Upper Eel Watershed Analysis

Cumulative Watershed Effects

Final Report

October 26, 2007

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF PHOTOGRAPHS

LIST OF APPENDICES

LIST OF MAPS

Maps are located in each respective module report with the same names listed below.

LIST OF ATTACHMENTS

LIST OF ABBREVIATIONS AND ACRONYMS

<	less than	in.	inches
>	greater than	m	meter
cfs	cubic feet per second	mm	millimeter
ft	feet	mi.	miles
ft^3	cubic feet	mi^2	square miles
g/m^2	grams per square meter		

ATM	Aquatic Trend Monitoring
CC	California coastal
CDEC	California Data Exchange Center
CDF	California Department of Forestry and Fire Protection
CDFG	California Department of Fish and Game
CGU	Channel Geomorphic Unit
CMZ	Channel Migration Zone
CSZ	Cascadia Subduction Zone
CW	Channel Width
CWE	Cumulative Watershed Effects
DBH	Diameter at Breast Height
DEM	Digital Elevation Model
ESU	Evolutionarily Significant Unit
GIS	Geographic Information System
GSA	Geological Society of America
HCP	Habitat Conservation Plan
LSF	Little Salmon Fault
LWD	Large Woody Debris
MTJ	Mendocino Triple Junction
MWAT	Maximum Weekly Average Temperature
NC	Northern California
nd	not determined/not detectable
NMFS	National Marine Fisheries Service
NOAA	National Oceanic and Atmospheric Administration
NRCS	Natural Resource Conservation Service
PALCO	The Pacific Lumber Company
PFC	Properly Functioning Condition
PSMFC	Pacific States Marine Fisheries Commission
RAIS	Riparian Aquatic Interaction Simulator
RMZ	Riparian Management Zone
SCS	Soil Conservation Service
SONCC	Southern Oregon/Northern California Coast
TMDL	Total Maximum Daily Load
USDA	U.S. Department of Agriculture
USDI	U.S. Department of the Interior
USEPA	U.S. Environmental Protection Agency
USGS	U.S. Geological Survey
WAU	Watershed Analysis Unit
WDNR	Washington Department of Natural Resources
WLPZ	Watercourse and Lake Protection Zone
yr	year

1.0 ABSTRACT

The Pacific Lumber Company (PALCO) initiated watershed analyses in 2005 on the Upper Eel Watershed Analysis Unit (WAU) in Humboldt County, California, per the requirements in PALCO's Habitat Conservation Plan (HCP) (PALCO, 1999). The purpose of the HCP watershed analysis is to determine the conditions of erosion and riparian processes in the watershed and their influence on aquatic habitat in and their sensitivity to past and future forest management. This information is then used to develop management objectives for protecting and, if necessary, restoring or enhancing the aquatic habitat of specified federal and state protected salmonids, amphibians, and reptiles. These species include the federally threatened Southern Oregon/Northern California Coast (SONCC) Coho, California coastal (CC) Chinook, Northern California (NC) steelhead, red-legged frog, yellow-legged frog, tailed frog, southern torrent salamander, and the western pond turtle.

As part of watershed analysis, sediment delivery from mass wasting sources was assessed from aerial photographs, with management-related sediment delivery evident during the history of land management in the watershed. A large influx of sediment from landslides occurred during the large regional storms that occurred in the 1950s and 1964, with much of this influx associated with historic logging practices. The high sediment delivery in this time period may be a reflection of construction of many new roads built with what are now archaic road construction practices, unrestricted harvesting in sensitive terrain, and extensive use of tractor yarding, combined with the size of the 1955, 1959, and 1964 storms. Landslide sediment has declined more than 95% since the photo period ending in 1966, even with large storm events occurring in 1996 and 2003. Other management-related sources of sediment include infilling of stream channels for use as skid trails and haul routes. A significant decrease in the overall sediment delivery rates, especially from landslides, may reflect less impacting management practices after adoption of the Forest Practice Rules in the early 1970s and PALCO's HCP in 1999.

Low gradient channels (<4%) are likely to be the location of the best salmonid and only coho habitat in the watershed. The available length of response reaches is relatively low in the WAU, and most of that is found in Larabee Creek and in the portions of the tributaries that flow on the Wildcat geologic formation (Chris Creek, Carson Creek, Newman Creek, and Thompson Creek). Some potentially good habitat is blocked from migration.

The mainstem of Larabee Creek responded to the influx of sediment in 1964 by infilling, braiding, and widening. Riparian forests were either removed by logging or by mechanisms triggered by the storm along the alluvial lower reaches and more confined upper reach, thus contributing to channel instability. Aggradation in the creek has declined in recent decades and the mainstem Larabee Creek has been

developing a more stable channel. Nevertheless, stream shading and Large Woody Debris (LWD) recruitment remains low in Larabee Creek. Hastening growth of mature redwood and Douglas fir forests on the floodplain and adjacent slopes will benefit both water temperature and fish habitat, which are generally not meeting habitat criteria for preferred conditions for salmonids. In a fully recovered condition, Larabee Creek is likely to contain some of the most important abundant and best quality steelhead and Chinook habitat within the WAU.

Smaller tributary streams draining to Larabee Creek and the mainstem Eel have also been impacted from historic channel disturbance. All riparian forests on PALCO lands have been previously harvested. Riparian forests are today dominated by redwood and Douglas fir along much of the length of the smaller tributary sub-basins. Shade levels are high and water temperatures are meeting Properly Functioning Condition (PFC) targets. Some of these forests are of sufficient size that they are beginning to recruit functional LWD. Most will achieve these conditions within the next several decades.

Channels within the response reaches of the tributary streams currently suggest persistence of sediment-induced cumulative adverse effects. Relative to preferred future condition criteria, effective LWD is generally low, pools are generally sparse and shallow, and streambed sediments are generally embedded with fines. However, channel conditions were found to vary systematically with location in the watershed relative to geology, and within individual tributaries where one or more or these conditions are currently meeting PFC habitat goals. Continued improvement in salmonid habitat is likely to occur as the input of larger pieces of LWD increases and sediment supply declines.

2.0 OVERVIEW AND BACKGROUND

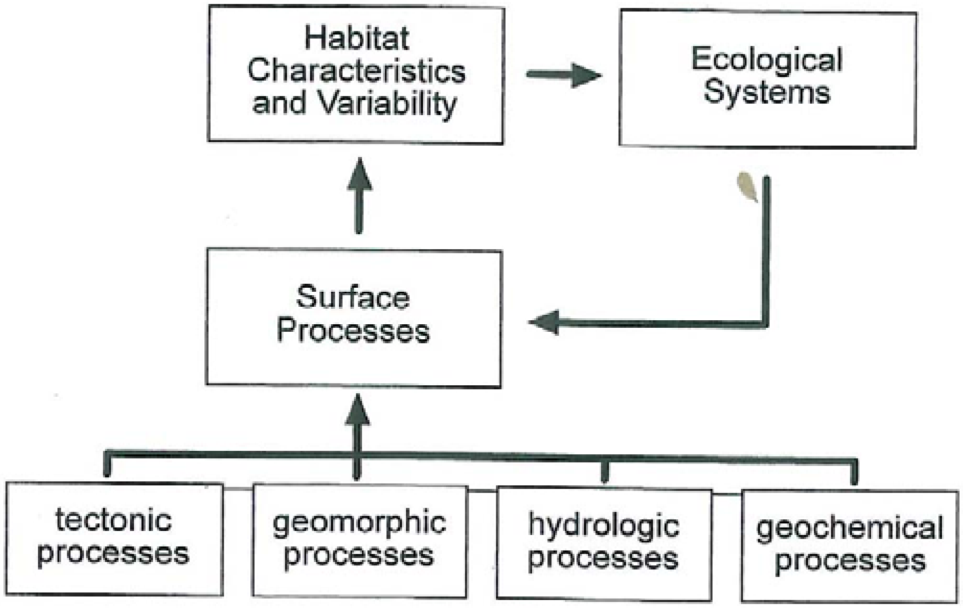
The goal of PALCO's HCP developed in agreement with federal and state agencies is to maintain or achieve over time a properly functioning aquatic habitat condition in streams and rivers affected by PALCO forest management activities. Aquatic species of concern include salmonids (coho, Chinook, and steelhead), along with other species of concern including amphibians (red-legged frog, yellow-legged frog, tailed frog, and southern torrent salamander) and the western pond turtle.

As part of the HCP agreement, PALCO conducts watershed analysis in each watershed where PALCO has significant ownership. Watershed analysis is a systematic procedure for characterizing the physical and biological processes active within a watershed; their spatial distribution, history, and linkages; past and current habitat and biological conditions; and the linkages between landforms, surface processes, and biological systems (Figure 2-1: Montgomery et al. 1995b). The information generated in a watershed analysis guides ecosystem-oriented land use planning and development of landscape-specific management prescriptions. The process also identifies and directs prioritization of restoration opportunities, and provides information necessary for development of an efficient monitoring program.

River processes are driven by general physical relations that govern the flow of water, sediment transport, and interactions with bed- and bank-forming materials (Figure 2-2). The key "currencies" of watersheds that are traded between a channel and its watershed are sediment, large woody debris, water, heat energy and nutrients. Riverine ecosystems have particularly tight coupling to geomorphological processes due to gravity-driven routing of materials and disturbances down channel systems (Montgomery 2001). River systems display rich and varied characteristics, dynamics and relations to ecological systems in spite of the generality of the underlying physics. Variability in factors such as local geology, climate, vegetation condition, and the resultant impacts of the history of land use practices create variability in the habitat quality in the watershed at a watershed, reach, and local level.

Watershed analysis involves systematic study of the condition of water, wood, and sediment in a watershed relative to aquatic habitat, and how land management affects this condition. The assessment operates on the basic premise that hillslope (upland and riparian) processes influence aquatic habitat conditions because they generate or modulate inputs of sediment, wood, water, and thermal energy; and that a change in erosion, runoff processes, or riparian function resulting from forest management is significant when it is sufficient to cause an adverse change in aquatic salmonid and/or amphibian habitat conditions. The study of the watershed is guided by the "Watershed Analysis Methods for PALCO Lands" (PALCO 2000), modified from the Washington Forest Practices Board Manual: Standard Methodology for conducting Watershed Analysis (Version 4.0, November 1997, WDNR).

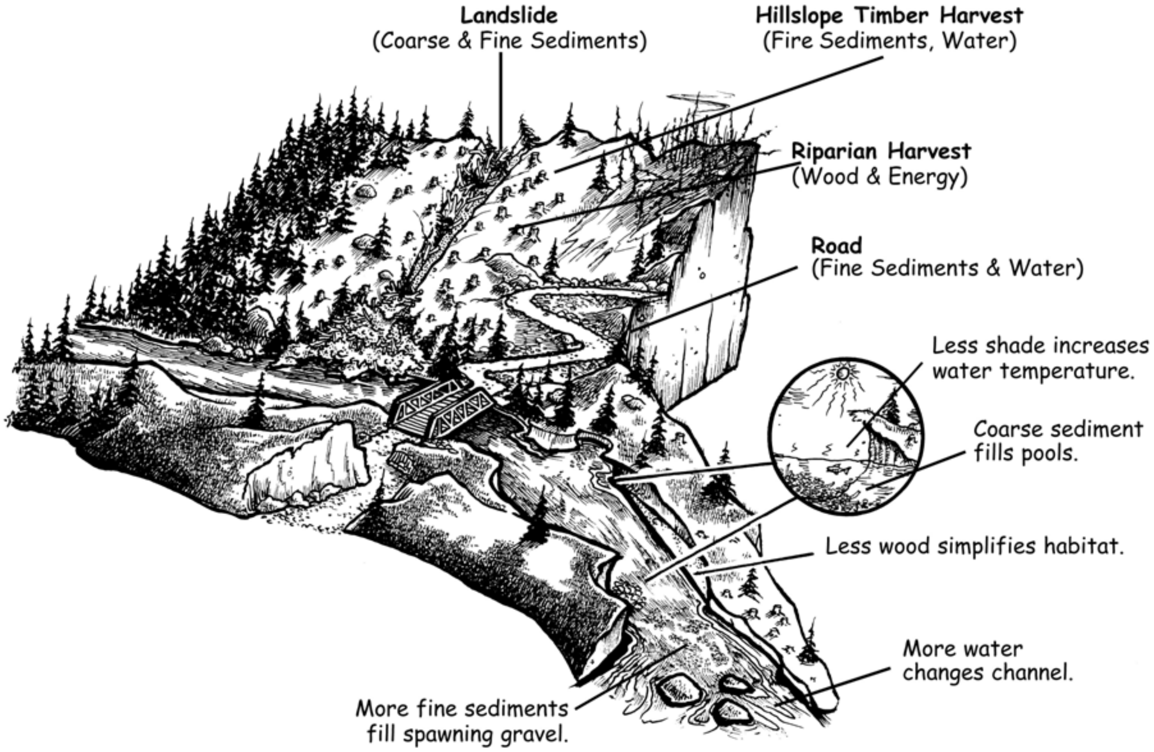
Figure 2-1. Schematic illustration of the role of surface processes on shaping habitat characteristics and variability and the potential for ecological systems to influence surface processes



Source: Montgomery 2001

The guiding philosophy behind watershed analysis is that, although a landscape and its ecosystems are complex and impossible to understand or characterize completely, there is enough pattern to the linkages within and between physical and ecological systems that reasonable models of how they interact can be developed through observation (Montgomery et al. 1995). The study of the watershed is accomplished with quantitative assessment supplemented by professional judgment using a weight of the evidence approach. Many individual assessments and analyses regarding these processes were performed in the Upper Eel WAU as described in modules and listed in Table 2-1, to assess watershed condition and cumulative effects of land management and natural disturbances.

Figure 2-2. Relationship between hillslope activities and stream effects through changes in the input factors of coarse and fine sediment, wood, water, or energy



This Cumulative Watershed Effects (CWE) Report presents a summary of the findings of the watershed analysis of the Upper Eel WAU. It describes the watershed setting and land use history. Results of individual module reports evaluating the relationship between land use activities and mass wasting and erosion processes (Appendices A and B), riparian forest condition (Appendix C), stream channel and fish habitat conditions (Appendices D and E), and amphibian and reptile habitat conditions (Appendix F) are synthesized and summarized.

This report emphasizes the erosion history of the watershed and riparian forest condition and disturbances. Studies of other watersheds in the mountainous regions of the Pacific Northwest, including the coastal region of northern California, have shown that the primary impacts of forest management on salmonid and amphibian habitat over the past 100 years are likely to be increased sediment input and loss of large woody debris and shade. The watershed analysis process addresses these issues as guided by the watershed analysis methods. To initiate the watershed analysis process, a public meeting[1] was held for the purpose of receiving public input and identifying any additional issues requiring study in the Upper Eel WAU.

This CWE report evaluates the effects of management practices—both individually and cumulatively—on aquatic resources; documents pertinent information and justification supporting the delineation of sensitive areas; and identifies specific management actions affecting aquatic resources.

Definitions of key terminology used for the Upper Eel watershed analysis are provided in Attachment 4.

Table 2-1. Analysis and data collection conducted during the Upper Eel Watershed Analysis

Type of Assessment or Analysis	Where Reported
Air photo landslide inventory and ground truthing	Appendix A
SEDMODL road surface erosion analysis	Appendix B
WEPP harvest unit surface erosion analysis	Appendix B
Harvest unit surface erosion field reconnaissance	Appendix B
Streamside landslide/bank erosion surveys	Appendices A and D
Classification of riparian forests in Riparian Condition Units through air photo analysis and field verification	Appendix C
Analysis of LIDAR-based (Light Detection and Ranging) longitudinal channel profiles	Appendix D
Air photo time series analysis of planform channel geometry for the mainstem Larabee Creek	Appendix D
Analysis of channel width with respect to drainage area	Appendix D
Time series review of cross sections and channel longitudinal profile data surveyed since the late 1990s	Appendix D
Collection and analysis of bulk sediment distribution surface and subsurface streambed sediment samples	Appendices D and E
Measurement of Large Woody Debris (LWD) within the stream channel, and characterization of the processes and rates of LWD recruitment	Appendices D and E
In-stream habitat surveys on total of 34,293 feet of stream for characterization of habitat features including pools	Appendices D and E
Mapping of Channel Migration Zones (CMZs) based on meander and flooding patterns from historical aerial photographs and LIDAR-based topographic and stream gradient maps	Appendix D
Review of historical aerial photographs of mainstem and tributary channels to understand short-term trends in sediment mobilization and storage	Appendix D
Review of direct anthropomorphic impacts to the channel network from historical aerial photographs	Appendix D

---

[1] A meeting was held on April 29, 2002 at the River Lodge Conference Center in Fortuna, and was advertised in the Eureka Times-Standard newspaper more than two weeks beforehand. No residents of the Upper Eel WAU were in attendance, and only one interested citizen attended. Due to lack of attendance, the meeting was adjourned early and no verbal or written comments were received.

Table 2-1. Analysis and data collection conducted during the Upper Eel Watershed Analysis

Type of Assessment or Analysis	Where Reported
Categorization of channels by dividing stream reaches into Channel Geomorphic Units (CGUs)	Appendix D
Fish surveys to determine upstream extent of fish distribution	Appendix E
Analysis of water temperature in streams	Appendix E
Review of gravel bar data for 24,313 feet of the mainstem Eel River	Appendix E
Species occurrence surveys, along with reviews of previously collected data for amphibians and reptiles	Appendix F

3.0 WATERSHED SUMMARY

This section provides a summary of the watershed setting, history, and key themes. The discussion includes background information on the geographic setting and study area delineation, topography, stream class, geology and seismic regime, soils, climate and hydrology, forest ecology, and aquatic resources. Attachment 1 provides specific watershed tabular information on watershed statistics at a detailed, sub-basin-specific level for use throughout the cumulative effects analysis and watershed analysis in general.

3.1 GEOGRAPHIC SETTING AND STUDY AREA DELINEATION

The Upper Eel WAU is located within the Eel River basin. The Eel River is located in California's rugged North Coast, southeast of the city of Eureka, and drains an area of 3,684 square miles. The watershed spans 3 counties of which 1,477 square miles are located along the mainstem. There are three main forks of the Eel River – the South Fork and the shorter North Fork and Middle Fork, both located to the south of the WAU.

The Upper Eel WAU is located approximately 14 miles southeast of Scotia, California, and is situated in the lower Larabee Creek valley and in the area immediately north and east of the confluence of the South Fork Eel River and the mainstem of the Eel River. The WAU encompasses a total of approximately 167 square miles, which includes approximately 43.7 square miles of forestlands managed by PALCO under its HCP. A summary of watershed parameters for the Upper Eel WAU is provided in Table 3-1, along with acres within and outside of PALCO ownership by sub-basin in Table 3-2.

Table 3-1. Watershed Parameters for the Upper Eel WAU

Parameter	Upper Eel WAU[1]
Total basin area (mi^2)	167
Total PALCO ownership (mi^2)	45.8
Total HCP Area (mi^2)	45.3

[1] Data are based on recent changes in areas under HCP management.

Table 3-2. PALCO Ownership and Non-PALCO Ownership by Sub-basin

Sub-basin	PALCO Ownership[1]		Non-PALCO Ownership[1] (Acres)	Total (Acres)
	HCP Lands (Acres)	Non-HCP Lands (Acres)		
Balcom Creek Complex	1,193	-	66	1,259
Boulder Creek	1,105	-	129	1,235
Bridge Creek	1,163	-	3,126	4,289
Burr Creek	-	-	6,648	6,648
Butte Creek	-	-	4,178	4,178
Cameron Creek	562	-	13,429	13,991
Carson Creek Complex	1,993	-	19	2,012
Chris Creek	974	-	52	1,026
Decker Creek	301	-	1,534	1,835
Elk Creek	839	-	6,361	7,200
Kapple Creek Complex	1,699	-	147	1,846
Main Stem Larabee I	1,791	-	593	2,384
Main Stem Larabee II	262	-	415	676
McCann Creek Complex	2,321	-	251	2,572
McMahan Creek	-	-	8,689	8,689
Mid Larabee Creek Complex	1,642	-	1,700	3,341
Mill Creek	978	-	14,057	15,035
Newman Creek	2,114	-	94	2,208
No Name Creek Complex	1,774	-	2	1,776
Ohman Creek	-	152	2,979	3,131
Poison Oak Creek Complex	2,815	-	898	3,713
Scott Creek Complex	1,919	-	-	1,919
Smith Creek	1,387	-	569	1,956
Thompson Creek	2,154	179	3,198	5,531
Thurman Creek	-	-	8,371	8,371
Grand Total	**28,986**	**331**	**77,505**	**106,821**

1 Data are based on recent changes in areas under HCP management. Also, Non-PALCO Ownership includes areas labeled “inholding” and “(blank)” in the PALCO database.

The Upper Eel WAU consists of all or a portion of 12 contiguous CalWater Planning Watersheds: Burr Creek, Cameron Creek, Canoe Creek, Decker Creek, Elk Creek, Lower Larabee Creek, McMahan Creek, Mill Creek, Ohman Creek, Poison Oak Creek, Thompson Creek, and Thurman Creek (Figure 3-1). These Planning Watersheds are further sub-divided into a total of 25 sub-basins (generally smaller in area) to reflect variation in geologic types and to yield higher resolution for larger Planning Watersheds with a significant proportion of PALCO ownership. The Burr Creek, Butte Creek, McMahan Creek, and Thurman Creek sub-basins are comprised solely of non-PALCO ownership and, therefore, are not the focus of this watershed analyses. The Eel River mainstem, which flows through the middle of the Upper Eel WAU, is addressed to a limited extent in the analyses; the mainstem of the Eel River is impacted primarily by upstream activities.

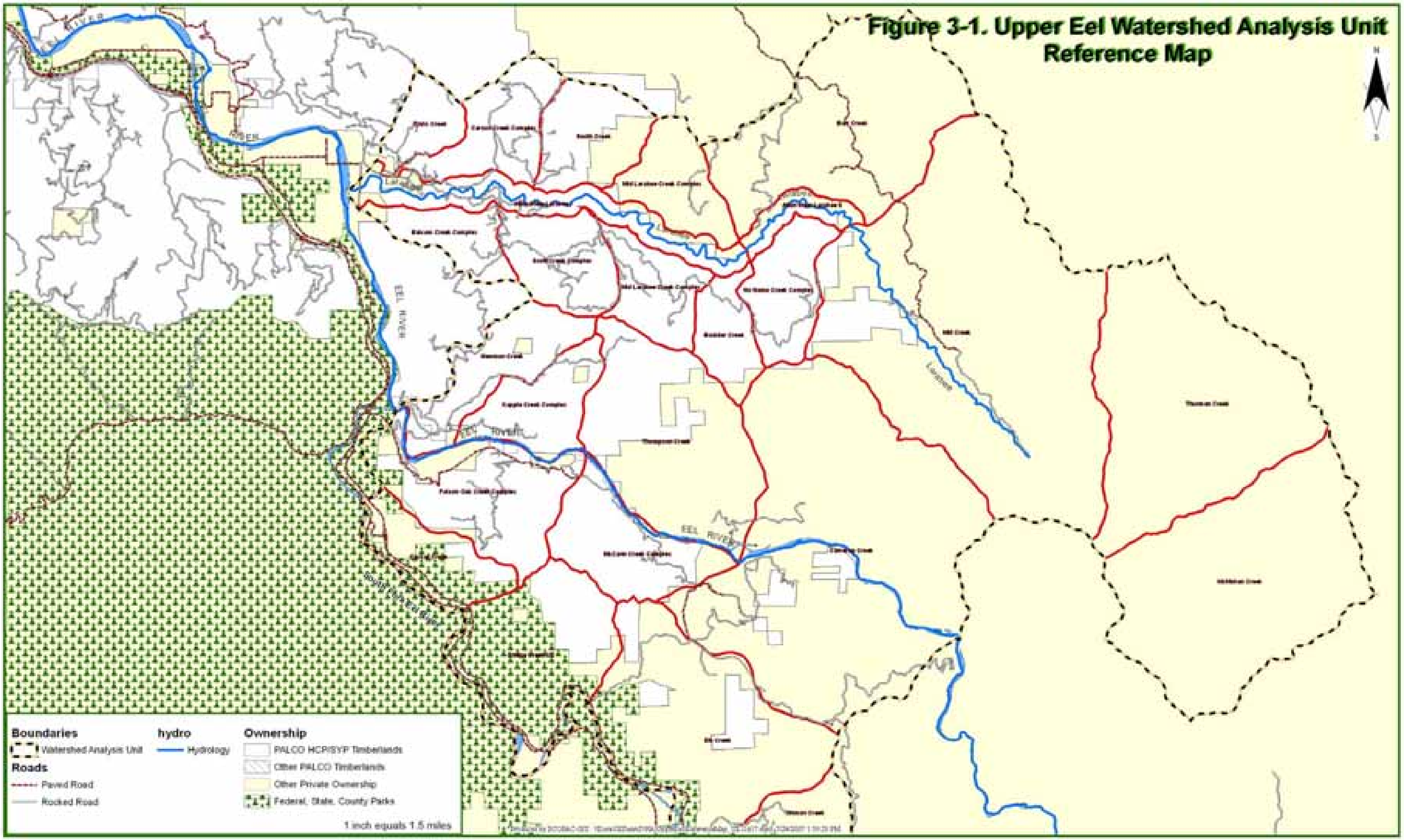


Figure 3-1. Upper Eel Watershed Analysis Unit Reference Map

3.2 GEOLOGIC SETTING

Coastal California north of Cape Mendocino lies on the tectonically active convergent margin of the North American plate. Since the Mesozoic, the geologic development of northern California's Coastal Ranges has been dominated by the plate convergence of the North American, Gorda, and Pacific Plates, known as the Mendocino Triple Junction (MTJ). The following discussion of the geologic and tectonic history of this area is synthesized from geologic and seismic studies conducted in the region: (Ogle, 1953; Irwin, 1960; Blake et al., 1982; Toppozada and Parke, 1982; Spittler, 1983; Nilsen and Clarke, 1987; Prentice, 1989; Clarke, 1992; Dengler et al., 1992; McPherson, 1992; PWA 1998a and 1998b; and Clague et al., 2000).

During the past 140 million years, subduction and the resulting continental accretion have welded a broad complex of highly deformed oceanic rocks to the western margin of the North American plate. Sediments eroded from the continent and deposited offshore in sedimentary basins have been highly deformed and then uplifted by the northward migration of the Mendocino Triple Junction (Map A-1). These rocks now comprise the Franciscan Complex which constitute the basement rocks of the northern coast of California.

Based on composition, structure, and geographic location, the Franciscan Complex has been divided into three broad tectonic belts--the Eastern, Central and Coastal. The primary Franciscan Complex units found within the Upper Eel Watershed Analysis Unit consist of the Central Belt Franciscan Complex and the Yager terrane of the Coastal Belt. The Yager Complex consists of dark gray indurated mudstone, shale, graywacke, siltstone, and conglomerate with interbedded limey siltstones capped by more competent sandstones. Within the WAU, the Yager formation is found to the east and comprises the largest aerial extent within this study area.

More recently, each of these belts has been further subdivided into a number of fault-bounded tectonostratigraphic terranes, each having a distinct stratigraphy. The Wildcat Group consists of a lower marine sequence and an upper nearshore and fluvial sequence. The Wildcat formation consists of open marine deposits of mudstone, siltstone and fine sandstone and an upper sequence of chiefly non-marine sandstones and conglomerates. Massive mudstones and siltstones are the most dominant geologic materials characteristic of the lower unit. The nearshore sequence is represented by the massive, bluff-forming Scotia Bluffs Sandstone in the HCP area. The Wildcat formation is found lower in the sedimentary sequence, and is exposed along the western portion of the WAU by the downcutting of the Eel River and the lower tributaries draining to it.

The lithology of the WAU includes Wildcat, Yager, and Franciscan formations. Approximately 62 percent of the HCP area is underlain by the Yager geologic terrane (Table 3-3). The remaining 38 percent of the HCP area is underlain by smaller areas of the Mesozoic Franciscan sandstone and melange, Pleistocene Wildcat Group lithologies, including the Scotia Bluffs sandstone, and Quaternary alluvium and terrace deposits.

Table 3-3. Distribution of Lithologic Units in HCP Area

Lithologic Unit[1]	**Area (acres)**	**Area (mi^2)**	**Percent of Area**
Stream channel and terrace deposits	1,805	3	6%
Scotia Bluffs sandstone (QTsb)	239	0	1%
Wildcat undifferentiated (QTwu)	5,520	9	19%
Yager formation (TKy)	18,041	28	62%
Franciscan mélange (KJfm)	331	1	1%
Franciscan sandstone (KJfs)	3,053	5	11%
Total	28,988	45	100%

[1] Data are based on recent changes in areas under HCP management.

Seismic Activity. The Upper Eel WAU is a seismically active region susceptible to frequent moderate to strong ground shaking located on the southern limb of the Eel River Syncline. It is experiencing rapid uplift as the MTJ migrates northward. Historical and potential seismic sources affecting western Humboldt County include the Gorda Plate, the Mendocino Fault, the Cascadia Subduction Zone, the Mendocino Triple Junction, the San Andreas Fault, the Mad River Fault Zone, and the Little Salmon Fault. Faults in the vicinity of the Upper Eel WAU have potential to generate large to great earthquakes.

The largest historical earthquake to affect the Upper Eel WAU was the M 8.3 San Andreas earthquake of 1906. In the historical record, more than 25 earthquakes of magnitude 6 or greater have originated in or offshore from Humboldt County. Recurrence intervals for great (M8+) earthquakes are estimated at 200 to 400 years for the San Andreas Fault (Prentice, 1989) and 300 to 600 years for the Little Salmon Fault / Cascadia Subduction Zone (LSF/CSZ). Most historical seismicity affecting the Upper Eel WAU has originated from the Gorda Plate, which generates large (approximate M 7) events approximately every 12 years. The Mendocino Fault and the Mendocino Triple Junction have generated historical earthquakes ranging from M 5.6 to 6.9.

The sources with the potential for generating the strongest ground motions in the study area are the CSZ and the LSF. The LSF is a thrust fault trending west to east with the mapped portion of its trace within 4 miles of the study area. The southernmost portion of the CSZ generated a M 7.1 event on April 25, 1992.

Radiocarbon dates on earthquake-related deposits and Japanese tsunami records indicate a great earthquake originating from the CSZ on January 26, 1700. The CSZ is estimated to have potential to generate earthquakes of Mw8.4+ Correlation of LSF offset dating with CSZ deformation dating indicates that LSF ruptures occur in concert with CSZ ruptures. Faults of the Mad River Fault Zone are estimated to have potential to generate large earthquakes with recurrence intervals on the order of hundreds or thousands of years.

Seismic activity provides an important disturbance mechanism that can cause increased landslides, surface erosion, and other effects in the watershed. The combination of rapid uplift and seismic activity result in a high background rate of sediment production (Lisle, 1990). Seismic shaking has been documented as a triggering mechanism for a large variety of landslides (Keefer, 1984). Uplift results in high rates of fluvial incision and the formation of inner gorges. Earthquakes in the vicinity have likely caused transient entrainment and movement of otherwise stable sediment deposits in and near streams over the years. Recent Humboldt County earthquakes of 1980, 1992, and 1994 caused significant damaging effects in the surrounding area and may have caused pulses in sediment movement in the Upper Eel WAU.

3.3 SOILS

Underlying geology and topography control soil texture. The Upper Eel WAU is dominated by sedimentary rocks that trend in a northwest to southeasterly direction from relatively incompetent mudstones in the lower elevations on the western side of the WAU to more competent sandstones on the eastern side of the WAU. A detailed description of the area geology is included in the Mass Wasting Assessment Report for the Upper Eel WAU.

Soils in the Upper Eel WAU were mapped by the Natural Resources Conservation Service (NRCS[2]) and the University of California (McLaughlin and Harradine, 1965). NRCS is currently updating soil maps for Humboldt County. Map SE-1 shows the most recent (1970s) map of soils in the Upper Eel WAU; note the coverage does not extend to the full area of the WAU. Table 3-4 summarizes the following properties of soils in the HCP area: soil depth, texture, drainage, permeability, and erosion hazard based on the NRCS database.

---

[2] Formerly known as the Soil Conservation Service (SCS).

Table 3-4. Properties of Soils in HCP Area of the Upper Eel WAU

Soil Series Name	Total HCP Acres	Percent Total HCP Area for WAU	Depth Range (in.)	Parent Material	Texture of Surface/ Subsurface	Drainage	Permeability
Yorkville	18	<1%	30-60	Metamorphosed rock	Clay loam/clay	* Moderately well to Well	* slow to very slow
Hugo	14,445	52%	30-60	Sandstone and shale	Gravelly loam/stony clay loam	* Well	* Moderately rapid
Melbourne	5,059	18%	30-60	Sandstone and shale	Loam/clay loam	* Well	* Moderate
Josephine	366	1%	30-60	Sandstone and shale	Loam/clay loam	*Well	Moderately Slow
Hoover	53	<1%	30-60	Sandstone	Gravelly Loam	No data	No data
McMahon	45	<1%	30-60	Sandstone	Clay loam/ clay	* Moderately well or somewhat poor (inferred)	* Slow (inferred)
Laughlin	564	2%	16-36	Sandstone and shale	Loam/loam	* Well	*Moderate
Tyson	26	<1%	18-48	Sandstone and shale	Gravelly loam/very gravelly loam	*Well	*Moderate
Maymen	39	<1%	4-16	Sandstone and shale	Gravelly loam/gravelly loam	*Somewhat excessively drained	*Moderate to moderately rapid
Larabee	5,464	20%	40-70	Soft sedimentary rock	Loam/clay loam	*Moderate	*Moderate
Larabee Gravel	24	<1%	40-70	Soft conglomerate	Gravelly loam/gravelly clay loam	*Well	*Moderately Slow
**Bottom Land	739	3%	64-70+	Sedimentary alluvium	Loam/Silt Loam	* Moderately well to imperfectly	*Moderately rapid to slow
**Terraces	49	<1%	64-70+	Sedimentary alluvium	Loam/Silt Loam	* Moderatly well to imperfectly	* Moderately rapid to slow
***Other	1,022	4%	*** Varies	*** Varies	*** Varies	*** Varies	*** Varies

* Information on soil drainage and permeability characteristics for these soils was obtained from the Soil Survey Staff, Natural Resources Conservation Service, United States Department of Agriculture. Official Soil Series Descriptions Available URL: **http://soils.usda.gov/technical/classifications/osd/index.html**.

** Mapping unites Bottomland and Terraces contain areas mapped by McLaughlin and Harradine (1965) as primarily Loleta and Russ soil series. Estimates of soil characteristics are based on these two series.

*** Mapping unit “other” contains areas classified by McLaughlin and Harradine (1965) as residential, business, and industrial areas. Also, this includes streams and areas with no soil type available. Soil characteristics can be inferred from adjacent map units.

Ninety percent of the HCP area is represented by one of three soils – Hugo (52%), Larabee (20%), and Melbourne (18%). Hugo soil textures range from gravelly loam to stony clay loam, whereas, Larabee and Melbourne soil textures are loam/clay loam. These soils are well to moderately drained and are generally deep, ranging in depth from 30 to 70 inches.

3.4 TOPOGRAPHY

Elevations within the analysis area range from approximately 80 feet at the mouth of Lower Larabee Creek to approximately 3,550 feet along the Brushy Mountain Ridge in the Thompson Creek sub-basin. Slope analysis was performed based on a LIDAR Digital Elevation Model (DEM) produced by laser altimetry. The slope gradient class map is shown in Figure 3-2, and results are listed in Table 3-5.

Table 3-5. Summary of Acres in Major Slope Gradient Classes in HCP Area

Sub-basin[1]	0-35% (Acres)	35-50% (Acres)	50-65% (Acres)	>65% (Acres)	Total (Acres)
Balcom Creek Complex	358	429	286	119	1,193
Boulder Creek	420	310	210	166	1,105
Bridge Creek	535	349	209	70	1,163
Cameron Creek	191	163	107	96	557
Carson Creek Complex	897	638	279	179	1,993
Chris Creek	253	282	292	136	964
Decker Creek	193	72	27	6	298
Elk Creek	503	185	101	42	830
Kapple Creek Complex	612	459	391	238	1,699
Main Stem Larabee I	752	304	287	466	1,809
Main Stem Larabee II	52	63	71	76	262
McCann Creek Complex	673	487	557	580	2,298
Mid Larabee Creek Complex	657	460	328	197	1,642
Mill Creek	225	205	215	333	978
Newman Creek	740	529	507	338	2,114
No Name Creek Complex	408	443	373	550	1,774
Poison Oak Creek Complex	929	591	647	647	2,815
Scott Creek Complex	614	518	422	345	1,899
Smith Creek	680	472	194	55	1,401
Thompson Creek	732	646	431	345	2,154
Total for HCP Area	10,424	7,606	5,935	4,985	28,949
Percent of Total	36%	26%	21%	17%	100%
Cumulative Percent Total	36%	62%	83%	100%	---

[1] Data are based on recent changes in areas under HCP management.

Slopes steeper than 65 percent account for 17 percent of the HCP area; these areas are located along the inner gorges of the major tributaries to Larabee Creek and the mainstem Eel River, including No Name Creek, Mill Creek, Poison Oak Creek, and McCann Creek. Other steep slopes are found in headwall areas underlain by the Wildcat Group sediments. Slopes less than 35 percent gradient account for 36 percent of the area. Very gently sloping ground is found along the lower, alluvial portions of Larabee Creek and the mainstem Eel River.

3.5 STREAMS AND RIVERS

The terrain of the Upper Eel WAU, is deeply dissected by several large mainstem rivers and their tributaries. Large mainstem watercourses that include the Eel River and Larabee Creek have created alluvial valleys that range from unconstrained to tightly constrained within the adjacent hillslopes, depending on location within the WAU. The WAU encompasses the junction of the mainstem Eel River and South Fork Eel River, and portions of the mainstem below their confluence. Smaller tributaries are widely distributed throughout the WAU and flow directly into Larabee Creek or Eel River.

3.5.1 Channel Types

At the most general level, river systems are made up of 3 dominant morphologies reflecting channel slope as a determinant of erosion, sediment transport, and deposition (Montgomery and Buffington 1993). Source reaches are steep and generally small. Most sediment input in a watershed usually occurs along these reaches as they make up a large portion of the defined channel network. Transport reaches are morphologically resilient, high-gradient (>4%), supply-limited channels that rapidly convey increased sediment inputs without storing much sediment. In general, steep alluvial channels tend to maintain their morphology while transmitting increased sediment loads (Montgomery and Buffington 1993). Response reaches are low-gradient (<4% gradient), transport-limited channels where the channel is alluvial in nature and the majority of sediments are stored. Alluvial gravels are a critical component of spawning and rearing habitat and response reaches are expected to provide the majority of suitable freshwater habitat for anadromous salmonids. Response reaches are capable of significant morphologic adjustment occurs in response to changes in sediment supply (Montgomery and Buffington 1993). This watershed analysis focuses on channel conditions and habitat quality in the response reaches of the WAU because of their importance to endangered anadromous salmonids.

