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ENVIRONMENTAL

Long Creek Watershed Analysis Resource Assessment Report

Project 68-003

Prepared for:

Weyerhaeuser Company

Prepared by:

Pentec Environmental, Inc.
120 West Dayton, Suite A7
Edmonds, Washington 98020
(206) 775-4682

February 22, 1994

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LONG CREEK WATERSHED ANALYSIS
RESOURCE ASSESSMENT REPORT

1.0 INTRODUCTION AND TEAM PERSONNEL

1.1 BACKGROUND AND PURPOSE

Natural resource managers in the upper Klamath River basin are concerned about the potential cumulative effects of forest practices on fish habitat and water quality in the Long Creek basin. Long Creek provides habitat for brook, redband, and bull trout. Bull trout populations have been depressed throughout the Klamath basin and elsewhere; therefore, resource managers are very concerned about any potential impacts to the remaining populations. In response to this concern, Weyerhaeuser Company initiated an investigation to develop a better understanding of watershed processes and management activities contributing to cumulative effects on resources in the Long Creek basin. Specific objectives of the investigation follow:

1. To identify and evaluate basin processes potentially affecting the aquatic environment including mass wasting, surface erosion, hydrologic regime, and riparian function.

2. To determine the stream channel response to channel forming processes and the relative influence of hillslope processes.

3. To describe the fish distribution and abundance and current fish habitat conditions and identify potential habitat concerns.

4. To identify and qualify linkages among forest practices, watershed processes, and their effects on resources.

The intent of the investigation is to provide resource managers with a technical basis for developing resource management prescriptions to effectively address cumulative watershed impacts.

An interdisciplinary team of resource scientists coordinated by Pentec Environmental, Inc. (Pentec), conducted the watershed investigation during September through December 1993. The watershed analysis methodology developed under the Timber/Fish/Wildlife (TFW) Agreement in Washington State (TFW 1993) was used as a general guide for the analysis. Specific watershed and stream channel processes are evaluated and described in Sections 3.0 through 7.0. Fish resources and fish habitat concerns are described in Section 8.0. The linkages between fish habitat, channel processes, and hillslope processes are described in the Synthesis (Section 9.0), and a summary of the analysis is presented in Section 2.0. The appendix provides data and information supporting the analysis.

1.2 PROJECT TEAM PERSONNEL

This project was performed by an interdisciplinary team of natural resource scientists and forest managers. Below is a list of personnel, their responsibilities, and affiliations.

Name	Responsibility	Affiliation
Lee Benda, Ph.D.	Mass Wasting Assessment Stream Channel Assessment	Independent consultant
Carol Coho, M.S.	Hydrology Assessment Surface Erosion Assessment	Pentec Environmental, Inc.
Terry Cundy, Ph.D.	Hydrology Technical Support	University of Washington, College of Forest Resources
Jeffery Light, M.S.	Technical Reviewer	Weyerhaeuser Company, Technical Center
Douglas Martin, Ph.D.	Technical Team Leader Fish Habitat Assessment	Pentec Environmental, Inc.
Jeff Johnson	Area Forest Manager	Weyerhaeuser Company, Klamath Falls
Chris Sokol	Regional Forest Manager	Weyerhaeuser Company, Klamath Falls
Kate Sullivan, Ph.D.	Technical Reviewer	Weyerhaeuser Company, Technical Center
Kathy Welch, M.S.	Riparian Assessment	Pentec Environmental, Inc.

2.0 WATERSHED ANALYSIS SUMMARY

2.1 WATERSHED OVERVIEW

2.1.1 Location and Description

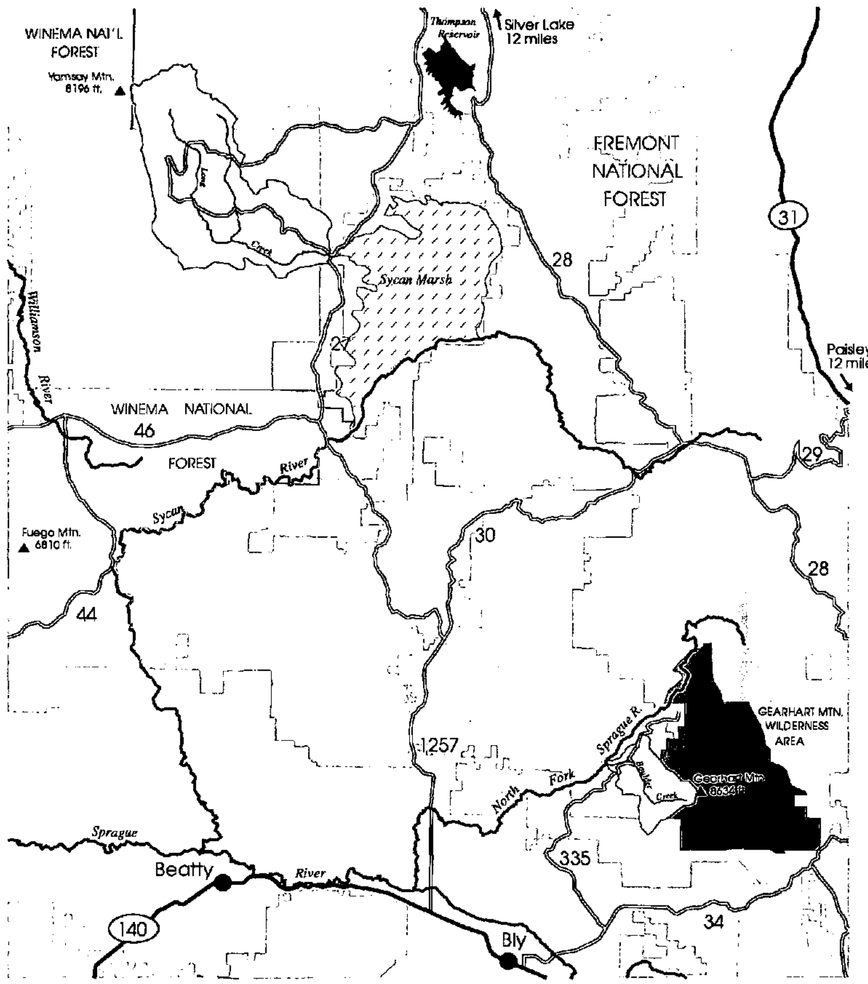
Long Creek is a fourth order (Strahler Method, Strahler 1952) tributary to the Sycan River in the upper Klamath River basin of south central Oregon (Figure 2-1). The basin drains an area of 26,421 acres and is formed by the mainstem, Calahan Creek, and a number of smaller first to second order tributaries (Figure 2-2 and Table 2-1). Many of these tributaries are intermittent and only flow during the spring runoff period. Springs contribute a significant source of water especially for the smaller perennial tributaries.

The Long Creek basin occurs in the basin-range physiographic region that originated by regional faulting during the Pliocene Epoch. It is characterized by fault block valleys bounded by steep scarp slopes and gently sloping to level plateaus (Duncan and Steinbrenner 1975). Long Creek occurs on a high lava plain that was formed from a complex of volcanic material including andesite and large pumice deposits. The location of more resistant rock strata controls the spatial distribution of certain channel gradients in the Long network (steeper canyons separating lower gradient reaches) and may control the location of a large meadow. These breaks in topography are steep, giving a bench-like appearance to the region.

Soils associated with the lava plains are composed of fine volcanic ash over deeply weathered basaltic rocks, tuffs, and buried soils developed from basaltic residuum and older volcanic ash. They are often stony, containing boulders weathered from pillow lavas. Meadows have clay-textured soils, which are remnants of old shallow lakes. Springs are often associated with these meadows (Duncan and Steinbrenner 1975).

The Long Creek basin lies within the "sub-humid" climatic zone at elevations ranging from 5,040 to 7,800 ft. Because the basin is located in the rain shadow of the Cascade Mountains, the area is relatively dry. Average annual precipitation ranges from 10 inches at lower elevations to 25 inches at higher elevations. Most precipitation occurs as heavy winter snow, and little rain occurs during the growing season. Mean annual temperatures range from 45 °F at low elevations to 41 °F at higher elevations (Duncan and Steinbrenner 1975).

Long Creek Watershed



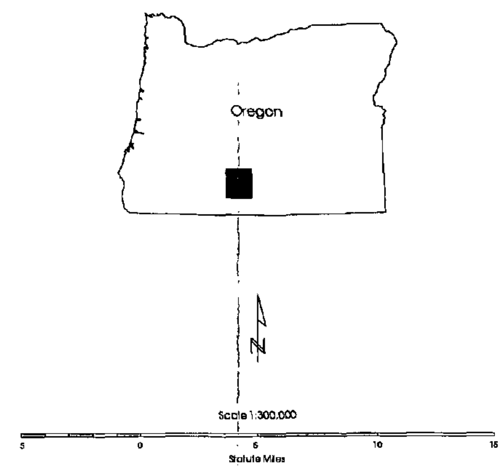


Figure 2-1
Watershed location.

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Long Creek Watershed

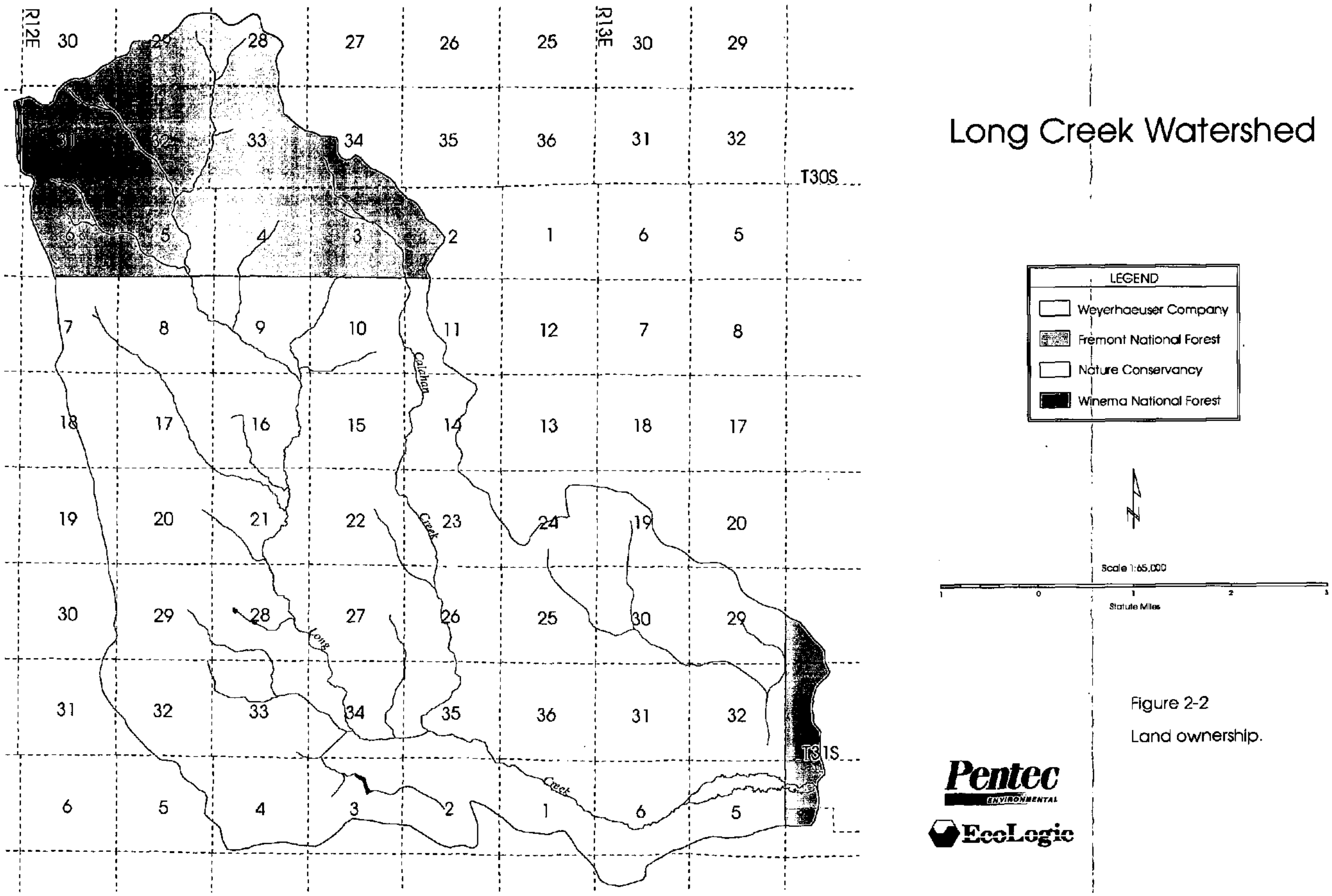

Figure 2-2
Land ownership.

Table 2-1 General characteristics of the Long Creek watershed.

	Subbasin				
Characteristic	USFS	Long	Calahan	Detached	Total
Area (acre)	3.442	16.377	3,787	2816	26,422
Elevation range (ft)	6.200-7.600	5.040-7.800	5,420-7,670	5.090-6.000	5,040-7,800
Stream length (mile)	8.2	33.3	8.7	5.9	56.2
Stream density (mi/mi^2)	1.52	1.3	1.48	1.35	—
Road length (mile)	3.5	149.7	33.1	20.3	206.5
Road density (mi/mi^2)	0.65	5.85	5.59	4.61	—

LENGTH
33.3 MILES

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Vegetation in the Long Creek basin is primarily ponderosa pine with bitterbrush and grasses at the lower elevations where there is lower precipitation. Manzanita, snowbrush, and white fir occur at higher elevations where there is higher precipitation. Lodgepole pine occur on poorly drained soils in slight basin-like depressions (Duncan and Steinbrenner 1975).

2.1.2 Land Use

Forest lands in the Long basin are managed by the Weyerhaeuser Company and the Fremont National Forest. The lower portion of the basin (78 percent) is owned by Weyerhaeuser and is managed for timber production (Figure 2-2). The upper portion of the basin (21 percent) is managed by the Fremont National Forest. A small portion of the basin (< 1 percent) located in the Sycan Marsh is owned by the Nature Conservancy. Partial-cut and clear-cut logging has occurred on the Weyerhaeuser land since the 1940s. Some timber harvest has occurred on the Forest Service lands. Much of the Weyerhaeuser land and some of the forest service land has also been used for cattle grazing. The basin has 206.5 mi of roads and road density ranges from 0.65 to 5.85 mi/mi^2 (Table 2-1).

2.1.3 Fish Resources and Habitat Issues

Long Creek provides habitat for brook, redband, and bull trout. Fish occur primarily in the mainstem channel up to the headwaters, in most of Calahan Creek, and in the lower portion of perennial tributaries. Fish access from the Sycan River to Long Creek is partially inhibited by an irrigation diversion dam at the mouth, and a 1.2-m-high waterfall at the US Forest Service (USFS) boundary is a barrier to upstream fish movement. Resident bull trout are isolated in a 2.6 km reach upstream of the barrier falls. Redband and brook trout occur downstream of the falls. All fish populations are currently maintained by natural reproduction; however, redband trout were supplemented by hatchery stocking in the past. The abundance of brook and redband trout is unknown, but the abundance of bull trout was determined by the Oregon Department of Fish and Wildlife (ODF&W) in 1991 (Dambacher et al. 1991). Bull trout densities in upper Long Creek were 319/km, which is one of the highest densities of bull trout recorded in the upper Klamath region.

The viability of the small isolated bull trout population in Long Creek is a concern of fisheries resource managers. Historically, bull trout most likely occurred throughout the Long Creek basin (anecdotal evidence, Ziller 1992), but competition with brook trout and habitat degradation are suspected to have impacted the population. In a study of bull trout population status in Oregon, Ratliff and Howell (1992) ranked the population in Long Creek as having a moderate risk of extinction. Low populations of bull trout in the Klamath basin in general have caused the Oregon Chapter of the American Fisheries Society to petition the US Fish and Wildlife Service (USFWS) to conduct a status review for the purpose of listing bull trout as a threatened or endangered species (OCAFS 1993). In response to this petition and another, which included bull trout populations throughout the Pacific Northwest, the USFWS initiated a status review in October 1992. This review is currently in progress and is not expected to be completed until spring 1994.

Habitat concerns in Long Creek include the loss of stream shading and large woody debris (LWD) recruitment from timber harvest and cattle grazing of the riparian zone, siltation of spawning gravels from hillslope and road surface erosion, and stream bed scour from changes in basin hydrology.

2.2 WATERSHED PROCESSES AND RESOURCE CONDITION

Changes in watershed processes due to timber harvest and cattle grazing that affect the formation of fish habitat by changes in basin erosion, LWD recruitment, stream shading, basin hydrology, and stream bank vegetation were identified and evaluated. Basin areas that influence the delivery of watershed input variables and that are directly linked to potential impacts on fish resources are identified and delineated. These areas are called resource sensitive areas and are shown in Figure 2-3. A summary of potential impacts on fish resources for each watershed input variable is presented in the following sections.

2.2.1 Fine Sediment from Hillslope and Road Surface Erosion

Soils within the entire Long Creek watershed are highly erosive. Areas without a protective organic layer from understory vegetation and forest debris are prone to gullying regardless of hillslope gradient. Clearcut areas had the worst erosion and partial-cut areas were prone to less severe gullying. Delivery of sediment to stream channels is greatest from riparian zones and steep slopes adjacent to riparian zones where the protective organic layer has been disturbed or removed (Figure 2-3). Areas that lack low gradient slopes (i.e., grade buffer) adjacent to the streams enable displaced sediments to enter the stream channels. Cattle grazing has reduced understory vegetation, suppressed vegetative recovery, and contributes to the lack of organic layer development in some riparian areas.

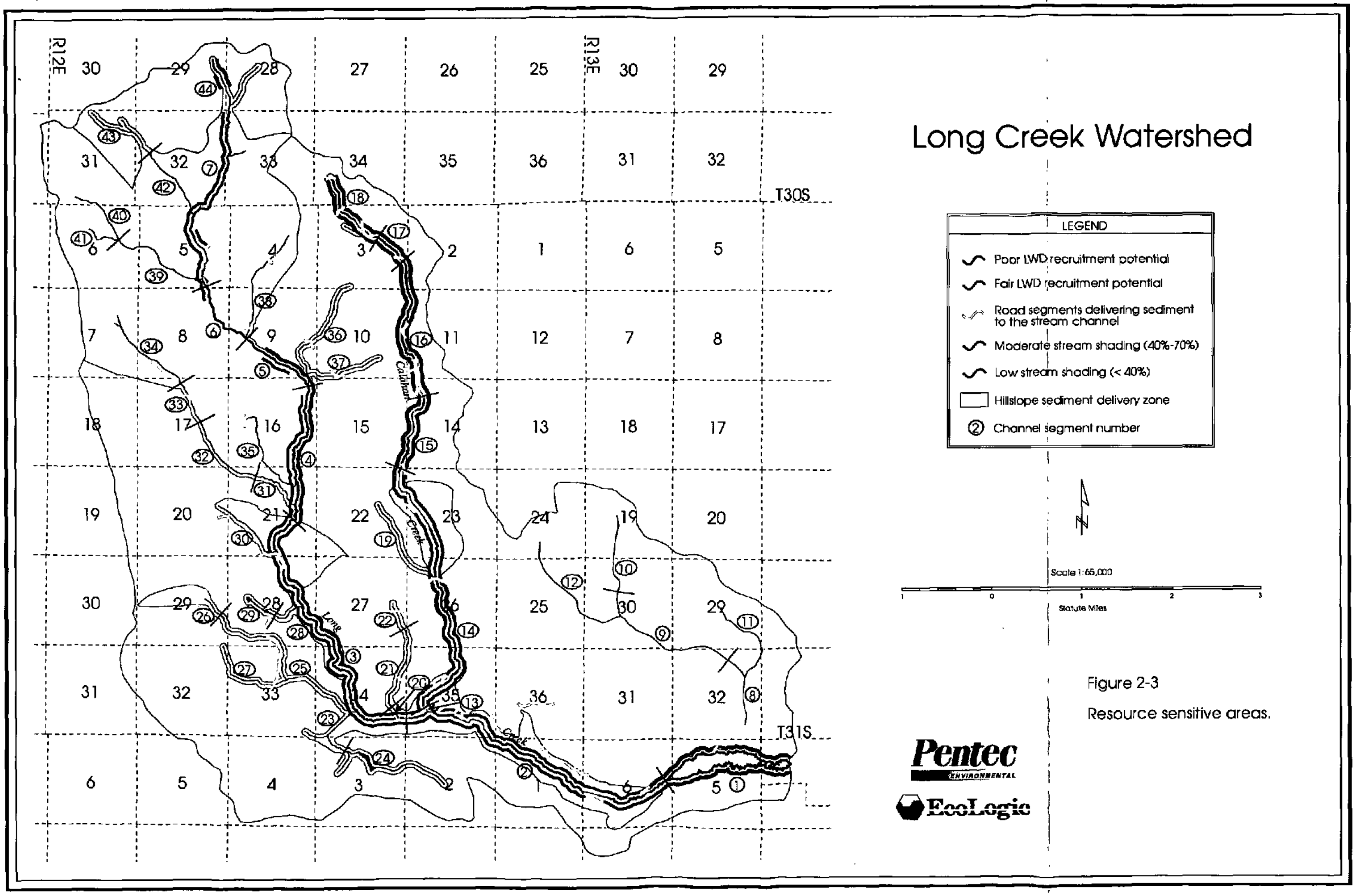

Figure 2-3

Resource sensitive areas.

Erosion of the road prism is widespread; however, delivery of sediment to the stream channel is limited to a small portion of the road system (Figure 2-3). These roads either cross the stream channels or are close enough to the channels to contribute sediment. Increases in sediment yields ranged from 21 percent in the USFS subbasin, to 287 percent in the Calahan subbasin.

Surface erosion from hillslopes and roads has contributed fine sediment to the stream bed and has affected the quality of spawning gravels in Long Creek. Moderate to high levels of fines occur in many of the low gradient segments that are most likely utilized for spawning for brook and redband trout. Fine sediments are not a potential problem in the upper segments of Long Creek where bull trout currently exist. Moderate levels of fine sediment occur in boulder/cascade areas and may reduce the amount of interstitial habitat available for fish cover.

2.2.2 Large Woody Debris and Riparian Vegetation Conditions

Clear cutting and partial cutting in or near the riparian zone and cattle grazing is responsible for reducing the amount of large size timber available for LWD recruitment to the stream (Figure 2-3). Riparian areas in several meadows are lacking any riparian vegetation including shrubs, and other forested areas with poor to moderate LWD recruitment potential are composed of either deciduous trees or small conifers. Neither of these conditions provides timber large enough to provide LWD. Recovery of the most severely impacted areas, which is a small portion of the stream network excluding meadows (Figure 2-3), may take 35 to 80 years.

LWD levels in several segments of Long Creek and a large portion of Calahan Creek are relatively low as a result of riparian disturbances. LWD is important for the formation of pools and complex cover habitat. Pool frequency is relatively low in several reaches of Long and Calahan creeks that have a low amount of LWD; therefore, past reductions of LWD may be affecting the amount of available rearing habitat.

2.2.3 Water Temperature, Stream Shading, and Riparian Vegetation Conditions

Water temperature data from summer 1993 indicated that the maximum water temperature in Long Creek is above 15 °C for short periods at lower mainstem locations and below 15 °C in the upper mainstem. Because bull trout are generally found in streams where the maximum water temperature is less than 15 °C, there is a potential concern for factors affecting water temperature in the lower mainstem. Comparisons of stream shade levels to temperature data indicated that water temperature increased in the meadow segments and other segments where trees provide < 40 percent shading (Figure 2-3). Moderate levels of shading in the Long Creek canyon did not influence water temperature suggesting that topographic shading from the canyon walls may override the effects of vegetative shading in this segment.

Several natural meadows on Long Creek had more impact on stream water temperature than did reduced shading in forest segments by logging activity. Heavy cattle grazing in the meadows and adjacent stream segments has significantly reduced shading from willows and other shrubs and has suppressed the growth of any riparian vegetation that could shade the stream.

2.2.4 Changes in Basin Hydrology

The lack of long-term streamflow data precluded any analysis of actual changes in flow that may have occurred within the Long Creek watershed. An analysis of stream flow from gaged basins in the vicinity of Long Creek indicate that annual peak discharge within the Long Creek watershed is dominated by spring snowmelt runoff. Studies on the effects of timber harvesting on the seasonal hydrograph of other managed basins suggest that the peak discharge on Long Creek may be occurring earlier in the spring, compared to the timing of the peak runoff before the basin was harvested. These studies also suggest that peak flows during spring may be slightly higher than they were prior to harvesting.

Bed Scour

Increases in peak flow are a concern because they can cause stream bed scour that may result in redd loss and disturbance of fish rearing habitat. An analysis of potential changes in peak flow suggests a moderate increase in peak flow may occur with the current level of timber harvest in Long Creek. An analysis of channel morphology, however, indicates there is no current evidence of significant scour in Long Creek. This suggests potential impacts from changes in basin hydrology have probably not had a significant effect on fish habitat.

Tree root

2.2.5 Loss of Streambank Vegetation

Riparian vegetation (i.e., shrubs and small trees) directly adjacent to the channel in meadows and adjacent stream segments has been significantly reduced and continues to be suppressed by cattle grazing. Because vegetation along the stream banks directly affect bank cohesiveness, reductions in vegetation density have resulted in the loss of undercut bank and pool habitat. Bank trampling and the loss of streambank vegetation by cattle has resulted in bank erosion that indicated that water temperature increased in the meadow segments and other segments where trees provide <40 % shading (Figure 2-3). Moderate levels of shading in the Long Creek canyon did not influence water temperature suggesting that topographic shading from the canyon walls may override the effects of vegetative shading in this segment.

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3.0 MASS WASTING ASSESSMENT

3.1 LANDSLIDE INVENTORY

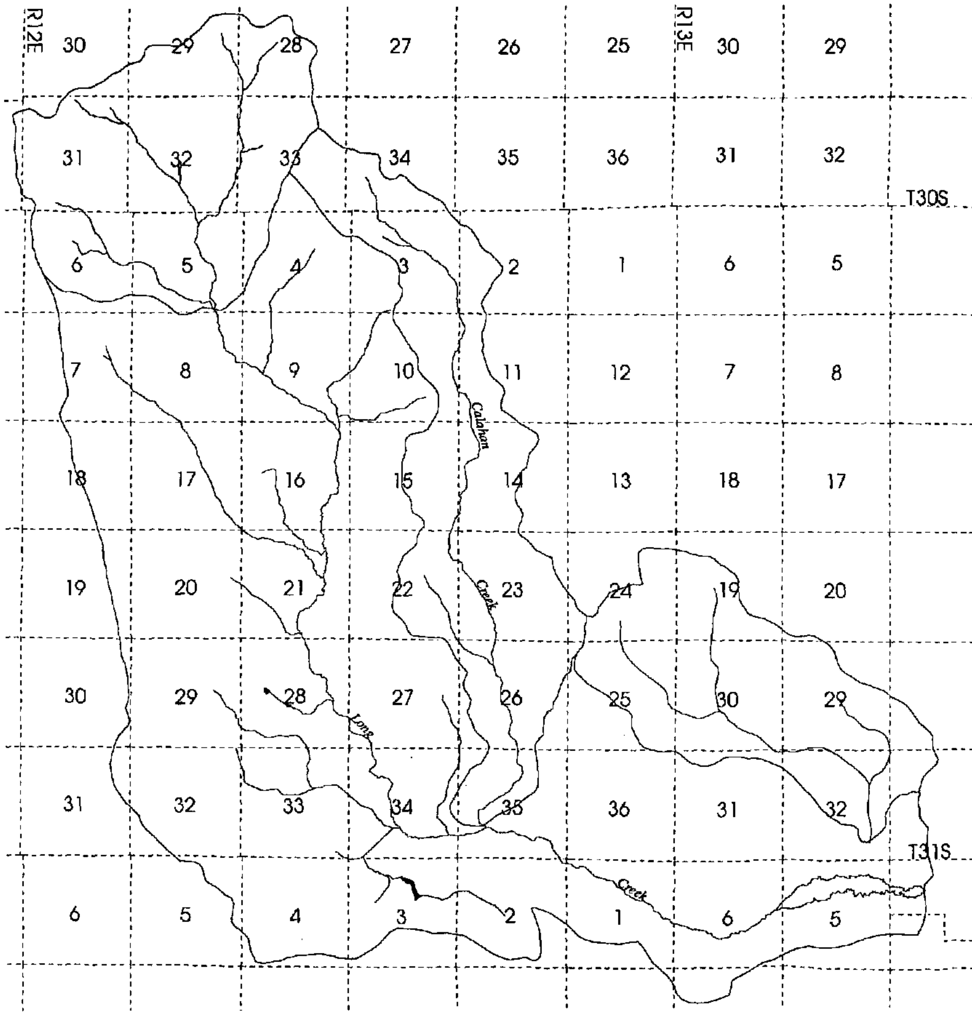
Landsliding is a relatively minor process in the Long Creek watershed. Only one landslide/debris flow was inventoried in the basin (Figure 3-1), and it appeared to be a natural event. The absence of steep slopes in combination with low precipitation results in low landslide occurrence. In addition, harvesting and road construction have apparently not triggered any landslides; therefore, loss of rooting strength and increases in soil saturation are not related to landsliding in the Long Creek basin.

The single landslide that occurred in upper Long Creek originated at a rock outcrop at the head of a bedrock hollow in T31S, R12E, Section 32.

3.2 EFFECTS OF FORESTRY ACTIVITIES ON SLOPE STABILITY

The landslide that was inventoried in the Long Creek watershed was not associated with land use activities; it was a naturally occurring event. Hence, it was not possible to analyze the effects of forestry activities on mass wasting in the Long Creek basin.

Long Creek Watershed



LEGEND

Landslide

Scale 1:65,000

1 0 1 2 3

Statute Miles

Figure 3-1

Mass wasting.

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4.0 SURFACE EROSION ASSESSMENT

4.1 INTRODUCTION

Surface erosion occurs when soil is detached from the hillside by overland flow or rainfall impact. Surface erosion can be exacerbated by anthropogenic activities that tend to remove any natural protective layer. This protective layer is composed of organic material which acts as an energy dissipator for both rainflow and surface flow. Human activity in the form of building structures and harvesting timber greatly disturbs the ground surface, often removing this organic layer. This report focuses on the effects of timber harvesting on surface erosion.

Contribution of sediment to stream channels in the form of surface erosion is the focus of this assessment. Undisturbed hillsides within the basin and range region of southern Oregon are usually not prone to significant overland flow or surface erosion. Disturbed areas, in the form of tractor tracks, skid trails, and roads, act as conduits to overland flow and may deliver fine sediments to stream channels. Compaction of the soil by heavy equipment increases overland flow because of decreased infiltration causing rills and gullies to form. Once formed, these conduits erode their own banks, increasing in width and depth and increasing the amount of sediment transported. Sediment transport will continue as long as conditions are favorable. Several factors can prevent sediment from reaching stream channels such as a decrease in slope, an increase in organic layer on top of the soil, or an increase in infiltration capacity of the downslope soil.

The Long Creek basin has been delineated into four subbasins for purposes of this assessment (Figure 4-1). The subbasins include the USFS subbasin, which ranges from the headwaters of Long Creek downstream to the Fremont National Forest-Weyerhaeuser boundary. Calahan Creek was assigned its own subbasin which includes the entire Calahan Creek watershed. The easternmost tributary from the north is referred to as the Detached subbasin. The word "detached" is used because streamflow from this basin forms distributaries as it enters the edge of the Sycan Marsh. None of these distributary channels form confluences with Long Creek. The remaining portion of Long Creek is the fourth subbasin and is referred to as the Long subbasin.

Long Creek Watershed

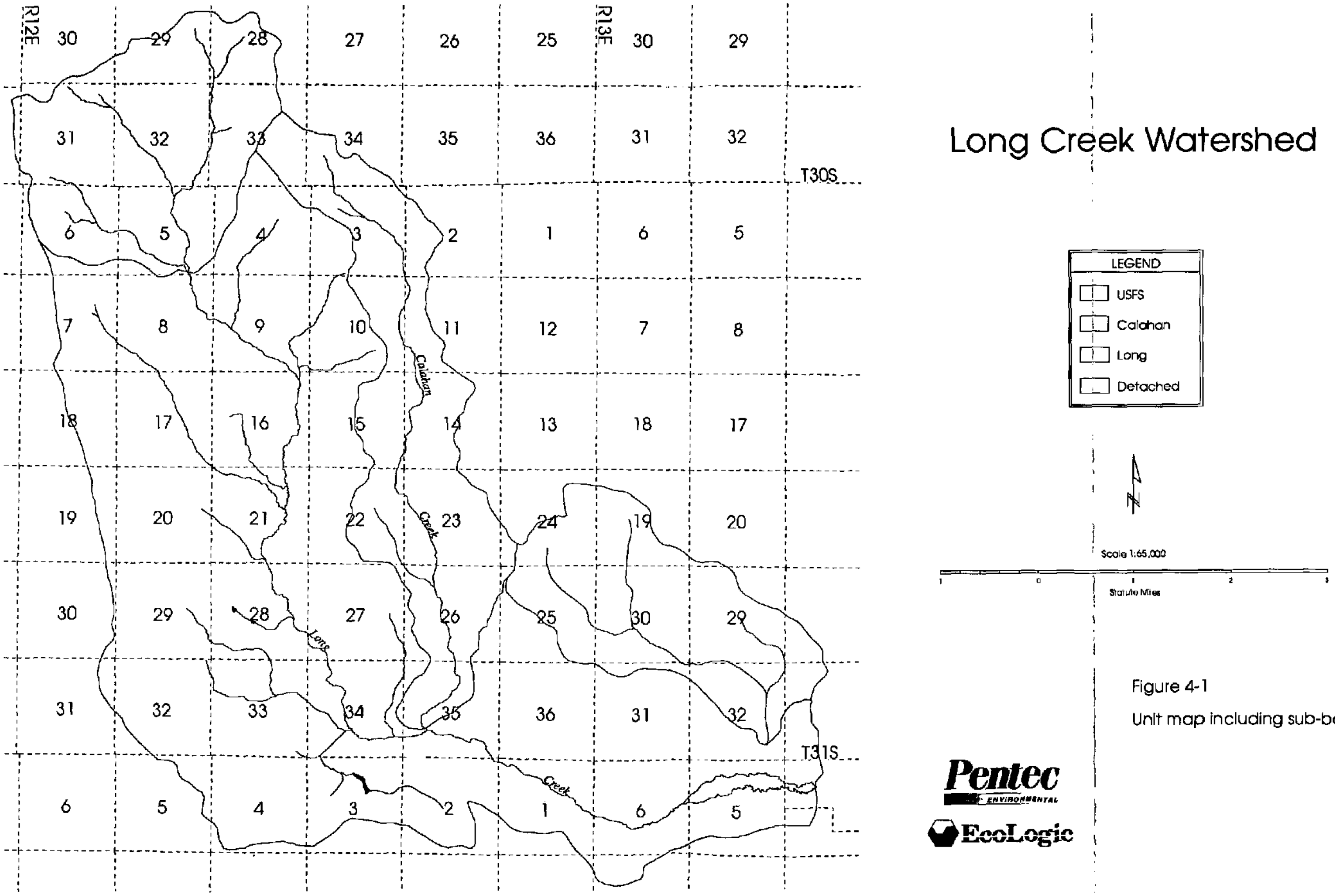

Figure 4-1
Unit map including sub-basins.

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4.2 GEOLOGY OF THE LONG CREEK WATERSHED

The Long Creek watershed drains the southeast slope of Yamsay Mountain (elevation 8,196 ft). Almost the entire basin is underlain by Pliocene and Miocene Olivine basalt—thin, commonly open-textured (dikytaxitic), subophytic to intergranular, intercalated with and grades laterally through palagonite breccia and tuff into tuffaceous sedimentary rocks. The areas shown in Plates 4-1 and 4-2, which are discussed in Section 4.4 (sections 29 through 32 of Township 31S, Range 13E) are underlain by Pliocene, Miocene, Oligocene and Eocene Silicic vent rocks—plugs and domal complexes of rhyolitic, rhyodacitic, and dacitic composition. Near-vent flows, flow breccia, and deposits of obsidian, perlite, and pumice also occur in the basin.

4.3 SOILS OF THE LONG CREEK WATERSHED

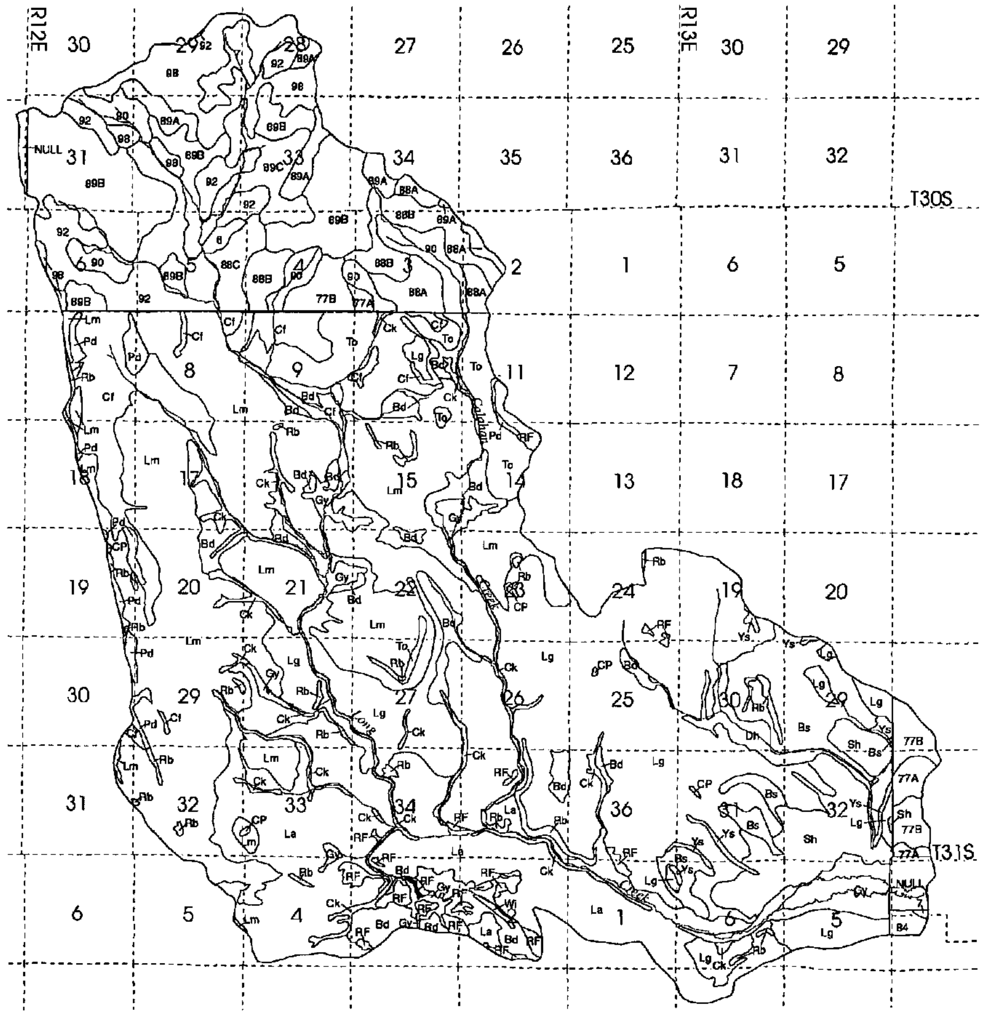
The portion of the Long Creek basin owned by the Weyerhaeuser Company has been delineated into 17 different soil series. Descriptions of the soil series according to Duncan and Steinbrenner (1975) follow, and the locations are shown in Figure 4-2.

