believed to be the groundwater contributing area for the lake.

STREAM CHANNELS

Stream channels can be compared to the arteries of a patient in that they provide a veritable means of assessing the overall health of the watershed. For this reason, Region-6 Level II Stream Inventory (version 9.6 protocol) and modified Pfankuch surveys have been conducted within the Lemolo/Diamond Lake watershed to primarily assess aquatic habitat and channel condition and stability. Neither of these surveys are designed to provide a thorough comprehensive assessment of erosional processes within stream channels; however, selected elements of the modified Pfankuch protocol do provide some insight into erosional processes within headwater streams in the watershed.

The modified Pfankuch survey and fish habitat surveys (see modified Pfankuch and fish habitat surveys in Appendices) show that stream channel stability is moderate to high for all types of geologic units surveyed, with little evidence of significant slope failure or mass wasting, and minimal amounts of excessive stream bank erosion or deposition of fine sediment. However, since portions of the watershed were heavily grazed, predominantly by sheep during the late 1800s and early 1900s, channel adjustments may still be occurring to riparian areas (soil compaction) and stream channels (width/depth ratios). Therefore, streams predominantly in meadow-like areas, can not be considered undisturbed and used as reference conditions, even though many of them have not been impacted by timber management and roading. Additionally, significant adjustments in channel morphology following elimination of grazing disturbance occur on a decadal time scale (Clifton 1989).

Table 34 shows values for selected elements (from the modified Pfankuch stream channel stability inventory) determined to be key identifiers of channel stability. These include mass wasting of upper stream banks, bank rock content, stream bank cutting, and deposition of fine sediment (including sand, silt, and clay size particles). According to the ranking scheme developed to evaluate stream stability-condition for the four selected elements in Table 34, the lowest achievable score (indicating the most stable stream condition) is 14, and the highest achievable score (indicating the most unstable stream condition) is 56.

The sum of the selected elements in Table 34for those headwater streams surveyed within drainages that do not have timber management and roading (tributary to the North Umpqua River in section 24, Thielsen Creek, Tolo Creek, and Warrior Creek) resulted in a range from 20.0 to 28.5, with a mean value of 25.9. These scores translate to stream channel stabilities of “excellent” to “good”. All of the individual elements rated either excellent or good, with the exception of bank rock content for these undisturbed streams which mostly rated “fair”. However, this element is not a result of channel process, but a representation of channel morphology and the sensitivity of the channel to bank erosion. Therefore, where bank cutting is not excessive, bank rock content is not a concern.

For those headwater streams surveyed within drainages experiencing timber management and/or roading (Calamut Lake tributary to the North Umpqua River, Poole Creek, Porcupine Creek, and Silent Creek) stream channel stability values ranged from 22.9 to 33.4, with a mean value of 27.7. All values translate to a rating of “good” stability. All of the individual elements rated either “excellent” or “good”, with the exception of bank rock content, and bank cutting in Porcupine Creek, which rated “poor” and “fair”, respectively. This is assumed to be the result of drainage network extension from abundant road crossings in the drainage and the subsequent increase in peak runoff events (their timing and duration). Overall, channel stability within managed areas does not significantly differ from those in unmanaged drainages, and are relatively stable with properly functioning systems which efficiently process both flow and sediment under current conditions. These systems appear to be inherently stable due to the nature of the stream flow regime which is characterized by moderate peak flows which rise and fall gradually in response to both snowmelt and rainfall events.

Additionally, modified Pfankuch total scores were compared for different geologic units within the watershed for different stream types (see Fish Appendix A). Headwater (Class III and IV, non-fish bearing) streams typically consist of “A”, “B”, and “E” stream types. Differences in the selected channel stability elements are not notable for geologic units, however, differences do occur for total scores. These differences are largely inherent for the landtype formed within the geologic unit. Several elements resulting in differences in total scores include potential large woody material, understory vegetation density, and pool habitat. The first two elements vary over a changing landscape and therefore are likely within a “natural” range of variability. Pool habitat is dependent on the large woody material component (as well as smaller pieces in some systems) provided by adjacent side slopes, rock content of the stream bed, and stream power. A larger data set is necessary to make a more detailed analysis.

Table 34. Results of Pfankuch Stream survey for selected elements. Values are the mean of the elements with all reaches of the identified stream channel.

Drainage	**Mass-wasting**	**Bank Rock Content**	**Bank Cutting**	**Deposition of Fines**	**Cumulative**
Face Drainage to Diamond Lake	5.0	7.5	5.0	4.1	21.6
Calamut Lake - Tributary to NUR	5.0	6.2	6.7	5.0	22.9
Tributary to NUR - Section 24	4.0	9.0	4.0	3.0	20.0
Poole Creek	4.0	12.0	6.0	3.0	25.0
Porcupine Creek	6.7	11.0	10.7	5.0	33.4
Silent Creek	6.2	10.8	7.7	4.8	29.5
Thielsen Creek	7.0	6.4	8.0	5.6	27.0
Tolo Creek	5.0	10.5	7.0	6.0	28.5
Warrior Creek	6.5	9.8	6.5	5.2	28.0
Mean	5.7	8.7	6.9	4.9	26.2
Ranking					
Excellent	4-6	3-4.5	4-6	3-4.5	14 - 21
Good	6.1-10	4.6-7.5	6.1-10	4.6-7.5	21.1 - 35
Fair	10.1-14	7.6-10.5	10.1-14	7.6-10.5	35.1-49
Poor	14.1-16	10.6-12	14.1-16	10.6-12	49.1-56

Fisheries habitat surveys were conducted on the following Class II, fish bearing streams, and are included in this analysis: the North Umpqua River (above Lemolo Lake), Poole Creek, Spring River, Bradley Creek, Warrior Creek, Tolo Creek and tributary, Lake Creek, Thielsen Creek, Sheep Creek, and Silent Creek. Approximately 48.5 miles of Class II streams were surveyed for fisheries habitat in 1996, and 1997. Of the total miles surveyed, stream channels of the “E” Rosgen stream types compose 43 percent, while “C”, “B”, and “A” stream types were also present at 33, 21, and 3 percent, respectively.

Stream channel substrate is predominantly composed of gravel size particles (79 percent), with sand and cobble reaches also present, composing 10 and 11 percent, respectively. The percent of fine sediment composing channel substrate is typically low for all stream types (Table 35). This is consistent with the low amount of fines found deposited in headwater streams draining into these channels, as identified by Pfankuch surveys.

The ratio of pools to riffles for all stream types is relatively low when compared to those found in Western Cascade streams. Both "E" and "C" stream types are characterized by Rosgen (1996) as having riffle/pool sequences dominating channels, while "B" stream types are typically riffle dominated. The low percentage of pools is not likely a result of a deficit in large woody material (LWD), since amounts are moderate with a frequency greater than 41 pieces per mile for all stream types, but instead due largely to the inherent nature of the drainages and the slow response to peak flow events, which shape the channel and potentially scour pools. Without sufficient stream flow peaks to scour new pools and maintain existing ones, riffles and glides dominate the system.

Table 35. Summary of fisheries surveys of streams in Lemolo/Diamond Lake watershed.

Rosgen Stream Type	Stream Length (miles)	Pool/Riffle Ratio	percent Fine Sediment	LWD/mile
E	20.85	16/84	37.4	55.9
C	16.10	13/87	24.2	48.1
B	10.05	10/90	11.6	41.8
A	1.50	2/98	19.5	66.0

There are notable activities in the watershed (in addition to timber management and roading) which likely made a significant impact on both riparian areas and stream channel morphology. The first activity, likely having the most adverse impact was sheep grazing, which occurred from the late 1800s to the 1940s. Beyond this period most sheep allotments were converted to cattle and horse allotments. Disturbance was high during the earlier period, as described by Waldo and Steel (Williams 1991), due to over grazing and practices associated with creating transient range by timber removal and burning. For example, Waldo and Steel described an area in the watershed as being "completely ravaged" by sheep in 1896, with 2000 head in the vicinity. Measurements characterizing channel conditions during this time of grazing do not exist. However, it is assumed that over the past approximately 50 years, since intensive sheep grazing ended in the watershed, stream conditions have greatly improved to a point where channels are functioning properly and efficiently processing both flow and sediment under current conditions. Channel adjustments, however, are still likely occurring.

The second activity of likely significance to stream channels was the 1954 drawdown of the Diamond Lake water level, which increased Lake Creek flows above bankfull stage for several months. Drawdown of Diamond Lake occurred during the period from July 15 to

September 21, 1954, as an Oregon Department of Fish and Wildlife (ODFW) project to eliminate undesirable fish in the lake. Streamflow in Lake Creek during the time of lake drawdown was not recorded, however, they are presumed to be approximately 180 cfs, based on information provided in U.S. Geological Survey documentation (U.S.G.S. 1963). Such a flow is greater than that which occurs during bankfull flows of approximately 108 cfs, and is comparable to a flood event likely to return every six years. However, for the approximately 70 days which the flow occurred, such an event is likened to greater than a 100 year event (U.S.G.S 1993). Flows at bankfull have been determined by Leopold (1964) to do the most work in building floodplains and channels, therefore, channel adjustments are assumed to have occurred during the event. However, observations of Lake Creek made by the Lemolo/Diamond Lake Watershed Analysis hydrologist and geologist, and fisheries surveys do not substantiate that assumption since evidence of significant slope failure or channel adjustment was not observed. Also, fisheries surveys of Lake Creek (1996) show that frequencies of large woody material are currently moderate to high in the upper reaches, ranging from 33 to 147 pieces per mile in high energy reaches prone to channel scour and woody material transport. Additionally, visual observations made in 1955 by Frank Moore (personal contact) who is familiar with Lake Creek before the event, indicate a system which efficiently processed both it's flow and sediment loads without notable adverse impacts following the drawdown event. Therefore, the assumed impacts of the 1954 drawdown on the Lake Creek channel is likely less extensive than intuitively assumed. However, without measurements or photographs a clear conclusion can not be drawn of the affects.

VEGETATION

Sensitive Plant Species

Sensitive plant species are those thought to be vulnerable to becoming threatened or endangered due to low population levels or significant threats to their habitat. Sensitive plants are determined by the Regional Botanist, who periodically reviews the population status of each proposed species. From time to time, the list of Sensitive plant species may change as more information is gathered with respect to the plants' abundance, range, threats, etc. Hence, new species may be added to the list, and others dropped, as more is learned about them and their habitats.

This watershed has never been thoroughly surveyed for Sensitive plants. Therefore, there is no base-level reference condition with which to compare current observations for a trend analysis, and there is no way of estimating the number of Sensitive plants which may have existed at various times in the past. Current practice is to survey project areas for Sensitive plants, and if found, complete a risk assessment that is included in the Biological Evaluation (BE) document. Management recommendations are usually provided in the BE, so that steps can be taken during the project activities to protect or ameliorate the impact to any Sensitive plants or their habitats. In the event of an unavoidable impact, the use of monitoring plots is advisable in order to provide a record of the impact, and its resultant effect on the Sensitive plant population.

Of the six Sensitive plant species documented to exist in this watershed, three have been found only at high elevation (above timberline). These are *Allium campanulatum*, *Arnica viscosum*, and *Haplopappus whitneyi*. The major threats to these species are the harsh environment and recreational impacts from mountain climbers. Of the other three Sensitive species, *Utricularia minor* is an aquatic species found only in stagnant marsh pools around Lemolo Lake. Likely threats to this species would most likely consist of alterations in the hydrology of the site, such as draining the marsh areas, or changing the amount or distribution of the inflow. The remaining two Sensitive species, *Asarum wagneri* and *Mimulus jepsonii*, are both considered to be “disturbance species”, since they appear to be resilient to moderate impacts and are frequently found around disturbed sites near Lemolo Lake and Diamond Lake. Likely threats to these species would be repeated fire, and excessive ground-disturbing activities such as road building or other construction activities.

Noxious Weeds

Noxious weeds are non-native species which are aggressive invaders that can compete with and displace native species. These are all introduced species, therefore the reference condition is no noxious weeds present. These invaders tend to follow man’s activities into the forest, occupying road shoulders and other disturbed sites, most likely using vehicles as primary distribution vectors. Ground-disturbing activities such as road building, timber harvesting, and clearing under power lines expose bare mineral soil and remove protective vegetation, thereby creating optimal habitat for weed invasion. Noxious weeds are generally prolific seed producers, and these seeds can be distributed by getting caught in vehicle tire treads, borne about attached to uncleaned equipment, or being jostled about in truck beds. Once established along roadbeds, noxious weeds can move into meadows, riparian areas, and forest openings.

In this watershed, noxious weeds are found distributed along the major routes, such as Highway 138, major forest roads, PacifiCorp canals, power lines, and roadways. Scattered populations and isolated individuals also exist in harvested units and along minor forest roads. The best management plan includes eradication of existing populations and prevention of new introductions. Current management practices utilize an integrated weed management approach, involving cooperation with other agencies, using an interdisciplinary approach, and incorporating a variety of methods for prevention and control. The major management practices being used in this watershed include the use of biological controls on St. Johnswort and tansy ragwort, along with hand pulling of these, and hand pulling spotted knapweed and Scotch broom. The major preventive measure is the maintenance of a ground cover of native plants, which helps to prevent re-invasion.

Human influence and a generally high degree of disturbance have resulted in noxious weeds becoming well established at the lower elevations of southwest Oregon, and gradually becoming established and proliferating at higher elevations. Management of forest resources with attention to the resident noxious weed situation can reverse this trend by using appropriate weed management techniques.

Vegetative Structure and Pattern

Analysis procedures, Assumptions, and Data Gaps

The analysis criteria used to describe vegetation included plant series, structural class (seral stage), and pattern. Information used to map plant series and structural class was obtained from timber stand exams, the GIS size class layer, 1949 aerial photography, and local district knowledge of the watershed. Because of the dynamic nature of vegetative structure on the landscape and the lack of information prior to 1933, no analysis of the range of variability was conducted for the watershed. Table 36 defines the structural classes used in the analysis.

Table 36. Vegetative structural classes of vegetation in the watershed.

Structural Class	Definition
Grass, Shrub	Grass, shrub, rock, water
Establishment (Early Seral)	Stands up to 20 years of age
Stem Exclusion (Mid Seral)	Stands 20 to 80 years old
Maturation (Late Seral)	Stands 80 to 140 years old
Stand Reinitiation (Late Seral)	Stands older than 140 years

Referenced and Current Condition

The year 1949 was used to characterize reference condition. There was little diversity in the structural class in 1949 due to a stand replacement fire in the early 1900s. Currently the stem exclusion stage dominates the landscape pattern (Figure 21).

Currently there is a great diversity of vegetative structure and pattern within the watershed. All structural classes are represented in various landscape patterns. The areas available for timber harvest have a wider variety of structural classes than the Mt. Thielsen wilderness and OCRA (Figure 22).

Differences or similarities between conditions

There is a greater diversity of vegetative structure and pattern within the watershed today than there was in 1949. There is a greater proportion of the establishment phase, and a large portion of the Stem Exclusion phase is approaching the Maturation stage.

Figure 21. Historic Stand Structure

Title:
Creator: ArcView Version 3.0
CreationDate: Wed Mar 11 13:51:42 1998

Figure 22. Current Stand Structure

Title:
Creator: ArcView Version 3.0
CreationDate: Wed Mar 11 14:00:05 1998

Process or Causal Mechanisms Responsible

The main causes for the difference between conditions are timber harvest and fire suppression. Timber harvest began in the 1950s and shaped vegetative structure and pattern up to the present day on about a quarter of the area. Historically the early seral stage component was achieved through natural disturbance, primarily stand replacing fire. Timber harvest fragments some areas of the watershed, while a stand replacing fire would concentrate the early seral stage in a more contiguous manner.

Future Trends

Timber harvest will continue to take the place of natural fire within the matrix land allocation. The vegetation within the matrix will be managed to maintain a diversity of habitats over time. The OCRA and the Wilderness will be managed to allow natural processes to operate as much as practical.

Influences and Relationships to Other Ecosystem Processes

The structure and pattern of vegetation relates to all other ecosystem processes taking place in the watershed. The dynamic nature of this ecosystem component is living proof that ecosystems are not static. Examples throughout this report show the relationships between vegetation and other ecosystem processes.

Coarse Woody Material

Analysis Procedures, Assumptions, and Data Gaps

Limited information on CWM levels in forested stands on the DLRD exists. Some information was collected on the Umpqua NF in region-wide studies (Spies et al. 1988) and on the DLRD in eco-plot monitoring and while collecting information from District stand exams. We assume that natural levels of CWM were similar to other areas from the southern Cascades. More specific information needs to be gathered on CWM levels in unmanaged and managed stands across the range of environmental gradients (slope, aspect, moisture levels, elevation, and topographic position). This will assist us in developing a landscape-level view of CWM.

There is no substantive scientific data that demonstrates what the optimum levels of CWM are across the landscape for various species, both plants and animals, that inhabit the different aged-stands. Some studies have shown what adequate levels of CWM are for a specific species at a particular stage of stand development (Carey and Johnson 1995). The CWM requirements of various species at different population levels is probably not a linear relationship. Furthermore, this relationship will be different for each species.

Reference Condition/ Current Condition/ Differences or Similarities Between Conditions

Coarse woody material (CWM) has likely decreased from historic levels because of green tree timber harvesting and logging practices that encouraged the removal of snags and down logs. Establishment and thinning stages under natural conditions had some of the highest levels of CWM because they developed after a fire or a major wind event that uprooted canopy trees. Now, many of the establishment and thinning-aged stands have low levels of CWM because they are a result of logging which has removed much of the stands' biomass and the remaining slash is usually burned after logging. During the transitional stages of stand development (beginning of old-growth conditions, 140 years+) the levels of CWM begin to increase, as CWM is recruited from trees dying in the stand. Because the current and historic stand structures were obtained from different sources, and the historic is base on estimates from size classes, comparing acreage differences between the two periods is not meaningful.

Information on CWM was gathered from 68 stands during the 1996 stand exam project. Levels of CWM (snags are not included in this analysis) were inventoried in ½ acre belt transects. Due to the relatively small sample size it is not possible to stratify on variables such as aspect, elevation, and plant series. All of these stands were in the maturation or stand reinitiation stages of development. The amounts of CWM ranged from 0-1172 linear feet/acre, with a mean of 279 linear feet/acre. Some of these stands had evidence of past salvage harvesting, so the range of the numbers is probably more meaningful than the mean. The results demonstrate the wide range in CWM across all stand types. The variability is a result of natural factors such as storm events, low intensity fires, insects, and disease, as well as human actions.

Future Trends

The recommended retention levels of CWM (250 linear feet) in matrix lands is probably not adequate to provide for the optimum development of late successional conditions. This was recognized in the NWFP, because one of the primary objectives of matrix lands is to provide timber volume not the conservation of late-successional forests. Other land allocations such as wilderness and LSRs will provide the best opportunity for the development of late successional stands.

Fire Disturbance

Fire has played a major role in development and maintenance of vegetation in the area. Evidence of large stand replacing and stand thinning fires is visible on the landscape in both the pattern of vegetation and species composition and structure. It is typical for large fires in western Oregon to burn until extinguished by fall rains.

Analysis Procedures, Assumptions, Data Gaps

All analyses are based on the area of the watershed that is currently managed by the Umpqua National Forest, approximately 102,960 acres. In relationship to the fire disturbance portion "this analysis", "the analysis area" and "the watershed" refer to the portion of the Lemolo / Diamond Lake watershed managed by the Umpqua National Forest.

Analysis of reference conditions, including fire return interval, fuel availability, and air quality, involved examining anecdotal information and studying vegetation patterns from older aerial photographs. Photos taken in the 1930s from lookouts with a view of the watershed were also assessed.

A fire history study specific to the analysis area was conducted. Studies from the surrounding areas were also used to get an idea of the 'big picture'. The studies were completed using methods and standards adapted from the Augusta Creek Fire Study (Connelly and Kertis 1991). Average fire return interval for the Lemolo / Diamond Lake Watershed Analysis Area was determined using data collected in the study. The study plots represented a range of aspect, elevation, and geographic location, but did not sample all elevations. In each plot, tree age, scar age, pitch rings, suppression, and release were determined. Reliability for each age was estimated. Scars and origins were analyzed to determine fire events. In some areas where there were no stumps increment cores were taken and tree age and latest fire scar date determined, no stumps were available within the wilderness or OCRA. Fires occurring prior to 1932 were used to determine the reference conditions. An independent literature search was conducted by the Diamond Lake District Heritage Program Manger. The purpose of this search was to find references for air quality, fire occurrence and the fire ecology in the Lemolo / Diamond Lake Watershed and age and tree species information from this fire history study.

The current natural fire regime was determined using the fire occurrence data, descriptions and observations of recent fire effects, current fuel models, and current air quality. Data were gathered from the Umpqua National Forest Fire Atlas for fires occurring between 1932 through 1963, fire size was recorded by size class, and cause was recorded as human or lightning. Fire data was retrieved from the National Fire Occurrence Data Library for fires occurring between 1970 and 1996, a total of 59 years of recent fire data were used. The current fuel model map on GIS (Geographic Information System) was also used. The fuel model map was developed from PMR data (Pacific Meridian) and UPAD data (Umpqua National Forest Project Activity Database). PMR is based on photo interpretation of the Anderson Land Use / Cover classification scheme, and UPAD is based on current information of managed stands.

Reference Condition and Current Condition

Size

Many large previously burned areas can be seen in the 1933 and 1936 lookout panoramic photographs and in other photographs taken in the Diamond Lake area from that time period. These photographs, historic diaries, and information gathered from the fire history study show that a large portion of the watershed burned in at least three or possibly more fire events that occured between 1880 and 1910. In the vicinity of Mt. Thielsen, Cinnamon Butte, and Bradley Creek (Windigo Pass) the fire(s) were stand replacing. Sheep Creek, Lake Creek, Kelsay Valley, Bunker Hill and the Calamut Lake areas experienced the same fire(s) but of a lower intensity.

These fires burned throughout the watershed including riparian areas. Fires naturally occurred within the riparian areas. Depending on numerous fire behavior factors many of these fires historically did consume much material due to the moisture found in riparian areas. At other times, the amount of available fuel, weather conditions, shape, slope and aspect of the drainage contributed to a hotter, more consumptive, fire that may have significantly altered riparian areas.

Judge John Breckenridge Waldo tells of being forced to camp on the south side of the North Umpqua River near Kelsey Valley because he " found the valley here on fire for miles along the north side" in August of 1886, of a fire that "has been running through by Mt. Thielsen" in August of 1883, and of large amounts of smoke preventing getting a photograph of Diamond Lake in August of 1896. In an interview conducted in 1938 George Aurther Bonebrake tells of numerous fires burning in 1910.

At times, during reference conditions, fires or a series of fires occurring in a short time period burned several thousand acres. Currently fires are suppressed as soon as possible following discovery. Detection is a high priority and few fires burn long prior to detection. Average fire size is 0.2 acres to 1.8 acres[3].

Shape and Pattern

The fire pattern on this landscape is very visible in the historical photographs. Openings created by fires in reference conditions range from random shaped ameboid and blobish, to rounded on the flatter slopes; to an occasional triangle or square with straightened edges on the steep slopes. Various sized and shaped lightly burned or unburned areas are visible in some of the fire created openings. The openings are areas that have been intensely burned.

Much of the watershed has a component of lodgepole pine. The following is an excerpt of a description of a lodgepole pine forest from Fire Ecology of Pacific Northwest Forests. "The most continuous fire vector is logs. Partially decayed logs, remnants of disturbances several decades earlier, carry most fires, so that fire behavior is more a function of coarse woody material than fine fuel dynamics. Climax lodgepole pine forests rarely grow for a century without a major disturbance by fire or insects. In the two areas where these stands have been most intensively studied (Crater Lake and Fremont National Forest), both log-to-log and crown fire activity have been observed or reconstructed from age data for forest stands."(Agee 1993).

Recently, wildland fire has no visible effect on the landscape [4]. Fires may burn and kill trees, usually this is in an area less than ten acres, due to successful initial attack.

Fire Return Interval

In reference conditions the average fire return interval was 72 years (with a standard deviation of 73 years). See the accompanying table (Table 37) for a summary of fire return interval by plot. An exception is lands managed by Crater Lake National Park within the watershed, where there have been prescribed natural fires and wild fires greater than 50 acres.

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[3] Range is due to record keeping method prior to 1970.

Table 37. Average Fire Return Interval in Years

Plot #	Fire return of the plot	Standard deviation	Aspect	Elevation
I1	**74**	51	S	4800
I2	**104**	-	N	5200
I3	**51**	23	N	5000
I4	**40**	25	E	4800
I5	**47**	-	SW	4300
3438	**16**	-	E	n/a
340080	**32**	22	N	5890
340081	**181**	-	S	5000
340082	**32**	48	NW	4770
340085	**none**	-	N	5200
340086	**24**	-	E	5180
340088	**26**	14	N	5100
340089	**68**	12	N	5220
340091	**33**	39	W	5120
340094	**60**	32	SW	4650
thin	**none**	-	N	5300
Average	**72**	**73**		

None = no fire interval found in these plots.

Two common patterns of Native American burning found in the Northwest may be represented in a small area in this watershed. Native Americans frequently burned westside prairies and adjacent dry Douglas-fir forests; and maintained small patches of open prairie for agriculture or hunting (Knudson 1980). This type of burning may have occured in the Kelsay Valley and adjacent Lemolo basin.

Between 1932 and 1996 (excluding 1964 to 1969[5]) there were 343 recorded fires (Figure 23) (a current fire occurrence map is located on the districts geographic information system). There was an estimated total of 71 to 610 acres burned, with an average range of 1.2 to 10.3 acres burned annually[6]. Lightning caused 71 percent of the fires, the remaining were person caused. Person caused fires have increased as access to the area has improved. The current average is six fires per year, with two of these being person caused.

Analysis of fire occurrence verifies that fires occurred throughout the watershed in the recent 59 year time period. This is approximately 5.8 fires per year in the watershed or 56 fires/ 10 years/ 100,000 acres. As a result of the current fire suppression policy, fire has been excluded from the watershed, and the average fire return interval is incalculably high.