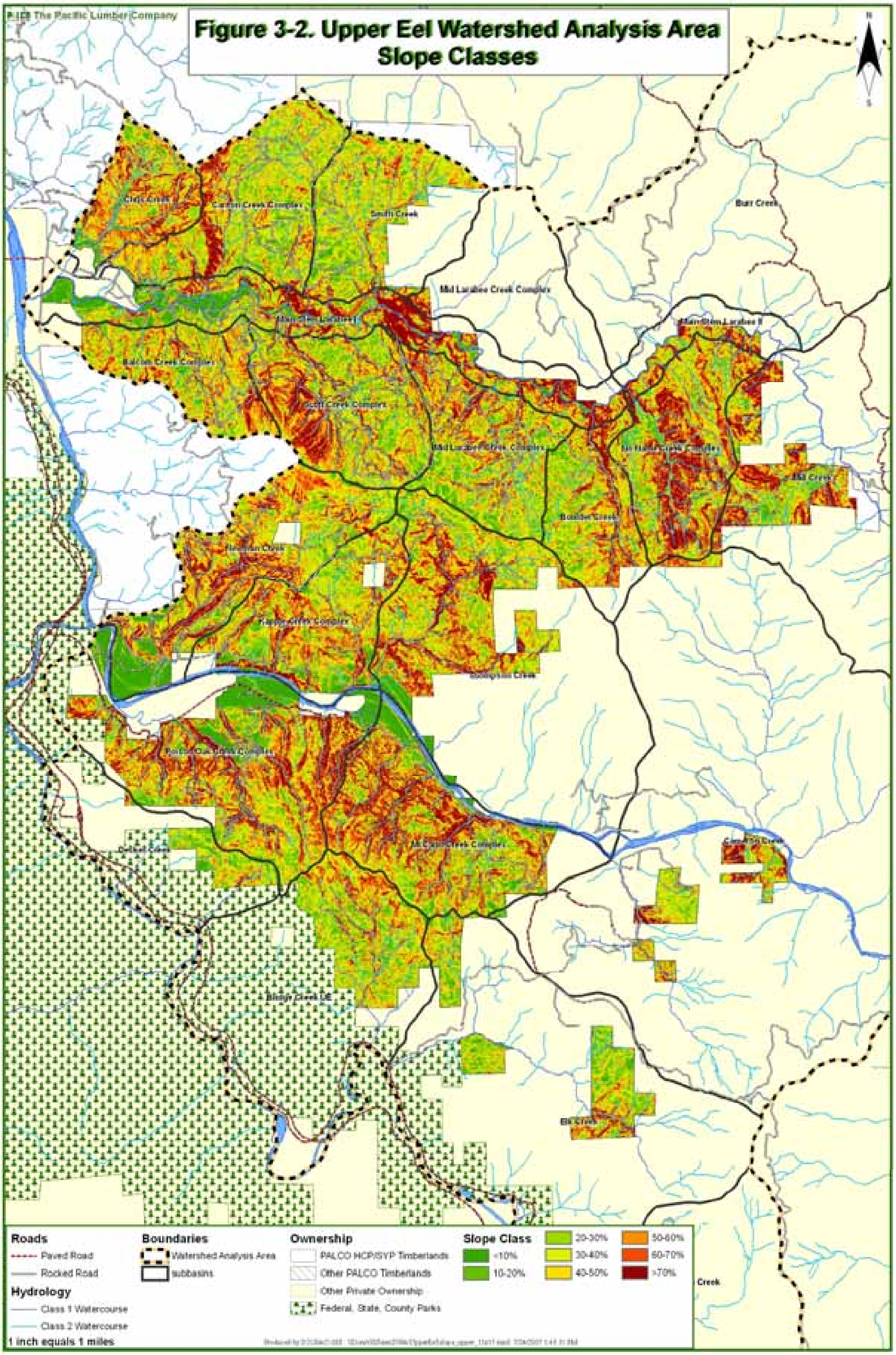


Figure 3-2. Upper Eel Watershed Analysis Area Slope Classes

The streams in the Upper Eel WAU vary significantly from one another in terms of the prevalence of low gradient response reaches. A stream gradient map based on a LIDAR DEM is shown in Map D-2. A notable feature of this WAU is that there is relatively little low gradient channel length available to anadromous fish. The alluvial mainstem of the South Fork Eel River, Eel River, and Larabee Creek are response reaches. Within the tributaries, lengthy contiguous reaches of low gradient stream occur nearly exclusively in streams formed on the Wildcat formation on the western side of the WAU including the lower reaches of Chris Creek, Carson Creek, Newman Creek, Elk Creek, and Thompson Creek.

Stream channels in the Upper Eel WAU are largely formed on the more competent Yager formation. Streams and the upper portion of Larabee Creek are dominated by confined, moderate and steep gradient transport reaches. Tributary streams formed on the Yager formation begin with steep gradients from their junction with Larabee Creek, and have virtually no length in low gradient alluvium. Additional discussion of stream gradients is provided in the Fish Habitat Assessment Report (Appendix E).

3.5.2 Stream Class

Stream classes are described in the California Forest Practice Rules by water class characteristics or key indicator beneficial uses. Stream classes are defined as CDF Class I, II, III or IV streams. CDF Class I streams include streams that supply domestic water and/or have fish that are always or seasonally present and includes habitat to sustain fish migration and spawning. CDF Class II streams include streams that have fish always or seasonally present, offsite within 1,000 feet downstream and/or streams that support aquatic habitat for non-fish aquatic species. CDF Class III streams includes streams that have no aquatic life present but have evidence of being capable of sediment transport to Class I or Class II streams. Class IV streams include man-made watercourses. Table 3-6 presents a summary of the Class I and II channel lengths by sub-basin in the HCP area of the Upper Eel WAU.

Table 3-6. Summary of Stream Channel Lengths in HCP Area

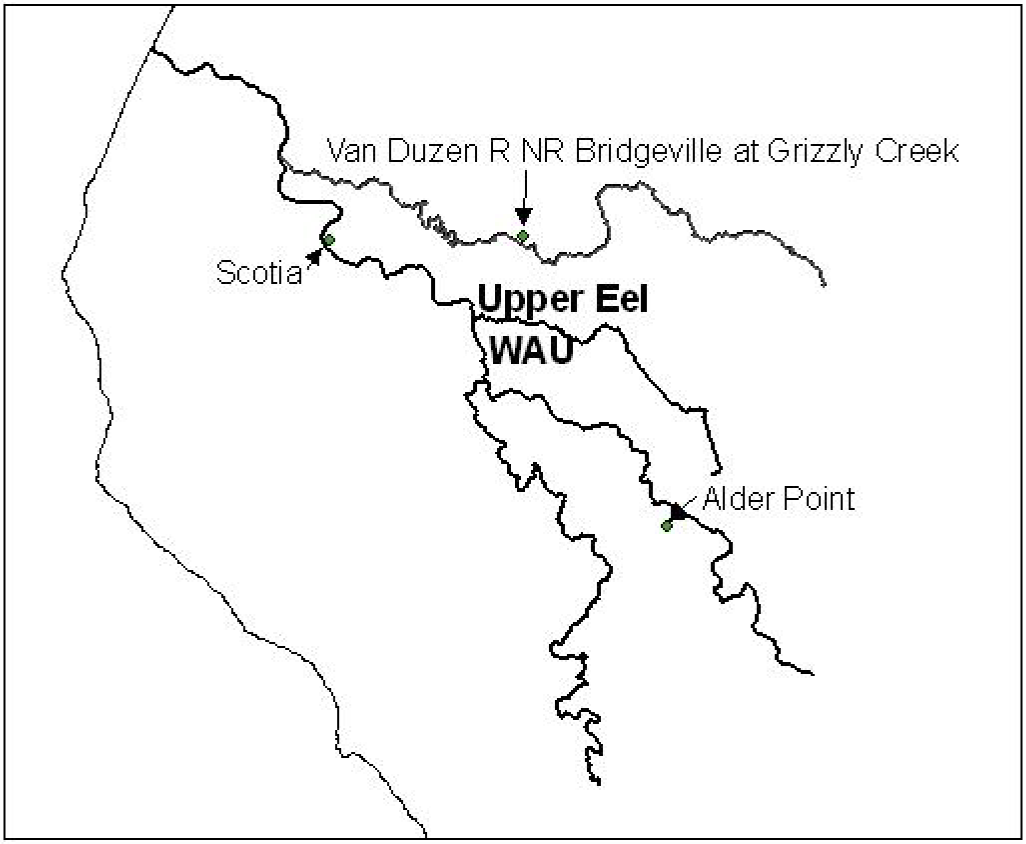
Sub-basin[1]	Class I (Miles)	Class II (Miles)	Total (Miles)
Balcom Creek Complex	-	7.49	7.49
Boulder Creek	0.04	6.86	6.90
Bridge Creek	0.50	7.88	8.38
Cameron Creek	1.09	3.30	4.39
Carson Creek Complex	0.34	11.92	12.26
Chris Creek	0.63	6.23	6.86
Decker Creek	0.12	1.09	1.21
Elk Creek	1.09	3.50	4.59
Kapple Creek Complex	1.43	9.07	10.50
Main Stem Larabee I	10.41	7.04	17.45
Main Stem Larabee II	1.59	1.45	3.04
McCann Creek Complex	2.39	11.71	14.10
Mid Larabee Creek Complex	0.26	12.45	12.71
Mill Creek	0.69	8.16	8.85
Newman Creek	3.28	10.33	13.61
No Name Creek Complex	0.13	15.36	15.49
Poison Oak Creek Complex	2.35	17.51	19.86
Scott Creek Complex	0.15	13.50	13.65
Smith Creek	-	9.67	9.67
Thompson Creek	3.10	10.53	13.63
Total for HCP Area	30	175	205

[1] Data are based on recent changes in areas under HCP management.

3.6 CLIMATE AND HYDROLOGIC SETTING

The climatic and hydrologic setting is summarized in the following discussion. Figures and tables are provided to illustrate data collected in the general area surrounding the Upper Eel WAU. The Upper Eel WAU experiences climatic conditions typical of coastal Northern California. Climate station locations in the vicinity of the WAU are shown in Figure 3-3.

Figure 3-3. Climate Stations in the Vicinity of the Upper Eel WAU



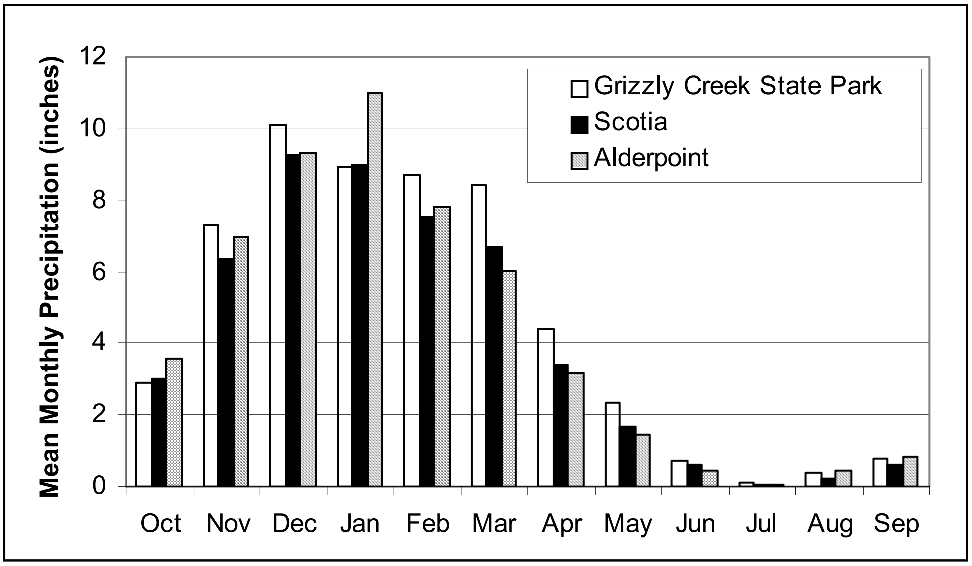
3.6.1 Climate

The Northern California coast has a completely maritime climate, marked by high levels of humidity throughout the year (NOAA, 2000). The rainy season runs from approximately October through April, during which time approximately 90% of the annual precipitation occurs (Table 3-7, Figures 3-3 and 3-4). Annual total precipitation for Scotia is presented in Figure 3-5, from 1926-2004, as obtained from the California Data Exchange Center (CDEC, 2006).

Table 3-7. Weather Stations for Climatic Data in the WAU Area

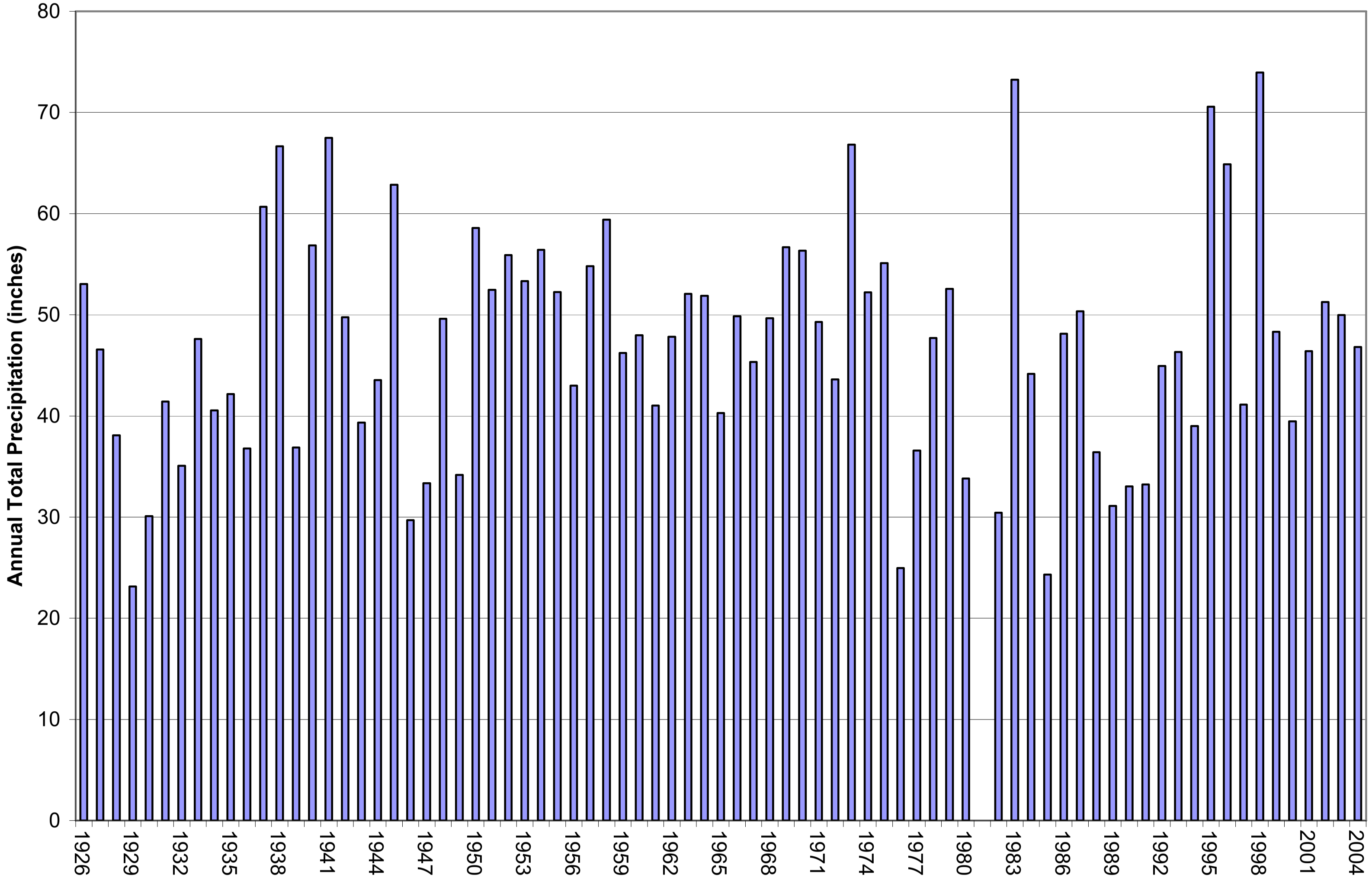
Station (ID#)	Latitude/ Longitude	Elevation (feet)	Data Used; Available Period of Record (may be missing values)
Grizzly Creek State Park (3647)	N 40° 29' W 123° 54'	410	Daily precipitation: 12/1/79 – 11/30/04 Daily snowfall: 12/1/79 - 11/30/04 Daily snow depth: 12/1/79 - 11/30/04 Daily min. & max. air temperatures: 12/1/79 - 11/30/04
Scotia (8045)	N 40° 29' W 124° 06'	140	Daily precipitation: 1/9/31 - 12/31/04 Daily snowfall: 1/9/31- 12/31/04 Daily snow depth: 1/8/31- 12/31/04 Daily min. & max. air temperatures: 1/9/31 - 12/31/04
Alderpoint (0088)	N 40° 11' W 123° 47'	460	Daily precipitation: 8/1/48 - 5/31/80 Daily snowfall: 8/1/48 - 5/31/80 Daily snow depth: 8/1/48 - 5/31/80 Daily min. & max. air temperatures: 8/1/48 - 5/31/80

Figure 3-4. Mean Monthly Precipitation at Several Climate Stations in the Vicinity of the Upper Eel WAU



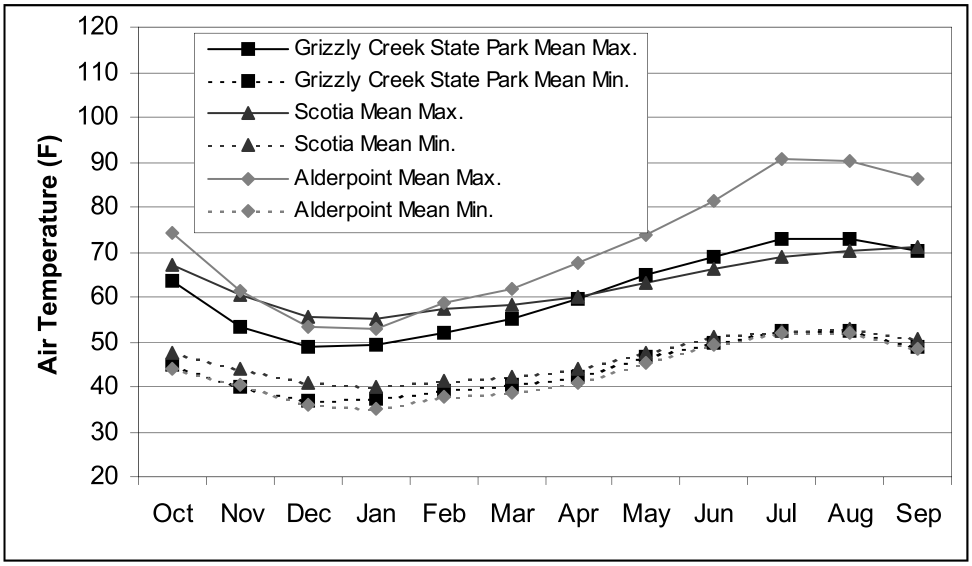
Air temperatures in the North Coast area are moderate and the annual fluctuation is one of the smallest in the conterminous United States (NOAA, 2000). Seasonal air temperature variation is small due to the close proximity to the Pacific Ocean. The prevailing northwest winds cross cold upwelling waters of the Pacific usually present along the Humboldt County coast. Mean minimum temperature in Scotia for the month of January is 40° F (Figure 3-6), and the coldest low temperatures in a typical winter are in the low 30s. Mean maximum temperatures in Scotia for the month of September is 71° F, while the highest temperatures are typically in the mid-70s. Inland locations (e.g., Grizzly State Park, Alderpoint) experience wider seasonal variation in air temperatures. Snow occurs only in the highest elevations of the WAU and is highly transient and variable from year to year. The snow pack has reached as much as 10 inches but for the most part is 0 or less than 2 inches (based on information from the Grizzly Creek State Park).

Figure 3-5. Annual Total Precipitation for Scotia, California (1926-2004)



Note: Missing data for 1981, 1982 (Jan to Sept), 1983 (March), and 1986 (April).

Figure 3-6. Mean Minimum and Maximum Monthly Air Temperatures in the Vicinity of the Upper Eel WAU



The dry season lasts from May through September. During the dry season, morning low clouds and fog are common, often clearing by early afternoon and returning by evening. Summer daily fog generally extends inland from the coast approximately 15 to 20 miles (Lewis et al. 2000). The transition from the fog zone to the drier, warmer inland climate occurs in the eastern portion of the Upper Eel WAU (Figure 3-1).

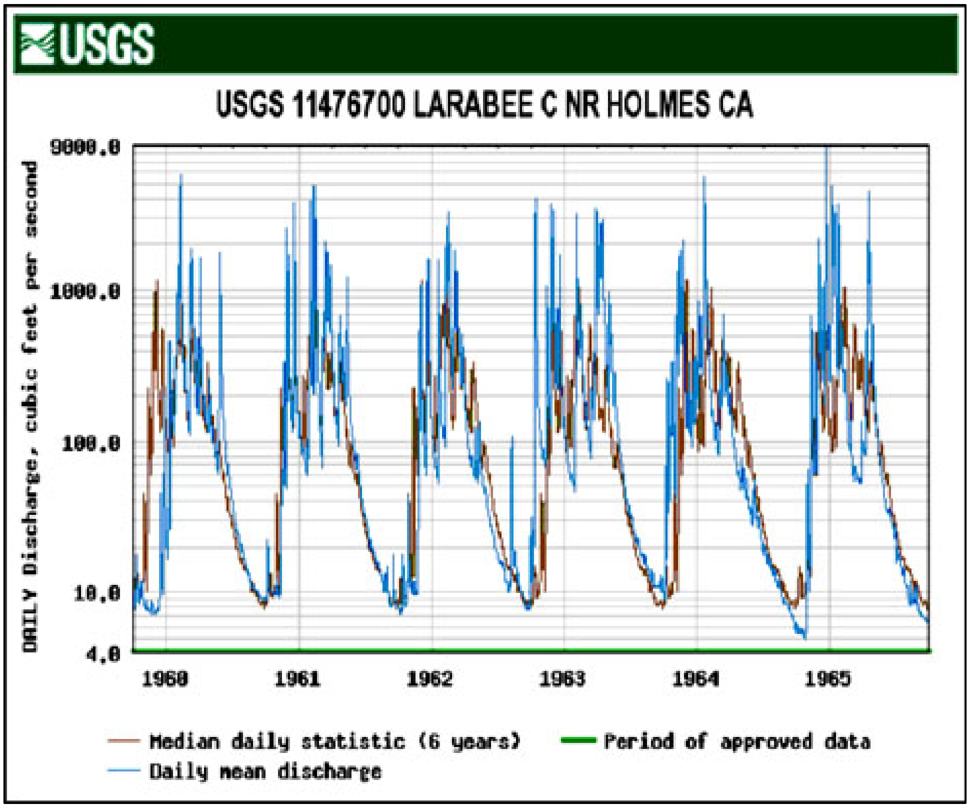
3.6.2 Hydrology

There is a wide range of basin size within the WAU. Portions of the South Fork and mainstem Eel River below their confluence within the WAU are large alluvial rivers with large basin areas that extend well upstream from the actual WAU boundaries. Larabee Creek flows into the mainstem Eel and is also a large alluvial river. These rivers are largely unregulated. However, there are two major dams located in the headwaters of the Eel River basin. The Cape Horn and Scott dams form the Van Arsdale Reservoir and Lake Pillsbury, respectively. These two dams, along with a 9,500-foot tunnel, form the backbone of the Potter Valley Project, which diverts water from the mainstem Eel River into the East Fork Russian River. The Potter Valley Project generates electricity and provides water for agricultural and municipal users in Mendocino and Sonoma counties. The Eel River from 100 yards downstream of Cape Horn Dam to the mouth at the Pacific Ocean is a federally designated Wild and Scenic River.

Though located far upstream, the Potter Valley Project may impact the Eel River within and downstream from the Upper Eel WAU. The Potter Valley Project has resulted in changes via diversions of water out of the Eel River basin and into the Russian River basin since the 1920s. This change in flow regime is not natural, yields less flow in the Eel River during average years, and possibly results in less flushing of sediments mobilized by storms coincident with reduced springtime flows. The summer and fall withdrawal periods may impact fish habitat the most, as flows in the Eel River are reduced to lower levels than normally would occur in these periods. The habitat impacts would be most pronounced near the diversion point, far upstream from the Upper Eel WAU, and would be less critical farther from the diversion. Therefore, impacts of the Potter Valley Project diversion on fish habitat in the Upper Eel WAU cannot be conclusively determined, although a low level of impact may be possible.

Streamflow has been monitored by the U.S. Geological Survey (USGS) at Scotia since 1910 (Station number 11477000). Streamflow in Larabee Creek was monitored briefly from 1960 to 1965 (Figure 3-7). Hydrology is summarized in terms of mean daily and mean monthly stream flow data, along with a summary of the flood history data for the area.

Figure 3-7. Daily streamflow record for Larabee Creek from 1959 to 1965



Mean Stream Flow. Mean daily stream flow records are available for three USGS gages in the vicinity of the analysis area (Table 3-8, Figure 3-8). Since the Upper Eel River WAU is located upstream of the Eel River at Scotia gage, it was used to assess seasonal runoff patterns for the area. Mean daily stream flow at the Eel River at Scotia gage ranges from 12 to 648,000 cubic feet per second (cfs) (0.004 to 208 cfs per square mile), with an average mean daily streamflow of 7,337 cfs (2.36 cfs per square mile). September has the lowest mean monthly stream flow at all locations (Figures 3-9 through 3-12).

Table 3-8. USGS Streamflow Gaging Stations Near the Upper Eel WAU

Station Name (USGS #)	Drainage Area (mi^2)	Daily Values Period of Record	Peak Flow Period of Record
Eel River at Scotia, CA (11477000)	3,113	10/01/1910 - 09/30/1914 10/01/1916 - 09/30/2004	WY1911- WY2003
Eel River at Fort Seward, CA (11475000)	2,107	9/01/1955 - 09/30/2004	WY1955 - WY2003
Larabee Creek Near Holmes, CA (11476700)	84.1	10/01/1959 - 09/30/1965	WY1960 - WY1965

Notes: Base discharges (the discharge above which partial peak flows are recorded) are 72,000 cfs for the Eel River at Scotia and 41,000 cfs for the Eel River at Fort Seward.

Figure 3-8. USGS Streamflow Gaging Stations in the Vicinity of the Upper Eel WAU

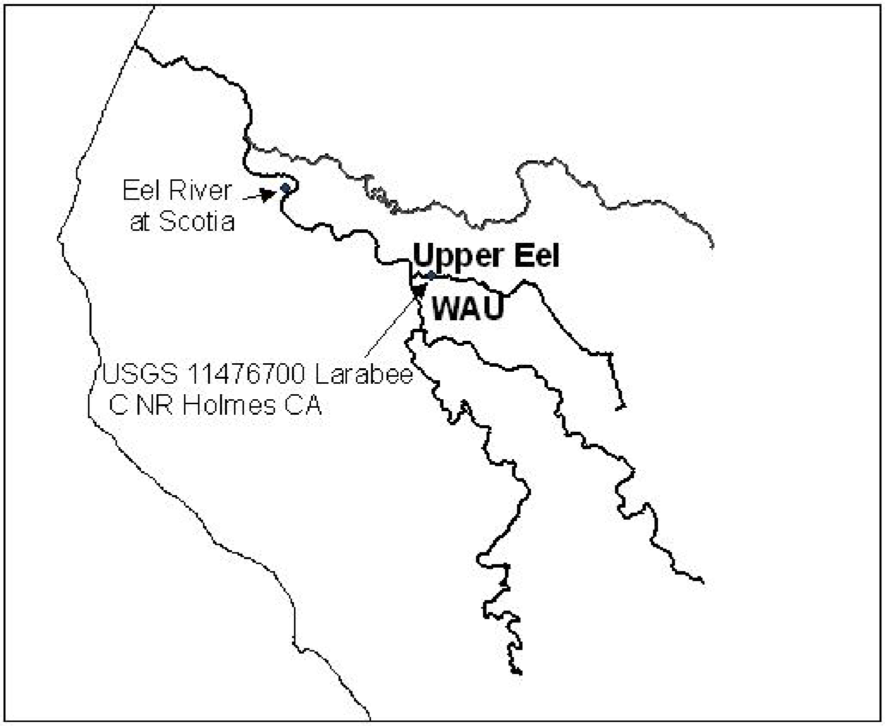


Figure 3-9. Mean Monthly Discharge for the Eel River at Scotia Gaging Station (1910-2004)

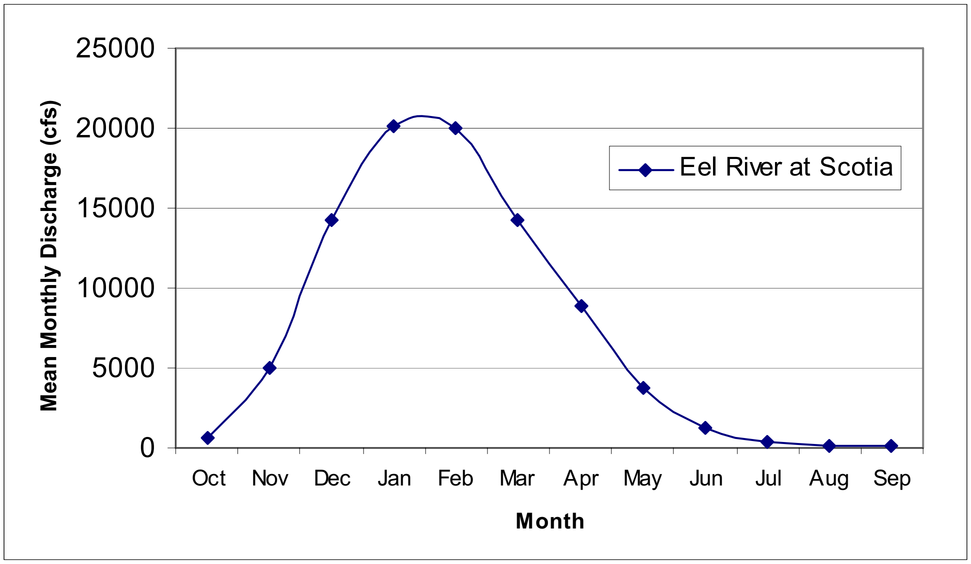


Figure 3-10. Mean Monthly Discharge for the Larabee Creek Gaging Station (1960-1965)

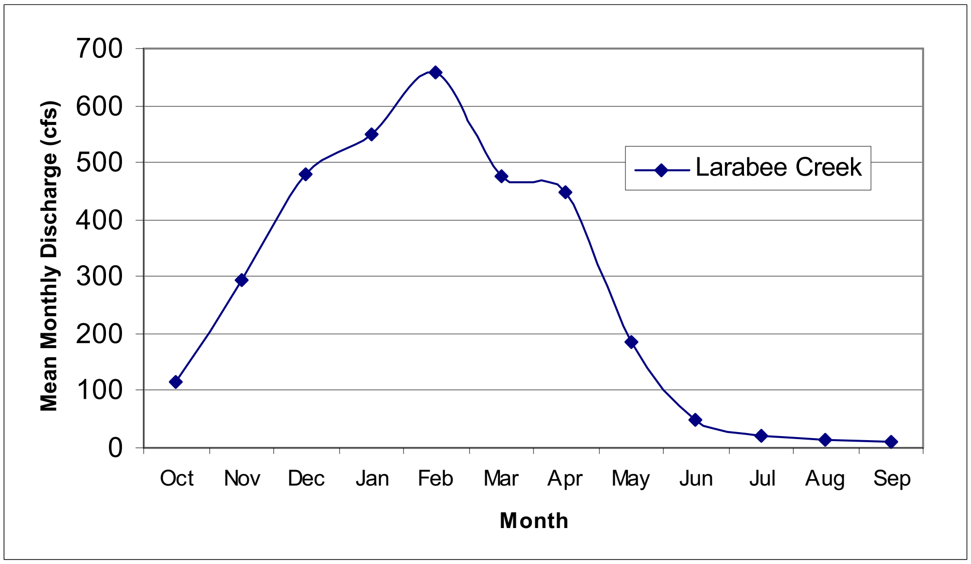


Figure 3-11. Mean September Discharge for the Eel River at Scotia Gaging Station over the Period of Record (1910-2004)

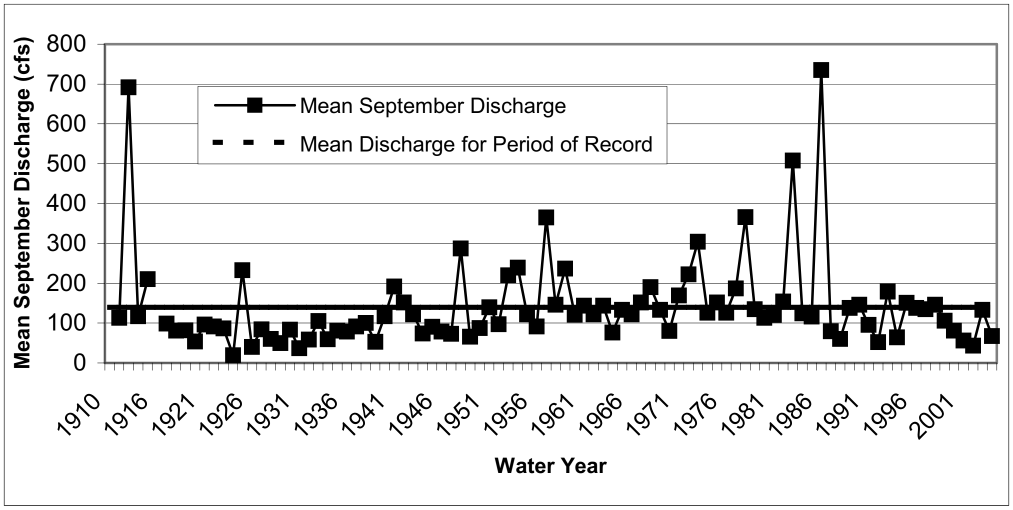
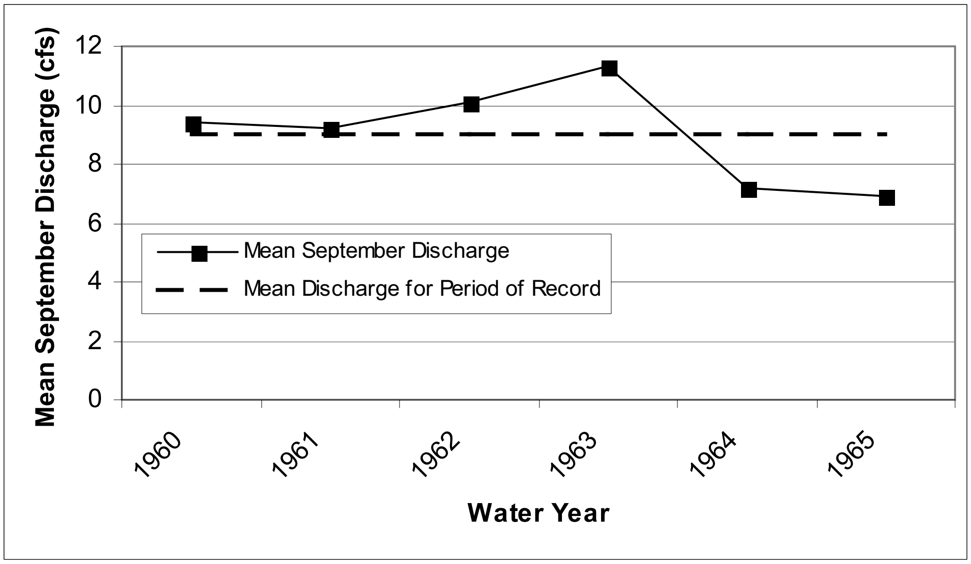


Figure 3-12. Mean September Discharge for the Larabee Creek Gaging Station over the Period of Record (1960-1965)



Flood History. A review of the flood history for streams in the Upper Eel WAU can provide an understanding of the role of flooding as a disturbance mechanism in floodplain areas. Also, periods of prolonged rainfall that may have caused increased landslides and other upland disturbances can be distinguished based on a review of the flood history. Section 4.2 of the PALCO methodology (PALCO, 2000) provides techniques for evaluating the flood history of a watershed. The primary reasons for investigating flood history are:

- Provide context for the Stream Channel, Riparian Function, and Mass Wasting analysts to interpret historical disturbances.
- Evaluate linkages between historic flooding and climatic conditions that will provide context for interpreting changes in flood peaks assessed in the following sections.
- Evaluate which processes (e.g., rain, rain on snow) are the dominant producers of peak flows in the watershed.

Annual peak flow data for the Eel River at Scotia gaging station is shown in Figure 3-13 and is summarized for this watershed analysis. Peak flows from Larabee Creek are not analyzed due to the short duration of the record but the peak flow data are shown in Figure 3-14. Annual peaks in the Eel River are listed chronologically in Table 3-9. The largest event recorded was 752,000 cfs on December 23, 1964, commonly referred to as the 1964 flood (actually occurred in water year 1965). Coincidentally, the top five annual peaks were each recorded approximately a decade apart between the mid-1950s to the mid-1990s. The lowest annual peak (5,790 cfs) was observed during the region-wide drought year of 1977 when virtually no rain occurred for an 18-month period.

Figure 3-13. Annual Peak Flows for the Eel River at Scotia Gaging Station (1910-2004)

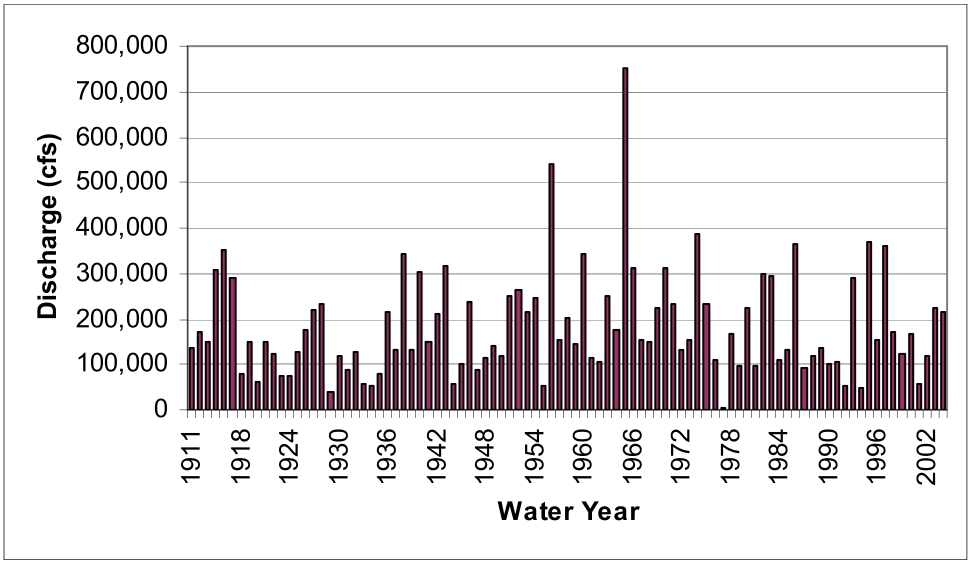


Figure 3-14. Annual Peak Flows for the Larabee Creek Gaging Station (1960-1965)

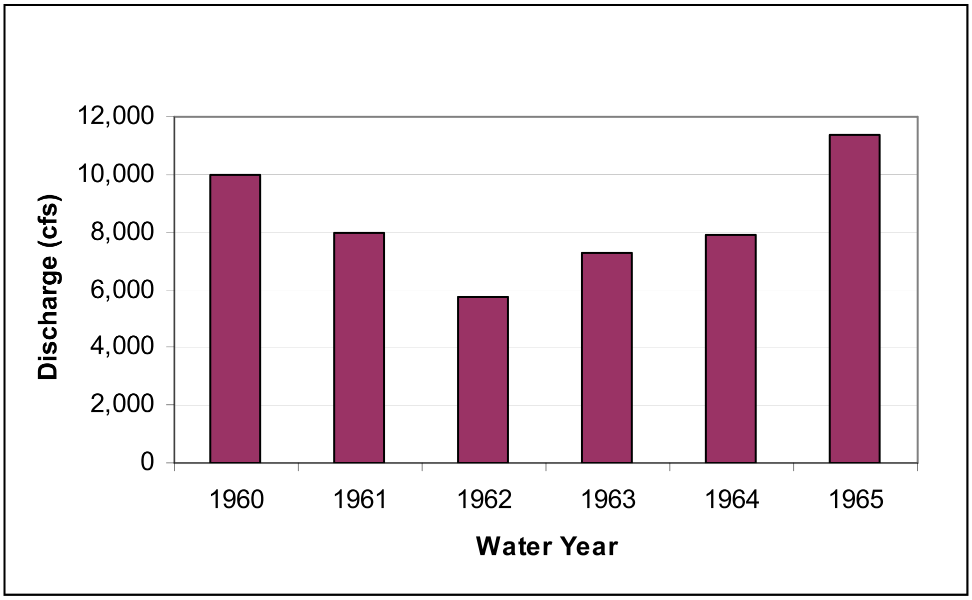


Table 3-9. Flood History of the Eel River at Scotia Gaging Station

(Annual Peaks Listed Chronologically)
Annual* Peak

Date	Water Year	Peak Discharge (cfs)	Peak Rank**
1/20/1911	1911	136,000	54
1/26/1912	1912	170,000	38
1/18/1913	1913	150,000	46
1/22/1914	1914	309,000	13
2/2/1915	1915	351,000	7
2/25/1917	1917	292,000	17
2/7/1918	1918	78,600	81
1/17/1919	1919	149,000	48
4/16/1920	1920	62,000	84
11/19/1920	1921	148,000	49
2/19/1922	1922	123,000	62
12/28/1922	1923	73,400	83
2/8/1924	1924	73,400	82
2/6/1925	1925	127,000	60
2/4/1926	1926	176,000	37
2/21/1927	1927	221,000	30
3/27/1928	1928	233,000	25
2/4/1929	1929	41,000	92
12/15/1929	1930	120,000	63
1/23/1931	1931	87,000	78
12/27/1931	1932	127,000	59
3/17/1933	1933	58,100	86
3/29/1934	1934	50,900	90
4/8/1935	1935	79,900	80
1/16/1936	1936	216,000	32
2/5/1937	1937	134,000	55
12/11/1937	1938	345,000	8
12/3/1938	1939	133,000	56
2/28/1940	1940	305,000	14
12/24/1940	1941	150,000	47
2/6/1942	1942	209,000	34
1/21/1943	1943	315,000	10
3/4/1944	1944	57,800	87
2/3/1945	1945	99,100	74
12/27/1945	1946	239,000	23
2/12/1947	1947	86,100	79
1/8/1948	1948	114,000	67
3/18/1949	1949	140,000	52

Table 3-9. Flood History of the Eel River at Scotia Gaging Station

(Annual Peaks Listed Chronologically)

Annual* Peak

Date	Water Year	Peak Discharge (cfs)	Peak Rank**
1/18/1950	1950	117,000	66
1/22/1951	1951	249,000	21
12/27/1951	1952	262,000	19
1/9/1953	1953	215,000	33
1/17/1954	1954	245,000	22
12/31/1954	1955	52,400	89
12/22/1955	1956	541,000	2
2/25/1957	1957	153,000	44
2/25/1958	1958	202,000	35
1/12/1959	1959	145,000	51
2/8/1960	1960	343,000	9
2/11/1961	1961	113,000	68
2/14/1962	1962	107,000	71
2/1/1963	1963	252,000	20
1/21/1964	1964	178,000	36
12/23/1964	1965	752,000	1
1/5/1966	1966	311,000	11
12/5/1966	1967	154,000	43
1/15/1968	1968	148,000	50
1/13/1969	1969	223,000	29
1/24/1970	1970	310,000	12
12/4/1970	1971	234,000	24
1/23/1972	1972	133,000	58
1/16/1973	1973	152,000	45
1/16/1974	1974	387,000	3
3/18/1975	1975	231,000	26
2/26/1976	1976	109,000	70
3/10/1977	1977***	5,790***	93***
1/17/1978	1978	169,000	40
1/11/1979	1979	96,100	76
1/14/1980	1980	226,000	28
1/28/1981	1981	98,700	75
12/20/1981	1982	300,000	15
1/27/1983	1983	296,000	16
12/9/1983	1984	112,000	69
11/12/1984	1985	133,000	57
2/17/1986	1986	364,000	5
3/13/1987	1987	94,500	77
12/10/1987	1988	118,000	65

Table 3-9. Flood History of the Eel River at Scotia Gaging Station

(Annual Peaks Listed Chronologically)

		Annual* Peak	
Date	**Water Year**	**Peak Discharge (cfs)**	**Peak Rank****
11/23/1988	1989	137,000	53
1/8/1990	1990	102,000	73
3/5/1991	1991	105,000	72
2/20/1992	1992	54,200	88
1/21/1993	1993	290,000	18
1/24/1994	1994	48,500	91
1/9/1995	1995	368,000	4
12/12/1995	1996	155,000	42
1/1/1997	1997	360,000	6
1/17/1998	1998	170,000	39
2/8/1999	1999	125,000	61
2/14/2000	2000	166,000	41
3/5/2001	2001	59,000	85
1/2/2002	2002	119,000	64
12/16/2002	2003	226,000	27
2/18/2004	2004	217,000	31

*Annual = largest event in that water year

**Relative size ranking out of the 93 events that occurred over the period of record

*** Statistical Outlier, not used in calculations

A flood frequency analysis was performed on the annual peak discharge data for the Eel River at Scotia Gaging Station. A log-Pearson Type III distribution with a regional skew coefficient of -0.3 was used to develop a frequency distribution for the gage using all data collected since 1910 with the exception of 1977 (see Table 3-10). The peak discharge from the 1964 flood of 752,000 cfs was estimated at nearly the 500-year event. The next three large peaks recorded in 1956, 1974, and 1995 water years were approaching the 100-year, 20-year, and 20-year events, respectively.