Bedpan Series (Bd). The Bedpan series is forming in 30 to 36 inches of pumice deposited over an older loam or clay loam textured alluvial soil. The series occurs in upland basin positions at elevations of 5,000 to 6,500 feet in the East Block and is timbered with lodgepole pine. The upper profile consists of two to three feet of brown, medium and coarse pumice with a loamy-sand texture that is loose, friable and rock-free. The subsoils are reddish-brown, stony loam or clay loam alluvium containing from 20 to 40 percent rock. A seasonally fluctuating water table may occur between 30 and 40 inches, becoming shallower toward the center of the basin. These basins are subject to frost at any time of the year with a high probability of frost heaving.

Blaisdell Series (Bs). The Blaisdell series is made up of stony loam soils developed from volcanic ash and colluvium derived from glassy rhyolitic rocks. They occur in the East Block on gentle to steeply sloping uplands at elevations of 5,000 to 6,000 feet with 20 to 25 inches of precipitation. The topsoil is a dark brown, granular loam about 6 to 8 inches thick. Subsoils are weakly structured stony loams. Total soil depth ranges from 36 to 60 inches. Rock is distributed throughout the profile, ranging from 20 to 40 percent in the upper profile and 80 to 90 percent in the lower subsoils. Some profiles are developed from a glassy, ashflow tuff containing pumice, obsidian, and rhyolite. On steep topography, this soil can be eroded if runoff waters are allowed to become channeled.

Chucktoot Series (Ck). These soils are moderately deep and loam textured, developing from alluvium of Recent age. They occur along small drainageways at elevations of 5,000 to 6,000 feet in the North and East districts of the tree farm where precipitation ranges

Long Creek Watershed



LEGEND	
Weyerhaeuser Soil Types:	USFS Soil Types:
Bd - Bedpan	6
Bs - Blaisdell	7
Cf - Coffeepot	77a
Ck - Chucktoot	77b
Gy - Guyer	84
Ht - Hoyt	88a
La - Lapine	88b
Lg - Longbell	88c
Lm - Lamm	89a
Pd - Paddock	89b
RF - (rockflat)	89c
Sh - Shanahan	90
To - Toolbox	92
Ys - Yoss	98

Scale 1:65,000

1 0 1 2 3

Statute Miles

Figure 4-2

Soil types.

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EcoLogic

from 20 to 25 inches. They have granular loam topsoils from 7 to 12 inches thick and loam subsoils with weak subangular-blocky structure. Lenses of fine pumice often occur in units associated with the Lapine and Longbell series. A water table is encountered between 20 and 30 inches, becoming higher close to the streams. Stones may be scattered throughout the soil profile but normally make up less than 10 percent of the soil volume.

Cinder Pit (CP). This miscellaneous mapping unit covers 286 acres of which 194 acres are Weyerhaeuser-owned. It consists of open excavations where cinders have been quarried for use in road construction.

Coffeepot Series (Cf). The coffeepot series is developing from coarse textured colluvium composed of andesite and pumice over a substratum of siliceous rocks consisting of rhyolites, ashflow tuffs and felsites. These soils occur on gentle to steeply sloping uplands surrounding old volcanic eruptive centers at elevations of 5,000 to 7,000 feet on the East Block with an average annual precipitation of 20 to 25 inches. They have a dark grayish-brown sandy loam topsoil from 4 to 8 inches thick and a weakly developed sandy loam subsoil containing about 10 percent rock. A buried soil is encountered at about 15 inches. This is a pale brown sandy loam, 36 to 60 inches deep containing 20 to 50 percent rock. Below this buried soil is fractured, light-colored andesite and felsite. Small inclusions of the shallow stony Paddock series may occur in some of the mapping units.

Deadhorse Series (Dh). The Deadhorse series contains imperfectly drained, gravelly loam soils developing from volcanic ash and rhyolitic alluvium. They occur along small drainageways emanating from rhyolitic uplands on the East Block at elevations of 5,000 to 6,500 feet where the average precipitation is 20 to 25 inches. Typically, they have brown, loam-textured topsoils about 8 inches thick and grayish-brown, gravelly loam or clay loam B horizons extending to about 25 inches. Parent materials are gravelly alluvium containing 60 to 80 percent gravel. A silica cemented pan often occurs at about 25 inches in depth. Over this pan is a perched water table. Mottling occurs in the subsoils of all profiles. Total soil depth varies from 25 to 36 inches and rock content from 20 to 40 percent. When dry, these soils are very light gray in color. Deadhorse soils are similar in appearance to the Cordelia series which is mapped on alluvial fans. Brownsworth soils are mapped in close association with the Deadhorse series but on the better drained areas.

Guyer Series (Gy). This series consists of poorly drained meadow soils occurring in upland basins at elevations of 5,500 to 6,000 feet within the pumice plains of the East Block. These soils have 1 to 2 inches of sedge peat over a grayish-brown clay topsoil. Subsoils are mostly stratified layers of clay loam or sandy loam. Total soil depth ranges from 36 to 60 inches but a water table occurs between 10 and 20 inches throughout most of the year. These soils are primarily used for grazing.

Hoyt Series (Ht). The Hoyt series consists of soils developed from a layer of pumice deposited over an older residual soil developed from deeply weathered basalt and tuff. They occur on nearly level to gently sloping uplands on the East Block at about 6,000 feet complex may occur as small inclusions within some mapping units. Principally located on the Longbell tract, some areas of Longbell soils reach into the southern portion of the Antelope tract.

Paddock Series (Pd). The Paddock series are shallow, stony soils developing from fine volcanic ash over andesite rock. The series occurs on steep slopes and ridge crests at elevations of 5,500 to 6,500 feet in the East Block under an annual precipitation of 20 to 25 inches. They have dark brown, granular sandy loam topsoils from 5 to 7 inches thick over dark brown, loamy subsoils to a depth of about 16 inches. The parent materials are fractured andesite bedrock. Total soil depth ranges from 12 to 24 inches and rock content from 20 to 80 percent. The shallower profiles may be a layer of volcanic ash over bedrock. Approximately 10 to 15 percent of the soil surface is covered by bare rock. Occurring on the steeper slopes, escarpments, and ridge crests, some rock outcrop may be associated with these soils. On the steeper terrain, inclusions of this shallow stony series will occur within units of the Coffeepot series.

Rock Flat (RF). This miscellaneous mapping unit includes non-forested areas vegetated with low sage, grasses and occasional juniper or mountain mahogany. Typically, the units contain shallow clay-textured soils containing 50 to 90 percent basaltic rock. The rock may be outcroppings of lava flows or floaters in the clay soils. In pumice areas, the surface may be covered by a few inches of pumice and ash. Many of the rock flats are slightly depressional in form with seasonally wet areas occurring near the center. A total of 49,590 acres were mapped with 14,677 acres in Company ownership. Rock flats are non-productive for timber but provide forage for livestock. These areas should present few problems in road construction.

Shanahan Series (Sh). The Shanahan series is made up of well-drained, coarse-textured soils developed from medium and fine pumice deposited over an older soil derived from fine ash and basaltic rock. The series occurs on gently sloping pumice plains at elevations of 4,500 to 6,000 feet in the East Block. The profile is characterized by a dark yellowish-brown, granular pumicy sandy loam topsoil from 9 to 12 inches thick over a subsoil of brown, very weakly structured pumicy sandy loam to a depth of 20 inches. Below the pumice mantle the buried soils are dark reddish-brown, stony, sandy loam or clay loam to a depth of 60 inches. The upper 20 inches of the profile are rock-free; the buried soil profile contains 30 to 60 percent rock. Depth of the ash surface will vary from 12 to 36 inches and depth of the total profile from 36 to 60 inches. Pumice size averages less than 2 mm in size. This series occurs in a transition zone between the coarse pumice soils of the Lapine and Longbell series and the non-pumice soils of the lava plains.

Rock Outcrop-Volcanic (Rb). This miscellaneous category contains outcroppings of volcanic bedrock. It usually occurs as rimrocks along escarpments and breaks to the streams. The areas may have a very thin soil mantle but are non-productive for timber. Of the 6,789 acres mapped, 3,532 acres are in Company ownership.

Toolbox Series (To). The Toolbox series contains coarse-textured, stony soils developed from pumice and andesitic colluvium. They occur on moderate to steep topography at elevations of 5,000 to 6,500 feet on the East Block. They are characterized by dark grayish-brown, granular, pumicy sandy loam topsoils about 12 inches thick. The subsoils to a depth of 24 to 36 inches are yellowish-brown, pumicy sandy loam. Below this depth the pumice mantle contacts a buried soil developing from fine ash and andesite. This buried soil is a dark brown, stony loam containing 40 to 80 percent rock. Thickness of the pumice surface will range from 10 to 36 inches with pumice ranging in size from very fine to larger than 4 mm. The larger pumice makes up 10 to 20 percent of the soil volume. Total soil depth ranges from 36 to 60 inches. Andesite rock is present throughout the soil, accounting for 20 to 50 percent of the soil volume. Large andesite stones occur on the soil surface. The profile is loose and very friable.

Wickiup Series (Wi). The Wickiup series includes poorly drained soils developing on coarse pumice deposited over stratified clays and sands. These soils occur in poorly drained, pumice basins timbered with lodgepole pine. The series occurs at 4,800 to 5,500 feet in elevation near Bear Flat in the Antelope unit. It is characterized by very dark grayish-brown, pumicy loamy sand topsoils about 10 inches thick and strongly mottled, pumicy loamy sand subsoils to depths of 30 inches. Below this depth, the pumice mantle contacts a buried soil which is highly mottled, stratified alluvium about 60 inches deep. The profile is wet below 20 inches through most of the year. Depth of the coarse pumice will range from 24 to 48 inches. The clay substratum ranges from 11 to 20 inches in thickness over sand or loamy sand. These soils may occur as inclusions within the Glade series.

Yoss Series (Ys). The Yoss series are shallow, stony, coarse-textured soils developing from fine volcanic ash and rhyolite. The series occurs on ridge crests and steep topography on the East Block at elevations of 5,000 to 6,500 feet. They have dark gray, granular sandy loam topsoils from 3 to 6 inches thick and stony, sandy loam subsoils to depths of 36 to 60 inches. The substratum is fractured rhyolite. Profiles on convex slopes and ridge crests may be as shallow as 18 inches. Rock makes up about 50 percent of the solum, increasing to 90 percent in the lower subsoils. On slopes with a southerly exposure, surface colors are lighter and grayer and have somewhat thinner and lighter colored topsoils. This series is associated with rhyolitic intrusive masses such as Razorback Ridge and occurs in close association with the Blaisdell series.

The portion of the Long Creek basin owned by USFS has been delineated into fourteen different series. The descriptions according to USFS (1980) follow, and the locations are shown in Figure 4-2.

Mapping Unit 6—Rugged rocky landforms at higher elevations. This mapping unit consists of steep, rocky, and stony slopes and ridges at higher elevations with stringers and patches of white fir, lodgepole pine, and whitebark pine. Trees are generally sparse and manzanita and snowbrush may be present. Soils are shallow, stony, and loamy. Bedrock outcrops are common and consist of basalt, andesite, rhyolite, and breccia. Talus areas and outcrops dominate the unit. Vegetation includes sagebrush, shrubby penstemon, ocean spray, pin cherry, pine mat, and mahogany. Slopes range up to 80 percent, and elevations range from 6,400 to 8,400 feet.

Mapping Unit 7—Alluvial-colluvial stringers. This mapping unit consists of narrow stringers of alluvial-colluvial soils occurring adjacent to stream channels. Soils are generally deep but they have a wide range of textures, drainage, gravel and stone content, and vegetation.

Mapping Unit 77A. Landtype 77A has shallow to moderately deep ashy soils over buried residual soils derived from rhyolite. Surface soil layers are very thin to thin and coarse textured. Subsoil layers are thin and coarse textured. The buried soils are moderately thick to thick, gravelly, and moderately coarse or coarse textured.

Mapping Unit 77B. Landtype 77B has shallow to moderately deep ashy soils over buried residual and colluvial soils associated with rhyolitic eruptive centers. Surface soils are very thin to thin and coarse textured. Subsoil layers are thin and coarse textured. Buried soil layers are moderately thick to thick, gravelly, and moderately coarse or coarse textured.

Mapping Unit 84. Landtype 84 has shallow to moderately deep ashy soils over buried basalt and tuff derived residual soils with ponderosa pine and lodgepole pine timber types. Surface soils are thin and coarse textured. Subsoil layers are thin to moderately thick and coarse textured. The buried soils are moderately thick, stony, and moderately fine textured.

Mapping Unit 88A. Landtype 88A has shallow to moderately deep ashy soils over reddish brown residual soils with mixed timber types. Surface and subsurface soil layers are thin and coarse textured. Buried soil layers are stony, thin to moderately thick, and medium or moderately fine textured.

Mapping Unit 88B. Landtype 88B has shallow to moderately deep ashy soils overlying buried residual and colluvial soils with mixed timber types. Surface soils are very thin to thin and coarse textured, and subsoils are thin and coarse textured. Buried soil layers are stony, moderately thick, and medium or moderately fine textured.

Mapping Unit 88C. Landtype 88C has shallow to moderately deep ashy soils overlying buried residual and colluvial soils with mixed timber types. Surface soil layers are very thin to thin and coarse textured. Subsoil layers are thin and coarse textured. Buried soils are moderately thick, stony, and medium or moderately fine textured.

Mapping Unit 89A. Landtype 89A has shallow to moderately deep ashy soils overlying buried residual soils at high elevations with lodgepole pine timber types. Surface soil layers are very thin to thin and coarse textured. Subsoil layers are thin to moderately thick and coarse textured. Buried soils are moderately thick, stony, and medium or moderately fine textured.

Mapping Unit 89B. Landtype 89B has shallow to moderately deep ashy soils overlying buried residual and colluvial soils with lodgepole pine timber types at high elevations. Surface soils are very thin to thin and coarse textured. Subsoils are thin to moderately thick and coarse textured. Buried soils are stony, moderately thick, and moderately fine to moderately coarse textured.

Mapping Unit 89C. Landtype 89C has shallow to moderately deep ashy soils overlying buried residual and colluvial soils located at high elevations with lodgepole pine timber types. Surface soil layers are very thin to thin and coarse textured. Subsoil layers are thin to moderately thick and coarse textured. Buried soils are stony, moderately thick, and moderately fine to moderately coarse textured.

Mapping Unit 90. Landtype 90 consists dominantly of Landtype 90 and minor amounts of Landtypes 7, 13, 25, and 89A. Landtype 90 is similar to Landtype 13 with the exception of vegetation type and soil drainage. Landtype 90 is similar to Unit 89A with the exception of soil depth, drainage, and position in the landscape.

Mapping Unit 92. Landtype 92 has shallow to moderately deep ashy soils overlying residual and colluvial soils at high elevations primarily on Yamsay Mountain. Surface soils are very thin to thin and coarse textured. Subsoils are thin and coarse textured. Buried soils are gravelly, moderately coarse to moderately fine textured, and moderately thick to thick.

Mapping Unit 98. Landtype 98 has shallow to deep pumiceous soils overlying buried residual soils located on high elevation upland flats. The unit is characterized by having very little ground cover vegetation, exposed mineral soil, and stunted, noncommercial lodgepole pine. Generally, the areas with the more shallow pumice units are located on Yamsay Mountain whereas the deeper units occur in the Timothy Butte-Wickiup Springs area. Surface soils are very thin or thin and coarse textured. Subsoils are gravelly, thin to thick and coarse textured. Buried soils are gravelly or cobbly, moderately coarse to moderately fine textured, and moderately thick.

4.4 SURFACE EROSION FROM HILLSLOPES ASSESSMENT

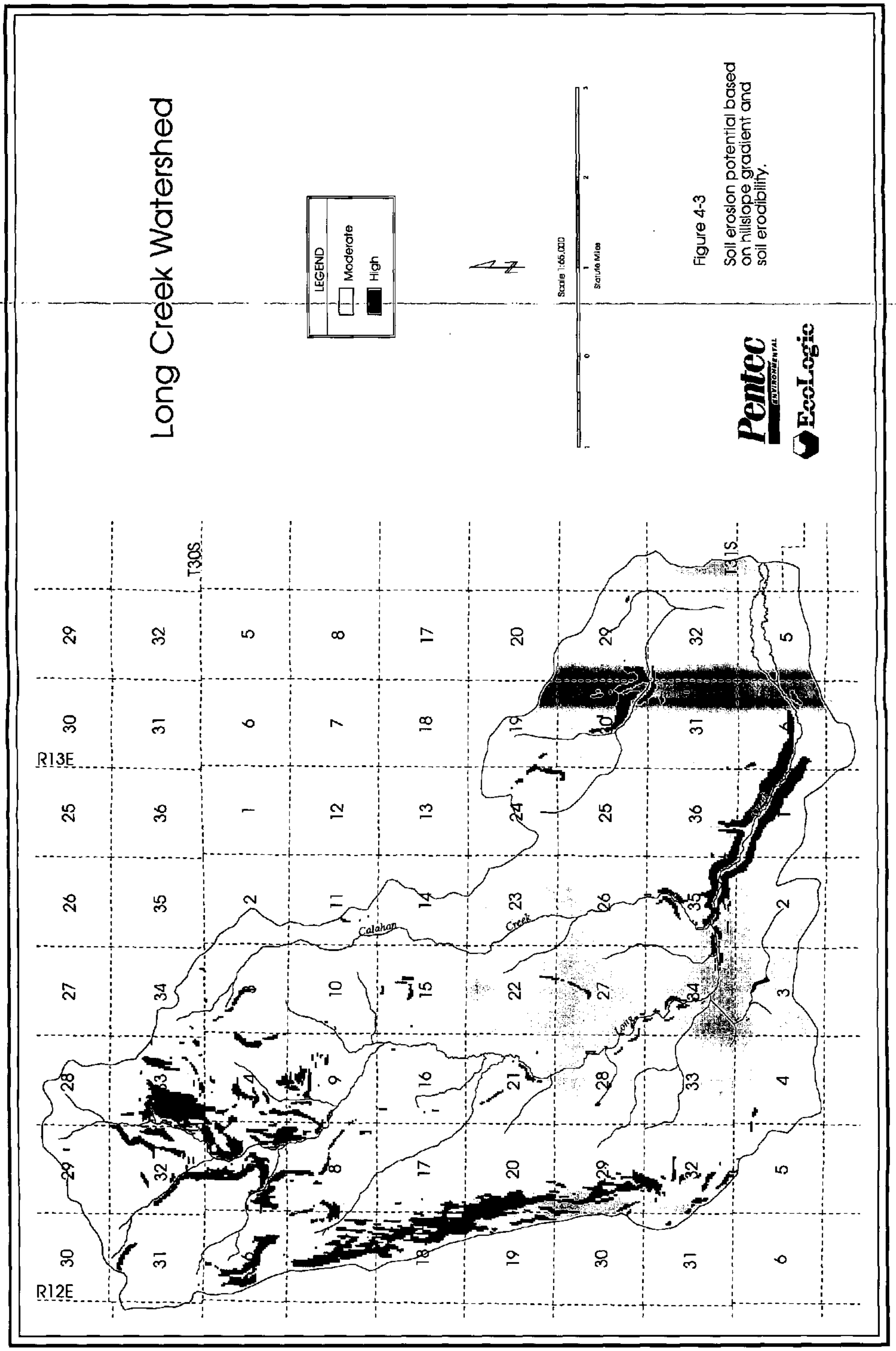
The potential for surface erosion is governed by the hillslope gradient, erodability of the soil, and vegetative cover. A preliminary soil erosion potential map was generated to reflect the first two parameters in the absence of human activity. Hillslope gradient was delineated into three classes in accordance with the Washington watershed analysis methodology (TFW 1993). Low gradient is less than 30 percent, moderate extends from 30 to 65 percent, and steep is greater than 65 percent.

Erodability was divided into three classes: low, moderate, and high (in accordance with the Washington state methodology). Normally, delineation is performed knowing the erodability "k" factor from the Revised Universal Soil Loss Equation. The "k" factor is included with all Soil Conservation Service (SCS) surveys. The Long Creek basin has not been surveyed yet by the SCS, so no "k" values were available. Erodability was not addressed within the Weyerhaeuser soil survey. Erodability was included in the soil survey conducted by the USFS. The USFS soil survey combined soil erodability characteristics and slope to determine erodability of the different units within their ownership. All of the 14 units included in the USFS survey, which are a combination of soil characteristics and slope, were rated at least moderate on a scale which included low, low-moderate, moderate, moderate-high, high, and severe. Units 77A, 84, and 88A are classified as moderate, units 90, and 98 are moderate-high, units 77B, 88B, 89B, and 98 are high, and 88C and 89C are severe. A field visit to the basin was conducted after the delineation of soils on USFS land was made. Most of the soil series within the Weyerhaeuser land were investigated and compared to the rated soils on the USFS land. When possible, areas of a particular series in undisturbed forest were compared to undisturbed USFS soils. The conclusion from the field visit was that there was no significant visual difference in erodability of soils between comparable USFS and Weyerhaeuser land.

A soil erosion potential map reflecting soil erodability characteristics and hillslope gradient was created from the above information using three classes of erodability and is shown in Figure 4-3. Only two classes of erosion potential exist: moderate and high. All areas below 30 percent hillslope gradient were assigned an erosion potential rating of moderate. All areas steeper than 30 percent were assigned an erosion potential rating of high.

Areas in which harvesting has taken place within the last 7 years are shown in Figure 4-4. Nearly all recent harvesting has been in the form of partial cutting (shown as light green). This harvesting had been extensive along Booth Ridge, on the western boundary of the basin owned by Weyerhaeuser, and just south of the Fremont National Forest boundary. Some partial cutting has occurred also along the lower mainstem of Long Creek. One area of clearcut harvesting is shown west of the mainstem of Long Creek (Township 31S, Range 12E, Section 16).

Aerial photographs from 1980 and 1993 were perused for evidence of surface erosion on the Weyerhaeuser land. Aerial photographs from 1988 of the Fremont National Forest and Winema National Forest were also perused. The scale of 1:12,000 was sufficient to identify management activity, roads, and skid trails but was insufficient to identify surface erosion on the hillslopes. The photos were useful, however, as an aid for planning the field investigation.



Long Creek Watershed
LEGEND
Moderate
High
Scale 1:65,000
Statute Miles
Figure 4-3
Soil erosion potential based on hillslope gradient and soil erodibility.
Pentec ENVIRONMENTAL
EcoLogic
R12E
R13E
T30S
T31S
Calahan Creek
Long

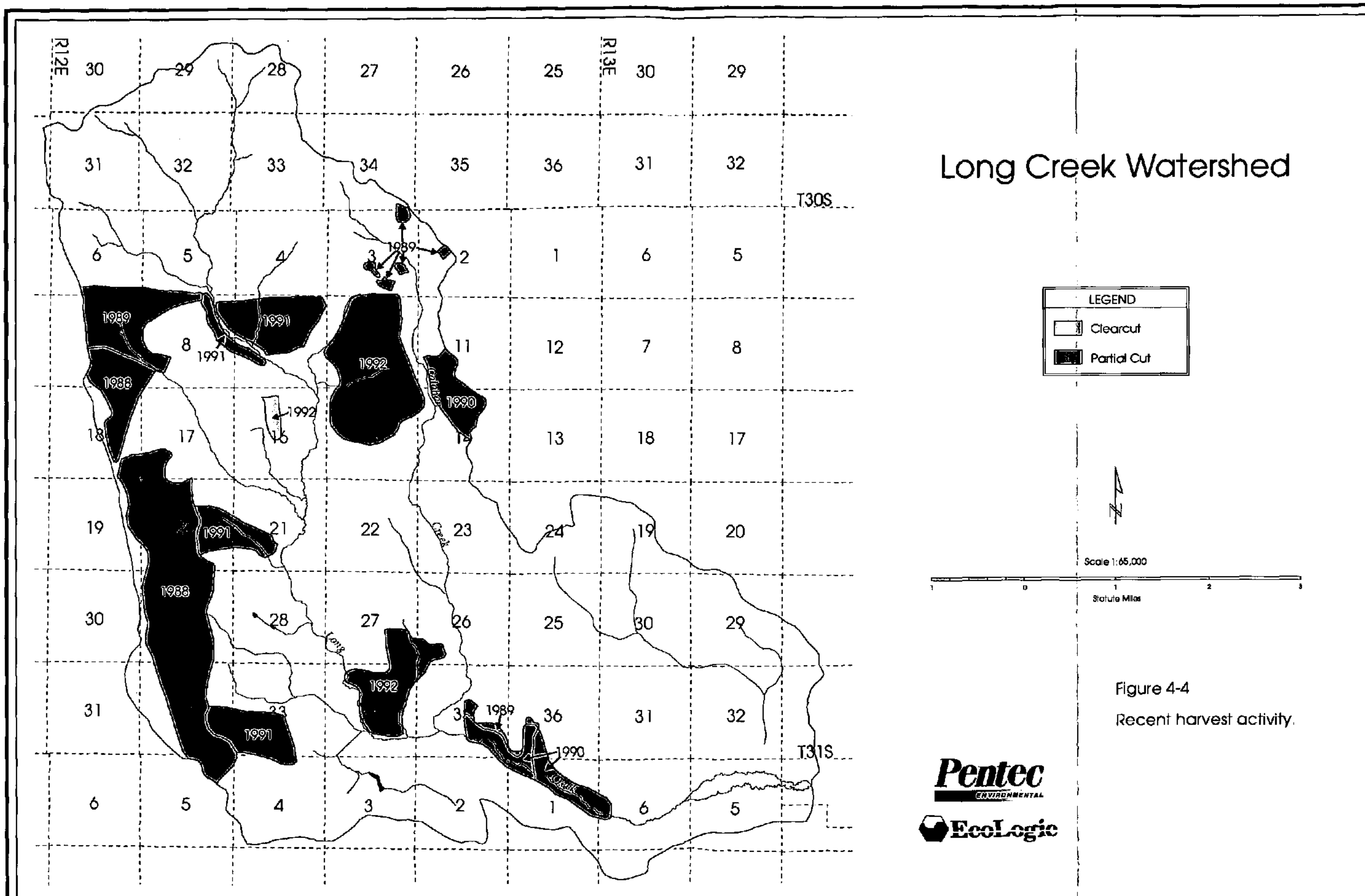


Figure 4-4
Recent harvest activity.

An overlay of recent harvest activity was placed on the preliminary erosion potential map. Areas of high erosion potential that had been harvested recently were identified as potential field sites. This field investigation involved visiting 17 different locations listed on the Hillslope Erosion Worksheet in the Appendix and shown in Figure 4-5. Descriptions of locations 1 through 17 are presented below. Photos from locations 1 through 6 are shown in plates 4-1 through 4-6.

Location 1: This area is underlain by the Shanahan soil series. The most severe gullying in the entire watershed was observed here. The area appears to have been clearcut and replanted within the last decade. No understory vegetation or organic material covers the exposed mineral soils.

Location 2: This area has been partial cut. Little understory vegetation or organic material is present. Moderate gullying is common on the 25 degree slope. A small break in grade along the stream channel is insufficient to prevent delivery of sediment from the hillslope gullies to the stream channel.

yet is mod. erosive zone

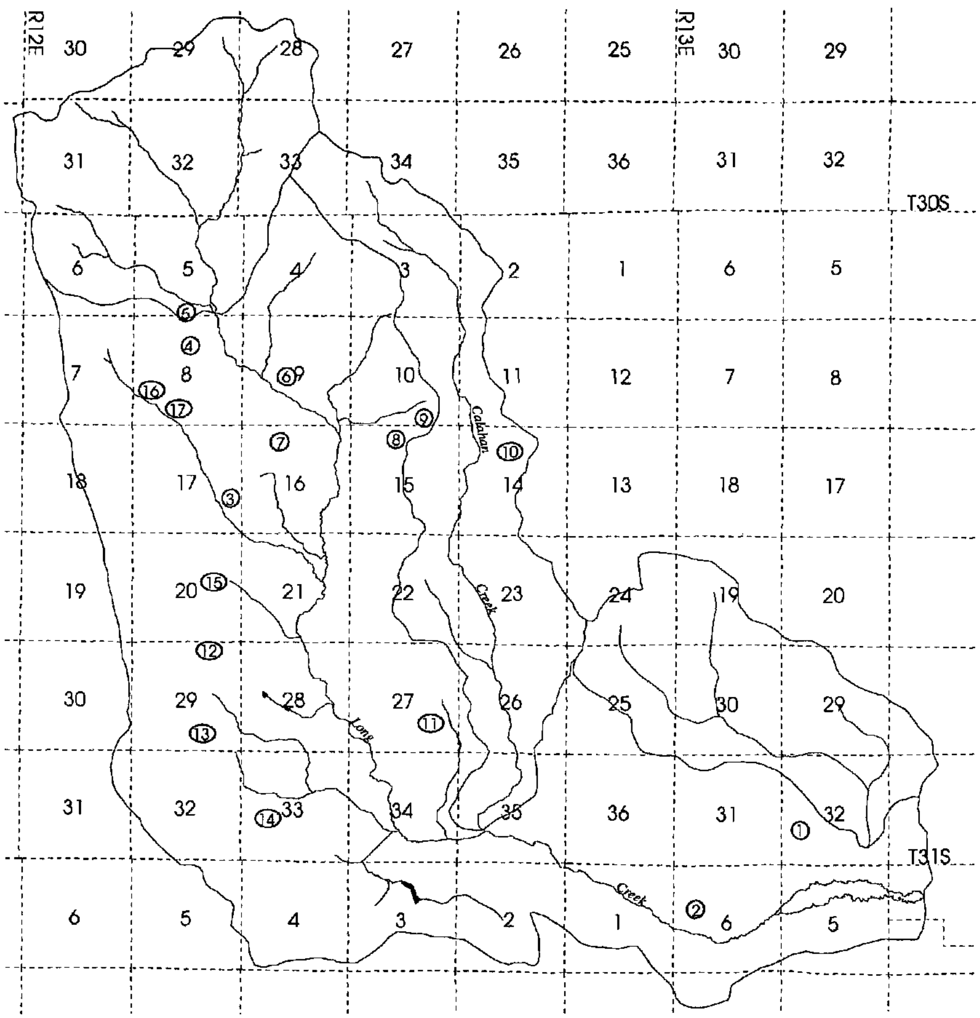
Location 3: This area is prone to severe gullying similar to that at location 1. Gullies 10 inches deep are common along the 5 to 10 degree hillslope gradient. Very little understory vegetation or organic material is present. Plate 4-4 shows organic material that has been floated into a roadside ditch.

Location 4: This area is low gradient and has been subject to heavy traffic across the entire landscape. Soils are highly compacted, and most understory vegetation has been removed. Organic material present appears to be remnants from harvesting operations. Widespread gullying is present.

Location 5: This area is close to location 4, but has not been harvested. A continuous layer of organic material 1/2 inch thick covers the soil. Understory vegetation is much more plentiful. Signs of rainsplash erosion and minor sheet flow are present. No gullying is present.

Locations 6 through 15: These areas had been partial cut or clearcut since 1988. Soils within these areas were exposed with significant gullying throughout the units. Little or no understory vegetative cover or surface litter was present. The clearcut areas had more severe gullying and less understory vegetation than the partial cut areas. These ten locations span several different soil units. No visible difference in the severity of erosion between soil units was noted for otherwise comparable locations, i.e., comparable hillslope gradient and stand density. Gullies

Long Creek Watershed



LEGEND
② Site Numbers

Scale 1:65,000

Statute Miles

Figure 4-5
Field verification sites.

Pentec Environmental
EcoLogic

Plate 4-1 Gullying on hillside at Location 1 on Figure 4-5.

00068\003\LONG\FIGURES\SECT4.PLT

Plate 4-2 More gullying on hillside at Location 1 on Figure 4-5.

Plate 4-3 Exposed and eroding soils on hillslope in Long Creek Canyon at Location 2 on Figure 4-7.

Plate 4-4 Gullying on hillside at Location 3 on Figure 4-5.

Plate 4-5 Exposed soils in skid trails at Location 4 on Figure 4-5

Plate 4-6 Forest floor in undisturbed Fremont National Forest at Location 5 on Figure 4-5.

from each location were investigated downhill to determine if sediment was delivered to the streams through these gullies. These gullies were determined to not deliver sediment to any of the streams because of hillslope gradient buffers surrounding the streams downhill from these locations.

Location 16 and 17. These areas had both been partial cut in 1989. They were very similar in appearance to most of the other harvested areas. Little or no understory vegetation or organic layer were present to protect the soil from erosion. Gullies were present throughout the units. These gullies were walked downhill and were found to contribute sediment directly to Long Creek.

The information gathered during the field investigation was used to produce the final soil erosion potential map (Figure 4-6). Generally, all areas within 200 ft of the stream channel were considered to have high erosion potential and to be capable of delivering sediment. This zone of delivery increases in size in areas of steeper hillslope gradient adjacent to the stream channel. For instance, locations 2, 4, 5, 16, and 17 are on hillslopes ranging from 10 to 30 degrees in which the hillslope gradient stays nearly constant to the stream channel edge. The remaining locations are on various hillslope gradients that are intersected by stream valley buffers or the extensive flats of the meadows. For example, location 3 is on a 25 degree hillslope that flattens to approximately 1 degree for an 80-ft distance adjacent to the stream channel. This 80-ft-wide buffer is enough to cause the gullies to dissipate. Flow from gullies into this buffer widens greatly and is impeded by the roughness of the riparian vegetation. Also, large gullies present at location 1 (Plates 4-1 and 4-2) actually form distributaries as the flow enters the western edge of the Sycan Marsh. None of these distributaries join Long Creek.

A correlation exists between surface erosion and harvest activity dating back longer than five-years which is the cut-off for "recent" management activity, as delineated in the Washington watershed analysis methodology (TFW 1993). Figure 4-4 shows harvest activity dating back to 1988. Many of the field sites were outside this recent harvest activity zone and therefore underwent management before the last 7 years. These sites showed erosion comparable to or sometimes more severe than the more recently managed sites (i.e., Location 1 on the Shanahan soil formation). Excluding hillslope gradient, the rate of surface erosion is related to the amount of organic material on the soil surface and understory vegetation. For instance, the extent of erosion at Locations 12 through 15 and Location 17 are comparable. Locations 12 through 15 were harvested from 1988 to 1991, and Location 17 was harvested in 1977. The amount of understory vegetation in both areas is similar and minimal, which has exacerbated the surface erosion. Timber regeneration in the Klamath basin (which averages 9 inches of precipitation

Long Creek Watershed

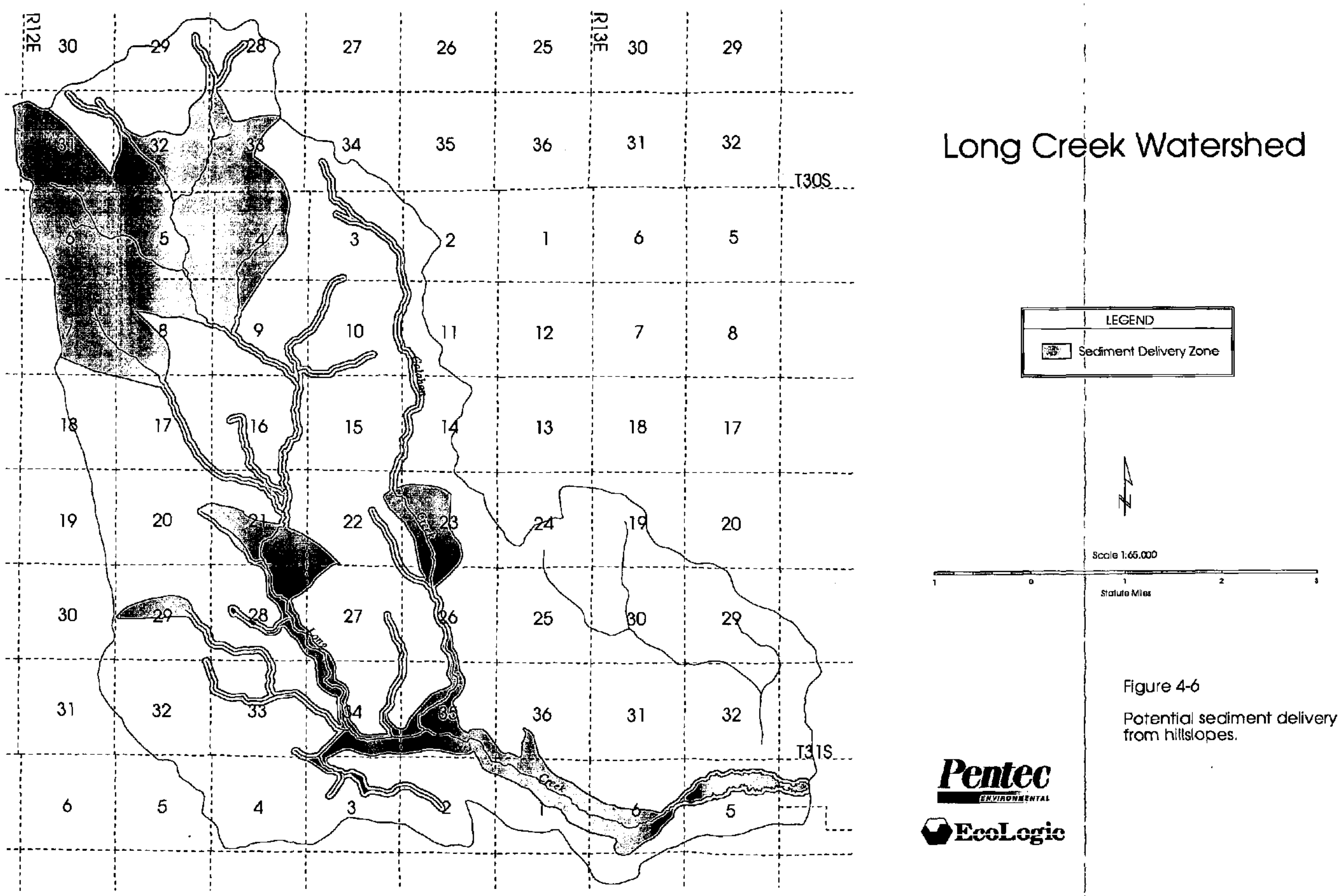


Figure 4-6

Potential sediment delivery from hillslopes.