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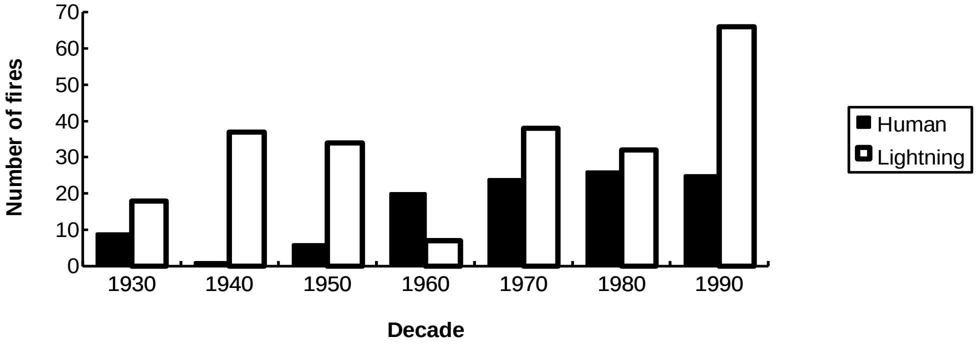
[5] No data was available for the time period 1964 to 1969.

[6] Range is due to record keeping method prior to 1970.

Figure 23. Number of Fires by Cause by Decade



1960s is through 1963 only.

1990s is through 1996 only.

Air quality

Air quality over this Watershed Analysis Area is a result of numerous factors, many originating outside of the analysis area. As air quality relates to natural disturbance, visibility is at times hampered by wildfires and other events that occur outside the area. This was the case in August and September of 1996 when smoke from the Spring Fire (located to the west of the watershed) intruded into the Lemolo / Diamond Lake Area. Particulate matter also originates from dust as a result of road use, and generally does not have a significant effect.

Letters and documents of events prior to 1932 describe fires that burn for many days or months.

Letters written by Judge Waldo described smoke and haze that made it impossible to photograph Mt. Thielsen or Crater Lake (Waldo 1883), Lemolo Falls (Waldo 1889), and Diamond Lake (Waldo 1896). An interview conducted by employees of the Work Progress Administration mentioned poor air quality in the Diamond Lake area in the summer of 1910, due to fires in the North Umpqua drainage (Perkins 1938). Horace Cochran, a district ranger tells of seeing 48 fires from one vantage point following a lightning storm in July 1917 (Darling 1963). Of these there were four ‘large fires’ all of which would have had a considerable effect on the airshed over the analysis area. Based on this and more general information, smoke was probably present at varying densities anytime from June to mid October in the Lemolo / Diamond Lake Watershed Analysis Area. Heaviest smoke periods probably occured in August.

Current detection methods have improved, wildfires are readily detected, more accessible, are managed with an appropriate suppression response and are usually controlled and mopped up within 24 hours. The result of this is negligible concern over air quality, with respiratory air quality being a concern only to the firefighters engaged in the suppression response.

Currently, prescribed fire activities have included underburning and pile burning. Prescribed fire activities cause greater impacts on the airshed as more particulate matter is released than from current wild fires. To mitigate this, treatments are developed and executed to have the least impact on the airshed. Prescribed burning is done in compliance to all aspects of the Clean Air Act. Air quality standards are administered in cooperation with the Oregon Department of Forestry by following the Oregon Smoke Management Plan.

The closest designated area[7] to the watershed is Roseburg which is approximately 60 miles to the west. The closest Class I Airsheds are the Diamond Peak Wilderness to the northeast, and Crater Lake National Park to the southeast. Burning is not done during the restricted period in the Oregon Visibility Protection Plan (July 1 to September 15.)

There has been a reduction trend in total suspended particulates from forest management activities (Umpqua Annual Fire Report 1996).

Fuel Model

Fuels are made up of various live and dead components of vegetation that occur on a site. The type and quantity of fuel models depend on many things one of which is the fire history of the area (Anderson 1982). Fuel amounts and arrangements have been classified into categories called fuel models. These classifications are based on material less than three inches in diameter. Fuel models are or have been converted to NFFL fuel models (National Forest Fire Laboratory). A forest area exhibiting characteristics of a fuel model 8 has had low intensity fire(s) in its past. Fuel model 8 poses little fire hazard under normal weather conditions. Forest fires burning in a fuel model 10 however, burn with greater intensity, cause greater mortality, and are difficult to suppress. Fuel model 10 is indicative of a forest that has not burned in many years. Fuel model type and relative distribution greatly influence fire behavior and effects. For more information on fuel models see the Fire Management Appendix (B). Fuel model distribution within any watershed is dynamic over time, fluctuating within a wide range. The accompanying chart (Figure 24) displays a 'snapshot' of the distribution at two points in time. The reference time period is prior to 1932, current distribution is in 1996. The current fuel model map is in the district geographical information system.

Fire Regime

The fire frequency, patterns on the landscape, historical accounts of fire occurrence and air quality indicate that the natural fire regime of most of this analysis area was a moderate-severity fire regime and the area along the crest of the Cascades where the predominant plant series is mountain hemlock (*Tsuga mertensiana*) was a high-severity fire regime during reference conditions. The area within the watershed managed by Crater Lake National Park may also be in this high-severity fire regime.

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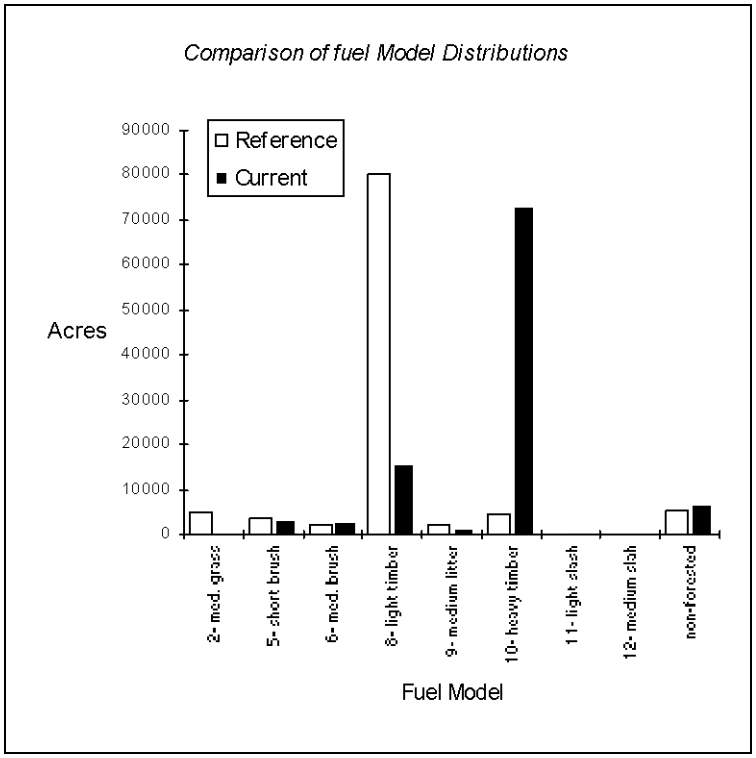
[7] Designated areas as delineated in the Smoke Management Plan Administrative Rule and defined by the rule as principle population centers.

Figure 24. Fuel Model Distributions



A moderate-severity fire regime is characterized by infrequent fires (25 to 100 years) and significant areas of high and low severity resulting in partial stand replacement. Fires typically burn weeks to months, and periods of intense behavior are mixed with periods of moderate to low intensity fire behavior. Moderate-severity natural fire regimes produce patchy stands of various sizes mixed with patches of multi-sized stands (Agee 1990).

A high severity-fire regime is described as fires usually being infrequent, (more than 100 years between fires) the fires are usually high intensity stand replacement. Most fires are stand replacement events because of the lack of fire resistance of the major tree species. Fire return intervals may not be cyclic (Agee and Flewelling 1983). Large fires are associated with drought years, east wind synoptic[8] weather types, and lightning (Huff and Agee 1991, Pickford et al. 1980). Fire return interval is also dependent on the development of a fuel complex capable of supporting crown fire behavior (Despain and Sellers 1977). Fires may burn only the crowns, sparing the understory during the spring when there is still snow on the ground.

The current natural fire regime was determined by using the recent fire occurrence data,

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[8] East wind weather conditions over a broad area or region at a given time. East winds are strong winds (20 to 40 mph) that bring warm, dry air to the western slopes of the Cascades on Oregon and Washington.

recent fire effects, current fuel models and current air quality. Although not a natural disturbance, there have been prescribed fires of less than 40 acres in harvest areas. The current natural fire regime consists of infrequent, artificially small fires, that have very little effect on the area, less than 1 percent of the analysis area burned during the 59 year period which represents current conditions. Current fuel model area and distribution, fire size information and stand composition indicate that the current fire regime most resembles a high-severity fire regime.

Pre-Attack Facilities

Prior to the establishment of the Forest Service in 1910 there were no pre-attack facilities. Currently there are various pre-attack facilities located in the Lemolo / Diamond Lake Watershed. These include seven helispots, 18 water sources, four emergency lookout locations, one fire camp site, one moderate size staging area, and one staffed lookout. Any proposed restorations or changes to these facilities should be coordinated through the district Fire Management Officer. Specifications regarding these facilities and a map displaying location are available in the district GIS database.

Differences Between Current and Reference Conditions.

- The current fire regime most resembles a high-severity regime; the reference fire regime for the preponderance of the area was a moderate-severity fire regime.
- Currently, fires generally burn for a period less than 24 hours; in reference conditions some fires burned from ignition until extinguished by fall rains, a period lasting several months.
- Current fires are smaller and influence considerably less overall area than fires burning in reference conditions.
- Currently, fires are generally limited to low intensities; fires burning in reference conditions exhibited a wide variety of intensities and effects, including high intensity.
- Currently, the total area of Fuel Model 10 is greater than reference conditions. (See Figure 24.)
- Currently, Fuel Model 10 is more continuous than in reference conditions.
- Currently, the total area of slash fuel models is greater than reference conditions.
- Currently, total area of fuel model 2 is less than in reference conditions; the total area of fuel model 6 is greater than in reference conditions.
- Currently there is less smoke, haze, and particulate produced from the analysis area than in reference conditions.
- Currently smoke affects the airshed for less time than in reference conditions.
- Currently the composition of species is more fire *in*tolerant than the mixture of fire tolerant and intolerant species in reference positions.

Similarities Between Current and Reference Conditions

- Lightning fires occurred throughout the watershed.
- Individual areas of Fuel Model 5 are widely dispersed.
- The crest of the Cascades had a natural high-severity fire regime. Fire suppression has not changed the fire regime in this case.

Processes or Causal Mechanisms Responsible.

The exclusion of fire due to the current fire suppression policy, timber management, and improved access to the area are the key elements responsible for the differences between current and reference conditions. The fire suppression policy was developed as a result of the severe fire season of 1902 when there were large, timber destroying, forest fires in almost every county on the west side of the Cascades of Oregon and Washington (Agee 1993). The policy was not very effective until the 1930s when fire detection, access, and fire suppression capabilities improved with the construction of lookouts, roads, and trails, and the establishment of the Civilian Conservation Corps camps. Even though the time from when a fire started to the time it was attacked was longer then (1930s) than now (1990s), fires were similar in size. One reason for this is the rain associated with most lightning storms. This moisture permits a period of time between detection and suppression, before the fuel dries and fire behavior can increase.

Improved access has increased the number of human caused fires and improved the access for fire suppression. This improvement has lead to greater success in fire suppression. Harvest and pre-commercial thinning without prescribed fire has created Fuel Model 11, 12, and 13.

Suppression of fires reduced overall amount of smoke, haze and total particulate. Reduced harvest and associated fuel treatment (prescribed fire) and change in prescribed burn timing and techniques has reduced overall haze and particulate during current conditions.

Future Trends

Without the re-introduction of fire into the watershed the total area of Fuel Model 10 will continue to increase. Large areas of Fuel Model 10 will remain relatively unbroken. The probability of a large stand replacing fire continues to increase as the area moves into an artificial high-severity fire regime. The area of natural high severity fire regime probably has not nor will not experience a dramatic change in fire regime.

Slash fuel models will continue to be present in very small amounts, the amount is based on timber harvest and pre-commercial thinning following timber harvest. There will be a reduction of Fuel Model 2 and 5 as these areas grow and the species change over time. Under current conditions; harvest, with slash disposal following harvest, are the only mechanism that produces and/or maintains theses fuel models. Person-caused fires will continue to increase with the continued increase in forest users.

The district has begun implementation of a prescribed burning project in the Lemolo Lake area which will eventually treat approximately 1500 acres in the watershed. The district is planning approximately 6297 acres in the Diamond Lake area, 697 of these will be ready for implementation in 1998. These projects will help convert fuel model 10 to fuel model 8, create and/or maintain openings, convert the stands in the area to a more fire tolerant stands, and begin returning the area to a moderate fire severity regime. The district also is preparing a plan to allow natural fires in the Mt. Thielsen Wilderness. With funding, district fire managers can continue to implement and plan these types of projects.

Influence and Relationship to other Ecosystem Processes

The change over time from reference conditions to current conditions influenced the overall natural fire regime.

A change in the fire regime will ultimately transform the entire ecosystem. Extended periods without fire allow more fire intolerant[9] tree species to grow to maturity, prevent the establishment of shade intolerant species and allow understory vegetation to grow profusely (where not hindered by other factors). Fire adapted species will become less numerous and in some instances over time may essentially disappear from the ecosystem all together. Fire adapted species include tree species or varieties having serotinous cones[10], species that thrive when resprouting from the stump and species that are shade intolerant.

Without fire or other drastic disturbance, Douglas-fir would gradually be replaced throughout much of its range by the more shade tolerant hemlock, cedar, and true fir. (Herman and Lavender 1990). Lodgepole pine will continue to encroach on meadows, open areas and ponderosa pine (*Pinus ponderosa*) savannas. Ponderosa pine stands may be reduced in size and overall health.

As more organic material (fuel in the form of dead limbs and logs) accumulates on the ground the potential severity of a fire will increase. High fire intensity and long duration fires (increased residence time) are the result. A fire burning under these conditions will consume greater amounts of vegetation, duff, and effective ground cover. These fires also kill more trees and other flora, can cause damage to soils, and can increase erosion. Heavy concentrations of smoke and particulate are probable during the late summer early fall during a large fire event.

Desired Range of Conditions

Desired condition for the majority of the watershed is a *moderate-severity fire* regime, with a small percentage of the area in a high-severity fire regime. This can be quantified by fire return interval, fuel model amounts and distribution, and fire effects.

Desired range of these conditions for the moderate-severity area are:

- Fire return interval averaging between 25 and 100 years.
- Fuel Model 8, to at least twice the area as fuel model 10 and more than half the overall area of the watershed. Fuel Model 10, non-continuous and less than one-third of the watershed.

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[9] Species with thin bark or in some other way unable to survive a moderate intensity fire.

[10] Cones that open in response to heat or fire.

- Desired average effect of fire is an underburn or stand thinning result.
- Desired average effect of fire is to convert and maintain fuel models to reference condition levels, and convert stands to a fire tolerant regime.

Desired range of these conditions for the high-severity area are:

- Average fire return interval greater than 100 years.
- Effect of fire stand thinning result and stand replacement.
- Average effect of fire is a change in species composition and structure.

SPECIES AND HABITATS

Resident Fish Species and Habitat

Analysis Procedures , Assumptions, and Data Gaps

Fishery surveys were conducted on all fish bearing tributaries to both Lemolo and Diamond Lakes using the USFS Region Six stream survey methodology. Lake Creek and Bradley Creek were surveyed by USFS personnel in 1996. All other stream surveys were performed in 1997 under contract by Tioga Resources Inc. (Roseburg, Oregon). Streams were either snorkeled or electroshocked to determine species presence and distribution. Data for the calculation of fish population estimates were not collected. Data analysis was performed using the USFS Stream Management, Analysis, Reporting, and Tracking (SMART) database system. Summary reports for each stream survey are located in Fish Appendix A. Lake habitat is discussed separately.

Current Condition, Differences from Historical Condition, Responsible Mechanisms, and Future Trends

Reference Condition

Fish Species and Habitat

It has not yet been, and may never be, conclusively determined whether any fish species were historically present in the North Umpqua River system above Toketee Falls. No documents clearly describing fish species or habitat conditions historically present in the analysis area are known to exist. However, several documents do provide limited information. The book "History of Southern Oregon" (Walling 1884), refers to Cowhorn Lake (now known as Diamond Lake) as being fishless. Text describing Umpqua National Forest characteristics printed on the reverse side of a 1933 Forest recreation map contains the following statements concerning fish distribution in the North Umpqua River: "There is good fishing everywhere in the North Umpqua and its tributaries below the Toketee Falls...Toketee Falls are too high for fish to jump, but Diamond Lake has now been stocked, and the upper streams are supplied from there." The book "Lone Rock: Free State" (Bakken 1970) refers to a survey of the North, South, and mainstem Umpqua Rivers conducted in 1902 by W.F. Briggs (county surveyor), containing 88 pages of written notes. This document may contain significant information about fish habitat and species in the analysis area. However, efforts to locate the document have not been successful.

Under the assumed reference condition, Toketee Falls and Lemolo Falls would have prevented anadromous fish access to the North Umpqua River mainstem and tributaries within the analysis area. It is possible that resident populations of native cutthroat trout, bull trout, and rainbow trout were historically present. However, it is also possible that native fish species either never successfully invaded the upper North Umpqua River system or were extirpated by natural forces. The above quote from the 1933 Forest recreation map text implies that fish were not historically present above Toketee Falls, but does not specifically state so. The expertise of the author is also unknown. It is also interesting to note that in one of the first reported attempts at stocking Diamond Lake (discussed in Chapter 2, Species and Habitats), fish were transported from below Toketee Falls by horse to Diamond Lake, rather than taking fish from a stream closer to the lake. The trail from Toketee Falls to Diamond Lake was adjacent to the Clearwater River for a distance and crossed Bear Creek.

If fish invaded the upper river system prior to the formation of Toketee and Lemolo Falls, and established populations within the analysis area, they would have been required to endure several periods of glacial activity, as well as periodic pyroclastic ash flows erupting from Mt. Mazama, in order to have survived to modern times. It is likely that pyroclastic ash flows were catastrophic events that sterilized many of the North Umpqua River tributaries above Toketee Falls.

It is likely that fish habitat in analysis area streams and lakes was in historical condition until the mid to late 1800s. Essentially no documentation of historical stream conditions exists. However, it is known that the High Cascades geology through which analysis area stream flow typically produces streams with slow storm runoff, low winter flood peaks, and high summer flows. Thus, in the reference condition, most analysis area streams likely provided fish habitat with high summer flows and unusually cold summer water temperatures. The cold summer water temperatures probably would have been an important limiting factor for fish production in many streams. Lake Creek, created by epilimnetic outflow from Diamond Lake, would have been an exception, and would have naturally contained much warmer water during summer months than other area streams. The headwaters of the North Umpqua River, created by epilimnetic outflow from Maidu Lake, may have also contained warm water during summer months, before being cooled considerably by groundwater and tributary input within a short distance downstream.

Large woody material that fell into area streams would have been likely to stabilize and accumulate, due to low flood peaks, and provide good habitat complexity. Low numbers of beaver are currently present in some analysis area streams. If beaver were historically present in higher numbers, beaver dams would have provided a positive contribution to fish habitat quality by providing sediment storage, pool habitat (overwintering areas), backwaters and side channels (juvenile rearing areas), and open pool areas with higher summer water temperatures. Stream substrates would be similar to those present today.

Current Condition, Future Trends, and Mechanisms of Change

Fish Species

The references cited in the Species and Habitats section of Chapter II document that efforts were underway by at least 1913 to establish a fish population in Diamond Lake. Fish stocking records for the Diamond Lake Ranger District from the 1940s contain some additional information about fish stocking in the analysis area, and are discussed below.

According to the stocking records, fish stocking in the analysis area had expanded beyond Diamond Lake to the upper North Umpqua River and Maidu Lake by 1927 (Table 38). Stocking of North Umpqua River headwater tributaries began in 1939.

The fact that such large numbers of fish were stocked in the uppermost tributaries of the North Umpqua River system implies that the upper stream system may have been fishless, and that an effort was underway to establish populations. Subsequent to the original stockings, the 1940 Diamond Lake Ranger District fish stocking plan recommended annual stocking of 40,000 rainbow trout fingerlings in Lake Creek, 10,000 in Bradley Creek, and 100,000 in the North Umpqua River between Toketee Falls and Maidu Lake. However, the 1940 stocking plan also recommended similar stocking in the North Umpqua River and some tributaries below Toketee Falls that historically had anadromous access and should have contained resident fish populations.

Current fish distribution is quite different than what might be expected from the historic stocking record. This is probably best explained by a combination of the implementation of a subsequent (and modified) stocking plan, unauthorized introductions, interspecific competition, and species habitat preference. As was discussed in Chapter II (Species and Habitats), brown trout inhabit the North Umpqua River and some tributaries above Lemolo Lake, Lemolo Lake, and most of the Lake Creek mainstem. Brook trout are present in most fish bearing streams in the analysis area, and Maidu Lake, with a few individuals present in Lemolo Lake. Rainbow trout are present in Diamond Lake, Lake Creek, and Lemolo Lake. Lemolo Lake contains a kokanee population that enters the North Umpqua River and Lake Creek inlets to spawn. The kokanee population in Lemolo Lake has one strong year class (in a generally three year life cycle). Surveys performed for PacifiCorp in 1992 (PacifiCorp, 1995) indicate that kokanee currently make up less than 2 percent of the total fish population in Lemolo Lake. Insufficient data exist to determine if this percentage is increasing, decreasing, or is stable.

Tui Chub are present in Diamond Lake, Lake Creek, and Lemolo Lake, and dominate the fishery in both Diamond and Lemolo Lakes. Golden shiners are only known to be present in Diamond Lake.

The above discussion of fish stocking and distribution does not directly address whether native fish were present in the analysis area, and if so, what factors led to their demise. All of the fish species currently present above Toketee Falls (rainbow trout, brown trout, brook trout, kokanee, golden shiners, and tui chub) are known to have been introduced. However, the fish stocking and land management activities that began shortly after the turn of the century have the potential to have extirpated any native salmonids that may have been present. Land management activities began in earnest in the early 1950s. At least three

Table 38. Summary of Diamond Lake Ranger District fish stocking records from the period 1927 to 1941 for streams and mountain lakes within the analysis area.

STREAM OR LAKE	1927	1928	1938	1939	1940	1941
North Umpqua River (at Kelsay Valley)	2,000 Rainbow fry	45,700 Rainbow fry	------	31,000 Rainbow fry	------	-------
Calamut Lake	------	------	3,000 Brook fingerlings	20,000 Brook fingerlings	------	7,000 Brook fingerlings
Maidu Lake	2,300 Rainbow fry	------	------	9,600 Brook fingerlings	-------	3,500 Brook fingerlings
Bradley Creek	------	------	------	11,000 Rainbow fry	20,000 Rainbow fry	35,000 Rainbow fry
Warrior Creek	------	------	------	-------	10,000 Rainbow fry	9,000 Rainbow fry
Tolo Creek	------	------	------	------	10,000 Rainbow fry	78,000 Rainbow fry
Lake Creek	------	------	------	19,000 Rainbow fry	31,000 Rainbow fry	67,000 Rainbow fry
Thielsen Creek	------	------	------	------	------	48,000 Rainbow fry
Poole Creek	------	------	------	------	15,000 Rainbow fry	26,000 Rainbow fry

factors associated with land development and non-native fish stocking act synergistically to extirpate native fish species; habitat alteration, interspecific competition, and fishing mortality. The direct and indirect impacts of forest management practices on salmonid habitat have been extensively documented by numerous authors and a thorough summary is provided by Meehan (1991). Cutthroat trout, bull trout, and rainbow trout (the species most likely to have been historically present) are all susceptible to population declines resulting from management related habitat degradation, with bull trout being highly susceptible. The introduction of brook trout can result in cutthroat trout population declines through interspecific competition (Griffith 1970, Griffith 1988). Bull trout and brook trout are closely related chars and crossbreed to produce a sterile hybrid. Due to the production of sterile hybrids, the early sexual maturity of brook trout, and other factors, the introduction of brook trout generally leads to a decline in bull trout populations. Bull trout are also aggressive predators and are highly susceptible to angling pressure. If native rainbow trout were historically present, crossbreeding with introduced strains of rainbow trout is likely to have reduced the genetic integrity of native fish.

Population trends in current fish communities vary in analysis area lakes. The relative abundance of rainbow trout and tui chub in Diamond Lake is clearly shifting to favor tui chub, despite the annual stocking of 400,000 rainbow trout fingerlings. The proposed rotenone treatment of Diamond Lake in 1999 would eradicate all fish species currently occupying Diamond Lake (rainbow trout, tui chub, and golden shiners). Restocking the lake with rainbow trout would presumably follow rotenone treatment. It is unclear what downstream effects would occur to Lake Creek and Lemolo Lake from the drawdown of Diamond Lake prior to rotenone treatment, the possible release of nutrient enriched water following rotenone treatment, and whether these effects would alter fish distribution, community structure, or population levels in Lake Creek or Lemolo Lake. The brook trout populations in Maidu Lake and Calamut Lake are likely to remain stable, due to continued stocking by Oregon Department of Fish and Wildlife. Without continued stocking, the brook trout populations in both lakes would probably decline rapidly.

The current fish distribution and population levels in stream habitats are likely to remain stable for the foreseeable future, with the possible exception of the Lake Creek mainstem. In the North Umpqua River, brown trout tend to dominate lower gradient reaches and tributaries, brook trout tend to dominate in tributaries upstream from brown trout. This distribution is most likely maintained by interspecific competition between the two species, and should remain stable. Fish populations in the Lake Creek mainstem are likely to remain stable, unless rotenone treatment occurs in Diamond Lake. If rotenone treatment does occur in Diamond Lake, it is possible that fish populations in Lake Creek will be indirectly affected to some degree by increased streamflow during lake drawdown in the months preceding rotenone treatment, and by increased nutrient supply for several years following rotenone treatment. Fish populations in Lemolo Lake may also be indirectly affected by both drawdown activity and subsequent increased nutrient supply following rotenone treatment in Diamond Lake.

Fish Habitat

Most analysis area streams currently provide moderate quality fish habitat. Some higher quality habitat is found in the North Umpqua River mainstem, Bradley Creek, and portions of Lake Creek. Cold summer water temperatures and high quality pool habitat are probably important factors limiting fish production in many streams. Reports from stream surveys conducted in 1996 and 1997 are contained in Appendix A, and provide detailed description of current stream conditions. The reports are summarized under Stream Channels in Chapter II.