Table 3-10. Flood Frequency Analysis Results

Return Period	Probability	Eel River at Scotia, CA Gage	
		1911-2004 (cfs)	1911-2004 (cfs/mi^2)*
1.01	0.990	38,700	12
1.25	0.800	95,900	31
2	0.500	157,000	50
5	0.200	254,000	82
10	0.100	325,000	104
20	0.050	398,000	128
50	0.020	497,000	160
100	0.010	575,000	185
200	0.005	657,000	211
500	0.002	771,000	248
Mean Annual Peak		184,855	59

*Drainage area of 3,113 square miles

3.7 AQUATIC ECOLOGY

Aquatic resources in the Upper Eel WAU, with focus on the HCP area of the WAU, are summarized in the following discussion. Fish species and distribution are summarized, followed by species and distribution of amphibians and reptiles.

3.7.1 Fish Species and Distribution

The Upper Eel WAU currently and historically supported Chinook salmon (*Oncorhynchus tshawytscha*), coho salmon (*O. kisutch*), and steelhead trout (*O. mykiss*) (Map E-2). Resident rainbow trout also occur within the HCP area of the Upper Eel WAU, inhabiting reaches upstream of anadromous salmonid barriers.

Steelhead

Steelhead are the most abundant anadromous salmonid species within the Eel River watershed. They utilize habitats in the upper reaches of most large tributaries but can also be found in many smaller tributaries with steeper gradients than typically utilized by other anadromous salmonids (unless barriers preclude their upstream migration). Two distinct runs of steelhead exist in the Eel River watershed, winter run fish and summer run fish. There is also a resident population. Winter steelhead typically enter the Eel River in the mid-fall and spawn in the winter and early spring. Summer steelhead typically enter freshwater in the spring and hold in deep (6 to 20 feet), thermally stratified pools throughout the summer while waiting to spawn in the fall. Juvenile steelhead tend to rear in freshwater for two to three years and migrate downstream to the estuaries and ocean in the spring. A smaller downstream juvenile migration occurs in the fall after water temperatures cool (Halligan 1999). Both runs belong to the northern California Evolutionarily Significant Unit (ESU). Of the two runs, winter-run steelhead are more widespread and numerous.

The Pacific States Marine Fisheries Commission (PSMFC) and the U.S. Fish and Wildlife Service (USFWS) reported that time-series data of winter steelhead in the upper Eel River at Cape Horn Dam show a decline from a maximum of 9,528 in 1944/45 to 102 in 2002/03 (combined wild and hatchery) (PSMFC and USFWS, 2004). However, these counts do not include any populations that may occur downstream, such as those in the Upper Eel WAU. In 1965, the California Department of Fish and Game (CDFG) estimated the winter-run steelhead population in the entire Eel River watershed at 10,000 individuals. Between 1957 and 1994, there were approximately 982,000 juvenile steelhead released into the Eel River between Cock Robin Island and Van Arsdale Dam. Most of these fish were cultured at the Mad River Hatchery.

Chinook

Chinook salmon populations were historically very abundant in the Eel River watershed. The CDFG (1965) estimated an escapement of 55,000 fish in the Eel River. Recent fish counts for the Eel River basin are few. Records of fish counts at Benbow Dam from the 1930s indicate that there were approximately 20,000 Chinook salmon. Wahle and Pearson (1987) estimated an abundance of 17,000 Chinook in the Eel River. An estimated few thousand adult Chinook were observed in the Singley pool (below Fernbridge) in the fall of 2003 (Halligan, unpublished observation). No population estimates are available specific to streams within the Upper Eel WAU.

There have been repeated efforts to artificially increase the Chinook runs in the Eel River beginning in 1897 in response to depletion of commercially viable in-river stock. At that time, the California Fish Commissioners built two hatcheries and four egg-taking stations on the Eel River, one of them in 1897 on Price Creek, just upriver from Grizzly Bluff. Ironically, the Price Creek hatchery had to import four million Sacramento River salmon eggs when it opened, because fishermen would not let enough fish get past their nets on the lower river to reproduce native stocks (Lufkin 1996). This supplemental source of eggs for Eel River hatcheries "dried up" by 1920, when Sacramento River stocks also became depleted. Chinook stocking continued from 1972 to 1994, with 24 releases totaling 2,869,782 juveniles (Myers et al. 1998). Of these, 625,853 juveniles were inter-basin transfers from Iron Gate Hatchery, which is outside the ESU.

Coho

Data indicate that coho salmon did not historically represent a large portion of the salmonid population in the Eel River watershed. In the Eel River system, coho formerly ascended 390 kilometers (km; 246 mi.) of stream in 69 tributaries (Mills 1983) of the South Fork Eel, the lower mainstem Eel River, and the Van Duzen River (Brown 1987).

Annual runs in the Eel River system in earlier years have been estimated at over 40,000 fish (U.S. Heritage Conservation and Recreation Service 1980). Records of fish counts at Benbow Dam from the 1930s indicate that there were approximately 15,000-17,000 coho salmon annually returning to this portion of the South Fork Eel River. A severe downturn trend in the number of anadromous fish can be seen in records of the Benbow Dam fish counts conducted by the CDFG from 1938 to 1975. They show a significant decline in salmonid stocks to approximately 20 percent of the numbers counted in the 1930s. It is currently estimated that about 1,000 adult coho salmon still return annually to the South Fork Eel River watershed (Figure 3-15). Coho salmon also return to the headwaters of the Eel River with runs entering Outlet Creek and Long Valley Creek. Limited coho salmon supplementation also occurred in the Eel River. The only record found reported that 5,957 coho fry (weight 259/pound) were stocked in the Redcrest area.

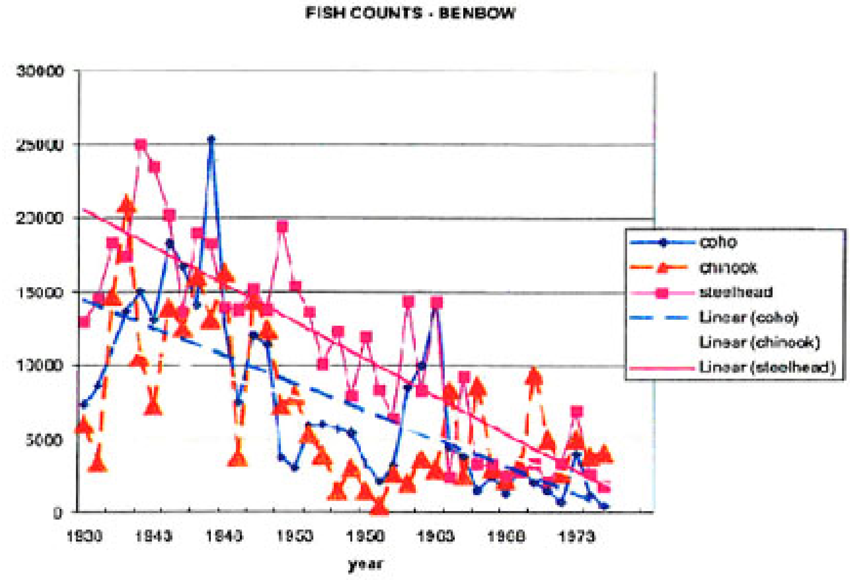


Figure 3-15. CDFG fish count records at Benbow on the South Fork Eel River from 1938 to 1974

Source: South Fork Eel River TMDL, USEPA, 1999.

Coho salmon have been observed in the Upper Eel WAU. One coho female carcass was observed by the California Conservation Corps in Elk Creek in 1987. Coho were observed in the lower half-mile of Newman Creek by the CDFG in 1963. Juvenile coho salmon were identified in Poison Oak Creek in

2005 during electrofishing surveys to identify the upstream extent of fish use in the WAU. It is possible that they inhabit the downstream reaches of other creeks in the WAU, but other information was available for this species in the WAU.

All of the anadromous salmonids found in the watershed occur primarily or exclusively in the low gradient response reaches of the mainstem and tributary systems. Resident species are found primarily in the steeper transport reaches in the mainstem and tributaries.

In addition to the salmonid species, the Eel River watershed also contains numerous non-salmonid fish species. Native resident fish include the Pacific lamprey (*Lampetra tridentata*), brook lamprey (*Lampetra pacifica*), prickly sculpin (*Cottus asper*), coast range sculpin (*C. aleuticus*), Sacramento sucker (*Catostomas occidentalis*), and the three-spine stickleback (*Gasterosteous aculeatus*). Non-native fish species introduced into the Eel River watershed include American shad (*Alosa sapidissima*), California roach (*Lavinia ssymmetricus*), speckled dace (*Rhinichthys osculus*), brown bullhead (*Ictalurus nebulosus*), largemouth bass (*Micropterus salmoides*), Sacramento pikeminnow (*Ptychocheilus grandis*), and green sunfish (*Lepomis cyanellus*). The Sacramento pikeminnow is a predatory threat to all salmonid species of concern where they are co-located.

3.7.2 Amphibians and Reptiles Species and Distribution

The five amphibian and reptile HCP species of concern occur in the Upper Eel WAU. These species include: Southern torrent salamander (*Rhyacotriton variegatus*); Tailed frog (*Ascaphus truei*); Northern red-legged frog (*Rana aurora aurora*); Foothill yellow-legged frog (*Rana boylii*); and Northwestern pond turtle (*Emys marmorata marmorata*). Existing habitat and potential habitat was documented for the headwater species and lowland species; headwater species include the southern torrent salamander and tailed frog, and lowland species include the red-legged frog, yellow-legged frog, and the northwestern pond turtle. Streams and riparian zones have had varying amounts of recovery time since initial harvest impacted watersheds adversely, but all appear to be in an improving condition with implementation of modern forest management governed by the California Forest Practice Rules. Factors contributing to the generally good habitat conditions include: primarily consolidated geologic types, high gradient transport reach streams with gravel and cobble substrates and cool water, relatively high canopy closure in upland areas, in-stream pool habitat in lowland areas, and pond habitat.

3.8 FOREST ECOLOGY

Forest types generally range from redwood (*Sequoia sempervirens)* forest in the western portions of the Upper Eel WAU to Douglas fir (*Pseudotsuga menziesii*) forest in the eastern, drier portions of the WAU (primarily in the Boulder Creek, No Name Creek Complex, and Mill Creek sub-basins). Hardwood stands, along with other conifer species, occur in isolated areas of the Upper Eel WAU.

3.8.1 Historic Vegetation

Available soil moisture and cool, moist climatic conditions have influenced the distribution of vegetation in the western portions of the Upper Eel WAU. The western half of the WAU is located within the coastal fog belt. This location has higher levels of available soil moisture and cool, damp climatic conditions. These forests tend to be dominated by redwood. The soils are relatively deep and well drained with high available water holding capacity. Flood deposits in alluvial floodplains and terraces further enhance the growth of redwood stands along the Eel River and lower Larabee Creek. Included in the WAU are the old growth redwood forests still found in Humboldt Redwoods State Park on the terrace topography bordering the South Fork Eel River and the western banks of the mainstem Eel River, from its confluence with the South Fork downstream to near the mouth of Larabee Creek. These predominantly redwood stands in the park reach heights of 360 feet (110 meters [m]) in the Park's more sheltered, inland alluvial terraces, especially in Bull Creek (Sawyer et al., 2000).

In contrast, the vegetation in the eastern portions of the Upper Eel WAU is, and has historically been, influenced by the drier, inland climate and Franciscan mélange, bedrock material that weathers to soil with a high clay content and poor drainage. As a result, seedling establishment of conifers, such as redwood or Douglas fir, is more difficult. Historically, redwood was found only in ravines or was entirely absent from this portion of the WAU. Grassland and oak woodland were the dominant vegetation types with stands of interspersed white oak (*Quercus alba*) and Douglas fir. Tan oak (*Lithocarpus densiflora*) grew in areas with higher soil moisture such as low-slope zones. Understory herbaceous plants included sword fern (*Polystichium munitum),* chain fern (*Woodwardia fimbriata*), evergreen huckleberry (*Vaccimium ovatum*), red huckleberry (*Vacinium parviloium*), and poison oak (*Toxicodendron diversilobum*).

3.8.2 Current Vegetation

Currently, the native riparian forests of the Upper Eel WAU are dominated by stands of coastal mixed conifer, including redwood and/or Douglas fir. Many stands have a mixture of both. Hardwood species including tanoak, Pacific madrone (*Arbutus menziesii*), California bay-laurel (*Umbellularia californica*), red alder (*Alnus rubra*), and big-leaf maple (*Acer macrophyllum*) are also commonly found in the riparian areas at varying levels. Understory herbaceous plants include sword fern, chain fern, evergreen huckleberry, red huckleberry, and poison oak.

Redwood transitions to Douglas fir and mixed Douglas fir/hardwood inland at a location consistent with the persistent location of the edge of the fog belt. This transition is marked by a warmer and drier inland climate and an increase in Franciscan bedrock material that weathers to soil with a high clay content and poor drainage, favoring Douglas fir and hardwoods over redwood**.** The eastern portion of the WAU falls in this zone.

3.8.3 The Role of Fire

In general, the pre-settlement composition and structure of forests in the watershed were greatly influenced by fire, with fire being the primary natural disturbance regime in the Eel River watershed, including the Upper Eel WAU (Downie et al., 1995). Important differences exist between the fire regimes of redwood and Douglas fir/hardwood, which changes the frequency, role, and nature of fire throughout the WAU. Redwood forests are generally able to resist effects of most but the most intense wildfires (Agee, 1993); most fires are low and moderate severity with local effect. Windthrow generally contributes to redwood losses more than fire. Douglas fir/hardwood forests are drier and subject to lightning occurrence, which is a common ignition source for these forests. Effects of fire in the dryer Douglas fir/hardwood forests can be severe and widespread, although a range of severity is typical for these forests (Agee, 1993).

Pre-European peoples also regularly burned of portions of the watershed resulting in significant disturbance to the landscape. These initial fire patterns were altered with historic and contemporary management of lands for timber production and grazing with the advent of European settlement. For the past 50 to 100 years, fire suppression has largely replaced previous large-scale burning. Both regular large-scale burning and fire suppression have impacted native species of wildlife and vegetation.

Fire records have been maintained for lands in the Upper Eel WAU since the 1950s (California Department of Forestry and Fire Protection [CDF], 2006). Most of the natural fires in this recent period of record occurred in the 1950s, and all of them initiated from lightning strikes. During the 1950s, two major fires (Pacific Lumber Co. #7 and T.P.L. #4) occurred in the Upper Eel WAU covering 550 and 1200 acres of the Kapple Creek Complex and Newman Creek sub-basins. Also, in the 1950s, several fires smaller than 125 acres occurred in the Thompson Creek, Boulder Creek, and Ohman Creek sub-basins. Then, in 1970, a major fire (Camp Grant) occurred in the Bridge Creek, Decker Creek, McCann Creek Complex, and Poison Oak Creek Complex sub-basins, covering a total of 2400 acres. Since 1970, no new natural fires have been recorded for PALCO HCP lands in the Upper Eel WAU.

Burning is conducted regularly as part of management for timber production. However, under present-day management, burning is limited to broadcast or pile burning on only a portion the units harvested and hardly qualifies as a disturbance considering its scale during pre-European history.

4.0 LAND USE

This section presents a summary of land use in the Upper Eel WAU, as well as a description of prehistoric land use, forest management from the early days of human settlement through initial harvest of the early 1900s, and recent harvest and road construction.

Land use in the WAU includes commercial timber production on PALCO-owned lands, and grazing of rangelands on lands not owned by PALCO. Recreational use includes a portion of Humboldt Redwoods State Park is located in the southwest area of the WAU. There is little residential or commercial use of land within the WAU. Private landowners and residences are located along the Eel River mainstem and in the valley floor near the mouth of Larabee Creek. Distribution of major land cover within PALCO HCP lands in the Upper Eel WAU is illustrated in Figure 4-1 and listed in Table 4-1.

4.1 PREHISTORIC

Athabascan family southern groups inhabited portions of the WAU area. Of these groups, the most likely inhabitants in the Upper Eel WAU area included the Mattole, Nongatl, and Lassik tribes. All of these tribes experienced a significant decline in population as European settlement increased (Kroeber, 1976). The Mattole were a small Athabascan tribe with some villages along the Eel River. The primary areas of inhabitation by the Nongatl tribe included the Larabee Creek, Yager Creek, and Van Duzen River drainages; a tribal settlement was located at the mouth of Smith Creek at its confluence with Larabee Creek. The Lassik tribe inhabited the Eel River upstream of the confluence with the South Fork Eel River, along with other areas to the east (Kroeber, 1976).

One important characteristic shared by these tribes was their seasonal land use pattern. In the winter they settled near streams where salmon were plentiful. In the summer they settled in the hillside and ridge areas where seeds, acorns, small game, deer, and elk were nearby (Kroeber, 1976). In these summer use areas, they would hunt deer and elk by lengthy pursuit until the animals would tire or, in some cases, would be captured in corrals constructed with bark and logs.

Of these tribes, the Lassik tribe was more dependent on hunting and fishing than other tribes in the area, although acorns were their main food of choice (Malinowski et al., 1998). The Lassiks practiced controlled burning to clear brush in upland areas. This burning management practice stimulated growth of edible vegetation, opened up the prairie land areas for improved hunting and travel, and reduced the rattlesnake population.

Figure 4-1. Timber Stand Type and Age Classes (as of 2005) for HCP Area of the Upper Eel WAU

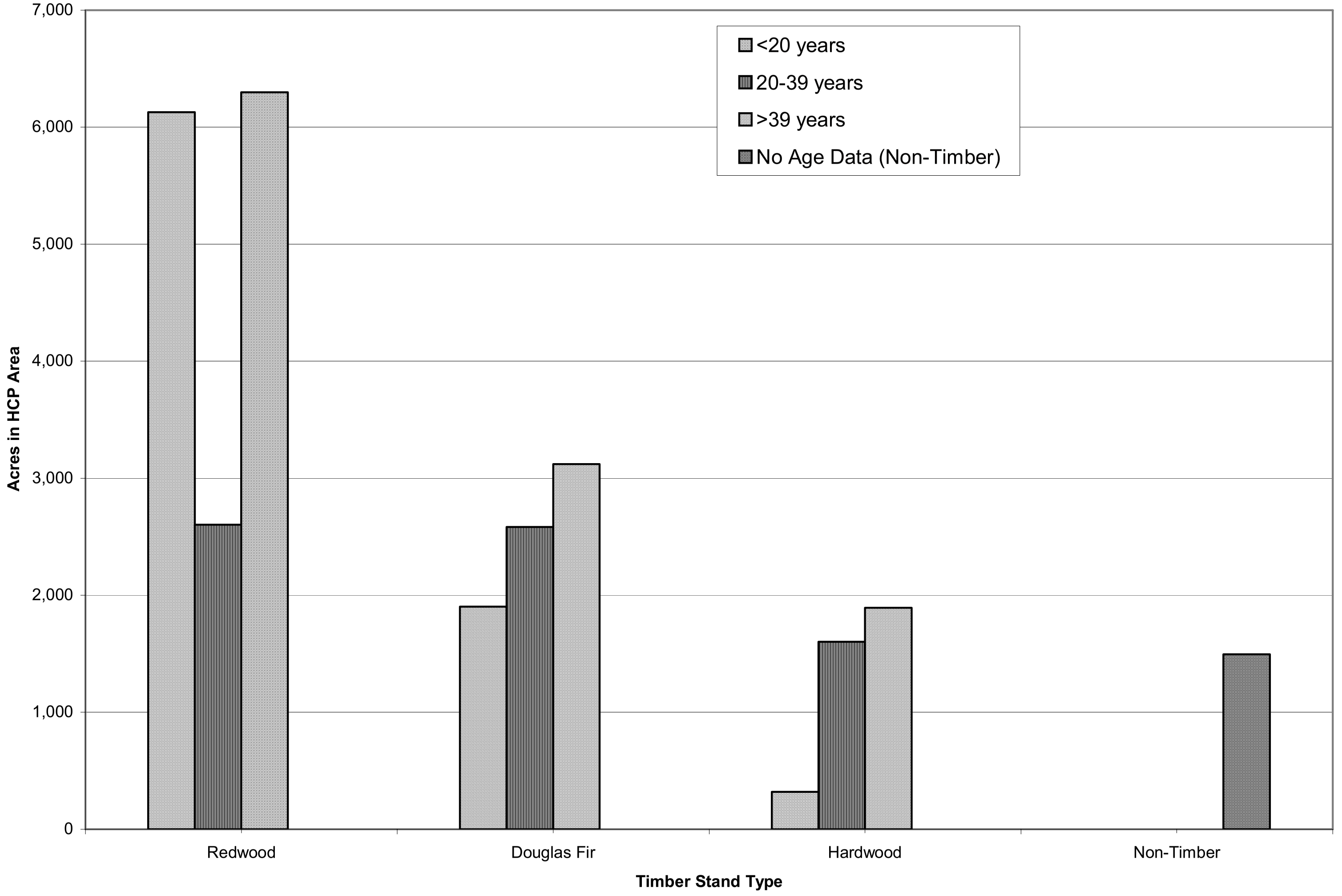


Table 4-1. Timber Stand Type and Age (as of 2005) in HCP Area

	Redwood (acres)			Douglas Fir (acres)			Hardwood (acres)				
Sub-Basin	<20 years	20-39 years	>39 years	<20 years	20-39 years	>39 years	<20 years	20-39 years	>39 years	Non-Timber (no age)	Total Acres
Balcom Creek Complex	794	2	354	3	-	38	-	-	1	2	**1,193**
Boulder Creek	38	-	-	224	242	114	-	253	219	16	**1,105**
Bridge Creek	-	143	-	-	129	-	-	87	5	13	**377**
Cameron Creek	47	10	28	116	-	83	33	-	122	57	**496**
Carson Creek Complex	811	25	1,017	26	6	7	16	20	48	18	**1,993**
Chris Creek	480	21	471	-	-	-	-	-	-	2	**974**
Decker Creek	76	165	40	-	-	-	-	-	6	15	**301**
Elk Creek	43	12	172	49	30	86	69	16	297	8	**781**
Kapple Creek Complex	483	87	666	-	-	108	-	22	41	144	**1,550**
Main Stem Larabee I	461	-	502	70	161	189	72	77	27	232	**1,791**
Main Stem Larabee II	-	-	-	29	11	195	-	27	-	-	**262**
McCann Creek Complex	28	788	588	-	328	7	-	187	286	108	**2,321**
Mid Larabee Creek Complex	257	13	57	91	746	277	14	143	32	12	**1,642**
Mill Creek	-	-	-	336	88	295	52	157	24	25	**978**
Newman Creek	784	6	600	50	25	107	17	78	36	176	**1,878**
No Name Creek Complex	-	-	-	561	245	722	9	139	63	33	**1,773**
Ohman Creek	-	-	-	3	3	61	-	-	71	14	**152**
Poison Oak Creek Complex	493	845	590	50	129	52	15	65	327	146	**2,713**
Scott Creek Complex	794	47	403	63	392	143	-	62	8	7	**1,919**
Smith Creek	336	-	461	96	-	230	17	7	113	122	**1,381**
Thompson Creek	203	441	317	134	49	408	4	263	168	347	**2,333**
Totals for HCP Area	**6,128**	**2,602**	**6,266**	**1,902**	**2,583**	**3,121**	**319**	**1,603**	**1,893**	**1,495**	**27,913**

After settlement by ranchers, the lower Larabee Creek area was burned repeatedly for grazing cattle for meat and also as work animals. This burning was also intended to facilitate deer hunting and improve wildlife habitat. During the early years of non-native settlement, Camp Grant on the mainstem Eel was manned as a military camp during the Indian Wars.

4.2 POST-EUROPEAN SETTLEMENT

Post-European type settlement of the region began in the 1850s when the first settlers came to the region from other parts of America and the world. The first 100 years of their activity had significant effects on the forests, rivers, and fish populations of the region and within the WAU.

Canneries were historically located along the Eel River, likely affecting fish populations in tributaries and the mainstem because of effects of these facilities on water quality and fishing pressures. During the 1860s to 1900s it was common to have a commercial salmon catch numbering in the hundreds of thousands of fish in the lower Eel River. In 1904, 345,800 salmon and steelhead were taken by fishing in the lower portions of the river (Lufkin 1996). In 1922, gillnetting for salmon on the Eel River was declared illegal by the State legislature.

Early timber extraction in the Upper Eel, in the late 19th century, began with ranchers hiring loggers to clear small parcels of land to provide additional grazing and agricultural land; few landowners made use of the timber resources on their lands because the tools/machinery and lack of transport infrastructure made timber extraction prohibitively expensive. Early timber company operations attempted to convert natural timber lands to grazing lands, with little success because the landscape and climate favored the natural vegetation regime. Only when accessibility was well established in the 1900s to 1910s did large-scale timber operations in the lower portions of the area develop to a significant extent.

There were no special provisions guiding management activities around streams until the adoption of the first set of Forest Practice Regulations in the 1970s. Until this time, forests were typically clearcut to the water’s edge. Yarding logs to landings was done with donkey skidder cableways or with oxen. Steam donkey and early tractor roads tended to use watercourse channels and draws as skid trails for dragging logs to landings. The use of log trucks and ground-based tractor yarding began in the 1940s and initiated a period of extensive road building and skid trail use. Railroad and early truck haul routes were commonly located near, or sometimes even within the stream channels.

The combination of the early railroad and pre-1970s logging practices had a profound impact on the watercourses of the Upper Eel WAU. Since implementation of Z’berg-Nejedly Forest Practice Act of 1973, protection for riparian areas has been incorporated into timber harvest operations. The protection has generally taken the form of a variable distance Watercourse and Lake Protection Zone (WLPZ) adjacent to streams supporting aquatic life, within which ground disturbance is minimized and timber removal is limited to uneven-aged (selective harvest) silvicultural regimes. The width of these zones and retention standards prescribed within, have increased over time so that areas harvested adjacent to streams in the 1970s and 1980s generally have less residual conifer canopy cover today as compared with areas harvested in the 1990s. For PALCO lands, additional reductions in impacts occurred with implementation of the HCP in 1999.

4.2.1 Spatial Distribution of Initial Harvest

Initial harvest generally proceeded from floodplain areas of mainstem creeks, followed by harvest up tributaries closest to the mainstem Eel River and Larabee Creek. First harvest then focused on upper, headwater areas of the drainages. Generally, in the Larabee Creek watershed, initial harvest progressed in an easterly direction away from the Eel River. The Mass Wasting Assessment Maps A-4 through A-9 also show areas of harvest, with time, according to the aerial photograph record for the Upper Eel WAU. Figure 4-2 illustrates the rate (percent of total) of first cut harvest on HCP lands from the 1890s to present. Acreages of first harvest, by decade, are summarized in Table 4-2.

The earliest first entry, in the 1900s and 1910s, occurred in the Lower Larabee Creek and the Poison Oak Creek planning watersheds. These areas were logged first because they were the most easily accessed as large-scale timber operations progressed upstream from established mills. Also, these areas typically had larger timber of greater value than areas upstream. More than 60 percent of the Lower Larabee Creek area, including significant portions of the Chris, Carson, Smith, Balcom, Dauphiny, Scott, and Arnold Creek drainages, was logged by the end of the 1920s; by the end of the 1930s more than 45 percent of the Poison Oak Creek area, tributary to the mainstem Eel, also was logged.

During most of the 1930s and 1940s, little first entry harvest was conducted in the Upper Eel WAU, with the exception of Poison Oak Creek. Then, significant first entry harvest occurred from the 1950s to 1970s, focusing on upper, headwater reaches of the Lower Larabee Creek as well as the Thompson Creek, Poison Oak Creek, Burr Creek, Canoe Creek, and Decker Creek planning watersheds. The 1960s saw the first entry into the high reaches of the tributaries of the Larabee and mainstem Eel (eastern portion of the WAU); the surrounding ridge tops were not harvested until the 1970s. Remnants of old-growth stands existed in small, isolated patches that were harvested in the 1970s and 1980s. Since initial harvest, second-cycle logging activities have been occurring throughout the Upper Eel for the past several decades.

Figure 4-2. First Cut Acreage for HCP area of the Upper Eel WAU

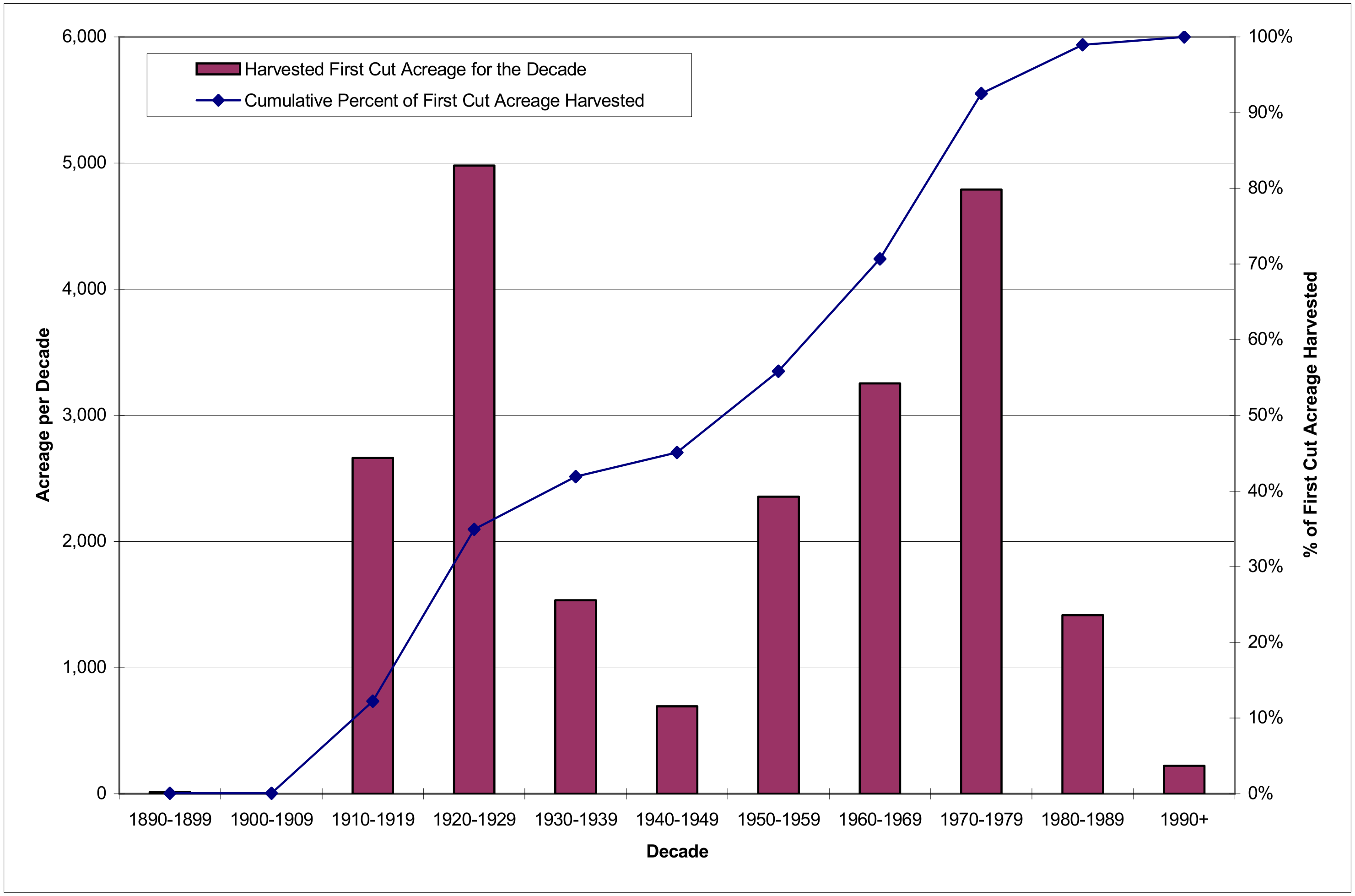


Table 4-2. First Harvest Entry in HCP Area

(acres)

SUBBASINS	1890-1899	1900-1909	1910-1919	1920-1929	1930-1939	1940-1949	1950-1959	1960-1969	1970-1979	1980-1989	1990+	All other Categories*	Total
Balcom Creek Complex	-	-	425	664	95	8	0.02	-	-	0.098	-	2	**1,193**
Boulder Creek	-	-	-	-	-	-	179	314	533	-	-	79	**1,105**
Bridge Creek	-	-	-	-	-	-	-	176	170	-	-	31	**377**
Cameron Creek	12	-	13	-	-	-	-	10	-	22	-	439	**496**
Carson Creek Complex	-	-	328	1,609	1	-	-	10	-	10	16	19	**1,993**
Chris Creek	-	-	738	229	-	-	-	-	-	-	-	7	**974**
Decker Creek	-	-	-	-	11	-	-	-	170	-	-	121	**301**
Elk Creek	-	-	-	-	-	-	-	18	-	-	-	762	**781**
Kapple Creek Complex	-	-	-	230	340	493	164	-	117	6	-	200	**1,550**
Main Stem Larabee I	-	-	666	381	51	-	82	121	9	143	22	315	**1,791**
Main Stem Larabee II	-	-	-	-	-	-	-	37	74	-	-	151	**262**
McCann Creek Complex	-	-	-	-	-	-	-	1,797	130	-	12	382	**2,321**
Mid Larabee Creek Complex	-	-	-	-	6	-	454	350	738	25	2	67	**1,642**
Mill Creek	-	-	-	-	-	-	17	-	54	386	-	522	**978**
Newman Creek	-	-	2	567	429	188	515	31	0.5	-	-	145	**1,878**
No Name Creek Complex	4	-	0.4	-	-	-	-	107	288	733	-	642	**1,774**
Ohman Creek	-	-	-	-	-	-	-	-	-	-	-	152	**152**
Poison Oak Creek Complex	-	-	2	153	560	-	0.031	32	804	80	99	983	**2,713**
Scott Creek Complex	-	-	488	500	43	3	399	52	378	0.7	3	52	**1,918**
Smith Creek	-	-	-	647	-	-	17	178	9	11	70	448	**1,381**
Thompson Creek	-	-	-	-	-	0.9	531	20	1,314	0.102	-	468	**2,333**
Grand Total	**16**	**0**	**2,662**	**4,982**	**1,535**	**693**	**2,357**	**3,253**	**4,789**	**1,417**	**224**	**5,985**	**27,913**

*Note: Other categories include; two unlabeled categories, old growth, unknown, acquired, out, and prairie.

After the initial harvest in most areas of the Upper Eel WAU, regeneration occurred by natural reseeding or sprouting. The exception to this occurred in the vicinity of Grant Camp (Poison Oak Creek area), where replanting was performed from the late 1910s to early 1930s. Also, tree planting was done in Newman Creek after a large fire in the 1950s. Notable increases in higher density, more productive stands resulted in the areas where replanting occurred.

One significant area that has not been harvested since the initial harvest is the McCann area (including McCann Creek and adjacent sub-basins). A large block of the McCann Creek sub-basin was first logged by tractor in the 1960s and 1970s by Willits Redwood. Soon after the initial harvest in McCann, Louisiana-Pacific Corporation purchased the tract and removed valuable down wood that had been left behind by Willits Redwood; this resulted in significant disturbance and effects to streambeds in these tributaries as logs were yarded down the stream channels. To this day, logs from the initial harvest remain in the streambeds, particularly in Devil's Elbow. Currently, the most degraded roads within the Upper Eel WAU are located in the McCann area.

4.2.2 Early Harvest, Yarding, and Hauling Methods and Locations

Much of the following discussion utilizes information on typical harvest, yarding, and hauling methods presented in previous watershed analysis (PALCO, 2004). Prior to the 1973 Z'berg-Nejedly Forest Practices Act, the management style for early logging was typical for most areas of the North Coast Practices included substantial ground disturbance, little protection of stream channels and riparian zones, extensive road construction, and little or no recognition of the potential influence of harvesting on inner gorge slope stability.

By the 1930s, tractors, bulldozers, diesel yarders, and swing-boom and heel loaders were used to haul logs to railroad landings where trains transported them to mills. Prior to the 1940s, large areas of clear cuts were logged with steam-driven cable and winch systems ("steam donkeys") and/or oxen. Harvesting with this method typically removed all merchantable trees, leaving only cull and broken trees. During this period, stream channels were themselves often the primary transportation corridor, with significant impacts resulting from this use. Steam donkeys worked their way up smaller streambeds by attaching the yarding cable to a standing tree upstream and, while hauling in the line, dragging the steam donkey apparatus up the channel bed. They then proceeded to haul cut timber down hillslopes to the valley bottom where the logs could be loaded or hauled with oxen to a rail line or to a larger river channel for floating. Alternatively, oxen and railroad haul roads were built straight up the tributary channels by covering (i.e., filling) the streams with a "road bed" of logs laid across the channel, referred to as corduroying. Corduroy roads were built both for oxen teams and for railroads. Railroad beds tend to use large logs spaced apart and placed high on the confined valley walls, to support the great weight of the machinery operating on them and because the rails spanned the gaps. Oxen team roads used smaller logs very densely packed on the streambed grade. Many channels, especially the smaller ones that were not subject to stream clearing of wood in the 1980s, still have remnants of these log roads and show evidence of channel scour. After yarded down from the hillslopes and out of tributary valleys, logs were transported to mills by rivers and railroads.

In the early years of timber harvest in the Upper Eel WAU, railroads extended up into the Dauphiny, Balcom, Carson, Chris, Smith, Newman, and Poison Oak Creek drainages; these drainages are major tributaries to the lower mainstem reaches of Larabee Creek or the Eel River. In the 1930s and 1940s, railroads, truck haul roads, and tractor skid trails associated with early tractor yarding spread to more remote areas of the Upper Eel with eventual replacement of railroad lines with truck hauling roads. Roads were constructed solely to gain access to timber for harvest and creeks were commonly crossed without considering fish passage.