Pentec ENVIRONMENTAL

EcoLogic

annually at the lower elevations) is much slower than on the west slope of the Cascades (which averages from 30 to 150 inches of precipitation annually).

Therefore, higher management-induced rates of erosion will continue for longer time periods because of the slow regeneration.

4.5 SURFACE EROSION FROM ROADS ASSESSMENT

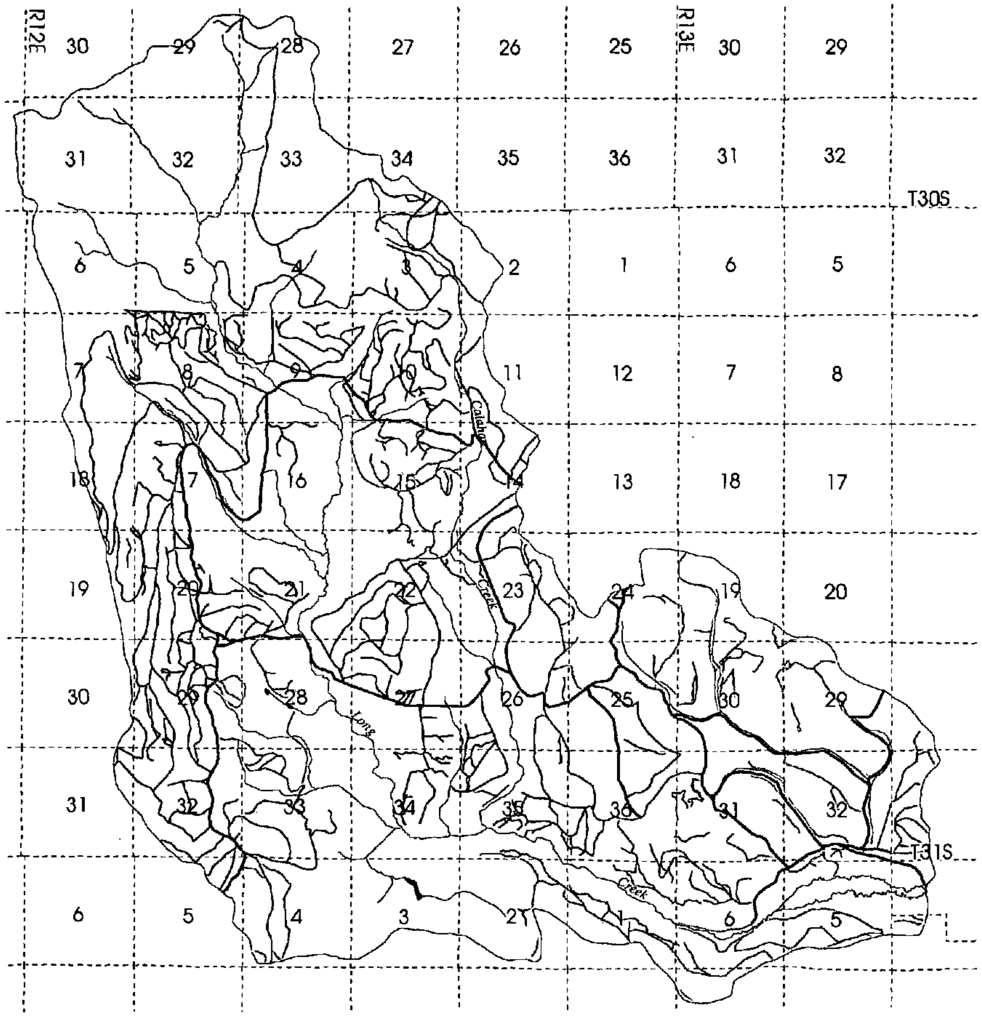
Surface erosion from roads is highest during construction and within the first 2 years afterwards. However, after the 2-year period, erosion continues at rates much higher than on the surrounding hillslopes because of compaction and lack of protective organic layer. The severity of erosion is related to the amount of traffic, especially to use by large vehicles such as log trucks (Reid and Dunne 1984). The focus of this assessment is to identify segments of roads within the Long Creek basin that are contributing a significant amount of fine sediments to Long Creek.

Roads within each subbasin were grouped into road segment types according to the parent material, surfacing material, and traffic use in accordance with the guidelines of the Washington watershed analysis methodology (TFW 1993). Following is the categorization according to surface material and road use:

	Abandoned	Inactive	Active Secondary	Active Mainline
Asphalt	AA	AI	AS	AM
Dust-oil	DA	DI	DS	DM
> 6" Gravel	6A	6I	6S	6M
2 - > 6" Gravel	2A	2I	2S	2M
Native	NA	NI	NS	NM

Active mainlines are the most susceptible to erosion due to logging truck traffic; abandoned roads are least susceptible. The least erosive road surface is asphalt, and the most erosive is native material. Road segment types are shown in Figure 4-7.

A field visit was conducted to determine which roads were contributing sediment to Long and Calahan creeks. Upon investigation, it was found that very few roads actually deliver



Long Creek Watershed

LEGEND
- Active Mainline, 2-6" Gravel
- Native Mainline
- Native Secondary
- Native Inactive
- Hydrography

N

Scale 1:65,000

1 0 1 2 3

Statute Miles

Figure 4-7

Road traffic ratings.

Pentec ENVIRONMENTAL

EcoLogic

sediment to the stream channels. Active erosion was observed on nearly all roads visited, but signs of erosion such as rills and gullies could not be traced to the stream channels in most cases. This lack of delivery is due to the intersection of hillslopes by the low-gradient meadow and stream valley areas. For example, all roads within the Detached subbasin were considered not to deliver sediment to Long Creek. Sediment from these roads is delivered to the stream within that subbasin, but that stream does not contribute sediment to Long Creek. Therefore, roads within the Detached subbasin were not included in further investigation. Only roads that were found to contribute sediment to the stream channels were analyzed further.

Roads were classified according to their age and parent material to estimate erosion rates. Categories are shown below (numbers represent erosion rates in tons/acre of road/year):

General erosion rate category	Parent material	Road age	
		New 0-2 years	Old > 2 years
High	Mica schist Volcanic ash Highly weathered sedimentary rock	110	60
High/Moderate	Quartzite Coarse-grained granite	110	30
Moderate	Fine-grained granite Moderately weathered rock Sedimentary rocks	60	30
Low	Competent granite Basalt Metamorphic rocks Relatively unweathered rocks	20	10

Highest erosion rates occur on roads built within the last 2 years that are composed of schist, ash, or highly weathered sedimentary rocks. The lowest erosion rates are for older roads composed of competent rock.

Cutslopes and fillslopes were also rated according to their erosion rates. Erosion on cutslopes and fillslopes depends on the amount of ground cover, including both vegetation and rock. No engineered ground covers are used in any of the Long Creek subbasins. The density of ground cover was assigned a multiplication factor for the basic erosion rate according to the table below:

Ground cover density	Factor
80%	0.18
50%	0.37
30%	0.53
20%	0.63
10%	0.77
0%	1.00

Next, a surfacing factor for erosion potential of the road tread was applied according to the table below:

Surfacing material	Factor
Paved	0.03
Dust-oil	0.15
Gravel. > 6" deep	0.20
Gravel. 2" - 6" deep	0.50
Native soil/rock	1.00

A factor of 1 is applied to native roads, indicating full erosion potential. The more erosion-resistant surfaces such as gravel, with which the mainlines are surfaced, were assigned smaller fractions to indicate a reduced erosion rate.

Traffic factors were applied to the adjusted erosion rates according to the table below:

Traffic use/road category	Annual precipitation < 1200 mm	Annual precipitation 1200 mm-3000 mm	Annual precipitation > 3000 mm
Heavy traffic/active	20	50	120
Mainline moderate traffic/active	22	4	10
Secondary light traffic/not active	1	1	1
No traffic/abandoned	.02	.05	.10

Note the range in factors. Heavily used roads are assigned a factor of 20. Abandoned roads are assigned a factor of 0.02.

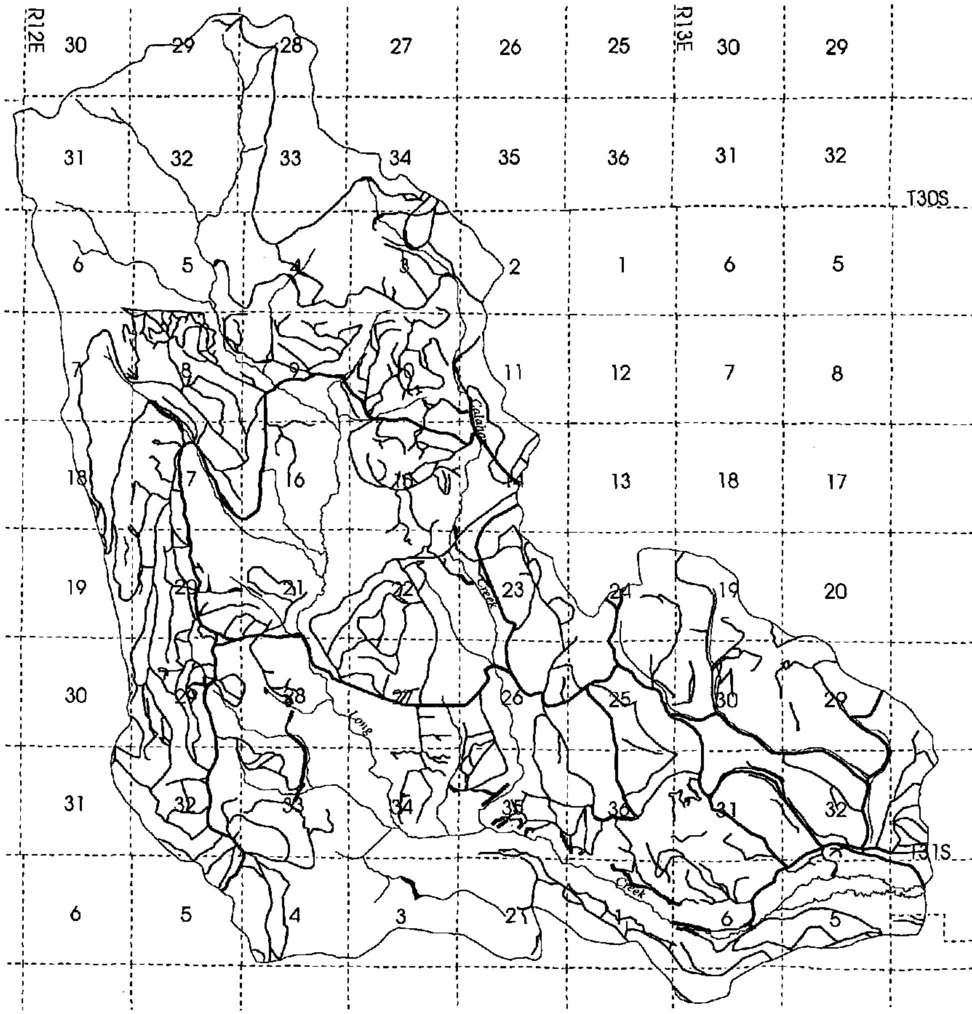
The percentage of delivery for each road segment is then calculated according to the following rules:

1. One-hundred percent delivery is assumed if the road drains directly into a stream channel via a ditch or gully.

2. Ten percent delivery is assumed if the road drains onto a hillslope within 200 ft of the stream.

3. No delivery is assumed if the road drains onto a hillslope greater than 200 ft from a stream.

The results for the USFS subbasin are shown in Table 4-1. There is only one delivering road segment, and it is shown in Figure 4-8. This road segment delivers 14 tons of sediment to upper Long Creek annually. The results for the Calahan subbasin are shown in Table 4-2. Four road types totalling 2.15 miles contribute 181 tons of sediment annually. Most of these segments cross Calahan Creek and deliver sediment directly into the stream channel. Five road segments run alongside the channel and also contribute sediment directly into the channel. These segments are also shown in Figure 4-8. The results for the Long subbasin are shown in Table 4-3. Four road types totalling 5.35 miles contribute 503 tons of sediment annually. Most sediment-contributing segments are native secondary and inactive roads that are close to Long Creek and its tributaries.



Long Creek Watershed

LEGEND
Sediment Delivery

Scale 1:65,000

Statute Miles

Figure 4-8

Road segments delivering sediment to the stream channel.

Pentec ENVIRONMENTAL

EcoLogic

Table 4-1 Annual road erosion potential for the USFS subbasin.

Road segments	Percent prism component	Road age class	Basic erosion rate	Ground cover factor	Road tread factor	Erosion potential (tons/acre/year)	Traffic/ precip.	Adjusted erosion rate	Percent direct delivery	Percent within 200 ft	Percent outside 200 ft	Sediment delivered (tons/acre/prism)	Road length (mi)	Average width (ft)	Total sediment delivered (tons/year)
Native mainline															
Tread	40	60	24	1	1	24	2	48	0.85	0.15	0	59.58	0.1	20	14
Cutslope	30	60	18	0.63	1	11.34		11.34					528		
Fillslope	30	60	18	0.53	1	9.54		9.54							
Total								68.88							14

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Table 4-2 Annual road erosion potential for the Calahan subbasin.

Road segments	Percent prism component	Road age class	Basic erosion rate	Ground cover factor	Road tread factor	Erosion potential (tons/acre/year)	Traffic/ precip.	Adjusted erosion rate	Percent direct delivery	Percent within 200 ft	Percent outside 200 ft	Sediment delivered (tons/acre/prism)	Road length (mi)	Average width (ft)	Total sediment delivered (tons/year)
1. Active mainline															
Tread	40	10	4	1	0.5	2	20	40	0.9	0.1	0	60.10	0.25	24	44
Cutslope	40	60	24	0.77	1	18.48		18.48					1,320		
Fillslope	20	60	12	0.63	1	7.56		7.56							
Total								66.04							
2. Native mainline															
Tread	40	60	24	1	1	24	2	48	0.8	0.2	0	56.48	0.2	20	27
Cutslope	30	60	18	0.63	1	11.34		11.34					1,056		
Fillslope	30	60	18	0.53	1	9.54		9.54							
Total								68.88							
3. Native secondary															
Tread	40	60	24	1	1	24	1	24	0.85	0.15	0	40.38	1.1	16	86
Cutslope	30	60	18	0.63	1	11.34		11.34					5,808		
Fillslope	30	60	18	0.63	1	11.34		11.34							
Total								46.68							
4. Native inactive															
Tread	40	60	24	1	1	24	0.02	0.48	0.85	0.15	0	20.03	0.6	16	23
Cutslope	30	60	18	0.63	1	11.34		11.34					3,168		
Fillslope	30	60	18	0.63	1	11.34		11.34							
Total								23.16							
Grand total sediment delivered (tons/year)															181

00068 003\LONG\TABLES\4-1&2.XLS

Table 4-3 Annual road erosion potential for the Long subbasin.

Road segments	Percent prism component	Road age class	Basic erosion rate	Ground cover factor	Road tread factor	Erosion potential (tons/acre/year)	Traffic/ precip.	Adjusted erosion rate	Percent direct delivery	Percent within 200 ft	Percent outside 200 ft	Sediment delivered (tons/acre/prism)	Road length (mi)	Average width (ft)	Total sediment delivered (tons/year)
1. Active mainline															
Tread	40	10	4	1	0.5	2	20	40	0.85	0.15	0	57.12	1.5	24	249
Cutslope	40	60	24	0.77	1	18.48		18.48					7,920		
Fillslope	20	60	12	0.63	1	7.56		7.56							
Total								66.04							
2. Native mainline															
Tread	40	60	24	1	1	24	2	48	0.8	0.1	0	56.28	0.4	20	55
Cutslope	40	60	24	0.63	1	15.12		15.12					2,112		
Fillslope	20	60	12	0.53	1	6.36		6.36							
Total								69.48							
3. Native secondary															
Tread	40	60	24	1	1	24	1	24	0.85	0.15	0	40.38	1.65	16	129
Cutslope	30	60	18	0.63	1	11.34		11.34					8,712		
Fillslope	30	60	18	0.63	1	11.34		11.34							
Total								46.68							
4. Native inactive															
Tread	40	60	24	1	1	24	0.02	0.48	0.85	0.15	0	20.03	1.8	16	70
Cutslope	30	60	18	0.63	1	11.34		11.34					9,504		
Fillslope	30	60	18	0.63	1	11.34		11.34							
Total								23.16							
Grand total															503

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Background sediment yields for each subbasin are calculated according to area, slope, soil depth, creep rate, and stream length. The results for all subbasins are shown in Tables 4-4 through 4-6 respectively. The background sediment yield for the USFS subbasin, shown in Table 4-4, is 66 tons/year. Therefore, the roads within this subbasin, which were estimated to deliver 14 tons of sediment annually, contribute an additional 21 percent of sediment annually. The background sediment yield for the Calahan subbasin, shown in Table 4-5, is 63 tons/year. The roads within this subbasin, which were estimated to deliver 181 tons of sediment annually, account for an increase in sediment delivery of 287 percent annually. The background sediment yield for the Long subbasin, shown in Table 4-6, is 252 tons/year. The Long subbasin roads, which were estimated to deliver 503 tons of sediment annually, account for a 200 percent increase in sediment delivery annually.

4.6 SUMMARY

Soils within the entire Long Creek watershed are highly erosive. As discussed previously in this chapter, areas without the protective organic layer are prone to gullying regardless of the hillslope gradient. The worst areas were those that had been clearcut; areas that had been partial cut were prone to less severe gullying. Delivery of sediment to the stream channels is expected to occur from whatever portion of the areas outlined in Figure 4-6 have had the protective organic layer removed. These areas lack any grade buffer alongside the streams, thereby enabling displaced sediments to enter the stream channels.

Erosion of the road prism is widespread; however, delivery of sediment to the stream channel is limited to the roads shown in Figure 4-8. These roads either cross the stream channels or are close enough to the channels to contribute sediment. Increases in sediment yields ranged from 21 percent in the USFS subbasin, to 287 percent in the Calahan subbasin.

Table 4-4 Background sediment yield for USFS subbasin.

Total area of basin	=	3,443 acres
Area of slope < 30 percent (creep rate = 0.001 meters/year)	=	2,929 acres
Area of slope >= 30 percent (creep rate = 0.002 meters/year)	=	515 acres
Weighted creep rate (CR)	=	0.00115 meters/year
L = 2 x stream length	=	26,262 meters
D = average soil depth	=	2 meters
CR = soil creep rate	=	0.00115 meters/year
E = erosion volume		
E = L x D x CR	=	60 cubic meters/year
	=	66 tons/year

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Table 4-5 Background sediment yield for Calahan subbasin.

Total area of basin	=	3788 acres
Area of slope < 30 percent (creep rate = 0.001 meters/year)	=	3716 acres
Area of slope >= 30 percent (creep rate = 0.002 meters/year)	=	72 acres
Weighted creep rate (CR)	=	0.001019 meters/year
L = 2 x stream length	=	28,127 meters
D = average soil depth	=	2 meters
CR = soil creep rate	=	0.001019 meters/year
E = erosion volume		
E = L x D x CR	=	57 cubic meters/year
	=	63 tons/year

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Table 4-6 Background sediment yield for Long Subbasin

Total area of basin	=	16,376 acres
Area of slope < 30 percent (creep rate = 0.001 meters/year)	=	15,252 acres
Area of slope >= 30 percent (creep rate = 0.002 meters/year)	=	1,125 acres
Weighted creep rate (CR)	=	0.001069 meters/year
L = 2 x stream length	=	107,323 meters
D = average soil depth	=	2 meters
CR = soil creep rate	=	0.001069 meters/year
E = erosion volume		
E = L x D x CR	=	229 cubic meters/year
	=	252 tons/year

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5.0 HYDROLOGIC ASSESSMENT

5.1 OVERVIEW

According to the Washington watershed manual (TFW 1993), Forest practices can alter the hydrologic performance of forested watersheds in several ways:

> Opening of the canopy by timber harvest can cause greater snow accumulation in winter (because snow on the ground is less affected by interstorm melt than is snow in the canopy) or increased snowmelt in spring (by removal of overstory shade); openings also allow accelerated melt rates, due to increased radiation and wind-assisted flux of sensible and latent heat to the snowpack. The loss of vegetative cover may reduce rates of interception and evapotranspiration, leaving more water to enter the ground. In some cases, loss of vegetative cover may actually decrease soil-water input, through reduction in the amount of fog-drip. Compaction of the soil on roads and skid trails reduces local infiltration, increasing the likelihood of overland flow at the expense of slower subsurface pathways. The magnitude or timing of streamflows could be elevated because of the augmentation of storm-runoff volume due to enhanced soil moisture or snowmelt, or because of reduced detention storage on the hillslope, or because road construction or other surface disruption extends the drainage network.

The purpose of this assessment is to address four critical questions concerning the potential effects of timber harvest on the hydrology of Long Creek:

1. What are the current watershed conditions influencing hydrologic response?
2. What is the history of floods and disturbances of hydrologic significance in the watershed?
3. What is the influence of land use on the water available for runoff?
4. What is the effect on flood peaks of changes in water available for runoff?

5.2 CURRENT WATERSHED CONDITION

5.2.1 Watershed Land Use Patterns

The headwaters and upper fifth of the Long Creek basin are within the Fremont National Forest. Some harvesting activity has occurred within the forest, but it is largely old growth. Most of the lower Long Creek basin is part of the Weyerhaeuser Klamath Falls Tree Farm which has been managed since the 1940s. The meadow land near the mouth is owned by the Nature Conservancy and is used for grazing.

In addition to harvesting, the entire basin owned by Weyerhaeuser has been heavily grazed for years (Johnson, B. Weyerhaeuser. August 17, 1993. Letter). The cattle have tended to concentrate in the riparian areas. Cattle were excluded from the entire basin during the summer of 1993.

The entire Long Creek basin was analyzed with respect to hydrologic maturity. Figure 5-1 shows the distribution of the hydrologically mature, intermediate hydrologically mature, and hydrologically immature areas. Table 5-1 lists the acreage for the four subbasins (HAUs) described in Section 5.1.3 according to hydrologic maturity within each precipitation zone (precipitation zones are discussed in Section 5.3.2). Hydrologic maturity was determined from analysis of 1993 and 1988, 1:12,000 aerial photographs provided by the Weyerhaeuser Company and the Silver Lake Ranger Station, Fremont National Forest. The classification of hydrologic maturity is shown in Table 5-2 (TFW 1993). Hydrologically mature areas are those in which the crown closure is at least 70 percent. Intermediate hydrologically matures area are those in which the crown closure is between 10 percent and 70 percent. Hydrologically immature areas have less than 10 percent crown closure.

The large region of hydrologically mature forest (green) lies mainly within the Fremont National Forest on the north side of the basin and extends downstream along the mainstem of Long Creek. Intermediate hydrologically mature areas reflect light partial cutting. Hydrologically immature areas have been clearcut recently or thinned severely (brown) or are naturally free of forest vegetation. The meadows (yellow) on Long and Calahan creeks are considered hydrologically immature areas.

Long Creek Watershed

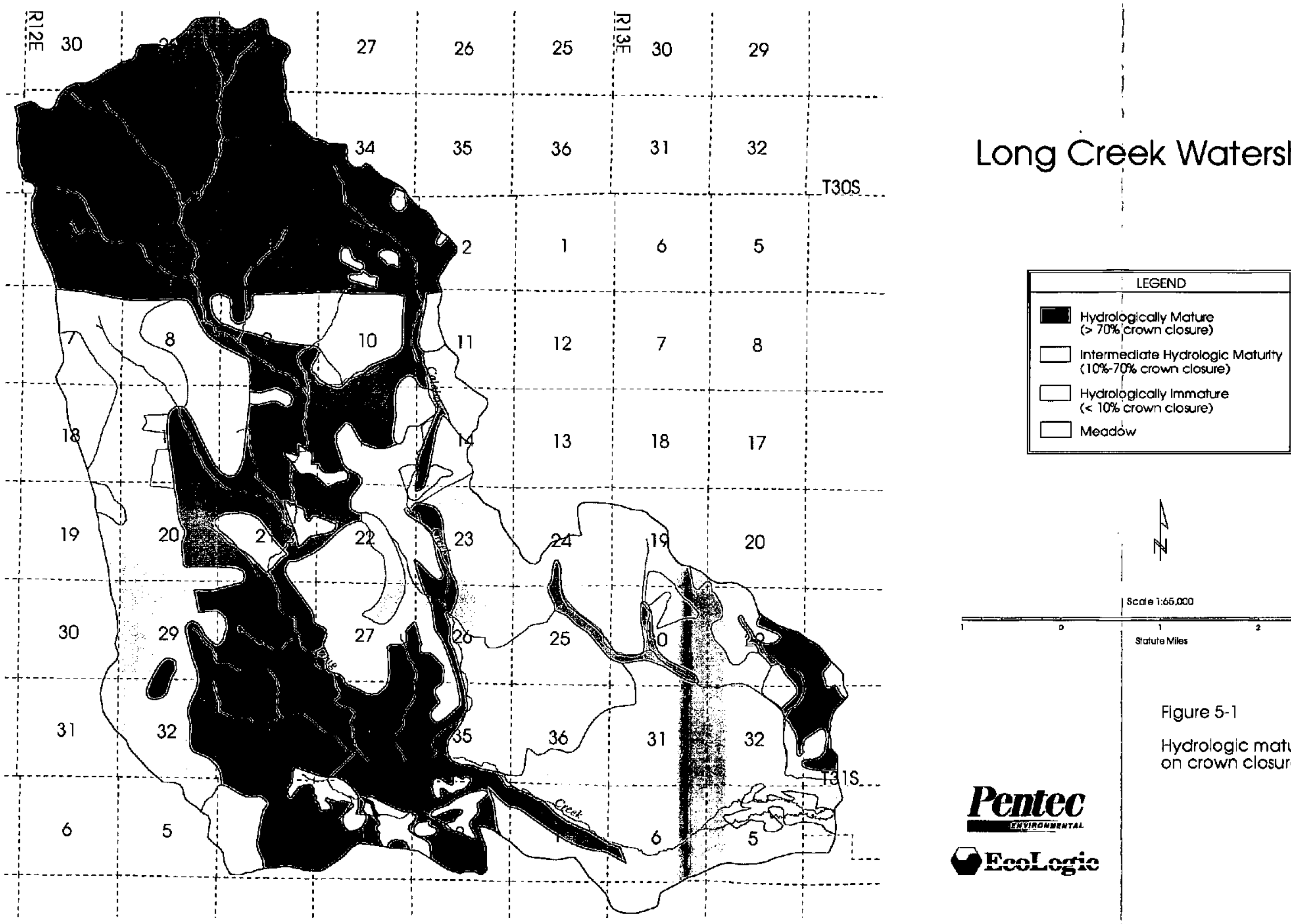

Figure 5-1

Hydrologic maturity based on crown closure.

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Table 5-1 Basin acreage by precipitation zone and land use/cover type.

Land use/cover type	Lowland	Rain dominated	Rain on snow	Snow dominated	Highland	Total	Percentage
Subbasin: USFS							
Hydrologically mature	0	0	1,012	2,418	0	3,430	
Intermediate hydrologically mature	0	0	0	0	0	0	
Hydrologically immature	0	0	0	0	0	0	
Total forested	0	0	1,012	2,418	0	3,430	100%
Open water	0	0	0	0	0	0	
Meadows	0	0	0	12	0	12	
Total non-forested	0	0	0	12	0	12	0%
Total	0	0	1,012	2,430	0	3,442	100%
Subbasin: Calahan							
Hydrologically mature	0	0	1,603	235	255	2,093	
Intermediate hydrologically mature			970	0	0	970	
Hydrologically immature			688	0		688	
Total forested	0	0	3,261	235	255	3,751	99%
Open water						0	
Meadows			36	0		36	
Total non-forested	0	0	36	0	0	36	1%
Total	0	0	3,297	235	255	3,787	100%

Table 5-1 (continued).

Land use/cover type	Lowland	Rain dominated	Rain on snow	Snow dominated	Highland	Total	Percentage
			Subbasin: Long				
Hydrologically mature	0	0	7.173	0	0	7,173	
Intermediate hydrologically mature	0	0	6,175	85	0	6.260	
Hydrologically immature	0	0	2.317	160	0	2.477	
Total forested	0	0	15.665	245	0	15.910	97%
Open water	0	0	0	0	0	0	
Meadows	0	0	467	0	0	467	
Total non-forested	0	0	467	0	0	467	3%
Total	0	0	16.132	245	0	16.377	100%
			Subbasin: Detached				
Hydrologically mature	0	0	535	0	0	535	
Intermediate hydrologic maturity	0	0	1,913	0	0	1,913	
Hydrologically immature	0	0	358	0	0	358	
Total forested	0	0	2.806	0	0	2.806	100%
Open water	0	0	0	0	0	0	
Meadows	0	0	10	0	0	10	
Total non-forested	0	0	10	0	0	10	0%
Total	0	0	2.816	0	0	2.816	100%

Table 5-2 Land use/cover types and description.

Land use/cover type	Description
Forested[1]	
Hydrologically mature	Maximum hydrological maturity > 70 percent total crown closure and < 75 percent of the crown in hardwoods or shrubs
Intermediate hydrologically mature	Intermediate hydrologic maturity 10 percent-70 percent total crown closure and < 75 percent of the crown in hardwoods or shrubs
Hydrologically immature	Minimum hydrologic maturity < 10 percent total crown closure and/or > 75 percent of the crown in hardwoods or shrubs
Non-forested[2]	
Urban	Residential/commercial/industrial
Agricultural	Cultivated and grazing lands
Open water	Lakes, ponds, reservoirs. inundated wetlands
Other	Naturally occurring open areas (e.g., talus slopes. meadows. barrens)

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1. Unmanaged or managed lands currently occupied by or capable of growing stands of trees of commercial size.

2. Lands permanently converted from forest or incapable of growing stands of trees of commercial size

5.2.2 Structural Features

OBSTRUCTIONS

Long Creek basin is free of any engineered structures such as weirs or dikes. A stream gage was installed in 1993 on the mainstem of Long Creek at the Weyerhaeuser-Fremont National Forest boundary (shown in Figure 5-2). Road crossings contain culverts and bridges. Downstream of the basin is the Sycan Marsh, a 40-mi^2 area used for grazing.

5.2.3 Hydrologic Analysis Units

The Long Creek basin was divided into four hydrologic analysis units (HAUs) as shown in Figure 5-2. The USFS HAU includes the headwaters of the mainstem of Long Creek within the Fremont National Forest land and extends down Long Creek to a tributary confluence slightly north of the Weyerhaeuser-Fremont National Forest boundary. The Calahan HAU includes the entire Calahan Creek watershed. The Detached HAU includes the watershed of the easternmost tributary to Long Creek. This tributary does not actually meet Long Creek because it forms distributaries where the flow enters the meadow. The remaining portion of Long Creek is referred to as the Long HAU.

5.3 HISTORIC TRENDS IN WATERSHED CONDITION

5.3.1 Flood History

Very limited stream gage data are available for Long Creek. Monthly and yearly mean discharge data from 1918 through 1929 from a gage installed near the 5,100-ft contour are available (shown in Figure 5-2). Approximately half of these data are missing due to large gaps in the record. In addition, daily stage-discharge relationships were recorded during this period; large gaps exist in this record also. A gage was installed in 1993 by the Winema National Forest on the mainstem of Long Creek just upstream of the Weyerhaeuser-Fremont National Forest boundary. These data are not yet available. The short period of records on Long Creek precluded statistical analysis; therefore, flood history was hypothesized using data from neighboring streams. Peak annual streamflow data from 21 gages on 15 different streams were extracted from Hydrosphere Inc. (1993) CD ROM. Table 5-3 shows a summary of information available. Years of record range from 2 for West Whiskey Creek to 77 for the Chewaucan River near Paisley. Drainage area ranges from 2.2 mi^2 on Brownsworth Creek to 568 mi^2 on the Sycan River. Gage datums range from 4,290 ft on the Chewaucan River at Hotchkiss Road to 5,480 ft on Brownsworth Creek.

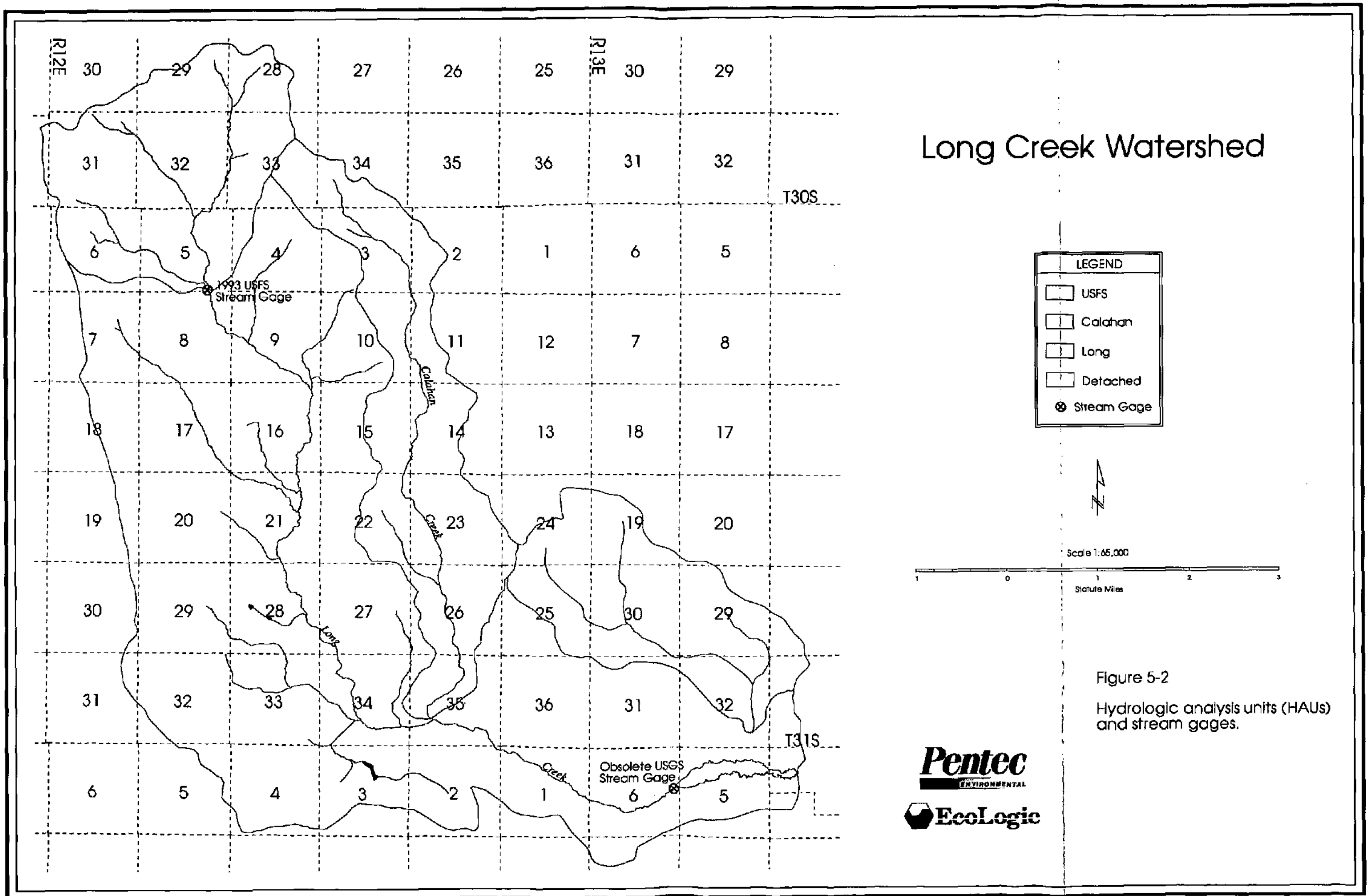

Figure 5-2
Hydrologic analysis units (HAUs) and stream gages.

Table 5-3 Summary of peak annual stream flow data.