It is likely that fish habitat in analysis area streams was essentially in historical condition until the mid to late 1800s. Impacts to fish habitat likely began in the late 1800s as a result of extensive sheep grazing in the analysis area (see Heritage Resource Overview Appendix C). Thielsen Creek, Sheep Creek, and Silent Creek are believed to have contained riparian meadows that were heavily grazed, resulting in moderate to severe impacts to the associated stream channels. Historical meadow reaches in the North Umpqua River mainstem, from the current site of Lemolo dam, upstream to and including Bradley Creek, are also likely to have sustained moderate to severe impacts. Some channel type conversion may have occurred as a result of grazing impacts. Sheep grazing continued until World War II, after which little to no grazing may have occurred in these areas. The exclusion of fire from the area has allowed conversion of much of the historic grazing area to forest. However, it is not clear whether the “historical” meadows were natural, or created and maintained with fire by humans.

The most obvious differences in habitat quantity and quality between the current condition and the historical condition are believed to be due to sheep grazing, timber management, road construction, recreational development, the exclusion of fire, and construction of Lemolo Lake. Management impacts to Lemolo Lake and Diamond Lake are discussed separately in Chapter IV. Specific impacts to streams include alterations in sediment supply and transport, bank and flood plain alteration, alteration of riparian function, removal of instream woody material, conversion to lacustrine habitat in the Lemolo Lake area, and alteration of nutrient processing in Diamond Lake. A lack of historical data allows only general discussion of management impacts.

Timber harvest impacts are localized and limited in scope, and have primarily affected only Lake Creek and Poole Creek. Impacts are associated with the removal of riparian vegetation, flood plain alteration, increased sediment supply, and possibly the removal of instream woody material. In the absence of these impacts, different fish habitat would be present in the affected stream segments.

Analysis area streams have few road related impacts, relative to other Diamond Lake Ranger District stream systems. Lake Creek and Poole Creek are the stream systems most affected. Effects to Poole Creek are probably greater in a relative sense, due to the much smaller watershed size. Effects to the Lake Creek system are primarily limited to the creek mainstem and small tributaries (including Sheep Creek) flowing from the east. Effects are generally limited to removal of riparian vegetation and increased sediment delivery. The culverts located at the Highway 138 crossing also probably create an upstream migration barrier at most streamflow levels.

Recreational impacts include campground development and trail use. Campground development primarily affects lower Thielsen and Bradley Creeks. Both campgrounds are located in riparian areas and localized impacts are high to the riparian areas and moderate to the stream channels. Stream channel morphology in upper Lake Creek, near the Diamond Lake outlet, is still affected by structures constructed for the Diamond Lake fish hatchery constructed in the 1920s.

The exclusion of fire from the analysis area may have allowed conversion of previously meadow type riparian areas to forest. However, as previously mentioned, it is not clear whether the "historical" riparian meadows were natural or created and maintained by human caused fire. It is believed that the meadows were located along the mainstem North Umpqua River (including the area inundated by Lemolo Lake), Bradley Creek, Sheep Creek, Thielsen Creek, and Silent Creek.

The expected future trend for fish habitat conditions in most analysis area streams is, in general, maintenance of the current conditions. The Lake Creek mainstem, and possibly the lower reaches of some tributaries, are the exception. The proposed drawdown, and subsequent rotenone treatment, of Diamond Lake may have effects to the morphology of the Lake Creek mainstem, and may affect water quality for several years. Probable effects to Diamond Lake and Lemolo Lake are discussed separately in Chapter IV. Road construction for timber harvest may affect some lower tributaries of Lake Creek through construction of road crossings. Due to the low stream density of High Cascades geology, runoff primarily through subsurface drainage, and implementation of the Aquatic Conservation Strategy, impacts to analysis area streams from timber harvest is likely to be minimized.

Insects and Pathogens

Current and Reference Conditions

Insects and pathogens are active in the Lemolo/Diamond Lake Watershed and are responsible for both large and small-scale disturbances across the landscape. The magnitude of insect and disease-related disturbance is greatly influenced by tree species composition, age class, stand structure, and history of other disturbances on a given site. Insects and pathogens themselves can also directly affect vegetative structure, stocking, and species composition over various spatial and temporal scales. A range of effects is present. Mortality occurs in small, scattered pockets of a few trees, in large openings acres in size, and as widespread impact to single species or groups of species.

Insects and pathogens of significance in the Watershed include mountain pine beetle, other pine and fir bark beetles, white pine blister rust, several root diseases, two species of dwarf mistletoe, and western gall rust. Due to its recent local visual impact, lodgepole pine needle cast will also be discussed. With the exception of *Cronartium ribicola*, the fungus that causes white pine blister rust, all of the insects and pathogens found in the Lemolo/Diamond Lake Watershed are native to the area; they have evolved with their hosts for millennia.

For this analysis, the impacts of insects and pathogens were determined by field reconnaissance and detailed surveys of individual stands. Mortality trend data and associated insect activity were examined using maps created during the Annual Aerial Detection Survey done by the Pacific Northwest Region's Insect and Disease group.

Pine bark Beetles

Mountain pine beetle (*Dendroctonus ponderosae*) has and will continue to exert a profound influence on stocking, stand structure, and stand age in the pine component of the watershed. Mountain pine beetle affects all species of pines. Predominantly lodgepole pine stands composed of mature or over mature trees greater than eight inches dbh, older than 80-years-old, and at stocking levels higher than 80 square feet of basal area per acre are considered to be at high risk for mountain pine beetle attack. High stocking in stands with mature and over mature lodgepole pine, western white pine, whitebark pine and ponderosa pine results in increased risk. Mountain pine beetles also attack young overstocked stands of ponderosa pine.

Mountain pine beetle adults emerge in late spring and fly until they find suitable pine hosts. They bore into the cambium and mate. The adult females then construct vertical galleries, laying their eggs along gallery sides. Larvae hatch and begin to feed in horizontal galleries. Blue stain fungi brought in by the beetles enter and grow in the xylem. Water flow blockage caused by the staining fungi and physical girdling of the cambium by feeding larvae kill trees. Beetles are attracted to low-vigor pines. Once beetle populations build in an area, even vigorous hosts can be attacked and killed.

Mountain pine beetle-caused mortality is an important part of the cycle of lodgepole pine forests and mortality has been high at various times in the past. Early reports prepared by the Bureau of Entomology refer to "An outbreak of the mountain pine beetle, which started in 1925 and almost completely destroyed the lodgepole forests between Diamond Lake and Crater Lake …...." (Keen 1933). In the mid 1970s a mountain pine beetle outbreak on the south and east shores of Diamond Lake killed thousands of trees and changed the vegetative structure of several campsites.

Mountain pine beetle has also caused large-scale mortality of western white pine. During the late 1960s, thousands of western white pines were killed in the Cascades from the north end of the Rogue River National Forest to the south end of the Willamette National Forest. Parts of the Lemolo/Diamond Lake watershed were affected by this outbreak. Reduced vigor of western white pines in the area was associated with white pine blister rust infection.

Currently, bark beetle-caused mortality levels are low in the watershed. Only small pockets (fewer than five trees) of mountain pine beetle-caused mortality have been observed in older lodgepole pine stands in recent years. Larger, scattered western white pines have also been killed. Recent bark beetle-caused mortality in whitebark pine has been observed. Mountain pine beetles working in combination with western pine beetles (*D. brevicomis*) are killing scattered individual larger ponderosa pines.

White Pine Blister Rust

One of the most important diseases in the Lemolo/Diamond Lake Watershed is white pine blister rust caused by *Cronartium ribicola*. *C. ribicola* is a non-native pathogen that was introduced to the West Coast of North America in 1910. Once established it spread rapidly, reaching the southern Oregon Cascades by the mid 1920s. White pine blister rust affects all five-needle pines, including western white pine and whitebark pine. The pathogen girdles and kills infected branches and stems. It causes top and branch death in larger hosts and outright mortality in seedlings, saplings, and pole-size hosts. Infections in larger trees can predispose these trees to mountain pine beetle attack.

The white pine blister rust fungus has a complex life cycle with five spore stages. It requires an alternate host in the genus *Ribes* and needs moist conditions in the summer and fall for intensification on *Ribes* and infection of pines. The disease is more severe on wet sites than dry sites and tends to intensify cyclically in “wave years” when particularly wet conditions occur.

White pine blister rust is actively killing tops, branches, and whole trees in western white pine regeneration throughout the watershed. Scattered top kill and branch flagging in overstory trees also occurs. White pine blister rust is also associated with branch die back and top kill of whitebark pine in the higher elevations of the watershed and may be associated with mortality. However, the impact of the disease on whitebark pine in the southern Oregon Cascades is not currently well understood.

Root Diseases

Root diseases also influence stand structure, species survival, tree densities, and canopy closure in stands of the Lemolo/Diamond Lake Watershed. Root diseases injure trees by decaying and killing roots or by preventing proper root functioning. Damage is expressed as reduced growth rates, butt decay, windthrow, death, and predisposition to bark beetle attack. Root diseases are diseases of the site; the fungi that cause them are able to maintain themselves for decades in stumps and woody root material. Annual rates of spread are slow relative to other disturbance agents, but effects may be great over larger spatial and temporal scales. Root diseases can cause scattered mortality of individual trees, preferring a single tree species or size class, or root diseases may cause large openings devoid of mature susceptible hosts.

Three major root diseases are present in the Lemolo/Diamond Lake Watershed. Laminated root rot, caused by the fungus *Phellinus weirii*, is causing the most substantial impacts. Armillaria root disease, caused by the fungus *Armillaria ostoyae*, occurs in small, scattered pockets. Annosus root disease, caused by the fungus *Heterobasidion annosum*, can be found where true firs have been harvested and/or where mountain hemlocks and true firs have been injured.

Laminated root rot is common in the Mountain Hemlock Plant Series and a significant portion of the acreage in this Series is affected by laminated root rot. Large, circular or sickle-shaped infection centers are readily visible on aerial photography. The margins of these centers contain dead and down trees. The area inside the centers regenerates to a mix of both disease-resistant and disease-susceptible species; large mature susceptible hosts rarely occur. The fungus spreads across root contacts. Inoculum may remain viable for up to 50 years in the root wood large stumps or standing dead material. Mountain hemlock is highly susceptible to the fungus; it is readily infected and killed. True firs adapted to higher elevations are often infected but not commonly killed. Lodgepole pine, western white pine, and whitebark pine are seldom infected and almost never killed. Laminated root rot centers have been present in these forests for hundreds of years or more. The fungus, along with fire, is critical to nutrient cycling and the creation of diverse, mixed-age and species stands.

In the laminated root rot pockets within the Mountain Hemlock Plant Series, western white pine is an important early seral species. It is resistant to *P. weirii* and thus is able to survive, grow, and achieve large sizes, unlike the more susceptible species that commonly seed into disease pockets. However, due to the active presence of white pine blister rust, the ability of western white pine to survive and grow to large size is compromised in many areas. Reproductive capacity of the species is lost, diversity is reduced, and the large tree component of these areas is nonexistent or decreased. An exotic fungus is actively interfering with stand dynamics.

Armillaria root disease is the most prevalent root disease in the White Fir Plant Series and is found throughout the Watershed. It predominantly affects white fir in small, scattered pockets, although other conifer species may be affected. The fungus spreads across root contacts or via rhizomorphs in the soil. Successful colonization of a host by the fungus is frequently associated with low vigor or tree stress. Compacted soils, old roads and skid trails, drought stress, and other insects and pathogens may leave trees vulnerable. Fir engraver beetles (*Scolytus ventralis*) are often found in association with Armillaria root disease mortality.

The S-type of *H. annosum* is present in true fir stumps throughout the Watershed. It is most readily identified in stumps created more than 15 years ago. In the White Fir Plant Series the fungus appears to be causing mortality of true firs adjacent to infected stumps. In the Mountain Hemlock Plant Series, the fungus is readily found in true fir and mountain hemlock stumps. It is also associated with wounded true firs and mountain hemlocks. Mortality does not seem to be occurring; however *H. annosum*-caused butt decay is common.

Stands where true firs and mountain hemlocks have been harvested have significantly higher levels of annosus root disease inoculum than unentered stands. Windborne spores from fruiting bodies colonize recently cut stumps or fresh wounds. The fungus then grows down through the stump or tree into the root system. When roots of susceptible species come into contact with infected root systems the fungus is transferred. Repeated entries into stands to harvest susceptible species create higher inoculum levels, provide additional entrance courts on wounded residual trees, and reduce host vigor when entries are made on compactible soils.

The number and size of root disease centers are probably at higher levels in the Watershed now then prior to the arrival of European Americans. This is particularly true for Armillaria root disease and annosus root disease because both of these diseases are enhanced by management activities such as soil compaction, stump creation, and fire exclusion.

Dwarf mistletoes

Significant impacts of mountain hemlock dwarf mistletoe and lodgepole pine dwarf mistletoe are occurring in the Lemolo/Diamond Lake Watershed. Dwarf mistletoes are parasitic, seed-bearing vascular plants in the genus *Arceuthobium* that infect conifer species. These parasites survive only on live hosts and obtain all of their water and most of their food from their hosts. Infection causes increased mortality, branch and top die back, reduced growth rates, stem deformities, and increased decay. Effects increase with increasing numbers of infections in a tree. Host branches usually react to dwarf mistletoe infection by producing a “witches’ broom” - an abnormal proliferation of many small twigs on the branch that appears as a clustered mass of twigs and foliage. Brooms monopolize water and nutrients at the expense of the rest of the tree. Sometimes pronounced swelling of the bole results from direct infection of the bole or from the spread of infection into the bole from an infected branch. Wood decay fungi often enter bark cracks and openings in these swellings.

Dwarf mistletoe plants produce berries in the fall that discharge seed by hydrostatic pressure outward and upward. The rate of spread of dwarf mistletoe depends on complex and interrelated factors. These include the composition of tree species, structure of the stand, and spacing of the trees. Stands with understory trees that are constantly exposed to dwarf mistletoe seeds from infected overstory trees will be highly impacted. The fastest spread and best development of dwarf mistletoe plants occurs in relatively open, multi-storied, stands where selective logging results in infected residual trees in a wide range of size classes. Regeneration harvest leaving many small infected residuals also results in rapid spread. The lowest infection rates are associated with very slow tree growth due to dense compact foliage with lower levels of seed interception between trees or rapid tree growth where internal infected branches are shed rapidly and tree height growth outpaces dwarf mistletoe movement within the tree. The slowest spread of dwarf mistletoe occurs in dense-single-storied stands of pure hosts, and in stands with large components of non-host species.

Western gall rust

Western gall rust, caused by the fungus *Peridermium harknessii*, is commonly found on lodgepole pine in the Watershed. It is also occasionally seen on ponderosa pine. It is characterized by round to pear-shaped galls as large as 12 inches in diameter on branches and stems of pines of all ages. Some brooming or proliferation of lateral branches may result from infection. On main stems, galls may become wide and flattened as the bole grows around infected tissue. The rust damages pines by killing seedlings, producing branch galls that are so numerous that growth loss or mortality result, or by producing trunk galls that reduce the strength of the tree and increase the likelihood of wind breakage.

In spring, yellow-orange aecia emerge from the living bark of globose galls and the marginal swellings of trunk or “hip” cankers. The aeciospores are carried by the wind for long distances to infect susceptible pine hosts. Infection occurs in young pine tissue. Unlike many other rust species, no alternate host is required to complete the life cycle.

In the watershed, snow breakage of smaller diameter lodgepole pine stems is common. Breakage is frequently associated with main stem galls caused by western gall rust.

Lodgepole pine needle cast

Moist springs since 1995 have resulted in the buildup of a needle cast fungus, most likely *Lophodermella concolor*, in lodgepole pine stands in the Watershed. This has resulted in a very visible orange-brown discoloration and subsequent casting of one-year-old foliage in the late spring and early summer of 1996 and 1997. Affected trees may be holding only recent year foliage and some appear “bottle-brushed”.

Needle cast fungi rarely kill trees directly. Repeated infection and foliage loss may weaken trees, making them more vulnerable to secondary agents.

Future Trends

Older lodgepole pine stands in the Watershed will experience another mountain pine beetle outbreak within the next decade or so. Based on past experience, large scale mortality during a three to five year period should be expected. Large scale mortality will lead to increased fuel loading and fire risk. Campgrounds and recreation sites on Lemolo Lake and Diamond Lake will lose the cover and structure provided by large lodgepole pine. Site conversion to hemlock and true firs as lodgepole pine is lost will result in different kinds of recreation site hazards. These species are easily injured and prone to decay.

Mortality due to mountain pine beetle and western pine beetle will continue to occur in western white pine, lodgepole pine, and ponderosa pine growing in overstocked mixed species stands. Whitebark pine will also continue to be killed by mountain pine beetle.

White pine blister rust will continue to reduce the vigor and kill western white pine on high hazard sites. Whitebark pine on high hazard sites will also continue to be affected by the pathogen. Laminated root rot pockets where western white pine normally provides large tree character will be changed structurally where blister rust is also a factor.

Root disease impacts will increase with increasing numbers of susceptible hosts and increased management where true fir and mountain hemlock stumps are created and trees are wounded.

Dwarf mistletoe will continue to spread and intensify in affected stands. Effects will be greatest where infected overstory trees are maintained above susceptible understory species.

Breakage associated with stem cankers caused by western gall rust will continue in affected stands.

Build up of lodgepole pine needle cast inoculum in stands near Lemolo Lake will continue if the pattern of moist spring weather continues. Trees affected several years in succession will have reduced vigor and will be susceptible to secondary agents.

Resident Terrestrial Species

The analysis for this topic was completed by reviewing data from various sources including inventory/monitoring reports, historical references, and conducting limited field visits. Little information had been collected on the animal species in the analysis area, until the 1980s, when spotted owl and elk surveys began.

Elk

Analysis Procedures, Assumptions, and Data Gaps

Elk habitat management, especially winter range, is important in this watershed due to public interest in elk viewing and hunting. Historical accounts of western Oregon were researched to ascertain if elk were native to the area. Information on elk stocking efforts and recommended winter range habitat proportions were collected from ODFW. Historical accounts of wildlife sightings at Crater Lake National Park were reviewed. The results from radio-telemetry studies conducted by ODFW in cooperation with the Forest Service were used to analyze elk movements.

One of the data gaps is that there is no accurate estimate of the elk population in the watershed. Furthermore, due to seasonal movements by elk across this watershed, the population changes throughout the year. We know from other studies, with easy access to areas inhabited by elk, that they are disturbed by human activity.

Reference Condition

History of Elk in the Lemolo Lake/Diamond Lake Watersheds

There is no evidence to suggest that elk were plentiful in the LDLWA prior to recent times. There are anecdotal comments on elk being in the high Cascades in the 1800s. By the late 1800s, few elk remained in Josephine County and the upper Umpqua River country. They were reported absent from Crater Lake National Park and Columbia County (ODFW report). Populations of elk are not identified in any historic accounts of the Upper North Umpqua, above Toketee Falls, until the 1920s, when Jesse Wright in "How High the Bounty" (Wright 1982) mentions seeing elk tracks for the first time in the Kelsay Valley and along the Calapooya Ridge. This corresponds to the release of 15 Rocky Mountain Elk from Yellowstone National Park into Crater Lake National Park in 1917 (Unrau 1987). However, it is unlikely that the Crater Lake elk moved north. Records indicate that they spent the summer in the Park and moved south, out of the Park in the winter.

ODFW attempts at establishing manageable populations are outlined in "Ecology and Management of Roosevelt Elk in Oregon". This document identifies release of seven elk in Copeland Creek (Douglas County) in 1948-49 and the establishment of a huntable population. During the 1960s and early 1970s, ODFW trapped and transplanted Roosevelt elk from the Coast Range into suitable habitat in the North Umpqua Drainage (ODFW 1994). These released elk are probably the progenitors of the elk herd on DLRD today.

Current Condition

Logging during the last four decades has enhanced elk habitat conditions, thus allowing the herd to increase. Regeneration harvesting has provided more forage and diversity of forest structures for the elk. The actual size of the elk population is unknown, but based on various indicators including the number harvested by hunters and winter aerial surveys by ODFW, the elk herd is stable. ODFW estimated that 2800+ elk live all or part of the year on the Diamond Lake Ranger District.

Elk on the DLRD are considered migratory, unlike the animals in the lower elevations of the Forest. Radio-collared elk from the Thorn Prairie winter range were monitored by ODFW from 1981-1982 and from 1985-1989. During the 1981-1983 study, they found that elk migration occurred during the latter part of October and into November. The fall/ winter migration route from the Deschutes NF appears to be from Windigo Pass southwest to Kelsay Valley; from Kelsay Valley north to Warm Springs Creek; and from Warm Springs Creek west along the North Umpqua River to Thorn Prairie Winter Range. Elk from other high elevation areas in the Forest also move into the Thorn Prairie areas during the winter.

Elk collared on specific winter ranges tended to return to those ranges in subsequent winters, thus exhibiting a strong fidelity to certain ranges. Twenty-one (75 percent) of the radio-collared elk used only one winter range during the period they were monitored (1-5 years). The severity of the winter weather (snow depth) is a strong factor in determining what portion of the winter range is utilized by elk. Due to the high elevations, no area in the LDLWA is classified as elk winter range. Elk winter range is considered as areas with elevations below 3500 feet and less than 70 percent slope.

None of the elk were located in the winter range areas during the summer, although non-radio-collared elk have been spotted near the winter ranges, but at higher elevations. Three of the elk monitored were often located in the upper Deschutes River Drainage in the Deschutes National Forest. Four elk were consistently found near Big Marsh (Deschutes National Forest). Other pairs of elk were found to summer in Kelsay Point, Mule Peak, Maidu Lake, and the Upper North Umpqua River drainage above Kelsay Valley (Beiderback 1994).

Differences or Similarities Between Conditions

There are great differences between the reference and current condition, since elk probably did not inhabit the area during the period of the reference condition. There has been an increase in logging activity created a checkerboard landscape of stand structures (clearcuts to late seral forests). This juxtaposition of the various habitats is important in the increase in the elk herd.

Future Trends

The elk herd will probably remain stable or increase due to the planned logging activities and active management throughout the District. Activities including prescribed burning are planned to enhance the elk winter habitat. Extensive timber harvesting could increase the foraging habitat but decrease the optimal habitat such that the overall carrying capacity is reduced. Elk are sensitive to human disturbances. Elk productivity could be negatively affected as numbers of people using the Forest increases, especially in the winter range areas.

Influences and Relationships to Other Ecosystem Processes

Elk require a diversity of habitat types. Therefore they are greatly affected by processes such as fire that leads to increased forage availability. Their numbers would probably decrease if logged areas were allowed to become reforested without new openings. Elk are sensitive to human disturbances, especially on the winter ranges. Closing roads and other actions that may prevent harassment of all wildlife, including elk, would be beneficial.

Wolverine

Analysis Procedures, Assumptions, and Data Gaps

Very few studies have been conducted on the wolverine in the United States. The lack of information is due to the difficulty and expense of studying a rare mammal that inhabits remote areas (Bianci 1994). During aerial surveys last year in the Mt. Thielsen Wilderness a set of wolverine tracks and a natal den site may have been sighted. Ground reconnaissance was not conducted until after the snow had partially melted, so no conclusive evidence was obtained. Aerial surveys will be conducted again during 1998.

Reference/Current Condition

Bailey (1936) stated that wolverines were rare in the United States, but probably not yet extinct in the Cascades. Wolverines populations were likely reduced significantly by the extensive wolf eradication programs carried out in the early 1900s (Bianci 1994). There are 23 records of wolverine sightings in Oregon from 1981-1992, compared to 57 records from 1913-1980. The current status in the state is unknown. The only place they are likely to be found on this ranger district in the Mt. Thielsen Wilderness and the adjoining areas in the Oregon Cascades Recreation Area (OCRA), since these are unlikely to be frequented by humans.

It is important to consider areas larger than this watershed when discussing wolverines since their home ranges cover large areas. Copeland (1993) found in Idaho that the home ranges varied from 39,000 to 126,800 acres. Wolverines can travel 15-25 miles per day in their normal movements (Haglund 1966). Wolverines that den in the Mt. Thielsen area may move into other remote areas on the Winema, Deschutes, and Willamette National Forests.

Future Trends

Wolverines will never be plentiful in this watershed. One of the most important factors in the preservation of any animals that inhabit this area, is the control and monitoring of recreationists. Wolverines are very sensitive to human disturbance. With the increasing use of snowmobiles and other winter vehicles, people are traveling greater distances into remote areas. Any increased access or use of the OCRA, or change in the status of the Mt. Thielsen Wilderness should be evaluated with the welfare of wolverine in mind.

Northern Spotted Owl

Analysis Procedures, Assumptions, and Data Gaps

The analysis procedures were to research data from past monitoring projects, review plans for logging activity, and review the district-wide owl distribution. More information is needed on the current status of the spotted owls in the historical activity areas, including a more careful analysis of the forest stand structure within the owl core areas.

Figure 25. Wildlife

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Reference Condition

There is no estimate of northern spotted owl numbers or distribution prior to the 1980s. They were probably never numerous in this watershed, since the forested areas are generally not optimum spotted owl habitat. Owls were not even considered to inhabit areas above 3500 feet at one time. Much of this watershed is above 5000 feet.

Current Condition

The area supports a lower density of spotted owls than other portions of the District, due to the high elevation and distribution of plant series. The five spotted owl cores are in the northwestern portion of the watershed in the White Fir plant series (see Figure 25). This plant series comprises 20 percent of the watershed and is found only in the western portion. Seventy-six percent of the watershed is comprised of series and unforested areas which are unsuitable for the spotted owls. The owl home ranges do not conform to the protection guidelines of maintaining at least 40 percent suitable habitat within 1.2 miles of the owl activity centers (classified as the home range) (Table 39). The amount of suitable habitat in each "owl circle" needs to be re-evaluated based on more recent aerial photography and vegetative information. The home ranges of three owls, with 100-acre core in other watersheds, overlap into the LDLWA (Table 40)

Differences or Similarities Between Conditions

Since there is no historical data on northern spotted owl numbers or distribution in the watershed, condition comparisons can only be postulated. The tree species composition and distribution, stand age and structure, and patch size of the forest stands are important factors that determine the distribution and numbers of spotted owls in the watershed. Most likely, the population of owls was never large in this analysis area, even before timber harvesting began.

Table 39. Summary of known spotted owl territories and suitable habitat within the Lemolo/Diamond Lake Watershed.