Between 1940 and 1987, the watershed was logged primarily using tractors on a dense network of skid trails. Hauling changed to multi-axled diesel trucks. Prior to 1974, timber harvesting typically removed 70 percent of the merchantable trees (following the ad velorum taxation rules) and did not typically leave riparian buffers. During the 1960s, silviculture was primarily clear cut with seed tree seed step in some areas; thinning was commonly applied in the early 1990s. Since 1974, silvicultural methods followed the California Forest Practice Rules, which were adopted with the Z'berg-Nejedly Forest Practices Act. Also, restocking has been consistently implemented after harvest in the Upper Eel since the early 1980s.

4.2.3 Harvest and Road Construction Rates

Total harvest area and constructed road lengths were interpreted as part of the mass wasting analysis using aerial photographs and recent PALCO harvest history data. The road construction and harvesting histories were primarily developed from the 1954, 1966, 1974, 1987, 1997, and 2003 aerial photographs. The 1954 photo year was used as the baseline for the HCP area. Prior to this time, about 45 percent of the old growth timber had been cut since logging began in the early 1900s (Figure 4-2). However, the area was largely unroaded at this time because of the early reliance on railroads as transportation systems and steam donkeys as yarding systems (Figure 4-3). Maps A-4 through A-9, developed in the Mass Wasting Assessment report (Appendix A) through aerial photograph analysis, show the progression of harvest throughout the analysis area.

Figure 4-3. Road Construction in HCP Area of Upper Eel WAU (from Historic Aerial Photos)

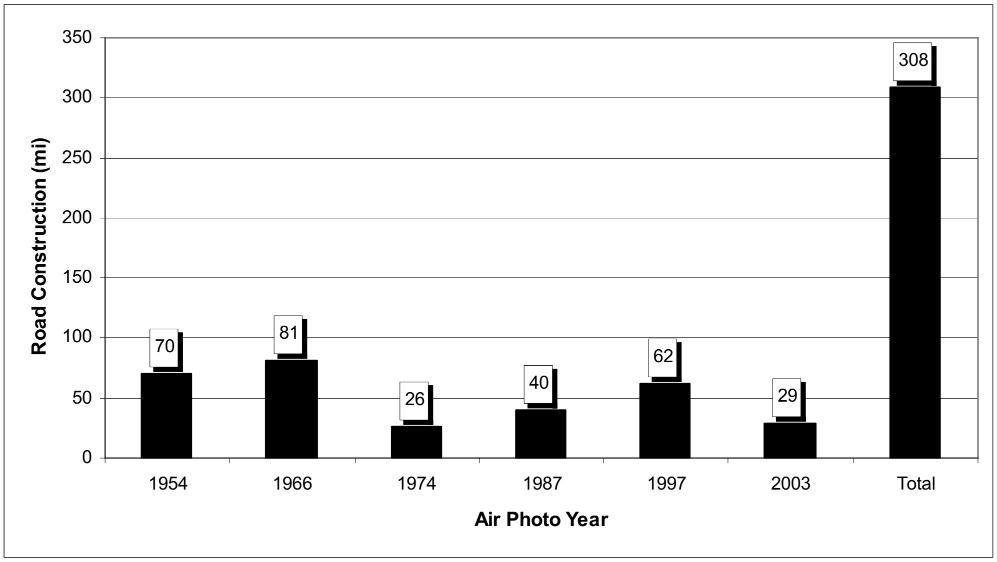
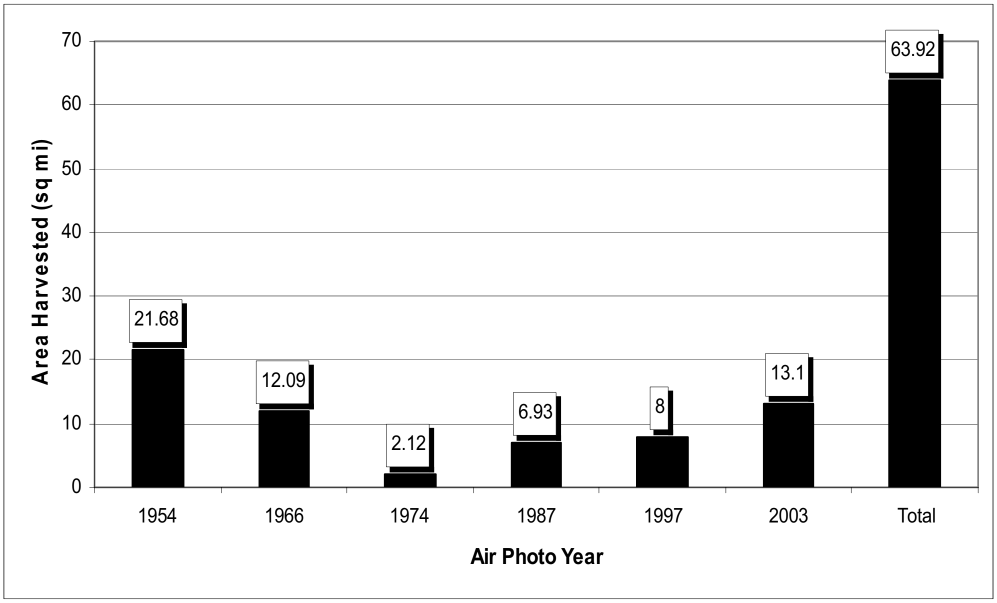


Figure 4-4 summarizes the harvesting and re-harvesting history for the HCP area as derived from the historic aerial photography beginning in 1954 (see Appendix A). By the time of the 1954 aerial photography, approximately 21.7 mi^2 had been harvested, primarily in the lower basin or western half of the area. Approximately 65% of the harvested areas identified in the 1954 aerial photography were yarded using steam-donkey methods. The remaining portion was tractor yarded.

Logging generally progressed eastward away from the established roads and railroad lines in the following decades. Between 1954 and 1966, nearly 12.1 mi^2 were harvested in the HCP area. Nearly all of the logging in the two decades from 1954 to 1974 was done using crawler tractors for downhill yarding, regardless of the type of terrain that was being operated on.

Logging increased to 0.53 mi^2/year between 1974 and 1987 with approximately 6.9 mi^2 of harvesting and tractor yarding. Cable logging came into use in the period from 1987 to 1997. Cable systems were used to conduct 56% of the logging during this interval. The remainder was tractor logged. Approximately 13 mi^2 were logged between 1997 and 2003 throughout the HCP area (2.1 mi^2/year). During this most recent period, helicopter yarding was introduced, accounting for 17% of the harvest. Cable systems were used to harvest 32% of the harvested area and about 50% was tractor yarded.

Figure 4-4. Harvest Totals in HCP Area of the Upper Eel WAU (from Historic Aerial Photos)



The density and placement of roads in the Upper Eel reflect the history and sequence of logging activities in different parts of the WAU and the types of yarding and transportation systems that were constructed to service those activities. Figure 4-3 depicts the general road construction history in the HCP area, as derived from the analysis of historical aerial photography. Roads constructed from the 1940s through the late 1980s were truck roads built to provide access primarily to tractor yarding systems. The earliest truck roads in the Upper Eel followed railroad grades, where present, and were often adjacent to major streams to take advantage of the gentle gradients. The channel infilling that began with corduroying for oxen and railroad tracks continued during the tractor-logging era of the 1940s to 1970s. Many low-order stream channels were filled in with soil and organic debris to form tractor-yarding corridors.

Table 4-3 lists road density, by sub-basin, for HCP and “non-HCP” roads in the HCP area. HCP roads are defined as open and maintained roads identified in the PALCO Geographic Information System (GIS). A total of 308 miles of road were constructed in the HCP area up to the date of the 2003 aerial photography. “Non-HCP” roads are defined as legacy roads in this area that are not currently maintained and have not been identified by PALCO GIS. Typically, these roads were built in the earliest air photo time periods (1954, 1966, and 1974) and were identifiable on the earliest photography within 10 years of construction. These legacy roads are difficult to identify on more recent air photo sets due to dense vegetation overgrowth.

Table 4-3. Road Density by Sub-basin in HCP Area

Sub-basin	Total road length (mi)	Sub-basin area (mi^2)	Total road density (mi/mi^2)	HCP road length (mi)	HCP road density (mi/mi^2)	Non-HCP road length (mi)	Non-HCP road density (mi/mi^2)
Balcom Creek Complex	15.40	1.86	8.27	15.40	8.27	0.00	0.00
Boulder Creek	11.03	1.73	6.39	9.23	5.35	1.80	1.04
Bridge Creek	5.11	0.59	8.68	3.87	6.57	1.24	2.11
Cameron Creek	5.87	0.77	7.57	4.76	6.14	1.11	1.43
Carson Creek Complex	24.08	3.11	7.74	21.57	6.93	2.51	0.81
Chris Creek	10.55	1.52	6.94	10.46	6.88	0.09	0.06
Decker Creek	4.69	0.47	9.97	2.31	4.91	2.38	5.06
Elk Creek	10.14	1.22	8.32	7.22	5.92	2.92	2.40
Kapple Creek Complex	16.49	2.42	6.81	14.00	5.78	2.49	1.03
Main Stem Larabee I	18.14	2.80	6.49	12.10	4.33	6.04	2.16
Main Stem Larabee II	1.90	0.41	4.65	0.37	0.91	1.53	3.75
McCann Creek Complex	26.36	3.62	7.27	18.77	5.18	7.59	2.09
Mid Larabee Creek Complex	19.94	2.56	7.78	15.79	6.16	4.15	1.62
Mill Creek	6.40	1.53	4.19	6.32	4.14	0.08	0.05
Newman Creek	19.13	2.93	6.52	18.74	6.39	0.39	0.13
No Name Creek Complex	19.46	2.77	7.03	18.46	6.67	1.00	0.36
Ohman Creek	1.85	0.24	7.78	1.00	4.21	0.85	3.58
Poison Creek Complex	26.29	4.24	6.21	20.30	4.79	5.99	1.41
Scott Creek Complex	24.09	3.00	8.04	22.30	7.44	1.79	0.60
Smith Creek	15.29	2.16	7.09	11.68	5.42	3.61	1.67
Thompson Creek	25.31	3.64	6.95	21.85	6.00	3.46	0.95
Total	**307.5**	**43.6**	**7.06**	**256.5**	**5.89**	**51.0**	**1.17**

Based on Historic Aerial Photos

The average observed road density for HCP and “non-HCP” roads in all sub-basins, as of the 2003 aerial photography in the HCP area, is approximately 7.2 mi/mi^2. The highest densities were observed in Decker Creek, Bridge Creek, Elk Creek, Balcom Creek Complex, and Scott Creek Complex (9.97 mi/mi^2, 8.68 mi/mi^2, 8.32 mi/mi^2, 8.27 mi/mi^2, and 8.04 mi/mi^2, respectively).

4.3 CONTEMPORARY

Implementation of the PALCO HCP in 1999 provided greater retention standards than those required by the Forest Practice Rules and, in essence, have eliminated timber harvest within 170 feet of fish bearing streams and within 130 feet of non-fish bearing streams for PALCO’s ownership. The HCP also mandates additional specific harvest restrictions on steep and/or unstable slopes beyond these minimum distances. Current timber harvesting is subject to HCP interim rules, and future harvesting will be subject to watershed-specific prescriptions developed from this Watershed Analysis. Also during this period, helicopter yarding has become more common in this WAU. Currently, yarding is performed using tractors, harvester/yarder machines, ground-based cable yarders, suspension cable yarders, or helicopters.

Timber harvest ground disturbances are associated with clearcuts or partial cuts, constructing layouts for tree felling, tractor/skidder trails, cable yarding, site preparation, and treatment of competing vegetation during revegetation with herbicides, hand thinning, or other applicable silvicultural methods. Over the past decade, site preparation has been performed on approximately half of the clear cut units. Approximately half of the site preparation involves broadcast burning, and the other half involves mechanical site preparation. Herbicides are used on an as-needed basis only, with all operators following state regulations for handling and application.

Along with total acres harvested each year, Figure 4-5 depicts yarding systems used from 1988 through 2003, and Figure 4-6 shows silviculture methods used during the same period. During this period, yarding systems shifted from a combination of tractor- and cable-based yarding (through 1998) to helicopter yarding starting in 1999. The majority of harvest in 2001 utilized helicopter yarding, both for clear-cut and partial-cut silviculture. For most years, clear cut was applied to more acres than partial cut silviculture, with an increased proportion of clear cut to partial cut occurring since 1998. The overall temporal trends in total acreage harvested indicate increasing use of helicopter yarding and variable annual utilization of tractor and cable-based yarding methods. Also, clear-cut silviculture is more common in recent years, with application in smaller individual units than in earlier years.

Figure 4-5. Acres Harvested in HCP Area by Yarding System from 1988-2003

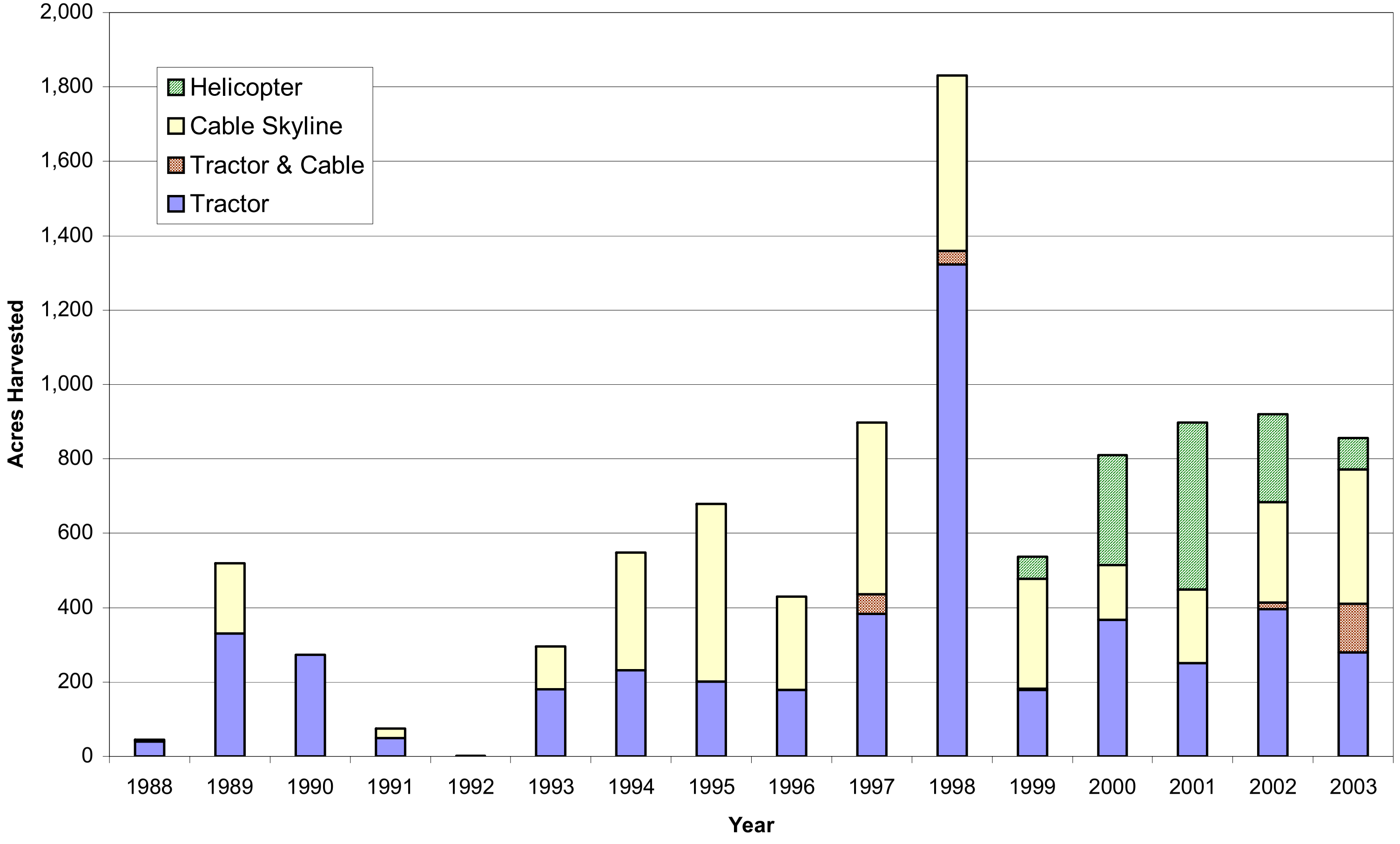
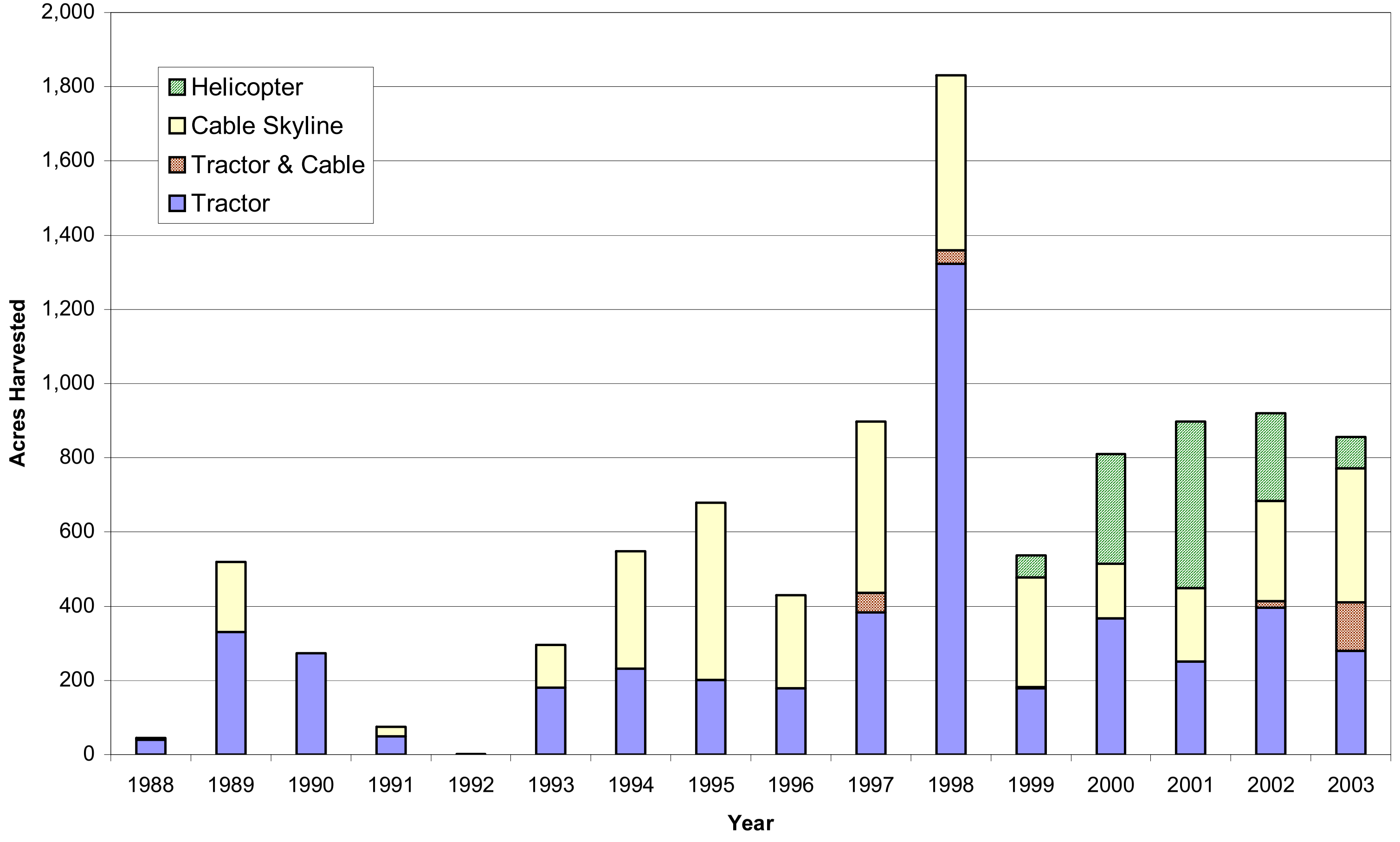


Figure 4-6. Acres Harvested in HCP Area by Silviculture Method from 1988-2003



A policy of allowing no road traffic during wet conditions was implemented on PALCO lands after 1998 to reduce what was believed to be the greatest source of road sediment generation and delivery to streams. PALCO's implementation of HCP road use restrictions involves ceasing all traffic, except for light pickups used for forestry, wildlife surveys, monitoring, and emergency repair work, when there is any significant rain. Road storm proofing, reconstruction, and upgrading have occurred on a significant portion of PALCO's roads in the Upper Eel to reduce sediment inputs to streams and to support harvesting. Much of this work has involved improving roads to levels that exceed the current forest practice standards, as required by PALCO's agreed-upon HCP maintenance objectives. A summary of current road types in the HCP area of the Upper Eel WAU is presented in Table 4-4.

Table 4-4. Summary of Road Types in HCP Area

Sub-basin	Regular				Upgraded Only		Stormproofed		Stormproofed HCP Closed & Abandoned	HCP Closed	Built Since 1999		Total Miles	Road Density (miles/mi^2)
	Paved	Gravel	Dirt	Proposed	Gravel	Dirt	Gravel	Dirt	Grassed Native	Grassed Native	Gravel	Dirt		
Balcom Creek Complex	-	2	9	<1	1	2	1	<1	-	-	-	-	**15**	7.9
Boulder Creek	-	<1	8	<1	1	-	-	-	-	-	-	-	**9**	5.4
Bridge Creek	-	-	4	-	-	-	-	-	-	-	-	-	**4**	6.6
Cameron Creek	<1	<1	4	1	-	-	-	-	-	-	-	-	**5**	6.4
Carson Creek Complex	-	2	10	1	5	<1	1	3	-	-	-	-	**22**	7.0
Chris Creek	-	1	6	<1	<1	<1	1	2	-	-	-	<1	**11**	7.1
Decker Creek	-	-	2	<1	-	1	-	-	-	-	-	-	**2**	5.0
Elk Creek	-	-	4	<1	-	4	-	-	-	-	-	-	**7**	6.0
Kapple Creek Complex	-	<1	6	1	3	1	<1	2	-	-	-	1	**14**	5.8
Main Stem Larabee I	-	4	6	<1	1	<1	2	<1	-	-	-	-	**12**	4.4
Main Stem Larabee II	-	-	<1	-	-	-	-	-	-	-	-	-	**0.4**	0.9
McCann Creek Complex	<1	4	16	2	-	-	-	-	-	-	-	-	**21**	5.8
Mid Larabee Creek Complex	-	4	9	<1	3	-	-	-	-	-	-	-	**16**	6.1
Mill Creek	-	<1	6	<1	-	-	-	-	-	-	-	-	**6**	4.1
Newman Creek	-	2	6	1	3	1	3	1	<1	<1	<1	1	**19**	6.4
No Name Creek Complex	-	4	13	1	-	-	-	-	-	-	-	-	**19**	6.7
Ohman Creek	-	-	1	-	-	-	-	-	-	<1	-	-	**1**	4.6
Poison Oak Creek Complex	2	1	11	-	5	1	<1	<1	-	-	-	-	**20**	4.8
Scott Creek Complex	-	4	11	<1	4	2	1	-	-	-	-	-	**22**	7.5
Smith Creek	-	2	8	1	1	<1	<1	<1	-	-	-	<1	**12**	5.7
Thompson Creek	-	-	18	<1	1	2	-	-	-	1	-	-	**22**	6.0
Total for HCP Area	**3**	**31**	**158**	**8**	**27**	**13**	**9**	**9**	**<1**	**1**	**<1**	**2**	**261**	**6.0**

Based on PALCO GIS Data

5.0 LAND USE EFFECTS ON WATERSHED PROCESSES AND THE CUMULATIVE EFFECT ON STREAM CONDITIONS

Stream channels link hillslopes to streams and couple terrestrial and aquatic ecosystems. Along with streamflow, channels pass the products of erosion from the surrounding hillslopes along with nutrients, organic matter, and large woody debris from the adjacent forest. Channel morphology reflects a balance between these materials, water and woody debris to a stream, the stream's ability to transport these materials, and the strength of its banks (Sullivan 1986). The form of the stream channel is influenced by its association with the hillslope and forest and by the character of the inorganic and organic matter supplied to it. The characteristics of streams reflect the natural controls of geology, tectonics, topography, climate, and vegetation, as they integrate these processes occurring both on watershed and local reach scales (Montgomery and Buffington 1993). Fish habitat is a function of channel and flow conditions, and thus the type, quality, and availability of habitat are variable within a watershed with the factors controlling channel morphology. Changes to sediment and input of large woody debris in the watershed through natural or land use disturbance can impact the morphology and composition of streambed sediments and degrade the quantity and quality of fish habitat.

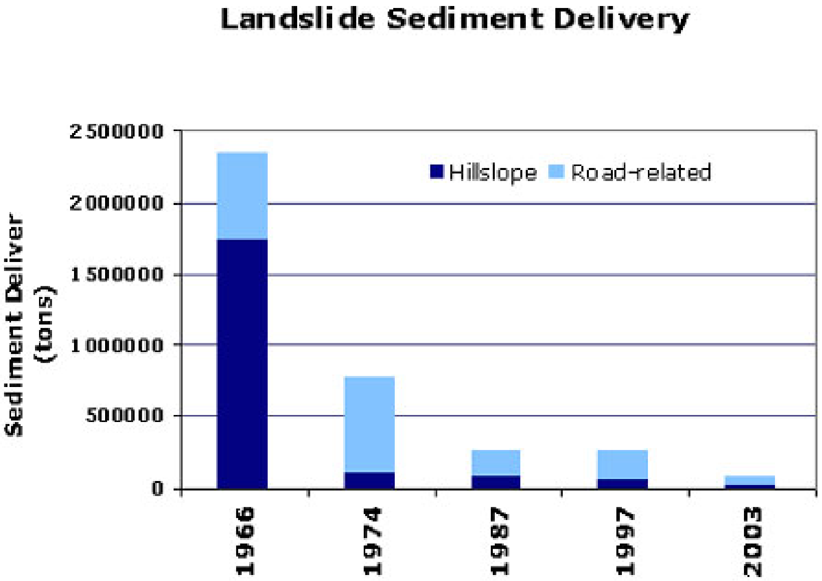
Erosion processes in each watershed determine the rate of input and type of sediment found in streams in natural and disturbed conditions. Sediment eroded in one part of a watershed is transported to downstream response reaches where it can accumulate. These depositional reaches are often the most productive habitat for salmonids because of the abundant gravels in which to build nests for laying eggs and over which form deep pools for rearing juveniles until they are large enough to migrate to the ocean. Streamside forests are the source of large wood that helps to form pools as well as shade that helps to maintain cool water temperatures. Forest management can disturb natural erosion processes and riparian forest conditions and alter the delivery of sediment, wood, and shade to streams and have a cumulative effect on the quality and quantity of aquatic habitat. Changes to channel morphology may include overall loss of hydraulic complexity, filling of pools, plugging or burying streambed gravel, increased turbidity, severe channel scouring, channel widening, accelerated bank erosion, and loss of streamside vegetation.

In the following section we review the overall changes in sediment loading and riparian condition observed in the WAU resulting from the past 50 years of land use and natural disturbance. Information generated in accompanying reports is synthesized and summarized in this section. Figures, tables, photographs, and text may be extracted from the modules for use with this Cumulative Watershed Effects report. Current stream conditions in specific locations within the WAU are discussed with reference to habitat indicators.

5.1 SEDIMENT INPUT FROM THE WATERSHED

Erosion processes include natural and management-related input of coarse and fine sediments from landsliding, runoff from road surfaces, erosion of road beds, rilling and gullying of exposed soil within harvest units and on skid trails, and bank erosion. Sediment sources in the WAU have been quantified using a variety of methods including historical air photo analysis, field surveys of roads and streamside landslide and bank erosion, and models (Table 2-1). Detailed results of these analyses are presented in Appendices A, B, and D.

Figure 5-1. History of landslide delivered sediment (in tons) in the Upper Eel WAU by photoperiod and general land use association



Landslides have been a dominant source of sediment over the past 50 years. The watershed experienced a large influx of sediment from landslides during the large storms of 1955 and 1964. The 1964 flood was experienced throughout the Eel River basin and had a recurrence interval of 500 years. Inner gorge (>65%) and streamside (50-65%) slopes were the most common points of origin for landslides identified in all years of the air photo inventory and in all portions of the WAU. The majority (73%) of the landslides identified with sediment delivery occurred in the Yager terrane where the inner gorges and steep streamside slopes are prevalent. Landslides identified in the Wildcat Group represent only 16% of the air photo-identified landslides with sediment delivery and only represent approximately 11% of the total sediment delivered to streams.

The high sediment delivery in this time period may be a reflection of construction of many new roads built with what are now archaic road construction practices, unrestricted harvesting in sensitive terrain, and extensive use of tractor yarding, coupled with the size of the 1955, 1959, and 1964 storms. An example of harvest techniques used on steep slopes near river floodplains is shown in Photograph 5-1. Sixty-eight percent of the management-associated landslides identified on harvested inner gorge slopes were associated with tractor yarding.

Landslide sediment has significantly declined since the photo period ending in 1966 (Figure 5-1). The decrease in the overall landslide delivery rates may reflect less impacting management practices after adoption of the Forest Practice Rules and PALCO's HCP in 1999. Contemporary forestry activities have been increasingly mitigated to avoid sediment delivery since the inception of the 1973 Z'Berg-Nejedly Forest Practice Act and numerous other state and federal environmental laws. The continued low landslide sediment input in the 2003 photoperiod is significant because one of the most rainfall intensive storms ever recorded in 118 years of record at Eureka occurred in December 2002. This storm far exceeded rainfall thresholds required to trigger landslides, and was larger than the 1964 and 1955 storms in this regard.

Photograph 5-1. Early railroad corridor located in stream valley

Within the WAU, the mainstem of Larabee Creek has been particularly impacted by landslides originating on steep inner gorge slopes adjacent to the channel. The highest sediment delivery from observed landslides within the study area was recorded in the Main Stem Larabee I sub-basin. All of the large observed landslides in this sub-basin delivered to the main stem of Larabee Creek. The Main Stem Larabee I sub-basin is underlain primarily by steep slopes formed on Yager and Wildcat terrane, with lesser amounts of Quaternary river terrace and stream channel deposits along the stream channel bottom and lower valley areas. Landslides observed within the Main Stem Larabee I sub-basin appear to be more likely triggered by stream undercutting caused by increased stream flows during large storm events and channel migration processes. The Main Stem Larabee I sub-basin showed the highest landslide delivery volume for representative air photo time periods of 1954-1974, 1975-1987, 1988-2003 (879,140 tons, 126,878 tons, and 142,598 tons, respectively).

5.2 CHANNEL PLANFORM RESPONSE TO SEDIMENT

5.2.1 Mainstem Alluvial Valleys

Larabee Creek within the alluvial valley of the lower watershed upstream of its junction with the Eel River responded to the large influx of sediment by straightening its channel, increasing gradient, and subsequently flushing sediment (approximately 190,000 tons into the Eel River over the last 50 years. Analysis of historical planform channel change were used to develop an envelope of maximum channel migration for Larabee Creek over the 49-year photograph period and to estimate changes in volume of sediment in storage on the floodplain (Figure 5-2).

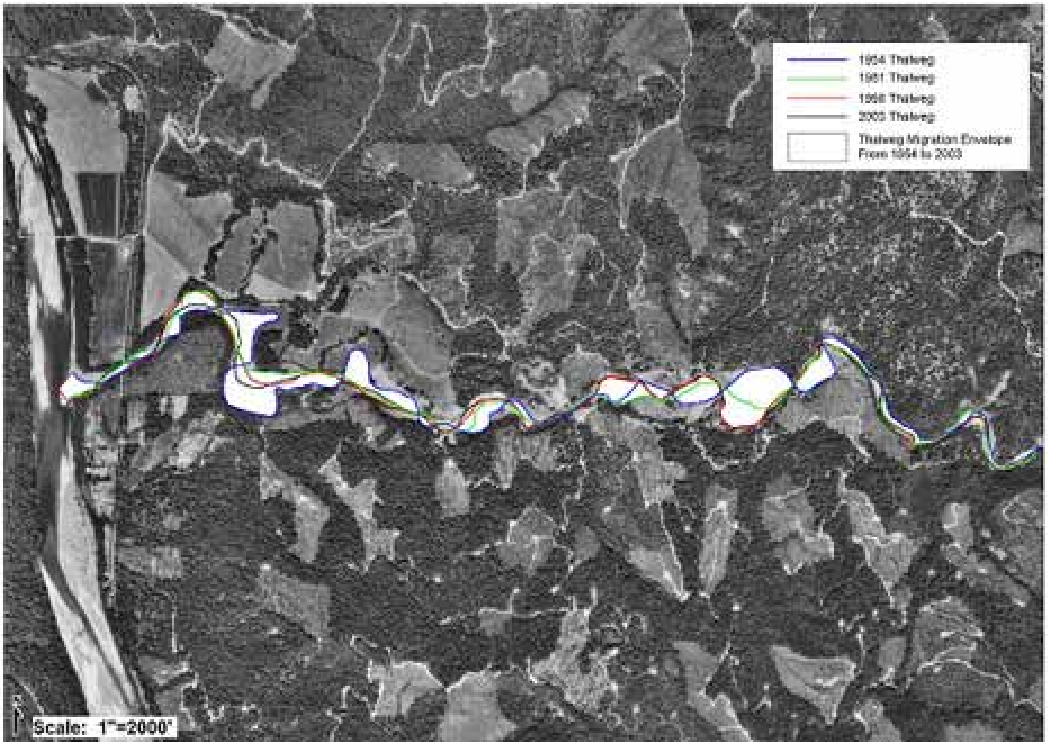
The alluvial valley shown with the trace of the thalweg in four time periods in Figure 5-2 represents the channel migration zone of Larabee Creek. This zone is sensitive, and has shown response to large amounts of sediment. The historical CMZ envelope is greatly diminished a short distance above the mouth of Carson Creek, which we attribute in part to a narrowing valley bottom and commensurate increase in channel confinement in the upstream direction with transition from the Wildcat to the Yager lithology.

Sediment mobilized from Larabee Creek primarily originated from floodplain deposits and secondarily from terraces. In response to increases in sediment yield and discharge, stream channels straighten (decrease sinuosity) in order to increase slope and stream power (Pazzaglia et al. 1999). Channel straightening was observed along the unconfined reaches of lower Larabee Creek from 1954 through 1981, during and following the period of large regional floods and influx of landslide sediments (Figure 5-2). In contrast, the channel lengthened by increasing sinuosity during the period from 1981 through 1998, suggesting lower levels of both sediment input and discharge. The channel migration from the 1954 to 1981 period represents a disproportionate majority of channel shortening relative to the 1981 to

2003 period. This finding suggests a more stable modern channel. Subsequent to the 1997 and 2002 storm events, the creek has decreased sinuosity and appears to be actively incising. Incision could result from a decrease in storage of sediment at the confluence of the Eel River and Larabee Creek.

During the same 49-year time period, the Eel River has stored approximately 6.5 million tons of sediment based on a similar analysis of planform. Unlike Larabee Creek that has been flushing sediment, the larger Eel River continues to experience aggradation due to several factors including a low channel gradient (0-1%), an extensive tributary system, which is exemplified by Larabee Creek, throughflow of substantial volumes of sediment from upriver, and possibly reduction in seasonal flows due to upstream water diversions (i.e. Potter Valley Project dams) reducing scouring power.

Figure 5-2. Historic CMZ of Lower Larabee Creek



CMZ is defined by the maximum channel thalweg migration over the 49-year photograph period. (Figure D-14, Stream Channel Module.)

The downstream movement of sediment occurs episodically during storms when streamflow is sufficient to mobilize gravel-sized and larger bed material. This flow is generally equivalent to a near bankfull event and typically occurs approximately once per year. The distance a gravel particle is transported during each mobilizing storm may be on the order of 1,500 feet. The mainstem Eel River and South Fork Eel

River that contribute to the section of the mainstem of the Eel River within the WAU have long lengths of aggraded reaches above the WAU, and the flushing of gravels deposited in the system as early as 1964 is probably still occurring.

Evidence of this aggradation is clearly observable on the mainstem Eel River at the Holmes Flat bridge, constructed by the Pacific Lumber Company in 1937. The bridge's concrete deck was originally 19 feet above the river bottom. Since the 1964 flood, the channel has steadily aggraded so that by 1996 the bridge deck was only 1.5 feet above the river bottom (U.S. Army Corps of Engineers 1999). However, despite aggradation, there has been little planform channel response in the mainstem Eel River to these sediment inputs.

There were no observable effects on the planform of the smaller tributaries distributed throughout the WAU from the large influx of sediment observed in the 1966 photos. Most of these streams have very small, if any, alluvial valleys and any changes were not detected given the scale of the aerial photography.

5.2.2 Tributary Channel Filling

Channels have also been significantly disturbed by direct filling with soil in order to use them for skidding logs to landings. This practice began with the use of oxen and continued even with use of tractors well into the 1970s. The modern application of practices allowed under the Forest Practice Rules prohibits equipment in any stream of any size. Among those fish-bearing streams affected was Chris Creek for which the channel was once filled with compacted road sediments (Photograph 5-2). Much of that sediment has washed away, restoring the channel to what appears to be its former bed. However, the stream still has visible effects; channel banks are still abnormally vertical, indicating there is additional material to erode to achieve a natural channel form. Not evident in Photograph 5-2 are a number of

Photograph 5-2. Response reach channel within Chris Creek showing remnants of channel filling when stream channel was used as skid trail for log hauling

Shear channel wall has resulted from sediment removal of the compacted road bed.

vertical wooden stakes still embedded in the active channel that were used to stabilize the road. The vertical and resistant channel banks may increase the frequency of channel bed scour by containing storm flow, and possibly increasing scour and reducing gravel stability.

Use of streams for roads and skid trails was widespread throughout the WAU. Aerial photo analysis of one sub-area within the WAU was used to determine that 21% of the total sampled channel length had been tractored during the photograph period, thus introducing substantial amounts of sediment to stream channels. It appears that many streams of all orders have been significantly impacted by tractoring with the highest percentage of these channels in 3rd order streams and the lowest in 4th order streams.

5.3 SEDIMENT BUDGET

Sediment is input to streams within a watershed through a variety of natural and anthropogenic mechanisms. Natural erosion mechanisms include landsliding and soil creep, which is the gradual downhill movement of soil under the force of gravity that is generally exhibited as bank erosion. Logging and other land use activities have historically input significant amounts of sediment into streams, especially in combination with record rainfall events. These activities have included:

- Railroad construction
- Use of creeks as skid roads, haul roads, and landing locations
- Skid road and haul road construction across steep and unstable slopes
- The filling of stream channels during stream haul road and skid road crossing construction
- Road surface erosion
- Road construction and timber harvest on unstable slopes
- Removal of streamside vegetation

As part of the Upper Eel watershed analysis, a sediment budget was prepared as a quantitative accounting of estimated sediment delivery to streams for the period from 1988 to 2003. The sediment budget is provided in Attachment 2 and includes sediment delivery estimates, by source type, for the HCP area of each sub-basin in the Upper Eel WAU. The complete sediment budget (Attachment 2) presents the definition, data source (module), and management association for each source type. Details of methods used to develop sediment delivery rates are provided in the Mass Wasting, Surface Erosion, and Stream Channel Assessment Reports (Appendices A, B, and D, respectively). Delivery rates were determined through air photo and field inventories or surveys for past erosion (e.g., landslide inventories); inventories or surveys for estimated site-specific future erosion (e.g., road surveys); modeling of harvest unit surface erosion; a combination of field surveys and modeling for road surface erosion; or use of available literature for processes difficult to observe in the field such as soil creep. The summarized sediment budget in Figure 5-3 shows the annual sediment yield for the sub-basins within the WAU with sources grouped in categories of natural, legacy, and management. The "legacy" category estimates ongoing sources of sediment delivery associated with historic land use activities, typically pre-dating implementation of the Forest Practice Rules (1974). These legacy practices are typically no longer used and include may of the land use activities listed above, while the "management" category estimates sediment delivery linked to more recent land-use activities. Table 5-1 shows the sources included in each group.