Station	ID	Years of record	Number of years	Drainage area (mi²)	Latitude	Longitude	Gage datum (ft)
Bridge Creek near Thompson Reservoir, Oregon	10390400	1965-68, 1970 81	16	10.6	43:01:30 N	121:12:00 W	4850
Brownsworth Creek near Bly, Oregon	11494800	1965, 1968, 1970-81	14	2.2	42:25:40 N	120:50:20 W	5480
Camas Creek near Lakeview, Oregon	10370000	1913-14, 1950 73	26	63	42:12:59 N	120:06.05 W	5472
Chewaucan River at Paisley, Oregon	10384100	1905-07, 1910-11	5	278	42:42:00 N	120:33.00 W	4390
Chewaucan River near Buck Mountain near Paisley, Oregon	10382550	1983-86	4	157	42:29:10 N	120:34:22 W	—
Chewaucan River below Coffeepot Creek near Paisley, Oregon	10382600	1983-86	4	216	42:34:07 N	120:35:40 W	—
Chewaucan River at Hotchkiss Fd near Paisley, Oregon	10386500	1914-20	4	430	42:33:00 N	120:19:00 W	4290
Chewaucan River near Paisley, Oregon	10384000	1912-21, 1925-91	77	275	42:41:05 N	120:34:08 W	4430
Chewaucan River at Narrows near Paisley, Oregon	10386000	1914-21	8	380	42:37:00 N	120:25:00 W	4300
Cottonwood Creek near Lakeview, Oregon	11340500	1909, 1911-19, 1924-26, 1928-81	67	32.9	42:14:05 N	120:30:05 W	4949
Crane Creek near Lakeview, Oregon	11341200	1966-81	16	11.4	42:07:05 N	120:17 25 W	5010
Currier Creek near Paisley, Oregon	11497800	1965-68, 1970-81	16	2.4	42:42:55 N	120:52:50 W	
Drews Creek near Lakeview, Oregon	11339500	1909-19, 1921-22, 1925-81	70	212	42:07210 N	120:34:45 W	4827
Long Creek near Silver Lake, Oregon	11498500	1918-23, 1927-29	9	40	42:50:00 N	121:13:00 W	5100
Salt Creek near Lakeview, Oregon	11341100	1964-81	18	5.6	42:17:35 N	120:20:45 W	4950
Silver Creek near Silver Lake, Oregon	10390000	1905-06, 1909-23, 1925-78	71	180	43:06:40 N	121:04.05 W	4361
Sprague River near Beatty, Oregon	11497500	1914-15, 1917-18, 1920-91	46	513	42:26:50 N	121:14:15 W	4305
Sycan River below Snake Creek near Beatty, Oregon	11499100	1980-91	12	568	42:29:10 N	121:16:40 W	4310
Sycan River near Beatty, Oregon	11499000	1912-14, 1916-19, 1921-25	12	540	42:33:00 N	121:19:00 W	4400
Thomas Creek near Lakeview, Oregon	11341000	1912-17, 1919, 1927-31, 1946-58	25	30	42:16:00 N	120:27:00 W	4800
West Fork Whiskey Creek near Beatty, Oregon	11499495	1980-81	2	4.4	42:22:32 N	121:22:52 W	—

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Peak annual flows with respect to the month of occurrence for the 21 gages are plotted in Figure 5-3. A total of 524 annual records were available from the 21 gages. The distribution is left skewed with a median month of April. Eighty percent of annual peaks occurred during March through June, reflecting spring snowmelt. Fifty-six percent of all peak annual flows occurred during April and May. Table 5-4 shows the seasonal distribution of annual peaks for each gage. The data in this table show the same seasonal trend in peak annual flow for all catchment sizes.

Of the 524 annual peak records, no annual peaks occurred during August or September. Eight peaks occurred in July and one in October. Three of the eight July peaks were on Cottonwood Creek (drainage area, 32.9 mi^2). The largest of these three peaks was 18 percent of the magnitude of the largest flood in 67 years of record. Five of the July peaks were on Drews Creek (drainage area, 212 square miles). The largest of these five peaks was 3 percent of the magnitude of the largest flood in 70 years of record. One of the eight July peaks was on Silver Creek (drainage area, 180 square miles). This magnitude was 3 percent of the largest flood in 71 years of record. The low frequency of peak annual flows in July, in combination with their relatively low magnitudes, indicates that summer precipitation events are not of concern for analyzing channel forming processes. The one October annual peak of the 524 records occurred on Drews Creek. The magnitude was 6 percent of the maximum flood on Drews Creek in 70 years of record.

Twenty-four of the 524 annual peaks occurred during November and December. These account for less than 5 percent of the annual peaks. Of these 24 peaks, 9 occurred during the December 22, 1964, storm. Return interval for this storm has been estimated at several hundred years (Brunengo, M. Washington Department of Natural Resources. January 3, 1994. Pers. comm.). Excluding this unusual storm, less than 3 percent of the annual peaks in this region occurred during fall and early winter (rain-on-snow [ROS] season). ROS is usually associated with fall rather than spring because of the higher seasonal precipitation occurring in the fall. Precipitation in this region, however, is only slightly higher in the fall (Figure 5-4). Rain-on-snow is assumed to occur frequently during spring snowmelt.

5.3.2 Disturbance History

Aerial photo analysis and field investigation of the Long Creek basin did not reveal any evidence of historical fire or insect damage.

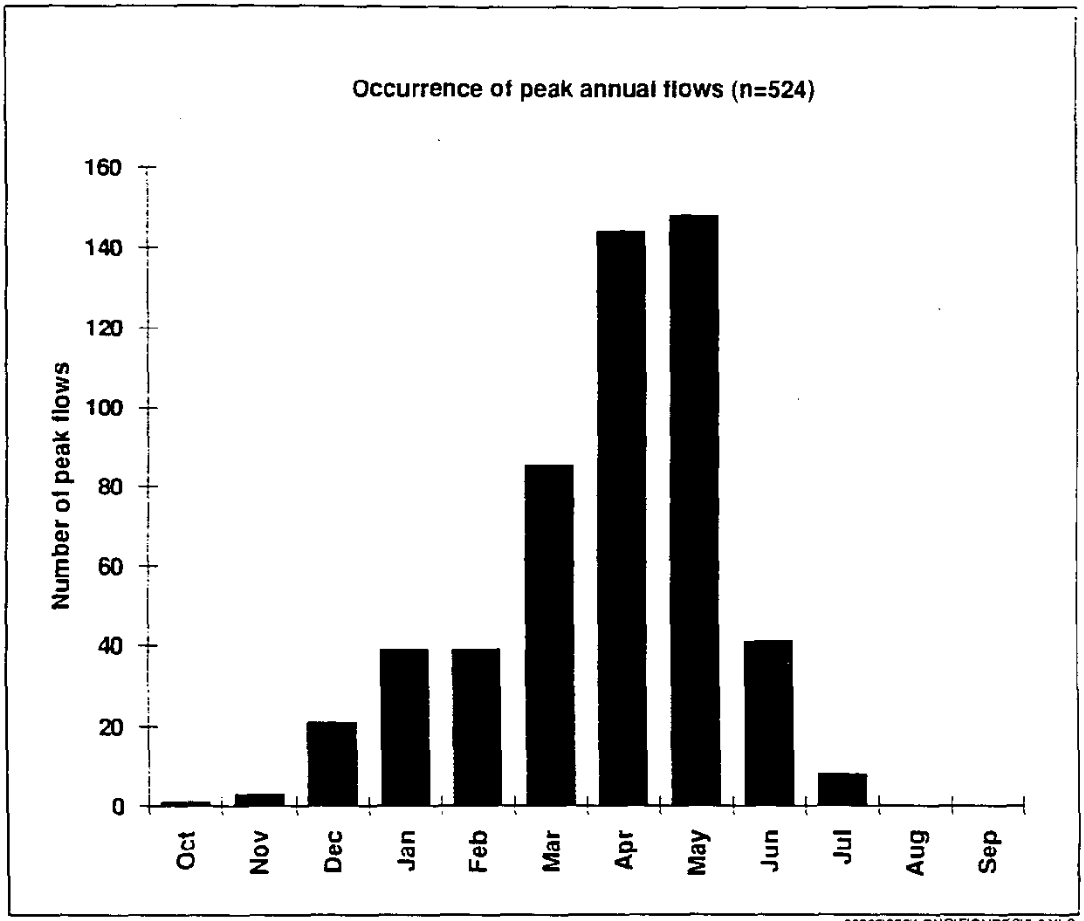

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Figure 5-3 Peak annual flows by month.

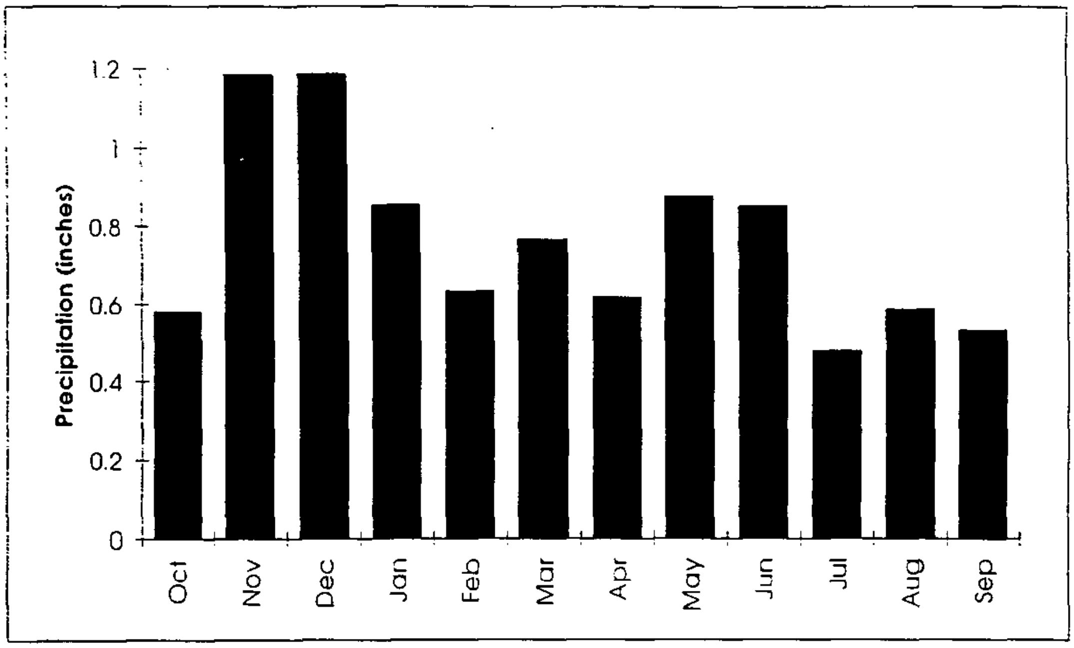

Figure 5-4 Average monthly precipitation, Silver Lake gage (25 years of record).

Table 5-4 Seasonal distribution of peak annual flows.

Station	ID	Month of peak annual flow											
		Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
Bridge Creek near Thompson Reservoir, Oregon	10390400			1	2		2	3	5	3			
Brownsworth Creek near Bly, Oregon	11494800		1	1	3		1	3	3	2			
Camas Creek near Lakeview, Oregon	10370000			2	3	4	1	12	3				
Chewaucan River at Paisley, Oregon	10384100		1		1	1			2				
Chewaucan River near Buck Mountain near Paisley, Oregon	10382550						1	1	2				
Chewaucan River below Coffeepot Creek near Paisley, Oregon	10382600						1	1	2				
Chewaucan River at Hotchkiss Fd near Paisley, Oregon	10386500				1	1		4	1				
Chewaucan River near Paisley, Oregon	10384000			4	4	8	9	21	26	5			
Chewaucan River at Narrows near Paisley, Oregon	10386000					1		5	2				
Cottonwood Creek near Lakeview, Oregon	11340500			2	1	1	13	16	20	12	2		
Crane Creek near Lakeview, Oregon	11341200				3	1	3	2	6	1			
Currier Creek near Paisley, Oregon	11497800			1	3		2	3	5	2			
Drews Creek near Lakeview, Oregon	11339500	1		1	4	3	14	19	14	9	5		
Long Creek near Silver Lake, Oregon	11498500						2	2	5				
Salt Creek near Lakeview, Oregon	11341100			1	3	1	3	2	6	2			
Silver Creek near Silver Lake, Oregon	10390000		1	3	1	4	5	23	29	4	1		
Sprague River near Beatty, Oregon	11497500			3	7	8	12	7	8	1			
Sycan River below Snake Creek near Beatty, Oregon	11499100				1	2	7	1	1				
Sycan River near Beatty, Oregon	11499000					2	5	4	1				
Thomas Creek near Lakeview, Oregon	11341000			2	1	2	4	14	2				
West Fork Whiskey Creek near Beatty, Oregon	11499495				1			1					
Total	524	1	3	21	39	39	85	144	143	41	8		

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5.4 INFLUENCE OF TIMBER HARVEST ON SEASONAL WATER YIELD

Water yield in a region can be altered by two processes: 1) alteration of snow accumulation and melt from changes in the aerodynamics and energy budget of a cleared forest, and 2) reduction of evapotranspirative losses from vegetation removal. This could affect volume and timing of runoffs. Since no stream gage data are available for Long Creek that might show changes in the hydrograph associated with harvesting, a literature review of relevant studies was conducted. Several studies of this issue have been conducted within the Rocky Mountain region. The general climatological conditions of the Rocky Mountain basins studied are similar to those of the Klamath basin. Semi-arid summers are followed by cold winters in which most precipitation is in the form of snow, and total precipitation amounts are comparable to those within the Klamath basin. Fool Creek is a 714-acre basin in the Frazer Experimental Forest. Forty percent of the watershed was cut using alternating cut-and-leave strips of varying width (Goodell 1959, Leaf 1975, Troendle and Leaf 1981). The resulting snow accumulation did not increase for the entire watershed, but the distribution was significantly altered by varying wind patterns within the series of clearcuts. The clearcuts did advance the snowmelt, causing an earlier rise in the spring hydrograph with an increase in the peak of 6 percent, but the recession limb was unaffected. A similar study was conducted on Deadhorse Creek (Troendle 1982) which was also partially clearcut. Snowmelt was advanced in the clearcuts, but the net effect was to desynchronize the timing of some of the flows with no significant increase in peak flow. Wagon Wheel Gap (Bates and Henry 1928, Van Haveren 1981), however, was entirely clearcut, and the peak discharge increased up to 50 percent. Studies in Alberta (Swanson and Hillman 1977), where up to 85 percent of the drainage was cut, showed an increase in peak discharge during the spring snowmelt.

Roughly half of the entire Long Creek watershed has been harvested, which has created a patchwork of zones of varying hydrologic maturity. Because of this overall decrease in hydrologic maturity, spring runoff is probably beginning sooner, with a slight increase in the peak flow. The studies detailed above suggest that the recession limb of the hydrograph has not changed. Further harvesting until the entire Long Creek watershed is hydrologically immature may significantly increase the peak flows during spring runoff.

5.5 QUANTIFICATION OF CHANGES IN PEAK FLOW DUE TO TIMBER HARVEST

The following peak flow analysis follows the Washington watershed analysis methodology (TFW 1993) to estimate peak flows under various climatological and forest canopy density scenarios.

5.5.1 Baseline Storm Precipitation and Peak Flows from US Geological Survey (USGS) Regional Regression Equation

Average values of the 24-hour precipitation for recurrence intervals ranging from 2 to 100 years were estimated from the National Oceanic and Atmospheric Administration (NOAA) precipitation atlas (Miller et al. 1973). The precipitation amounts are shown in Table 5-5.

Average values of peak flows associated with the above 24-hour precipitation amounts are calculated for each subbasin using the USGS regional regression equation for southeastern Oregon (Harris and Hubbard 1983):

$$Q_T = KA^aL^bTI^cP^d(1+F)^e$$

where Q_T = discharge for selected exceedance probability
K = regression constant
A = drainage area (square miles)
L = channel length (miles)
TI = temperature index, the mean minimum January temperature (°F)
P = mean annual precipitation (inches)
F = forest cover (percent).

The results are shown in Table 5-6.

5.5.2 Snow Accumulation

Precipitation zones were delineated for each basin for better estimates of snow accumulation and melt. The lower zone is considered the ROS zone, and it extends from 5,000 to 7,000 ft elevation. The upper zone is considered the snow zone, and it extends from 7,000 ft to the summit of Yamsay Mountain (7800 ft) (Figure 5-5). The precipitation zones were delineated by analyzing winter storm temperatures at the Silver Lake rain gage and applying the saturated adiabatic lapse rate to the recorded temperatures.

Snow accumulation was calculated using the relationship between average January 1 snow-water equivalent and elevation within Washington State. No relationship is known for the

Long Creek Watershed

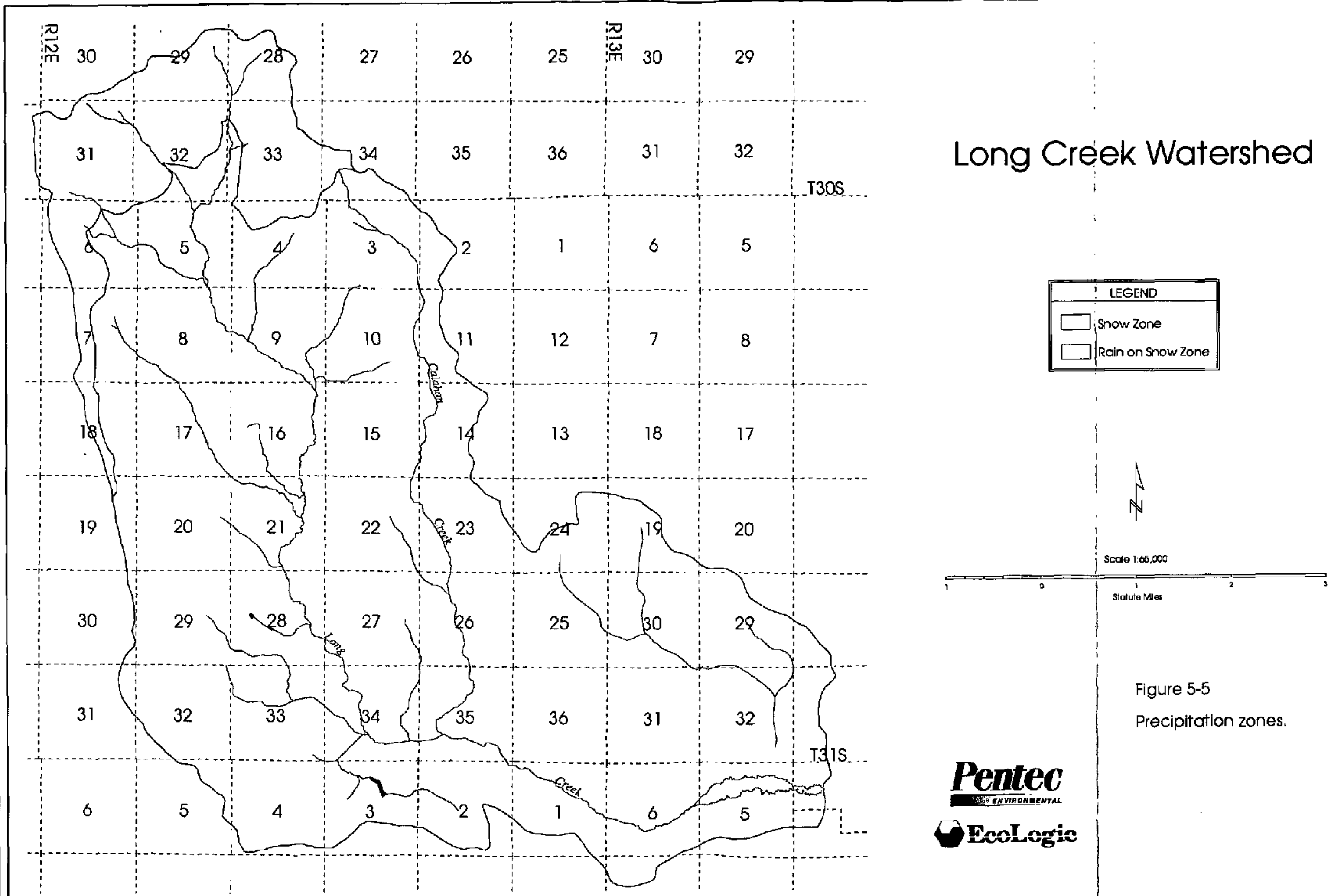

Figure 5-5
Precipitation zones.

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Table 5-5 Discharge predicted from the USGS regression equation.

Return interval (years)	Drainage area (square miles)	Temperature index (degrees F)	Discharge (cfs)
USFS Subbasin			
2	5.378	12	25
5	5.378	12	52
10	5.378	12	77
25	5.378	12	112
50	5.378	12	137
100	5.378	12	168
Calahan Subbasin			
2	5.917	12	27
5	5.917	12	56
10	5.917	12	83
25	5.917	12	120
50	5.917	12	147
100	5.917	12	180
Long Subbasin			
2	25.589	12	86
5	25.589	12	174
10	25.589	12	257
25	25.589	12	359
50	25.589	12	448
100	25.589	12	540
Detached Subbasin			
2	4.4	12	21
5	4.4	12	45
10	4.4	12	66
25	4.4	12	96
50	4.4	12	117
100	4.4	12	144

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Table 5-6 Twenty-four-hour precipitation amounts for given storm recurrence interval.

Recurrence interval (years)	Precipitation (inches)	(centimeters)
2	2.00	5.08
5	3.00	7.62
10	3.50	8.89
25	3.75	9.53
50	4.50	11.43
100	5.75	14.61

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basin and range region of southern Oregon. A regression equation for the eastern portion of the southern Cascades in Washington State was chosen (Brunengo, unpublished):

$$SWE = .03350*E_z - 13.518$$

Within each precipitation zone, snow accumulation is adjusted for vegetative cover using the relationship shown in Table 5-7 (Brunengo, unpublished). The results are shown in Table 5-8.

Brunengo's equation may overestimate the snow accumulation for our region of interest. This overestimation, however, does not affect the snowmelt, water available for runoff, or consequently, peak flow. Snow accumulation is taken into account only if the accumulation is less than the estimated snowmelt. This is not the case as is shown in the next section.

5.5.3 Snowmelt

Snowmelt is calculated using the general US Army Corps of Engineers' (Corps) equation taking into account the storm temperature, wind speed, and return interval of the precipitation event. Storm temperature was estimated for each precipitation zone based on a regional lapse-rate equation developed from analysis of storm temperature at the Paisley weather station over the last 45 years. Average storm temperature was calculated, and a regression equation was developed assuming a saturated adiabatic lapse rate. (This is the same method used in the Washington State watershed analysis methodology [TFW 1993]). The equation developed is as follows:

$$T_z = 14.7 - (0.006*E_z)$$

Therefore, a storm temperature of 1.16 °C is calculated for the snow zone, and 3.36 °C is calculated for the ROS zone. These temperatures indicate that rain occurs (to a lesser extent) in the snow zone. This is consistent with the Washington State precipitation zone delineation; i.e., the ROS zone is the most prone to precipitation in the form of rain, but precipitation in the snow zone may occur as rain.

Wind speed is calculated using the equation from Dunne and Leopold (1978) which accounts for the amount of forest cover. No wind data were available for the study area, so a representative frequency curve for wind during storms (Figure C-6 of Washington State

Table 5-7 Coefficients for use in snow accumulation and melt calculations (Brunengo, unpublished).

	R (snow water equivalent ratio)					
Land use/cover type	Lowlands	Rain dominated	Rain on snow	Snow dominated	Highlands	Fc
Forested						
Mature	1	1	1	1	1	0.85
Intermediate	2	1.75	1.5	1.25	1	0.40
Immature	3	2.5	2	1.5	1	0.07
Non-forested						
Urban	3	2.5	2	1.5	1	0.07
Agricultural	3	2.5	2	1.5	1	0.07
Open water	0	0	0	1.5	1	0
Other	3	2.5	2	1.5	1	0.07

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Table 5-8 Snow Water Equivalent (SWE).

SWE(z1) = d1+ (d2*Ez)

Long Creek basin

				Mature				Intermediate			Immature/Non-forest		
	Ez(m)	d2	d1	V coeff.	SEE	SWE av (cm)	SWE u (cm)	V coeff.	SWE av (cm)	SWE u (cm)	V.coeff.	SWE av (cm)	SWE u (cm)
> 7000'	2225	0.0335	-13.52	1.00	11.255	61.0195	72.2745	1.25	76.27	87.53	1.50	91.53	102.78
5-7000'	1859	0.0335	-13.52	1.00	11.255	48.7585	60.0135	1.50	73.14	84.39	2.00	97.52	108.77

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watershed analysis manual [TFW 1993]) was used. This frequency curve for wind during storms is thought to represent wind conditions in the study area fairly well because the winter storm systems in the study area are similar to those in Washington State. A wind speed that is exceeded 50 percent of the time at Stampede Pass, Washington, representing average storm conditions, was chosen.

Precipitation for the various return intervals was estimated from the NOAA precipitation atlas (Miller et al. 1973)).

With wind speed and storm temperature calculated and the precipitation for the given return intervals known, snowmelt was calculated using the Corps (1956) equation:

$$SM = T_z[0.133+(0.086*U) + (0.0126*P_{24})] + 0.23$$

Snowmelt under unusual conditions, in which the storm temperature and the wind speed are higher, is also calculated. Two degrees Celsius is added to the storm temperature, and the wind speed is increased in accordance with the Washington watershed analysis manual to that which is exceeded 16 percent of the time. Results are shown in Table 5-9.

5.5.4 Water Available for Runoff

Water available for runoff is calculated by adding the lesser of the calculated snowmelt and calculated snow accumulation to the precipitation amount estimated from the NOAA precipitation atlas (Table 5-10).

5.5.5 Peak Flow Estimation

The goal of the analysis is to predict the discharge associated with the various rainfall events. Several precipitation-discharge models exist, but they are cumbersome and beyond the scope of this analysis. Therefore, a simple regression of precipitation (estimated from the NOAA

Table 5-9 Snowmelt calculations for Long Creek basin (inches).
SM24R = Tz[0.133+(0.086*Uv)+(0.0126*P24R)]+0.23

Storm intensity	Average	Average	Average	Average	Average	Average
Return interval (yrs	2	5	10	25	50	100
P24	5.08	7.62	8.89	9.53	11.43	14.61
> 7000 ft elevation						
Tz	1.35	1.35	1.35	1.35	1.35	1.35
Uv						
Mature	1.63	1.63	1.63	1.63	1.63	1.63
Intermediate	3.47	3.47	3.47	3.47	3.47	3.47
Immature	4.81	4.81	4.81	4.81	4.81	4.81
Snowmelt (cm)						
Mature	0.69	0.73	0.75	0.76	0.79	0.85
Intermediate	0.90	0.94	0.96	0.97	1.01	1.06
Immature	1.05	1.10	1.12	1.13	1.16	1.22
Snowmelt (in)						
Mature	0.27	0.29	0.30	0.30	0.31	0.33
Intermediate	0.35	0.37	0.38	0.38	0.40	0.42
Immature	0.42	0.43	0.44	0.45	0.46	0.48
5000-7000 ft elevation						
Tz	3.55	3.55	3.55	3.55	3.55	3.55
Uv						
Mature	1.63	1.63	1.63	1.63	1.63	1.63
Intermediate	3.47	3.47	3.47	3.47	3.47	3.47
Immature	4.81	4.81	4.81	4.81	4.81	4.81
Snowmelt (cm)						
Mature	1.43	1.54	1.60	1.63	1.71	1.85
Intermediate	1.99	2.10	2.16	2.19	2.27	2.41
Immature	2.40	2.51	2.57	2.60	2.68	2.82
Snowmelt (in)						
Mature	0.56	0.61	0.63	0.64	0.67	0.73
Intermediate	0.78	0.83	0.85	0.86	0.89	0.95
Immature	0.94	0.99	1.01	1.02	1.06	1.11

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Table 5-10 Water available for runoff (inches).

Recurrence interval Storm intensity	2 years Average	5 years Average	10 years Average	25 years Average	50 years Average	100 years Average
USFS subbasin						
Fully forested	2.36	3.38	3.89	4.15	4.92	6.20
Current condition	2.36	3.38	3.89	4.15	4.92	6.20
Young forest	2.57	3.60	4.11	4.37	5.13	6.42
Calahan subbasin						
Fully forested	2.54	3.58	4.11	4.37	5.15	6.45
Current condition	2.68	3.72	4.25	4.51	5.29	6.59
Young forest	2.91	3.95	4.47	4.74	5.52	6.82
Long subbasin						
Fully forested	2.56	3.60	4.12	4.39	5.17	6.48
Current condition	2.71	3.75	4.27	4.54	5.32	6.63
Young forest	2.94	3.98	4.50	4.77	5.55	6.85
Detached subbasin						
Fully forested	2.56	3.61	4.13	4.39	5.17	6.48
Current condition	2.76	3.81	4.33	4.59	5.37	6.68
Young forest	2.94	3.99	4.51	4.77	5.56	6.86

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precipitation atlas [Miller et al. 1973]) versus discharge (from the USGS regression equation) is calculated for each subbasin:

$$Q_{USFS} = 10^{(0.851200)} P_{24R}^{(1.906375)}$$

$$Q_{Calahan} = 10^{(0.884919)} P_{24R}^{(1.902772)}$$

$$Q_{Long} = 10^{(1.401884)} P_{24R}^{(1.847540)}$$

$$Q_{Detached} = 10^{(0.780341)} P_{24R}^{(1.913945)}$$

Next, the water available for runoff (WAR) values are substituted into the regression equation to produce a new estimate of discharge associated with a precipitation event of a given recurrence interval (Table 5-10). This estimate of discharge takes into account the various amounts of snow accumulation calculated in Table 5-7. The control discharge is that which occurs in the fully forested condition. Discharge at the current condition of harvesting and a hydrologically immature forest is compared to the discharge from a fully forested watershed (Table 5-11). Percent increases are shown in bold.

Percent increases in peak discharge from the USFS subbasin range from 0.02 percent for the 100-year average storm to 0.04 percent for the 2-year average storm. These percent increases are negligible because current hydrologic maturity conditions are very similar to fully forested conditions within this lightly managed subbasin. Percent increases in peak discharge from Calahan subbasin range from 4 percent from the 100-year average storm to over 10 percent for the 2-year average storm. The percent increases from the Calahan subbasin are higher than those in the USFS subbasin because the Calahan subbasin contains a greater percentage of hydrologically immature forest land, and the Calahan subbasin has a greater area within the ROS zone. Percent increases in peak discharge from the Long subbasin are nearly identical to those from the Calahan subbasin. This similarity can be attributed to similar hydrologic maturity and basin elevation. Percent increases in peak discharge from the Detached subbasin are the highest of all subbasins. The increases are slightly higher than those from the Long and Calahan subbasins, reflecting the lesser hydrologic maturity and lower elevation of the Detached subbasin.

These estimations of peak flow increases due to ROS conditions may be higher than estimations for basins on the west side of the Cascades. The increases are due to additional water available for runoff produced by additional snowmelt during ROS phenomena. The amount of water from snowmelt accounts for a greater portion of the total water available for runoff. Therefore, when this amount is increased (as is done for current and hydrologically immature conditions), a larger increase in peak flow is expected than would be expected from a basin in which precipitation accounts for a greater portion of the water available for runoff.

The peak flow increase analysis presented above does not account for overland flow that is occurring along the logging roads of the entire basin or within gullies of the hydrologically immature areas. Surface water transport from the precipitation location to the stream channel by flow along logging roads and through hillslope gullies may cause the flood peaks to be higher and steeper and occur sooner. This is because the flow velocities along roads and gullies (on the order of meters per second) are much higher than flow velocities of subsurface or sheet flow (from 10 to 500 meters per hour) (Dunne and Leopold 1978). Severe gullying is present throughout the hydrologically immature areas. Moderate gullying is present within the areas of intermediate hydrologic maturity. Evidence of sheet flow is present within the undisturbed old growth areas. To quantify the effects of gullying on the shape, timing, and magnitude of flood peaks requires extensive field data from each hydrologic zone that is considered other than mature. Controlling factors of the velocity and volume of flow through these gullies are hillslope gradient and geometry, soil characteristics, and precipitation intensity and duration. Estimates of each of these parameters for each hydrologic zone could be used to predict individual hydrographs. Individual hydrographs could also be produced for contribution from road segments within each subbasin. To predict the discharge at a selected location on Long Creek, each of these hydrographs would have to be routed through the Long Creek drainage system.

5.6 SUMMARY

HIGH FLOWS

Peak annual discharge within the Long Creek watershed is dominated by spring snowmelt runoff. Lack of long-term streamflow data precludes analysis of actual changes that have occurred within the Long Creek watershed due to forest management. Because we do not have an appropriate model to simulate changes in the spring runoff hydrograph due to forest management that is within the scope of this watershed analysis, a literature review on the subject was undertaken. Studies on the effects of timber harvesting on the seasonal hydrograph of other managed basins suggest that the peak discharge on Long Creek may be occurring sooner in the spring, when compared to the timing of the peak before the basin was harvested. These studies also suggest that this peak may be slightly higher than that prior to harvesting. The Washington TFW rain-on-snow model was applied to the Long Creek basin. These rain-on-snow phenomenons are relatively rare in occurrence and may produce very high discharges. Increases

Table 5-11 Peak discharge estimates (cfs).

Recurrence interval	2 years discharge	2 years *% Increase*	5 years discharge	5 years *% Increase*	10 years discharge	10 years *% Increase*	25 years discharge	25 years *% Increase*	50 years discharge	50 years *% Increase*	100 years discharge	100 years *% Increase*
USFS subbasin												
Fully forested												
Average storm	36.36		72.39		94.75		107.09		147.94		230.17	
Current condition												
Average storm	36.37	***0.04***	72.41	***0.03***	94.77	***0.02***	107.12	***0.02***	147.97	***0.02***	230.21	***0.02***
Young forest												
Average storm	42.94	***18.12***	81.42	***12.47***	104.97	***10.79***	117.91	***10.11***	160.51	***8.50***	245.62	***6.71***
Calahan subbasin												
Fully forested												
Average storm	45.28		87.09		112.77		126.90		173.46		266.65	
Current condition												
Average storm	50.10	***10.65***	93.62	***7.50***	120.14	***6.53***	134.68	***6.13***	182.47	***5.19***	277.67	***4.13***
Young forest												
Average storm	58.50	***29.20***	104.80	***20.34***	132.68	***17.66***	147.91	***16.56***	197.69	***13.97***	296.18	***11.08***
Long subbasin												
Fully forested												
Average storm	142.97		269.15		345.64		387.49		524.50		795.63	
Current condition												
Average storm	158.84	***11.10***	290.21	***7.83***	369.22	***6.82***	412.31	***6.41***	552.96	***5.43***	829.99	***4.32***
Young forest												
Average storm	184.50	***29.05***	323.73	***20.28***	406.53	***17.62***	451.51	***16.52***	597.68	***13.95***	883.68	***11.07***
Detached subbasin												
Fully forested												
Average storm	36.49		70.23		90.98		102.40		140.10		215.67	
Current condition												
Average storm	42.13	***15.45***	77.86	***10.87***	99.59	***9.46***	111.50	***8.88***	150.63	***7.52***	228.57	***5.98***
Young forest												
Average storm	47.62	***30.49***	85.16	***21.26***	107.77	***18.46***	120.13	***17.31***	160.57	***14.61***	240.66	***11.59***

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in peak discharges associated with forest management determined using this method did not exceed 10 percent for current management conditions.

6.0 RIPARIAN FUNCTION ASSESSMENT

A riparian function assessment was conducted on Long and Calahan creeks using the criteria for eastern Washington in the Washington watershed analysis manual as a guideline (TFW 1993). Modifications to the procedures recommended in the manual were required in some cases because of environmental conditions specific to the study area.

The watershed analysis was conducted using 1993 color aerial photographs for Weyerhaeuser-owned properties and 1988 photographs for USFS lands. In addition, ground-truthing was performed at several sites along both creeks and their tributaries.

6.1 LARGE WOODY DEBRIS ASSESSMENT AND RESULTS

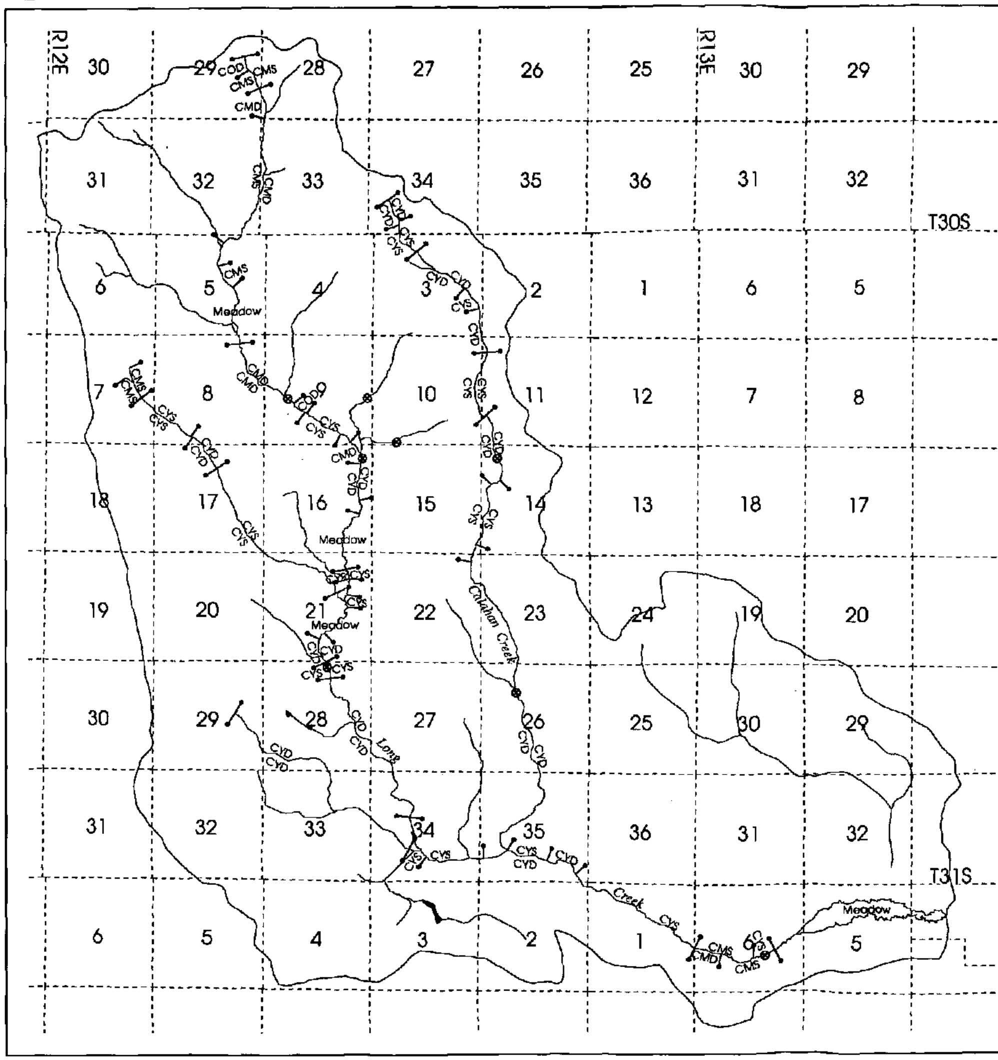
In order to determine near- and long-term LWD recruitment potential along Long and Calahan creeks, color aerial photographs were examined to evaluate the riparian zone along each creek according to predominant tree type (conifer, deciduous, mixed), age/size class (young, mature, old), and timber stand density (sparse, dense). Field verification was conducted at eight stations distributed among the various riparian condition types (Figure 6-1).