Owl Number	Last Surveyed	Suitable Habitat (acres) a/	Suitable Habitat (%) b/
810	1997		
830	1990	441	15
831	1994	994	34
834	1990	617	21
835	1990	265	9

a/ Number of acres of suitable owl habitat within 1.2 miles of owl activity center.

b/ Proportion (%) of suitable owl habitat within 1.2 miles of owl activity center.

Table 40. Distribution of the Northern Spotted Owl home ranges located in the Lemolo/Diamond Lake Watershed.

Owl Number	Home Range[a/] entirely in LDLWA	100 acre core area in LDLWA	Portions of Home range in other Watersheds
810	No	Yes	Yes
830	No	Yes	Yes
831	No	Yes	Yes
834	Yes	Yes	No
835	Yes	Yes	No
807	No	No	Yes
826	No	No	Yes
829	No	No	Yes

a/ Home range is defined as the area within 1.2 miles of the owl activity center.

Future Trends

Since the areas where the owls occur are matrix lands, which comprise only 25 percent of the watershed, suitable habitat could be reduced from timber harvesting. Owl numbers will change, depending on the amounts of timber harvested and the silvicultural system used. Commercial thinning operations that remove intermediate and suppressed trees and favor the best dominant trees for retention may speed the development of suitable owl habitat. This is one of the least harvested watersheds on the district, since 86 percent of the available matrix lands are in the mature or transition structural stages, but is the watershed with one of the lowest amounts of the matrix land allocations.

Bald Eagles

Analysis Procedures, Assumptions, and Data Gaps

Bald eagle records were reviewed. Eagle nest monitoring in the LDLWA has been occurring for many years, at least since 1978. No systematic study has been conducted on bald eagles on the District, although nesting areas are relatively easy to find during the breeding season, due to the size and behavior of the birds. Furthermore the nest is usually built near large water bodies. All of the large water bodies on the District are also near recreational sites, so eagle activity is normally reported.

Reference Condition

No information on the reference level populations is available, but since eagles normally nest near water and feed on fish, their numbers were probably never large in the LDLWA. Diamond Lake was historically fishless, with stocking occurring during the early part of the 1900s. It is doubtful that the eagles nested there before the stocking occurred. Lemolo Lake was constructed in the early 1950s, so previously eagle nesting was unlikely.

Current Condition/Future Trends

There is currently one active eagle nest near Lemolo Lake and one or two near Diamond Lake (Figure 25). Various nests have been built by eagles and used near Diamond Lake and Lemolo Lake over the last 20 years. Recorded nesting of bald eagles has occurred at Diamond Lake since 1978, in various nest sites along the north, west, and south shore. Nests near Lemolo Lake have been exclusively in the Bunker Hill and Poole Creek areas. Eagle use has been monitored annually by USFWS and/or district biologists. During some years, even during the summer, non-nesting eagles have used Diamond Lake for feeding and roosting.

Successful nesting and fledging of young has been sporadic at both the Lemolo Lake and Diamond Lake sites. When the bald eagles at Diamond Lake fail to produce young it is in the early phase of nesting, before or just after eggs hatch. Nest failure could be attributed to several factors; including severe weather conditions, human disturbance, and the lack to a readily available source of prey early in the nesting cycle due to ice covering the lakes. The Diamond Lake nest sites are at one of the highest elevations in the Cascades and eagles there must contend with harsh nesting conditions. Eagle nesting activity is not expected to change significantly unless additional recreation sites are built that might further disturb the nesting birds. The proposed drawdown and rotenone application at Diamond Lake could potentially affect eagle nesting for 1-2 years.

Spotted Frog

Analysis Procedures, Assumptions, and Data Gap

Amphibians, including spotted frogs, have not been systematically surveyed on the DLRD except as associated with the Demonstration of Ecosystem Management Options Study (DEMO) and in some areas during the preparation of the Federal Energy Regulatory Commission (FERC) license sought by PacifiCorp. None of the DEMO survey grids nor the PacifiCorp surveying was in this watershed. Observations of amphibians associated with other field activities has not yielded any spotted frog locations.

Reference/Current Condition

The spotted frog ranges from extreme southeastern Alaska through western Alberta, western Montana and northwestern Wyoming to northern Utah and central Nevada and west to the Pacific coast in Oregon and Washington. The species has been subdivided into various separate populations, including a western Oregon/Washington population. There are only about 20 verified historic locations of the spotted frog occurring in the Pacific drainages of

Oregon (U.S. Fish and Wildlife Service 1993). This species appears to be nearly extirpated west of the Cascades, with only one known population. Reduction, elimination, or alteration of wetland habitats has been a primary factor in the reduction of these populations (Gomez 1994).

Next to habitat loss, the second major factor affecting west coast population is the introduction and naturalization of nonnative predacious fishes and other nonnative aquatic species such as bullfrogs, that prey on tadpoles of spotted frogs. Spotted frogs probably were found in the LDLWA in wetland areas prior to the stocking of non-native fish in the early 1900s. In fact, there is credible evidence that this entire watershed was fishless prior to the stocking. Herpetologists from the Biological Research Division (BRD) of the U.S. Geologic Survey believe that spotted frogs may still be found in this watershed in isolated wetlands, since it is remote and relatively undeveloped.

Future Trend

It is unlikely that spotted frog populations will increase, if they exist, in the LDLWA. Nonnative fish populations which eat amphibians are present and are not expected to decline. Systematic surveys for spotted frogs, and protection of their wetland habitats are needed.

HUMAN USES

Recreation

Analysis Procedures, Assumptions, and Data Gaps

The analysis procedures used data from available sources. No new surveys or studies were conducted. Information concerning recreation inventory, use, user, and management goals and objectives was obtained from many sources. Recreation type, inventory, and use was obtained primarily from infrastructure data provided by District recreation personnel. Information about user preferences, type, and trends was derived from previous market and user surveys, draft management plans for the North Umpqua Hydroelectric Project, FERC Project 1927, and interviews with permitee and Forest Service personnel responsible for delivering recreational services. The 1990 LMRP and 1994 NWFP were the primary resources for management goals and objectives.

In analyzing future trends it was assumed that use would increase as the population increases. Historical trends and short term fluctuations (one to five years) are often due to economic and user preference fluctuations. Due to changes in USFS methodology for reporting recreation use, Recreation Visitor Days (RVDs) to Activity Occasions (AO) in 1990, and subsequent problems in converting AO to RVDs, using these figures to draw use comparisons was difficult. Many documents quoted different use figures for the same time periods. Therefore, RVDs and AO are shown for informational purposes only and to show the scope of recreation use. Use trends were determined from looking at use counts for overnight camping and lodging, previous market studies and observations by recreation employees, and permitees who have worked in the area for many years.

Reference Condition

The period from the early 1900s to 1990 was used as the reference condition for recreation. A more detailed account of earlier human uses in the watershed is found in the *Heritage Resource Overview* of the Lemolo Lake and Diamond Lake Watershed Analysis Area.

Diamond Lake Recreation Area

The earliest consistent recreation use coincides with the stocking of Diamond Lake with fish in 1910. There were some USFS camps in the area before 1920 and in 1922 a USFS special use permit was issued to the Diamond Lake Improvement company to construct a resort at the north end of Diamond Lake. The resort consisted of a few tents, a store, and a lodge. Around the same time, special use permits were issued for Recreation Cabins along the west shore. Primary access to the area was from the south via Medford and Klamath Falls. The USFS estimated 1500 persons visited Diamond Lake in 1921. Over the next three decades more improvements were made to USFS facilities, the Resort, and additional cabins were built in the Summer Home tract (previously identified as Recreation Residences). By the mid 1960s the development of recreation camps and facilities in the Diamond Lake area was similar to what is found today.

The campgrounds had water from springs, vault/pit toilets, and developed camp sites. Diamond Lake Campground even had a flush toilet. The Diamond Lake Resort had expanded the lodge, added cabins, boat docks, and other services. The last of the Recreation Residence special use permits had been issued, the RV park was built and Diamond Lake was known as one of the premier fishing spots in the northwest after the chemical treatment of the lake (for tui chub removal) and restocking with trout in 1954-55.

Access had also improved, with paved highways from Roseburg, Medford and Central Oregon leading into the area. Recreation use at this time was primarily seasonal and centered around fishing and camping. In conversations with cabin owners, campers, and the Resort owners, it appears this is the period during which second generation users were coming to Diamond Lake and many of today's users were coming for the first time as children. Historical records and interviews indicate the majority of users were from Oregon. From the late 1960s to the early 1990s, improvements to facilities and changes in the use season were major influences to impact this area. Due to the growing use at Diamond Lake and concerns that this increased use would significantly impact the water quality of the lake, major water and sewer facilities were constructed in four phases from 1968 through 1972, at a cost of over two million dollars. Major components built during this development phase include:

- Deep wells and storage reservoirs for domestic (potable) water supply
- Approximately 13 miles of water lines
- Flush restrooms and water hydrants
- Fish cleaning stations
- Trailer dump stations
- Approximately 11 miles of sewer lines

- Approximately 11 miles of underground electrical lines
- Sewage pump stations
- Sewage treatment lagoons
- Connection of the Diamond Lake Resort and RV Park to the sewage collection system

Also in 1968, the resort went from seasonal (April – November) operation to a full year operation offering winter recreation opportunities such as snowmobiling and cross-country skiing.

As improvements were made, fishing remained good and as the general population grew, so did recreational use. The highest use during this period was in 1978 when 783,700 RVDs were reported and the campgrounds reached full capacity on 18 occasions. Creel census by ODF&W report 138,700 angler trips and 342,000 fish caught in 1978. The 1978 Diamond Lake Composite Plan identified fishing and camping as the primary activities during the summer and snowmobiling and cross-country skiing as the major winter activities. The majority (greater than 50 percent) of the visitors were from Oregon with the majority from southwestern and central counties (those areas within 200 miles of Diamond Lake). Similar user demographics applied to the Diamond Lake Resort visitors and over 80 percent of the owners of Summer Homes were from Oregon.

In the mid 1980s through the early 1990s more improvements were made to both Forest Service and permitee facilities to meet demand, user preferences, and for resource protection and enhancement. During this time, in excess of three million dollars were spent to upgrade campgrounds, facilities, and recreational opportunities. Some of the most significant improvements to the campgrounds were:

- Remove approximately 15 lake shore campsites
- Reducing campground roads from approximately ten to seven miles
- The paving of all campground roads and spurs
- The hardening of campsites and the replacement and fixed placement of tables and fire rings to limit the area of use
- Adding barriers to keep vehicles and campsites in designated areas
- Improving and paving boat ramps and docks
- Remodeling some campsites and restrooms to make them handicap accessible
- Adding two shower facilities and an amphitheater
- Adding water accessible vault toilets and paving roads and spurs at Thielsen View Campground
- Reconstruction and paving of the South Shore Picnic Area
- Construction of an 11 mile paved bike path around Diamond Lake

Also during this period, Diamond Lake Resort built more cabins, expanded the main lodge, and started snow cat skiing on Mt. Bailey. Use during this period was down from the high of 783,700 RVDs in 1978 and remained fairly steady during the 1980s with an average of approximately 650,000 RVDs annually. A market feasibility analysis done in 1985 still showed fishing and camping as the primary reason people visited Diamond Lake, with the majority being repeat visitors from Oregon.

Lemolo Lake Recreation Area

Early maps and records show a few small USFS camps located within the area now dominated by Lemolo Lake. USFS camps were located along streams, primarily Lake Creek and Poole Creek, where they joined the North Umpqua River. Completed in 1955, the Lemolo Lake inundated some of the camps but with the creation of the 430+ acre lake, new opportunities were created.

Poole Creek Campground was the largest campground in the area. Records show a water right issued for domestic water use for Poole Creek Campground in 1963. The campground had approximately 40 sites with pit/vault toilets and dirt roads and spurs. Major reconstruction of this campground occurred from 1982 to 1984 to improve facilities and for resource protection. Improvements included:

- ☐ Drilled well and new waterlines and hydrants
- ☐ Accessible vault toilets
- ☐ Paved roads and spurs
- ☐ Barriers to manage traffic and use
- ☐ Paved boat launch and new dock
- ☐ Construction of group use site

There is limited information about the other developed campgrounds like East Lemolo but it can probably be assumed that these started out as popular dispersed sites that were improved and developed over a period of time in response to increased use and resource concerns. One exception is the Kelsay Valley Trailhead which is shown on a 1925 USFS map.

In 1963 a USFS special use permit was issued for the construction and operation of a resort to be located on the west shore of Lemolo Lake. Initial construction consisted of a restaurant, store, four cabins, and a marina. Over the years, an RV park, more cabins, and gas station were added. The Resort initially operated seasonally (April – November) and went to year-round operation in 1979.

Fish management of Lemolo Lake began in 1955 with the stocking of different species until 1972 when brown trout became the primary species in the lake. An ODF&W creel census estimated 5,100 anglers visited Lemolo Lake in 1976. Compared to the Diamond Lake Area, recreation use was light but steady, with primary users coming from the local communities in southwestern and central Oregon.

Wilderness/OCRA

The Mt. Thielsen Wilderness and the Oregon Cascade Recreation Area (OCRA) were designated as part of the Oregon Wilderness Act of June 26, 1984. Prior to the creation of the Mt. Thielsen Wilderness, man-made structures had been constructed at Lucile and Maidu Lakes. Diamond Lake Horse Corrals conducted guided horse trips into the area for sightseeing, hunting, and camping. Many of the trails currently in the wilderness and ORCA today were established during this early use period. Recreation use was primarily light dispersed in nature.

Other

Early in this century, recreation appears to have been heaviest around the Diamond Lake Area. Access into other sections of the watershed was more difficult and had less dominant features to attract visitors. Although some camps probably existed, the construction of the Lemolo 1 Project (part of the PacifiCorp North Umpqua Hydroelectric Project) in the 1950s and the completion of Oregon State Highway 138 in the early 1960s contributed to increased demand and use throughout the remaining areas of the watershed. Old construction or mill sites, once abandoned, often became recreation sites used today. It is known that trails existed and were used in the early and mid-1900s, but limited information is available as to the amount or type of use they received.

Current Condition

Diamond Lake Recreation Area

As previously described in Chapter Two, the Diamond Lake Recreation Area is a high use, developed, destination recreation area offering both summer and winter recreation opportunities. It is the highest-use recreation area on the UNF. USFS campgrounds, Diamond Lake Resort, Diamond Lake RV Park and the Summer Homes have a total of 780 available units. A unit is defined as an overnight camping or lodging opportunity. Including day use areas the combined Persons At One Time (PAOT) capacity is 5,619 (Table 41). Approximately 75 percent of the Diamond Lake shoreline is utilized for some form of developed recreation, with the USFS facilities (38 percent), and the Summer Home tract (33 percent) being the largest uses. The area is managed for concentrated developed recreation with an Recreation Opportunity Spectrum (ROS) class of rural. Overnight camping in the area is restricted to designated areas (campgrounds, resort etc.) by special order.

Facilities in the area, both USFS and private operator, have been constructed over the years to help meet the demand and expectations of the recreationists, including many handicap-accessible facilities such as boat ramps, the amphitheater, campsites, and trails. A summary of USFS and permitee facilities is contained in the Recreation Appendix D.

.Water and Sanitation

From 1968 through 1972, water and sanitation facilities were constructed to meet the demands and pressure occurring from the high, concentrated use around Diamond Lake. Domestic (potable) water supply for the campgrounds, Resort, RV Park, and Summer Homes consist of both central and individual systems. Water for USFS developments from

Table 41. Persons At One Time Capacity - Diamond Lake Recreation Area

SITE	DAILY PAOT	MANAGED SEASON DAYS	PAOT DAYS
Diamond Lake Campground	1,398	190	265,620
Broken Arrow Campground	994	110	109,340
Thielsen View Campground	341	162	55,242
South Shore Picnic Area	368	184	67,712
North Shore Boat Ramp	148	189	27,972
Medford Overflow	150	5	750
Noble Fir Picnic Area	10	164	1,640
Howlock Mountain Trailhead	60	364	21,840
Howlock Horse Camp	10	190	1,900
Diamond Lake Horse Corrals	20	190	3,800
Diamond Lake Resort	1,000	365	365,000
Diamond Lake RV Park	700	152	106,400
Diamond Lake Recreation Residences	510	365	186,150

the North Boat Ramp through Broken Arrow Campground are supplied from two deep wells and an extensive distribution system. Thielsen View Campground has a deep well and a small distribution system. The Diamond Lake RV Park has its own well and the Resort has developed springs and distribution system. The Summer Home residences have individual systems that vary from some with no water, others with shallow hand dug wells, and others with drilled wells. Data is incomplete on the number of Summer Homes that have water. Active water rights in the area are shown in (Table 42). Incomplete records are available for all water use since domestic use less then 15,000 gallons per day (gpd) does not require an Oregon State water right. In 1997, average daily water use for the USFS campgrounds during the peak use months of July and August was approximately 64,000 gpd. There are no figures available for the Resort or RV Park.

Table 42. Water Rights in the Diamond Lake Recreation Area

OWNER	***USE***	***POINT OF DIVERSION***	AMOUNT
USFS	Diamond Lake & Broken Arrow Campgrounds	2 – Wells	0.26 cfs
USFS	* Thielsen View Campground	Diamond Lake	0.015 cfs
USFS	Emergency supply	Spruce Creek	0.30 cfs
Diamond Lake Resort	Domestic – Resort	Two Bear Springs	0.10 cfs
Diamond Lake Resort	Domestic – Resort	Two Bear Springs	0.30 cfs
Diamond Lake Resort	Domestic – Resort	Admin. Site Springs	0.02 cfs
Diamond Lake RV Park	Domestic – RV Park	Short Creek	0.025 cfs

* Surface water permit still active but not currently being used.

The USFS central sewage system extends from the Resort through Broken Arrow Campground. Wastewater from the restrooms, wastewater sumps, fish cleaning stations, trailer dump stations and shower buildings in the campgrounds, and other USFS buildings, Resort, and RV Park is collected and pumped to a 20 acre sewage lagoon system. The sewage lagoons are located north of USFS road 4795 near the Resort's Hill Top Shop. The lagoons are beyond the Diamond Lake sub-watershed and are in the Lake Creek sub-watershed. There is no point discharge of effluent from the lagoons. Effluent is managed by surface evaporation and percolation in a secondary cell within the lagoon area. The sewage system was designed to treat an average daily flow of 196,900 gpd with a maximum flow of 281,300 gpd. Different reports have estimated the system will accommodate a population of 5,000 to 10,000 people. Average daily flows during the peak use months of July and August, 1997 were 86,250 gpd. July 5th was the highest flow day in 1997, at 152,000 gallons.

Thielsen View Campground, Noble Fir Park, Medford Overflow, and the ODF&W cabin have holding tanks (vaults) which are pumped and the waste taken to the treatment lagoons. The facilities in the area that have individual, on-site disposal systems are the Summer Homes, and three buildings (one USFS and two Resort that have septic tanks and drainfields). Of the 102 Summer Homes, approximately 75 percent have pit toilets and 50 percent septic tanks and drainfields. Some Summer Homes have both, with the pit toilet used only as a back up during power outages or during the winter months.

Use

While use in the Diamond Lake Recreation Area remains high, the recent decline of the fishery in Diamond Lake has influenced use and use patterns. Use during the shoulder seasons (Spring and Fall) is down from previous years in the campgrounds, Resort and RV Park. Use remains about the same during the summer months and is increasing slightly during the winter months, depending on snow conditions. The heaviest use periods are holidays and weekends. In 1997, the USFS campgrounds averaged 43 percent site occupancy during the summer (June-August) and 7 percent site occupancy during the shoulder seasons (April-May and September-October) (Table 43). There was one overflow occasion during the July 4th weekend. The Diamond Lake Resort reports 95 to 100 percent lodging occupancy during the summer and approximately 40 percent during the shoulder seasons. The RV Park estimates use at 55 percent occupancy during the summer and 30 percent occupancy in the shoulder seasons. Reported AO and visitors in 1997 are shown in Table 44.

Table 43. 1997 Site Occupancy - USFS Diamond Lake Area Campgrounds

* Excludes Broken Arrow Campground group sites.

MONTH	DAYS	* TOTAL SITES AVAILABLE PER MONTH	TOTAL OCCUPANCY PER MONTH	OCCUPANCY PERCENT
April 25 – 30	6	2,472	75	3
May	31	12,772	1,279	10
June	30	12,360	2,834	23
July	31	12,722	6,838	54
August	31	12,772	6,636	52
September	30	12,360	1,661	13
October	31	12,772	190	< 2

Many recreational opportunities are available within and near the recreation area. Activities include sightseeing, hiking, camping, fishing, bicycling, boating, and swimming. Visiting Crater Lake National Park and the Rogue River are other popular activities within a 30-minute drive. Many people visiting Crater Lake also visit Diamond Lake. A 1996 USFS user survey shows camping and fishing as the two primary reasons people visited Diamond Lake, with bicycling, hiking, and sightseeing being other popular reasons. Trails to the top of Mt. Bailey and Mt. Thielsen and the paved bicycle path around Diamond Lake are major attractions and activities for visitors. As mentioned, fishing demand and success has decreased in recent years. A creel census by ODF&W estimates 35,000 angler trips and 70,100 trout caught in 1996. Visitors to the area are primarily families and over 70 percent have been to Diamond Lake at least once before. The Resort estimates 90 percent of their customers during the Summer are families, with about 40 to 50 percent of those families being from Oregon. Of the 102 Summer Home permitees, 84 list Oregon as their place of residence, with over 85 percent of those being from the surrounding counties.

Table 44. Activity Occasions/Visitors in 1997- Diamond Lake Recreation Area

SITE	CAMPING/LODGING	BOATING	VISITORS
Diamond Lake Campground	49,500	13,500	65,000
Broken Arrow Campground	9,000	NA	18,000
Thielsen View Campground	9,000	3,000	19,000
South Shore Picnic Area	NA	2,100	30,500
Medford Overflow	750	NA	3,500
North Shore Boat Ramp	NA	3,900	24,000
Noble Fir Picnic Area	NA	NA	500
Howlock Mountain Trailhead	NA	NS	500
Visitor Information Center	NA	NA	16,000
Diamond Lake Resort	51,000	11,200	228,100
Diamond Lake RV Park	21,100	NA	27,500
Diamond Lake Recreation Residences	12,700	NA	Not Available

Winter recreation activities account for five to ten percent of the total recreation use on the DLRD and almost all of that use is in the watershed. Since the majority of the use is either around or originates from the Diamond Lake Area, the following includes the entire watershed. Almost 150 miles of motorized Winter trails are maintained in the Diamond Lake and Lemolo Lake area. There are five winter snowparks and two trailheads that serve as winter recreation sites. Winter activities include snowcat skiing for intermediate to advanced skiers on Mt. Bailey, snowmobiling, cross-country skiing, inner-tube sledding hill, and general snow play activities.

Total reported AO for winter activities in 1997 were 8,650 for cross-country skiing, 17,000 for snow play, and 14,265 for snowcraft travel. Snow play activity has the greatest number of participants but is for short duration. Snowmobiling and cross-country skiing dominate the remainder of the winter recreation activities. The Diamond Lake Resort estimates the majority of their winter overnight use is by snowmobilers. Snow play activities, like the sledding hill, dominate day use. The Resort estimated 90 percent lodging occupancy on weekends and 10 percent during the week. A 1991 winter recreation analysis done for the Resort indicates the greatest percentage of winter users are families and 80 percent are from Oregon. The report also identifies over-the-snow activities and sightseeing as the primary activities of those visiting the area.

Economics

As mentioned, there has been extensive development and investment in the Diamond Lake

Recreation Area by both the public and private sectors. Investment in water and sewer facilities and campgrounds by the USFS, between 1969 and 1991 alone, has been in excess of five million dollars. Replacement cost of facilities and campgrounds would be many times higher. Douglas County places a Real Market Value (RMV) on the property of the Resort, RV Park, and Summer Homes at just over seven million dollars. They do not assess the value of the land since it is publicly owned. In 1996, $184,000 was collected in fees from the USFS campgrounds. Permitee payments by the Resort, RV Park, and Summer Homes were $186,000. Recreation use at Diamond Lake is also important to the local economies of the surrounding counties. ODF&W estimates that anglers coming from outside the area to fish for trout in the southwest angler zone spent about $17.82 per angler visit (Diamond Lake Fish Management Issues, ODF&W 1996). With ODF&W's management goal of an average of 100,000 angler trips per year for Diamond Lake, this equates to 1.78 million dollars in revenues to the area. Besides the economic benefit to the surrounding counties from people traveling to Diamond Lake to recreate, the area also provides employment opportunities. Diamond Lake Resort employs approximately 135 people during the summer and approximately 100 people during the winter months.

Lemolo Lake Recreation Area

The five USFS campgrounds and the Lemolo Resort are situated along the lake shore or inlets to the lake. The USFS campgrounds and Lemolo Resort have a total of 141 available units and a PAOT capacity of 841 (Table 45).

The Lemolo Lake recreation Area is managed as Special Management Area II (MAII) for developed recreation. The ROS class is roaded natural (RN). The two special interest areas (MA6), Crystal springs and Spring River are managed for recreation and to protect their unique features

Table 45. Persons At One Time (PAOT) Capacity - Lemolo Lake Recreation Area

SITE	PAOT	MANAGED SEASON	PAOT DAYS
Poole Creek Campground	355	188	66,740
East Lemolo Campground	75	184	13,800
Crystal Spring Campground	5	152	760
Inlet Campground	71	182	12,922
Bunker Hill Campground	25	183	4,575
Lemolo Lake Resort	310	365	113,150

Water and Sanitation

Poole Creek Campground and the Lemolo Resort are the only developed facilities with potable water. Both have drilled wells and small distribution systems. Sewage systems are individual. Lemolo Resort has septic tanks and drainfields. Poole Creek Campground has newer, accessible vault toilets. The remaining campgrounds have older vault toilets. Waste from the vault toilets is pumped and taken to the sewage lagoons at Diamond Lake.

Use

Current use in the Lemolo Lake area is much less than at Diamond Lake. The heaviest use period is during the summer and on weekends and holidays. USFS campgrounds and the Lemolo Resort will normally be at capacity on the 4th of July weekend only. Poole Creek Campground will experience its highest use during late July and August, when the weather is best and the lake temperature is warm enough for water skiing and swimming. Table 46 shows reported AO for 1997.