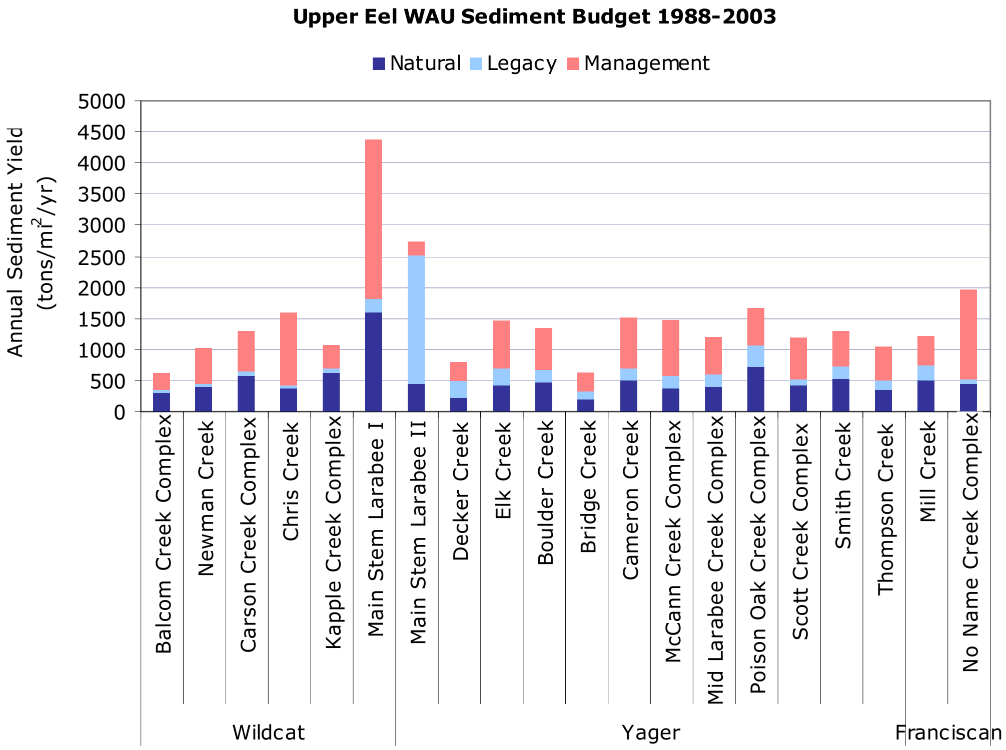
The purpose of the 1988-2003 Upper Eel sediment budget is to assist in identifying significant sources of past sediment delivery, and to what extent these sources were associated with land use. Where management-associated delivery is found to be significant, relative to background, specific management activities can be further scrutinized to determine the extent to which they are controllable in the future through feasible mitigation. The sediment budget is informed through watershed analysis and provides a baseline rate of delivery based on recent watershed performance. The sediment budget does not necessarily provide an estimate of current or future delivery, as this will be determined by the frequency and magnitude of storm events combined with the effectiveness of contemporary best management erosion control practices.

Table 5-1. Sediment sources included in each land use association category

Natural	Legacy	Management
Deep-seated landslides Shallow landslides Small Streamside landslides Soil Creep Bank Erosion	Landslides from untreated abandoned roads Landslides from tractor-harvest units (15-30 year old partial cut and 20-30 year old clearcut) Small Streamside landslides Surface erosion from untreated abandoned roads Bank Erosion Channel Incision	Landslides on PALCO HCP roads Hillslope landslides in partial cuts < 15 years Hillslope landslides in clearcuts <20 years Small streamside landslides Surface erosion in harvest units Road surface erosion Road washouts and gullies Bank erosion Channel incision

Sediment sources are assigned to categories during inventory by analyst.

Figure 5-3. Annual sediment budget for sub-basins in the Upper Eel WAU for the period 1988 to 2003



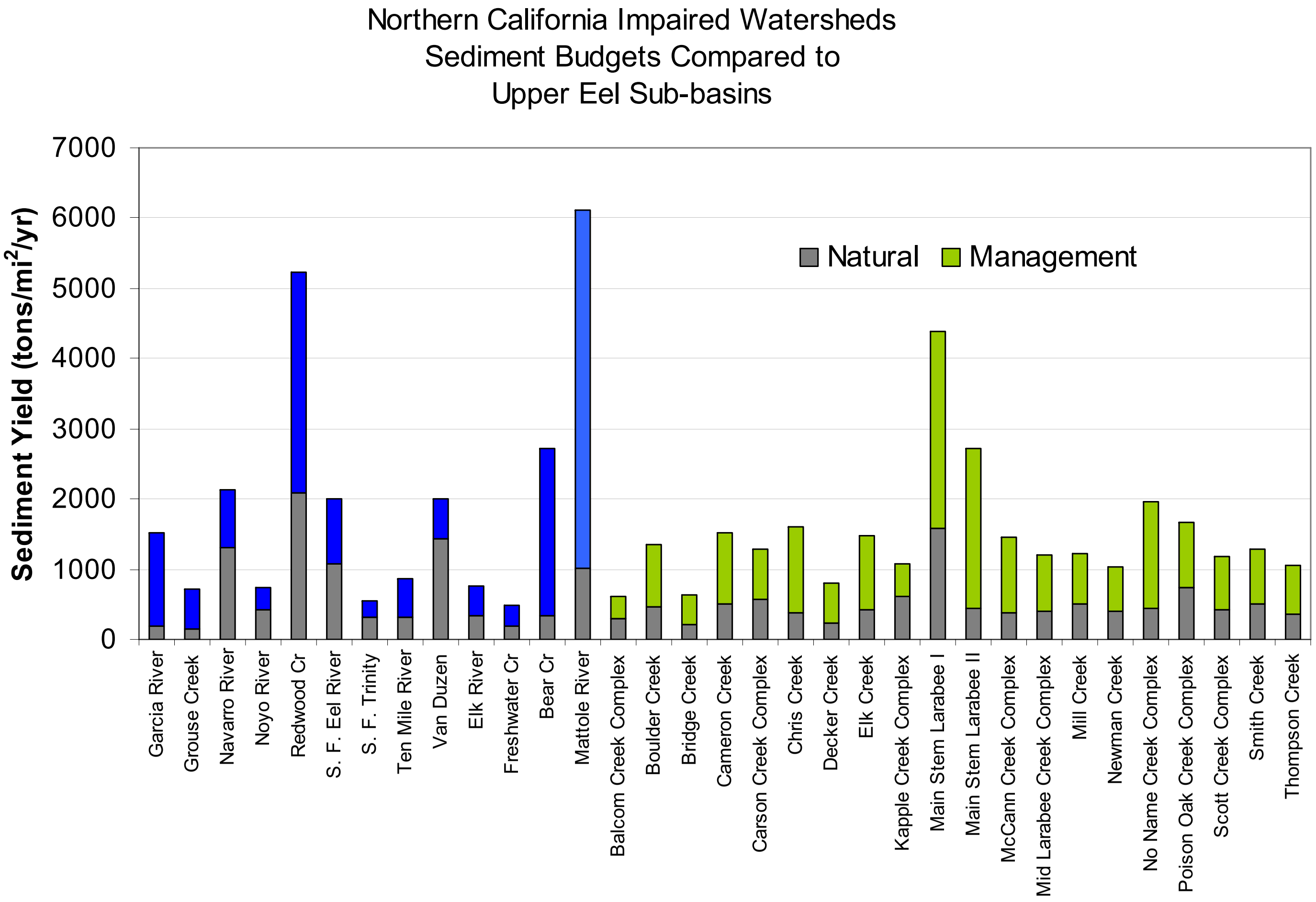
Annual sediment input for the 1988 – 2003 sediment budget period is highest in the area along the mainstem of Larabee Creek (Main Stem Larabee I and II sub-basins), with sediment yields of more than 4,300 and 2,700 tons/mi^2/year, respectively. Sediment delivery is greatest along the mainstem of Larabee Creek where steep inner gorge slopes prone to stream-channel induced landsliding exist. Legacy sources continue to introduce sediment in the upper portion of the mainstem of Larabee Creek. For the other sub-basins, sediment yield ranges from about 600 to 2,000 tons/mi^2/year.

For comparison, Figure 5-4 shows the sediment yields of other rivers in the coastal region of northern California along with data from the sub-basins in the Upper Eel WAU. Estimates of sediment yield for other rivers was compiled by various agencies and companies as a basis for sediment Total Maximum Daily Loads (TMDLs) using similar techniques as used in this Upper Eel watershed analysis. Throughout the northern California coastal region, large amounts of rain fall on a landscape composed of pervasively sheared sedimentary bedrock and tectonic activity. These factors contribute to unstable terrain and streams with exceptionally high total suspended sediment yields (Kelsey 1980). Watersheds vary locally in the composition of the bedrock and their proximity to faults and earthquake zones.

In all watersheds, land use since the advent of "European" settlement has been determined to have increased sediment yield above natural rates. Sediment yield values observed in the Upper Eel WAU are within a similar range as observed in other North Coast rivers; the mainstem Larabee Creek has rates comparable to Redwood Creek and somewhat lower than the nearby Mattole River. Interestingly, estimates of natural sediment rates tend to be similar to, or somewhat higher, than the estimated sediment yield for other rivers. Management-related sediment delivery estimates are similar, or somewhat higher, in the Upper Eel WAU. This may in part reflect differences in methods and interpretations among analysts.

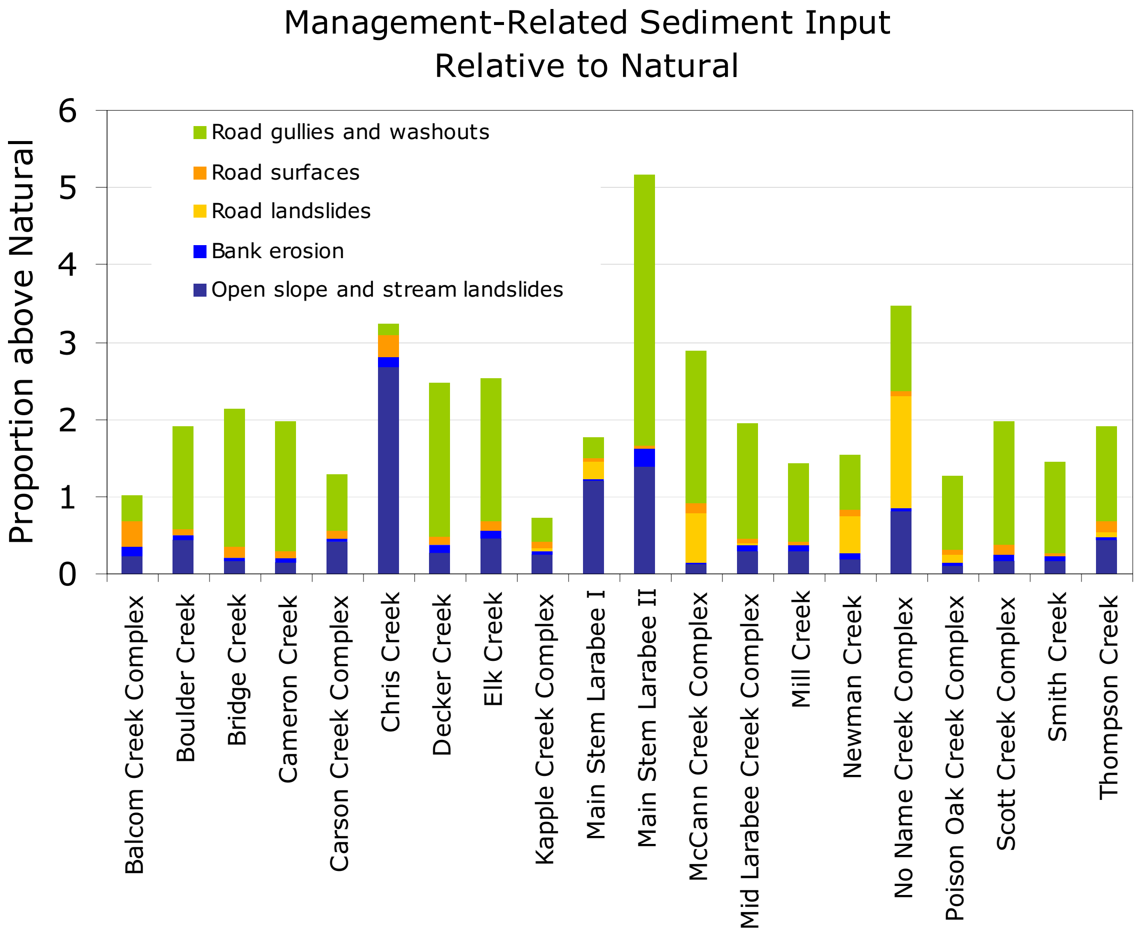
Figure 5-5 shows only the management-related and legacy sediment sources in the Upper Eel WAU expressed as a proportion above background as an indication of relative importance and impact. (A value of two means that current management plus legacy sediment is 200% greater than the estimated natural baseline rate.) This figure facilitates comparison of the relative level of excess sediment among the sub-basins within the WAU, as well as identifies their management associations.

Figure 5-4. Annual sediment yield for sub-basins within the Upper Eel WAU compared with other watersheds in the coastal region of northern California



Bars with green are for PALCO-related management in the Upper Eel sub-basins. Blue are management-related sediment in other watersheds (where PALCO has no ownership).

Figure 5-5. Relative importance of management-related and legacy sediment sources by sub-basin in the Upper Eel WAU

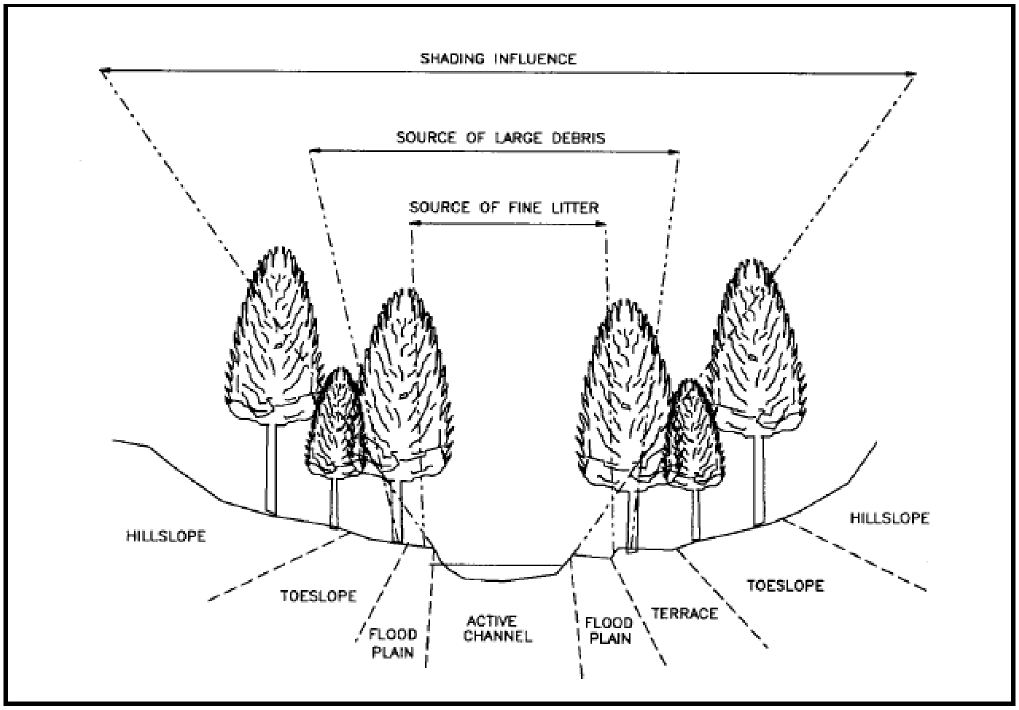


For the 1988 to 2003 period, open slope landslides and bank erosion were dominant sediment sources only along lower Larabee Creek and in Chris Creek. Road-related landslide sediment delivery was a problem in the lower Larabee Creek, McCann Creek, and No Name Creek areas. Road surfaces contributed some sediment in each sub-basin, but are a significant source only in Balcom Creek and Chris Creek. Based on unit rates developed from road inventories conducted in nearby watersheds with similar geologies, road gullies and washouts were determined to be the most prevalent sources of sediment delivery in many of the sub-basins of the WAU. However, foresters familiar with the Upper Eel WAU road system as it existed in the 1990s reviewed these estimated road gully and washout delivery rates, and indicated the rates may be over-estimated. Given the large relative magnitude of this source, this adds uncertainty to the sediment yield estimates.

5.4 RIPARIAN FUNCTION: WOOD AND SHADE

Riparian function can be defined as the interaction of various hydrologic, geomorphic, and biotic processes within the riparian environment (WDNR 1997). Riparian areas are transition zones between terrestrial and aquatic ecosystems and provide important functions for stream ecology, including temperature regulation and input of Large Woody Debris (LWD), organic matter, and nutrients (Gregory, Lamberti et al. 1987). Riparian forests both affect and can be affected by the active stream channel as well as by geologic and topographic features. Riparian forests affect stream channel complexity, bank cohesion, fish and wildlife habitat, thermal factors determining stream temperature and riparian microclimate, and the aquatic and terrestrial food web in the form of insect and organic matter (Figure 5-6). These processes may be lost or degraded as riparian vegetation is altered in size, density, or species composition (USDA 1995).

Figure 5-6. Diagrammatic representation of functional roles of riparian zones



Source: Lamberti and Gregory 1989. (Figure C-1, Riparian Module)

5.4.1 Riparian Assessment

To determine the current and future LWD recruitment functionality and micro-climate value of riparian areas in the HCP area of the WAU, the species composition, tree size, stand density, and overstream canopy cover were assessed using field-verified air-photo analysis as described in the Riparian Function Assessment (Appendix C). The assessment area includes 100 feet on each side of a Class I or II watercourse, beginning at the edge of the bank-full channel width, or the channel migration zone, where present, on larger streams and rivers (e.g., Figure 5-2). In all, 4,015 acres of Class I and II riparian forest was classified in this manner. The assessment classifies forests into 27 categories based on overstory species composition (redwood or Douglas fir conifer, hardwood, or mixed); tree size (large, medium, small); and stand density (dense, moderate, or sparse). Each of these categories has a general interpretation of current and potential LWD recruitment potential based on assumptions of growth and stand mortality as they affect the recruitment rate of properly sized trees to the streams. The general ratings are high (good potential for recruiting large conifers now), moderate (good potential for recruiting large conifers within 50 years), and low (low potential for recruiting large conifer for a long time, if ever, into the future). The stand characterizations and ratings are provided in Table 5-2.

Table 5-2. RCU code crosswalk to LWD recruitment potential.
(H is high, M is moderate, and L is low)

Species	**Size Class/Canopy Closure**								
	Large (>24")			**Medium** (12-24")			**Small** (<12')		
	Dense	Moderate	Sparse	Dense	Moderate	Sparse	Dense	Moderate	Sparse
Conifer (>66%)	H	H	M	M	M	L	M	M	L
Mixed (33-66%)	H	M	L	M	M	L	M	L	L
Hardwood (>66%)	M	L	L	L	L	L	L	L	L

Table C-12, Riparian Module

The fundamental assumptions behind the potential rating are that:

- Conifers are better than hardwoods for providing instream functions;
- Larger trees are needed to provide hydraulic roughness and influence channel morphology, especially in moderate to larger size streams; and
- Dense stands are necessary for trees to die of natural mortality, the assumed primary mechanism of recruitment in natural conditions.

Stands meeting these criteria are currently or likely to reach recruitment goals within the next several decades. Younger stands will grow and, thus, recruitment may be high in the future but it will take time to reach goals. Hardwood-dominated stands, sparse stands, and small trees are not likely to reach goals within the next 50 years. The riparian goal for PALCO's HCP is that the average conifer tree size in the riparian area is to exceed 24 inches Diameter at Breast Height (DBH). It is especially important that forests along Class I streams so that when trees are recruited to the stream, they can influence salmonid habitat.

5.4.2 Riparian Forest Composition

PALCO lands in the Upper Eel WAU are located in the general vicinity of the confluence of the mainstem Eel River and South Fork Eel River. The western portion of this ownership is located within the cool moist coastal zone where fog surges up the Eel River valley almost daily in the summer, often referred to as the "coastal fog belt." Redwood forests historically and currently dominate the riparian and upland forest in this region. The eastern portion of the ownership lays further inland where the marine air influence is overcome by inland heating. These forests are historically and currently dominated by Douglas fir and hardwood species better suited for drier climates.

Old growth forests were common throughout the region prior to the start of logging in the early 1900s. Some magnificent old growth forests still exist within Humboldt Redwoods State Park located within the general boundaries of the WAU. The stands along Bull Creek and the South Fork Eel contain some of the tallest living redwoods (Photograph 5-3).

Logging in the area encompassed within the Upper Eel WAU progressed through the 1900s using the traditional methods of the time. These were high impact practices, resulting in nearly complete removal of riparian forest stands and considerable disturbance within the stream channels. In many locations the stream corridors were used as transportation corridors with railroads and skid roads built directly in them (e.g., Photographs 5-1 and 5-2). Virtually all of the riparian forests in the WAU have been cut at least once during the 100 years of forest management in the watershed. Early logging and ranching operations since the late 19th century had no special provisions for management activities around streams and have resulted in significant alterations to pre-existing riparian stand and in-stream wood loading conditions.

Photograph 5-3. Old growth riparian forest along Bull Creek, a tributary to the South Fork Eel River in Humboldt Redwoods State Park

Adoption of the first set of Forest Practice Rules in the 1970s changed the manner by which riparian forests were managed. Timber harvest was allowed in the riparian areas under the forest practice regulations until the 1980s. Since that time, riparian areas have harvest and equipment prohibitions.

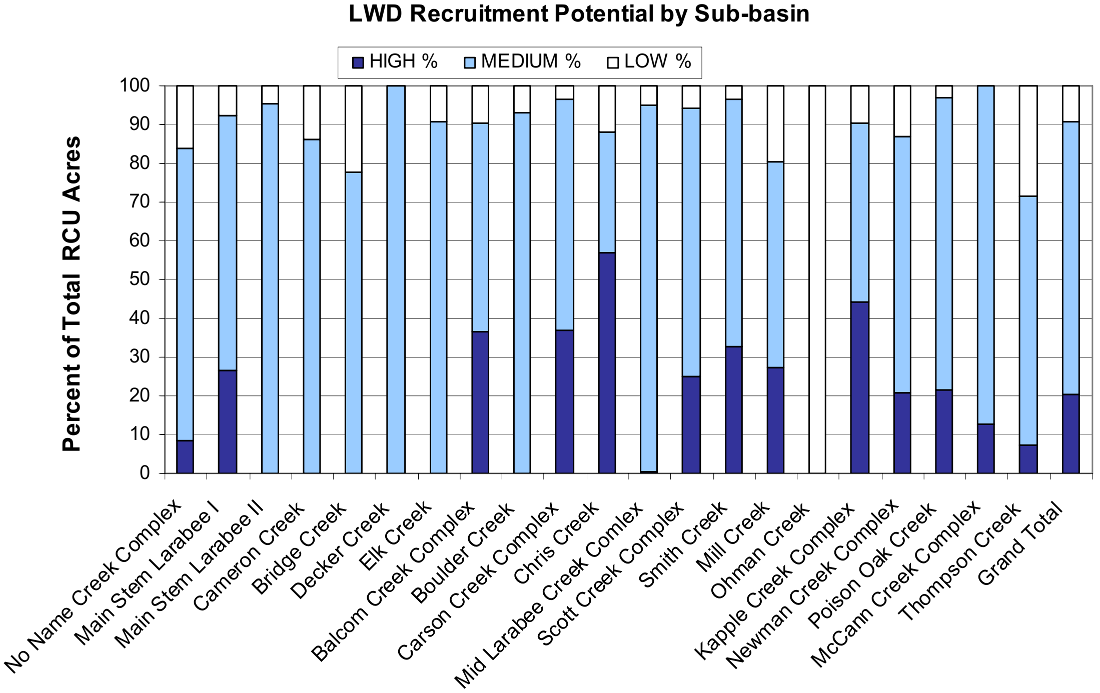
The forest ecosystem is dynamic and, because of lengthy intervals between timber harvests (i.e., 50-60 years on average), recovery from impacted conditions can and does occur. Natural regeneration of riparian forest stands harvested in the first half of the century has created the relatively even-aged conifer-dominated stands present today. These riparian stands are for the most part densely stocked with 125 to 200 conifer stems per acre ranging from 12 to 30 inches at DBH. Photographs 5-4, 5-5, and 5-6 show redwood dominated second growth redwood riparian areas along Class I waters in several streams within the WAU.

Photograph 5-4. Riparian forest along fish-bearing reach of Carson Creek

Photograph 5-5. Riparian forest along the fish-bearing reach of Chris Creek

Photograph 5-6. Riparian area along the lower reaches of Newman Creek

Figure 5-7. Percent of LWD Recruitment Ratings between sub-basins in the Upper Eel WAU



Source: Figure C-5, Riparian Module

The distribution of riparian forest recruitment potential for Class I and II streams in each sub-basin is shown in Figure 5-7. These riparian forests are found distributed throughout the WAU, and are prevalent along several of the most important reaches for coho fish habitat. Approximately 20% of the riparian forest area along Class I and II streams is occupied by moderately to densely spaced dominant and co-dominant trees greater than 24 inches DBH, which indicates high recruitment potential. The riparian forests shown in Photographs 5-4, 5-5, and 5-6 are classified as having high recruitment potential.

Another 70% of the riparian forest is similarly occupied by moderately to densely spaced dominant and co-dominant conifers (mostly redwood), but is slightly younger in age and smaller in size with trees typically ranging from 12 to 24 inches at DBH. This stand type, due to its smaller individual tree size, does not currently meet riparian goals but is rated as having moderate recruitment potential as it can provide functional wood for Class II and smaller Class I streams and is projected to achieve Properly Functioning Condition (PFC) matrix targets through growth within the remaining life of the HCP. Thus, the near- and long-term LWD recruitment potential for riparian forests in the HCP area of the Upper Eel WAU shows an advanced stage of recovery from historical streamside harvesting, with most riparian areas not currently meeting PFC matrix targets on track to do so within the life of the 50-year HCP.

There is a small amount of riparian forest on the PALCO HCP ownership dominated by hardwood species (Figure 5-7). These are nearly all located along Class II streams. It should be noted that most conifer-dominated riparian forests in the WAU have at least some hardwood component, often in the seasonally inundated areas immediately adjacent to the stream. The presence of hardwood as a minor component can increase biological diversity and add needed nutrients to the stream. Hardwood species such as red alder, big-leaf maple, willow, black cottonwood, and tanoak help to maintain a healthy prey-base for fish and amphibians due to more easily decomposed litter fall, increased terrestrial insect fall, and nitrogen fixation beneficial to aquatic invertebrates. However, hardwood dominated stands are not likely to recruit long-term functional LWD to streams for a century or more. There is little evidence of any significant land use-influenced transition from conifer to hardwood occupancy on HCP-covered lands as nearly all of the riparian forests adjacent to Class I streams have a significant conifer component.

Photograph 5-7. Thompson Creek riparian forest hardwood-dominated stand with low recruitment potential

The riparian conditions along the lower fish-bearing reach of Thompson Creek represent the most impacted condition relative to LWD recruitment potential due to hardwood species composition (Photograph 5-7). As a result of intensive logging operations conducted in the late 1980s and early 1990s, the riparian situation along this stream reach is dominated by a young and, therefore, relatively small diameter (less than 12 inches DBH), mixed conifer/hardwood forest with large (24 to 48 inches DBH and greater) with residual timber occurring infrequently throughout. While a dense canopy cover exists in the immediate vicinity of the stream, the outer edge of the riparian assessment area has a sparse canopy cover due to the influences of the approximately 15-year-old clearcut. As a result, approximately 40 percent of the total riparian stand situated along the fish-bearing reach of Thompson Creek has a low recruitment potential. Significant LWD recruitment from this area is unlikely within the next 40 years.

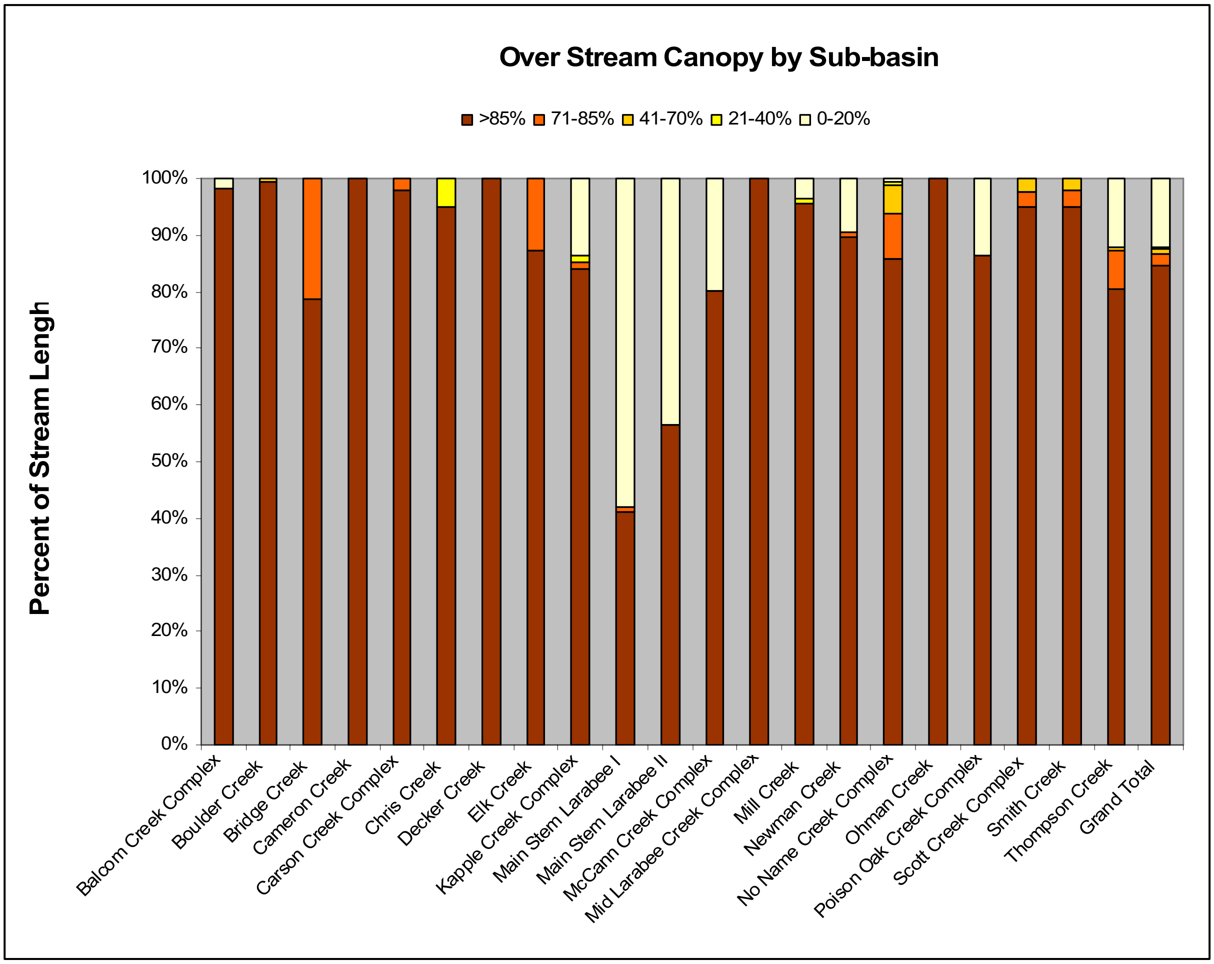
Approximately 12 percent of the Class I riparian stands are not likely to achieve the PFC riparian LWD recruitment goals within the next 40 years (Figure 5-7). This is due to one or more of the following elements: sparse stocking (less than 40% canopy cover), young age/small size, and/or hardwood dominance. The relatively minor amount of Class I riparian area exhibiting low LWD recruitment potential is due primarily to young stand ages resulting from timber harvest activities conducted in the 1980s when Forest Practice Rules allowed removal of the majority of larger trees located along Class I watercourses.

The results of this assessment indicate tree size is currently the critical limiting factor for recruitment of fully functional "key-piece" size LWD to fish-bearing streams. Based on current conditions and established growth rates, nearly 90 percent of the riparian forests will meet or exceed the riparian composition goal within 40 years. Greater than 25% of the Class I riparian forests in the following sub-basins currently exhibit high recruitment potential due to more mature stand conditions: Balcom Creek Complex, Carson Creek Complex, Kapple Creek Complex, Newman Creek Complex, and McCann Creek Complex.

5.4.3 Canopy Closure

Another important function of the riparian forest is to provide shade to the stream to help maintain cool temperatures. The general condition of riparian forests in the WAU is conducive to having full canopy closure as allowed by the stream width. The riparian forests are generally dominated by dense conifer forests with trees of moderate to large diameter and height. Streams in the sub-basins in the WAU are small with narrow channels ranging from 10 to 30 feet. This size stream is reasonably well shaded by even young forests (less than 30 years) that are relatively short in height. Therefore, shade is at potential from the standpoint of shade even when trees have not reached full potential height. Even under current riparian stand conditions, stream temperature in the tributary streams is likely minimized to the extent it is affected by riparian canopy. Figure 5-8 shows the proportion of stream length in each sub-basin in each canopy closure class. Most have full or nearly full canopy closure for the entire length of streams in the sub-basin. Nearly all of the sub-basins have canopy closure exceeding 85%. The streams shown in the photos all have high canopy closure.

Figure 5-8. Overstream Canopy Cover by Sub-basin



Source: Figure C-8, Riparian Module

It is important to note that canopies may look more closed in aerial photography than they may measure from underneath for view-to-the sky using such instruments as the spherical densiometer.

The major exceptions to full canopy closure are the mainstems of Larabee Creek and the Eel River. In the middle portion of Larabee Creek, the channel width is approximately 80 feet; farther upstream near the upper extent of PALCO ownership, the channel width is approximately 50 feet. The mainstem Eel River is hundreds of feet wide. In the alluvial lower reach of Larabee Creek (Photograph 5-8), the riparian forest in the floodplain is within one of the areas that was highly disturbed during the 1964 flood and does not generally provide shade to the stream. In the tightly constrained reach (upper left of Photograph 5-8), the stream is narrower and the riparian forest provides more, though not complete, shade. Throughout the reach, the riparian conifer trees are small to mid-sized. Larabee Creek appears to be well established within a stable channel and does not appear to be actively migrating across the floodplain. However, the low floodplain in the channel migration zone is only slowly re-vegetating. Shade and LWD recruitment will be limited in this section of river for a considerable length of time. This photograph marks the upper extent of the channel migration zone shown in Figure 5-2 (rightmost white area). This condition extends downstream to a greater or lesser extent on nearly the entire length of Larabee Creek shown in the photograph.

Photograph 5-8. Larabee Creek example of disturbed riparian area open to the sky

5.5 SALMON HABITAT DISTRIBUTION

5.5.1 Low Gradient Alluvial Channels

Contiguous reaches of low gradient response reaches (less than 4% channel gradient) that are connected to the Larabee Creek and mainstem Eel River migratory corridors constitute the most important potential spawning and rearing tributaries for anadromous salmonids within the WAU and will be the focus of this analysis in this cumulative effects report. These channel types are also the most responsive to changes in sediment and LWD input in the contributing watershed (Montgomery and Buffington 1993).

A notable feature of this WAU is that there is relatively little available low gradient stream channel. From their mouths headward, the streams cross the Wildcat group for relatively short lengths, and then abruptly increase in gradient when they cross the Yager formation that overlies the Wildcat. Those tributaries that drain directly to Larabee Creek and originate entirely within the Yager terrane are steep, immediately from their junction headward (e.g., streams in the Scott Creek complex). Location of response reaches relative to geologic type is shown in Figure 5-9. Length of response reaches by stream is shown in Figure 5-10.

The lower gradient Wildcat group tributaries contain the most suitable habitat for anadromous salmonids in the WAU, especially for coho. Although bedrock in the Wildcat tends to be very fine-grained (mudstones and siltstones), the habitat in these streams is enhanced by the gravels supplied from the more competent Yager Formation found upstream in their headwaters. Only Chris Creek is formed entirely on Wildcat. Thus, gradients are low and substrates are typically of good size for spawning habitat and occur in abundant quantities. Newman Creek and Thompson Creek provide the most abundant fish habitat in terms of overall fish-bearing stream miles.

A notable exception is Elk Creek, which is a tributary to the South Fork Eel River. Elk Creek contains over three miles of low gradient fish-bearing habitat as it crosses the Yager geologic formation. This low-gradient stream in Yager terrane has a much larger watershed than Wildcat tributaries. The Stream Channel Assessment (Appendix D) describes the characteristics of streams related to geologic and geomorphic position in greater detail.

Figure 5-9. Response reaches (channels <4% gradient) and geology in the Upper Eel WAU

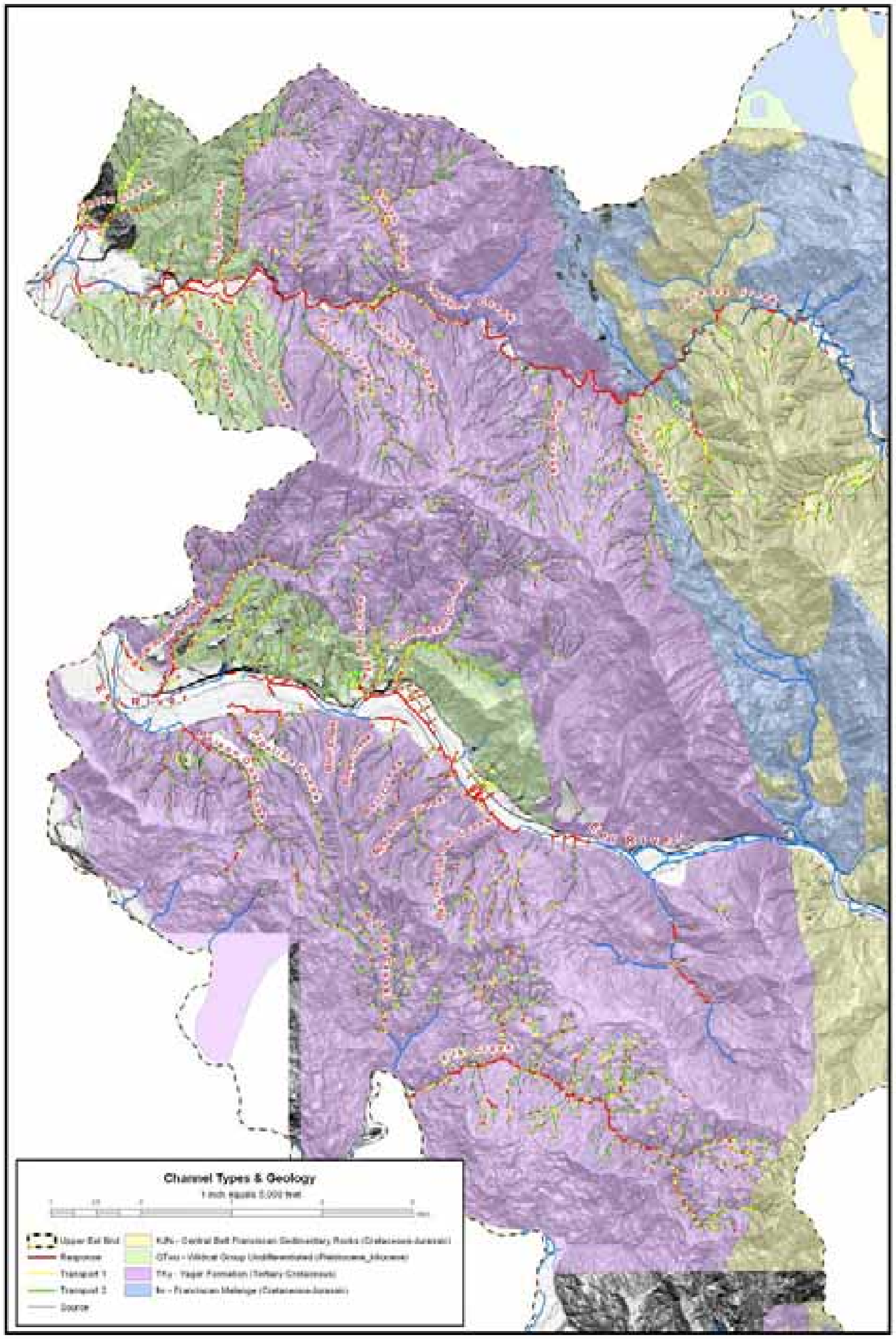
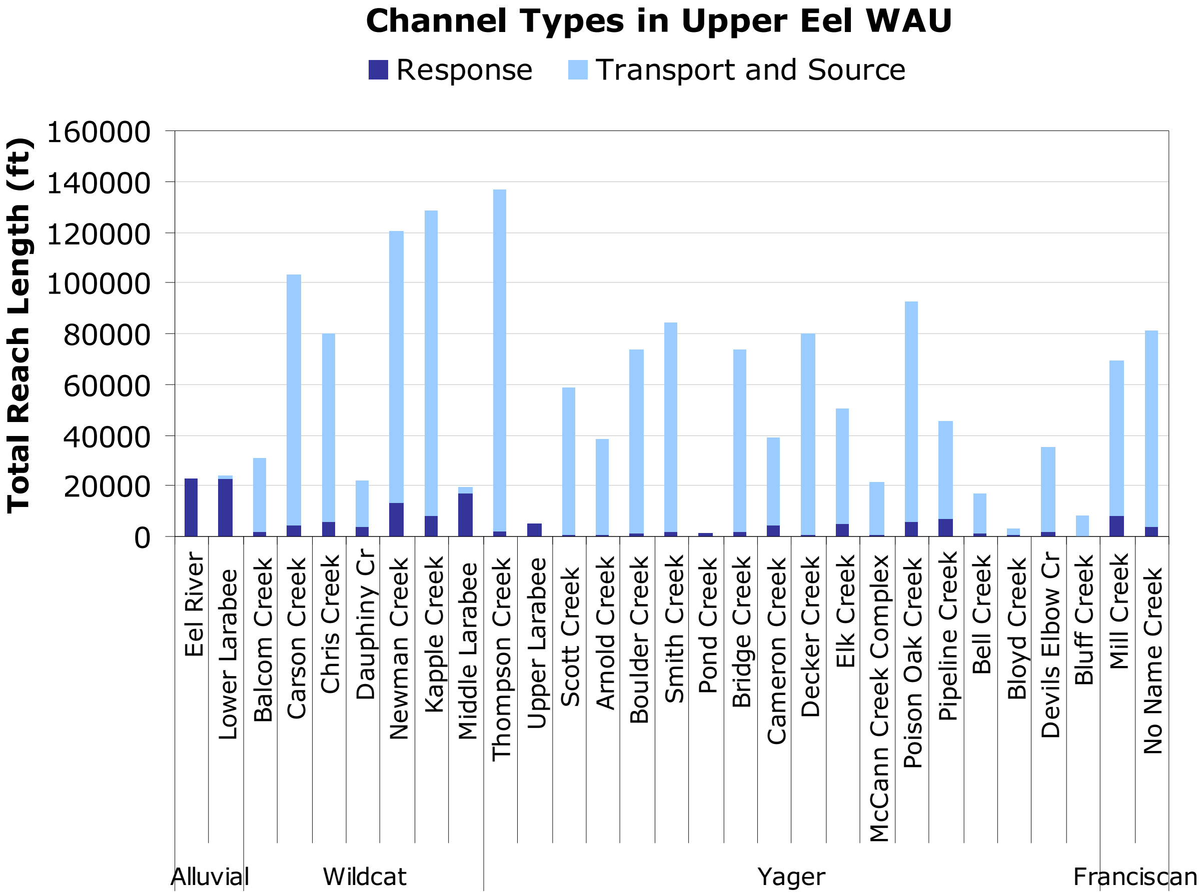


Figure 5-10. Length of channel types (Montgomery and Buffington 1993) by stream within the Upper Eel WAU



Response reaches have stream gradients <4%. Transport and source reaches combine all other channel length.