Data on in-channel LWD of some stream reaches provided by the ODF&W (Dambacher et al. 1992) were used in combination with the riparian condition estimates to assign a low, moderate, or high recruitment potential to each stream segment (Figure 6-2). LWD recruitment potential for the Long Creek watershed was assessed separately for Weyerhaeuser property and USFS lands to allow comparison of logged with unlogged conditions.

For unlogged lands, 25 percent of the riparian corridor had good LWD recruitment potential; 45 percent had fair recruitment potential; 30 percent had poor recruitment potential due to natural causes, specifically the swampy meadows common to the region.

For logged lands, 5 percent had good LWD recruitment potential; 51 percent had fair recruitment potential; 20 percent had poor recruitment potential due to logging activities nearby; 24 percent had poor recruitment potential due to natural conditions such as meadows and beaver activity.

Long Creek Watershed



LEGEND		
⫯	Riparian Unit Boundary	
C	Conifer	(1st Letter)
Y	Young	2nd Letter
M	Mature	
O	Old	
S	Sparse	3rd Letter
D	Dense	
⊗	Field Verification Site	

Note: Unrated streams are non-fishbearing waters.

Scale 1:65,000

Statute Miles

Figure 6-1

Riparian vegetative condition for LWD recruitment.

Pentec ENVIRONMENTAL

EcoLogic

Long Creek Watershed

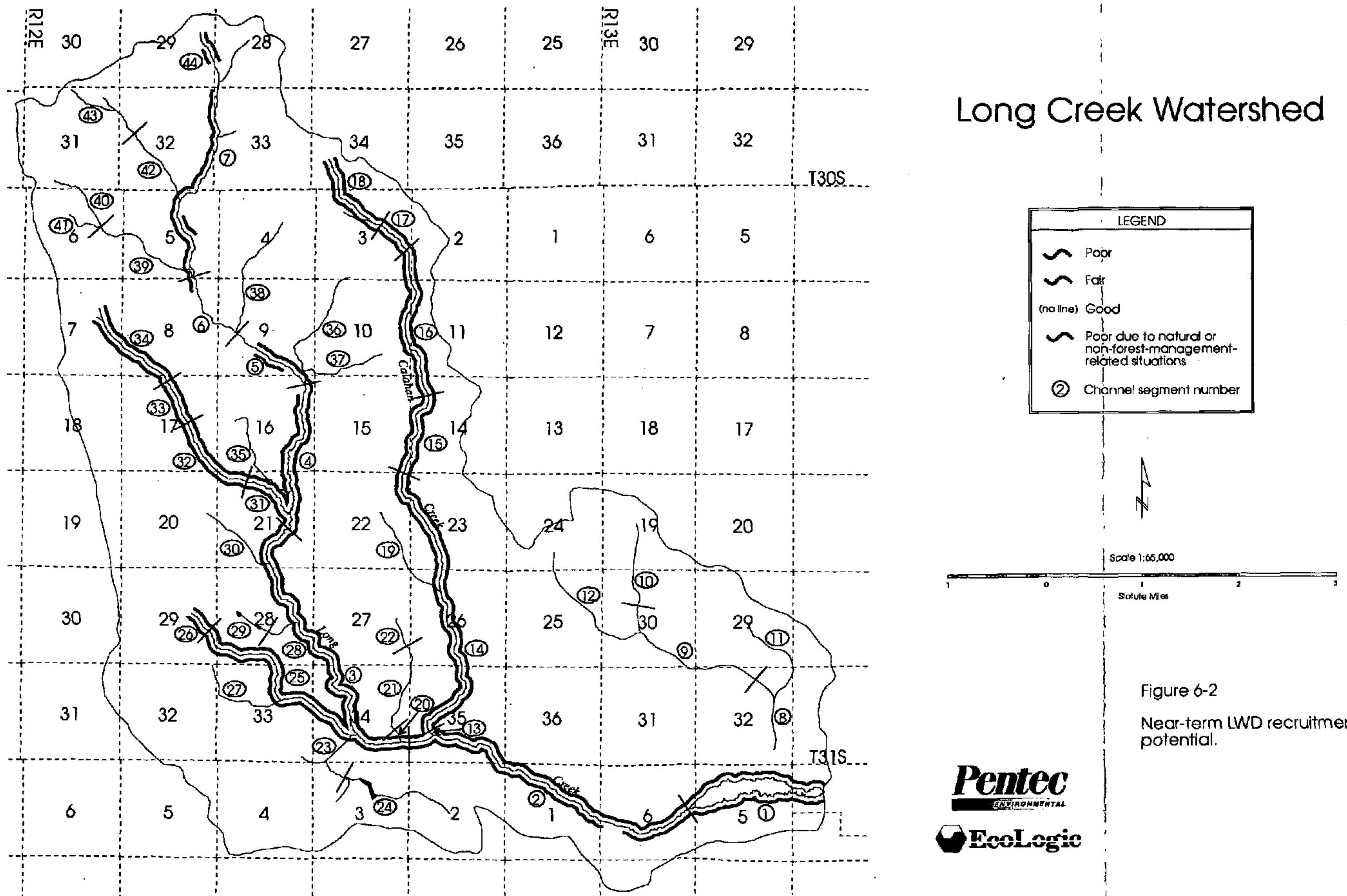


Figure 6-2

Near-term LWD recruitment potential.

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EcoLogic

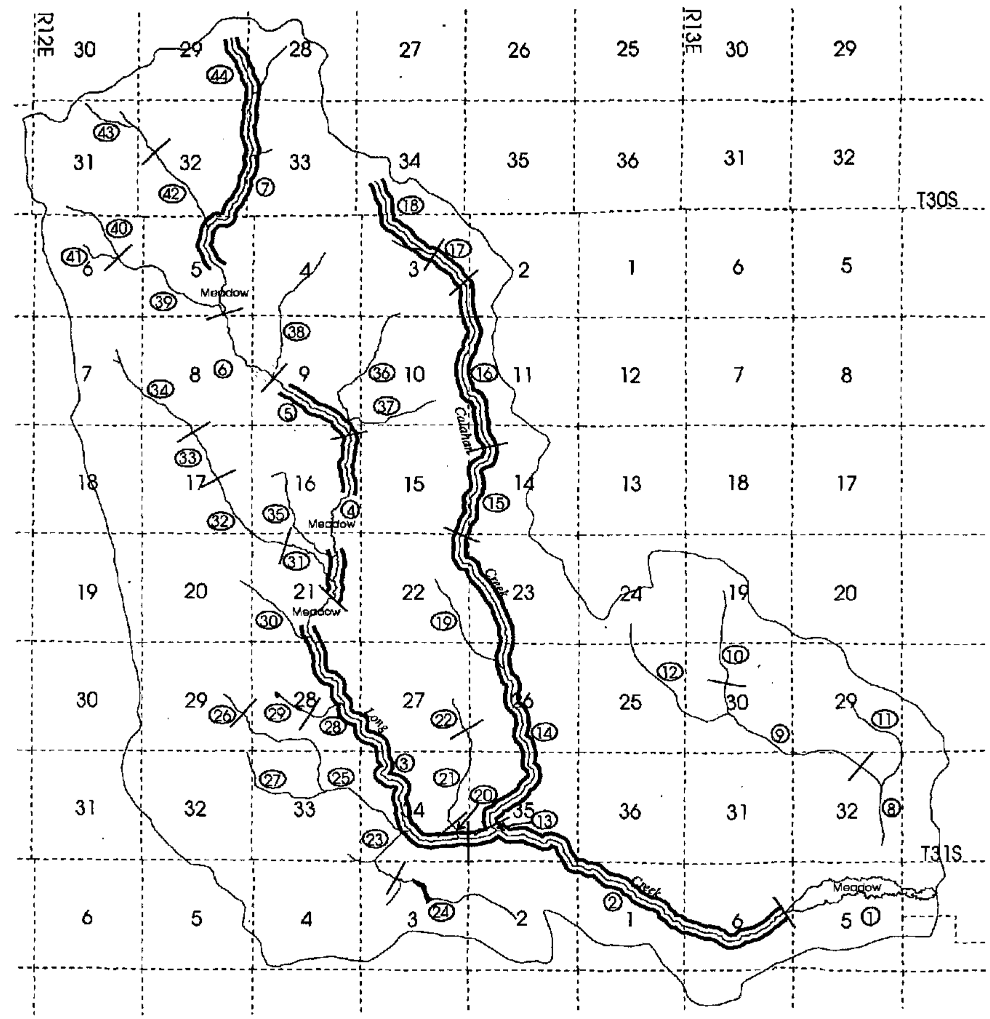
As indicated in Table 6-1, logged sites show a much greater percentage of poor and fair LWD recruitment potential than do unlogged sites. Weyerhaeuser land has good LWD recruitment potential along one-twentieth of its streams, and USFS land has good recruitment potential along one-fourth of its streams. This difference is related to selective harvesting in the riparian zone on Weyerhaeuser property, subsequent replanting with small conifers, and delayed reestablishment of trees along the streams banks because of heavy grazing and browsing by cattle.

Habitat parameters for in-channel LWD counts (debris pieces per channel width) established in the fish habitat module of the Washington watershed analysis manual (TFW 1993) are based on habitat conditions for western Washington and may not be applicable to eastern Oregon. As discussed in Section 8.4.2.6 of this report, the natural level of in-channel LWD in this eastern Oregon habitat is probably lower than that in western Washington because of lower natural forest density. Since Long Creek Reach L7 is USFS land and has never been logged, it may have an in-channel LWD count that is more reflective of natural LWD levels of portions of the watershed. However, it should be noted that the channel characteristics of Reach L7 are very different from the characteristics of the rest of the watershed. Specifically, the channel along Reach L7 is much steeper and more confined than the rest of the channel. In-channel LWD in stream reaches that have a lower gradient and are unconfined are expected to be higher due to bank erosion and undermining of trees (Murphy and Koski 1989). Thus, for all reaches of Calahan and Long creeks except L7, the natural level of in-channel LWD is estimated to be between 1 and 2 debris pieces per channel width (see Section 8.4.2.6). Because the riparian zone of Reach L7 is unlogged, the calculated in-channel LWD of 0.34 debris pieces per channel width (Dambacher et al. 1993) is considered the natural level for this reach.

In-channel LWD counts made by the ODF&W (Dambacher et al. 1993) for many reaches of Long and Calahan creeks either equal or exceed the estimated natural levels. Figure 6-3 summarizes the near-term LWD recruitment situation based on in-channel LWD counts and current recruitment potential. In situation RF1, both in-channel and riparian zone LWD are adequate; in situation RF2, riparian zone LWD is adequate but in-channel LWD is inadequate; in situation RF3, there is adequate in-channel LWD but inadequate riparian zone LWD; in situation RF4, neither riparian zone LWD nor in-channel LWD is adequate (Figure 6-3).

Table 6-2 summarizes the percentage of each riparian recruitment situation for Long and Calahan creeks excluding the meadow areas for Weyerhaeuser and USFS lands. Weyerhaeuser property has a larger percentage (44 percent) of stream length with inadequate riparian zone and

Long Creek Watershed



LEGEND

- RF1 - Adequate riparian and in-channel LWD
- RF2 - Inadequate riparian and adequate in-channel LWD
- RF3 - Adequate riparian and Inadequate in-channel LWD
- RF4 - Inadequate riparian and in-channel LWD
- ② Channel segment number

Scale 1:65,000

Statute Miles

Pentec ENVIRONMENTAL

EcoLogic

Figure 6-3

Near-term LWD recruitment situation.

Table 6-1 LWD recruitment potential on logged and unlogged lands.

Stream reach location	Portion (%) of stream within each recruitment potential category: Good	Fair	Poor	Poor due to natural causes
Logged land	5	51	20	20
Unlogged land	25	45	-	30

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Table 6-2 Riparian recruitment situation summary.

Stream reach location	Portion (%) of stream within each recruitment situation (excluding meadows): RF1	RF2	RF3	RF4
Logged land	8	3	45	44
Unlogged land	93	0	7	0

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in-channel LWD (RF4); USFS land has a larger percentage (93 percent) of stream length with adequate levels of riparian zone and in-channel LWD (RF1).

In general, clear-cutting and partial cutting in or near the riparian zone and moderate to heavy grazing appear to be primarily responsible for the higher percentages of low and moderate LWD recruitment potential along the creeks on Weyerhaeuser property. There is also an increase of young deciduous saplings such as willow and red alder along stream banks, which are often stunted by browsing. Neither of these conditions provides timber large enough to provide LWD. Recovery of the most severely impacted portions of the creek may take 35 to 80 years based on the mean growth rate of white fir, ponderosa pine, and lodgepole pine reported in Fremont National Forest by the USFS (Shafer, M. Fremont National Forest. January 18, 1994. Pers. comm.).

6.2 CANOPY CLOSURE/STREAM TEMPERATURE ASSESSMENT

When assessing canopy closure and stream temperature, the Washington watershed analysis manual (TFW 1993) recommends the exclusion of streams above 4,450 ft elevation in eastern Washington; however, all streams in the Long Creek watershed are above that elevation. Therefore, the general techniques for assessment suggested in the manual were used, but the baseline criteria were not. Instead, an attempt was made to relate degree of canopy closure, measured stream temperatures, and other significant variables such as the location of springs entering the creeks to better evaluate the riparian shade and stream temperature relationships for this watershed.

6.2.1 Canopy Closure Measurements

In order to assess current riparian canopy closure, color aerial photographs were examined to determine percentage of canopy closure along Long and Calahan creeks. Estimates were made based on the amount of stream surface and/or stream banks visible in a segment, and the shade percentage was expressed as a range (Figure 6-4). Shade percentages were also measured in the field at five sites along Long Creek using a densiometer. Table 6-3 compares estimated shade with measured shade.

Long Creek Watershed

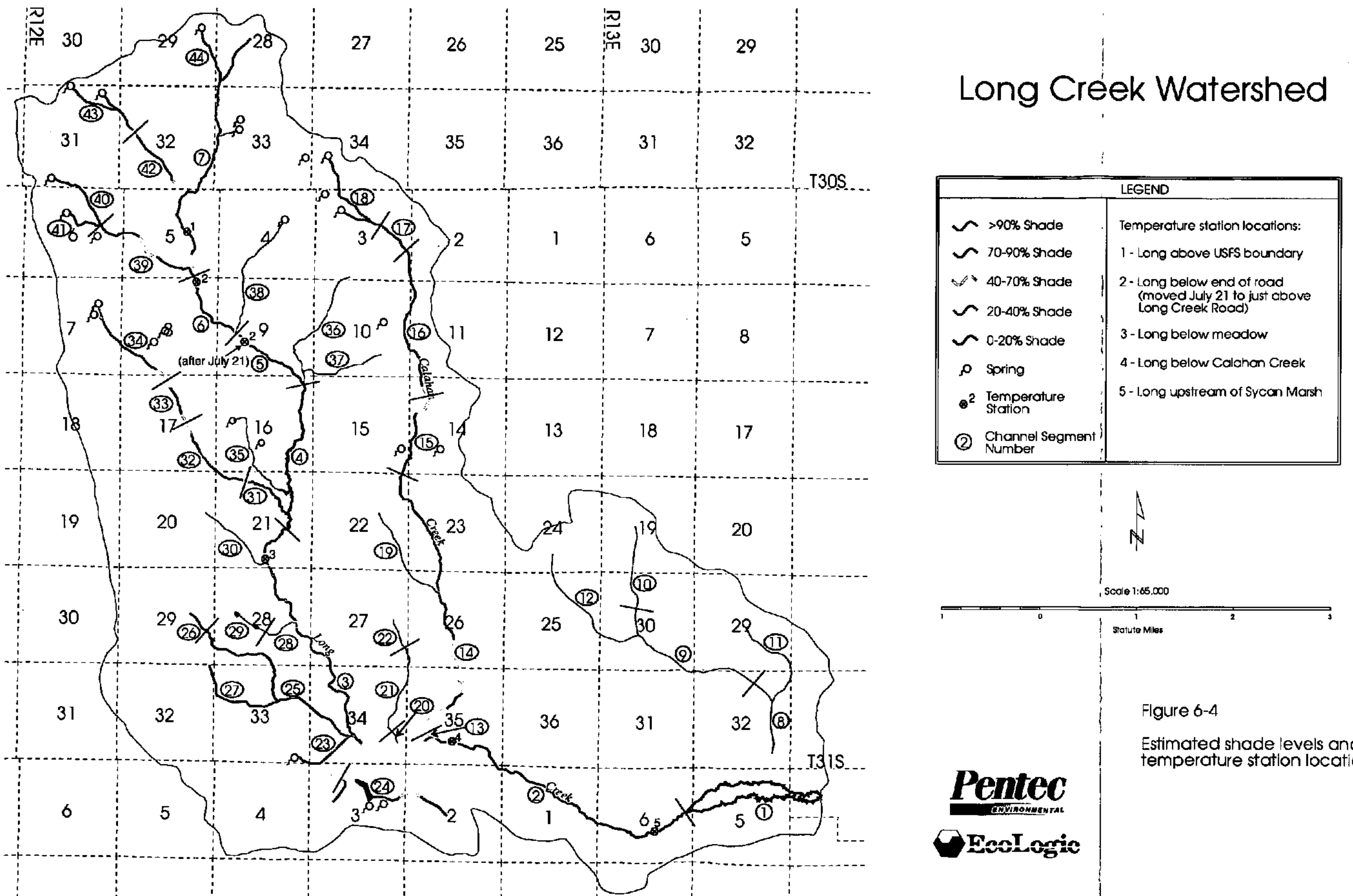

Figure 6-4

Estimated shade levels and temperature station locations.

Table 6-3 **Comparison of canopy shade measured by densiometer and estimated from aerial photographs for stream reaches located upstream of temperature monitoring stations.**

Stream	Temperature station locations	Shade (%) Measured	Shade (%) Estimated
Long	1 Long above USFS boundary	40.5	20-40
	2 Long below USFS boundary (moved July 21 to just above upper 400 Road Crossing)	53.2	20-40
	3 Long below meadow	36.8	20-40
	4 Long below Calahan Creek	39.5	20-40
	5 Long upstream of Sycan Marsh	34.1	20-40

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6.2.2 Water Temperature Measurements

Water temperature gages were installed at five stations on Long Creek; temperatures were monitored from June 8 through September 28, 1993 (Figure 6-4). Figure 6-5 shows the daily maximum water temperature at each temperature gage station. Temperature Station 2 was moved from just north of the Fremont National Forest boundary at the junction of Long Creek and the Section 5 tributary to 60 m above Long Creek Road on July 21, 1993. USFS also measured water temperature at the USFS boundary from November 16, 1992 to October 12, 1993 (Figure 6-6).

6.2.3 Results and Discussion

Estimated shade levels for the Long Creek watershed ranged from 0 to greater than 90 percent (Figure 6-4, Table 6-4). A comparison of estimated shade on Weyerhaeuser land with shade on USFS land (Table 6-5) shows that USFS stream reaches have a greater percentage of stream length with shade levels above 90 percent and that stream reaches on Weyerhaeuser property have a greater percentage of stream length with shade levels below 90 percent. This is consistent with partial and clear-cutting of timber practiced in and near riparian zones on Weyerhaeuser property. A comparison of shade levels less than 40 percent, however, shows little difference between Weyerhaeuser and USFS stream segments: on Weyerhaeuser property, 67 percent of the stream length has less than 40 percent shade; on USFS lands, 59 percent of the stream length has less than 40 percent shade. On Weyerhaeuser property, shading on about three-fifths of the stream length with shade levels less than 20 percent is caused by natural meadows with little or no canopy development; shading on the other two-fifths is a result of partial cutting and moderate to heavy grazing in the riparian zone.

Approximate mean daily maximum (MDM) water temperatures measured on Long Creek range from 6 °C at the confluence of Long and the tributary that enters Long in Section 5 from the northwest, to about 14 °C at temperature gage Stations 3, 4, and 5 (Figure 6-5). Water temperatures at all gage stations approximately parallel air temperatures (i.e., higher water temperatures correspond to higher air temperatures). However, water temperatures are generally lower than air temperatures and fluctuate less.

high water temps

Mean daily maximum water temperature measured by the USFS above the Section 5 tributary is about 9 °C, three degrees higher than the MDM water temperature at the confluence of Long Creek and the Section 5 tributary (Station 2). When Station 2 was moved to the second

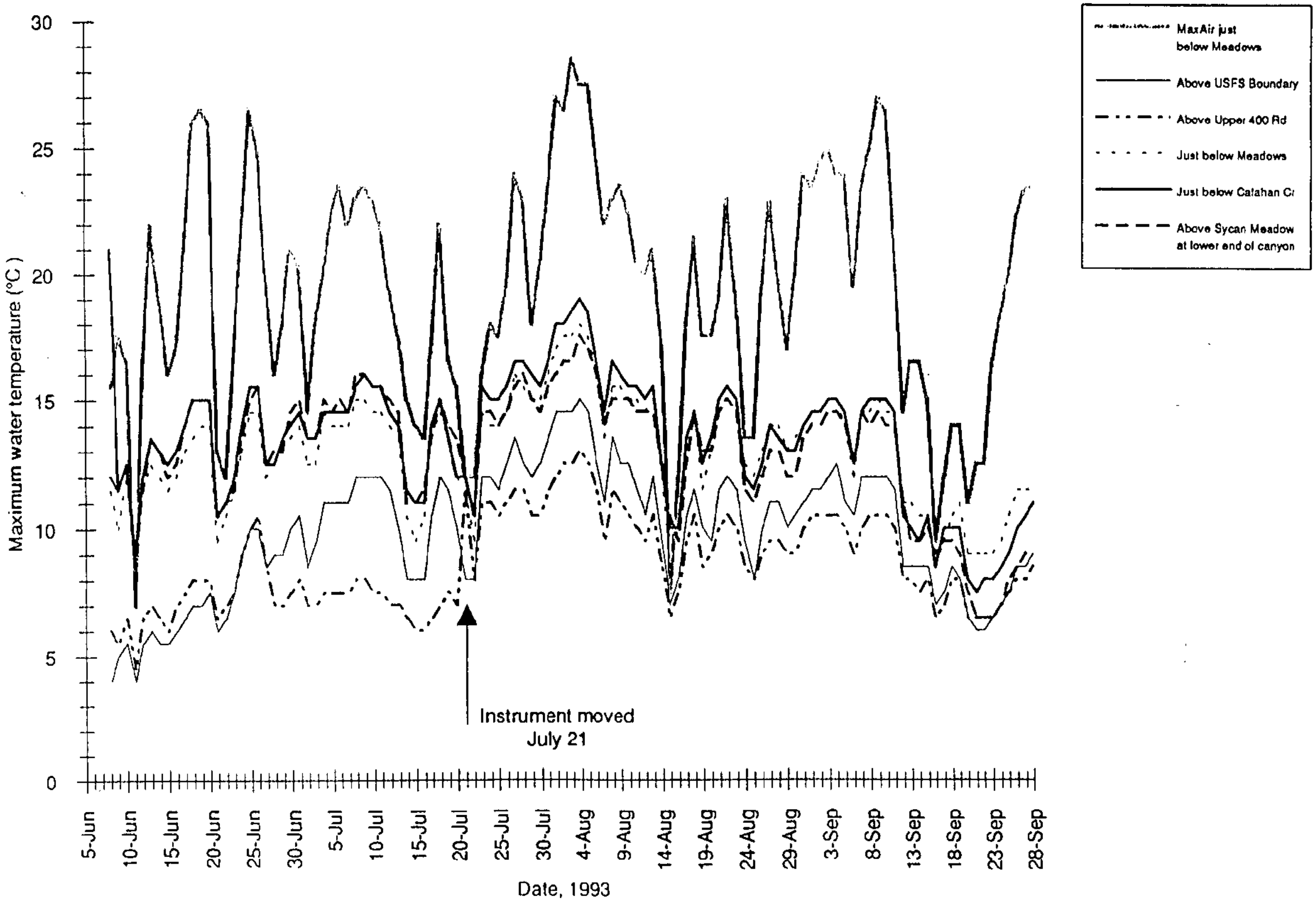

Figure 6-5 Daily maximum water temperature in Long Creek during summer 1993.

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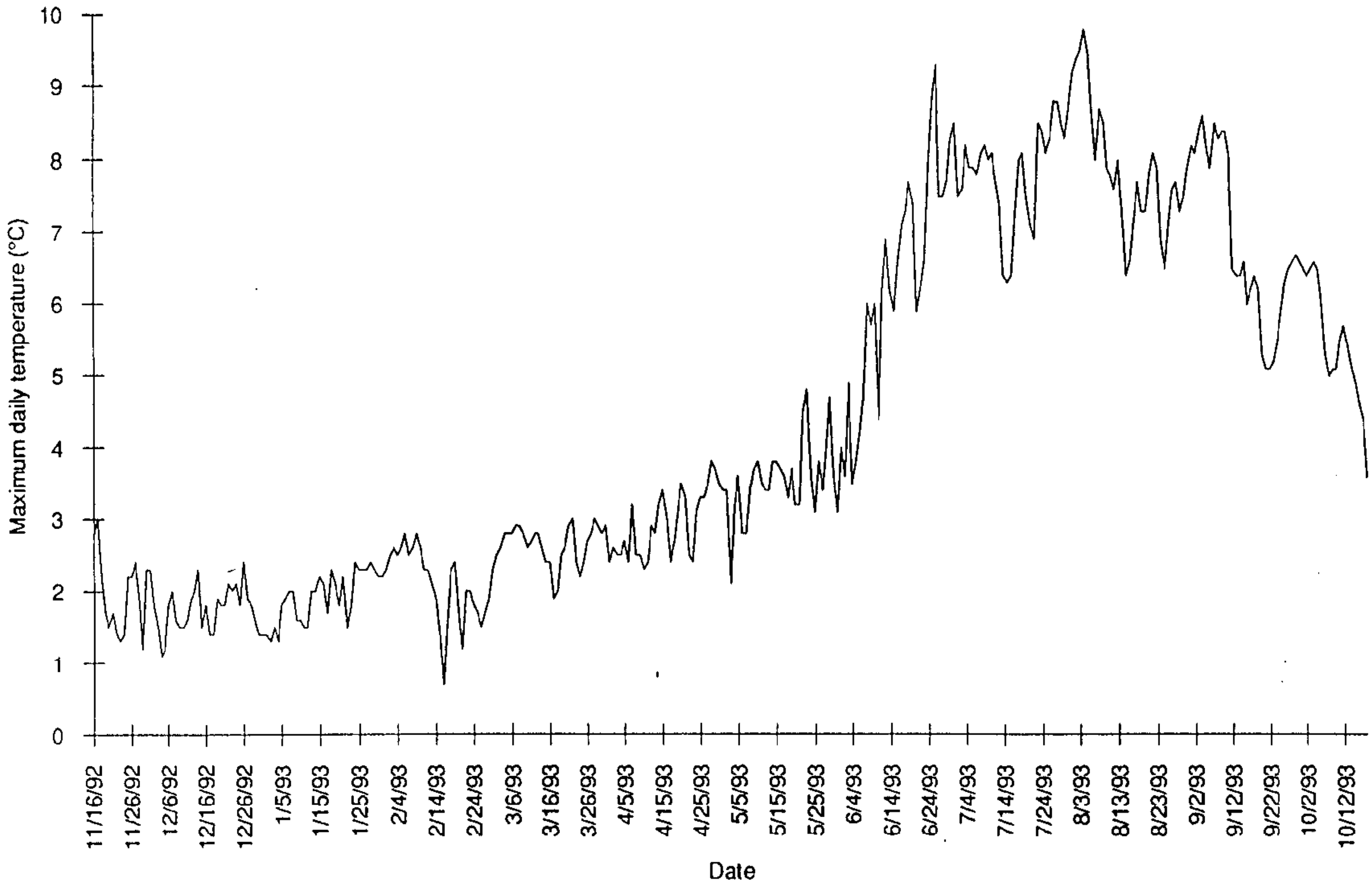

Figure 6-6 Maximum daily water temperature of Long Creek at Forest Service boundary (USFS data).

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Table 6-4 Estimated level of shade for Long Creek stream reaches between or above water temperature monitoring stations.

Stream reach	Portion (%) of stream reach within each shade category				
	0-20	20-40	40-70	70-90	> 90
Source spring to Sta. 1	17	52	0	31	0
Above USFS boundary (Sta. 1) to above upper 400 Road (Sta. 2)	0	68	15	17	0
Upper 400 Road (Sta. 2) to below meadow (Sta. 3)	83	17	0	0	0
Below meadow (Sta. 3) to below Calahan Creek (Sta. 4)	0	77	23	0	0
Below Calahan Creek (Sta. 4) to above Sycan Marsh (Sta. 5)	16	66	0	18	0

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Table 6-5 Percent of estimated shade on logged and unlogged lands.

Stream reach location	Portion (%) of stream within each shade category				
	0-20	20-40	40-70	70-90	> 90
Logged land	31	36	13	16	4
Unlogged land	19	40	8	18	15

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location on July 21, 1993, it registered a MDM water temperature of 9 °C. Thus, it appears that at the first location, Station 2 registered a lower temperature because of the input of colder spring water from the Section 5 tributary.

In relating shade and stream temperature, it is necessary to look at canopy closure upstream of each of the temperature stations. Sixty-nine percent of the stream reach above Station 1 is in the 0 to 40 percent shade category. The MDM water temperature at Station 1 is about 10 °C. Although no temperature measurements were made at the source spring of Long Creek, it may be inferred that the water temperature at this site falls within the same range (i.e., 5.5 to 7 °C) as the measured temperature at the source spring of Boulder Creek. Thus, between the source spring of Long Creek and Station 1, it is estimated that the MDM water temperature increases a minimum of three degrees. This indicates that the low level of shading caused by the meadows along this reach allows some increase in water temperature.

Shading between Station 1 and Station 2 (at the Fremont National Forest Boundary location—used until July 21) is in the 40 to 90 percent ranges. As discussed earlier, the lower water temperature measured at Station 2 is probably related to the cooler spring water from the Section 5 tributary rather than to the amount of canopy closure.

Downstream of Station 2, Long Creek passes through an extensive meadow and an area of partially cut timber. At temperature Station 3, the MDM water temperature is about 14 °C, an increase of 5 degrees. Again, it is apparent that the temperature along this reach is affected by the lack of canopy. The presence of several springs along the tributary that enters Long Creek in Section 21 from the northwest seems to have little mitigating effect on the increase in water temperature along this reach.

Between Stations 3 and 4 and Stations 4 and 5, there is little change in MDM water temperature even though most of the shading along these reaches is below 40 percent due to partial cutting of timber and heavy grazing. Apparently, canopy development is adequate for maintaining the temperature, and any negative effect of reduced shading is mitigated by the cooler water from the tributary that enters Long Creek in Section 34 from the northwest. Between Stations 4 and 5 there is also topographic shading from the canyon walls.

On the whole, it appears that the natural meadows located along the creek have more impact on water temperature than reduced canopy caused by logging. In the meadows, the water is shallower and the stream course is more meandering, allowing more opportunity for the temperature of the water to increase. Heavy to moderate grazing and browsing in the riparian zone has also significantly reduced canopy provided by willows.

It should be noted that the conclusions in this report are based on temperature measurements from a single season. Data from years with higher air temperatures may show a greater impact on MDM water temperature from loss of shading. However, a comparison of 1993 daily maximum air temperatures with daily maximum air temperatures recorded at Paisley, Oregon, for 1948 through 1992 shows that 1993 temperatures fall within the range of temperatures and are neither significantly higher nor significantly lower than average temperatures for 1948 through 1992.

7.0 STREAM CHANNEL ASSESSMENT

7.1 CHANNEL SEGMENTS

The channel network of the Long Creek basin is divided into seven geomorphic units based on analysis of topographic maps, aerial photographs, and field surveys. Descriptions of the seven units are contained in Table 7-1. The locations of the seven units and corresponding stream segments in the Long Creek basin are shown in Figure 7-1. Plates 7-1 through 7-8 show examples of geomorphic Units A, B, D, E, and F.

In general, the volcanic geology determines some of the types and distributions of channel units. For example, the meadow (Unit A) apparently is located on top of a resistant layer of volcanic rock. Stream erosion through the edge of the resistant layer has created steeper canyon reaches, classified as Unit B downstream of the meadow.

To illustrate the relationship between channel gradient and geomorphic units, Figure 7-2 shows the longitudinal profile of a portion of Long Creek, and it indicates the locations of the upper and lower meadow units and the canyon unit. In addition to different channel gradients, each of the channel units has different substrate sizes, widths, and width/depth ratios.

7.2 HISTORIC TRENDS

Limited aerial photographic coverage (1980 and 1993) of the Long Creek basin limits the amount of information that can be obtained to determine time trends in channel and floodplain morphology. No major channel changes are evident on aerial photographs during the period 1980 to 1993. The absence of significant mass wasting and other forms of erosion and relatively low precipitation would promote a quasi-steady-state channel and floodplain morphology. The major form of erosion in the Long Creek basin that supplies the channel with coarse sediment is relatively continuous and low-magnitude bank erosion; therefore, large changes in the supply of coarse sediment are a low-probability occurrence. The evidence for this is the lack of large deposits of coarse-textured sediment (i.e., mid-channel bars, islands, recent aggradational terraces, etc.) along the valley floor.

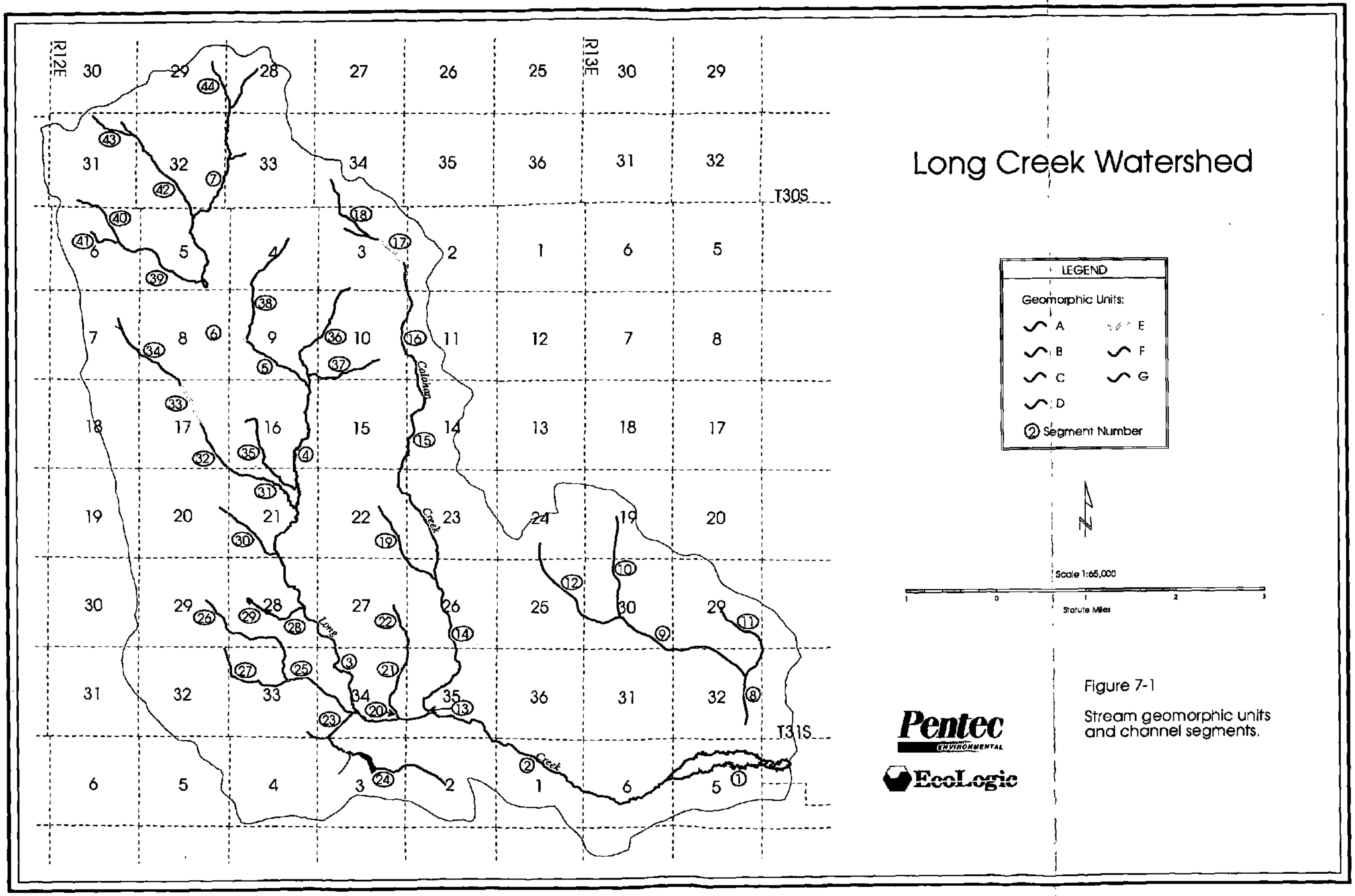

Figure 7-1

Stream geomorphic units and channel segments.