Table 46. 1997 Activity Occasions/visitors - Lemolo Lake Recreation Area

SITE	CAMPING/LODGING	BOATING	VISITORS
Poole Creek Campground	9,900	4500	20,200
East Lemolo Campground	2,200	NA	5,000
Crystal Spring Campground	15	NA	100
Inlet Campground	900	NA	1,500
Bunker Hill Campground	985	NA	1,500
Lemolo Lake Resort	5,200	4000	37,000

Prior to 1997, Poole Creek Campground was the only fee campground in the area with collections averaging about $15,000 annually. Collections in 1997, with four other campgrounds requiring fees, were approximately $29,000. Peak season (May – September) activities in the area include camping, boating, fishing, hiking, sightseeing, and ATV and bicycle riding. In addition to Lemolo Lake itself, other attractions in or near the watershed attract people to Lemolo Lake. People often stay in the area and visit Diamond Lake, Crater Lake, the wilderness area, and OCRA. Lemolo Lake Resort often receives referrals and guests when Diamond Lake Resort is full.

A 1992 – 1994 survey conducted by PacifiCorp showed that over 75 percent of the visitors to the Lemolo area were from Oregon and that the majority of those were from the southwestern Oregon region. In the fall, the area experiences heavy use by hunters during the elk season. During the winter months, the area is usually covered with snow and the campgrounds and roads are closed. The exceptions are the Lemolo Lake Resort and FSR 2610 from Oregon State Highway 138 to Lemolo Dam. There are numerous snowmobile and cross-country ski trails in the area. Routes go around the lake area and also connect to the trails from the Diamond Lake area. The primary activities are cross-country skiing, snowmobiling, and general snow play. Though surveys have not been conducted for winter use, it can be assumed the majority of the users are from the local (200 mile) area, because of the high percentage of local summer use and the winter recreation analysis done for Diamond Lake demonstrating the majority of users there were from Oregon.

Wilderness/OCRA

Of the 55,100 acre Mt. Thielsen Wilderness, 22,700 acres are in the watershed. The area is managed as wilderness with a Wilderness Resource Spectrum (WRS) management objective of 22,200 acres as Primitive and 500 acres as semi-primitive. Climbing Mt. Thielsen is by far the greatest use within the wilderness. It is estimated that 40 people per day use the climbing trail (1456) from mid-July through early September. This equates to approximately 60 percent of the total use during this period. Other popular trail routes are the Maidu Lake Trail (1414) and the Pacific Crest Trail (2000). Secondary uses include horse riding, camping, fishing, and hunting. Activities around Maidu and Lucile Lakes were determined to be in excess of Limits of Acceptable Change (LAC) guidelines and man-made structures were removed in 1992 to conform to acceptable use. Primary use trails (Thielsen, Maidu, and Pacific Crest) are currently within LAC criteria. Current management direction is to manage the wilderness in a manner that will have no net change in the WRS class and, where possible, to move to a higher class. The Diamond Lake Resort has the only commercially permitted activity within the wilderness with guided horse rides into the area using the Howlock (1448) and Thielsen (1449) trails. This guided use in the wilderness is less than 30 persons per year.

Winter use consists mostly of cross-country skiing and snowshoeing. A few hearty enthusiasts have been known to climb Mt. Thielsen during the winter.

There were an estimated 8,000 visitors to the wilderness in 1997. The OCRA, established along with the Mt. Thielsen Wilderness, has four zones within the watershed. Current management direction is to manage the area to provide for a wide range of recreation activities. Table 47 lists the different ROS classes and estimated use in 1997. Besides use, activities also vary throughout the Zones. The main activities in Zone 3 are centered around Calamut, Charline, and Linda Lakes and are dominated by camping, fishing, and hiking.

Table 47. OCRA Classification and Use

ZONE	ROS	VSQ	ESTIMATED VISITORS: 1997
3 Calamut Lake	SPM	Retention	1000
5 North Umpqua	SPNM	Retention	1300
6 Thirsty Point	SPM	Retention	1600
7 West Thielsen	SPNM	Retention	6200

SPM:	Semi-Primitive Motorized
SPNM:	Semi-Primitive Non-Motorized

Use in Zones 5 and 6 is more dispersed and is primarily hiking, hunting, horse riding, and cross-country skiing. Zone 7 gets heavier use primarily as an access to the Mt. Thielsen Wilderness. Main activities in Zone 7 would be hiking, horse riding, hunting, and mushroom harvesting.

There were no valid mineral claims found for the wilderness or OCRA.

Other Sites

As described in Chapter II, there are seven other developed recreation sites in the watershed excluding snowparks/and trailheads with a combined PAOT of 208. They have vault toilets, tables, and fire rings. None have water. Sewage from the vault toilets is pumped and taken to the sewage lagoons at Diamond Lake. Primary uses are camping, hiking, fishing, and hunting. In 1997, there were an estimated 2,451 AO for camping at these sites. Dispersed sites are mostly unimproved camps and are used for camping, hunters camps, and mushroom pickers. There are approximately seven special use permits issued each year for recreation events. These are typically group uses by organizations such as the Boy Scouts or Nordic Ski Clubs.

The ODOT sand shed and maintenance building at the Lemolo Junction (Oregon State Highway 138 and FSR 2610) are owned by the State of Oregon and used for highway maintenance needs. There is a well, septic tank and drainfields, but no housing at the site.

There are two facilities on Cinnamon Butte. One is a USFS Lookout operated seasonally by DLRD. The other is a communications site with buildings and towers for communications equipment, antennae, and dishes. Users include the USFS, Douglas County, Diamond Lake and Lemolo Resorts, and Ramcell Communications.

There are approximately 360 miles of trails within the watershed. There are also roughly 150 miles of winter trails. Many of the roads or trails, blocked by snow during the winter, comprise the winter trail routes and are for motorized (snowmobile, ATV) or Nordic (cross-country skiing) use. A more detailed summary of the trail systems, lengths, and use is contained in other sections of this report.

The predominant Visual Quality Objective (VQO) assigned by the LMRP for the watershed is retention. Interpretive opportunities have been developed along the Oregon State Highway 138 corridor as part of Rogue Umpqua Scenic Byway.

Differences or Similarities Between Conditions

Diamond Lake Recreation Area

The most dramatic and obvious differences in the area from the turn of the century to the present time is its development and use as a destination recreation area. The stocking of fish, subsequent development of facilities, and visitors to the area over the years have all had an impact on the surrounding environment. These conditions, however, have also provided recreation, relaxation, and memories for millions of people.

Other changes that have occurred more recently are:

- Improvements in facilities (showers, accessible sites, roads, boat docks, and trails)
- Re-vegetation of high use sites and campgrounds
- Diamond Lake Resort going to year-round operation in 1968
- Increasing winter use and developments to meet that use
- Decrease in fishing since 1992
- Decrease in overall use since 1992

Some similarities that exist are:

- Scenic quality and enjoyment
- User demographics – primarily families, local area, and repeat users
- Camping and fishing are still the top two reasons people visit Diamond Lake

Lemolo Lake Recreation Area

Probably the most dramatic differences in current conditions compared to the reference conditions are the increased use in the area and the concentration of use around Lemolo Lake and the associated water related activities. Associated with this came the development of USFS campground facilities and a Resort.

Wilderness/OCRA

The major differences between conditions are increased use and the changes in appropriate, acceptable uses in the area since the passage of the Oregon Wilderness Act. Use has increased over the years and most significantly along the trail accessing the summit of Mt. Thielsen. Unacceptable use, such as mushroom picking and mountain bike use, is increasing.

Other Sites

Limited information is available about the Reference Condition. It is obvious that recreation use increased in the entire watershed. This increased use has impacts on the small developed and dispersed sites, trail systems, and even in the number of vehicles traveling the road systems. Increased seasonal use by hunters and mushroom pickers is also effecting small campsites and dispersed sites. Problems with trash are increasing as people leave trash at their sites rather than removing it when they leave. Another difference is the development of the communications site on Cinnamon Butte.

Processes of Causal Mechanisms Responsible

Diamond Lake Recreation Area

The stocking of fish, increasing populations, improved transportation systems, and user expectations have been the primary influences on the recreation area. These factors have influenced the decisions to build campgrounds, trails, cabins, and other developments. Besides development, use and user pressures have also influenced decisions to enhance and protect the resource. An example of these types of decisions can be seen in the reconstruction of the campgrounds that occurred in the mid 1980s. Improvements were made to both enhance facilities and improve resource conditions primarily along the lake shore. Some examples are:

- Making many campsites and restrooms accessible to persons with disabilities
- Paving of roads, trails and campsite spurs
- Paving of boat ramps and construction of docks
- Reducing the number of campsites in Diamond Lake Campground including some highly impacted shoreline units.
- Hardening of campsites
- Construction of an amphitheater and day use pavilion
- Installation of barriers, and rock walls and steps in high use areas to manage traffic and reduce erosion.

The result was that many areas, both within the campgrounds and in the South Shore Picnic area, that either wouldn’t grow grasses or became bare soil areas by mid-August, now have bushes and grasses growing throughout the summer and stay green well into the fall. Because of this, along with the hardening of sites and paving, soil erosion during periods of heavy rain has also been significantly reduced.

One of the more dramatic changes in use in the last few years has been the decline in the fisheries at Diamond Lake. Use in the area was at its highest level in the late 1970s, then decreased in the 1980s, in part due to increased fuel prices and the state of the economy in general. Use increased in 1992 to a level similar to 1978 (highest use year). Then, in 1992, the tui chub was found to be in Diamond Lake again. As the chub increased in population, the trout decreased and thus fishing success also decreased. Angler trips started to severely decline from 82,400 angler visits in 1989 to 35,000 angler visits in 1996, and fewer in 1997. Campground occupancy has also declined in recent years (40 percent decline from 1992 to 1997) (Table 48).

Table 48. Campground Occupancy 1989 - 1997 for Major Campground Facilities

	ANNUAL OCCUPANCY IN THOUSANDS								
Campground	1989	1990	1991	1992	1993	1994	1995	1996	1997
Diamond Lake	64.6	65.8	70.1	70.6	62.4	65.4	62.8	57.9	49.5
Broken Arrow	10.8	12.7	13.8	16.8	15.8	15.1	15.9	11.4	9.0
Thielsen View	16.1	18.7	22.5	24.2	23.4	17.4	14.7	9.3	9.0
Total	91.5	97.2	106.4	111.6	101.6	97.9	93.4	78.6	67.5

Another indication of the influence fishing has had on use is that campground use has declined during the shoulder seasons when fishing was traditionally the best. Summer use, though, has remained steady even with the declining fishery. An analysis done of the seasonal use change in Diamond Lake Campground shows noticeable drops in April, May, and October use (Table 48).

In 1996, Diamond Lake Resort did a sales analysis for the period from April through October for the years 1990 through 1996. The analysis showed that even with price increases, gross sales were down during the shoulder seasons approximately 30 percent and sales of fishing related services such as boat rentals and fishing tackle sales were down over 50 percent. Similar to the USFS campgrounds, Resort summer use remained fairly static. The RV Park has also experienced about a 50 percent drop in occupancy during the shoulder seasons.

Another dramatic change effecting the area was the Resort going to a year-round operation in 1968. With that, came the ability for people to conveniently visit and recreate in the area during the winter for more than a day at a time. Diamond Lake Resort and the Diamond Lake Area became a staging area for winter recreation and thus came the development of snowmobile and ski trails, day use play areas, and snow parks to accommodate the demand.

User demographics in the Recreation Area have remained constant over time. User surveys conducted in 1978, 1984, and 1996 show that Oregonians account for approximately 50 percent of the users, with families being the predominant recreationists. Over 70 percent have visited Diamond Lake before, and camping and fishing remain the primary reasons for coming to the area. One may assume that user demographics have remained fairly constant because of the high percentage of repeat recreationists to the area.

Statements like…

> "*I came here as a child with my parents and I wanted to bring my children here…*"

are often heard. Another reason user demographics have not significantly changed may also be that even though improvements and services have changed, the basic recreation experience and scenic qualities have not dramatically changed over the years.

Lemolo Lake Recreation Area

An obvious cause responsible for the change in conditions from the historic in the area was the creation of Lemolo Lake (a reservoir) by PacifiCorp. With this came the increased recreation demand associated with water such as camping, fishing, water skiing, and boating. Similar to Diamond Lake, increased populations, improved transportation systems, and the desire for people to recreate have also contributed to the increased use in the area.

Wilderness/OCRA

The creation of the Mt. Thielsen Wilderness and the OCRA has helped dictate management decision and uses in the area. The removal of recreation structures within the wilderness and guidelines and restrictions or use types and density help shape and manage recreation use. At the same time, increasing populations and the numbers of people recreating have increased use. Because of its proximity to Mt. Thielsen, the high visitor use at Diamond Lake significantly contributes to the use on the Mt. Thielsen trail. The development of trailhead facilities along Oregon State Highway 138 has also attracted visitors, thus increasing use.

Other Sites

As many developed campgrounds became fee sites, some users have gone to non-fee or dispersed sites increasing use. Use at smaller developed and dispersed sites has also been influenced by the rising number of elk hunters and mushroom pickers using the watershed.

Future Trends

Results from the survey, Outdoor Recreation In The United States; USDA 1997, shows that 94.5 percent of Americans 16 years of age or older, participate in some form of outdoor recreation. Oregon's population increased by 36 percent between 1970 and 1996 and is continuing to grow. Along with this, the elderly (defined as persons 65 years of age and over) will make up a greater percentage of the population. The USFS forecasts an increase in recreation demand well into the next century. Even though recreation demand and use may fluctuate from year to year, often due to weather or economic changes, all indications are that use and demand for recreation opportunities in the watershed will increase in the future. According to the Oregon Statewide Comprehensive Outdoor Recreation Plan (SCORP), Region 9 data (OSPRD 1988 and 1994), the annual increase in the top dozen recreation activities in SCORP Region 9 (which includes this watershed) has been from five to twelve percent annually and expected to continue. Activities expected to increase in the future include:

- Day and overnight hiking
- Camping (RV and tent)
- Bicycling
- Boat fishing
- Swimming
- Sightseeing
- Non-motorized boating
- Nature study/observation
- Visitor Information Centers

Diamond Lake Recreation Area

As mentioned previously, recreation use and demand is expected to increase in the future and Diamond Lake should be no exception. The proximity to Crater Lake, travel access, the scenic beauty, and developed facilities will continue to draw people to the area. Assuming ODF&W restores the Diamond Lake fishery and their management goal of an average 100,000 angler trips per year is met, the area could experience an increase of 50,000 to 60,000 extra anglers and an estimated 150,000 extra visitors per year. The majority of this increase should be seen in the spring and fall months and in day use on weekends. With this scenario, increased populations, and no significant economic downturns, Diamond Lake could experience use near or exceeding 1978 levels.

According to the Oregon Parks and Recreation Department (1991 Diamond Lake Resort Winter Recreation Analysis, August 1991), winter sports activities are expected to increase in southwestern Oregon by two to five percent annually. The greatest growth rate is expected in sightseeing activities and cross-country skiing. Another factor that may increase winter use would be the development of downhill skiing on Mt. Bailey. Mt. Bailey is identified in the LMRP as Special Management Area 3 (MA-3) to

> *"...provide appropriate area for future developments of a winter sports site..."*

Though the identified development area is not in this watershed (western slopes of Mt. Bailey), the base area for lodging and housing would likely be the Diamond Lake Resort. This increased use at the Resort could possibly exceed their existing capacity on weekends and holidays since the Resort currently experiences near full lodging capacity on these days when snow conditions are good.

Lemolo Lake Recreation Area

The Lemolo Lake Recreation Area will experience increased use and demand for recreation for many of the same reasons that will influence recreation throughout the region. In their 1995 Draft Recreation Resource Management Plan, PacifiCorp states that the demand for developed recreation in the Lemolo Lake Recreation Area may double by the year 2030. Another factor that may directly influence recreation in the area would be due to Diamond Lake reaching visitor capacity more frequently in the future. Recreation activity demand for this area should be similar to those identified for the southwestern region (SCORP Region 9).

Since the ODF&W manages Lemolo Lake as a trophy brown trout area versus the high catch plan for Diamond Lake, demand for fishing should be steady and increases not as dramatic as may occur at Diamond Lake. Winter use and demand will also increase in the future with cross-country skiing possessing the greatest growth potential for the area.

The proposed FERC re-licensing of the North Umpqua Hydroelectric Project will also affect future growth and development in the area. Proposed recreation agreements between PacifiCorp and the UNF will help define the management, use, funding, and development of recreation facilities in the area.

Wilderness/OCRA

As recreation demand and use increases, use in the Wilderness and OCRA may increase more dramatically as the desire for solitude increases and available opportunities decrease. Additionally, as more people seek business opportunities in the field of recreation, pressure to issue permits for commercial activities within the wilderness will increase.

Other Sites

Use of dispersed sites will increase as developed sites reach capacity or by those wanting to camp at non-fee sites. Dispersed site usage could also increase as a result of people wanting a more isolated recreation experience. The current popularity of mountain bikes may also create an increase in demand for suitable trails and routes to accommodate this activity.

Human Occupation

Analysis Procedures, Assumptions, and Data Gaps

Twenty-one percent of the watershed received surface reconnaissance for cultural resources prior to compilation of results for this document. Archaeological testing performed on sites within the watershed is minimal. Information on prehistoric and historic occupation within the watershed was compiled by Angie Snyder (Heritage Director for the Diamond Lake Ranger District) through literature searches and cultural resource surveys conducted on the Umpqua National Forest. A more detailed account of this subject may be found in "Heritage Resource Overview of the Lemolo Lake and Diamond Lake Watershed Analysis Area" report (Heritage Appendix C).

Prehistoric Overview

Increasing archaeological evidence suggests the existence of an "indigenous mountain people" occupying the Cascades over a considerably longer period than previously hypothesized. Aboriginal use within the Diamond Lake Ranger District was occurring prior to the major eruption of Mount Mazama in the Early Archaic Period, approximately 7,000 years ago. Use was occurring in the Middle and Late Archaic Periods covering a time period 6,000 years before present to the time of contact with European-American cultures. Prehistoric sites within the study area appear to be short-term task specific sites, or seasonal base camps from which foragers exploited the resources of the rivers, springs and marshes, and uplands. Collectively, they indicate a foraging existence, in which people followed a well-defined annual pattern, probably within recognized cultural territories.

Fifty-eight percent of the prehistoric sites identified within the study area are lithic scatter sites and 8.33 percent are lithic scatter sites with ground stone tools. These scatters indicate a dominance of hunting, hide processing, tool manufacturing, and to a lesser amount plant food processing. Obsidian is present in all sites containing lithics, indicating long-distance trade and/or travel to the east side of the Cascades was occurring throughout the prehistoric periods. Seventeen percent of the sites identified are cairn sites. Cairn sites are usually a stack or mound of piled rocks. Some cairns were constructed as part of vision quest rituals, others may be trail markers, prayer monuments, or memorials. These sites are usually associated with a ridge line or crest, with a vista of a place of power. Of the remaining prehistoric sites identified within the study area, 8.33 percent are peeled tree sites, and 8.33 percent are lithic scatter sites with peeled trees. At peeled tree sites, ponderosa pine trees show rectangular scars where the bark was "peeled" from the tree to allow access to the cambium layer. The pitch and cambium layer from these trees were used by the Indians as medicine to cure a sore throat, to treat bronchial and intestinal ailments, and to eat as a starvation food. Pine pitch was also used as glue, and to waterproof baskets.

The presence of multiple task sites, seasonal camps, and/or peeled tree sites may be indicators of maintenance burning by Indian groups. Multiple task sites require a variety of plant and animal resources to sustain that site type. These “edge effect” locations are often the result of fire. In *How High the Bounty*, Jesse Wright a local homesteader, tells us that the Indians burned Oak Flats and Big Camas for deer forage. The beautiful meadows and succulent grasses described by John Waldo along the North Umpqua River (the region now inclusive of Lemolo Lake and Kelsay Valley), and the meadows of Diamond Lake, both of which are located within the watershed, could have also been burned by the Indians.

Ethnographic Overview

The watershed is located within the ethnographic territory ascribed to the Southern Molala. The language, culture, and history of the Southern Molala are poorly documented. The limited ethnographic information available on the Southern Molala and neighboring tribes who lived in similar surroundings, provide a limited picture of Southern Molala life ways. The Molala traversed the western slopes of the Cascades from the Mount Hood area to Crater Lake. Three band divisions have been suggested for the Molala: the Southern Molala ranging the uplands of the Rogue and Umpqua river drainages in the Cascades; the Upper Santiam or Santiam band occupying an intermediate position in Linn and Lane counties; and the Northern Molala centering near Mount Hood.

A mountain people with a toehold in the valleys, the Southern Molala life way seems to have revolved around the snows of their upland territory. In the winter they apparently lived in settlements located along streams at mid-valley elevations. They probably occupied semi-subterranean houses near the snow line because deer were easier to take when they floundered in the snow. In spring families moved to higher elevations, ranging long distances to forage for foodstuffs. In the summer they shared the uplands with other tribes, meeting at favored huckleberry gathering places like those southwest of Crater Lake. Hunting was the mainstay of the Southern Molala subsistence.

Not known as a very populous group, the Molala were adversely affected by European-American settlement of the Oregon Territory. Before the arrival of settlers to the Umpqua basin, epidemics of small pox, measles, flu, and dysentery were introduced by Europeans, then spread through Indian populations via the Indian trade network. Lowland inhabitants retreated to the safety of the mountains as prime valley lands were converted to farms. The treaty of 1855 designated the Siletz and Grand Ronde reservations for Indians remaining in the Umpqua basin. Southern Molala were among Indians sent there. The total population of the entire Molala was less than forty by 1891.

Historic Overview

This historical overview summarizes the sequence of European-American inroads and developments in the watershed.

Pioneers and Settlers

The earliest maps of the area indicate that the Umpqua basin was generally avoided by early travelers and settlers due to rough terrain, lack of trails, and lack of suitable land for homesteading. Perhaps the earliest documented entry into the upper North Umpqua River came in 1813. A Pacific Fur Company expedition, led by John Reed and Alfred Seton, wintered in the Willamette Valley and crossed over the divide into the upper reaches of the Umpqua basin during this trip. As early as 1856, the John Day Road, a 250 mile supply route from Jacksonville to the gold fields in John Day crossed the Cascades south of Diamond Lake. In 1863, Lorin L. Williams documented the first known reconnaissance of the headwaters of the North Umpqua River. His band of explorers probably used the Calapooya Divide Trail established by aboriginal peoples. Remnants of this trail can be found east and west of Bird's Point and east of Warm Spring's Butte. The trail continued east to Cowhorn Mountain along the northern boundary of the watershed.

As early as 1875, Bill Bradley made his way to the Illahee country on the North Umpqua River. Bradley was a pioneer trapper and mountain stockman. He traded venison and hides with the Indians for horses. His trade opened up a travel route through the forest, often following old Indian paths. The Bradley Trail went from his cabin near Dry Creek, east past Pine Bench, the Medicine Creek Indian Cave, Mountain Meadows, Thorn Prairie, Poole Creek, and Kelsay Valley; and then along Bradley Creek and over Windigo Pass to Eastern Oregon. Sixteen miles of Bradley's trail crossed the watershed. Bradley made at least two late-season crossings of the Cascades, in 1903 and his last trip in 1909, by way of Diamond Lake, Dog Prairie, and Big Camas, to Illahee. He is said to have had a cabin at Diamond Lake.

John Breckenridge Waldo traveled in the Cascade Mountains ranging from Mt. Hood to Mt. Shasta for some thirty years from 1877-1907. A manuscript containing letters and diary entries written during his 1880-1907 journeys contain descriptive accounts of the landscapes and wildlife encountered during his travels. Specific accounts include vivid descriptions of his visits to Kelsay Valley, Lemolo Falls, Diamond Lake, and Crater Lake. Waldo was instrumental in the creation of the Cascade Range Forest Reserve in 1893, and together with William G. Steel, assisted in the creation of Crater Lake National Park in 1902.

Surveys were conducted of exterior and subdivisional lines in the Cascade mountains by the General Land Office between 1883 and 1931. The earliest survey was of the Sixth Standard Parallel and was conducted by U.S. Deputy Surveyor, Samuel C. Flint in 1883. The Sixth Standard Parallel crosses through the north end of Diamond Lake.

A person called "Uncle Ben Taylor" and his family were living in a house at the southeast corner of Diamond Lake and keeping cattle in 1889. The location has not been verified.

In 1903 the Southern Pacific Railroad conducted a reconnaissance for a standard gage railroad route from Roseburg east to the Williamson River. The proposed route entered the watershed northwest of Diamond Lake going south, followed the east side of the lake and went east over the pass between Mt. Thielsen and Crater Lake.

Grazing

The practice of sheep ranchers grazing their flocks on the unassigned lands of the Cascades was quite common. So common in fact, sheep interests lobbied heavily against the creation of the Cascade Range Forest Reserve and the formation of Crater Lake National Park. The earliest documented observation of use of the watershed for sheep grazing was at Diamond Lake in 1896, according to John Waldo's writings. In 1889, Waldo described the vicinity of the Kelsay Valley as being on fire for miles, likely caused by cattlemen or sheepmen who wished to bring stock to forage the next year. “Free grazing” likely continued after the creation of the Umpqua National Forest in 1908. Sometime after that, grazing under permit began. Use of the high country for sheep grazing continued into the World War II years, when it went into decline. Some sheep ranges were converted to cattle ranges after World War II and were active into the 1990s.

Forest records indicate parts of three different sheep grazing allotments existed within the watershed. The McGowan Allotment stretched from the headwaters of Deer Creek to Cowhorn Mountain. The Kelsay Valley Allotment stretched from the Lemolo Falls area to Windigo Pass and southward to within a mile of the Lake Creek outlet of Diamond Lake. At one time, the Dog Prairie Allotment included Dog Prairie, Clear Creek to Trap Mountain, the slopes of Mt. Bailey and Rodley Butte, the meadows within a mile of the south end of Diamond Lake, and it stretched all the way to Summit Rock. The size of these ranges lessened through the years. Records indicate from 1200 to 2250 sheep grazed in each allotment each summer.

Forest Service

On September 23, 1893, a twelve-mile wide strip of public domain land along the crest of the Cascade Range of Oregon was withdrawn from homesteading and designated as the Cascade Range Forest Reserve. In 1908, a portion of the South Cascade National Forest and the one-year old Umpqua National forest (now the Siuslaw N.F.) became the new Umpqua National Forest. The first ranger districts were established soon after the organization of the North Pacific District (now the Pacific Northwest Region) in Portland in 1908. Letters indicate that these early ranger districts were closely connected with forest grazing districts. There were as many as seven ranger districts on the Umpqua National Forest in 1913.