Of the total stream length in the Upper Eel WAU, including the Eel River, 52% of the stream length is in response reaches. However, 44% of the total is found in the mainstem segments of the Eel River and Larabee Creek. If only Larabee and the tributary streams are considered, only 8.4% of the channels are low gradient response reaches (130,944 ft or 24.8 miles). The mainstem of Larabee has nearly 30% of all the response reach length in the Upper Eel WAU. Of the total response reach length in Larabee and the tributaries, 36% occurs in streams in the Wildcat group. The length is disproportionately large relative to the area in this geologic type in the Upper Eel WAU (Figure 5-9). There is very little length of response reaches on streams in the Yager terrane. The small amount that is listed for some of these watersheds may actually exist as alluvial reaches or, in the case of Thompson Creek, represent reaches where the stream crosses a short length of Wildcat before joining the Eel River. The streams on the eastern side of the WAU in the Franciscan Complex also have higher proportions of response reaches than Yager-associated streams. This makes it important for potential habitat for salmonids. The length of response reaches is nearly identical to the length of Class I streams in the Upper Eel WAU, although these two lengths often differ from stream to stream because of blockages. In some cases, natural barriers do not allow response reaches to be occupied, so suitable habitat remains unoccupied. In other cases, fish are found using habitat in steeper transport reaches. When summed at the watershed scale, the lengths of response reaches and fish-bearing streams are nearly equal.

5.5.2 Salmonid Migration and Distribution

Salmon migrate from the ocean up the Eel River and into tributaries where they spawn. The Upper Eel WAU is located only 26 miles from the ocean and has no natural or anthropogenic blockages to migration within these mainstems of the Eel River or Larabee Creek (Photograph 5-9). Although temperatures are warm within the mainstem during the summer, they do not form a migration barrier.

One or more salmonid species distribute themselves throughout the suitable habitat in the WAU. Chinook salmon inhabit Larabee Creek up to the Smith Creek gorge as well as Newman, Carson, and Elk Creeks. Coho salmon are rarely documented. They have been found in low numbers in Poison Oak Creek. Coho may also inhabit Carson, Newman, and Elk creeks, but sightings are few and measurements even more rare. Coho also seasonally inhabit Larabee Creek and the Eel River during migration periods. Gravels in the mainstem and South Fork Eel River are suitable for spawning, but the spawning capacity of the mainstem Eel is unknown.

Photograph 5-9. Main migratory route of salmon into the WAU—the Eel River

However, the high winter flows that commonly exceed 100,000 cfs may scour redds and may be a prohibitive factor in the reproductive success in the mainstem, except perhaps in instances of low winter flow years. The mainstem Eel, and lower alluvial zone of Larabee Creek, also have robust populations of warm-water species such as pike minnow that prey on juvenile salmonids, further challenging population success.

Steelhead is the most widely distributed and abundant anadromous salmonid in the WAU. Steelhead are distributed throughout the WAU up to natural anadromous barriers. Juvenile (age 2+) steelhead have been observed with regularity in these microhabitats in the assessment area during the summer months.

Although lower gradient response reaches provide the best and most productive habitat at a population scale, steelhead or resident trout may be found in streams as steep as 15 to 20% gradient. Fish-bearing streams upstream of the low gradient response reaches are small, shallow, and limited in usable habitat. Steeper transport reaches (4 to 15% gradient) are dominated by steep channel units (step-pools and cascades). Often the uppermost reaches are inhabited by resident trout that spend their entire life in freshwater. The natural uppermost extent of fish occurrence is usually found at high gradient cascades, waterfalls, or bedrock steps. Photograph 5-10 shows a typical uppermost location of salmonids in the Yager terrane. In this case, a waterfall prevents further upstream migration. This is a common upstream migratory barrier in streams formed on the Yager terrane within some areas of the WAU (e.g., the Scott Creek complex). Uppermost distribution may also occur where streams are simply too small and too shallow to support fish. Within a given geologic unit, this point often occurs in similar topographic and basin size situations. The stream lengths containing fish are classified as Class I streams and require habitat protection. Streams were sampled to identify the upper extent of fish distribution in many locations in the WAU. Results are presented in the Fish Habitat Assessment (Appendix E).

Photograph 5-10. Typical location of the upstream extent of fish on Yager terrane

5.5.3 Migration Barriers

Fish distribution surveys identified locations in the watershed where migration to suitable habitat is blocked. Culverts were identified at road and railroad stream crossings that create what appear to be complete or seasonal barriers to upstream migration (Photograph 5-11). A number of characteristics can render a culvert crossing impassable to fish. These include, but are not limited to: excessive water velocities within the culvert; excessive drop at the outlet, resulting in too high of an entry leap or too shallow of a jump pool below a crossing; lack of water depth within the culvert; excessive water velocity at the culvert inlet; and debris accumulation in the barrel of the culvert (Taylor and Love 2003).

Photograph 5-11. Lower Poison Oak Creek highway crossing as an example of early construction practices at stream crossings—this culvert is not a barrier to passage during low flows

A number of these barriers occur along the railroad and highway transportation corridors that follow the Eel River valley along portions of their routes. Transportation crossing barriers were identified on Chris (Larabee Ranch road), Pipeline (railroad), Bell (railroad), McCann (county road), and Bloyd (railroad) Creeks. Refer to Table E-1, Map E-3, and the sub-basin summaries provided in Section 4.0 of the Appendix E (Fish Habitat Assessment Report) for a description of these barriers and the opportunities for restoration that exist.

These blockages have reduced the distribution of fish in the WAU from historically occupied locations. Much has been learned about how to build passable structures since the roads and railroads were originally built. There are opportunities for increasing access to existing fish habitat by removing or modifying these migratory barriers. These opportunities are predominantly in non-PALCO ownership, with benefits to streams flowing through PALCO ownership.

A naturally occurring probable anadromous barrier in the form of a large redwood log exists 850 feet up from the mouth of Carson Creek, inhibiting access to 2,200 feet of anadromous habitat. PALCO could increase access to this additional habitat by notching a passageway in the redwood log.

5.6 CURRENT CHARACTERISTICS OF STREAM CHANNELS AND FISH HABITAT

Sediment load, water discharge, and structural elements—the controlling independent variables of channel morphology—determine the shape of the channel and habitat along the stream network. Salmonid habitat is determined by the hydraulic characteristics of streamflow; therefore the shape, gradient and roughness of channels, and the volume of flow all play a part in determining habitat availability. Channel form reflects a balance between the channel's capacity to carry sediment away from that point and the influx of sediment to that point. A stable channel is one for which morphology, roughness, and gradient have adjusted to allow passage of the sediment load contributed from upstream (Sullivan et al. 1987). However, a stable channel does not necessarily ensure good habitat conditions, as the channel will adjust to higher or lower volumes of sediment and wood input. Each combination of sediment input and LWD loading will have characteristic and persistent channel morphology (Montgomery and Buffington 1993).

Most of the readily available sediment in moderate to large streams is stored within low gradient response reaches in gravel bars—sediment accumulations within the channel that are one or more channel widths long. Shallows over bars are known as riffles; deeps located between the bars are pools. In steeper and narrower channels within transport reaches, bars are absent and gravels deposit in small patches around obstructions. Woody debris forms abundant storage sites for sediment in forest streams in channels with 1 to 4% gradient, where storage is otherwise limited by steep gradients and confinement of channels between valley walls. Channel obstructions, ranging from single logs lying along a stream bank to major bedrock bends, greatly diversify channel morphology and hydraulic conditions and add to channel stability (Keller and Swanson 1979). By influencing hydraulic conditions, these structural features store and sort sediment, enhance scour and deposition of the bed material, diversify velocity and depth, and fix the positions of bars and pools (Lisle 1986; Bilby and Ward 1989).

Forest management can affect channel morphology by changing the amount of sediment or water contributed to streams, thus disrupting the balance of sediment input and removal. Excessive input of sediment can aggrade the channel and change the composition of the streambed. Removing LWD from channels reduces sediment storage and eliminates the local hydraulic variability associated with the obstruction. Loss of habitat diversity and quality by either mechanism may reduce or change the fish species found in a stream reach (Sullivan et al 1987).

PALCO's HCP contains numerical targets for stream conditions that indicate suitable salmonid habitat. The PFC criteria for in-stream habitat conditions were developed by the National Oceanic and Atmospheric Administration (NOAA) National Marine Fisheries Service (NMFS), based on research conducted throughout the Pacific Northwest in 2nd to 4th order streams. The list of criteria, termed the

PFC matrix, establishes goals for streambed (spawning gravel) and channel (rearing habitat) conditions, in-stream LWD, water temperature, streamside riparian forest conditions associated with microclimate including shade canopy, and LWD recruitment potential. Some of the criteria are qualitative while a number of others are numeric.

At this time, the habitat objectives in the PFC matrix are generally “one-size-fits-all” thresholds. It is well established that stream characteristics such as width, depth, pool spacing, LWD functional size, and shade potential are directly proportional to channel size (usually indexed by channel width) (Bilby and Ward 1989, Montgomery et al 1995, Welty et al 2002). Thus, it is likely that PFC targets cannot be expected to apply to streams of all sizes, including the mainstem streams in the Upper Eel WAU. Variation dependency on stream size is especially important in this WAU because it encompasses large mainstem rivers. PALCO channel monitoring methods are drawn from methods used in these same studies, and their application is also limited to moderate sized streams. Habitat data from the larger rivers in the Upper Eel is very limited.

Natural factors in this region may also influence the applicability of PFC criteria developed elsewhere in the Pacific Northwest. Underlying lithology will influence the sediment characteristics of the streambed due to the erodibility of the bedrock. The native forest vegetation, including the unique qualities of redwood, is likely to influence conditions of LWD loading rates and volume. Despite these limitations, the PFC targets are a useful guide for assessing the quality of salmonid habitat.

The PFC matrix has over 35 criteria in narrative or numeric form. In this summary, we report on a selected group of the mostly widely recognized parameters for sediment, gravel, pool characteristics, LWD, and water temperature. Values for other parameters in the matrix are provided for individual streams in Attachment 3 and discussed in various modules (Appendices C, D, and E).

Habitat conditions have been quantified throughout the WAU with a series of habitat surveys and monitoring projects conducted over the last four decades. The methods and intensity with which certain habitat conditions were measured varies with project and are described in the Fish Habitat Assessment (Appendix E). These include an in-stream habitat and LWD inventory conducted in 2005; electrofishing surveys to determine upper extent of fish use; PALCO Aquatic Trend Monitoring (ATM) sites that provided detailed streambed, habitat and temperature information over a period of recent years; CDFG stream surveys conducted in 1963 and 1981; and surveys performed on the mainstem Eel River as part of gravel extraction projects.

Although methods vary among the projects, we set aside differences that arise from measurement techniques and annual variability in this analysis and combine information in order to achieve a broader perspective of conditions in space and time. Some errors will occur by ignoring the variability induced by climate and methodological differences. In this cumulative effects analysis, we strive to make no interpretations that are less than the variability introduced by methodological issues, using judgment based on experience with the study of watershed processes and from the scientific literature.

All of the surveys assess the basic qualities of pools as a fundamental element of salmon habitat. Surveys conducted since 1980 also include woody debris measurement. However, the surveys range from infrequent, light intensity counts made over large portions of the fish-bearing stream network to intensive, frequent measurements at permanently established plots in a few locations (see Appendices D and E). Large woody debris within the stream channel is measured to determine the number, size, volume, and spacing of large wood available for creating fish habitat as well as its influence on channel morphology. Channel morphology is characterized by measuring the area, residual depth, and spacing of pools. Streambed gravels are sampled in a few locations. The characteristics of the streambeds are measured by sieving samples dug from the bed and sampling the surface sediments to determine the size distribution of particles.

5.6.1 Streambed Sediment and Pool Habitat Characteristics

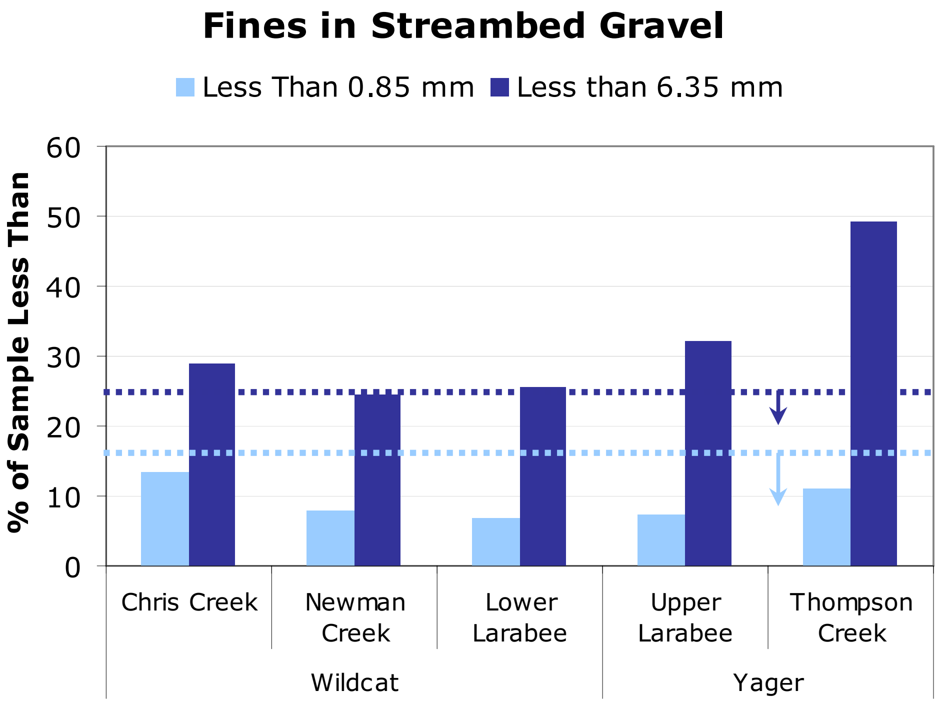
Sediment is an important and vital component of in-stream habitat. Gravels deposited in the streambed provide the nest where eggs are laid. Salmonids require sorted and well-distributed gravel reaches to spawn and rear successfully. The gravel must be reasonably free of fine sediment in order for eggs and embryo to survive and emerge as fry (Flosi, Downie, et al., 1998). Transport and storage of sand-sized and smaller particles is particularly important to the spawning habitat of salmonids as it influences the incubation environment. Fine sediment deposited on the bed surface may also interfere with feeding and growth of juveniles (Suttle et al. 2004).

The characteristics of sediment load imposed on the stream are determined by the nature of the sediment transport processes active on the hillslope and by the soil and bedrock types present. The type, amount, and timing of sediment input influences channel morphology. Each sediment delivery process produces characteristic volumes of grain sizes of sediment and each grain size has an influence on different aspects of habitat for fish and aquatic organisms (Everest et al. 1987).

There have been a number of habitat surveys in the Upper Eel WAU, but few have included sediment sampling. Streambed samples have been collected at only 5 locations in the WAU at PALCO long-term ATM sites. Three are located in the Chris, Newman, and Thompson Creek sub-basins and two sites were sampled in the mainstem Larabee. Because the monitoring methods used in the ATM program were inappropriate for the size and nature of the stream in Larabee Creek, measurement with the ATM methodology was discontinued. Since streambed data is so limited in the watershed, however, measures from these two mainstem sites are included in this discussion, with that caveat. Methods used in the ATM program also have undergone revision during the 8-year life of the project preventing identification of any trends that may have occurred in recent years. The 7-year pattern of data collected at the ATM sites is discussed in greater detail in the Stream Channel Assessment (Appendix D). There were no apparent trends within the 7 years since implementation of PALCO's HCP within the annual variation observed at each site. Therefore, short-term trends are not discussed further in this Cumulative Effects Report.

The quality of streambeds that relates to embryo survival is measured by the percent of the streambed gravel sediment sample less than 0.85 mm (Everest et al 1987). The PFC establishes a goal of less than 11 to 16% of the bed particles less than 0.85 mm as an indicator of suitable habitat for incubation. Figure 5-11 shows the composition of the bed samples at 5 ATM sites. Fines in the gravels are low and meet PFC targets at all of the sampling locations. Data from the sites are grouped by the dominant geologic unit in which the stream is located. There is no pattern in fines composition of the streambed related to geology or sediment yield in the watershed.

Figure 5-11. Percent of streambed gravel sample less than sediment size fraction, by sub-basin



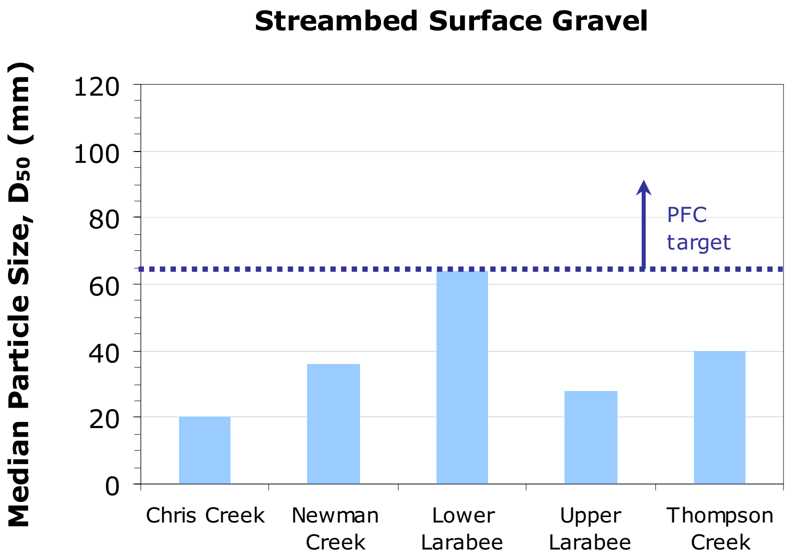
Light blue is sediment less than 0.85 mm, with PFC target of <11-16%. Dark blue is sediment less than 6.35 mm, with PFC target of <20-25%.

The quality of streambeds that characterizes the potential entrapment of alevins emerging from the streambed after incubation is the percent of the streambed gravel sediment sample that is less than 6.35 mm (Bjorn and Reiser 1991). The PFC establishes a goal of less than 20 to 25% of the bed particles smaller than this grain size. Figure 5-11 shows the composition of the bed samples less than 6.35 millimeters (mm) at the 5 locations. Particles less than 6.35 mm in streams in the Wildcat group are close to or meeting this target. Streams in the Yager terrane have high content of this size fraction and exceed the goal, indicating impairment.

Reduced sediment storage may translate to streambed conditions within the active channel. Thompson Creek has particularly high composition of particles less than 6.35 mm. Larabee Creek, where the sediment fluxes are particularly high, are at or near the target values. Larabee Creek has been shown to be generally flushing sediment at the valley scale over the past several decades.

The sediment fraction on the streambed surface is generally of small size. The PFC establishes a goal of a median surface particle diameter of 65 to 95 mm. Figure 5-12 shows the composition of particles on the surface of the bed at the 5 ATM locations. Median particle size of the bed surface of most of the streams are small for gravel-bedded streams, and well below the PFC target, suggesting the bed surfaces are embedded with fine grain sediments. Small surface particles may help explain the low fines in the streambed. Lisle (1989) noted that intrusion of fines into the gravel bed was inhibited by accumulation of fine sediments on the bed surface. Embeddedness of the surface may impact salmon productivity and growth (Suttle et al. 2004).

Figure 5-12. Median particle size (D_{50}) of the bed surface at ATM stations



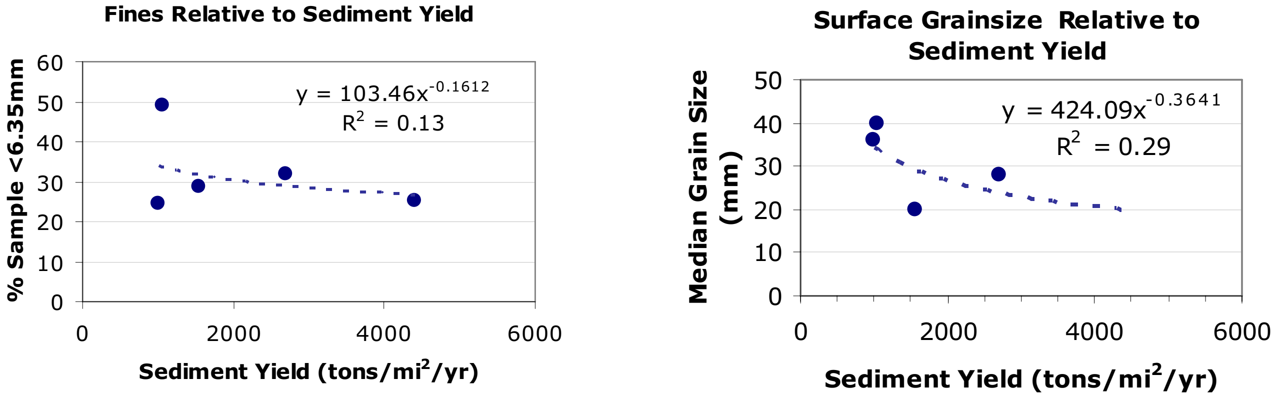
Only Lower Larabee Creek meets the goal for surface particle size. This result is again surprising given the high sediment input to this portion of the stream. Photograph 5-12 shows the streambed in the lower Larabee stream reach, and the surface clearly has an abundance of smaller gravel sizes on the bed surface. Although there is no scale in this photograph, an experienced surveyor in the Wolman pebble count method will recognize that the median grain size in this photograph is significantly smaller than 64 mm as reported in Figure 5-12.

Photograph 5-12. Streambed sediment at ATM site 2 on Lower Larabee Creek

It may be that sediments are sorted throughout the reach and sampling was not sufficient in this large stream to fully characterize the reach-averaged particle size (D_{50}). Thus, there is uncertainty associated with Lower Larabee sediment data.

The relationship of fines less than 6.35 mm and median surface grain size to sediment yield is shown in Figure 5-13. All five sites are included in the sub-surface streambed measurement (% less than 6.35 mm) and Lower Larabee data is removed from the surface streambed measurement (D_{50}) in consideration of the above caveat regarding sampling. There is a tendency for sediment yield to affect streambed characteristics at these sites. However, relationships are very weak and data is very limited. It is somewhat surprising that relationships are not stronger given the wide range in upstream sediment inputs affecting the 5 locations. Subsurface bed sediment (less than 6.35 mm) was greatest in a stream with relatively lower sediment yield. Sediment yield appears to have little effect on subsurface sediment size in the other four streams. The surface sediment size (D_{50}) shows something of a trend with sediment yield. Particle size of the bed surface tends to decline with increasing sediment yield, especially in the three tributary streams (points with sediment yield less than 2,000 tons/mi^2/year). A greater sample size over a wider distribution of sites will be needed to detect future trends in bed sediment.

Figure 5-13. Particle size in the streambed in relation to sub-basin sediment yield



Of the areas in the upper Eel that were analyzed, the mainstem reaches of Larabee have the largest sediment delivery rates, by a large margin. Therefore, it is somewhat surprising that the effect on streambed sediments is not greater given the high sediment load, although method issues may contribute to the results. However, it is important to note that the sediment yield numbers may also not represent the sediment load delivered to the Larabee Creek mainstem. The values reported are the inputs from PALCO-owned lands in a band along the mainstem. Although this area is an important local source of large amounts of sediment, the mainstem channel of Larabee is in equilibrium with the sediment and water supply from the entire contributing watershed area. Based on the sediment yields of the tributaries, and assuming the sediment yield from the watershed upstream of PALCO ownership is no larger, the actual sediment yield is likely to be closer to the average yield of the watershed (1,500 tons/mi^2/year).

Larger grain size armoring the surface of the streambed is the preferred condition in salmon streams. The bed surface grain size (D_{50}) was found to be small at the few sites measured in the Upper Eel WAU. A relationship between the grain size of the streambed and sediment yield suggests that bed surface grain size may decrease with higher sediment yields from the contributing watershed (Figure 5-13). This result is consistent with Dietrich et al. (1989), Lisle et al. (1993), and Buffington and Montgomery (1999), who suggest a fining of the bed surface accompanies high sediment loads. If these limited data are indicative of the watershed, reducing sediment inputs within the watershed should result in coarsening of the bed and improved habitat conditions and achievement of PFC targets.

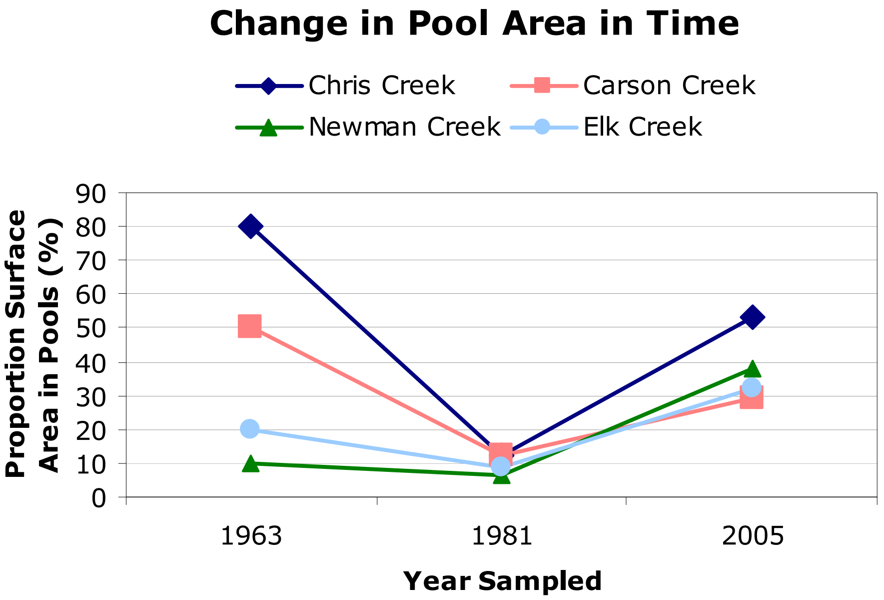
The availability of deeper slow-water habitats is important for providing adequate rearing habitat for juvenile fish. Pools are important, especially for rearing of juvenile salmonids. Pools provide space for juveniles to rear that is slow in velocity and deep to provide cover and space for older, larger age classes. Such habitat is necessary for juvenile rearing and, in some cases, adult holding during summer migration.

Many of the pools in forested streams form around structural elements (Sullivan et al. 1987). In the relatively steep channels typical of mountain rivers, LWD provides hydraulic roughness that interferes with flow, forcing the deposition of sediment and increasing the availability of pool habitat (Montgomery et al. 1995). Large obstructions, of which woody debris is often the most abundant in small channels, may fully or partially block the flow, thus regulating the scour and deposition of sediment and creating areas of high and low velocity in their vicinity. Pools vary in shape and size as a function of obstruction characteristics such as size, degree of channel constriction, vertical displacement relative to bankfull depth, and horizontal angle of deflection (Sullivan 1986). The hydraulic significance of an obstruction generally increases as its length and width relative to channel width increases. Stable structural features promote stable channels as long as the sediment throughput and flow regime are not too erratic (Sullivan et al. 1987). For streams to provide good habitat, pools need to be deep enough, of sufficient area, and frequently spaced. In moderate-sized fish bearing streams between 1 and 4% gradient, these characteristics will be strongly influenced by the amount of channel roughness, usually occurring in the form of wood, and the volume of sediment introduced from the watershed (Montgomery and Buffington 1993, Montgomery et al. 1995).

Every stream survey conducted in the Upper Eel WAU over the last 40 years has assessed pool characteristics, although the method and level of detail varies. CDFG habitat surveys assess most of the length of fish-bearing streams in a watershed by counting pools and taking basic measurements of wood piece size and frequency. Pools are measured in greater detail over short distances in the more recently established PALCO ATM sites.

Data on pool area was collected 3 times over a 40-year period in four streams in the WAU. Data was collected according to CDFG methods that were reasonably similar for the surveys conducted in 1981 and 2005. The methods used in a 1963 survey were less well documented, although riffles and pools were well recognized by this time (Leopold, Wolman and Miller 1964). The four streams include Chris Creek, Carson Creek, Newman Creek, and Elk Creek, all potentially important streams for coho in particular. Results are shown in Figure 5-14.

Figure 5-14. Portion of stream surface area composed of pools during three surveys conducted over a 40-year period in tributaries within the Upper Eel WAU



There was a distinct shift from pool-dominated to riffle-dominated channel morphology in the decades following the 1964 flood as evidenced in the 1981 surveys. The prevalence of riffles (or lack of pools) suggests channel filling and probably lack of LWD due to management and possibly loss during the 1964 flood. There was considerable influx of sediment due primarily to landsliding during this storm (Figure 5-1). Nearly all pools were eliminated in all of the streams following the 1964 storm, with the effects persisting at least 17 years after the storm event. Pool area improved in all four streams in the 2005 survey conducted 23 years after the previous survey and 42 years after the destructive storm. Pool area in Newman Creek and Elk Creek was low before the storm and has now increased to above its 1963 level. The portions of Chris and Carson Creeks in pools was high before the storm and is now 30 to 50%, but has yet to recover to 1963 levels. These four streams could differ in type and timing of management history at the time of the 1964 storm influencing the response in each. Newman and Elk Creeks may have already been in an impacted state at the time of the 1964 storm.

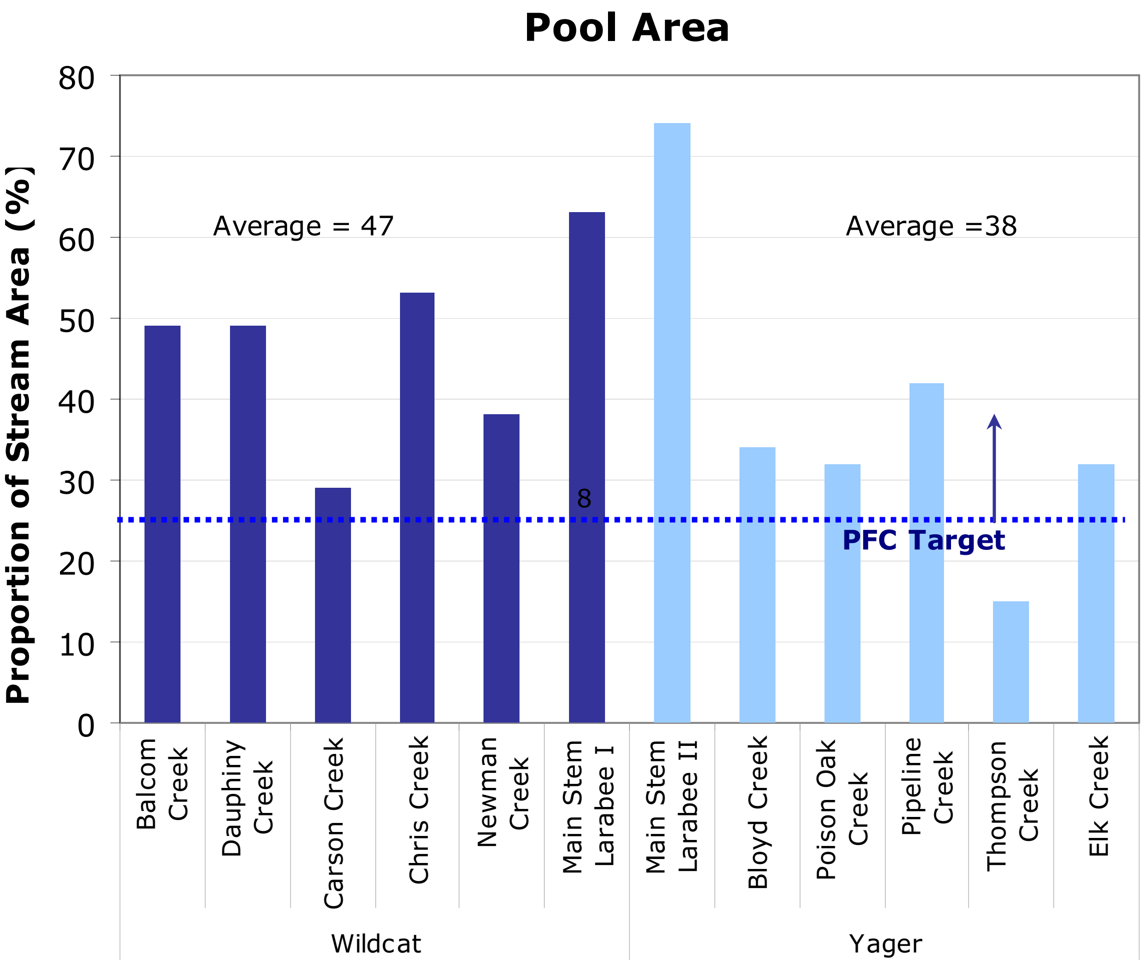
Importantly, the change in pool area after the 1964 storm, evident in Figure 5-14, demonstrates that the effects of increased sedimentation and stormflow were not just confined to the mainstem segments of Larabee Creek and the Eel River discussed earlier, but were widespread in the WAU sub-basins and smaller tributaries. The 1964 storm appears to have reset streams that previously had salmonid habitat to an impaired condition with increased sedimentation and significant loss of pool habitat.

Similar impacts and recovery associated with the 1964 storm have been thoroughly studied in Redwood Creek, a heavily impacted river in the northern California coastal region. Recovery of channel form and habitat following significant aggradation in the 1964 storm has occurred in the watershed, albeit slowly (Madej and Ozaki 1996, Madej et al. 2006). There may be many important lessons to learn from Redwood Creek with regards to Larabee Creek given the similarities in watershed size, impact, and sediment yields (Figure 5-4).

The amount of pool area measured in recent stream surveys in a number of streams in the WAU is shown in Figure 5-15. The PFC matrix establishes a goal of a minimum of 25% stream area in pools. Generally, a 50:50 ratio of pool area to riffle area would be considered a balanced habitat condition. (There is some risk from having too much pool area, in that riffles are the primary location for in-stream food production.)

Currently, all of the fish-bearing streams in the sub-basins, except Thompson Creek, exceed the minimum pool area. A number of the tributaries in the WAU are close to 50% pool area. There is a clear association of pool area with the dominant geology of the sub-basin. Streams in the Wildcat group currently average close to 50% pool area. Streams in the Yager terrane average 38% pool area, and 31% if the mainstem of Larabee is excluded.

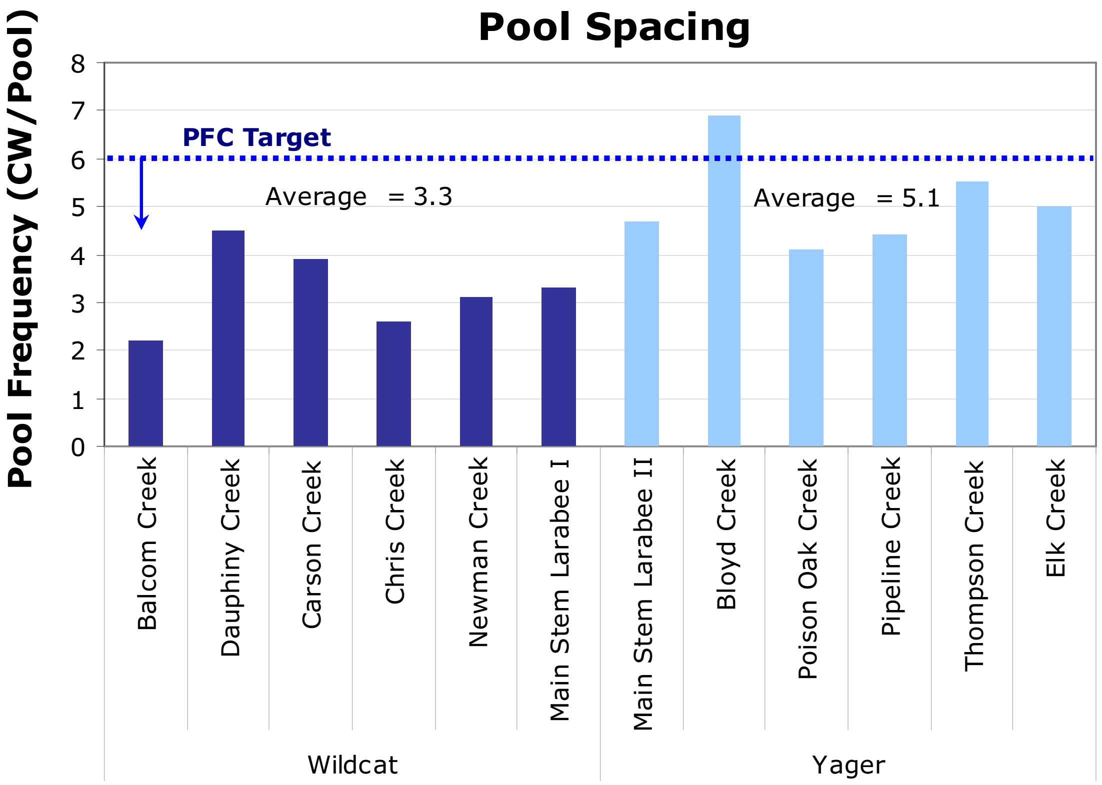
Figure 5-15. Proportion of stream area occupied by pools in 2005, shown by sub-basin



Preferred habitat conditions would have significant pool area located in many closely spaced pools, rather than in a few large pools. The PFC matrix specifies a maximum spacing of 6 Channel Widths (CW)/pool. A minimum spacing would be approximately 1 to 2 CW/pool (Montgomery et al. 1995). As with pool area, pool spacing is more frequent in streams in the Wildcat group than in the Yager terrane (Figure 5-16). All but Bloyd Creek have pools spaced closer than the maximum PFC target. Only Balcom Creek is currently near the minimum spacing of Montgomery and Buffington (1995).

In summary, streams in the Wildcat group have greater area located in more frequently spaced pools than streams in the Yager terrane. The association of pool spacing characteristics with geologic substrate is clear, although the underlying mechanism that explains the role that geologic substrate plays in determining pool area and spacing is not obvious.

Figure 5-16. The spacing of pools with distance along the channel expressed in units of channel width for pools in sub-basins of the Upper Eel WAU



The depth of pools is important for providing rearing space to larger age classes of salmon. PFC criteria call for average pool depths to exceed 3 feet. Only in the larger streams (Larabee Creek and the Eel River) are these criteria currently met. Average pool depth in most of the smaller tributary streams is typically only 1.5 feet. Pools in Newman Creek are notably shallow relative to other streams of similar size.