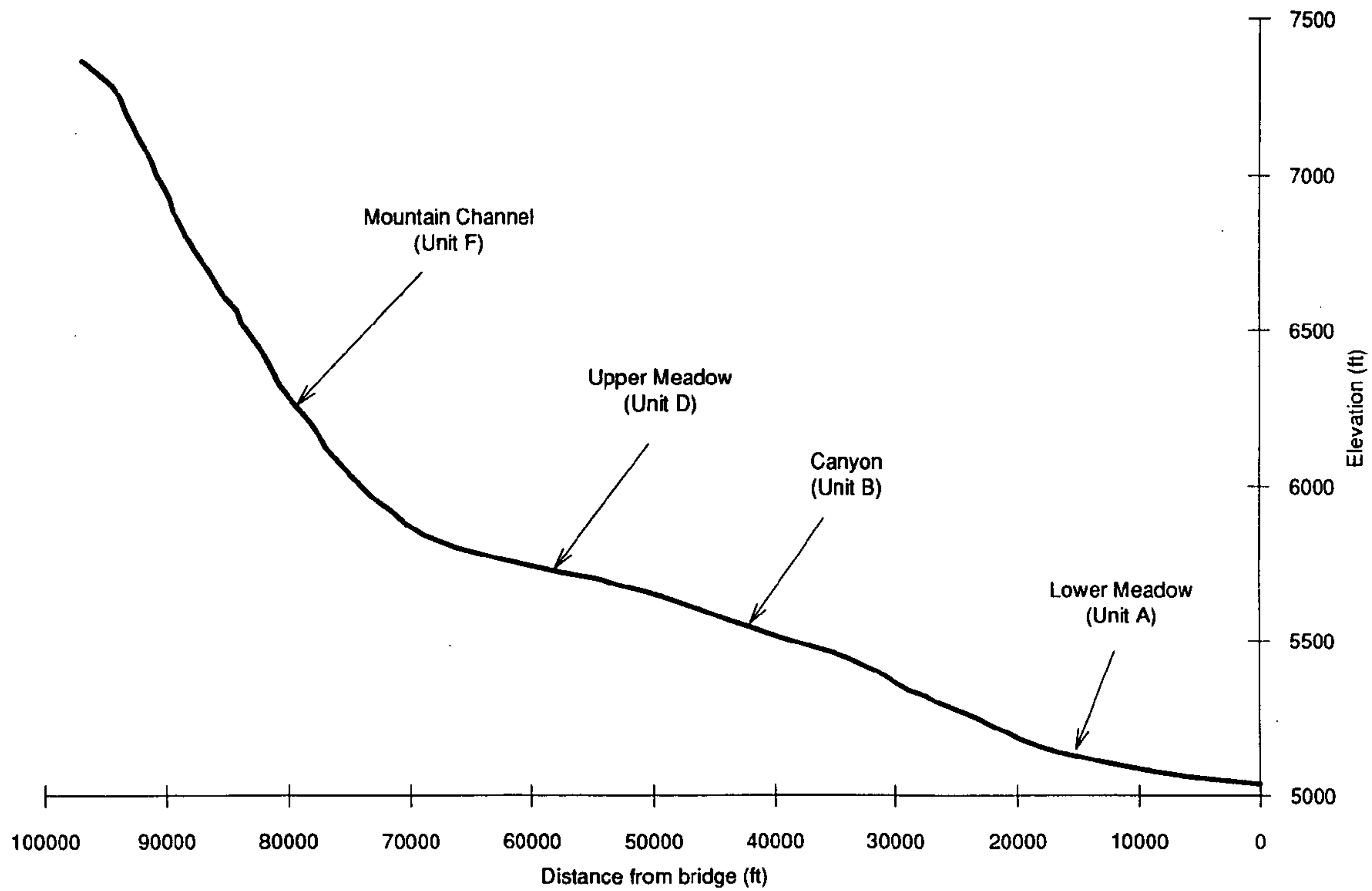

Figure 7-2 **Longitudinal profile of Long Creek showing the location of selected geomorphic units.**

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Table 7-1 Description of the seven geomorphic units and unit location by channel segment for the Long Creek basin.

Geomorphic Unit	Segments	Description
A	1, 4, 15, 22, 24, 29, 31, 35	Lowest gradient segment in network: < 1%. Width/depth ratio varies from a low of 4 in incised reaches in meadows to a high of 20 in shallow, riffle reaches (also in meadows); substrate: cobbles, gravels pebbles; distribution of this segment type in watershed is probably defined by lithologic strata—basalt layers; site of much spring activity (possibly perched aquifer); actual channel dimensions can vary according to position in network and therefore discharge; no direct hillslope influences; sinuosity is high; bank erosion is high (possibly due to loss of vegetation from grazing; pool and riffle morphology, i.e., morphology governed by the spatial distribution of lateral and vertical hydraulic forces.
B	2, 9	Canyon reach, channel cutting through basalt layers; direct hillslope influences (fans, scree slopes, rockfalls, avalanches); slope 2-4%; substrate is very coarse—contains boulders originating from hillslope processes; terraces can be 4X channel width so generally not constrained; morphology is generally a step-pool; forced pool.
C	13, 20	Very short, local steep reaches (8-20%) that climb out of the canyon reach-Unit 2; substrate dominated by large boulders creating a cascade channel type; narrow bedrock or scree controlled banks.
D	3, 5, 8, 14, 16, 21, 23, 25, 27, 28, 30, 32	Gradient 2-4%; high width/depth ratio (8-15); substrate dominated by gravels, cobbles, and fine sand; pool-riffle morphology with numerous wood-formed pools and wood-formed habitats; low and relatively wide terraces (at least 2-4X channel width) create relatively high sinuosity necessary for pool-riffle development; in general channels not directly affected by hillslope processes.
E	6, 17, 33	A transition reach between geomorphic Unit D and Unit F; gradient 2-4%; substrate cobbles and boulders; some pool-riffle near meanders but increasing amount of step-pools and cascades.
F	7, 10, 11, 18, 26, 34, 36, 37, 38, 39, 42, 43	Steeper mountain channel; gradient 4-8%; direct hillslope influences (debris flows, deep-seated landslides; rockfalls etc); channels may convey debris flows short distances; boulder, cobble, and gravel bed; relatively narrow valley floor; low sinuosity; local areas of aggradation indicate periods of concentrated bedload movement (waves); step-pool morphology and cascades; some local wood influence on morphology but a second-order effect.
G	12, 19, 40, 41, 43, 44	Upper tips of the network where channel declines in slope; gradients between 4-8%; these channels were not investigated.

Plate 7-1 Example of Geomorphic Unit A in Sycan meadow (Segment 1).

Plate 7-2 Example of Geomorphic Unit A in Long meadow (Segment 4).

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Plate 7-3 **Example of Geomorphic Unit A in Calahan meadow (Segment 15). Note collapsed banks.**

Plate 7-4 **Example of Geomorphic Unit B in canyon downstream of Calahan Creek (Segment 2).**

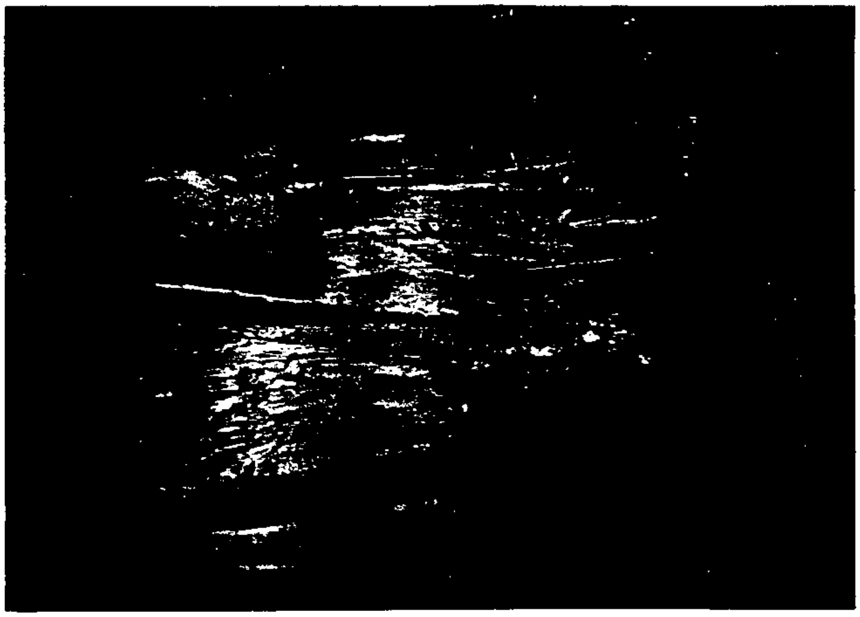

Plate 7-5 Example of Geomorphic Unit D in Long Creek (Segment 3).

Plate 7-6 Example of Geomorphic Unit D in Calahan Creek (Segment 14).

Plate 7-7 Example of Geomorphic Unit E in Long Creek (Segment 6).

Plate 7-8 Example of Geomorphic Unit F in USFS reach of Long Creek (Segment 7).

7.3 CURRENT CHANNEL CONDITIONS

7.3.1 Channel Geometry

There is a diversity of channel morphology in the Long Creek basin ranging from low-gradient meadows (Unit A) to boulder-bedded mountain channels (Unit F). Refer to Tables 7-2 and 7-3 for details of channel characteristics based on surveys by ODF&W. Information on current channel conditions can be used to determine whether a channel has changed its morphology in response to a change in sediment supply, hydrology, large organic debris, and riparian vegetation. Overall, the relatively stable channel morphology (i.e., lack of large-scale lateral migration, changes in channel-bed elevation, bed scour, etc.) suggests that major changes in channel morphology have not occurred in recent times (last decade). Two of the major reasons for this are the steady sediment supply (no significant mass wasting) and low annual precipitation. In addition, the relatively large amounts of organic debris in channels and boulders in canyon reaches (Unit B) and mountain channel reaches (Units D and F) provide roughness that also promotes vertical and horizontal channel stability.

There is evidence for a change in the amount and type of riparian vegetation because of grazing in the Long Creek watershed. According to Weyerhaeuser foresters, grazing has been occurring in the Long Creek basin for decades. Cattle typically consume riparian vegetation (e.g., willows and grasses) and can reduce or eliminate certain types of vegetation along streams. There is evidence in the meadow unit (Segments 1, 4, and 15) and along other channels that cattle have severely reduced or eliminated riparian vegetation, and in some locations cattle have trampled banks (e.g. Plate 7-3). In one of the major meadows (Segment 4) in Long Creek basin, numerous old beaver dams attest to a historical supply of willow. At present, beaver activity is minimal because of the lack of willow apparently caused by cattle grazing.

Theoretically, the reduction or elimination of riparian vegetation should reduce the effective cohesion of stream banks. This is important because channel geometry (e.g., width-depth ratio) is controlled by such things as bank material composition and strength in addition to substrate size, channel slope, and channel roughness. Reducing bank cohesion may increase bank erosion in Long Creek, and this should widen channels and make them shallower. For example, Platts (1991) showed that the elimination of riparian vegetation by grazing in Nevada resulted in increases in channel width between 40 and 200 percent during large storms. Although raw banks should be associated with large changes in channel width by bank erosion, this should be most evident during the period immediately following the removal of the riparian vegetation. Our surveys, in addition to channel surveys completed by ODF&W in Long Creek, show

Table 7-2 Summary of stream channel characteristics of Long Creek based on Dambacher et al. (1993).

Parameter	Stream reach	1	2	3	4	5	6	7	8	9	10	11
	Segment	1	1-2	2	2	2-3	3	3	4	5	6	7
	Geomorphic unit	A	A-B	B	B	B-D	D	D	A	D	E	F
Length (m)		4098	1699	1263	1684	1939	717	4547	2677	2228	2277	2635
Width (m)		3.7	5.2	6.3	5.3	6.1	6.2	6.0	5.1	7.5	6.9	5.3
Gradient (%)		0.6	1.0	1.9	1.6	1.8	1.2	1.4	0.9	1.6	3.4	6.5
Mean channel confinement (vw/cw)		20	10.7	1.4	3.8	1.8	4.3	2.4	14.8	17.0	1.3	1.3
Habitat unit area (%)	Pool	46	32	4	12	4	18	15	31	49	5	6
	Riffle	52	31	6	12	21	36	28	63	18	2	20
	Bldr. rapid/ cascade	2	35	89	76	74	46	56	6	33	86	72
	Step/falls	< 1	2	1	< 1	< 1	< 1	< 1	< 1	1	1	2
Pool freq.	(pool/km)	38	28	5	10	4	18	12	22	30	6	15
	(cw/pool)	7.1	5.7	33.4	18.7	45.4	8.9	14.3	9.1	4.5	25.4	12.7
Surface substrate size composition (%)	Silt	21	12	8	7	7	15	11	20	28	8	4
	Sand	32	24	18	20	20	25	24	25	32	15	3
	Gravel	34	33	23	27	23	32	29	33	30	25	33
	Cobble	12	28	28	29	28	24	26	21	10	28	30
	Boulder	0	4	23	17	21	4	10	1	0	21	22
	Bedrock	1	0	0	0	0	0	1	0	0	2	9
Bank erosion (%)		35	21	6	10	20	56	42	59	33	13	1
LWD	(no./100 m)	15.3	26.0	24.6	29.0	15.6	12.8	17.4	3.8	45.0	17.6	6.4
	(no./cw)	0.57	1.35	1.55	1.54	0.95	0.79	1.04	0.19	3.37	1.21	0.34

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Table 7-3 **Summary of stream channel characteristics of Calahan Creek based on Dambacher et al. (1993).**

Parameter	Stream reach	1	2	3	4	5	6	7
	Segment	13	14	14	14	14	15	16
	Geomorphic unit	C	D	D	D	D	A	D
Length (m)		504	517	865	432	3505	816	1835
Width (m)		7.3	3.0	4.0	3.3	3.7	2.0	4.7
Gradient (%)		4.9	2.1	2.4	1.8	1.7	1.4	3.1
Mean channel confinement (vw/cw)		1.3	9.8	2.5	4.7	2.6	20.0	1.8
Habitat unit area (%)	Pool	6	23	9	28	33	0	1
	Riffle	0	0	0	9	34	0	0
	Bldr. rapid/ cascade	94	76	91	63	31	0	0
	Undefined small channel	0	0	0	0	0	100	99
Pool freq.	(pool/km)	14	27	13	19	13	0	0
	(cw/pool)	9.9	12.3	19.7	16.4	20.1	0	0
Surface substrate size composition (%)	Silt	8	16	13	18	20	21	16
	Sand	15	28	26	26	31	37	24
	Gravel	16	33	28	31	30	32	31
	Cobble	28	21	23	19	14	3	20
	Boulder	30	2	10	6	3	0	5
	Bedrock	4	0	0	0	1	7	3
Bank erosion (%)		8	31	24	56	35	35	26
LWD	(no./100 m)	15.7	15.5	17.9	13.2	15.7	0.4	18.5
	(no./cw)	1.15	0.46	0.72	0.43	0.58	0.01	0.87

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extensive bank erosion, which should indicate a currently widening channel. However, because grazing has been occurring over such a long period in Long Creek basin, the channel may have attained a new, equilibrium channel form; therefore, Long Creek would not necessarily be eroding its banks because of reduced bank cohesion that has been occurring for decades. Therefore, we propose a hypothesis that at least portions of Long Creek, in particular the meadows (Unit A) and low-gradient mountain channels (Unit D), have undergone a change in their morphology since the onset of grazing. The change in channel morphology is most likely a moderate increase in width and a minor decrease in depth. There is, however, no direct evidence for an increase in channel width because we are unable to determine the channel morphology prior to cattle grazing (no field surveys prior to grazing and no historical aerial photographs are available).

7.3.2 Fine Sediment

The proportions of fine sediment (< 0.81 mm) in channel substrates were determined from sediment samples obtained by shovel from the subsurface material at seven locations in the Long Creek basin. The results from a wet sieve analysis are plotted in Figures 7-3 through 7-9. In addition, samples of paleo-substrate were obtained from stream-adjacent fluvial terraces at three of the sample sites, and these results are plotted in the figures. All of the sediment samples excluded particles greater than approximately 40 mm because the objective was to determine the proportion of fine sediment in spawning gravels. Samples were obtained at spawning sites selected by the fisheries biologist.

Figure 7-10 plots the proportion of fine sediment (< 0.841 mm) for all of the sampled segments, including the paleo deposits. The highest levels of fine sediment (> 20 percent) are found in the meadow reaches (Unit A) and the lower-gradient mountain channels (Unit D). Lower proportions of fine sediment (< 15 percent) are found in the steeper reaches of the canyon (Unit B) and the higher-gradient mountain channels (Units E and F). These results are similar to surface textural analyses listed in Tables 7-2 and 7-3 indicating that the proportion of fine sediment (sand and smaller) on the surface of the channel bed is indicative of the proportion of fines in the subsurface sediments.

Paleo substrates in fluvial terraces (age of terraces unknown but at least several hundred years old based on trees growing on them) were sampled in Long Creek to provide some indication of the historic levels of fine sediments in stream gravels. All of the paleo-gravel samples have high levels of fine sediment (Figures 7-3, 7-4 and 7-7). Part of the reason for high levels of fine sediments in the paleo gravels is that terraces may have been formed during

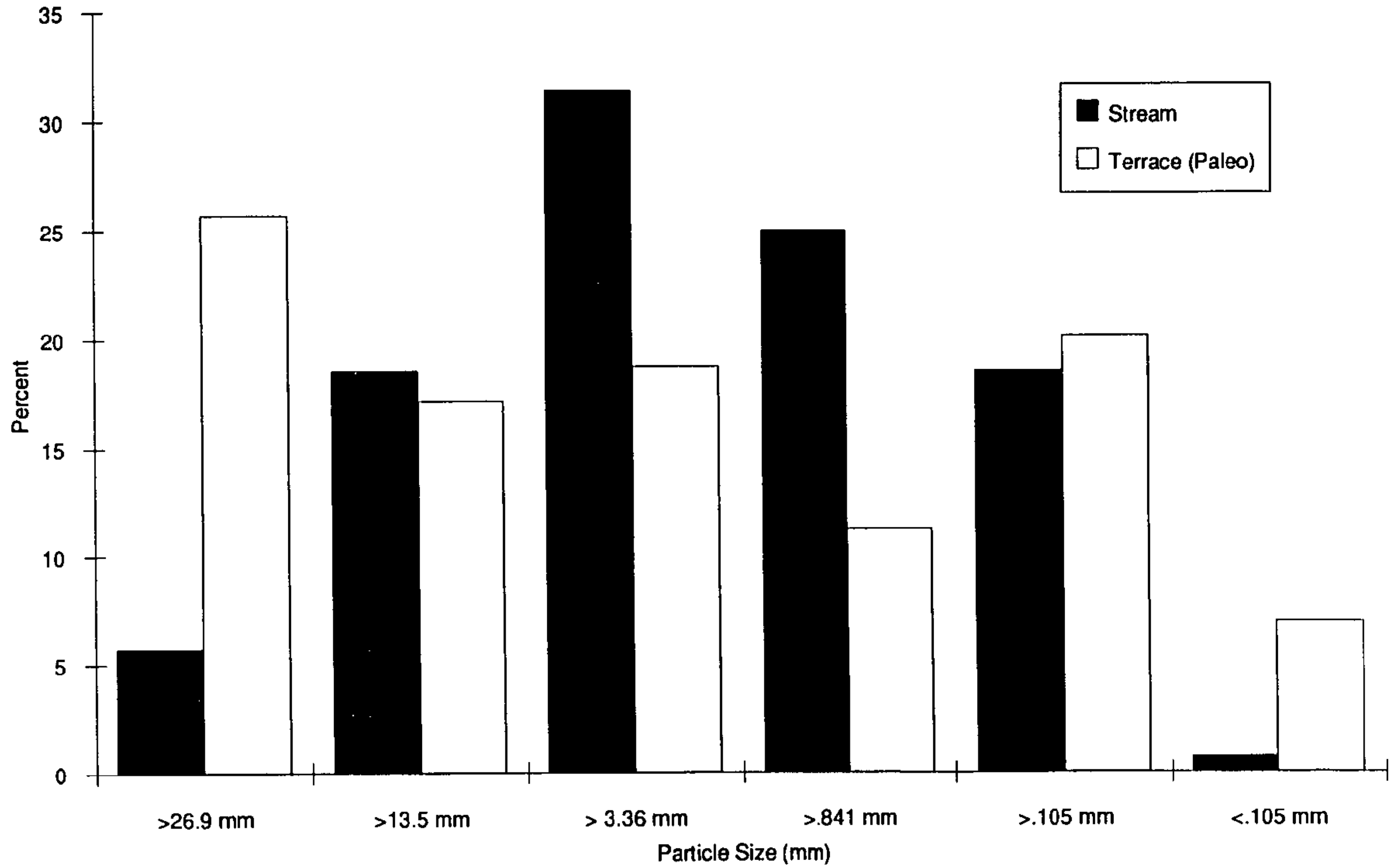

Figure 7-3 Particle size distribution of subsurface sediment from the stream and from an adjacent fluvial terrace in Segment 3 (Unit D).

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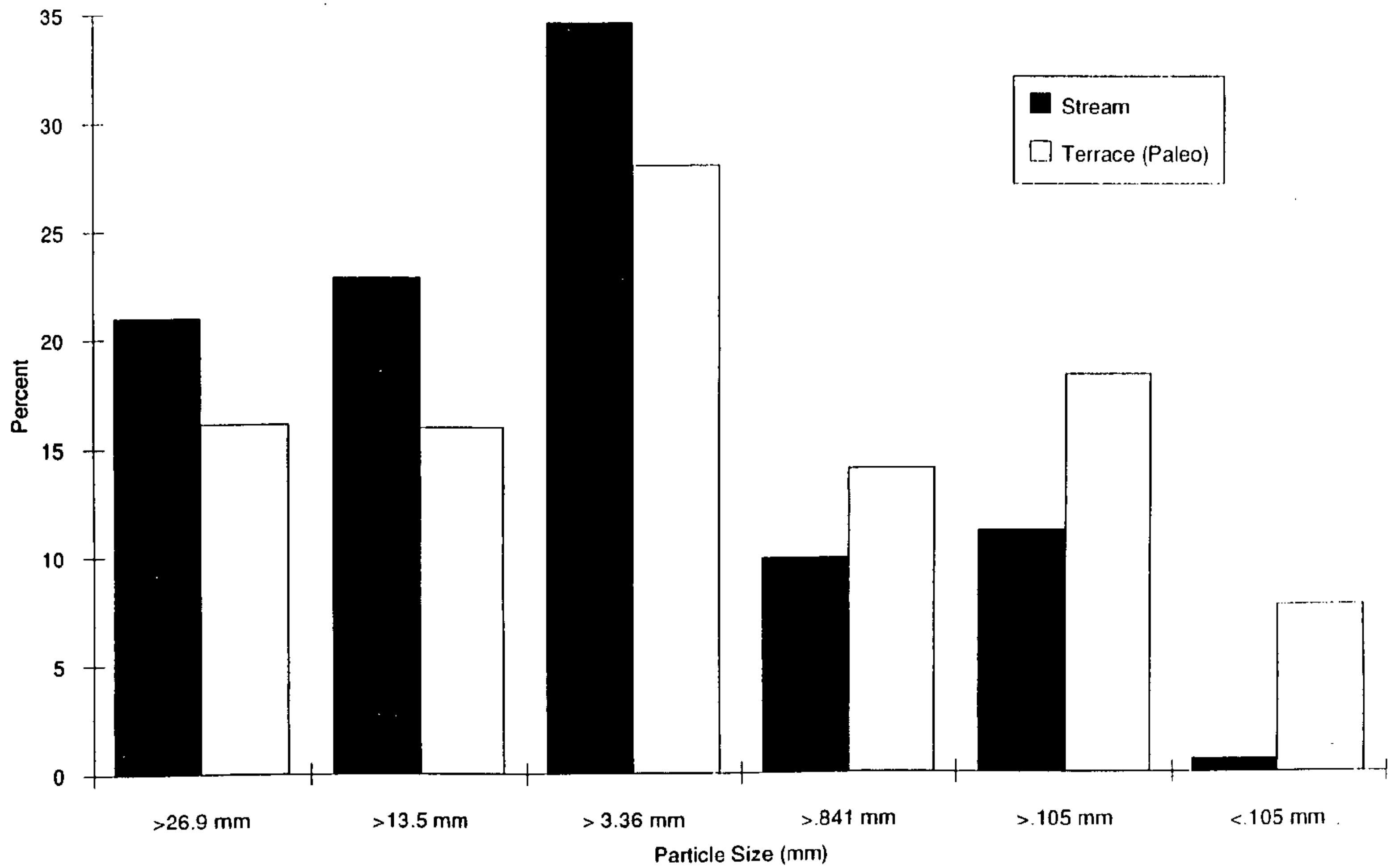

Figure 7-4 Particle size distribution of subsurface sediments from the stream and from an adjacent fluvial terrace in Segment 4 (Unit A).

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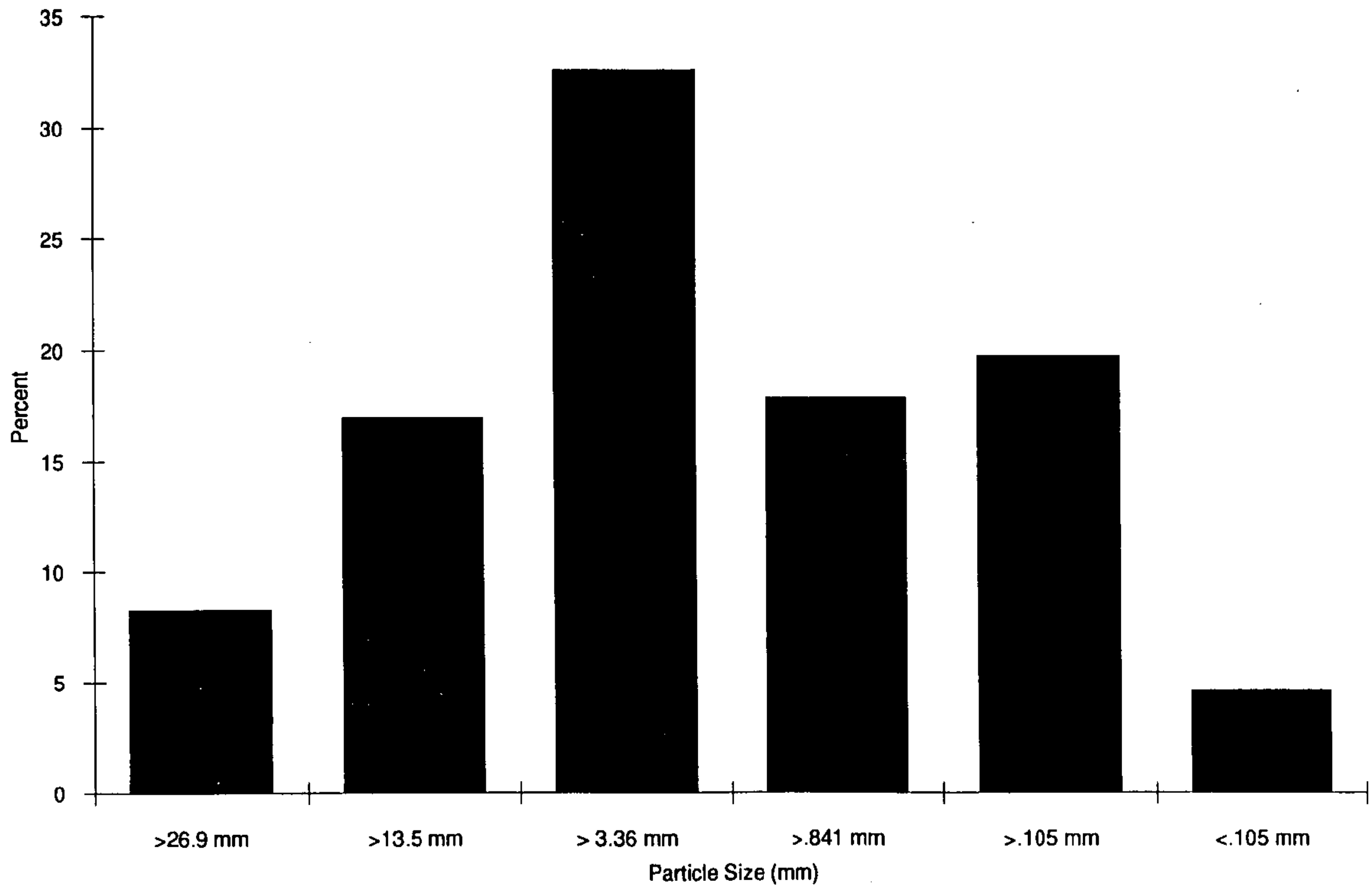

Figure 7-5 Particle size distribution of subsurface sediments from the strream in Segment 5 (Unit D).

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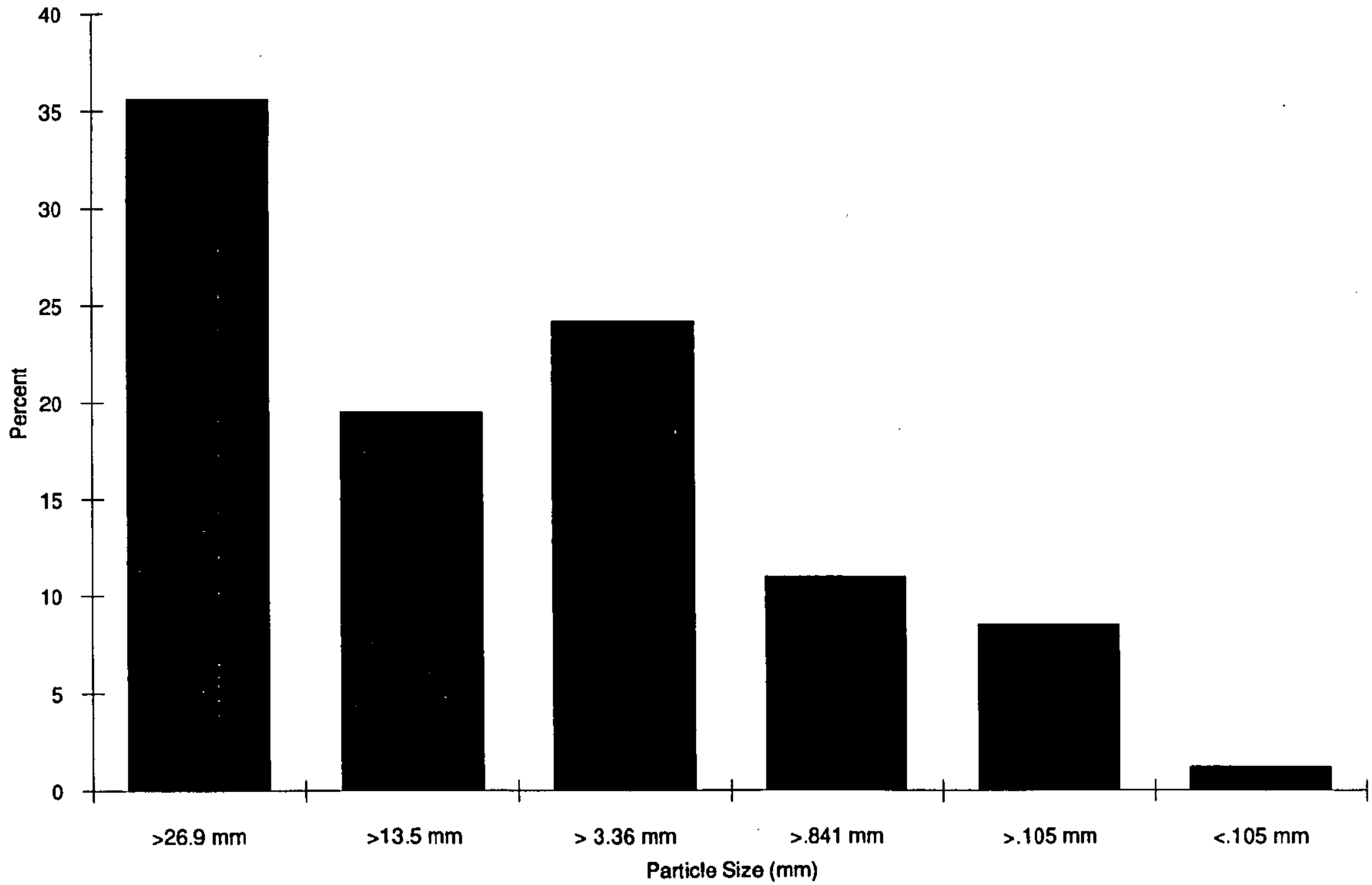

Figure 7-6 Particle size distribution of subsurface sediments from the stream in Segment 6 (Unit E).

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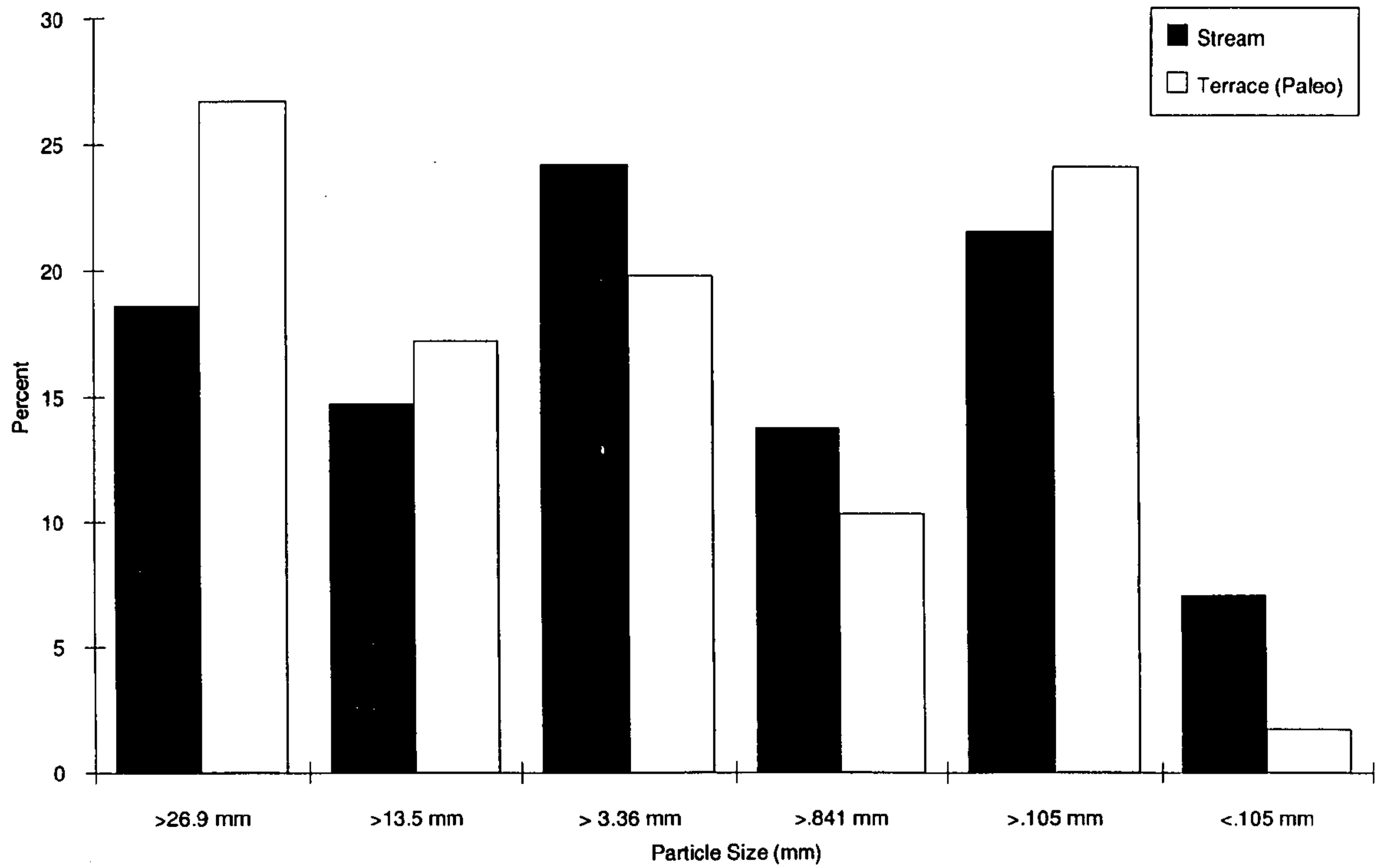

Figure 7-7 Particle size distribution of subsurface sediments from the stream and from an adjacent fluvial terrace in Segment 1 (Unit A).

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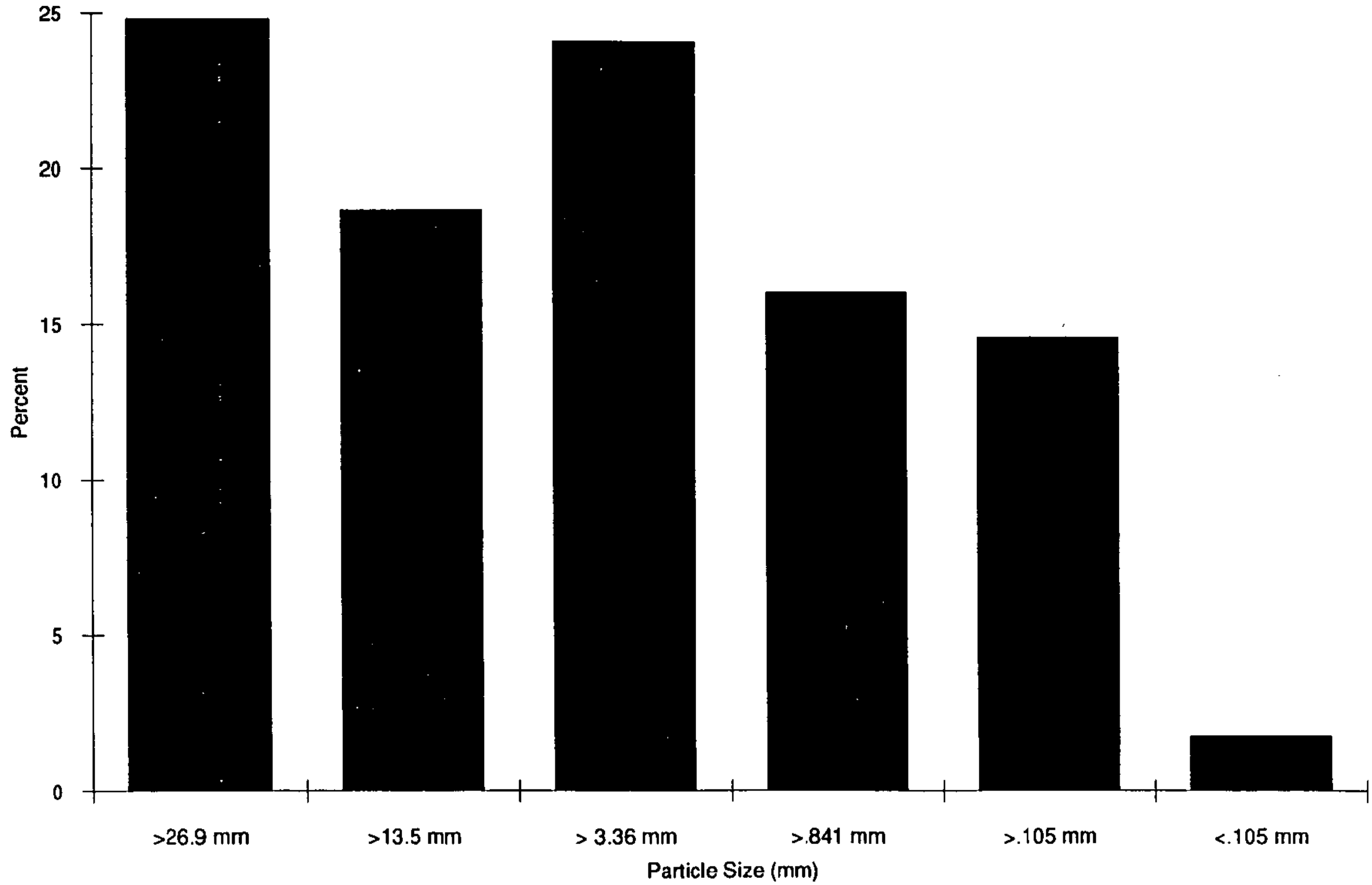

Figure 7-8 Particle size distribution of subsurface sediments from the stream in Segment 2 (Unit B).