The old Silent Creek Ranger Station was built in 1905. An administrative land withdrawal of 80 acres, 60 in pasture and the rest in timber with an existing cabin was made in 1908. This administrative site straddled Silent Creek at the southwest corner of Diamond Lake. A newer structure was built in 1909-1910. The Cowhorn Ranger Station had an administrative land survey and withdrawal request of 235 acres along the eastside of Diamond Lake, from Short Creek to Porcupine Creek, made in 1909. The Cowhorn Ranger Station name changed through the years to the Mt. Thielsen Ranger Station and the Diamond Lake Ranger Station. This station eventually replaced the Silent Creek Ranger Station. It appears on maps mid-way on the eastside of Diamond Lake in 1924. Records indicate a new structure was built sometime after 1932, moved, and later replaced by the Civilian Conservation Corps constructed ranger station (Diamond Lake Visitor Center) in 1938.

The Kelsay Valley Ranger Station location was surveyed and an administrative land withdrawal request for 140 acres was made in 1909. The location was described as being 80 acres of pasture and the remainder in timber. While the request was not approved, photographs indicate a cabin, pasture fence, and telephone connection existed there.

A listing of the present Forest Service facilities can be found in Chapter Two under the Human Uses Core Topic. Information on Forest Service lookouts and shelters, permitees, camps, trails and early roads within the watershed can be found in Appendix C. This information is contained within the “Heritage Resource Overview of the Lemolo Lake and

Diamond Lake Watershed Analysis Area" report compiled by Angie Snyder.

North Umpqua Hydroelectric Project

The North Umpqua Hydroelectric Project began with some reconnaissance work done by the California Oregon Power Company (COPCO), who filed an application for a preliminary permit for engineering studies in 1922. A series of debates, surveys, and licensing requirements followed, which were interrupted by World War II. In February of 1947, the Federal Power Commission issued COPCO a license. Road clearing and camp construction began that year.

In the watershed, work began on the Lemolo I Project in 1952. The Slide Creek Camp was moved to the work site in 1953 and a school was opened for use during the construction of this project. The plant was put in operation in June of 1955. The project included the Lemolo dam on the North Umpqua River, 16,705 feet of waterways, 454 acre Lemolo Lake, 7,328 feet of penstock, a power plant, and a sub-station. Part of the construction camp would later become the location of the Lemolo Lake Lodge. Present day facilities within the watershed are described in Chapter Two.

Forest Products

Timber

Analysis procedures, Assumptions, and Data Gaps

The Umpqua Project Activities Database, GIS, and Forest Vegetation Simulator were used to collect and analyze data. Information from timber stand exams and bare ground projections were used to populate the FVS model.

Reference and Current Condition

Regeneration harvest began in the early 1950s, accessing the higher volume stands . Prior to the 1950s, there was incidental harvest to support the human activities in the area, but there was no formal harvest or sales of timber. The mountain hemlock ecoclass has endemic levels of root diseases, and would have had these levels in the past. Harvest by decade is shown in Table 49, while Figure 26 shows the spatial distribution of regeneration harvest by decade.

The commercial forest land base within the watershed has declined from the 1950s to the present due to changes in land allocation, including the Thielsen Wilderness, the Oregon Cascades Recreation Area, and the areas around Diamond and Lemolo Lakes dedicated to recreational activities. About one third of the area is matrix as defined in the NWFP, and about twenty percent of the area is available for timber harvest. There are approximately 21,000 acres of land available, including approximately 4,500 acres of Lodgepole plant series. Table 1 displays the land allocation within the watershed.

Figure 26. Timber Harvest by Decade

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Table 49. Distribution of Regeneration Harvest by Sub-Watershed

Sub Watershed	*Total Acres*	*1950s Harvest Acres*	*1960s Harvest Acres*	*1970s Harvest Acres*	*1980s Harvest Acres*	*1990s Harvest Acres*	*Total Harvested Acres*	*Percentage of Total Acres*
Whisper	14,100						0	0
Bailey	5100		17				17	0.3
Diamond Lake Composite	6800			157			157	2.3
Lake Creek	5100			30		81	111	2.2
Sheep Creek	16,300	125	77	100	86	146	534	3.4
Thirsty Creek	31,500		170	245	135		550	1.8
Grits	16,100	3	357	28	347	229	964	6.0
Natural	4500	12	43	367	271		693	15.4
Lakeview	3500	4	214	208	161	65	652	18.6
Total	103,000	144	878	1135	1000	521	3678	3.6%

Table 50. Available Plant Series by Sub-Watershed, Adjusted for unmapped Riparian Reserve and Green Tree Retention

Sub-Watershed	*CD, CH, CR, CW*	*CM*	*CL*	*Total*
Whisper	398	2222	1513	4133
Bailey				0
Diamond Lake Composite				0
Lake Creek	877	241	72	1190
Sheep Creek	946	314	213	1473
Thirsty	821	12	752	1585
Grits	1691	1640	83	3414
Natural	455		1663	2118
Lakeview	1040	98	172	1310
Total	6228	4527	4468	15223

The current available commercial forest land base is capable of producing 5.4 mmbf per year with rotations based on culmination of mean annual increment and includes both regeneration and thinning harvest. The lodgepole plant series accounts for about 0.8 mmbf of this, and the other plant series account for the remaining 4.6 mmbf.

Processes or Causal Mechanisms Responsible

There are many biological, economic, and political reasons responsible for the timber harvest trends from 1950 to the present. In general, the increase from the 1950s to the 1980s was based on economic supply and demand. The decrease since then was based on political and biological reasons that dealt with old growth forests, the northern spotted owl, and the decline of anadromous fisheries in the Pacific Northwest.

Future Trends

These watersheds will continue to provide timber to the local mills over the next decade from the matrix land allocation. Harvest will continue to be primarily regeneration harvest using both uneven aged and even aged systems. There is little opportunity for commercial thinning within the matrix allocation.

Influences and Relationships to Other Ecosystem Processes

Relationships to other processes are discussed throughout this document under other core topics. In most cases, past timber harvest has been one of the major causal agents affecting other ecosystem processes.

Special Forest Products

Analysis Procedures, Assumptions, and Data Gaps

Collection of special forest products is by permit, either personal free use or by sale. The quantities from this area were estimated from the total number of permits on the district, and knowledge of the activities to know where the products were located. No reference condition has been established. Demand for these products has been low, with the exception of matsutake mushrooms and live plants.

Current Condition

Table 51 shows the quantities of products harvested on an annual basis.

Table 51. Estimated Quantities of Special Forest Products Harvest Annually

Product	Amount
Firewood	550 cords
Transplants	4000 plants
Posts and Poles	50 mbf
House Logs	20 mbf
Christmas Trees	300 trees
Boughs	20 tons
Other Greenery	15 tons
Conifer Cones	500 bushels
Pumice and Flagstone	minor amounts
Mushrooms	several tons
Berries	minor amounts

Future Trends

The market for posts, poles, and firewood is expected to increase moderately due to increasing population pressure and to the reduction in land available for those products. The demand for mushrooms is expected to increase, with most of the demand placed on matsutake.

Influences and Relationships to Other Ecosystem Processes

The impact of harvesting mycorrhizal mushrooms, such as matsutake, on the long term productivity of the mushrooms and on the productivity of the vegetation dependent upon the mycorrhizae is unknown. The Diamond Lake Ranger District is involved in investigating matsutake and mycorrhizal management in the National Long Term Site Productivity Study and the Matsutake Harvest Study. These efforts will provide more information on the relationships between mushrooms and vegetation.

Transportation System

Analysis Procedures, Assumptions, Data Gaps

GIS maps were generated showing roads, trails, streams, 6th field watershed boundaries, and FPLAN Management Areas. Stream crossing by roads and trails, and road or trail encroachment into Riparian Reserve Areas were noted. Roads and trails were selected for field investigation and data was recorded on Reconnaissance-Level Stream Crossing/Culvert Condition/Road Stability Form for the Diamond Lake/Lemolo Watershed. Trails were examined less intensely by noting areas of active erosion, rerouting of hydrologic flow paths and presence of a vegetation buffer between trail and aquatic areas. Intensive examination was done on FSRs 4795 and 6592. Deficiencies were noted where culverts were clogged with sediment, there was inlet damage, diversion potential, inadequate capacity, and ditchline erosion. The rustline method was used to determine culvert capacity.

Reference Conditions

Pre-history and early use to 1900

Early use of the trails of the area was to access the John Day Wagon Road, which crossed the Cascade Crest just south of Diamond Lake. Modern day Highway 230 is the approximate location. As early as the turn of the century there was demand for recreational access to Diamond Lake. In 1907 the Forest Service began to locate roads and trails in the area. The formation of the High Cascade Forest Preserve brought more roads. The Crater Park/Crescent Lake road was in construction in 1925 and parts of this route became the Cascades Lake Truck Trail. Photos from circa 1928 show roads in the Diamond Lake area being gravel surfaced, an early attempt to create a more stable road and coincidentally less impact on adjacent resources.

Way trail period 1900 to 1940s

The Way Trail period came about by the need for access to a system of fire lookouts and fire suppression activities. These trails tended to take a direct route with little concern for steep pitches or avoiding environmentally sensitive areas. Drainage was a concern when trail damage became evident. Since access for grazing was still needed, the road network continued to expand.

Early Timber sale period 1940 to 1960

The first timber sale in the Mowich area was in 1947. The purchaser constructed the road system to the Cascade Summit Pass. Logs were hauled to Yamsey Siding for shipment to Klamath Falls. The roads were constructed so that non-standard vehicles could be used for log haul. Little is known about standards for water and sediment control, if any. A 1934 map shows 66.25 miles of road. By 1956, roads totaled 90.5 miles. The Windigo Timber Sale began during this period. The Windigo Sale offered 100 mm board feet of timber in scattered areas, in order to "road the area". Timber was transported to mills in the present day Lemolo Junction area. Standards for soil and water protection, although becoming more stringent, were inadequate by today's standards.

Table 52. Miles of Road Constructed by Decade

Sub-watershed	1950s	1960s	1970s	1980s	1990s
01 Whisper	8.42	4.93	0.5		
02 Bailey	1.25	0.93	2.33		
03 Diamond Lake	12.26	16.6	3.72	0.26	
01 Lake Creek	2.81	1.2	2.19	2.64	
02 Sheep	5.79	6.61	9.16	5.93	
03 Thirsty		8.49	3.55	2.24	
04 Thirsty					
05 Grits		26.17	10.52	9.38	
06 Natural	1.7	10.38	0.64	4.2	
07 Lake View	2.79	6.62	8.67	4.57	
Totals	**35.02**	**81.93**	**41.28**	**29.22**	**0.00**

1960 to present

This period saw about the greatest amount of road building and also the beginnings of serious resource protection awareness. About 82 miles of road were built during the decade of the 1960s. Construction standards included burying slash in the roadway and other activities later to be found undesirable. Beginning in the 1980s, Regional and Forest Plans began to address road and resource issues and put forward objectives and standards and guidelines for their construction and maintenance. The Best Management Practices concept began to be applied to Northwest forests in the 1970s and 1980s, mainly to address water quality and cumulative effects issues. In addition to these, FEMAT evolved into NWFP, with the Aquatic Conservation Strategy (ACS), and with objectives and land allocations. Forest Service Manual and Handbook direction became more specific during this period.

CURRENT CONDITIONS

Today there are over 183 miles of road in the watershed generally in stable condition, but with sites diverting or concentrating water and causing sedimentation above natural levels. Potential situations exist that threaten to create more sediment in the future. Conditions have been identified such as undersize culverts, culverts with diversion potential, culverts partially plugged, stream network extension from lack of ditch relief culverts, and roads inside Riparian Reserve areas that parallel streams. The period of major road construction is past, relegating concerns about new road location and large numbers of stream crossings to a secondary level. Reconstruction, maintenance and rehabilitation/restoration are topics of concern, at least for the remainder of the decade.

Table 53. Miles of Road by Surface Type

6th Field Sub-watershed	ASPHALT	AGGREGATE	NATIVE	TOTAL
01 Whisper	7.34	2.71	3.80	13.85
02 Bailey	0.00	0.93	3.58	4.51
03 Diamond Lake	25.31	4.58	2.95	32.84
01 Lake Creek	3.79	1.24	3.81	8.84
02 Sheep	6.43	11.47	9.59	27.49
03 Thirsty	0.51	3.91	8.69	13.11
04 Thirsty	0.00	0.00	0.00	0
05 Grits	4.15	21.47	20.45	46.07
06 Natural	3.44	4.26	9.22	16.92
07 Lake View	5.16	5.80	11.69	22.65
Totals	56.13	56.37	73.78	186.28

The area occupied by 183 miles of road equate to 1194 acres or 0.01 percent of the watershed area. Roads will be a part of the landscape far into the future. Roads may increase connectivity for some plants and animals (noxious weeds) or may serve as barriers for others (mollusks and amphibians). Most of the Diamond Lake/Lemolo roads have been in existence for 10 or more years. Extreme geologic, water and soils conditions are not as widespread in this watershed as in others nearby. Most slopes and ditches have been revegetated. Surface erosion is the principle source of sediment. The amount of sediment entering streams may exceed the processing and storage capability of a stream system when erosion processes are affected by roads. Common causes of mass movements related to roads are improper placement and construction of road fills, inadequate road maintenance, insufficient culvert sixes, very steep sideslopes, unstable placement of sidecast of excess material, poor road location, removal of slope support by undercutting, and alteration of drainage by interception and concentrating of surface and subsurface water (Wolf 1982).

Surface erosion may contribute excess sediment from roadbed surfaces, drainage ditches, and cut/fill slope surfaces. Cederholm et. al. (1981) found that fine sediment in spawning gravel increased when more than 2.5 percent of watershed area was roaded. The amount of surface erosion is related to erodibility of the soil, slope steepness, surface runoff, and ground cover. Surface erosion is reduced as time passes by the growth of natural vegetation. The source of sediment changes with the age of the road. Roads that have been in existence for more than 5 years contribute less sediment due to stabilization by vegetation and natural armoring of surfaces. Mulching, reseeding and mechanical slope protection reduce surface erosion hasten roads into this state. Heavy traffic increases erosion from the road surface. Increased maintenance and surfacing with quality aggregate reduces sediment from road surfaces. Other sources of sediment can come from inadequate compaction or woody material incorporated into fill areas, flow restrictions at stream crossings, and failures at stream crossings by breaching, diversion or placement of unstabilized material in the floodplain.

Table 54. Miles of Road by Maintenance Level

6th Field Sub-watershed	**ML 1**	**ML 2**	**ML 3**	**ML 4**	**ML 5**
01 Whisper	0.00	3.80	2.71	7.34	0.00
02 Bailey	0.00	3.58	0.93	0.00	0.00
03 Diamond Lake	2.42	2.48	2.73	10.16	15.05
01 Lake Creek	3.91	1.07	0.07	1.02	2.77
02 Sheep	7.54	10.52	3.26	0.38	5.79
03 Thirsty	3.77	7.50	2.50	0.00	0.51
04 Thirsty	0.00	0.00	0.00	0.00	0.00
05 Grits	20.54	7.66	13.72	0.00	4.15
06 Natural	6.08	4.95	2.45	0.00	3.44
07 Lake View	10.16	5.16	1.66	0.10	5.57
Totals	**54.42**	**46.72**	**30.03**	**19.00**	**37.28**
percent of total	**29.03**	**24.92**	**16.02**	**10.14**	**19.89**

Table 55. Miles of Summer Trail by Maintenance Level

6th Field Sub-watershed	**ML 1**	**ML 2**	**ML 3**
01 Whisper	0.00	0.00	18.00
02 Bailey	0.00	0.00	3.26
03 Diamond Lake	0.00	0.00	10.83
01 Lake Creek	0.00	1.78	6.75
02 Sheep	0.00	8.61	15.00
03 Thirsty	0.00	3.79	3.79
04 Thirsty	0.00	18.50	28.74
05 Grits	0.00	4.14	11.96
06 Natural	0.00	0.30	0..30
07 Lake View	0.00	0.00	0.30
Totals	**0.00**	**37.12**	**61.54**

Table 56. Miles of Winter Trail

6th Field Sub-watershed	road	trail	total
01 Whisper	13.03	22.65	35.68
02 Bailey	0	1.66	1.66
03 Diamond Lake	24.56	21.94	46.5
01 Lake Creek	1.25	3.45	4.70
02 Sheep	9.95	10.5	20.45
03 Thirsty	5.5	0	5.5
04 Thirsty	0	0	0
05 Grits	16.25	0	16.25
06 Natural	6.4	0	6.4
07 Lake View	5.5	5.3	10.8
Totals	82.44	65.5	147.94

CHAPTER FIVE

RECOMMENDATIONS AND ANSWERS TO THE KEY QUESTIONS

INTRODUCTION

The purpose of this chapter is to:

☐ Answer the key questions based on what was learned through this watershed analysis.

☐ Outline a desired range of conditions based on an understanding of the physical, biological, and human processes and features and their interactions within the watershed.

☐ Make management recommendations that are responsive to ecosystem processes identified in the analysis.

☐ Identify monitoring and research activities that are responsive to the issues and key questions.

Timber Harvest/Sustained Yield/Site Productivity

1. What is the available land base for timber production?

Chapter Four contains a more detailed discussion of this. The net land available for timber production is about 16,500 acres plus about 4,500 acres in the Lodgepole ecoclass.

2. What is the timber productivity of the available land base? What is the probable sale quantity based on the recommendations of this watershed analysis?

The land available for timber production is growing 4.6 mmbf per year with the lodgepole ecoclass adding an additional 0.8 mmbf per year, for a total of 5.4 mmbf per year. See Chapter Four for more information. If the recommendation to include the Lodgepole ecoclass in the timber base is accepted, the probable sale quantity from the watershed would be approximately 54.0 mmbf per decade.

Table 57. Tree Growth on Forest Land Available for harvest by Sub-Watershed and Plant Series

Sub-Watershed	*CD, CH, CR, CW*		*CM*		*CL*		*Total*	
	mcf/yr	mbf/yr	mcf/yr	mbf/yr	mcf/yr	mbf/yr	mcf/yr	mbf/yr
Whisper	46.9	244.2	100.0	400.0	68.1	273.3	215.0	916.5
Bailey							0	
Diamond Lake Composite							0	
Lake Creek	103.5	538.1	10.8	43/4	3.2	13	117.5	594.5
Sheep Creek	111.6	580.5	14.1	56.5	9.6	38.3	135.3	675.3
Thirsty	96.9	503.8	0.5	2.1	33.8	135.4	131.2	641.3
Grits	199.5	1037.6	73.8	295.2	3.7	14.9	277.0	1347.7
Natural	53.7	279.2			74.8	299.3	128.5	578.5
Lakeview	122.7	638.1	4.4	17.6	7.7	31.0	134.8	686.7
Total	734.8	3821.5	203.6	814.8	200.9	804.2	1139.3	5,440.5

3. How and where have past management practices affected timber productivity?

Timber productivity has been adversely affected by unrestricted use of ground based equipment and multiple entries, resulting in compaction exceeding the standard of 20 percent increase in bulk density and 20 percent of the area detrimentally affected. This has occured where ground based equipment was used to harvest the timber without restricting the equipment to designated skid roads. This has been further exacerbated by the piling of logging slash using ground based equipment, further compacting and displacing the soil. These practices were common into the 1970s, but have been discontinued.

4. How can timber harvest approximate natural disturbance processes at the stand and landscape scales?

The primary natural disturbance processes in the watershed are fire and insects. Both of these agents work together at times, and create both small scale and large scale disturbances. To approximate this pattern, regeneration harvest areas could have a variety of sizes, and include placing new units adjacent to relatively recent units that are regenerated to approximate larger scale disturbances.

5. What should the harvest priorities be? Where should they occur and why?

There are few elements which would drive the location of timber harvest priorities in this watershed. Lodgepole pine stands which are older than about 70 years and are overstocked should be targeted for harvest to reduce the potential for mountain pine beetle epidemics. There is an opportunity to commercially thin on the hillsides which face into Lemolo Lake so that timber can be harvested from this matrix land without adversely impacting the visual resource. When harvesting, there should be an emphasis on limiting increases in fragmentation so that we maintain interior forest habitat, as identified during interdisciplinary planning processes.

6. Should any harvest activities take place within the riparian reserves? If so, under what set of circumstances and to meet what objectives?

Harvest activities should only take place within riparian reserves if the need and treatment are consistent with the Aquatic Conservation Strategy (ACS) objectives, as outlined in the NWFP. The question of whether harvest activity is consistent with the ACS objectives can only be addressed by site specific analysis considered in a watershed context. Very significant water quality issues in the North Umpqua River system remain unresolved, and the habitat conditions and needs of riparian dependent species other than fish have not been assessed in the analysis area. The timber harvest management strategy in riparian areas should be to harvest only to improve riparian function or habitat conditions for a specific riparian dependent species or species guild. Therefore, before a decision is made to harvest in a riparian area, the consequences of harvest and habitat needs of both target and non-target species should be carefully and thoroughly considered.

7. Should the Lodgepole plant series in matrix be included in the timber base? How would this affect public and commercial fire wood?

The Lodgepole plant series is subject to severe infestations of mountain pine beetle epidemics when the stands age and are overstocked. To help alleviate this, the lodgepole plant series should be included in the timber base to allow management activities which would control stocking and harvest of deteriorating stands. Natural regeneration has been shown to be prolific and reliable in the lodgepole, so there would be minimal reforestation costs associated with any regeneration harvest. Timber sales would provide a positive economic benefit because of the low reforestation costs, and would reduce or eliminate large scale epidemics which would kill large numbers of trees.

Mountain pine beetle is a normal, endemic species in the lodgepole stands, and will continue to kill individual trees in managed stands. This normal mortality would result in no appreciable affect on the firewood supply in the area. Due to the concerns of both black-backed woodpecker habitat and the supply of firewood, there should not be any regular salvage of material within the Lodgepole ecoclass so that the dead material remains on site for other uses.

8. What miscellaneous forest products are harvested? What is the sustainability?

See Chapter Four for a discussion on harvest of forest products. We do not have enough data or knowledge of growth patterns and productivity to adequately assess the sustainability of the greenery or the mushroom harvest. Harvest of wood products and boughs appears to be sustainable at the present harvest rates, and boughs could be sustained at much higher harvest rates with active management of the program.

9. What should be done to reduce the incidence of insects and diseases?

Young lodgepole pine stands should be thinned to increase vigor in order to delay bark beetle-caused mortality. Young stands associated with recreation sites on Lemolo Lake and Diamond Lake should be given high priority for treatment.

Little can be done to reduce the current risk of bark beetle infestation in older lodgepole pine stands. Consideration should be given to future stand development. Treatments to remove large trees and regenerate lodgepole pine that are done in the near future will capture mortality, reduce fire risk, and create a mosaic of lodgepole pine stands of various ages that will respond differently to future mountain pine beetle outbreaks.

Vegetation management plans should be developed for all recreation sites within the Watershed that consider lodgepole pine mortality and site conversion to decay prone species.

If scattered, large, older ponderosa pines and western white pines are to be maintained, competing vegetation of all types should be removed to a distance of approximately ten to 20 feet past the drip line of individual trees. Where trees are scattered throughout stands, thinning should be conducted to reduce basal areas to below 140 square feet per acre (for western white pine) and below 120 square feet per acre (for ponderosa pine).

Efforts should be made to introduce white pine blister rust-resistant western white pine into stands to maintain and protect the species where feasible. This is critical for large laminated root rot pockets where western white pine provides the large tree component.

An assessment of the current status of whitebark pine should be completed. This should contain information on whitebark pine size and age class distribution, white pine blister rust infection levels and mortality, bark beetle-caused mortality, and the interaction of blister rust and bark beetles.

Transportation System/Road Management

1. What are the existing road densities and stream crossing by sub-watershed and erosional risk? Is there an upper limit to road density or stream crossings by sub-watershed and if so, why?

Road densities in the Diamond Lake/Lemolo watershed area are less than in neighboring watersheds. Densities are considerably less than the several maximum densities listed by Umpqua 1990. Concentrating on reconstruction, maintenance and restoration/rehabilitation is a better use of limited resources than adherence to a road density figure. Aquatic Conservation Strategy is met by minimizing road and landing location in Riparian Reserves. A watershed analysis must be completed before any construction of new roads or landings in Riparian Reserve areas.

Based on roads surveyed approximately 33 percent of the stream crossings have diversion potential and 33 percent are under capacity. Erosional risk for stream crossings increases with geomorphic land type, diversion potential, amount of fill material, type of drainage structure, capacity, and plugging potential. In the Diamond Lake/Lemolo Watershed the mountain slope landtype is more predominant, but with erodable coverings of pumice, ash, or glacial till. Maintenance of vegetative or mechanical soil protection and dispersion of water concentrated by roads is necessary.

Road and stream densities are shown in Table 58 and Table 59.

Specific guidelines on road density have not been determined.

Table 58. Road Density by 6th Field Sub-Watershed

6th Field Sub-Watershed	Sub-drainage Area	Road Miles	Road Density
01 Whisper	48.27	13.85	0.29
02 Bailey	8.00	4.51	0.56
03 Diamond Lake	10.67	32.64	3.06
01 Lake Creek	7.95	8.84	1.11
02 Sheep	25.49	27.49	1.08
03 Thirsty	23.46	14.28	0.61
04 Thirsty	25.72	0.00	0.00
05 Grits	25.09	46.07	1.84
06 Natural	7.08	16.92	2.39
07 Lake View	5.40	22.65	4.19
Totals	**187.13**	**187.25**	**1.06**

Table 59. Number of Stream Crossings by Sub-Watershed

6th Field Sub-watershed	Class 1	Class 2	Class 3
01 Whisper		2	1
02 Bailey			
03 Diamond Lake	3	4	2
01 Lake Creek			3
02 Sheep	2	5	1
03 Thirsty	1		1
04 Thirsty			
05 Grits	1		1
06 Natural	1		
07 Lake View	2		2
Totals	**10**	**11**	**11**

Recommendations from Standard and Guidelines in LRMP, BMP, NMFP, and Forest Service Manuals and Handbooks.

-Inventoried aquifer lands have an upper limit of 5 percent of land area or 5.3 miles of road per square mile.

-Combined total of unacceptable soil condition (detrimental compaction, displacement, puddling, or severely burned) within an activity area should not exceed 20 percent of the area.