It is important to recognize that contributing watershed area will play an important role in determining channel dimensions. Stream size explains much of the variation observed in stream depth in the Upper Eel WAU streams. Figure 5-17 shows there is a strong relationship between the residual pool depth and the estimated bankfull depth of streams. Within the variation introduced by stream size, there is no indication of an influence of geology on pool depth (Figure 5-18). Many of the streams have cut down to bedrock and have only a thin lens of gravel substrate indicating pool depth is maximized. This may suggest that an increase in LWD loading in the future may enable some streams to achieve greater depth with greater storage of sediment. However, the average pool depth in proportion to the total bankfull depth is nearly 70 to 100% (Figure 5-17), suggesting that pools have already achieved substantial depth relative to the channel dimensions.

Figure 5-17. Relationship between residual pool depth and estimated bankfull depth for streams in the Upper Eel WAU

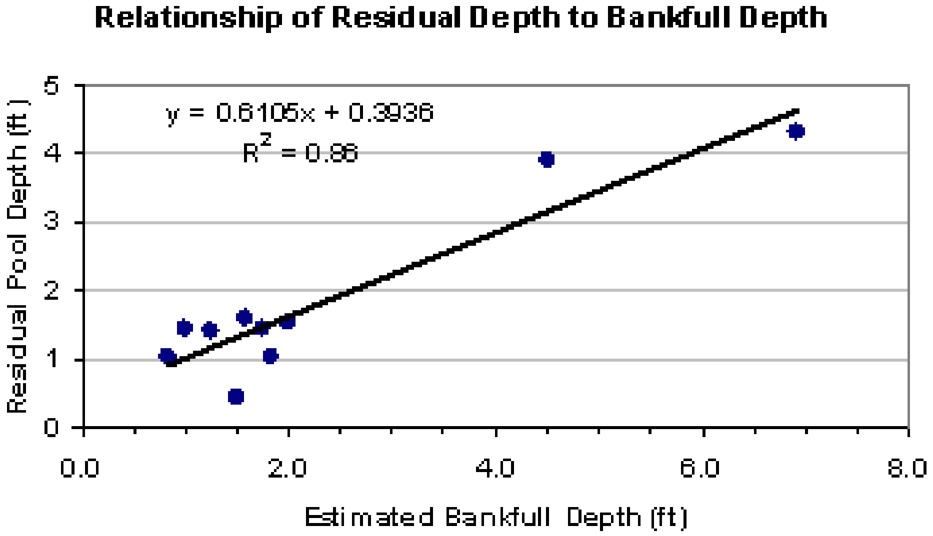
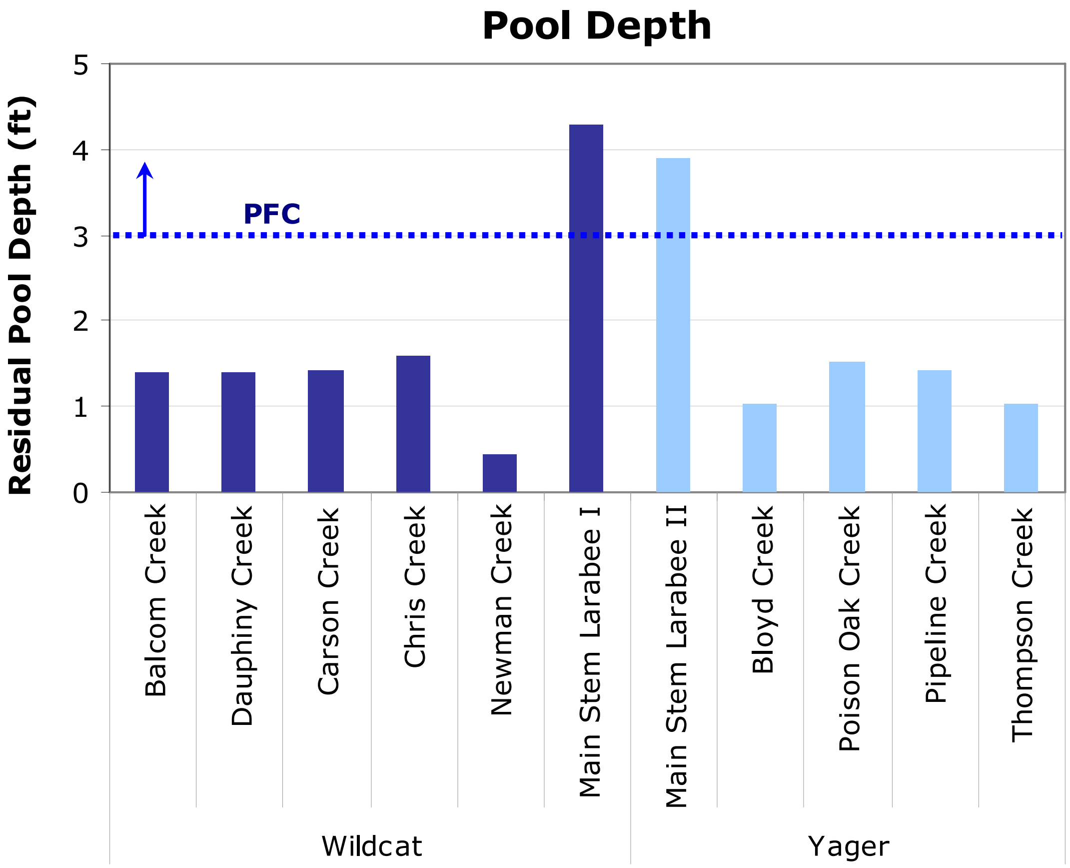


Figure 5-18. Average residual pool depth of streams in the Upper Eel WAU



Larabee Creek pools exceed the PFC target pool depths easily due to stream size, but also despite the influx of sediment documented following the 1964 event. The channel planform assessment indicates that sediment has been flushing from the system. That interpretation is supported by the presence of relatively deep pools observed in recent surveys.

Maximum pool depths are very deep in the Eel River. Channel surveys conducted in association with gravel extraction operations found deep pools ranging from 9 to 26 feet, with an average depth of 14.3 feet. Channel planform analysis found that this reach of the Eel River is continuing to experience ongoing aggradation. Therefore, these pools exist despite the influx of sediment that continues to affect the Eel River and the lack of large wood or jams to influence the channel morphology. The Eel River has low gradient (less than 1%) where gravel bars, riffles, and pools are self-forming rather than forced (Montgomery and Buffington 1993). Pools made up about 31% of the reach lengths surveyed in the Eel

River. Nevertheless, pool depths may still be shallower than they were historically before the storm events of the 1950s and 1960s. Comparison to PFC pool depth criteria is not appropriate for the Eel River.

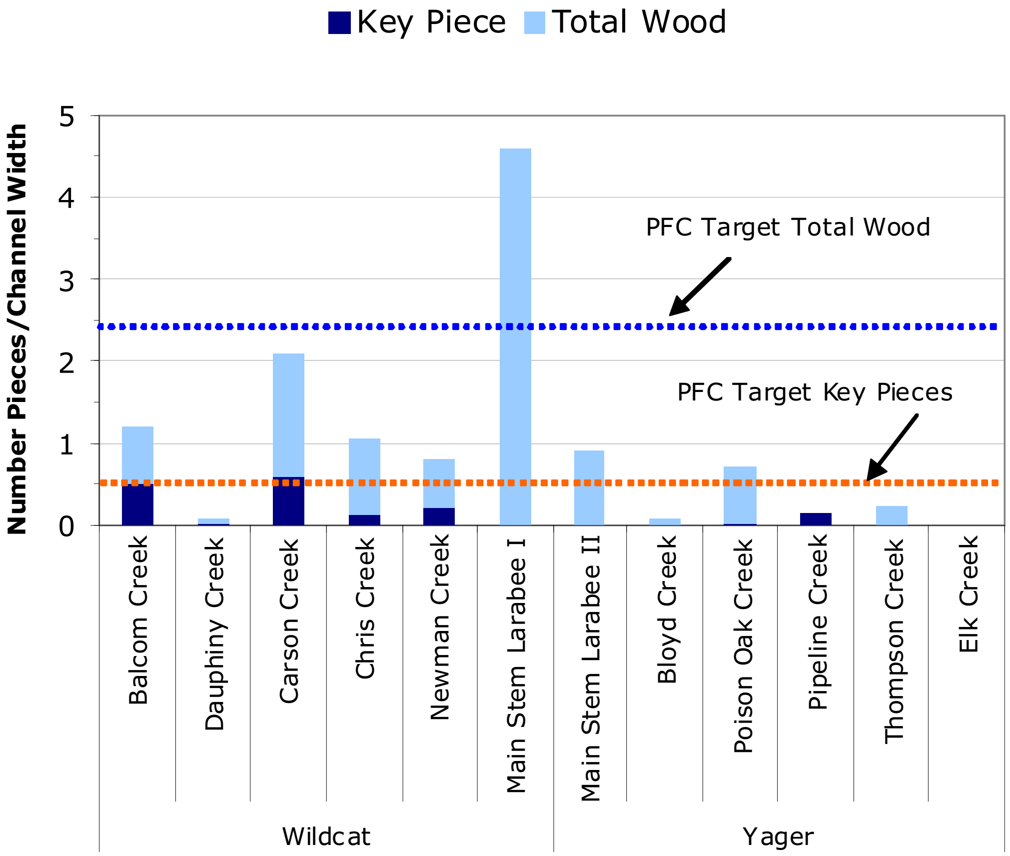
5.6.2 Large Woody Debris

Large pieces of woody debris in streams influence the physical form of the channel, the movement of sediment, the retention of organic matter, and the composition of the biological community (Bilby and Ward 1989). The diameter and length of pieces determine the degree that each piece functions in shaping the channel (Bilby and Ward 1989). Most of the pools in forested streams tend to form around structural elements. In Prairie Creek and its tributaries, 50 to 90% of the pools were associated with woody debris (Keller and Tally 1979).

In-stream wood-related cumulative watershed effects can occur when land use activities either introduce an over-abundance of wood to streams (a rare event in modern times) or reduce in-stream large wood and/or the forest's ability to contribute large wood on a sub-basin or watershed-wide scale (a common condition in the watershed). It is unclear whether there is an adverse effect from too much wood. For example, large rivers in the Pacific Northwest prehistorically had large debris jams that may have benefited salmon habitat in these rivers (Collins and Montgomery 2001). It has been well established that too little in-stream large wood in response reaches, especially of 2 to 4% gradient, is likely to result in channel simplification and loss of pool habitat (Bilby and Ward 1989, Montgomery et al. 1995).

The woody debris surveys conducted in the WAU sample two categories of wood. Total number of pieces of woody debris includes woody stems exceeding a minimum size (6 inches in diameter and 10 feet in length). All pieces that exceed the minimum size found anywhere within the active channel are counted, regardless of whether they individually contribute to channel scour. A key piece is a functional definition that focuses on woody debris actively causing scour and deposition as it deflects flow and influences local hydraulics (Fox 1994). The PFC criteria further define 'key piece' as a log and/or rootwad that is independently stable in the stream bankfull width (not functionally held by another factor such as pinning by another log, buried, trapped against a rock or bedform, etc.); and is retaining (or has potential to retain) other pieces of organic debris. There is no minimum size for key pieces, but they tend to be larger than the minimum piece size included in total wood counts (Fox 1994). Key pieces are typically found partially or fully embedded in the streambed or bank within the active channel. A key piece, whether a log or a rootwad, has a surface area that is substantial relative to the cross-sectional area of the stream. A minimum blockage of 25% is needed to deflect flow enough to force scour and deposition (Sullivan 1986). With either type of survey, the size of functioning and stored wood in the stream typically increases with increasing channel size because larger size is necessary to be stable and resist movement during floods. There will be a greater number of total pieces in a wood survey because there are often pieces of wood in a channel that are not directly causing scour. The PFC target for total wood is 2.4 pieces/channel width. The goal for key pieces is 0.5 pieces/channel width. These values would indicate fully functional habitat. Results from the watershed analysis are summarized in Figure 5-19.

Figure 5-19. Frequency of total wood and key piece sized large woody debris in sub-basins in the Upper Eel WAU



The number of pieces of LWD is generally low in most of the streams in the WAU considering either total pieces or key pieces (Figure 5-19). Only mainstem Larabee I currently meets total wood goals. LWD estimates of total wood in Larabee Creek may overstate the degree of wood functioning in these big channels because floatable wood is caught in jams. Each piece in a log jam is counted in a total wood survey. Note that there are no key pieces in Larabee Creek. Photographs 5-13 through 5-18 show tributary and mainstem reaches of streams in the WAU with woody debris counts ranging from low to high.

Photograph 5-13. Newman Creek, low LWD reach

Photograph 5-14. Newman Creek, higher LWD reach

Photograph 5-15. Dauphiny Creek, low LWD

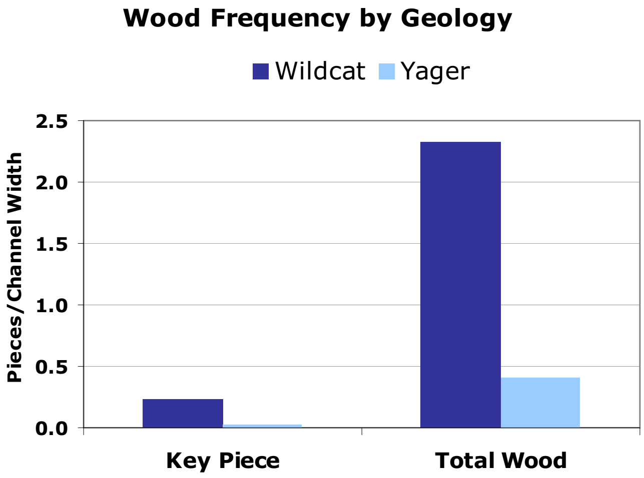
Photograph 5-16. Carson Creek, high total wood count and abundant key pieces

Photograph 5-17. Larabee Creek in tightly constrained canyon reach upstream

Photograph 5-18. Larabee Creek at upper end of lower reach at PALCO bridge

Total wood count is only 1 piece per channel width or less in many of the streams. Key pieces were not found in many streams. Carson Creek (Photograph 5-16) is the only stream in the WAU that currently has adequate key piece wood frequency.

Figure 5-20. Frequency of total wood and key pieces averaged by geology



There is a strong signature of geology in the channel wood counts (Figures 5-19 and 5-20). Both total wood and key pieces are significantly higher in streams in the Wildcat group than in the Yager terrane, where key pieces are almost non-existent (Figure 5-20). The underlying mechanisms that explain differences associated with geology are not clear. Possible explanations are that Wildcat streams tend to be lower gradient and, therefore, store wood better; also, there is a greater prevalence of bank erosion from channel meander in streams in the Wildcat. Field observers have noted that buried logs in the filled channels are being exposed as the channels incise through them (e.g., Photograph 5-2). This pattern could also be related to the history of management activities. Streams on the Wildcat are closest to the transportation corridors and, therefore, would have received management earlier. Riparian forests in these areas have had longer to grow to a size where they recruit sufficient sized pieces of wood.

The long-term trend for LWD in streams in the Yager terrane is difficult to predict. There will certainly be a temporal lag in LWD amounts as the riparian stands in these areas mature. The rate of recruitment of LWD from landslides should eventually be lower if management-related landslides continue to decline. Trends in amount of LWD could decrease over time in Yager terrane and in steep channels if the current logging-related wood decays or flushes from the system, although redwood logs have good longevity in the stream.

In streams the size of lower Larabee Creek (Photographs 5-17 and 5-18), very large pieces of LWD will be required in the future to provide hydraulic roughness. Based on the relationship of key piece size with channel width (Fox 1994), a 100-foot wide channel would require a log 58 inches in diameter and 140 feet in length to likely function as a key piece. Redwood can certainly achieve this size, but it is unclear whether pieces this long would survive due to the tendency for redwood boles to break. Multiple piece jams are more likely required to improve the hydraulic roughness of Larabee Creek. Importantly, many reaches along Lower Larabee Creek currently do not have an established conifer riparian area growing near the channel (e.g., Photograph 5-8), so future recruitment is in doubt. In the upper reach of Larabee Creek in the narrow canyon shown in Photograph 5-17, large boulders of Yager sandstone and conglomeratic rock have cleaved from the canyon wall and created boulder gardens. Large pools have formed around the boulders and create good fish habitat. Thus, LWD is not the only factor contributing to pool habitat in at least some locations in the WAU.

It is important to note that key pieces may be underestimated. The additional requirement in the definition of a key piece in the PFC matrix that a LWD piece retain other pieces of organic debris as well as serve as loci of scour and gravel deposition may exclude many functioning pieces in PALCO surveys. This standard is not applied in other studies that allow a piece of wood to function in scour without snaring other pieces of organic debris (Fox 1994). Thus, PALCO surveys probably underestimate the count of key pieces, possibly significantly. For example, Newman Creek and Poison Oak Creek contained 11 and 6 log/rootwad scour pools, respectively, in which the wood responsible for the pool formation was stable and had been so for multiple years. However, these pieces did not meet the ‘key piece’ criteria for one reason or another (i.e. was partially buried, pinned by another log, trapped against a rock, etc).

The percentage of pools associated with LWD (wood scour pools or key piece associations) was much greater in channels in Wildcat group (Chris Creek, Carson Creek, Balcolm Creek, Newman Creek) than channels in Yager terrane (Bloyd Creek, Thompson Creek, Poison Oak Creek).

5.6.3 Interaction Between LWD, Sediment, and Channel Morphology

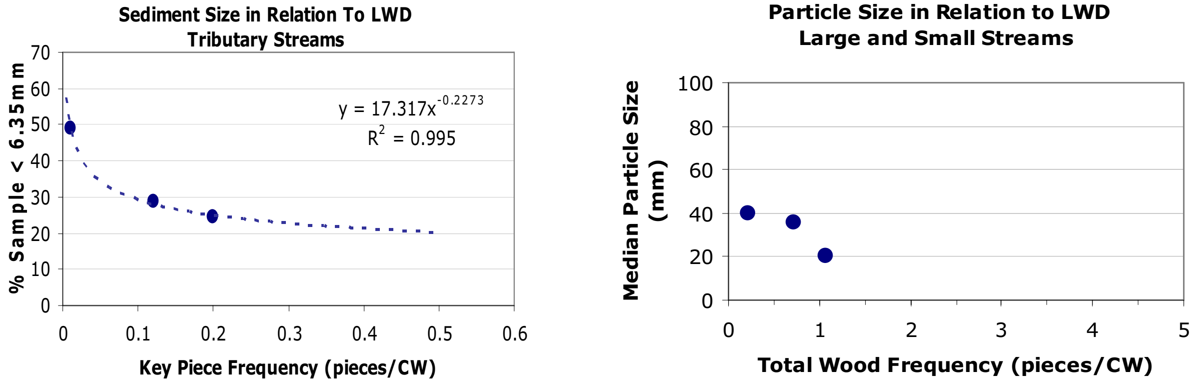
Sediment load, water discharge, and structural elements—the controlling independent variables of channel morphology—determine the shape of the channel and habitat along the stream network. Stream channel morphology integrates the effects of sediment supply, flow, and their interaction with large roughness elements simultaneously. Streambed sediment, pool, and LWD loading characteristics have been discussed in the previous sections. In this section, we briefly explore any interrelationships between woody debris loading, streambed, and pool characteristics.

Preferred habitat conditions have low amount of fine sediments in the interstices of the streambed gravels. The proportion of streambed sediment less than 6.35 mm was found to be generally fairly low in the few field sites where samples were collected, a desirable condition (Figure 5-12). The streambed composition was not strongly related to the geologic substrate or sediment yield in the watershed (Figure 5-13).

Figure 5-21 shows the relationship between the streambed sediment composition and the frequency of the large key pieces of LWD for the smaller tributary streams. Within this very limited data set, there is a strong tendency for the large roughness elements that direct scour and deposition to sort the streambed and promote the deposition of gravels relatively free of fine sediment. This result is consistent with Dietrich et al (1989), Lisle et al. (1993), and Yarnell et al. (2006) who conclude that large structural elements sort and diversify the sediment deposits.

At the same time, surface particle size has a tendency to decline with influx of LWD (Figure 5-21). All debris and obstructions add hydraulic roughness to the channel that expends energy that would otherwise be used to transport sediment. Such fining of the bed surface as wood accumulates may prevent or delay streams from reaching the PFC target.

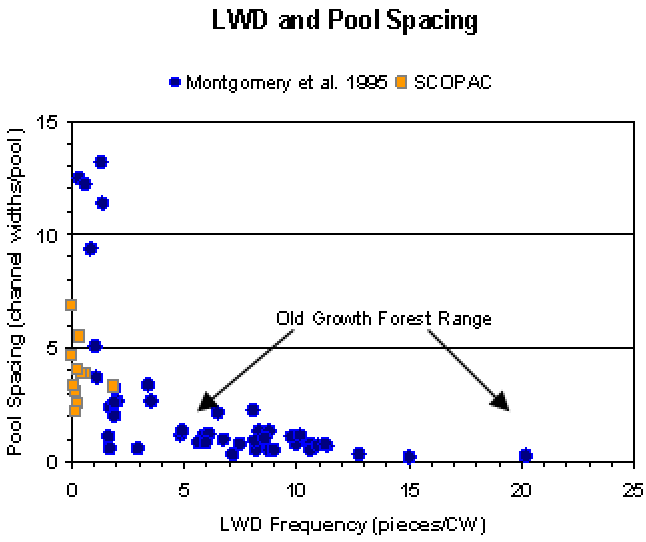
Figure 5-21. Proportion of streambed sediment less than 6.35 mm in relation to key piece frequency and median grain size of the streambed surface in relation to total wood frequency in the three tributary streams – Chris Creek, Newman Creek, and Thompson Creek



The woody debris also strongly influences the pool characteristics that develop in the streams. Large obstructions, of which woody debris is often the most abundant in smaller streams, may fully or partially block the flow during storms when sediment is in transport, thus regulating the scour and deposition of sediment by creating areas of high and low velocity in their vicinity. Obstructions and bends produce strong secondary currents that scour the bed, generally producing the deepest pools (Sullivan et al. 1987). Large woody debris, especially key pieces, focus the scour and deposition, and tend to anchor the location of pools that result from the scour. The hydraulic significance of an obstruction generally increases as its length and width relative to channel width increases, which is why key pieces are generally larger.

The frequency of wood pieces affects the frequency of pools, as shown by Montgomery et al. (1995). A relationship between LWD frequency and pool spacing in their 1995 paper is shown in Figure 5-22. (We have translated their data from pieces per meter of channel to pieces per channel width. The same general trend persists with either metric.) Both wood frequency and pool spacing can span a wide range. Photographs 5-13 to 5-18 and elsewhere in this report illustrate this same range. The relationship shown in Figure 5-22 shows an almost threshold-like response of pool spacing when wood frequency approaches about 2 pieces per channel width (Montgomery et al. 1995 report total wood). PALCO's PFC target is 2.4 total pieces per channel width. Increasing amount of wood above this level has a relatively small effect on pool spacing.

Figure 5-22. Pool spacing in relation to LWD frequency combining data from Montgomery et al. (1995) and from the Upper Eel WAU



Data on pool and total wood frequency from the Upper Eel WAU is also plotted on Figure 5-22. This graph suggests that streams of the Upper Eel are behaving consistently with those streams observed by Montgomery et al. (1995) at the current wood loading level. As such, it suggests that increasing the wood loading to streams is likely to result in increased pool frequency.

At the low LWD frequency range of the data, the streams in the Upper Eel WAU appear to have somewhat closer pool spacing at the current level of wood or, at least, lack the extremely wide spacing observed by Montgomery et al. (1995). The LWD piece frequency in Upper Eel streams is low compared to streams with adjacent old growth riparian forests in Figure 5-22.

Clearly, the interrelationship between sediment supply and large roughness will have synergistic and antagonistic effects on achieving the preferred habitat conditions within the streambed and in the hydraulically diverse channel units of pools and riffles that occur as the stream flows over them. Predicting the future direction of these habitat variables as channels respond to reduction in sediment supply and increase in wood supply that are key objectives of PALCO's watershed management practices is difficult to do with confidence. However, if the trends suggested by Figures 5-21 and 5-22 turn out to be valid, they suggest that increased woody debris accumulation, especially of large key pieces, could help channels achieve the PFC pool and streambed targets.

Table 5-3 provides data on channel characteristics, including several parameters not discussed in this summary report. The PFC matrix also specifies criteria for the volume of individual pieces of LWD.

Table 5-3. Summary of channel and habitat data for Upper Eel WAU

Stream Segment	Chris Creek	Carson Creek	Larabee Creek #2[1]	Larabee Creek #170[1]	Poison Oak Creek	Balcom Creek	Dauphiny Creek	Bloyd Creek	Pipeline Creek	Newman Creek	Thompson Creek	Elk Creek[3]
Dominant Geology in Fish-bearing Reaches	Wildcat	Wildcat	Alluvial Sediment	Alluvial Sediment	Yager	Wildcat	Wildcat	Yager	Yager	Wildcat	Yager	Yager
Gradient (%)	1-4	1-8	0.9	0.4	1-8	1-8	1-4	1-4	1-8	1-8	1-8	1-4
Unit Length (ft)	3,213	4,154	1,640	1,531	7,664[2]	1,870	3,690	720	2,096	8,116	1,518	18,615
Bankfull Width (ft)	8.9	21	83	54	24	~15	21	10	12	18	22	~30
# Pools in survey (pools per mile)	56 (93)	60 (76)	nd	nd	48 (45)	48 (135)	30 (32)	8 (59)	29 (73)	108 (70)	11 (38)	134 (38)
Pool Frequency (channel widths/pool)	2.6	3.9	3.3	4.7	4.1	2.2	4.5	6.9	4.5	3.1	5.5	5
Percent Pool by Length	38	25	nd	nd	25	45	22	14.5	22	33	18	19.5
% Pool Area	53	29	63	74	32	49	49	34	42	38	15	32
% Pools Associated with LWD	61	66	67	33	12	48	30	0	62	55	0	57
% Pools >=3 ft Deep	7	9	nd	nd	2	8	8	0	4	<1	0	5
Pool:Riffle:Flatwater Percentage	38:18:44	25:45:30	nd	nd	25:53:22	45:25:30	22:35:43	15:65:20	22:33:50	33:42:25	18:82:0	20:40:40
Pieces LWD/100 ft >1 ft dia. & >6 ft long	12	10	5.6	1.7	3	8	0.4	1	4	4.5	1	nd
Volume LWD/100 ft.	205	823	149.6	88	52	542	31	54	323	275	92	nd
Mean LWD piece volume (ft^3)	53	81	12	20	97	72	72	55	80	61	116	nd
# Key Pieces / 100 ft	1.3	2.7	nd	nd	0.07	3.1	0.1	0	0.3	0.9	0.07	nd
Ave. Key LWD Piece Volume (ft^3)	59	116	nd	nd	276	72	192	0	388	116	353	nd
Key LWD Pieces / Channel Width	0.12	0.57	nd	nd	0.02	0.5	0.02	0	0.14	0.2	0.01	nd

[1] Habitat criteria based on data from ATM sites

[2] Poison Oak Creek survey length included 2,100 feet of dry channel

[3] Elk Creek data from a 1992 CDFG stream inventory report.

Note: LWD key piece counts may be biased low due to subjectivity inherent in the key piece definition. A number of log scour pools were not included in the key piece tallies since the logs may not have had the potential to hold back other pieces of LWD even though they were stable and forming pools. For example, Newman Creek contained 11 log/rootwad scour pools that did not have a recorded key piece association. In addition, LWD volumes are artificially low due to field measurement errors on rootwads.

5.7 WATER TEMPERATURE

Water temperature is a dominant factor in the life of aquatic organisms within the stream environment (Hynes 1970). Water temperature affects important stream functions such as processing rates of organic matter, chemical reactions, metabolic rates of macro-invertebrates, and cues for life-cycle events (Sweeney and Vannote 1986). Water temperature plays a role in virtually every aspect of fish life, and adverse levels of temperature can affect behavior (e.g., feeding patterns or the timing of migration), growth, and vitality (Groot et al. 1995).

Salmonid species found in the Upper Eel WAU include Chinook (*Oncorhynchus tshawytscha*), coho (*O. kisutch*), and steelhead (*O. salmo*). These three species are the most temperature tolerant of the anadromous species in the Salmonidae family and are distributed throughout northern California. Steelhead have higher net temperature tolerance, are widely distributed within northern California and within the Upper Eel WAU, and occupy a broader range of habitats including larger rivers and smaller streams. Coho have the lowest net temperature tolerance of the salmonids found in California, and are found primarily where temperatures are coolest for most of the year. Use of the Upper Eel WAU by Chinook is limited to a fall-winter run with juveniles returning to the ocean by the following June. Thus warm summer temperatures are not an issue for this species.

Although temperature tolerance varies somewhat between coho and steelhead, both species grow best in a similar range of temperatures. Expressed as the average of the daily maximum temperature measured over the warmest 7 days of the summer period, the minimum temperature for optimal growth is 10^{o}C and the maximum is 16.5^{o}C for coho and 20.5^{o}C for steelhead (Sullivan et al. 2000). These upper threshold temperatures based on daily maximums translate to the average of the daily mean of the 7 warmest days (Mean Weekly Average Temperature [MWAT]) of approximately 14.8^{o}C for coho and 17^{o}C for steelhead. The PFC matrix establishes an MWAT target at 16.8°C for late summer juvenile coho salmon rearing. Steelhead grow well over a wider range of temperature because their habitat utilization and feeding habits enable them to generally obtain a greater ration of food, thus enabling them to grow at a higher rate, even if the growth rate is less than optimum because of the higher temperature (Sullivan et al. 2000).

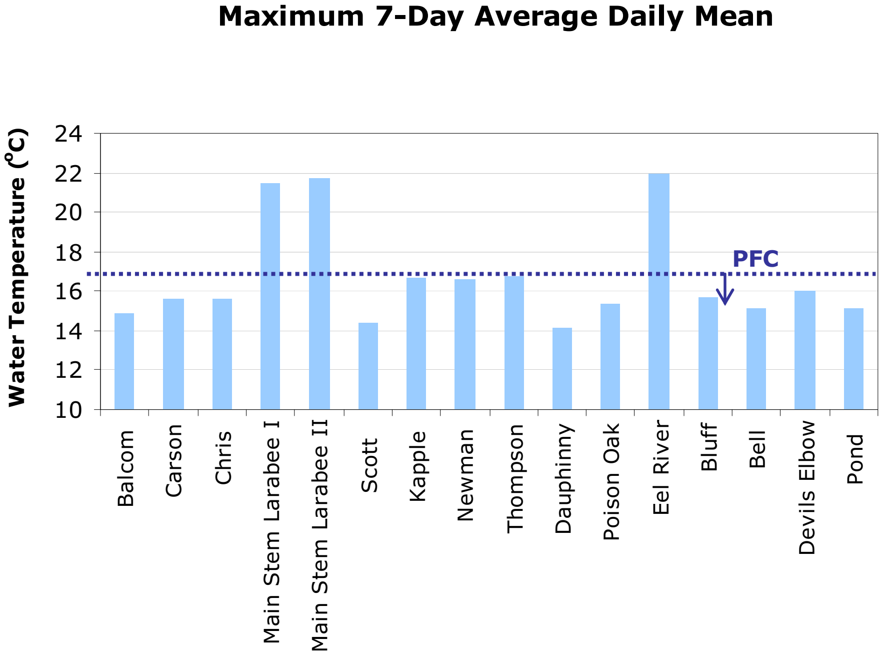
Both species experience stress at temperatures above 22^{o}C. When water temperature rises above this threshold, salmon move to thermal refuges where they are available (Nielsen et al. 1994.) Temperatures from 22 to 24^{o}C may be stressful, but are not typically a direct cause of mortality (Brett 1956). Temperatures that cause thermal stress after longer exposures, ranging from weeks to months, are termed chronic temperature effects. Endpoints of lengthy exposure to temperature that are not physiologically optimum may include loss of appetite and failure to gain weight, competitive pressure and displacement by other species better adapted to prevailing temperatures (Reeves et al. 1987), change in behavior, or susceptibility to disease. The temperature where death occurs within hours to minutes of exposure is termed the ultimate incipient lethal limit and is approximately 30°C for coho and steelhead.

5.7.1 Stream Temperature Data and Patterns Within the WAU

Water temperature has been measured during the warmest part of the year (June through September) with continuous recording data logger devices (Hobos or Optic Stowaways) at a number of locations within the Upper Eel WAU. Temperature is measured each year at the ATM stations. A number of additional meters were placed in streams throughout the WAU in 2005 to augment information for this watershed analysis.

The tributary streams in the WAU have cool water temperatures that meet the PFC criteria of 16.8°C for the average daily mean temperature for the warmest consecutive 7 days during the season (MWAT) (Figure 5-23). MWATs in the Class I tributaries within the WAU range from 14.5 to 16.5°C. This temperature is close to optimal for growth of coho and steelhead. Water temperatures in the mainstem Eel River and Larabee Creek are high and exceed stressful thresholds for salmonids.

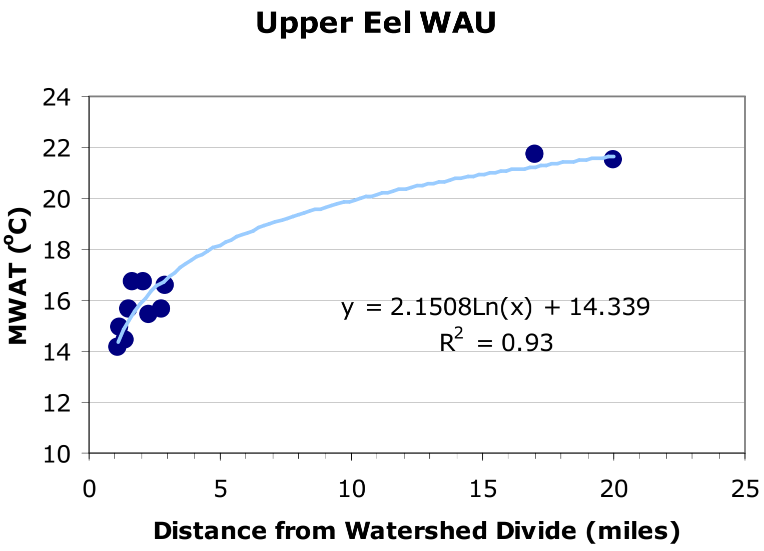
Figure 5-23. Average of the seven consecutive warmest days for sub-basins in the Upper Eel WAU



Current riparian canopy conditions provide high levels of shade for the fish-bearing tributaries flowing into Larabee Creek, the Eel River, and the South Fork Eel River (Figure 5-8). While many, if not all, of these streams experienced substantial reductions in shade canopy as a result of logging and ranching operations in the early and mid-twentieth century, it is evident through air photo analysis and field observation that the riparian areas have since revegetated and grown to provide for a high level of canopy closure (Photographs 5-4, 5-5, and 5-6).

Patterns in stream temperature in the WAU can be explained by watershed size. Stream temperature tends to increase in the downstream direction from headwaters to lowlands (Hynes 1970, Theurer et al 1984). The dominant environmental variables that regulate heat energy exchange, for a given solar loading, and determine water temperature are stream depth, proportional view-to-the-sky, rate and temperature of groundwater inflow, and air temperature (Moore et al. 2005). Increasing temperature in the downstream direction reflects systematic tendencies in these critical environmental factors. Air temperature increases with decreasing elevation (Lewis et al. 2000). Riparian vegetation and topography shade a progressively smaller proportion of the water surface as streams widen (Bartholow 1989, Beschta et al. 1987), until at some location there is no effective shade at all (Beschta et al. 1987, Sullivan et al. 1990). Streams gain greater thermal inertia as stream flow volume increases (Beschta et al. 1987), thus adjusting more slowly to daily fluctuations in energy input. Given the large number of published records and analyses of water temperature as a function of stream size (Sullivan et al. 1990, Lewis et al. 2000), the larger mainstem rivers cannot be expected to meet the PFC criterion.

Figure 5-24. Temperature as a function of distance from divide for streams, excluding the Eel River, in the Upper Eel WAU



Water temperature in the Upper Eel WAU increases with distance from divide in the Upper Eel WAU as shown on Figure 5-24. The two Larabee Creek sites are located approximately 22 and 19 miles from the watershed divide while the tributary streams have less than 2 miles of stream length. Channel widths are relatively narrow on the tributary streams and the ability of the overstory riparian forest blocks the stream's view-to-the-sky to a large extent (but not completely).

The riparian canopy closure of the Class I streams in this dataset explains the water temperature observed in the Upper Eel WAU streams. The water temperature (MWAT) at each site is plotted in relation to the percent of each tributary length that has 85% or greater canopy closure in Figure 5-25. In Figure 5-8, Larabee Creek is reported to have as much as 40 to 55% of its length with greater than 85% overstream canopy cover. However, there appears from photographs to be very little effective shade along the mainstem Larabee itself for most of its length. The streams with high canopy closure are the small tributaries that drain to the mainstem in the area around the mainstem mapped within the mainstem sub-basins. For purposes of stream temperature, only the riparian conditions along Larabee Creek are relevant. We, therefore, assume that the canopy closure of the lower zone is not more than 20% and that along the upper reach is no more than 40%; these estimates are probably too high. The tributary streams currently have high canopy closure along their lengths and temperatures are low. There is small variation among the streams in how much of their length has high canopy closure, and that difference is expressed in the water temperature.

Figure 5-25. Water temperature in the tributaries and mainstem rivers of the Upper Eel WAU in 2005 in relation to portion of the stream length with canopy closure greater than 85%

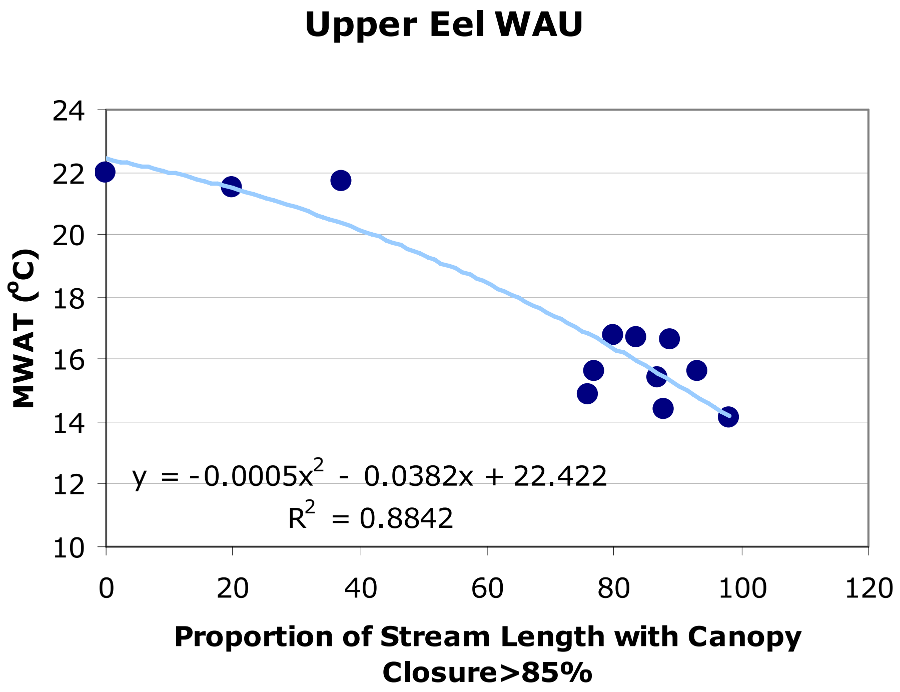


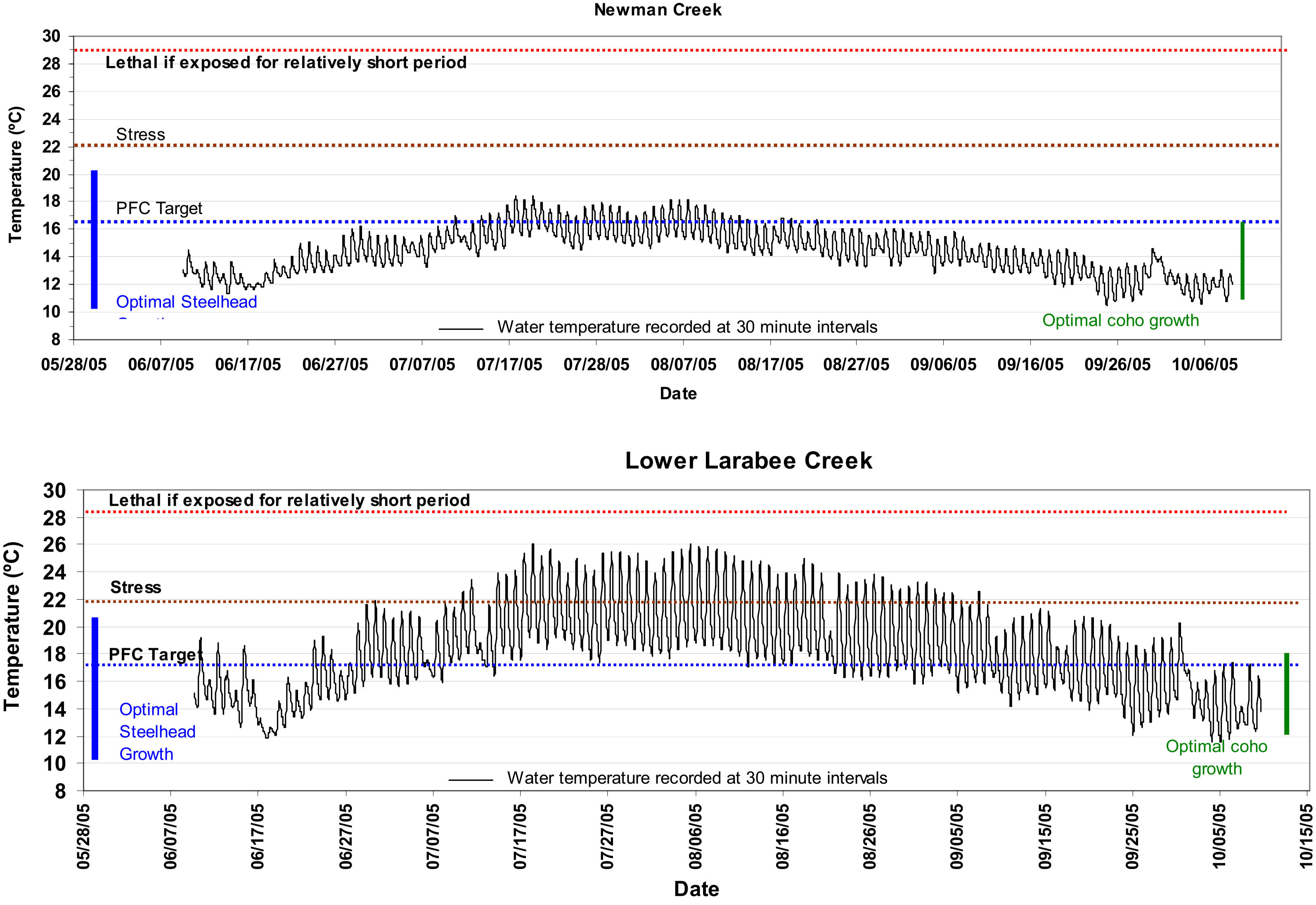
Figure 5-25 can be used as a general model of the effect that overstory canopy removal can have on water temperature in this WAU. Removal of overstory vegetation along the Class I streams would raise temperatures up to 22°C, equivalent to the open streams, depending on length of stream affected. Figure 5-25 also suggests that streams that cannot be blocked by vegetation due to their width cannot achieve the PFC temperature goal.