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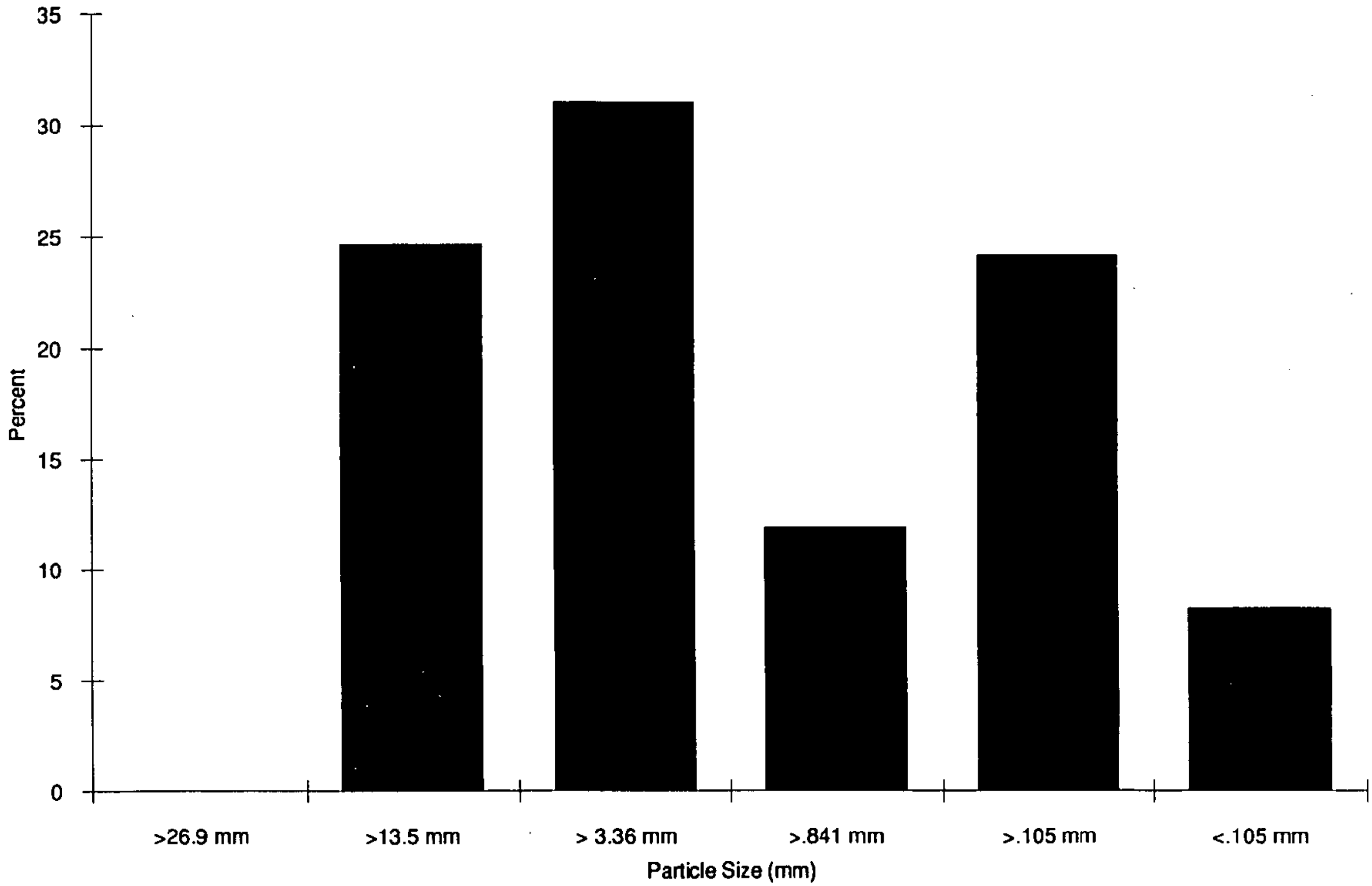

Figure 7-9 Particle size distribution of subsurface sediments from the stream in Segment 14 (Unit D).

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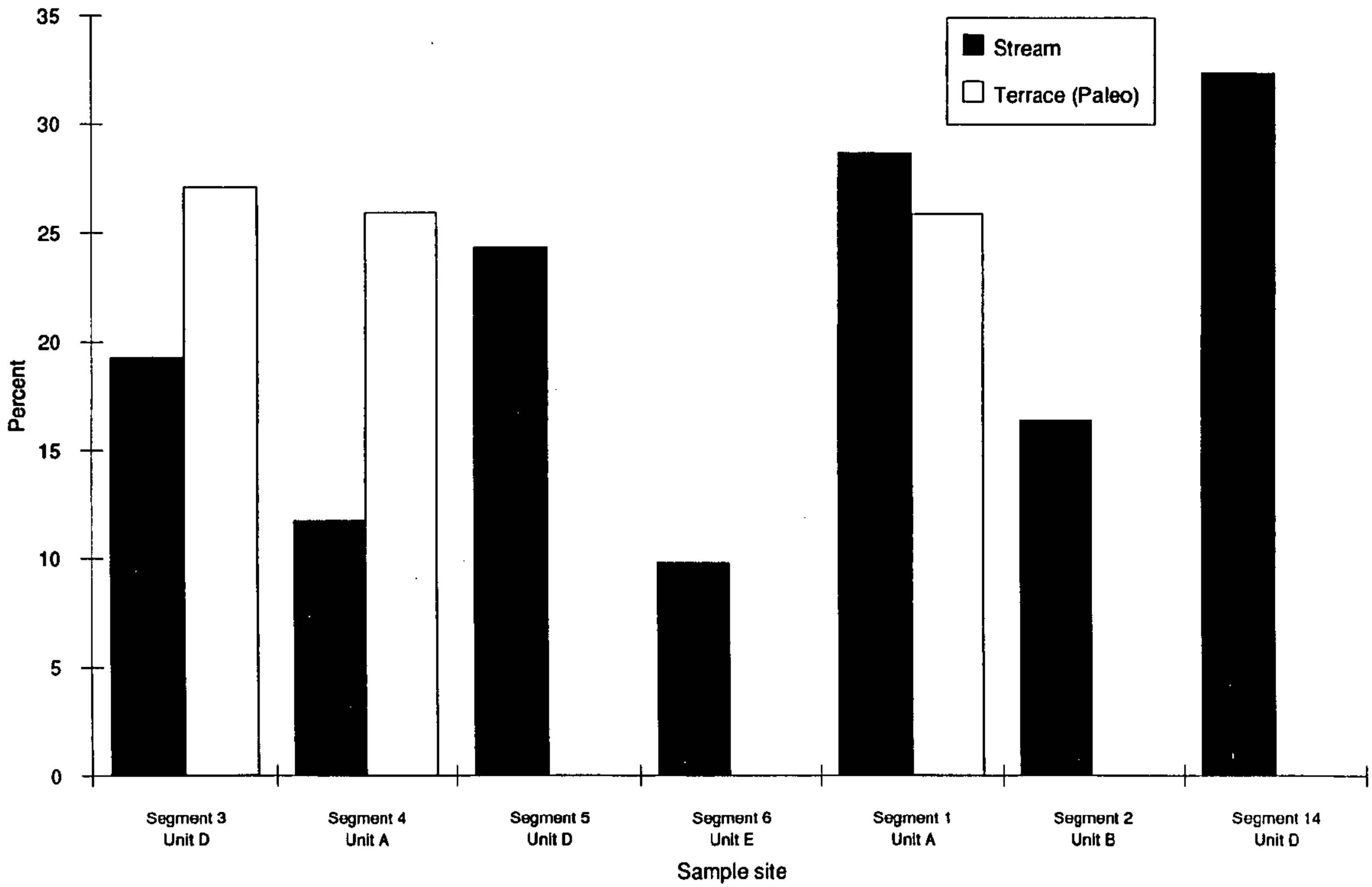

Figure 7-10 Percentage of fine sediment (<0.841 mm) from seven stream and three terrace sample sites in Long Creek.

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periods of high sediment supply when higher levels of fine sediment would be expected. In that case, terrace sediments are probably not directly comparable to present-day channel substrate unless they were both formed during similar sediment supply regimes. Therefore, we do not formally use the results from the paleo gravels analysis in Long Creek.

Fine sediment originates from several sources in Long Creek: bank erosion, logging roads, surface erosion on hillslopes (sheet, rill, and gully erosion), and particle attrition. We are not able to determine quantitatively the relative contribution of each of these sources because a sediment budget was not constructed. Our field surveys and those of ODF&W (Tables 7-2 and 7-3) indicate that bank erosion in some reaches is a significant source of fine sediment. Sheetwash and gully erosion related to logging are major sources of fine sediment (see Surface Erosion, Section 4.0). In addition, there is evidence of surface runoff and sheetwash erosion on the forest floor in unmanaged parts of the Long Creek watershed. The absence of a significant organic layer on the forest floor in conjunction with high precipitation intensities (and relatively low infiltration capacities) promotes overland flow and surface erosion.

7.3.3 Coarse Sediment

Because mass wasting is an insignificant process in the Long Creek basin (see Section 3.2), the major source of coarse bed material is bank erosion of fluvial terraces. A lesser source of coarse sediment, primarily in the size categories of cobbles and boulders, is rockfall along the canyon reach (Unit B) and small, streamside landslides (and debris flows) along some parts of Unit E. Although large influxes of coarse sediment would cause a change in channel morphology in virtually any reach in Long Creek, the absence of significant mass wasting makes channel change by coarse sediment a low probability occurrence. The only exception is debris flow deposits and associated increases in bed-material supply in some parts of Segment 7.

7.3.4 Channel Morphology

There are many different types of channel morphology in the Long Creek basin ranging from boulder-bedded, steep mountain channels (Unit B) to low gradient, highly sinuous meadow streams (Unit A). A complete description of channel morphologies and associated habitats is provided in Table 7-1 (stream unit descriptions) and Tables 7-2 and 7-3 (ODF&W channel survey).

In general, channel morphology is a mix of pool-riffle meandering channels (Units A and D), forced pool-riffle channels (Unit E), and step-pool cascades (Units B and F). Substrate is dominated by sand-gravel in the meadows, gravel-cobble in the forced step-pool units, and cobble-boulder in the cascades. Other aspects of channel morphology such as channel confinement, pool frequency, degree of bank erosion, and substrate composition are located in Tables 7-2 and 7-3.

7.4 HABITAT FORMING PROCESSES

Long Creek consists of both low-gradient meadow reaches (Unit A) and steeper mountain channels (Units B through F). Many of the segments are contained within relatively wide terraces that allow for meandering and high sinuosities to develop, particularly in Units A and D. Narrow floodplains and lower-sinuosity channels are characteristic of the canyon (Unit B) and the steep mountain channels (Units E and F). Meandering channels develop pools at the inside of meanders and riffles at the downstream end of meanders. Large organic debris can alter this morphological sequence, although wood generally enhances habitat by creating more pools and cover and by adding diversity.

The recruitment of gravel from bank erosion of fluvial terraces, toeslope erosion, and some limited mass wasting provides an approximately steady-state supply of coarse sediment (spawning habitat). Large obstructions in the channel, such as boulders and large wood, in conjunction with the deformable bed of gravels and pebbles creates hydraulic scour pools throughout Long Creek. Hence, recruitment of LWD from riparian forests is an important habitat forming process. The effects of wood on channel morphology varies with geomorphic type and is highest in Units A and D and lowest in Units B and F.

Beaver dams may have contributed substantially to pool formation throughout Long Creek but primarily in Unit A (meadow) and Units D and E.

7.5 POTENTIAL CHANGES TO CHANNEL MORPHOLOGY

7.5.1 Riparian Vegetation and Grazing

The elimination of streamside vegetation by grazing can reduce bank cohesion. A reduction in bank cohesion may lead to an adjustment of channel geometry: channels may widen and shallow. If grazing has been occurring over long time periods (more than a few decades), a permanent change in morphology can occur and not be evident by eroded banks in the present day.

7.5.2 Coarse Sediment

The relative insignificance of mass wasting or other large sediment producing processes in the Long Creek basin limits the probability of large changes to channel morphology from coarse sediment anywhere in the basin but particularly in Units A, B, C, D, and E. The exception is limited to Unit F where mass wasting may cause changes in channel morphology and local aggradation. Channel changes may include local scour of substrate, burial of substrate under sediment and logs, development of multiple channels, and an increase in fine sediment. Therefore, future landsliding and debris flow deposits in channel Segment 7 have a large potential for changing channel morphology and affecting fish habitat.

Infrequent rockfalls along channel Segment 2 (Unit B) may result in local (tens of meters) changes to channel morphology in the canyon reaches. These effects may have both negative and positive consequences for fish habitat.

7.5.3 Fine Sediment

The sieve data indicate that fine sediment can collect in the substrate of channels and that the levels are relatively high (i.e., many over 20 percent). In addition, surface substrate and pools also contain relatively large amounts of fine sediment. The sources of fine sediment in Long Creek include sheetwash and gully erosion (the latter primarily in managed lands), bank erosion, and mass wasting. Because of the large surface areas involved with sheetwash and gully erosion, these are apparently the dominant source of fine sediment in Long Creek basin. By inference, therefore, the source of the majority of the fine sediment in spawning gravels appears to be sheetwash and gully erosion associated with land management activities.

7.5.4 Flooding

An increase in flood magnitudes or durations can increase the depth of bed-material scour and therefore can put at risk fish eggs in the gravel. An increased depth of bed scour implies an increase in the rate of bed material transport and erosion, and this can lead to channel degradation (downcutting), particularly when coarse sediment supply is not increased.

The effects of flooding on channel morphology can be complicated by changes in the erosion regime, and therefore changes in sediment supply to a channel network. Fortunately, this is generally not the case in the Long Creek basin where mass wasting is a relatively insignificant process. Channel bed scour or erosion and bank erosion causing an increase in meandering or channel bifurcations would be evidence of an increase in flood magnitudes (or durations) caused by forestry activities in the Long Creek basin, particularly if the magnitude of forestry-related flooding is variable over time (i.e., the amount and location of immature forest in the basin is variable over time).

The volume of bed sediments in storage in the channel reflects the sediment mass balance within a channel reach (i.e., sediment inflow - sediment outflow + hillslope erosion = change in storage). Hillslope erosion of coarse sediment (fine sediment is not considered here), according to field observations and aerial photograph analysis, is small and insignificant. The majority of bedload-size sediment (not boulders) that is contained within the channel bed originates from the channel banks through the process of erosion of older fluvial terraces. Channel bank erosion is generally a very slow and continuous process. If bed scour has increased over the last several decades because of forestry activities and coarse sediment input is small and insignificant and has not increased, there should be a net loss of bed material (i.e., the bed material should be mined). Under this hypothesis, channels should be deeper and scoured, and there should be extensive deposits of bed material in the form of mid-channel bars and terraces in low-gradient areas. There is no field evidence of mining of bed material in Long Creek, either in significant bed scour or in the creation of depositional areas. Long Creek appears to be vertically stable as evidenced by the absence of recent terraces that would have been left behind as the channel incises into its bed. Increased floods may also increase bank erosion with subsequent increases in meandering and channel bifurcations (creation of secondary flood channels, etc.). No evidence of significant bank erosion or channel changes are found in the Long Creek network.

A complicating factor to an analysis of flood effects on channel morphology is the possible change to channel geometry caused by reducing or eliminating riparian vegetation (i.e., reducing bank cohesion). An increase in channel width by reducing bank cohesion may increase the channel capacity and therefore accommodate an increasing flood (by forestry activities). It is not known how to quantitatively relate potential changes in channel geometry caused by reduced bank cohesion to changes in channel geometry caused by increased peak flows. Again, we feel that the only guide in this case is to look for evidence of channel changes in the vertical (new terraces formed or incision) and in the horizontal (new channels or multiple channels, and abandoned channels). There is a lack of field evidence of these major types of channel changes.

Similar to the case of bank cohesion, if changes in hydrology have been steady over the last several decades, permanent changes to channel morphology may have already occurred. Thus, channel geometry may have already been altered. Although it is not possible to positively determine this, large changes to channel morphology that would imply increases in bed scour are not supported by field evidence.

7.5.5 Large Woody Debris

The role of LWD in creating certain types of channel morphology vary with the geomorphic units. Unit A (the meadow) is probably strongly controlled by LWD, both standing live and fallen dead, because of the low gradients and the wide channels that allow wood to create off-channel habitats and pools. Other low-gradient units such as D, E, and G can also be strongly affected by LWD. In these segments wood may create pools, trap gravels, and contribute to habitat. Wood in the canyon or higher-gradient units (B and E) plays a lesser role in shaping channel morphology, although wood should create local gradient breaks and pools in any channel segment.

8.0 FISH HABITAT ASSESSMENT

8.1 HABITAT EVALUATION APPROACH

The fish habitat assessment is patterned after Version 2.0 of the Washington watershed analysis methodology (TFW 1993). This approach uses information concerning fish distribution and abundance, historical habitat data, and current habitat data to define the fish habitat conditions in the basin and to identify habitats of potential concern, including degraded habitats, habitats of concentrated fish use, and habitats of limited availability. The procedure involves an initial identification of habitat issues (concerns) based on existing knowledge of fish populations and habitat conditions in the basin. Then current habitat data and historical information are used to conduct a diagnostic analysis of habitat conditions. The results of this analysis are used to evaluate the initial concerns and identify any additional potential concerns. This information is used in combination with information from the channel assessment (Section 7.0) to determine the vulnerability of fish habitat to management-caused changes in basin input variables (i.e., sediment, temperature, LWD, stream flow). The vulnerability analysis is performed as part of the Synthesis (Section 9.0).

The diagnostic evaluation of habitat conditions used in this analysis is modified from the Washington watershed analysis methodology. The latter could not be used because habitat condition reference values provided in the Washington methodology are not suitable for bull trout and the eastern Oregon ecoregion. Habitat reference values presented in the Washington methodology are primarily based on salmon habitat. For the Boulder Creek basin analysis, the fish habitat diagnostic screen was performed by comparing existing habitat conditions with habitat conditions in the wilderness reach, where appropriate, and with descriptions of preferred habitat from the technical literature.

8.2 SALMONID DISTRIBUTION, ABUNDANCE, AND STOCK STATUS

The species composition and distribution of salmonids in the Long Creek basin are shown in Figure 8-1. This distribution map is based on population survey data collected by ODF&W (Dambacher et al.) in 1991, field observations made by ODF&W during a recent fish habitat inventory (Dambacher, J. ODF&W. September 27, 1993. Pers. comm.), and from field observations by Pentec. Brook trout is the most widely distributed species occurring in the basin. They inhabit all mainstem channels except for the upper basin and most likely occur in

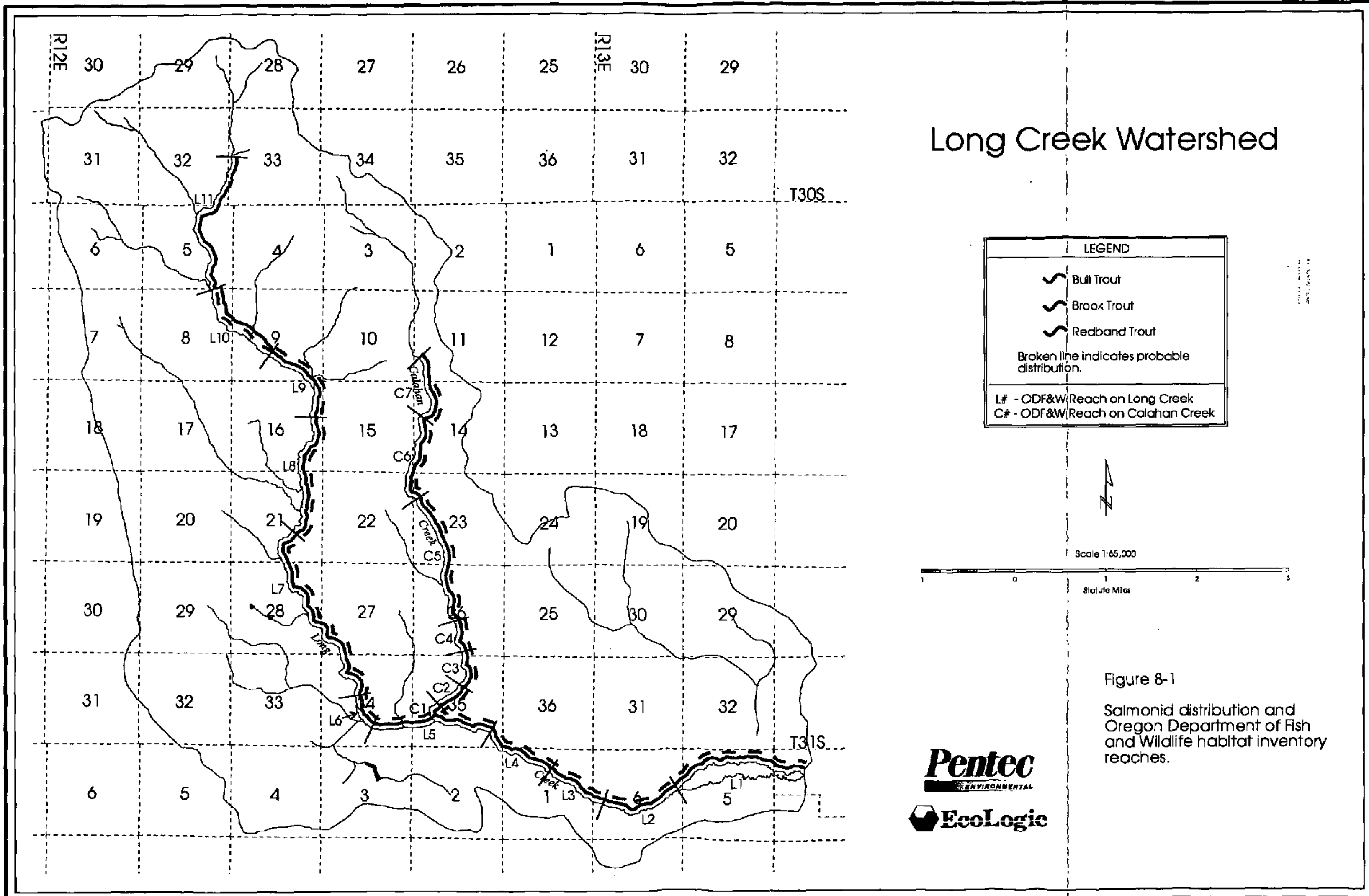

Figure 8-1

Salmonid distribution and Oregon Department of Fish and Wildlife habitat inventory reaches.

the lower portion of large perennial tributaries. Redband trout (rainbow) are suspected to co-exist with the brook trout, but their distribution is not confirmed. Bull trout only occur in the upper mainstem, upstream of a 1.2-m high falls. This falls is a barrier to upstream migration by most fish; however, the catch of one brook trout upstream of the falls (Dambacher et al. 1991) suggests that the falls is not an absolute barrier. Small numbers of bull trout occur below the falls along with brook x bull trout hybrids. Rainbow trout were stocked (2000 to 3000 fish) in the basin during 1949 to 1957. There is no record of brook trout stocking.

The abundance of trout in Long Creek has not been investigated, but a population inventory was conducted for bull trout in the upper mainstem by ODF&W in 1991. Dambacher et al. (1991) estimated the late summer bull trout population size was 842 fish for a 2,638-m reach. The density of bull trout is $0.11/m^2$ or 319/km. A comparison of bull trout densities among upper Klamath basin streams indicates that Long Creek has one of the highest densities in the region (Table 8-1).

The viability of the small isolated bull trout population in Long Creek is a concern of fisheries resource managers. Historically, bull trout most likely occurred throughout the Long Creek basin (anecdotal evidence, Ziller 1992), but competition with brook trout and habitat degradation are suspected to have impacted the population. In a study of bull trout population status in Oregon, Ratliff and Howell (1992) ranked the population in Long Creek as having a moderate risk of extinction. Low populations of bull trout in the Klamath basin in general have caused the Oregon Chapter of the American Fisheries Society (OCAFS) to petition the US Fish and Wildlife Service (USFWS) to conduct a status review for the purpose of listing bull trout as a threatened or endangered species (OCAFS 1993). In response to this petition and another, which included bull trout populations throughout the Pacific Northwest, the USFWS initiated a status review in October 1992. This review is currently in progress and is not expected to be completed until spring 1994.

8.3 HABITAT ISSUES

Habitat conditions suitable for the natural production of salmonids in Long Creek are a primary concern identified by several groups interested in protection of bull trout. OCAFS (1993) indicated that habitat degradation due to grazing and timber harvest is an important factor affecting bull trout in the upper Klamath basin. Ratliff and Howell (1992) inferred from a review of agency records that habitat degradation is one of the primary factors suppressing the bull trout population in Long Creek. Ziller's (1992) study of bull trout in the Klamath basin

Table 8-1 Estimated density of bull trout in Long Creek and in other upper Klamath basin streams.

Stream	Fish Density		Year	Source of information
	No/m²	No/km		
Long Creek	0.11	319	1991	Dambacher et al. 1992
Boulder Creek	---	109	1989	Ziller 1992
Boulder/Dixon Creek	0.02	43	1992	Dambacher et al. 1992
Brownsworth Creek	---	240	1989	Ziller 1992
Deming Creek	---	321	1989	Ziller 1992
Leonard Creek	---	207	1989	Ziller 1992

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suggested that temperature increases due to riparian loss from logging and livestock grazing may be a cause for the decline in bull trout. Water temperature may be an important factor influencing egg survival, growth, and distribution of bull trout (Pratt 1992, Goetz 1989). The Oregon Department of Environmental Quality identified bull trout as one of the most temperature sensitive species in Oregon.

The ODF&W bull trout working group has identified and prioritized the habitat-limiting factors affecting bull trout in Long Creek (ODF&W, unpublished files). These factors in order of priority are as follows:

1. Habitat degradation.

    - Riparian habitat loss.
    - Temperature impacts.
    - Siltation.
    - Loss of instream cover.

2. Passage barriers/problems.

    - Road culverts are a partial barrier.
    - Water diversion dam near mouth may be a partial barrier to upstream passage, and unscreened diversion may divert downstream migrants.

Another issue that could have an effect on fish habitat in this basin is a potential change in the annual hydrologic regime. Timber harvest may affect the timing and magnitude of peak flow events, which may affect redd scour, habitat stability, and fish movement conditions.

8.4 HABITAT CONDITION

8.4.1 Channel and Fish Habitat Inventory Data

An inventory of stream channel and fish habitat conditions in the Long Creek basin was conducted by ODF&W during summer 1991 and 1993 (Dambacher et al. 1991 and 1993). Habitat data were collected by a reach inventory procedure (Moore et al. 1993) that covered most of the fish-bearing waters in the basin. The mainstem of Long Creek was subdivided into 11 reaches, and Calahan Creek was subdivided into 7 reaches (Figure 8-1).

The results of the ODF&W inventory were used for the habitat diagnostic analysis to determine the current status of fish habitat conditions in the basin. Indices of habitat quantity and quality for each life phase were derived from the habitat inventory data (Table 8-2). Additional data needed to support the analysis were also collected by Pentec during several reconnaissance field surveys. General observations made during these surveys provided information concerning channel morphology, habitat forming factors, and subsurface gravel composition at selected sites in the basin.

A review of the literature was conducted to identify indices of preferred habitat conditions for bull trout with the intent of using this information for the diagnostic analysis. Almost no quantitative descriptions of habitat conditions were found. Most of the literature, which is summarized by Goetz (1989), Pratt (1992), and Thomas (1992), provides only qualitative descriptions of habitat by life phase. A summary of habitat conditions associated with viable bull trout populations that were reported in the literature are presented in Table 8-3. These observations are used, in part, to evaluate the quality of habitat conditions observed during the habitat inventory.

8.4.2 Habitat Evaluation

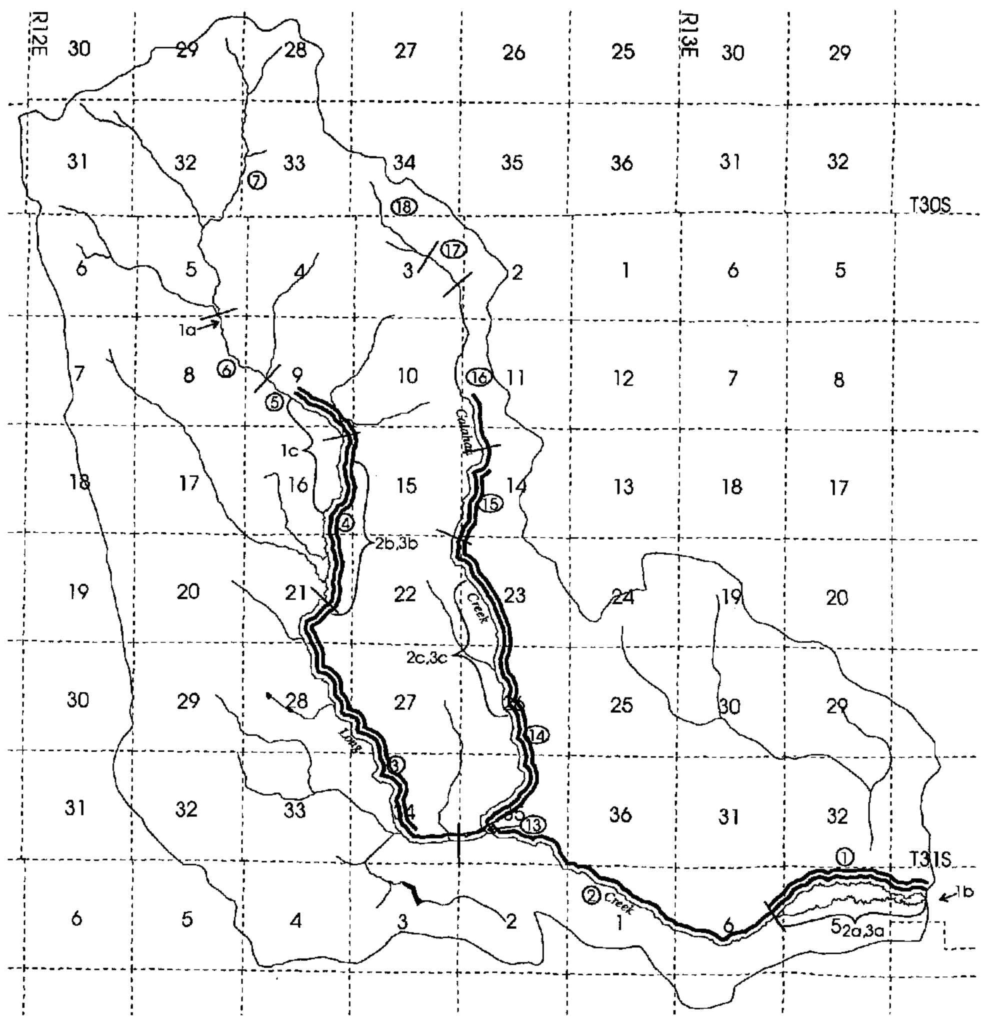
The fish habitat evaluation is stratified by three salmonid life phases (migration, spawning, rearing) and by potential habitat concerns. Specific locations and reaches with habitat concerns based on this evaluation are identified on maps in Figures 8-2 and 8-3.

8.4.2.1 Access During Spawning Migration (Potential Habitat Concern 1)

No specific barriers to upstream passage by spawners are known except for the 1.2 m falls at the upper end of Segment 6 and the water diversion structure near the mouth of Long Creek (Concerns 1a and 1b, Figure 8-2). The barrier falls is currently considered important to maintain because it minimizes the upstream movement of brook trout into the bull trout habitat. To ensure that bull trout remain isolated, the USFS altered the falls during fall 1993 to make it impassable to all fish. The diversion dam is currently not considered a significant problem because bull trout do not occur in the lower mainstem.

Fish movement in upper Long Creek Reaches L8 and L9 may be inhibited by frequent beaver dams (Concern 1c, Figure 8-2). These dams may prohibit the upstream passage of bull trout spawners during early fall when stream flows are relatively low. The dams are probably not a

Long Creek Watershed



LEGEND

1) Fish movement and migration barriers
2) Spawning gravel quality
3) Susceptibility to redd scour
Fine sediment concern
Bank erosion concern
② Channel segments

Scale 1:65,000

0 1 2 3

Statute Miles

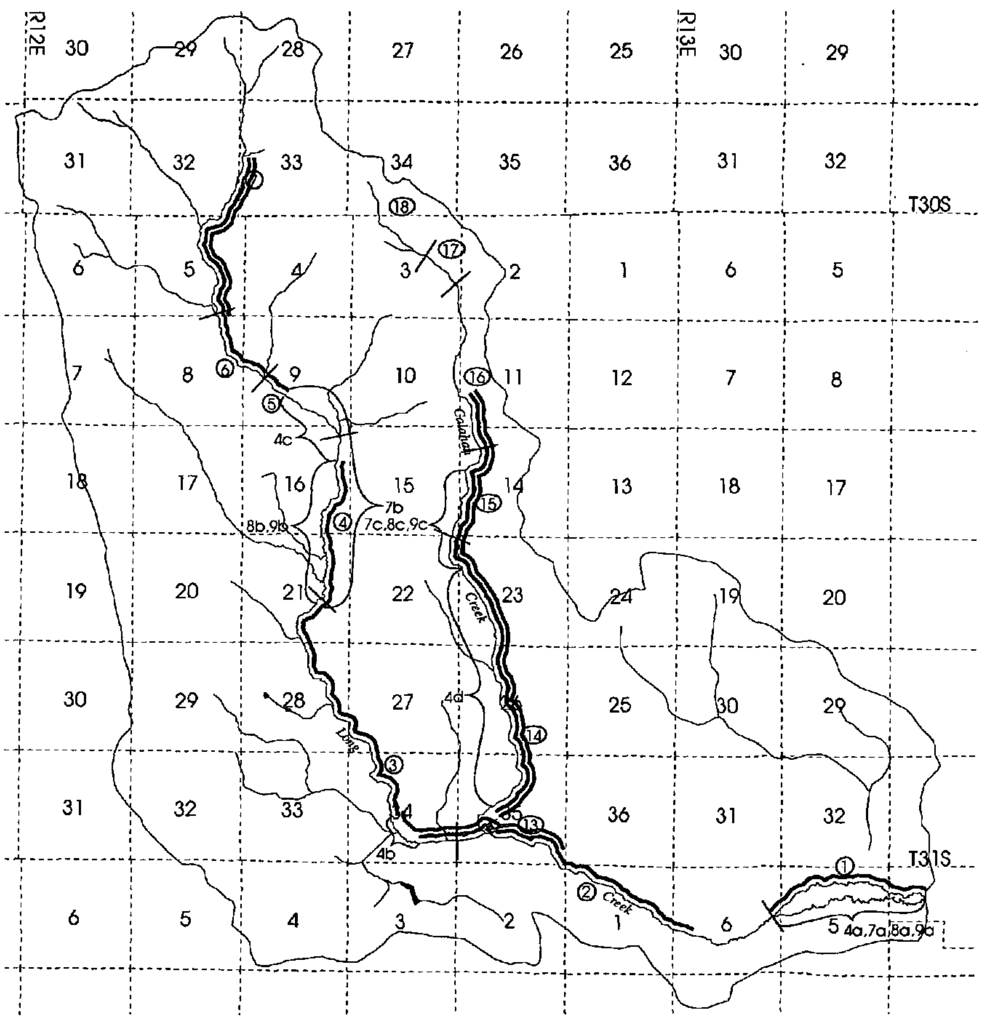
Pentec ENVIRONMENTAL

EcoLogic

Figure 8-2

Potential fish habitat concerns for migration, spawning, and incubation.

Long Creek Watershed



LEGEND
4) Sediment in boulder rearing habitat
5) Low pool frequency
6) Low LWD level
7) Beaver dam formed rearing habitat
8) Loss of undercut bank habitat
9) Lack of stream shading
② Channel segments

Scale 1:65,000

Statute Miles

Figure 8-3

Potential fish habitat concerns for rearing.

Pentec ENVIRONMENTAL

EcoLogic

Table 8-2 Description of habitat indices selected for a diagnostic analysis of fish habitat conditions.

Habitat Indices	Descriptions
Length. width. gradient	General physical characteristics of inventory reach.
Channel confinement (valley width/channel width. vw/cw)	Ratio of valley width to channel width, which indicates the amount of channel confinement.
Habitat unit area (%)	Indicates relative quantity (percentage of wetter area) of habitat by unit type.
Pool frequency (pool/km) and (channel width. cw/pool)	Indicates the relative quantity of rearing habitat based on the frequency of pool units. Frequency is expressed by two parameters; pool/km is based on a fixed unit length and cw/pool is based on a variable unit length that is standardized by channel width. The latter removes the effect of stream size on pool frequency, which reduces bias when making comparisons among streams.
Surface substrate size composition (%)	Indicates the stream bed substrate size composition.
Silt/sand:gravel composition of riffles (%:%)	Indicates relative quality (percentage of wetted area) of riffle habitat for spawning based on the relative amount of silt/sand and gravel substrate in riffles.
Bank erosion (%)	Indicates potential sediment source and channel stability based on the relative amount of bank erosion in reach. Also indicates potential for redd scour from peak flows.
Sand substrate in boulder cascade and rapid (%:%)	Indicates the suitability (quality) of channel units with boulder bed material to provide rearing habitat associated with substrate interstitial spaces. Habitat suitability is assumed to decrease with increases in the relative amount of sand (percentage of wetted area in cascades and riffles).
Undercut banks (%)	Indicates the relative amount (percentage of channel length) of undercut bank rearing habitat.
No. beaver pools	Number of pools formed by beaver dams.
Large woody debris (LWD)	Indicates the amount of wood (pieces > 15 cm diameter and > 3 m long) available to provide habitat forming structures and fish cover. Amount is expressed by two parameters; pieces/100 m is based on a fixed unit length and pieces/cw is based on a variable unit length that is standardized by channel width. The latter removes the effect of stream size on LWD amount. which reduces bias when making comparisons among streams.
Open sky (%)	Indicates the relative amount of shading by vegetation and topography based on the percentage of open sky. Shade increases as open sky decreases.