-2.3 percent of basin area covered by roads will cause fine sediment to begin to appear in spawning gravels.

-Maintain or establish vegetation or mechanical soil stabilization buffer on areas where road encroaches on Riparian Reserve.

-Obliterate roads in Riparian Reserves where appropriate, considering short and long term transportation needs.

-Maintain or establish shade and large woody material at stream crossings and Riparian

Reserve areas.

-Use reconstruction fund, KV funds from timber sales, or rehabilitation funds to manage road density and reduce erosional risk.

2. Where will we avoid building new roads and why?

Use Standards and Guidelines from LRMP, BMP, NWFP, and Forest Service Manuals and Handbooks

-Long range planning by teams of specialists can identify environmental problems and constraints resulting in less road mileage.

-Appropriate standards and design will produce a road that is easier and more cost efficient and with less impact on streams.

-Ridgetop roads are preferable to midslope roads.

-Ridgetop roads should avoid headwalls of tributary drainages.

-Avoid inner valley gorge roads, earthflow terrain, and debris slide basins.

-Slopes with water or with wet site plant indicators should be avoided.

-Slopes where sidecast material can enter streams or where large cuts and fills are needed should be avoided.

-Avoid wetlands entirely.

3. What specific road systems pose the highest risk of mass-failure (landslides) or significantly influence chronic stream erosion as a result of fill failures, failed culverts at stream crossings, stream diversion, or stream network extension?

The Diamond Lake/Lemolo watershed is in better condition than surrounding watersheds. This is due in large measure to the fact that road density is less, and geologic and geomorphic land types are less severe. Several roads where noted that present some problems.

4795300	drainage affecting Silent Creek and Diamond Lake
4795300	drainage affecting Diamond Lake
4792000	drainage affecting Lake Creek
4792600	drainage affecting Riparian Reserve
4792700	stream crossing
6000000	Bradley Creek stream crossing
6000940	stream crossing affecting Crystal Spring and Crystal River

4. Where should we look for restoration/rehabilitation opportunities and to meet what objectives?

The following objectives and principles are useful in evaluating restoration projects and other road related activities.

Restoration is the process of encouraging a system to maintain its function and organization without continued human intervention (NRC 1992).

If a system has been shifted outside its range of performance under natural conditions, restoration attempts to move the system toward that range of performance in the future .

Fundamental Principles

-The goal is to reestablish the ability of the system to maintain its function and organization without human intervention.

-Restoration should not be a substitute for appropriate ecosystem management.

-Resource analysis must precede any effort. Consideration of basin, watershed and local characteristics to determine which factors to change direct the ecoprocesses of concern.

-Practices leading to the degradation must be changed to prevent or reduce environmental damage.

-Time frames and expected recovery should be described.

-Actions should be reversible.

-Stream and river restoration should protect and restore flood plain and channel function.

-Natural disturbances i.e. floods, fires, windthrow, and diseases are major agents of basin and forest landscapes……

-Success of restoration efforts are evaluated based on ecofunctions and responses with the dynamics of the system.

Standard and Guidelines from LRMP, BMP, NWFP, and Forest Service Manuals and Handbooks

<u>Recommendations</u>

-Minimize disruptions of hydrologic flow paths.

-Minimize sediment delivery to streams.

-New culverts, bridges and other stream crossings shall be constructed, and existing culverts, bridges and other stream crossings determined to pose a substantial risk to riparian conditions will be improved, to accommodate at least the 100 yr. flood, including associated bedload and debris. Priority for upgrading will be based on the potential impact and the ecological value of the riparian resources affected.

-Crossings will be constructed and maintained to prevent diversion of streamflow out of the channel and down the road in the event of crossing failure.

-Dispersal of sub-surface drainage associated with roads will be accomplished in an area capable of withstanding increased flows. Energy dissipaters, armoring slopes or rip-rap may be necessary. Rip-rap used to armor streambanks and drainage ways, must be of sufficient size, quality, and cleanliness to not be a source of sediment

-Minimize the erosive effects of water concentrated by road drainage, disperse runoff, and minimize sediment generation from the road..

-Provide and maintain fish passage at all road crossings of existing and potential fish-bearing streams.

-Maintain or improve soil stability adjacent to all streams.

-Streams or portions of streams, where fish production is demonstrably below potential due to habitat restrictions, will be rehabilitated using whatever measures are appropriate based on the analysis.

-Plan and conduct restoration programs on lands where range, road construction, timber harvest or other management activities cause soil and watershed conditions that do not meet standards and guidelines.

-The most important components of a watershed restoration program are control and prevention of road related runoff and sediment production, restoration of the condition of riparian vegetation, and restoration of in-stream habitat complexity.

-Active silvicultural programs will be necessary to restore large conifers in Riparian Reserves.

-In stream restoration will be accompanied by riparian and upslope restoration.

-Mitigation and planned restoration will not be substituted for habitat protection.

-Restoration projects may be generated by annual maintenance inspection and planning, when work is beyond the scope of maintenance.

5. What types of road maintenance practices are needed and why? What are their priorities?

Reconnaissance of drainage features of the roads sampled showed plugged and undersize culverts, stream crossings with diversion potential, and stream network extension.

Standard and Guidelines from LRMP, BMP, NWFP, and Forest Service Manuals and Handbooks

Recommendations

-Periodic and preventive maintenance is essential to control sediment. Sediment production from road surfaces can be controlled by grading, watering, dust oiling, sealing, aggregate surfacing, chip-sealing, or paving. The treatment depending on the traffic, soils, road design standards, road objectives and funding.

-When grading and shaping road surfaces conserve existing material and designed shape.

-If the existing design is not working grading and shaping may correct drainage problems.

-Excess material is hauled to a designated waste area and placed in a stable condition.

-Ditches and culverts must be inspected frequently and cleaned when necessary.

-Debris obstructing drainage must be removed promptly.

-Vegetation will not be removed from ditches unless necessary to restore ditch function.

-Slide and sloughs, ditch cleaning, and other excess material is not sidecast, but placed in designated areas in stable embankments.

-Roads with water streaming down wheeltracks may be stormproofed by adding closely spaced water bars that direct water into the ditchline or onto stable slopes, when routine grading and shaping is not available.

-A Flood Emergency Road Maintenance (FERM) plan is in existence to provide for road protection and maintenance during storm events.

Priorities

-Drainage and erosion control structures and features, including bridges.

-Arterial roads, collector roads, trailhead roads, recreation site access, campground roads.

-Identify and correct road drainage problems that contribute to degrading of riparian resources.

-All roads shall receive at least minimal custodial maintenance needed to maintain drainage, protect the road investment, and minimize damage to adjacent resources and land.

6. What type of work needs to be done to bring the existing road system up to the current standards? How should it be prioritized?

If maintenance activities can not bring a road up to current standards or the current road design standards are inadequate the road should be reconstructed and/or redesigned.

Standard and Guidelines from LRMP, BMP, NWFP, and Forest Service Manuals and Handbooks

Recommendations

-Periodic blading and shaping

-More frequent ditch relief culverts in areas of stream network extension.

-Stormproofing roads receiving low traffic volume, but accessing trailheads or other features

-Closing Maintenance Level 1 roads that have been breached

-Establishing road entrance information on Maintenance Level 2 roads that do not presently have it

-Drainage work on bike path,

-Monitoring of Maintenance Level 1 roads for drainage problems.

Priorities

same as previous question

7. What types of roads should be obliterated and why?

Roads classified as “other” in Access and Travel Management II, or listed as Maintenance Level 1 in the Road Management objective will be evaluated by an interdisciplinary team at the planning area level. Roads with no specifically identified purpose or need are candidates for obliteration.

Standard and Guidelines from LRMP, BMP, NWFP, and Forest Service Manuals and Handbooks

Recommendations

-Roads that are no longer needed for specific access needs should be closed and reclaimed.

-Roads with ongoing or potential effects to Aquatic Conservation Strategy should be obliterated after giving consideration to short and long term transportation needs.

-Roads crossing areas identified as high risk for mass movement should be considered for obliteration. These roads should be closed to return the land to production, begin the process of eliminating excess sediment production, and for monetary reasons.

-Every road shall receive a minimum level of maintenance that includes functional drainage and periodic monitoring. If the amount of attention and monitoring can be reduced, other roads can receive needed maintenance.

-Temporary roads are closed at the end of the contract period.

8. What types of roads should be blocked and why?

Standard and Guidelines from LRMP, BMP, NWFP, and Forest Service Manuals and Handbooks

-Unsurfaced roads should be closed at least during wet periods.

-If not needed for some specific access roads should be placed in Maintenance level 1 status and closed.

-Roads temporarily closed for over 1 year shall be shall be maintained at Maintenance Level 1 standards.

-Roads that parallel sensitive Riparian Reserve areas may need to be closed during wet periods.

9. What geomorphic terrains pose the highest erosional risk for road construction? Where are the consequences to beneficial uses the greatest?

Geomorphic terrain types posing the highest erosional risk include earthflow terrain, debris slide basins, inner gorge, and mountain slopes. Both rapid and chronic sediment production result from natural and management related events. Road related disturbances can commonly be traced back to inadequate drainage or undesirable road location. The resultant triggering of a mass wasting event may produce an amount of sediment beyond the capacity of the system to resist or recover. The Upper North Umpqua Watershed Analysis, page 20-21 and the corresponding Appendices/Analysis File contain a more detailed discussion of Geomorphic land type of the upper North Umpqua River basin. This discussion is applicable to the Diamond Lake/Lemolo watershed. The most common Geomorphic terrain type in the watershed is the mountain slope type. In steep areas with deep coverage by ash, pumice or glacial till, surface erosion processes may be severe.

Recommendations

-Avoid road building in earthflow terrain, debris slide basin, and inner gorge geomorphic terrain types.

-Use appropriate vegetative or mechanical means, design standards, and construction standards in mountain slope geomorphic terrain type.

-Consider obliteration of problem roads or roads that threaten high value riparian resources

10. Should new roads cross streams and riparian reserves? If so, where and how? If not, why?

There is no specific prohibition of stream crossing.

Standard and Guidelines from LRMP, BMP, NWFP, and Forest Service Manuals and Handbooks

Recommendations

-Long range planning to provide the most efficient transportation system, minimizing the number of stream crossings.

-Consideration of alternative logging systems to eliminate road building.

-Stream approaches should be kept at a 90 degree angle.

-Sites should be selected where large cuts or fills are not needed.

-For each site a specific stream crossing plan should be created with specific direction for stream diversion/de-watering, equipment limitations, erosion control, and operation time period.

-Consider allowing equipment to cross the stream only once during construction where sensitive areas may be affected.

11. Is firewood cutting creating a problem with the creation of roads?

Generally firewood has been plentiful enough so that leaving the road has not be necessary. If supplies of firewood become scarce it this may become a problem.

Recommendations

-Continue to monitor firewood cutting areas.

-Retain a portion of the permit fee to be used for cleanup of firewood cutting slash

Water Quality and Fisheries

1. What is the trophic status and history of Diamond Lake?

This was answered in Chapter 4.

2. How is the trophic status affected by recreation in the Diamond Lake area?

This was answered in Chapter 4.

3. How does the tui chub influence the recreational fishery?

The effects of the tui chub on the recreational fishery at Diamond Lake is discussed in Chapter 4.

4. What is the effect of the introduction of non-native species?

This was answered in Chapter 4.

5. What are the erosion processes that affect Lemolo Lake?

This was answered in Chapter 4.

Recreation

Diamond Lake

1. How is recreation use influencing lake shore erosion?

The greatest recreational influence on Diamond Lake shore erosion is likely a result of dispersed lake accessibility and associated bank trample. Boat slips or landings are common particularly along the western shore providing lake access from summer homes and camp sites at Mt. Thielsen Campground. Slips typically extend onto the lake shore, where access to and from boats occurs on the bank. As a result localized bank failure, erosion, and compaction occurs. Shoreline disturbance associated with this type of recreational use is compounding erosion associated with lake level adjustment and the natural disturbance of wave action and ice scour. Accelerated shore erosion has likely resulted in changes to riparian function because of the loss of bank and riparian vegetation. However, our understanding of recreation use impacts to these areas is not complete. Therefore, additional information is required to make a conclusive determination of impacts to riparian function.

Shoreline derived sediments are generally not a concern due to the nature of the sediment produced from these sites. Since banks of Diamond Lake are composed of ash and lucustrine deposits, fine particle size sediments of silt and clay are predominantly absent. As a result, sediments derived from bank erosion do not remain in suspension for lengthy periods of time, and therefore, settle out on the lake bottom without greatly impacting tubidity of the water column, nor is it transported downstream.

It is recommended that the number of dispersed boat landings be reduced and replaced by permanent docks. Sharing of existing docks is also recommended and should be encouraged to reduce the number of docks and shoreline impacted. Those landings remaining should be hardened with coarse gravel. Additionally, it is recommended that trees along the shoreline will not be cut unless docks or boats are threatened.

2. What is the recreation use and what are the trends?

Current recreation use and trends are discussed in Chapter 4.

3. What are the impacts of recreation use on riparian function?

Impacts associated with recreation use on riparian function are occurring within riparian areas around Diamond Lake. The significance of these impacts to riparian habitat function and riparian dependent species is not fully understood. However several impacts have been identified including bank erosion, reduced infiltration due to soil compaction, and conversion of riparian areas to campgrounds, boat ramps, lawns, buildings, roads, and parking lots. The removal of riparian vegetation has likely altered riparian microclimate from a cool, moist environment to one experiencing temperature, precipitation, and wind extremes, which are likely to have adverse effects on riparian function as habitat for both plant and animal species.

It is recommended that the assessment of the impacts of recreation use on riparian function continue and focus on how those uses affect water quality and the attainment of Aquatic

Conservation Strategy objectives. Based on current understanding of riparian condition, the recommendation is made to reduce the number of roads presently used by motor vehicles within the Summer Home Tract. Riparian roads (those within 300 feet of the lake shore) are of particular concern, as well as those which are delivering sediment to the lake. Roads which would be closed to motorized access could be converted to trails for non-motorized use, therefore reducing compaction and starting a trend toward improving riparian condition. Those roads remaining require improvements such as aggregate surfacing to reduce erosion and improve access to homes.

Additional recommendations include: 1) leaving trees of all sizes and down coarse woody material greater than 12 inches in diameter within 300 feet from the lake shore within undeveloped areas and the Summer Home Tract; 2) no further expansion of lake shore or riparian area (300’ from the shore) facilities would occur around the entire lake; and 3) reduce dispersed lake access, through education and path closure, to promote riparian vegetation growth by reducing disturbance.

4. Are Current recreation facilities adequate for future use? If not, what should be done, where should new facilities be located?

From the information collected for and contained in this analysis it is difficult to accurately determine if the existing facilities will be adequate for future use. It does appear though, that the existing facilities should be adequate in the near (5 – 15 years) future. Since campground and overnight lodging make up the greatest percentage of use in the area and often account for the day use activities, some estimates can be made. Based on a six to eight percent annual increase in camping demand as predicted by SCORP (SCORP Region 9), and a restoration of the Diamond Lake fishery, the area may experience use similar to that seen in 1978 and the early 1990s. At those times, use was within acceptable guidelines, and water and sewer facilities were utilized at 50 percent or less of design capacities.

Though the capacity of the existing facilities appears to be adequate for the short-term, future use, there are areas that need improvements.

Recommendations:

- Accomplish backlog maintenance of water and sanitation facilities, buildings, and campsites.
- Continue with traffic control measures (barriers) in the area, primarily within Thielsen View Campground.
- Improve and increase the number of facilities available to people with disabilities and the elderly.
- Development of the Administrative Site Area north of Forest Service Road 4795. Relocate employee (Diamond Lake Improvement Co.) housing and administrative buildings away from the Resort area.
- Continue re-vegetation of campgrounds to replace trees lost to blow down and mountain pine beetle.

- Due to the already extensive developments and use around Diamond Lake and within the riparian zones, if or when demand exceeds the existing practical capacity of the recreational facilities, any new developments, if made, should be located so that there are minimal impacts on riparian areas.

- Update the existing Diamond Lake Recreation Composite Plan.
- No expansion of existing campgrounds or development of new recreation sites within the riparian zone.
- Limit expansion of Resort facilities to areas away from the shoreline and utilize areas previously occupied by facilities that would relocate to the Administrative Site.

5. What is the carrying capacity for boating and other recreation uses?

Since the highest percentage of use in the area is from overnight camping and lodging, and much of the day use activity is from these users, an estimate of capacity can be obtained by looking at PAOT capacities for overnight camping or lodging. The USFS has found that a 60 percent occupancy level is the Practical Carrying Capacity (PCC) for developed facilities that are properly designed and maintained. Applying the formula PCC = PAOT x Managed Use Season (MUS) x .60, to the information from the PAOT Table 41 in Chapter 4, the PCC in the Diamond Lake Area for camping and overnight lodging would be approximately 653,000 for the MUS. This would equate to a PCC of approximately 1.3 million RVDs per year. (2.0 RVDs/PAOT for overnight facilities.

Due to the 10-mph speed limit on Diamond Lake, it can be assumed the majority of boating use is for angling. According to U.S. Department of the Interior, Bureau of Outdoor Recreation, (USDI BOR) standards, angler boats require 3.4 acres per boat. Since Diamond Lake is approximately 3,000 surface acres, the maximum boating capacity would be approximately 882 boats. Thus the PCC would be 529 boats at one time. (PCC = Maximum Capacity x .60) Though this may be the PCC for angler boating on Diamond Lake, in reality, boats tend to cluster where the fishing is good and densities far exceed one boat per 3.4 acres.

Recommendations:.

- Further analysis of recreational capacities for activities other than camping and overnight lodging.
- Analysis of the relationship and impacts of ODF&W fish management goals on recreation facilities and lake capacities. The intent would be to insure a balance between demand and the ability of the facilities and the environment to sustain the activity.

Lemolo Lake

1. What are the impacts of recreation use on lake shore erosion and riparian function?

Impacts associated with recreation use on lake shore erosion and riparian function are occurring within riparian areas around Lemolo Lake. For a discussion of lake shore erosion refer to the Geology section of Chapter 4. The significance of these impacts to riparian habitat function and riparian dependent species is not fully understood. However several impacts have been identified including bank erosion, reduced infiltration due to soil compaction, and conversion of riparian areas to campgrounds and dispersed sites, boat ramps, buildings, roads, and parking lots. The removal of riparian vegetation has likely altered riparian microclimate from a cool, moist environment to one of temperature, precipitation, and wind extremes, which are likely to have adverse effects on riparian function as habitat for those both plant and animal species.

It is recommended that the assessment of the impacts of recreation use on riparian function continue and focus on water quality issues and how those uses effect the attainment of Aquatic Conservation Strategy objectives. Based on current understanding of riparian condition, the following additional recommendations are made: 1) to improve campsites to reduce surface and shore erosion; 2) close dispersed campsites due to water quality concerns, and restrict camping to designated sites; and 3) place a speed limit on the reservoir extending 200 feet from the shore to reduce shore erosion caused by wave action.

2. What is the recreation use and what are the trends?

The current recreation use and trends is addressed in Chapter 4.

3. What is the carrying capacity for boating and other recreation uses?

The Draft Recreation Resource Management Plan by PacificCorp (September 1995) for the Lemolo Lake Recreation Area analyzed capacities for recreation and boating. Though PAOT and MUS values identified in this analysis are different than those in the PacifiCorp Plan, the same criteria for establishing the PCC can be used. Applying the information from the PAOT Table in Chapter 4, the PCC for camping or lodging at the existing developed sites would be 127,168 (PAOT x MUS x .60). Using the PAOT to RVD conversion factor of 2.0 this would equate to approximately 254,000 RVD per year as the PCC for the existing developed facilities.

Unlike Diamond Lake, dispersed (non-developed) camping is allowed in the Lemolo Lake Recreation Area. PacificCorp, in their study estimated the PCC for this area as 18,551 RVD per year. In analyzing the surface area capacity for boating on Lemolo Lake, PacificCorp, based on surveys, assumed 75 percent of the boating use was angler boats and 25 percent non-angler boats. According to USDI BOR standards, these uses require 3.4 acres and 7.1 acres each, respectively. With a surface area of 435 acres, they estimated the maximum capacity as 101 boats. Thus the PCC (60 percent) capacity would be approximately 60 boats.

4. What is the relationship between recreation and FERC relicensing?

PacificCorp is in the process of re-licensing the North Umpqua Hydroelectric Project with the Federal Energy Regulatory Commission (FERC). The new license has not been issued at this time but once issued, it is anticipated to be in effect for 30 years. PacifiCorp recognizes that their project facilities (Lemolo Lake etc.) have encouraged and created recreation demand and use in the vicinity of the North Umpqua Project. Thus, PacificCorp has accepted a shared responsibility with the USFS for the recreation planning and management.

As part of this effort, PacifiCorp has prepared a Recreation Resource Management Plan (RRMP). The RRMP establishes goals and objectives for managing recreation resources in the project vicinity, identifies proposed measures for existing and proposed recreation resources, and describes programs designed to implement those measures. PacificCorp and the USFS also intend to enter into a Recreation Agreement which will define roles and responsibilities between the two parties for implementing the recreation measures described in the RRMP. When a new license is issued to PacificCorp for the North Umpqua Project, the RRMP will be the framework for the operation, maintenance, and development for recreation facilities within the Lemolo Lake Recreation area.

5. Are current recreation facilities adequate? If not, what should be done, where should new facilities be located?

According to the analysis done for the RRMP (PacificCorp 1995), the developed campgrounds in the Lemolo Lake Recreation Area are currently meeting demand though some need improvements to enhance visitor experience and for resource protection.

Recommendations:

- Install new accessible (ADA) toilets at Inlet, Bunker Hill, and East Lemolo campgrounds.
- Improve sites at East Lemolo and Bunker Hill campgrounds by including traffic control measures (barriers), campsite boundaries, road repair and improvement, erosion control, signs and re-vegetation.
- Improve interpretive facilities in the area for information and environmental education.
- Improve the existing group reservation campsite at Poole Creek Campground including a new accessible (ADA) toilet.

The RRMP looked at future recreation needs in the Lemolo Lake Area beyond the year 2000. Based on projected increases in demand and recreation needs, future development was identified in two phases. Phase 1 (2000 – 2015) and Phase 2 (2015 and beyond). As stated in the RRMP goals and objectives, any future development will be coordinated with existing and proposed state and federal land and resource management plans and be compatible with other resources. The following is a summary of the Phase 1 and Phase 2 recommendations made in the RRMP for the Lemolo Lake Area.

Recommendations:

- Develop a new campground and an additional group campground.
- Complete construction of Lemolo Lake Loop trail for hiking and biking
- Provide parking and trail needs for winter users (snowmobile, ATV, and cross-country skiing)
- Provide additional boat launch and swimming facilities.
- Monitor boater, camping, and vehicle use.

6. Are regulations concerning dispersed recreation needed around the lake?

Direction in the NWFP states that recreational facilities including dispersed sites should be designed to be consistent with the goals and objectives of the ACS. As identified in other sections, there are concerns about soil erosion and water quality at Lemolo Lake. Though recreation use at the present time is moderate, compared to other areas in the watershed, it is expected to increase in the future, including dispersed recreation within the riparian zone. The best way to limit resource impacts from recreation in areas that experience high use is to manage that use at developed sites.

Recommendations:

- Traffic control measures (barriers) to stop access to dispersed campsites by vehicles.
- Increase interpretive program and opportunities for environmental education.
- Regulation (CFR) restricting camping to designated sites only, similar to
- restriction in force in the Diamond Lake Recreation Area.

Other Areas

1. What are the appropriate recreational uses around high elevation lakes?

Available information indicates that the current management and use levels at Calamut, Lucille, and Maidu Lakes do not appear to be causing water quality or unacceptable riparian area degradation. Fish stocking in high mountain lakes has the potential to cause lake eutrophication, reductions in amphibian populations, and degradation of banks and riparian areas. Eutrophication does not appear to be occurring as a result of fish stocking at Calamut and Maidu Lakes. The effects of fish stocking on amphibian populations at Calamut and

Maidu Lakes are currently unknown, but some level of adverse effects are likely to have occurred. Increased use associated with fishing does not appear to be causing unacceptable bank erosion and riparian area degradation to either lake. In the past, unacceptable impacts have occurred at Lucille and Maidu Lakes associated with use of shelters located within the riparian area. The shelters were removed from both sites in 1992.

Recommendations: In order to keep the lakes in their current condition, use of the lake shore and immediate riparian area should be limited to foot traffic. Camping and livestock grazing and watering within the immediate riparian area should be discouraged. This is particularly important on the south shore of Maidu Lake, along the path of groundwater inflow. This can probably best be accomplished by signing at trail heads and lakes. If information becomes available in the future that fish stocking is causing unacceptable adverse effects to water quality or amphibian populations in Calamut or Maidu Lakes, the practice of fish stocking should be reconsidered. Fish stocking should also be reconsidered if unacceptable riparian area degradation occurs associated with fishing.

2. Are the current recreation uses in the OCRA appropriate?

As identified in chapter 4, the identified recreation uses within the OCRA are appropriate. An area of potential conflict with management direction for the OCRA is the use of mountain bikes or trails in the OCRA that access the Mt. Thielsen Wilderness. Mountain bike users on trails that lead into the wilderness often encroach into the wilderness.

Recommendations:

- Increased monitoring of use within the OCRA
- Increased interpretive opportunities and signing at trailheads identifying the appropriate uses and environmental education.

3. Are the current winter trails adequate?

The motorized winter trail system appears adequate for current use. Though the existing trail system is sufficient for current use, funding for managing, maintenance, and grooming are a continuing problem.

The non-motorized trail system appears to be adequate for current use. There is some question however, as to why it is adequate. Is the system adequate due only to low use, or rather due to it being a system that does not insure higher demand. The 1991 Winter Recreation Analysis done for Diamond Lake Resort identified the overlap of motorized and non-motorized trail use around Diamond Lake as a major constraint associated with cross-country skiing. The analysis also indicated that users were not going to Diamond Lake with cross-country skiing in mind.

Recommendations:

- Further analysis of cross-country skiing demand and opportunities in the area.
- Seek partners or co-operators to develop and promote cross-country skiing

opportunities.

- Consider/analyze the possible development of a non-motorized groomed trail system in the OCRA or other areas away from the motorized trail system.
- Development of a user fee system to help pay for the operation and maintenance of a groomed, non-motorized trail system.

4. What are the current and potential winter recreation activities on Mt. Bailey?

This question is addressed in Chapter 4.