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Table 8-3 **Habitat conditions associated with viable bull trout populations.**

Habitat life phase	Source
Spawning	
• Cold spring-fed streams.	Ratliff 1992
• Typically occurs at sites with ground water infiltration and temperature less than 9 °C.	Pratt 1992; Goetz 1989
• Aggrading areas of streams and pockets with loosely compacted gravel and cobble.	Pratt 1992; Goetz 1989
• High embryo survival with fines < 30 percent of gravel composition.	Pratt 1992; Goetz 1989
Rearing	
• Cool water temperatures less than 15 °C.	Pratt 1992; Thomas 1992
• Juveniles use small pockets of slow water near high velocity, food-bearing water. Small pockets are created by rock or wood objects that provide cover.	Pratt 1992; Thomas 1992
• High juvenile densities are associated with gravel and cobble substrate. Cobble embeddedness may limit densities.	Pratt 1992; Thomas 1992
• LWD, turbulence, and undercut banks provide critical cover in some streams.	Pratt 1992; Thomas 1992
• Juveniles and adults prefer pools over riffles and glides.	Pratt 1992; Thomas 1992
• Young-of-year fry prefer clean gravel-cobble-rubble substrate and can be found in shallow, slow backwater side channels or eddies often in association with logging residue.	Pratt 1992; Thomas 1992
• Juveniles are associated with cobble, rubble, and boulder substrate in some rivers and with coarse and fine woody debris in other systems.	Dambacher et al. 1992; Goetz 1989
• Adults show preference for deep pools, cool water, rubble-boulder substrate, and woody debris.	Dambacher et al. 1992; Goetz 1989

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barrier to redband trout spawners because stream flows are high during the spring spawning period.

8.4.2.2 Quantity and Quality of Spawning Habitat (Potential Habitat Concern 2)

The quantity of gravel available for spawning is probably not limiting spawning habitat in Long or Calahan creeks. The bed material of both streams is approximately 30 percent gravel (Tables 8-4 and 8-5). In Long Creek most of the spawning habitat occurs in riffles, which comprise a large portion of the habitat in Reaches L1, L2, L6, L7, and L8. Spawning habitat also probably occurs in gravel patches within boulder rapids and small riffles of Reaches L3, L4, L5, L9, L10, and L11. In Calahan Creek riffles are rare in all reaches except C5. Most spawning habitat in this stream occurs in patches within the rapids and small channel units.

The quality of gravel available for spawning may be degraded by moderate to high levels of fine sediment in most areas of Long and Calahan Creeks. Silt and sand comprise more than 30 percent of the riffle bed material in Reaches L1, L4, L8, L9, C4, and C5 (Tables 8-4 and 8-5). Silt and sand also comprise a significant portion of the bed material in other habitat units. Only Reaches L10, L11, and C1 have relatively low amounts of silt and sand substrate. Measurements of the fine sediment (size < 3.35 mm) content of subsurface gravels from potential spawning sites generally concur with the results of the ODF&W habitat inventory (Table 8-6). High levels of fine sediment occur in samples from Reaches L1, L5, L7, L9, and C5. These results indicate that high levels of fine sediment are a potential habitat concern for spawning and incubation habitat in all reaches but L10, L11, and C1 (Figure 8-2). Reaches with the most amount of riffle area (L1, L8, and C5) may provide the highest concentration of spawning habitat and are of special concern (Concern 2a, 2b, and 2c, Figure 8-2).

8.4.2.3 Susceptibility to Redd Scour from Peak Flows (Potential Habitat Concern 3)

Peak flows from large flood events can cause stream bed scour that may result in redd loss and a reduction in fry recruitment. Large floods in fall and spring during the brook and rainbow trout incubation periods, respectively, have caused a reduction in embryo survival of trout populations of Sagehen Creek, California (Seegrist and Gard 1972). Because the magnitude and frequency of peak flow events may be affected by timber harvest, there is a potential concern for peak flow impacts in Long Creek. The magnitude of a peak flow event required to cause redd scour, however, is unknown. The recurrence interval of flood events that caused

Table 8-4 Summary of stream channel and fish habitat conditions in Long Creek based on Dambacher et al. (1993).

Parameter	Stream reach	1	2	3	4	5	6	7	8	9	10	11
	Segment	1	1-2	2	2	2-3	3	3	4	5	6	7
	Geomorphic unit	A	A-B	B	B	B-D	D	D	A	D	E	F
Channel characteristics												
Length (m)		4098	1699	1263	1684	1939	717	4547	2677	2228	2277	2635
Width (m)		3.7	5.2	6.3	5.3	6.1	6.2	6.0	5.1	7.5	6.9	5.3
Gradient (%)		0.6	1.0	1.9	1.6	1.8	1.2	1.4	0.9	1.6	3.4	6.5
Mean channel confinement (vw/cw)		20	10.7	1.4	3.8	1.8	4.3	2.4	14.8	17.0	1.3	1.3
Habitat unit area (%)	Pool	46	32	4	12	4	18	15	31	49	5	6
	Riffle	52	31	6	12	21	36	28	63	18	2	20
	Bldr. rapid/ cascade	2	35	89	76	74	46	56	6	33	86	72
	Step/falls	< 1	2	1	< 1	< 1	< 1	< 1	< 1	1	1	2
Pool freq.	(pool/km)	38	28	5	10	4	18	12	22	30	6	15
	(cw/pool)	7.1	5.7	33.4	18.7	45.4	8.9	14.3	9.1	4.5	25.4	12.7
Spawning and incubation habitat indices												
Surface substrate size composition (%)	Silt	21	12	8	7	7	15	11	20	28	8	4
	Sand	32	24	18	20	20	25	24	25	32	15	3
	Gravel	34	33	23	27	23	32	29	33	30	25	33
	Cobble	12	28	28	29	28	24	26	21	10	28	30
	Boulder	0	4	23	17	21	4	10	1	0	21	22
	Bedrock	1	0	0	0	0	0	1	0	0	2	9
Silt/sand:gravel composition (%) of riffles		40:42	28:36	25:29	31:32	27:25	28:33	25:31	37:38	43:41	24:33	11:52
Bank erosion (%)		35	21	6	10	20	56	42	59	33	13	1
Rearing habitat indices												
Sand substrate in bldr. cascade and rapid (%)		22	17	10	12	10	23	15	19	26	11	1
No. beaver pools		0	0	0	0	0	0	0	2	11	0	0
Undercut banks (%)		5	11	0	2	0	2	5	12	8	3	0
LWD	(no./100 m)	15.3	26.0	24.6	29.0	15.6	12.8	17.4	3.8	45.0	17.6	6.4
	(no./cw)	0.57	1.35	1.55	1.54	0.95	0.79	1.04	0.19	3.37	1.21	0.34
Mean open sky (%)		82	65	52	59	46	60	50	76	51	45	56

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Table 8-5 Summary of stream channel and fish habitat conditions in Calahan Creek based on Dambacher et al. (1993).

Parameter	Stream reach	1	2	3	4	5	6	7
	Segment	13	14	14	14	14	15	16
	Geomorphic unit	C	D	D	D	D	A	D
Channel characteristics								
Length (m)		504	517	865	432	3505	816	1835
Width (m)		7.3	3.0	4.0	3.3	3.7	2.0	4.7
Gradient (%)		4.9	2.1	2.4	1.8	1.7	1.4	3.1
Mean channel confinement (vw/cw)		1.3	9.8	2.5	4.7	2.6	20.0	1.8
Habitat unit area (%)	Pool	6	23	9	28	33	0	1
	Riffle	0	0	0	9	34	0	0
	Bldr. rapid/ cascade	94	76	91	63	31	0	0
	Undefined small channel	0	0	0	0	0	100	99
Pool freq.	(pool/km)	14	27	13	19	13	0	0
	(cw/pool)	9.9	12.3	19.7	16.4	20.1	0	0
Spawning and incubation habitat indices								
Surface substrate size composition (%)	Silt	8	16	13	18	20	21	16
	Sand	15	28	26	26	31	37	24
	Gravel	16	33	28	31	30	32	31
	Cobble	28	21	23	19	14	3	20
	Boulder	30	2	10	6	3	0	5
	Bedrock	4	0	0	0	1	7	3
Silt/sand:gravel composition (%) of riffles		---	---	---	40:50	40:39	---	---
Bank erosion (%)		8	31	24	56	35	35	26
Rearing habitat indices								
Sand substrate in bldr. cascade and rapid (%)		13	25	21	21	22	---	---
No. beaver pools		0	0	0	0	0	0	0
Undercut banks (%)		3	6	1	4	5	3	3
LWD	(no./100 m)	15.7	15.5	17.9	13.2	15.7	0.4	18.5
	(no./cw)	1.15	0.46	0.72	0.43	0.56	0.01	0.87
Mean open sky (%)		37	56	41	44	46	75	38

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Table 8-6 Percentage fine sediment at potential spawning sites in Long and Calahan creeks (based on one sample per site taken during September 1994).

Stream Reach (ODF&W)	Location	Geomorphic unit	Segment	Percentage Subsurface Fines: Size < 0.84mm	Percentage Subsurface Fines: Size < 3.36 mm
L1	At bottom of braided section	A	1	28.7	42.4
L5	Downstream of Calahan Creek	B	2	16.3	32.4
L7	100 m upstream of lower 400 road	D	3	19.3	44.3
L8	At bottom of meadow reach	A	4	11.7	21.6
L9	122 m downstream of upper 400 road	D	5	24.3	42.2
L10	200 m upstream of upper 400 road	E	6	9.7	20.7
C5	50 m upstream of lower 400 road	D	14	32.4	44.3

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redd scour in Sagehen Creek was not reported by Seegrist and Gard (1972). Normal bankfull flow events did not cause a reduction in fry recruitment; therefore, flows that impacted the fish population had to be larger than the annual peak flow event. It is unlikely that annual bankfull flows cause significant redd scour; otherwise, the trout population would not remain viable. Because trout mature at 3 to 5 years old, the rate of fish recruitment must equal or exceed the natural mortality from all causes during this length of time. Therefore, natural mortality from redd scour is probably not significant to the population from peak flow events with a recurrence interval of at least 3 to 5 years. Peak flow events large enough to cause significant redd scour likely recur at five-year or greater intervals.

Incubation habitat in Long Creek may be susceptible to redd scour, especially in reaches that are sensitive to bank erosion. High amounts of bank erosion (i.e., > 30 percent) in Reaches L1, L6, L7, L8, L9, C2, C4, C5, and C6 (Figure 8-2) indicate that the bed and banks of these areas have been scoured during recent peak flows. Redd scour by peak flows is a potential habitat concern for all areas where spawning may occur and especially for areas of concentrated riffle habitat (Concern 3, Figure 8-2).

8.4.2.4 Sediment in Boulder-dominated Rearing Habitat (Potential Habitat Concern 4)

Based on the literature review, rubble-boulder units are preferred rearing habitat for bull trout. In Long Creek, boulder rapid and cascade units are the dominant rearing habitat available in Reaches L4 to L7, L10, L11, and C1 to C4 (Tables 8-4 and 8-5). The quality of boulder habitat is a function of the complex hydraulic conditions and interstitial spaces that are created by boulders in rapids and cascades. Fine (sand) and coarse (gravel) sediment deposition in boulder habitats is a potential concern because it can fill the interstitial spaces or bury boulders, reducing habitat complexity. In the mainstem, sand in boulder cascade and rapid units is relatively low (< 20 percent) in most reaches and is moderately high (20-50 percent) in Reaches L1, L6, and L9 (Table 8-5). Sand is moderately high in all boulder-rapid reaches of Calahan Creek. Reaches with moderate amounts of sand are potential habitat concerns (Concern 4, Figure 8-3).

8.4.2.5 Quantity of Pool Rearing Habitat (Potential Habitat Concern 5)

Pools are important summer and winter rearing habitat that are used for cover and refuge by juvenile and adult trout. Stream reaches with a low frequency of pools are a concern because rearing habitat may be limiting fish populations in these areas. In Long Creek, pool frequency is relatively low (> 10 cw/pool) in Reaches L3, L4, L5, L7, L10, L11, and C2 to C7 (Tables 8-4 and 8-5). Because pool frequency may be affected by impacts from land management (e.g., reduced LWD recruitment and bank erosion), there is a potential habitat concern for pool formation in reaches with low pool frequencies (Concern 5, Figure 8-3).

8.4.2.6 LWD and Formation of Rearing Habitat (Potential Habitat Concern 6)

LWD is important in streams for the formation of habitat units and for providing fish cover; therefore, stream reaches with low levels of LWD are a concern. In Long Creek, it is not known whether the current level of LWD is below natural recruitment levels as a result of historic timber harvest in this basin. A comparison of the amount of LWD in these streams with the levels of LWD reported in the literature could provide an index, but no published information could be found for this ecoregion. A comprehensive review of the literature by Peterson et al. (1992) reported on the findings of eight studies, all of which were based in western Washington and Southeast Alaska. LWD levels reported in these studies ranged from 0.46/cw to 14.38/cw with most occurring from 2/cw to 4/cw. In Long Creek natural LWD levels are most likely lower than levels reported for the western Cascades because of the lower tree density in this region. LWD levels were below 2/cw in all reaches except Reach L9 (Tables 8-4 and 8-5). Reach L11, which is the only reach not affected by logging, had one of lowest levels of LWD (0.34/cw). Reach L11, however, is probably not indicative of LWD levels for other reaches in Long Creek because of its higher gradient and confined channel. Lower gradient alluvial channels tend to have more LWD because bank erosion in these unconfined channels causes LWD recruitment (Murphy and Koski 1989). In Long Creek all other reaches except L8 and C6, which flow through meadows, have greater LWD levels than Reach L11. The assumption based on this analysis is that natural LWD levels for Long Creek are probably less than 2/cw but more than 1/cw.

Reaches of Long Creek with low LWD levels (< 1/cw) that may be a potential habitat concern are L1, L5, L6, L8, and C2 to C7 (Concern 6, Figure 8-3).

8.4.2.7 Beaver Dam Formed Rearing Habitat (Potential Habitat Concern 7)

Beaver dams are a dominant factor affecting the formation of pools in Reach L9 and to a lesser extent in Reach L8 (Table 8-4). Beaver dams in Reach L9 have created more pool area and a greater pool frequency than in any other stream reach. These pools provide good cover and refuge habitat during both summer and winter. Emergent vascular plants and associated macrofauna are abundant along the shallow areas, providing food that is used by rearing trout.

Beaver dams can help to form pools in the meadow reaches where LWD is lacking. Existing beaver dams and potential beaver dam sites need to be protected and are a potential habitat concern (Concern 7, Figure 8-3).

8.4.2.8 Loss of Rearing Habitat Formed by Undercut Banks

Undercut banks provide excellent cover and refuge habitat for trout. They generally occur in low gradient meadow areas where roots from trees, shrubs, and grasses provide a stable and erosion-resistant bank. In Long Creek, significant bank erosion may have reduced the amount of undercut banks and may be prohibiting the formation of this type of habitat. Reaches L1, L8, and C6 (meadow reaches) most likely had more undercut bank habitat than currently exists. These reaches have a significant amount of bank erosion (Tables 8-4 and 8-5); therefore, the loss of undercut banks is a potential habitat concern (Concern 8, Figure 8-3).

8.4.2.9 Water Temperature and Summer Rearing Habitat

Water temperature data from summer 1993 (see Section 6.0) indicate that the maximum water temperature in Long Creek is above 15 °C for short periods at lower mainstem locations and below 15 °C in the upper mainstem. Because bull trout are generally found in streams where the maximum water temperature is less than 15 °C, there is a potential habitat concern for factors affecting water temperature in the lower mainstem.

A comparison of stream shade among the habitat inventory reaches of Long Creek and Reach L11, which is undisturbed by timber harvest, indicates that shading is lower than the reference level in some reaches of the mainstem (Table 8-4). These reaches (i.e., L1, L2, and L8) may have reduced shading as a result of riparian disturbances and are a potential habitat concern (Concern 9, Figure 8-3). A more complete analysis of stream shade and potential areas of concern is presented in the Riparian Assessment (Section 6.0).

9.0 SYNTHESIS

9.1 FISH HABITAT VULNERABILITY

Fish habitat vulnerability is the degree to which fish habitat or habitat-forming processes could be affected by changes in watershed processes. Vulnerability is established by linking a potential habitat concern to a habitat-forming process that is influenced by one or more of the watershed input variables. The relative level of vulnerability (i.e., high, moderate, low) is based on the responsiveness of stream water quality or channel morphology to changes in the watershed input variables. Below is an evaluation of fish habitat vulnerability for each potential habitat concern. Results of this evaluation are summarized in Table 9-1. Stream segments that are not listed in this table are assumed to have low vulnerability to the input variables.

9.1.1 Access During Spawning Migration

The barrier falls at the USFS boundary was recently modified to prevent brook trout from invading upstream areas inhabited by bull trout. The barrier is being used as a management tool to prohibit competition between brook and bull trout to maintain the only viable bull trout population in Long Creek. This barrier is located at the lower end of Segment 7, which is the only geomorphic unit that is susceptible to debris flows. Stream bed aggradation by a debris flow could alter the effectiveness of this barrier and enable fish passage upstream; therefore, vulnerability to coarse sediment is high.

The beaver dams in Segments 4 and 5 (Reaches L8 and L9) are natural obstacles unaffected by forest management activities. These dams may function as barriers to fish movement during low flows but are mostly likely passable during bankfull flows.

The water diversion at the mouth of Long Creek (Segment 1) is operated for irrigation during the summer; therefore, it may prevent upstream passage during the summer and fall low flow period. Fish passage at the diversion is highly vulnerable to irrigation operations, especially during a lower than normal stream flow in summer.

Table 9-1 Fish habitat vulnerability to watershed input variables and management influences.

Fish habitat concern	Input variable or management influence	Segment	Vulnerability
Fish movement and migration	Coarse sediment	7	High
Fish movement and migration	Diversion dam	1	High
Spawning gravel quality	Fine sediment	1, 3, 4, 5, 14, 15	High
Susceptibility to redd scour	Peak flow	All	Low
Sediment in boulder rearing habitat	Fine sediment	1, 3, 5, 14	Moderate
Low pool frequency	Coarse sediment	2, 7	High
Low pool frequency	LWD	3, 14, 15, 16	High
Low pool frequency	Bank vegetation	3, 14, 15, 16	High
Rearing habitat formed by LWD	LWD	1, 3, 4, 5, 14, 15, 16	High
Rearing habitat formed by LWD	LWD	6, 17	Moderate
Rearing habitat formed by beaver dam	LWD	1, 4, 5, 14	High
Rearing habitat formed by undercut banks	Bank vegetation	1, 4, 15	High
Water temperature and summer rearing habitat	Shade	1, 3, 4, 5, 14, 15, 16	High
Water temperature and summer rearing habitat	Shade	2	Moderate

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9.1.2 Spawning Gravel Quality

The levels of fine sediment at several potential spawning sites (Table 8-6) were moderate to high indicating that embryo survival may currently be affected at some locations and that anyincrease in fines could likely affect embryo survival. Stream reaches with more than 30 percent sand substrate are indicators of areas with a potential fine sediment problem. These conditions are concentrated in several reaches of Long Creek that correspond to geomorphic Units A, D, and E. Units A and D are low gradient with a high width to depth ratio; therefore, fine sediments are likely to collect in these areas. Spawning habitat within these units (i.e., Segments 1, 3, 4, 5, 14, and 15) are highly vulnerable to fine sediment.

9.1.3 Susceptibility to Redd Scour From Peak Flows

Redd scour due to peak flows in Segments 1, 3, 4, and 14 (Reaches L1, L6, L7, L8, and C5) could have the greatest impact on fish populations because these segments have the largest amount of riffle habitat, and potentially a significant portion of the fish population could spawn in these areas (Figure 8-2). These segments currently have relatively high amounts of bank erosion, which suggests the channel is relatively unstable as a result of lateral scour from past peak flow events. The channel analysis, however, concluded that much of the apparent bank erosion is actually a loss of bank cohesion resulting from devegetation by cattle grazing. Other evidence of vertical or horizontal scour is not apparent in the channel network, including areas with low grazing. The morphology of units with the largest spawning potential (i.e., Units A and D) is less susceptible to scour because of the high width to depth ratio of the channel. The potential energy available for stream bed scour at peak flows larger than a bankfull flow is relatively small in these unconfined channels. Vulnerability to peak flows is considered low for Long Creek.

BED SCOUR

9.1.4 Sediment in Boulder-dominated Rearing Habitat

The filling of interstitial spaces in boulder habitat may be limiting available refuge in reaches with a moderate amount of fine sand and where boulder rapids are the dominant rearing habitat. Segments with these conditions (1, 3, 5, and 14) occur in geomorphic Units A and D. Because these units are susceptible to fine sediment deposition (see Section 9.1.2) and moderate amounts of sediment occur in boulder habitats, the boulder habitat areas are moderately vulnerable to sedimentation.

The beaver ponds function as sediment storage reservoirs minimizing potential sedimentation impacts downstream. LWD in the beaver ponds and flood plains contribute to these dams and help to store sediments.

A reduction in LWD recruitment to reaches with beaver dams or potential beaver dam sites could affect the habitat forming processes and sediment storage associated with beaver activity; therefore, these segments (1, 4, 5, and 15) are highly vulnerable to LWD.

9.1.8 Rearing Habitat Formed by Undercut Banks

Bank erosion in the meadow segments (1, 4, 15) has reduced the potential amount of undercut habitat that is important for summer and winter rearing. Bank erosion in these segments is due to the loss of bank cohesion resulting from devegetation. The loss of roots from riparian shrubs and trees has reduced bank cohesion and subsequently the formation of undercut banks. The formation of undercut banks in these segments is highly vulnerable to the presence of erosion-resistant bank vegetation

9.1.9 Water Temperature and Summer Rearing Habitat

Maximum water temperature in Long Creek exceeds the preferred temperature range for bull trout in mainstem areas downstream of Segment 4. High water temperatures were associated with low amounts of riparian shading especially in segments with meadows. Summer temperatures increased significantly just downstream of the meadow in Segment 4 and remained high in reaches downstream. This suggests that meadow areas (i.e., Unit A) are currently highly vulnerable to temperature increases. The mainstem channel downstream of Segment 4, down to the Sycan Marsh, is composed of B and D geomorphic units. Unit D has a high width/depth ratio making it sensitive to temperature increases if shading is low; therefore, segments within this unit are highly vulnerable to temperature increases. Segments within Unit B are less sensitive or moderately vulnerable to temperature increases because they have a lower width/depth ratio and they occur in a canyon with topographic shading.

Segments in steeper mountain tributaries (Unit F) have a low vulnerability to temperature increases because they are either intermittent (not flowing during summer) or fed by springs.

9.2 RESOURCE SENSITIVE AREAS

The objective of synthesis is to identify and delineate areas of the basin producing or potentially producing changes in the delivery of watershed input variables (i.e., sediment, LWD, flow, temperature) that can significantly affect fish habitat and water quality. Basin areas that influence the delivery of watershed input variables and that are linked to significant impacts on vulnerable resources are called resource sensitive areas. Resource sensitive areas are identified for each watershed input variable by establishing clear linkages among input sources, delivery potential, and vulnerable resources. Only resource sensitive areas that can be linked to fish habitats with a moderate or high vulnerability are delineated. Fish habitats with low vulnerability to input variables are assumed to not be significantly affected by changes in timing or magnitude of input variables. The impact potential of an input variable is rated as high, moderate, or low depending on the potential disturbance caused to a vulnerable fish habitat.

Resource sensitive areas and the associated segments influenced by input variables are listed in Table 9-2.

9.2.1 Coarse Sediment

Evidence from an old debris flow in Segment 7 indicates that mass wasting from steep slopes in the USFS subbasin can affect fish habitat in upper Long Creek. Hillslope areas that may be prone to landsliding are shown in Figure 3-1. Because debris flows are relatively rare and the potential area affected is relatively small, these resource sensitive areas are considered to have a moderate impact potential.

Coarse sediment from rockfalls could enter the stream in the Long Creek canyon, but the frequency of these events is rare and the volume of material is small. No resource sensitive areas are identified for potential impacts from rockfalls.

9.2.2 Fine Sediment

Fine sediment that is delivered to any tributary in the Long basin is assumed to be routed to vulnerable fish habitats in Long Creek. This assumption is supported by the presence of sediment deltas that have formed at the junction of first order tributaries with the mainstem. The deltas are formed by the deposition of fine gravel and sand transported by upstream erosion processes. The analysis indicates that hillslope erosion from riparian areas that have been

Table 9-2 Resource sensitive areas, segments affected by input variable, and impact potential.

Resource sensitive area	Segments affected	Impact potential
Coarse sediment		
Mass wasting delivery zone (Figure 3-1)	7	Moderate
Fine sediment		
Hillslope erosion delivery zone (Figure 4-8)	All	High
Road erosion delivery zones (Figure 4-7)	1-3, 7, 14-18, 21, 22, 25-27, 29, 30, 33-38	High
Large woody debris		
Recruitment situation RF4 (Figure 6-3)	3 (lower), 14, 16	High
Recruitment situation RF2 and RF3 (Fig 6-2)	3 (upper), 5, 6, 17	Moderate
Water temperature		
Riparian zones with < 40% shade (Figure 6-4)	1, 3, 4, 5, 14 (center), 15,	High
Riparian zones with 40-70% shade	3 (lower), 14 (lower), 16 (center)	Moderate
Bank vegetation		
Riparian zones in meadows and adjacent segments	1, 3, 4, 5, 14, 15, 16	High

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disturbed by logging or grazing is delivering sediment to the stream; therefore, all riparian zones are considered highly sensitive areas. In addition, fine sediment from erosion of steep hillslopes that are adjacent to riparian zones is contributing to the problem; therefore, these areas are included as having a high impact potential (Figure 4-8).

Significant surface erosion was observed from roads, but most roads did not contribute sediment to streams. Only roads and road segments that were directly adjacent to streams or that were observed to drain into streams were considered to be a resource sensitive area (Figure 4-7). Most of these roads had significant surface erosion and were considered to have a high impact potential.

9.2.3 Hydrology

The timing and yield of water during spring runoff in Long Creek is most likely changed as a result of timber harvest in the basin. The magnitude of these changes is not known, however, because no flow data are available. The potential impacts of these changes on fish and fish habitat are not well understood. It is possible that an increased peak flow during spring runoff may have an affect on stream bed scour and could influence the distribution of fish. In the latter case fish may be displaced by high flows or they gain access to different channel segments because barriers are flooded. No information is available to determine any of these potential effects except those caused by peak flows. Increases in peak flows, if they occur, probably have not had any significant effect on the channel because no evidence was found for significant changes in vertical and horizontal scour in the stream channels.

Moderate increases in the magnitude of peak flows as a result of timber harvest activities were predicted by the hydrology analysis. Under current vegetative conditions peak flows were estimated to increase by a maximum of 11 percent in the Long and Calahan subbasins. These increases were predicted for a two-year peak flow event; therefore, all large events had smaller changes in peak flows. These changes in peak flows are apparently not sufficient to cause a disturbance to trout spawning habitat because there is no evidence of channel scour as described above. Based on these results, no resource sensitive areas are identified for hydrology.

9.2.4 Large Woody Debris

Riparian zones with a poor or fair LWD recruitment potential that correspond to channel segments with a high habitat vulnerability to LWD are resource sensitive areas. Zones that currently have an inadequate recruitment situation and a low level of LWD in the channel have a high potential impact on fish habitat (see RF4 Figure 6-3). This situation occurs in several segments including the meadows, but the meadow segments are excluded as resource sensitive areas because the absence of trees is natural. Riparian zones with an inadequate recruitment and adequate LWD level (RF2) or the reverse situation (RF3) have a moderate potential impact on fish habitat where they correspond with segments of high or moderate fish habitat vulnerability. This situation occurs in all remaining fish-barring segments except the canyon and USFS reaches (Segments 2, 7, 18).

9.2.5 Stream Water Temperature

Increased water temperatures below Long Creek meadow (Segment 4) indicated that the low amount of shading in the meadow and in adjacent segments (Figure 6-4) affected the summer temperature regime of Long Creek. Because maximum daily temperatures below the meadow exceed the preferred maximum temperature (15 °C) for bull trout, the meadow and adjacent upstream segments with low shading (< 40 percent shade) are resource sensitive areas with a high impact potential. Fish-bearing segments that have a high vulnerability to temperature and that have similar levels of shading (i.e., < 40 percent shade) are also delineated as resource sensitive areas with a high impact potential. The low shading in the canyon segment (Segment 2), however, is considered to have a only a moderate impact potential because of topographic shading. Segments with a moderate amount of shading (i.e., 40-70 percent) that correspond to segments with a high habitat vulnerability have a moderate impact potential.

9.2.6 Bank Vegetation

Riparian vegetation directly adjacent to the channel that has been suppressed by cattle grazing is a resource sensitive area. Because vegetation along the stream banks directly affects bank cohesiveness, changes in vegetation density can have a high impact potential on the formation of undercut bank and pool habitat. This potential impact to fish habitat is greatest in the meadows and adjacent stream reaches where grazing had been concentrated in the past.

10.0 CAUSAL MECHANISM SUMMARY

The processes or mechanisms by which forest practices may trigger detrimental changes in watershed input variables are identified by a causal mechanism assessment. The purpose of this summary is to briefly define the triggering mechanism and linkage between a resource sensitive area and the effects on a vulnerable resource. This information is used by forest managers as a guide for developing management prescriptions to protect and restore fish habitat in the basin.

A causal mechanism summary is presented by input variable and for each resource sensitive area or areas that have a specific triggering mechanism. The summary format of Tables 10-1 through 10-4 follows the Washington watershed analysis methodology (TFW 1993) except no rule calls for management are given. Rule call responses only apply to forest practices in Washington.

Table 10-1 Fine sediments.

Resource sensitive area:	Riparian zones and adjacent steep slopes
Potential impact:	High.
Situation:	Surface erosion caused by disturbances from logging and grazing in riparian zones and on steep slopes adjacent to riparian zones is entering streams through rills, gullies, and ephemeral channels causing an increase of fine sediment in spawning gravels and reducing the quality of habitat for fish embryo incubation.
Triggering mechanism:	Energy dissipators that trap surface sediments and are formed by ground and understory vegetation and dead and down woody debris have been reduced as a result of cleared paths on skid trails, debris clearing in clearcuts, and other silvicultural treatments designed to promote tree regeneration. Vegetative ground cover has also been reduced in riparian zones and in some forested areas by cattle grazing. Compaction on skid trails has reduced infiltration causing overland flow resulting in increased surface erosion.
Comments:	Grazing in riparian zones below steep slopes may affect sediment delivery to streams by reducing understory vegetation that could otherwise trap sediments from resource sensitive areas of high erosion potential.
Resource sensitive area:	**Portions of logging roads draining directly to streams**
Potential impact:	High.
Situation:	Sediments from surface erosion of logging roads is entering streams through ditches, water bars, and culverts that convey runoff directly to the tributary network causing an increase of fine sediment in spawning gravels reducing the quality of habitat for embryo incubation.
Triggering mechanism:	Roads that cross or closely parallel streams intercept runoff and drain directly to streams as a result of slope direction and direct drainage connections. Direct drainage occurs as a result of locating ditches and cross drains that convey runoff to streams and as a result of overflow from plugged drains. Erosion occurs as a result of exposed native surface material, sparsely vegetated cut slopes, and from infrequent or plugged drains resulting in erosion of road surfaces by concentrating runoff in wheel tracks.
Comments:	In addition to erosion from roads, road segments that deliver sediment to streams also may convey sediments from adjacent hillslope erosion.

Table 10-2 Large woody debris.

Resource sensitive area:	Riparian zone in Segments 3 (lower portion), 14, and 16
Potential impact:	High.
Situation:	A reduction of large conifers and large deciduous trees from past logging in the riparian zone has reduced the availability of large decay-resistant trees that provide a future supply of LWD needed for channel stability, pool formation, and complexity of fish cover habitat.
Triggering mechanism:	Clearcut and partial cut timber harvest of the riparian zone in the past reduced the number of large trees available for LWD recruitment.
Comments:	Grazing of riparian areas suppresses timber regeneration and may prolong recovery of trees directly adjacent to streams.
Resource sensitive area:	**Riparian zone in Segments 3 (upper portion), 5, 6, 17**
Potential impact:	Moderate
Situation:	A reduction of large conifers and large deciduous trees from past logging in the riparian zone has reduced the availability of large decay-resistant trees that provide a future supply of LWD needed for channel stability, gravel retention, pool formation, and complexity of fish cover habitat.
Triggering mechanism:	Clearcut and partial cut timber harvest of the riparian zone in the past reduced the number of large trees available for LWD recruitment.
Comment:	Grazing adjacent to streams suppresses timber regeneration and may prolong recovery of trees directly adjacent to streams.

Table 10-3 Stream water temperature.

Resource sensitive area:	Riparian zones in segments 2, 3, 5, 14, and 16
Potential impact:	Moderate and high, depending on location.
Situation:	A reduction of tree density from past logging and grazing in the riparian zone has reduced stream shading, increasing ambient air temperature which causes water temperature increases that could exceed preferred levels for bull trout rearing during warm summer periods.
Triggering mechanism:	Areas of low or moderate stream shading are a result of clearcut and partial cut harvest in the riparian zone. Grazing may contribute to the loss of shade by suppressing tree and shrub regeneration.
Comment:	Shading in the canyon segment is not as important as in the other segments because the steep canyon walls provide topographic shading.
Resource Sensitive Area:	**Riparian zones in meadow segments 1, 4, 15**
Potential impact:	High
Situation:	A reduction of shrub density from past cattle grazing in the riparian zone has reduced stream shading, increasing ambient air temperature which causes water temperature increases that could exceed preferred levels for bull trout rearing during warm summer periods.
Triggering mechanism:	Grazing has eliminated almost all native shrubs (e.g., willows) that could provide shade and has suppressed tree and shrub regeneration.
Comment:	Recovery of willows in the meadows would provide 80 to 100 percent shading of the stream in Calahan meadow and at least 50 percent shading of the larger channels in other meadows. This could have a significant effect on water temperature

Table 10-4 Streambank Vegetation.

Resource Sensitive Area:	**Riparian zones in meadow segments 1, 4, 15**
Potential impact:	High
Situation:	The loss of shrubs and trees from past cattle grazing in the riparian zone and bank trampling from cattle has reduced the amount of undercut banks, which provide summer and winter rearing habitat.
Triggering mechanism:	Cattle grazing reduces bank vegetation causing a reduction in the vegetative root mat and a reduction in cohesion of the upper banks. A reduction of bank cohesion has reduced resistance to erosion resulted in bank collapse. Undercut banks also collapse as a result of bank trampling by grazing along the stream edge and by frequent stream crossings.
Comment:	The loss of bank vegetation by continued grazing creates an unstable bank that contributes fine sediment to the stream by continued bank erosion.

Appendix—
Hillslope Erosion
Worksheets

Analysis Unit (Sub-basin)	Site	Soil Erosion Potential Code (H/M/L)	Activity (Nature & Year)	Erosion hazard from soil-disturbing activities (H/M/L) (See Table B-3)	Photo or other evidence of erosion? (Y/N)	Photo or other evidence of delivery potential? (Y/N)	Field Verification: Field Verified? (Y/N)	Field Verification: Erosion Active? (Y/N)	Field Verification: Delivery to channel? (Y/N)	Comments
Long	15	M	partial cut 1991	H	Y	Y	Y	Y	N	[illegible] from [illegible] due to gentle topography
Long	16	H	partial cut 1989	M	Y	Y	Y	Y	Y	deep (76" gullies present direct delivery to channel
Long	17	H	partial cut 1989	H	Y	Y	Y	Y	Y	very similar to site 16

Form bb-1. Hillslope Erosion Worksheet

Analysis Unit (Sub-basin)	Site	Soil Erosion Potential Code (H/M/L)	Activity (Nature & Year)	Erosion hazard from soil-disturbing activities (H/M/L) (See Table B-3)	Photo or other evidence of erosion? (Y/N)	Photo or other evidence of delivery potential? (Y/N)	Field Verification: Field Verified? (Y/N)	Field Verification: Erosion Active? (Y/N)	Field Verification: Delivery to channel? (Y/N)	Comments
Long	1	M	Clearcut pre 1988	H	Y	N	Y	Y	N	big gullies to flat meadow - distributary is form - no delivery
Long	2	H	Partial cut 1990	H	Y	Y	Y	Y	Y	steep slope in canyon, gullying Delivery ✓
Long	3	M	partial cut pre 1988	H	Y	Y	Y	Y	N	deep gullies - [illegible] hillslope to [illegible] RD flat buffer prevents delivery
Long	4	M	partial cut pre 1988	H	Y	Y	Y	Y	Y	no stream buffer - gullies numerous Delivery ✓
USFS	5	M	OLD GROWTH	L	N	N	Y	N	N	good organic layer no signs of erosion
Long	6	M	partial cut 1991	M	Y	Y	Y	Y	N	gullies present - good buffer
Long	7	H	Clearcut 1992	H	Y	Y	Y	Y	N	gullies present buffer grade prevents delivery

Form bb-1. Hillslope Erosion Worksheet

Analysis Unit (Sub-basin)	Site	Soil Erosion Potential Code (H/M/L)	Activity (Nature & Year)	Erosion hazard from soil-disturbing activities (H/M/L) (See Table B-3)	Photo or other evidence of erosion? (Y/N)	Photo or other evidence of delivery potential? (Y/N)	Field Verification: Field Verified? (Y/N)	Field Verification: Erosion Active? (Y/N)	Field Verification: Delivery to channel? (Y/N)	Comments
Long	8	M	partial cut 1992	M	Y	Y	Y	Y	N	gullies [illegible] Buffer grade prevent delivery
Long	9	M	partial cut 1992	M	Y	Y	Y	Y	N	"
Calahan	10	M	partial cut 1990	H	Y	Y	Y	Y	N	"
Long	11	M	partial cut 1992	H	Y	Y	Y	Y	N	"
Long	12	M	partial cut 1988	H	Y	Y	Y	Y	N	"
Long	13	M	partial cut 1988	H	Y	Y	Y	Y	N	"
Long	14	M	partial cut 1991	M	Y	Y	Y	Y	N	"

Form bb-1. Hillslope Erosion Worksheet