Wilderness

1. What is the desired future condition for recreation in Wilderness?

The desired future condition for recreation in the Mt. Thielsen Wilderness should be consistent with the objectives identified in the LRMP (Appendix C - 5, of the LRMP).

2. Are there any valid mineral claims in the wilderness?

There were no valid claims discovered.

3. Are there any valid mineral claims in the OCRA?

There were no valid claims discovered.

4. Are we meeting our wilderness management guidelines?

As identified in Chapter 4, activities around Lucile and Maidu Lakes, and on the three trail systems are within guidelines. Further inventory and monitoring of the other trails within the wilderness needs to be done to determine if use is within LAC. Suspected unacceptable uses within the wilderness include the commercial harvest of mushrooms and mountain bike use on trials.

Recommendations:

- Monitor and evaluate remaining trails and uses in the wilderness.
- Increased interpretive and regulatory signing at trailheads where suspected inappropriate use originates.

- Continued monitoring of the Mt. Thielsen trail to evaluate use and compliance with LAC.

Wildlife

1. What are the important elk movement corridors?

This question is addressed in Chapter 4.

2. What is the relationship between recreation use and wildlife disturbance?

Recreational affects on wildlife are varied, dependent on the location, time of year, and recreational activity. For example, 1-2 people hiking in the Mt. Thielsen Wilderness during the summer has a lot less impact than 1-2 people driving a snowmobile from Diamond to Lemolo Lake in the winter. Different species have different responses to disturbances. Wolverines may leave an area after only 1 encounter with a human, whereas otters may approach humans during certain times of the year. Elk are disturbed, especially in the winter range areas, by people and vehicles. Other factors that have affected wildlife as an indirect result of providing recreational opportunities are the stocking of non-native species for consumptive users. The stocking of non-native trout has led to a decrease in the native amphibian populations, especially in areas that were historically fishless, such as high elevation lakes.

Some research has been completed on the effects of recreation on wildlife, especially on endangered species such as bald eagles, but more work is needed. In this watershed there are many data gaps. Basic information needed to evaluate recreational effects include: 1) An estimate of the number of people that utilize the high mountains lakes, both in the OCRA and in Mt. Thielsen Wilderness. 2) The number and distribution of winter recreationists, especially snowmobilers.

In order to reduce disturbance to various species of wildlife, the roads within the watershed should be evaluated to determine their necessity. As many roads as possible should be decommissioned or closed. If roads are needed for administrative uses, the construction of locked gates should be considered. The removal of roads from the transportation system will lower the maintenance costs, if they are properly decommissioned.

Any proposed new roads/trails or the extension of roads/trails should be reviewed in relation to potential effects on elk movements. There is an important elk migration route through this watershed. Any further road/trail development could lead to increased disturbance of the migrating animals. In a recent study on road management and elk movements (Cole et al. 1997) it was found that elk moved less when roads within their home ranges were closed, which could lead to increased survival rate and productivity.

3. What is the distribution of spotted frogs?

This question is addressed in Chapter 4.

Vegetation

1. Are appropriate measures being taken to protect Sensitive plants and their habitats?

Answered in Chapter 4.

Recommendations:

1) Manage known sites in a manner consistent with the survival of the species. The best management practice will vary with species and situation.
2) Continue to survey project areas for Sensitive species. Document and map new sites.

2. Are restoration/landscaping projects using appropriate native plant species?.

Yes. Native grass seed, trees, and shrubs are used in restoration projects

Restoration Projects

Recommendations:

Use native species for all restoration projects, such as road obliteration, erosion control on cut banks, etc.

Develop a source of native grass seed mix for use in erosion control projects.

3. Are noxious weeds being managed effectively.

This question is addressed in Chapter 4.

Recommendations:

1) Manage to eradicate or control the spread of noxious weeds at known sites, consistent with the Forest EA.
2) Continue to survey for new infestations in project areas.
3) Encourage the use of weed-free hay/straw for all stock entering the forest, particularly those traveling in fragile ecosystems and wilderness areas.

Fire Disturbance

1. Under what circumstances should prescribed fire not be allowed in riparian reserves**?**

The Final Supplemental Environmental Impact Statement on Management of Habitat for Late-Successional and Old-Growth Forest Related Species Within the Range of the Northern

Spotted Owl (FSEIS) speaks to fire in the riparian reserves numerous times. It recommends limiting the size of all wildfires in the riparian reserves, yet recognizes and identifies instances when some fire suppression measures could be damaging to the reserve. The FSEIS also recommends recognizing the role of fire in ecosystem function and that some natural ignitions be allowed to burn upon the completion of this analysis.

Some key elements in a riparian system that can be affected by wildfire or prescribed fire are large coarse woody material, riparian vegetation, duff, and potential for future large woody recruitment, and riparian dependent wildlife species.

It is recognized that fires naturally occurred within the riparian areas. Depending on numerous fire behavior factors many of these historically did not burn many acres due to the wetter nature of riparian areas. At other times the amount of available fuel, shape, slope and aspect of the drainage contributed to a hotter, more consumptive fire.

An accepted approach to minimizing wildfire size and of minimizing the impacts of fire suppression is to reduce the amount or continuity of ground and ladder fuels prior to the start of a wildfire.

Recommendations

Prescribed fire will only occur when the project meets the intent of the Aquatic Conservation Strategy. All proposed prescribed fire projects will go through the NEPA process with an interdisciplinary team (ID team). Treatments such as hand piling, swamper burning, jackpot burning or underburning at the wet end of the prescription are some alternatives that can be used to use to meet the requirements of the riparian reserve.

When treating fuels for hazard reduction purposes, determine if the hazard can be effectively alleviated without treatment occurring in the riparian reserve. For instance, the fire hazard around existing buildings in the Diamond Lake composite can not be alleviated without treatment occurring within a riparian reserve due to the proximity of the buildings to the reserve, or the buildings actually being within the riparian reserve.

Another consideration when proposing hazard reduction treatments is whether or not the treatment can be effectively or practically undertaken without also occurring in an adjacent riparian reserve. An example of this is on the north side of Diamond Lake where the steepness of the slope, aspect and continuous heavy fuels combine to make hazard reduction treatment difficult to implement without treatment also occurring in a riparian reserve.

Management ignited prescribed fire for ecosystem maintenance and restoration should be allowed to burn within riparian reserves as fire did historically. Planned fires utilized to restore ecosystem function also restore diversity and complexity to a riparian reserve. These fires also can provide large woody recruitment if planned and implemented carefully. In most instances duff, vegetation and coarse woody material consumption would be kept to a minimum. Only very minor planned ignition should occur within the riparian reserves. Instead, fire should be allowed to back towards and into the reserve where a change in the micro-climate (higher humidity, slope, fuel moisture and amount of fuel) or weather produces a change in fire behavior. Due to the exclusion of fire from the ecosystem for at least the last 60 years, a prescribed fire will not always behave as a natural fire, some ignition within the reserve may occur as a method of controlling direction and rate of spread.

Burning in a riparian reserve to improve the functioning of the reserve or to reduce the fire hazard of the reserve itself is usually not necessary or desirable. An example of a possible exception to this is an aspen grove within a riparian reserve. Without fire the grove will not be self sustaining. An underburn in this example area may be desirable to improve the health and vigor of the grove.

Naturally ignited prescribed fire for ecosystem maintenance and restoration should be allowed to burn within riparian reserves as fire did historically. These fires will be utilized to restore function and diversity to the ecosystem. Under a prescribed natural fire plan a risk assessment and burn plan are completed. If there is good probability of success and the fire meets the objectives, the fire will be allowed to burn while being monitored.

Measures needed to keep a fire outside of a riparian reserve maybe more destructive than allowing the reserve, or portions of the reserve to burn. In this instance, prescribed fires should be allowed to burn within the reserve.

Summary

Prescribed fire should not be allowed in riparian reserves under the following conditions:

1. When the effects of prescribed fire are likely to be inconsistent with the intent of the aquatic conservation strategy.
2. When hazard reduction (reducing the fuel loading in and around an area of value) can be accomplished without treating the riparian reserve. Recognizing that in the event of a wildfire the riparian reserve may be at greater risk than the surrounding treated area.
3. When the hazard reduction can not take place and maintain the coarse woody material, vegetation or duff levels as determined are desirable by the ID team for the proposed project.
4. When the high fuel loadings are a hazard to the riparian reserve itself and no other resource such as a building, plantation, timber etc. Recognizing that in the event of a wildfire the entire reserve is at risk of a high intensity fire.
5. When an ID team has determined that the riparian area at a landscape level is degraded such that the riparian reserves are not functioning properly and may be further degraded by applying fire.

Areas With Current and Future Proposed Prescribed Fire Projects in Riparian Reserves

The area that is adjacent to the north side of Diamond Lake should have prescribed burning treatments. Fuel loadings are high and expected fire behavior is going to be greater than 4 foot flame lengths with high intensity. This area is heavily used by the public and person-caused risk is quite high.

The areas with high fuel loadings on the westside and south side of Diamond Lake should be treated. Some of these areas are adjacent to Diamond Lake and Teal Lake. These areas have high public use and, due to improvements (summer homes, south shore store, and south shore forest service facilities), values at risk are high.

The areas adjacent to Lemolo Lake with high fuel loadings, particularly on the North Side of the Lake. This area is also subject to high public use, with high values at risk from the Forest Service facilities as well as the facilities and improvements at the Lemolo Resort.

These areas are clearly identified on the Predicted Fire Behavior Map located on GIS. Both the Diamond Lake and Lemolo Lake are in Risk Zone 1 as defined in the Umpqua National Forest Hazard Reduction Standards.

Additionally, underburning may be proposed in some planning areas in this watershed near riparian reserves. Ignition will not be proposed inside the riparian reserves. Instead the fire will be allowed to back naturally and stop burning when a change in fuels, vegetation or wetter environment of the riparian area is reached.

2. What areas would benefit the most from prescribed fire?

Areas that would benefit the most are areas of high resource value, combined with high fire hazard.

Value can be expressed many ways, and should not be limited to the following examples. Areas can have a high monetary value such as near buildings, other improvements, a high value for wildlife habitat where burning improves a degraded habitat, a high value in time invested such as a 30 year old progeny plantation, or a high human value such as the risk associated with fire suppression in a particular area.

High fire hazards are usually found on the steeper southern aspects that have high fuel loads. The Predicted Fire Behavior Map located on GIS is one method that can be used to determine the hazard; higher predicted fire intensities are an indicator of greater hazard. Risk zones, as defined in the Umpqua National Forest Hazard Reduction Standards, should be used as guidelines for determining the relative risk and assisting in setting priorities and acreage’s.

The following areas have been specifically identified as benefiting from a resource and fire hazard stand point:

- North Shore of Diamond Lake (includes the resort and associated area).
- West Shore of Diamond Lake.
- The remaining areas within the Diamond Lake Composite.
- Lemolo Lake Area.

Recommendations

Continue planning and implementing the Diamond Lake and Lemolo Lake natural fuels reduction plans.

Identify other areas as more information becomes available or conditions change.

3. What is the natural fire disturbance process?

The fire frequency, patterns on the landscape, historical accounts of fire occurrence and air quality indicate that the natural fire regime of much of the analysis area was a *moderate-severity* fire regime. The patterns on the landscape, historical accounts of fire and research conducted in similar areas indicate the natural fire regime of the area along the crest of the Cascades in the mountain hemlock plant series was a *high-severity* fire regime.

A moderate-severity fire regime is characterized by infrequent fires (25 to 100 years) and significant areas of high and low severity resulting in partial stand replacement. Fires typically burn weeks to months, and periods of intense behavior are mixed with periods of moderate to low intensity fire behavior. Moderate-severity natural fire regimes produce patchy stands of various sizes mixed with patches of multi-sized stands (Agee 1990).

This moderate severity fire regime is true for most areas within the watershed including the lodgepole pine plant series. Climax lodgepole pine forests have a moderate-severity fire regime. Fire frequency studies in adjacent Crater Lake National Park and other areas indicate a probable fire return interval of 60-80 years (Agee 1993).

In this plant series the most continuous method of fire spread is logs. Partially decayed logs carry most fires, so that fire behavior is more a function of coarse woody material, rather than fine fuel dynamics. Climax lodgepole pine forests rarely grow for a century without a major disturbance by fire or insects. In the two areas where these stands have been most intensely studied (Crater Lake and Fremont National Forest), both log-to-log and crown fire activity has been observed or reconstructed from age data for forest stands. (Agee 1993).

Some areas along the crest of the Cascades within the Thielsen Wilderness, the OCRA and on Mt. Bailey are a sub-alpine ecosystem. The predominant plant series here is mountain hemlock (*Tsuga mertensiana*). The historic natural fire regime most resembles a high severity fire regime. Some of the area within the watershed managed by Crater Lake National Park may also be in this high severity fire regime.

A high severity-fire regime is described as fires usually being infrequent, (more than 100 years between fires) the fires are usually high intensity, stand replacement. Most fires are stand replacement events because of the lack of fire resistance of the major tree species. Fire return intervals may not be cyclic (Agee and Flewelling 1983). Large fires are associated with drought years, east wind synoptic[11] weather types and lightning (Huff and Agee 1980, Pickford et al. 1980). Fire return interval is also dependent on the development of a fuel complex capable of supporting crown fire behavior (Despain and Sellers 1977). In some instances fires burn only the crowns sparing the understory during the spring when there is still snow on the ground.

Recommendations

- A *moderate-severity* fire regime be returned and maintained on most locations of the Lemolo / Diamond Lake Watershed. Fire return interval, fire size, fire effects, and fuel

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[11] East wind weather conditions over a broad area or region at a given time. East winds are strong winds (20 to 40 mph) that bring warm, dry air to the western slopes of the Cascades on Oregon and Washington.

model will have to be modified to more resemble the reference conditions.

- The average fire return interval should be 75 years, the fire return interval on two thirds of the moderate intensity area in the watershed will vary from 25 to 100 years. Fire size will vary greatly from 1/4 an acre to two to three thousand acres. Effects of fires will also vary greatly, from slight underburn, to underburn that kills portions of the understory, to fires that kill portions of the overstory, to fires that are stand replacement in some areas. Prescribed fires should be timed to achieve the effects of a ‘natural’ fire when possible, for example, burning in the fall rather than the spring.
- Use prescribed fire as a tool to return most of the area to a moderate severity fire regime as well as meet the objectives of other management prescriptions; such as meadow maintenance or expansion for wildlife, thinning for some silvicultural prescriptions, forage and browse creation or maintenance for big game. Where appropriate use prescribed fire to modify areas of Fuel Model 10 to Fuel Model 8.
- When resource managers decide to harvest timber, design timber sales to approximate fires natural disturbance at the stand and landscape scale, and help return the watershed to moderate severity fire regime. This can be done by putting less emphasis on the volume removed per acre, and placing more emphasis on diverse silvicultural prescriptions. To accomplish this more acres may need to be harvested, at times units may need to be larger and more diverse, on the scale of 100 + as opposed to the traditional 20 to 60 acres. Have a variety of silvicultural harvest prescriptions, which may include a commercial thin, shelter wood, and seed tree prescriptions, as well as areas which are exempt from harvest. Once harvest is complete prescribed fire should be used to treat activity created fuel as well as being reintroduced to areas which were not harvested within in the sale area.
- Recognize that the portion of the watershed near the crest of the Cascades is in a high severity fire regime. Fire is a force of change in these areas, plant composition changes drastically following a high intensity fire and may not resemble the pre-fire stage for hundreds of years.

4) How prone is this watershed to high intensity fire?

The current fire regime of high-severity is described as fires being infrequent, usually high intensity, stand replacement fires. In lodgepole pine the typical wildfire either burns a small area of ground litter or a larger area of stand replacement.

A Potential Fire Intensity Map has been created for the forest using the fuel model map, slope, aspect, a set of weather conditions, and BeHave, a fire behavior prediction program. This fire behavior map is available in GIS or from fire management.

Direct attack of fires exhibiting flame lengths greater than four feet is impossible due to the intensity of the fire front. In this analysis, areas with predicted flame lengths greater than five feet are potential areas for high intensity fires. There are approximately 41,570 acres or 40 percent of the watershed in this category.

Recommendations

The potential for high intensity fires is dependent on the weather, topography, and fuels. Fuels is the only variable that can be modified.

- Continue to verify and map fuel models in the watershed. Implement a database in conjunction with the fuel model database that characterizes canopy closure and vertical arrangement.
- Continue to use prescribed fire where appropriate, following harvest, to meet the Umpqua National Forest Hazard Reduction Standards and Guidelines.
- Some of the area with high intensity potential is in the OCRA (Oregon Cascades Recreation Area) and Mt. Thielsen Wilderness area. Use natural ignitions as a method to return and maintain the natural moderate-severity fire regime to the wilderness and the OCRA.

5) Are there areas within the watershed where management could reduce the risk of high intensity fire and its adverse effects on soils, water, and other resources?

There are areas within the watershed where the risk of high intensity fire and possible adverse effects on soils, water, and other resources could be reduced. The district has identified some large unbroken areas with potential for high intensity fires.

- North Shore of Diamond Lake.
- Bunker Hill.
- The area immediately south of Kelsay Point.
- Elbow Butte Vicinity.
- The area north and west of Bradley Creek to its confluence with the North Umpqua River and north of the North Umpqua to Bunker Hill.
- South and East of the Highway 138 and Highway 239 junction in the Oregon Cascades Recreational Area.
- North of the North Umpqua River, south of Warrior Creek and West of Tenas Peak.

Recommendations

- Determine in conjunction with other resource specialists what the adverse effects may be. Examples of adverse effects could be a wildfire burning an entire drainage at high intensity or a high intensity fire killing and consuming timber effectively removing the acreage from the timber base for a time.
- Areas of potential high intensity fires have been mapped. Portions of some of these areas are already planned to be burned for other reasons. The vast areas mapped as high intensity should be reviewed. Appropriate treatments should be planned as forest priority and funding allow. Treatments may consist of general underburning, underburning or hand pile and burn in selected locations to create diversity within the

areas; and timber harvest, when harvest in the planning area is already scheduled.

6) Should prescribed natural fire be allowed to play its historic role in the Thielsen Wilderness Area? In the Oregon Cascades Recreation Area?

The watershed analysis has determined that during reference conditions this area was under a moderate-severity fire regime as well as a high-severity fire regime in the higher elevations, with a transition zone occurring in the middle elevations. The current condition for the entire watershed is a high-severity fire regime. This has been due to 75 years of very successful fire suppression. Presently the effect of fire is artificially small with little or no effect on the landscape.

Recommendations

- A prescribed natural fire plan is being prepared for the Mt. Thielsen Wilderness Area. This plan should be completed and implemented. This plan will allow fire to be returned to the ecosystem within the wilderness.
- The appropriate fire effect of a prescribed fire within the area of high-severity natural fire regime may be stand replacement. Each fire will be assessed by a team to determine if the fire should burn under natural conditions with a good probability for achieving objectives or be suppressed.
- This plan includes the Oregon Cascades Recreation Area as an implementation area. Fires which become Prescribed Natural Fires may be allowed to burn into this area when this has been previously identified by the team in the Risk Assessment and Burn Plan.

7) Should management ignited fire be used to meet resource management objectives in the Thielsen Wilderness Area? In the Oregon Cascades Recreation Area (OCRA) ?

Watershed analysis has determined that during reference conditions this watershed had a moderate severity fire regime while current condition resembles a high severity fire regime. This has been due to 75 years of very successful fire suppression. Presently fire effects are artificially small with little or no effect on the landscape. To return this watershed to a moderate severity fire regime, fire should be allowed to play it’s natural role.

Management ignited fire could help strengthen wilderness and OCRA boundaries to help contain future Prescribed Natural Fires and wild fires by reducing the chance of a high intensity fire. Management Ignited fire could also be useful in areas of probable concern. Areas of probable concern are defined in the wilderness prescribed fire plan as areas with high fuel loadings and potential to escape the wilderness or OCRA boundary.

Recommendations

- Initiate the NEPA process to analyze the effects of management ignited fire in the Mt. Thielsen Wilderness. If this process determines that prescribed fire would be the preferred alternative, then a plan should be developed and implemented. This project planning should be initiated as funds become available.

- District fire managers have developed a proposed action for prescribed fire in a relatively small portion of the OCRA. Continue with the proposed action as funds become available to complete the planning and begin implementation.
- Develop a fire management plan to allow management ignited fire to be used to return the Thielsen Wilderness and OCRA to a moderate severity fire regime.

Monitoring

All prescribed fire activities will be monitored to assure the results meet the objectives of the project and of the Umpqua National Forest Land and Resources Management Plan as amended February 1994. Future planning and implementation may be adjusted based on the results of monitoring.

Implications for Achieving Land Management Strategies.

Management of the watershed is in accordance with the guidelines from the Umpqua National Forest Land and Resource Management Plan. The Lemolo / Diamond Lake Watershed Analysis area falls into the following management areas;

1 Unroaded recreation semi-primitive (Mt. Bailey),

2 Concentrated developed recreation in and around Lemolo and Diamond Lakes,

4 Thielsen Wilderness,

5 Oregon Cascades Recreation Area,

6 Remarkable geologic, botanic, paleontologic, historic and scenic special interest areas (Crystal Springs and Spring River), and

10 Timber production.

The various prescriptions for these areas require an appropriate suppression response, either contain, confine, or control, the choice of which is dependent on the values at risk and cost efficient fire suppression strategies. Examples of values at risk are plantations, timber, improvements and unique habitat.

Some of the prescriptions associated with these management areas focus on the use of prescribed burning as a management tool.

Implications for achieving Aquatic Conservation Strategies.

The Standards and Guidelines for Management of Habitat for Late-Successional and Old Growth Forest Related Species Within the Range of the Northern Spotted Owl was reviewed to insure that any fire management activities will be in compliance with this plan.

Fire management activities are described on page C-35 and C-36 of the Standards and Guidelines. Fuel treatments and fire suppression activities and strategies should be designed to meet the Aquatic Conservation Strategy. These should minimize the disturbance of riparian ground cover and vegetation. Strategies should recognize the role of fire in the ecosystem function and identify those instances where fire suppression or fuels management activities could be damaging to long term ecosystem function.

Prescribed burning would, in many instances, maintain this strategy by reducing the risk of stand replacement fires in or near riparian areas. Planning prescribed burns in natural or activity created fuels when conditions are right to meet resources objectives, such as hazard reduction, maintenance of large coarse woody material, and protecting the riparian area, is an alternative to unplanned ignition during periods of high fire behavior. The impacts on riparian area from suppression such as humans, chemicals and fire effects will be far greater.

Fuels analysis for current timber sales in the watershed are already utilizing these standards and guidelines in the development of fuels treatment alternatives.

Heritage Resources

1. Do we have sufficient information about heritage resources in the Lemolo Lake and Diamond lake Watershed Analysis Area?

Twenty-one percent of the study area received inventory survey for heritage resources prior to the watershed analysis. These surveys are located in a contiguous area on the northwest side of the study area. A larger and more geographically balanced inventory would provide a clearer picture.

Volunteers under the Passport in Time Program could be used to accomplish surface inventory surveys of the Mt. Thielsen Wilderness Area and the Oregon Cascade Recreation Area. These areas represent the majority of the acres not yet surveyed.

Archaeological evaluations are needed to determine site size and eligibility for inclusion on the National Register of Historic Places. Archaeological information on sites within the study area is minimal. Further studies would provide information on the past life ways of Indians who were using the area.

Data gaps exist in the historic record as well as in the prehistoric record.

The history of the recreation cabin tract at Diamond Lake needs to be researched and the tract evaluated for a determination on whether it is eligible for inclusion on the National Register of Historic Places.

Building plans need to be completed for the Diamond Lake Visitor Center and the nearby “sleeping cabin” to assure our continued use of these buildings in keeping with their historic value. Both of these historic structures are listed on the National Register of Historic Places.

2. What could be done to increase public understanding of history in the Lemolo Lake and Diamond lake Watershed Analysis Area?

Several opportunities exist to increase public knowledge and understanding of the history of the Lemolo Lake and Diamond Lake Watershed Analysis Area.

- Interpret John B. Waldo, his travels in the Cascades, and his influence in the creation of the Cascade Range Forest Reserve, the Forest Service, and Crater Lake National Park.

- Interpret the history of the Cascade Range Forest Reserve and the beginnings of the Forest Service, the Cascade South National Forest, and the Umpqua National Forest in the Cascades of Oregon.
- Use the Passport in Time program or the Heritage Expeditions program to rebuild a replica of the Silent Creek Ranger Station. This location could be used for an annual living history program interpreting early Forest Service days.
- Interpret the rise and fall of sheep grazing in the study area; how the practice came to be and how it developed; the influence seen today in place names, and forest and park boundaries; and the effects of World War II and the creation of synthetic fabrics on grazing. A potential location for this could be the Kelsay Valley horse camp vicinity.
- Interpret Civilian Conservation Corps (CCC) history in the study area. Keep and maintain the CCC developed/improved Thielsen Creek Forest Camp location along Highway 138 in a manner that is compatible with riparian needs. Use the CCC style in picnic tables and fireplaces. Discuss the importance of the North Umpqua Road access to the area and its improvement by the CCCs, as well as CCC improvements to recreation camps.
- Continue to preserve Civilian Conservation Corps history by establishing a rental plan for the “sleeping cabin” at Diamond Lake. This plan should be compatible with the building’s use and finance needed “in kind” repairs, upkeep, and interpretation for the structure.
- Interpret the natural history of the Diamond Lake area, the wildlife, the lake, and the fishery at the Lake Creek outlet area. This would include fish stocking, the early hatchery years, and the 1954 drawdown remains visible at the outlet area. The hatchery buildings should be evaluated for inclusion to the National Register of Historic Places. The use of these buildings as a natural history interpretive center would be appropriate, should they become available.
- Interpret the John Day Road, an early supply and travel route. This can be done on site at the Mt. Thielsen viewpoint on Highway 230.
- Continue to provide interpretive discussions and displays on Indian life ways.
- Foster respect and understanding of history and prehistory in every interpretive presentation. Educate visitors about the damage recreational collecting can create.
- Interpretive programs, displays, and texts with historic themes provided by the Forest Service or by permit holders on the Forest should be reviewed for historic accuracy prior to use.

CHAPTER SIX

LIST OF PREPARERS

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- A.S. Natural Resources - Haskell Indian Nations University, Lawrence KS, 1997
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- Wildlife Management, Univ. of Massachusetts, 1979
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CHAPTER SEVEN

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