The MWAT is an indexing variable that characterizes the temperatures for the warmest days of the year. Given that chronic temperature effects mostly occur with long-term exposure to temperature, we show the detailed 30-minute record of water temperature for the entire summer for Newman Creek, a well-shaded tributary, and the lower mainstem of Larabee Creek for the summer period in Figure 5-26 to improve awareness of salmonid exposure to temperature. Also shown on each graph are the range of optimal temperatures for growth of coho and steelhead and temperatures where stress and death occur.

Salmonids living in Newman Creek (and other similar tributaries) experience near optimum temperatures all summer (Figure 5-26). Although this stream meets the PFC target based on the daily mean temperature, daytime maximum temperatures make excursions to near 18°C during the warmest weeks. Welsh et al. (2001) target this value as a threshold of concern for the occurrence of coho based on observation of distribution of coho relative to watershed temperature in the nearby Mattole River. All observed temperatures are within the optimal temperature window of steelhead, and most temperatures are within the optima for coho. Growth of both coho and steelhead would be maximized in Newman Creek.

Salmonids attempting to live in Larabee Creek face a much more adverse condition. Optimal temperatures are rarely experienced, even at night when the temperatures drop 7°C from the daytime highs. Stressful temperatures are reached most days from mid-July to the end of August. Although temperatures are stressful, they are not of sufficient magnitude and duration to induce direct mortality. Steelhead are better suited to the higher temperatures and positive growth is likely to occur. Steelhead utilize Larabee Creek for rearing. Nevertheless, stress and competition from exotic species such as the pike minnow remain a concern for steelhead in Larabee Creek with the temperatures observed throughout the summer.

Figure 5-26. Thirty-minute temperature record for the entire summer period for Newman Creek (a well-shaded tributary) and Larabee Creek



A limited amount of fish population data is available from Newman Creek and Upper Larabee Creek. PALCO sampled populations during the summer months using electro-fishing 3-pass methods in Newman Creek and in the upper reach of Larabee Creek from 1999 to 2004 (Figure 5-27). Juvenile steelhead were the only salmonids occurring at either site. The density of the salmon population measured as the number of individuals per unit area (grams per square meter [g/m^2]) is relatively low. The populations increased significantly in each stream from 1999 to 2004.

Newman Creek had greater population density than Larabee Creek. It is hard to make inferences about any effect that temperature may play in determining fish population characteristics in these two streams, except to say that temperatures were better in Newman Creek than Larabee. Many other habitat characteristics of Newman Creek were not particularly good, including shallow pool depths, relatively infrequent pools, and small gravel sizes. The Larabee Creek condition is better than Newman Creek for each of these parameters.

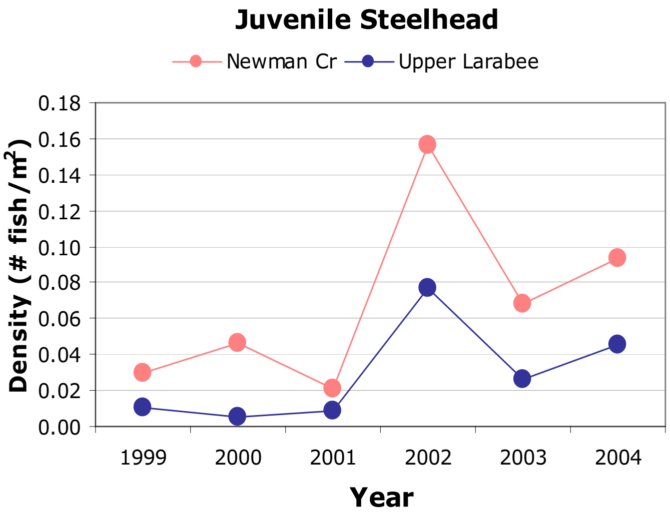


Figure 5-27. Density of juvenile steelhead populations in Newman Creek and upper Larabee Creek

The availability of thermal refugia may help steelhead cope with higher temperatures in the mainstems. Micro-habitats include tributary junctions where the cooler water in tributaries provide local cool water refuges. However, coho are not likely to utilize Larabee Creek or the mainstem Eel River because of these high temperatures. Madej et al. (2006) found coho restricted use to lower segments of Redwood Creek where mainstem temperatures were cooled by the oceanic influence and daily maxima during the summer averaged less than 20.6°C. Middle reaches of Redwood Creek have significantly higher temperatures and were devoid of coho. Similarly, Welsh et al. (2001) found that coho were absent from streams in the Mattole basin that exceeded 16.8°C. Coho have not been observed in the mainstem of Larabee Creek. Results in Larabee Creek are inconsistent with these observations in other northern California streams.

A similar temperature story would be true for the Eel River mainstem. Temperatures observed in the Eel River are also at equilibrium with air temperature and similar to those observed in Larabee Creek. Hyporheic or intragravel flow within the streambed can be significantly cooler than surface waters flowing over them. Water moving through the streambed may preferentially enter the pools and can provide patches of cool water (Ebersole et al. 2003).

Fish utilization and temperatures in the mainstem Eel River have received some study by PALCO as part of gravel extraction permits. Steelhead microhabitat utilization was observed by diving and temperatures were spot-checked with handheld thermometers. Cool water upwelling also was observed in critical micro-habitats such as narrow riffles with elevated velocity and overhanging vegetation. The base of riffles, with a combination of vegetation and velocity, had a higher likelihood of utilization by steelhead (PALCO 2004). Nevertheless, the temperature differences in a few bar/pool sequences that were measured in the Eel that were measured with handheld thermometers were quite small (less than 1°C.), and the location and value of hyporheic flow in providing refugia in the mainstems is not sufficiently confirmed.

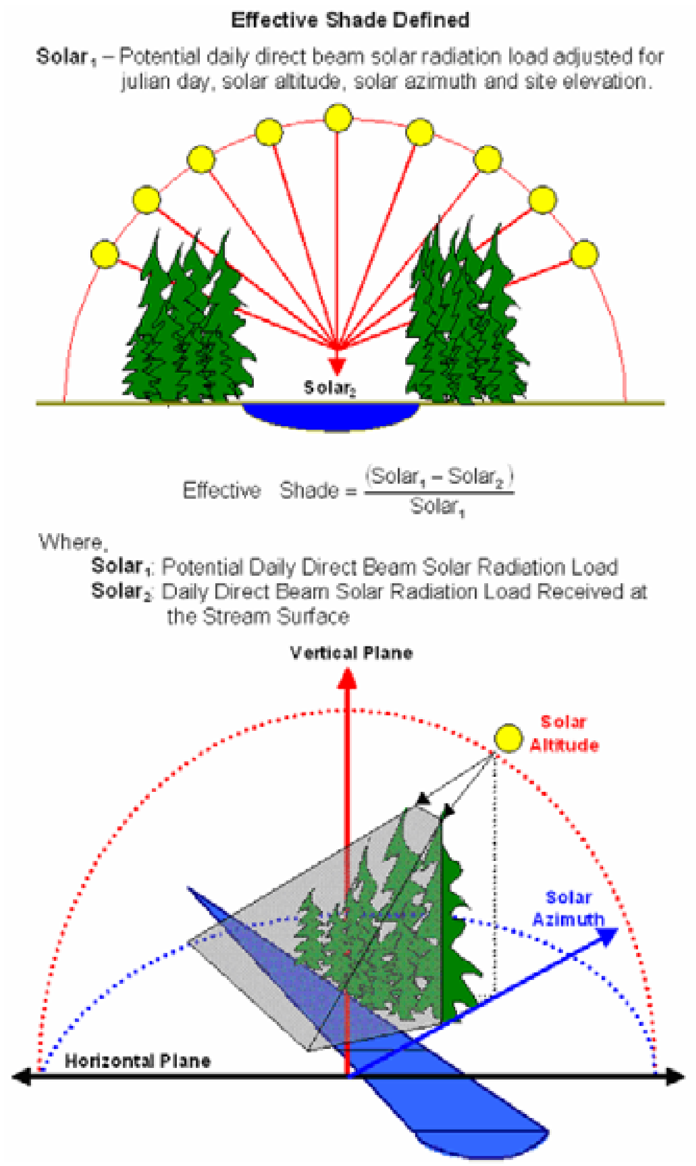
5.7.2 Management Implications for Water Temperature

Canopy closure is currently high along most Class I and II streams in the smaller tributary streams in the WAU. Water temperatures in fish-bearing streams in all locations where measured are meeting PFC targets, with the exception of the mainstems of the large watercourses in the WAU. Welty et al. (2002) demonstrated that riparian buffers 60 to 100 feet wide provide full shade value for all stream widths 30 feet or less. With the exception of Larabee Creek, all streams in the WAU on PALCO ownership are less than this width. Currently canopy closure levels are consistent with maximum closure based on stream width modeled by Welty et al. (2002).

Larabee Creek has high water temperature and little effective shade along the mainstem Larabee itself for most of its length. Photograph 5-8 shows a typical reach of the lower mainstem Larabee with little riparian forest and no shade. The questions are, can Larabee Creek achieve higher canopy closure given its width and, if so, would water temperature be improved?

For a forest canopy to be effective in blocking direct beam solar radiation, it must block the stream's view to the sky within the overhead hemisphere above the stream from 30 degrees from horizon to the zenith above the stream as illustrated in Figure 5-28. Direct beam radiation arriving at the stream from angles lower than 30 degrees come in at too oblique an angle to be absorbed and do not contribute to heating.

As streams naturally widen, the ability of streamside vegetation to block incoming solar radiation diminishes to zero in the effective hemispheric view (Boyd and Kasper 2007, Welty et al. 2002). This occurs where the streamside vegetation apparent height from the perspective of the stream falls within 30 degrees of the horizon.



Source: Boyd and Kasper, 2007.

Figure 5-28. Description of effective shade

Topography can contribute to shading by directly blocking incoming radiation and by raising the effective height of the trees. The height of vegetation along Larabee Creek for most of its length is currently too short to provide much blocking, especially on the lower segment. In fact, for much of the length there is little or no shade at all. Similarly, the mainstem Eel River, which is 750 feet wide, has no effective vegetation. Because Larabee Creek and the Eel River are unaffected by riparian shade, each has reached an equilibrium with air temperature reaching an upper maximum temperature of approximately 22^{o}C (MWAT) (Figure 5-24).

Photograph 5-19 shows the blocking effect of an old growth redwood forest on the South Fork Eel River near its junction with the mainstem Eel within the WAU. The redwood forests lining the stream bank are nearly 300 feet tall. The trees are blocking vegetation within the 120^{o} view above the horizon where effective shade must occur, although note that the view-to-the sky is still actually quite open. Thus, the blocking factor of this stream may be on the order of 20 to 25%. The South Fork Eel River at this location is 200 ft wide and flows in the north/south direction in this location, enhancing the apparent shading qualities of the riparian forest as seen in the photograph.

Photograph 5-19. South Fork Eel River at junction with mainstem showing effective shade of redwood old growth stand

Larabee Creek has two main types of channel reaches within PALCO ownership. The lower reach begins at the confluence of Larabee Creek with the Eel River and extends upriver to just above where the PALCO bridge crosses Larabee near Balcom and Dauphiny Creeks. This marks the end of the Wildcat and mapped alluvial units on the geologic map. The length of this reach is approximately 2.2 miles. The river flows in a fairly wide alluvial valley that was highly disturbed during the 1964 storm, and has widened and stripped away vegetation along most of the length. The riparian area lies within the alluvial flood plain, and has still not established itself for much of the length (see Photograph 5-8). Larabee Creek is approximately 100 feet wide for most of this length.

The upper reach extends approximately 8 miles upstream from the lower reach to the edge of PALCO property. In this reach, Larabee Creek is steeper and more moderately to tightly constrained between steep hillslopes as it flows across the Yager terrane within narrow alluvial valleys. The hillslopes form steep canyon walls in some locations. The river is approximately 50 to 65 feet wide for most of this length. The riparian forest is growing on the hillslope that is well stocked with young to moderate age Douglas fir and redwood, which diminishes in the easterly direction. The river flows in an east to west direction.

Welty et al. (2002) presented modeled and empirical information for stream canopy cover provided by old growth Douglas fir forests as a function of channel width. We use this relationship here to estimate the blocking factor that may be achieved by a mature conifer forest along these two reaches of stream. At bankfull width of approximately 100 feet, the blocking factor could get as high as 60%. At 65 feet in width, blocking could reach 75%. This does not include any additional blocking from the steep hillslopes in the upper reach. Thus, when the riparian forest fully matures, the increase in canopy closure for the entire length of Larabee Creek within PALCO ownership could be substantial relative to what it is now.

With these levels of shade, it is feasible that water temperature in Larabee could be at least 2 to 3^{o}C cooler during the warmest time of the year. Improvements in temperature could be even greater, although the east-west direction of the stream will tend to have more heating, and the incoming temperature at the uppermost boundary of PALCO property may influence temperatures within the PALCO reach for some distance as it takes time and, therefore, distance to equilibrate to new riparian conditions. Madej et al. (2006) report that average daily summer temperatures have decreased by 3.5^{o}C in portions of Redwood Creek that were severely aggraded during the 1964 storm. Reductions in temperature have accompanied the return of the streambed to former levels and the re-establishment of riparian vegetation and canopy closure over Redwood Creek.

Active riparian management could accelerate such recovery of shade and LWD recruitment along Larabee Creek. In the lower reach, efforts to reestablish conifer forests within the alluvial floodplain along the stream banks are needed in many places. In the upper reach, conifer forests are established, but silvicultural treatments could accelerate growth of trees to the large sizes necessary to provide effective LWD and shade on this moderately large stream.

5.8 SUMMARY OF FINDINGS

The historic distribution of anadromous salmonids within the WAU was more widespread than during the period following the onset of road and railroad construction and the initial logging entry. Long-term habitat degradation and fishing pressure has contributed to the steady decline in salmonid population and distribution throughout the 1900s that ultimately gave rise to the ESA listings of the species. Anadromous salmonid distribution, and consequently their populations, contracted due to a number of anthropomorphic and natural events including:

- Historic logging practices (railroad construction, downhill yarding, using creeks as skid roads) resulted in significant disturbance to normally functioning streams by filling channels—this has degraded the limited amount of anadromous habitat available in tributary streams.
- Deposition of logging debris coupled with sediment deposition created numerous log jams that blocked upstream migration by adult salmonids, thereby restricting spawning opportunities.
- Blockages to salmon migration to spawning streams are found on County/State roads and railroad crossings along the Eel River. A road crossing on the Larabee Ranch blocks anadromous fish access to Chris Creek. A log jam approximately 200 feet upstream of the road appears to at least partially block access to the upper reaches of Carson Creek.
- The 1964 flood triggered landslides on previously harvested and unharvested slopes and filled in usable in-stream habitat with sediment.
- Ocean conditions in the 1970s-1990s resulted in poor survival of salmonids once they migrated out of the freshwater environment.
- The droughts of 1976-1977 and 1986-1992 that severely reduced freshwater spawning and rearing opportunities for salmonids.

Reduction of LWD in fish-bearing streams and the ability of the forest to produce LWD for in-stream recruitment has occurred at varying degrees throughout the watershed due to past land use activities including stream cleaning and intensive riparian timber harvest. While neither practice occurs on PALCO lands today, the effects of these past practices linger. Large woody debris is low in most of the fish-bearing streams in the WAU. Less large wood than historically present in low gradient response reaches likely means an overall reduction in quality and quantity of rearing and spawning habitat; younger, smaller riparian forests means there is a time lag of at least two to three decades before most riparian forests are of sufficient size to steadily contribute fully-functional LWD. Riparian forests are today dominated by redwood and Douglas fir along much of the length of the smaller tributary sub-basins and mainstem Larabee Creek. Shade levels are high and water temperatures are meeting PFC targets. Some of these forests are of sufficient size that they are beginning to recruit functional LWD. Most will achieve these conditions within the next several decades. Only the riparian forests along Larabee Creek may require additional consideration. Large woody debris in channel is low, but apparently improving as recruitment begins as the stands mature. Streams in the Wildcat group especially are experiencing wood accumulation.

There is little controversy over whether sediment-induced cumulative adverse effects have occurred in the watershed. It is well documented that many of the streams in the WAU were directly and significantly impacted by early and mid-twentieth century logging methods which often utilized stream channels as transportation corridors, constructed poorly designed stream crossings, or decreased slope stability through substantial ground disturbance on steep or otherwise unstable slopes. However, the development and expansion of logging and other land use mitigation measures arising from environmental laws established in the late 1960s and 1970s appear to have effectively reduced sediment inputs to a level that, combined with natural hydrologic processes, have allowed for some watershed recovery.

Current stream channel conditions suggest persistence of sediment-induced cumulative adverse effects from the early and mid-twentieth century catastrophic influx of sediment, although the aggradation of Larabee Creek has declined and the channel has reestablished itself in a relatively stable channel. Smaller tributary channels that support salmon spawning show evidence of embeddedness with fine sediments. Evidence from the watersheds suggests that habitat conditions will continue to improve towards PFC target criteria for clean bed sediments, deep and frequent pools, and abundant wood as sediment supply is reduced and wood recruitment is increased as is likely with time.

The contemporary reduction in sediment delivery through improved road and logging system design and implementation is evidenced by the substantial decline in mass wasting observed over the last thirty years despite significant triggering events (e.g., earthquakes and severe winters). The results of harvest unit field inspections and modeled road and harvest unit sediment delivery runs are presented in Appendix B.

The Eel River and Larabee Creek are identified as the most productive salmonid streams in the WAU. Tributary streams of notable importance due to the amount of salmonid habitat available are Newman Creek, Thompson Creek, Chris Creek, Carson Creek, Poison Oak Creek, and Dauphiny Creek. Numerous other Class I streams with less, though also important, fish habitat are present on HCP covered lands in the WAU. Class II streams, seeps, and springs provide necessary habitat for amphibians. Moderating sediment inputs, insuring short- and long-term LWD recruitment opportunity, and maintaining, or restoring to the extent feasible, cool water temperatures for this range of aquatic habitat are the primary objectives of riparian and upslope management prescriptions and recommendations.

6.0 MANAGEMENT RECOMMENDATIONS

In addition to adhering to all applicable forest management practices and conservation measures set forth in the rules and regulations of the landowner's Habitat Conservation Plan, the California Forest Practice Rules, the California Fish and Game Code, and the California Water Code, the following watershed-specific management recommendations have been derived from the findings of this watershed analysis:

6.1 HILLSLOPE MANAGEMENT

- ***Limit harvest on inner gorge slopes to single tree selection***. This inherently unstable land form is generally described as consisting of steep streamside slopes exhibiting a history of shallow debris sliding caused primarily by downslope stream erosion, with slopes often in a sparsely vegetated condition. The Mass Wasting Assessment (Appendix A) found that, over the last 20 years, approximately two-thirds of the total number of landslides and three-quarters of the total landslide delivery volume originated from steep (>65%), inner-gorge slopes. Specific sub-basins on HCP covered lands within the WAU where mass wasting discharge from inner gorge and other steep slope conditions were the highest and therefore focused mass wasting avoidance prescriptions may be warranted include Larabee Creek, No Name Creek Complex, Boulder Creek, and the Poison Oak Creek Complex.
- ***Avoid use of ground based equipment (i.e. tractors) and new road construction across inner gorge slopes.*** Due to the inherent unstable condition of inner gorge slopes, activities involving significant cut and/or fill disturbance including skid trail and road construction should be avoided to the maximum extent feasible. The Mass Wasting Assessment (Appendix A) found that over half of the road-related landslides which occurred over the last 20 years on HCP lands in the WAU originated from inner gorge slopes; and that over three times as much mass wasting delivery originated from tractor logged slopes compared to cable-yarded slopes.
- ***Retain a minimum of 50% forest canopy cover on steep streamside slopes above Larabee Creek and in the No Name and Poison Oak Creek Sub-basins.*** According to the Mass Wasting Assessment approximately two-thirds of total landslide related discharge occurring over the last 20 years originated from steep streamside slopes above Larabee Creek and in the No Name and Poison Oak Creek sub-basins, with nearly half of the delivery coming from slopes above Larabee Creek alone. Retention of at least partial forest canopy on steep stream-side slopes identified by recent

aerial photograph analysis as susceptible to landsliding is recommended for the purpose of maintaining existing slope stability through root strength retention, rainfall interception, and minimizing logging-related ground disturbance.

- ***Conduct or otherwise assemble a comprehensive watershed-wide road sediment source inventory.*** An applied rate analysis for estimating past road erosion from stream crossing failures, gullies, and fill/slope failures indicates ***non***-upgraded/storm-proofed roads may be the leading source of land-use associated sediment discharge on HCP covered lands in the WAU (Surface Erosion Assessment – Appendix B). A comprehensive watershed-wide assessment of current road conditions is necessary to determine the accuracy of this estimate. Furthermore, such an assessment will facilitate the prioritizing and scheduling of road upgrading and storm-proofing necessary to address and remedy this potentially significant issue.
- ***Prioritize and schedule road upgrades/storm-proofing based at least in part on imminence of potential discharge to fish-bearing streams, with particular attention paid to tributary streams providing the greatest amount of fish-habitat (i.e. Newman Creek, Elk Creek, Thompson Creek, and Carson Creek).***
- ***Maintain firm, compacted running surfaces during active operations and throughout the year on roads situated on Wildcat Geologies, particularly within Riparian Management Zones (RMZs).*** Surface erosion from roads located in the Chris Creek, Balcom Creek, Carson Creek, Scott Creek Complex, Kapple Creek, and Thompson Creek sub-basins is modeled as being notably higher than that found elsewhere on HCP covered lands within this WAU (Surface Erosion Assessment – Appendix B). These higher rates of surface erosion generally correspond with the presence of the Wildcat Formation, which typically has highly erodable sandstone, siltstone, and mudstone materials near the surface. To address the issue of fine particle discharge from native, un-rocked road surfaces in these sub-basins, it is recommended that special attention be paid to road surface conditions in hydrologically-connected road segments during active operations as well as during the wet-weather season, and that best management practices including routine road watering during summer months and wet-weather road use restrictions be strictly adhered to.

6.2 RIPARIAN MANAGEMENT

- ***Actively manage for increased forest growth rates along Class I and II streams throughout watershed and particularly along Larabee Creek.*** The Riparian Function Assessment (Appendix C) identifies an opportunity to improve riparian function through active growth-promoting silviculture, particularly along Larabee Creek, where larger trees are required to provide functional LWD and shade canopy due to the hydrologic power and width of the stream. Currently approximately two-thirds of the Class I and II riparian forests are dominated by 12-24-inch DBH conifers. Active silviculture resulting in the selective spacing of the trees increasing light, water, and nutrient uptake can accelerate growth to produce larger trees faster and all the benefits for shade canopy, large woody debris recruitment, and habitat diversity thereof.

- ***Retain large streamside timber for shade canopy, large woody debris recruitment, and habitat diversity throughout the watershed, particularly along Class I streams.***
- ***Retain all large streamside timber along Thompson Creek for purpose of shade canopy and large woody debris recruitment.*** Harvesting conducted prior to approval and implementation of HCP RMZ standards resulted in removal of much of the overstory canopy along the fish-bearing portion of Thompson Creek. Retention of remaining streamside timber is necessary for LWD recruitment, shade canopy, and terrestrial habitat diversity.

6.3 STREAM CHANNEL/FISH HABITAT

- ***Promote removal of complete or seasonal barriers to upstream migration.*** Off-property transportation crossing barriers were identified on Chris Creek (Larabee Ranch road), Pipeline Creek (railroad stream crossing), Bell Creek (railroad stream crossing), McCann Creek (county road), and Bloyd Creek (railroad). On HCP covered lands, opportunities for improving fish passage were observed on Chris Creek and Carson Creek where full spanning individual logs currently constitute partial barriers. Fish passage at these individual log locations could be improved by cutting a notch in the logs to reduce barrier height and concentrate stream flow.
- ***Place large woody debris in Thompson Creek.*** LWD in the lower response reach of Thompson Creek occurs at low levels resulting in less than optimal pool habitat area and depth. Considering current riparian stand conditions (e.g., typically hardwood overstory with understory dominated by young conifers) small conifers with significant hardwood component) relative to conifer tree size and frequency along this same reach of stream, it is recommended that LWD be placed in the stream for immediate near term benefits while riparian stand development occurs. These benefits include pool development and the capturing of gravels resulting in increased spawning habitat.

6.4 MONITORING

- ***Maintain existing ATM station locations and continue monitoring program including annual reporting.***
- ***Repeat CDFG methodology stream channel surveys of low-gradient fish-bearing streams within ten years prior to watershed analysis re-visitation.***
- ***Revisit watershed analysis in ten years (circa 2017) to determine HCP effectiveness on hillslope, riparian forest, and stream channel/fish habitat conditions and trends.***

7.0 ADDENDUM—DESIGNATION OF PALCO OWNERSHIP WITHIN HCP

At the time of watershed analysis initiation, PALCO owned and managed approximately 30 percent of the lands located in the 167-square-mile Upper Eel WAU. PALCO ownership in this area includes both HCP lands (87 percent of PALCO ownership) and non-HCP lands (13 percent of PALCO ownership). Table 3-2 provides an overview of PALCO ownership and non-PALCO ownership in the Upper Eel WAU by sub-basin at the time when watershed analysis was initiated. During preparation of the cumulative effects analysis, a total of 2,900 acres of PALCO-owned lands were sold in the following sub-basins: Butte Creek, Cameron Creek, Elk Creek, and Ohman Creek. Along with these transactions, transfers to or from non-HCP and HCP management occurred, yielding a net addition of 1,039 acres of PALCO lands into HCP management. Sub-basins for which lands were added into HCP management included: Bridge Creek, Cameron Creek, Elk Creek, Kapple Creek Complex, Newman Creek, Poison Oak Creek Complex, and Smith Creek.

Attachment 1 provides data for the HCP managed lands in the Upper Eel WAU at the time of watershed analysis initiation *and* for those HCP lands added or deleted at the later stage. Because of the timing of these changes, individual module analyses utilized the initial HCP ownership. Any lands brought into HCP management will be included in the prescriptions developed for the corresponding sub-basin in which they are located. These lands also will be included in the re-visitation of watershed analysis in the future.

8.0 REFERENCES

Agee, J.K. 1993. Fire Ecology of Pacific Northwest Forests. Island Press. Washington DC and Covelo, CA.

Bartholow, J.M. 1989. Stream temperature investigations: field and analytic methods. Instream Flow Information Paper No. 13. Biological Report 89(17). U.S. Fish and Wildlife Service, Fort Collins, Colorado.

Beschta, R. L., R. E. Bilby, G. W. Brown, L. B. Holtby, and T. D. Hofstra. 1987. Stream temperature and aquatic habitat: fisheries and forestry interactions. Pages 191-232 *in* E. O. Salo and T. W. Cundy, editors. Streamside management: forestry and fishery interactions. University of Washington, College of Forest Research, Seattle.

Bilby, R.E. and J.W. Ward. 1989. Changes in characteristics and function of woody debris with increasing size of streams in western Washington. Trans. Am. Fish. Soc. 118: 368-378.

Bjorn, T.C. and D.W. Reiser. 1991. Habitat requirements of salmonids in streams. American Fisheries Society Special Publication 19: 83-138.

Blake, Jr. M.C, D.G. Howell, and D.L. Jones, 1982, Tectonostratigraphic terrane map of California, U.S. Geol Survey, Open File Rep. 82-593 Scale 1:750,000.

Boyd, M. and B. Kasper. 2003. Analytical methods for dynamic open channel heat and mass transfer methodology for HeatSource model. Version 7.0.

Brett, J.Fr. 1956. Some principles in the thermal requirements of fishes. 1956. The Quarterly Review of Biology. 31(2): 265-323.

Brown, L.R. 1987. The fishes of the Eel River drainage: a review and annotated bibliography. Unpubl. Rep., Dept. Wildlife and Fisheries Biology, University of California, Davis. *In* Moyle, P.B., R.M. Yoshiyama, J.E. Williams, and E.D. Wikramanayake. 1995. Fish Species of Special Concern In California. California Department of Fish and Game, Sacramento.

Buffington, J.M. and D.R. Montgomery. 1999. Effects of sediment supply on surface textures of gravel-bed rivers. Water Resources Research 35(11): 3523–3530, November 1999.

California Data Exchange Center (CDEC). 2006. Scotia precipitation data (1926-2004); http://cdec.water.ca.gov/cgi-progs/stamap?SCA

California Department of Fish and Game (CDFG). 1992. Stream inventory reports for Balcolm, Scott, and Elk creeks. California Dept. of Fish and Game, Inland Fisheries. Fortuna, CA.

California Department of Forestry and Fire Protection (CDF). 2006. Fire and Resource Assessment Program website for fire history data. http://frap.cdf.ca.gov/data/frapgisdata/select.asp. NR:CDF.

Clague, J.J., P.T. Bobrowski and I. Hutchinson. 2000. A review of Geological records of large tsunamis at Vancouver Island, British Columbia, and implications for hazard, *Quaternary Science Reviews*, 19, pp. 849-863.

Clarke, S.H., Jr. 1992. Geology of the Eel River basin and adjacent region: implications for late Cenozoic tectonics of the southern Cascadia subduction zone and Mendocino triple junction: American Association of Petroleum Geologist Bulletin, v. 76, n. 2, pp. 199-224.

Collins, B.D. and D.R. Montgomery. 2001. Importance of archival and process studies to characterizing pre-settlement riverine geomorphic processes and habitat in the Puget lowland. In: Dorava, J.M., D. R. Montgomery, B.B. Paccsak, and F.A. Fitzpatrick, Eds. Geomorphic processes and riverine habitat. Water Science and Application 4: 227-246. American Geophysical Union, Washington D.C.

Dengler, L. A., R.C. McPherson and G.A. Carver. 1992. Historic Seismicity and Potential Source Areas of Large Earthquakes in North Coast California: *in* R.M. Burke and G.A. Carver eds., Pacific Cell, Friends of the Pleistocene guidebook for the field trip to Northern Coastal California, A look at the southern end of the Cascadia Subduction Zone and the Mendocino Triple Junction, pgs. 112-119.

Dietrich, W.E., J.W.. Kirchner, J. Ikeda, and F. Iseya. 1989. Sediment supply and the development of the coarse surface layer in gravel-bedded rivers. Nature 340:215-217.

Downie, S., D. Fuller and L. Chapman. 1995. State of the Eel – 1995; An Overview of the Eel Basin with Current Issues, Questions, and Solutions. Summarized from EelSwap Meeting of March 25, 1995.

Ebersole, J. L., W.J. Liss, and C.A. Frissell. 2003. Cold water patches in warm streams: physicochemical characteristics and the influence of shading. J. Am. Water Resources Assoc. 2003(Apr): 355-368.

Everest, F.H., R.L. Beschta, J. C. Scrivener, K.V. Koski, J.R. Sedell, and C.J. Cederholm 1987. Fine sediment and salmonid production: a paradox. In: Salo, E.O. and T.W. Cundy. Streamside management: forestry and fishery interactions. Proc. Symposium Streamside Management: Forestry and Fishery Interactions. Held U. of Washington, Feb 12-14, 1986. Pg. 98-142.

Flosi, G., Downie, S., Hopelain, J., Bird, M., Coey, R., and Collins, B. 1998. California Salmonid Stream Habitat Restoration Manual. Third Edition. Inland Fisheries Division, California Department of Fish and Game.

Fox, Martin 1994. Draft revisions of the WSA Fish Module Diagnostic Martic: LWD assessment. Muckleshoot Indian Tribe Fisheries Department.

Groot, C, L. Margolis, and W.C. Clarke. 1995. Physiological ecology of Pacific salmon. UBC Press, Vancouver, CA. 511 pp.

Halligan, D. 1999. Final report – 1998 fisheries monitoring program for gravel extraction operations on the Mad, Eel, Van Duzen, and Trinity Rivers. Natural Resources Management Corporation, Eureka, California.

Hynes, H.B.N. 1970. The ecology of running waters. University of Toronto Press, Waterloo. 555 pp.

Irwin, W.P., 1960, Geologic reconnaissance of the northern Coast Ranges and Klamath Mountains, California, with a summary of mineral resources: California Division of Mines Bulletin 179, 80 p.

Keefer, D.K. 1984. Landslides caused by earthquakes. USGS, Menlo Park, CA. GSA Bulletin, v. 95; no. 4. April 1984. pp. 406-421.

Keller, E.A. and F.J. Swanson. 1979. Effects of large organic material on channel form and fluvial processes. Earth Surface Processes 4: 361-380.

Keller, E. A., and T. Tally. 1979. Effects of large organic debris on channel form and fluvial processes in the coastal redwood environment, in Rhodes, D. D., and Williams, G. P., eds., Adjustments of the fluvial system: Annual Geomorphology Symposia Series, 10th, Binghamton, New York, September 21-22, 1979, p. 169-198.

Kelsey, H.M. 1980. A sediment budget and an analysis of geomorphic process in the Van Duzen River basin, north coastal California, 1941-1975. Geol. Soc. Am. Bull. 91:1119-1216.

Kroeber, A.L. 1976. Handbook of the Indians of California. Dover Publications, Inc. New York.

Leopold, L. B., M.G. Wolman and J.P. Miller 1964. Fluvial processes in geomorphology. W.H. Freeman and Company. 522 pp.

Lewis, T. E., D. W. Lamphear, D. R. McCanne, A. S. Webb, J. P. Krieter, and W. D. Conroy. 2000. Regional assessment of stream temperatures across Northern California and their relationship to various landscape-level and site-specific attributes. Forest Science Project. Humboldt State University Foundation, Arcata, CA. 420 pp.

Lisle, T.E. 1986. Stabilization of a gravel channel by large streamside obstructions and bedrock bends, Jacoby Creek, northwestern California. Geo. Soc. Am. Bull. 97: 999-1011.

---. 1989. Sediment transport and resulting deposition in spawning gravels, north coastal California. Wat. Resour. Research. 25(6):1303-1319

---. 1990. The Eel River, northwestern California; high sediment yields from a dynamic landscape. Pages 311-314, in: M.G. Wolman and H.C. Riggs (ed.), Surface Water Hydrology, v. O-1, The Geology of North America, Geological Society of America.

Lisle, T.E., Iseya, F., and Ikeda, H. 1993. Response of a channel with alternate bars to a decrease in supply of mixed size bedload: a flume experiment. Wat. Resources Res. 29(11):3623-3629.

Lufkin, A. 1996. The Story of the Eel River Commercial Salmon Fishery. The Humboldt Historian, 44(2):4-8.

Madej, M.A. and V. Ozaki. 1996. Channel response to sediment wave propagation and movement, Redwood Creek, California, USA. Earth Surf. Proc. Landforms. 21: 911-927.

Madej, M.A., C. Currens, V. Ozaki, J. Yee, and D.G. Anderson. 2006. Assessing possible thermal rearing restrictions for juvenile coho salmon (Oncorhynchus kisutch) through thermal infrared imaging and in-stream monitoring, Redwood Creek, California. Can. J. Fish. Aquat. Sci. 63: 1384-1396.

Malinowski, S., A. Sheets, J. Lehman and M.W. Doig (eds.). 1998. The Gale Encyclopedia of Native American Tribes, Volume IV, California, Pacific Northwest, Pacific Islands. Gale Research, Inc. Detroit, Michigan.

McLaughlin, J. and F. Harradine. 1965. Soils of Western Humboldt County California. Department of Soils and Plant Nutrition, University of California, Davis, in cooperation with County of Humboldt, California. November.

McPherson, R. C. 1992. Style of Faulting at the Southern End of the Cascadia Subduction Zone: *in* R.M. Burke and G.A. Carver eds., Pacific Cell, Friends of the Pleistocene guidebook for the field trip to Northern Coastal California, A look at the southern end of the Cascadia Subduction Zone and the Mendocino Triple Junction, pp. 97-111.

Mills, T.J. 1983. Utilization of the Eel River tributary streams by anadromous salmonids. Appendix H *in* Reynolds, F.L. (editor). 1983. Status report of California Wild and Scenic Rivers: salmon and steelhead fisheries. California Dept. of Fish and Game. 57 pp.

Montgomery, D. R. 2001. Geomorphology, river ecology, and ecosystem management. In: Geomorphic processes and riverine habitat. Water Science and Application Volume 4; 247-253. American Geophysical Union, Bethesda, Md.

Montgomery, D.R. and J. M. Buffington. 1993. Channel classification, prediction of channel response, and assessment of channel condition. Timber/Fish/Wildlife Report FTW-SH-93-002. Washington Department of Natural Resources, Olympia, WA. 84 pp.

Montgomery, D.R.. J.M. Buffington, R.D. Smith, K.M. Schmidt, and G. Pess. 1995. Pool spacing in forest channels. Wat. Resources Res. 31(4): 1097-1105.

Montgomery, D.R., G.E. Grant, and K. Sullivan. 1995. Watershed analysis as a framework for implementing ecosystem management. Water Resources Bulletin. 31(3): 369-386.

Moore, R.D., D.L. Spittlehouse, and A. Story. 2005. Riparian microclimate and stream temperature response to forest harvesting; a review. J. Am. Water Resources Assoc. August: 813-833.

Myers, J.M., R.G. Kope, G.J. Bryant, D. Teel, L.J. Lierheimer, T.C. Wainwright, W.S. Grant, F.W. Waknitz, K. Neely, S.T. Lindley, and R.S. Waples. 1998. Status review of Chinook salmon from Washington, Idaho, Oregon, and California. U.S. Dept. Commerce, NOAA Tech. Memo. NMFS-NWFSC-35, 443p.

National Oceanic and Atmospheric Administration. 2000. Northwest California climatic characterization (http://www.wrh.noaa.gov/Eureka/climate/climate.html). NOAA-National Weather Service, Eureka Office, 300 Startare Drive Eureka, CA 95501.

Nielsen, J.L., T.E. Lisle, and V. Ozaki. 1994. Thermally stratified pools and their use by steelhead in northern California streams. Trans. Am. Fish. Soc. 123: 613-626.

Nilsen, T.H. and S.H. Clarke, Jr. 1987. Geologic evolution of the late Cenozoic basins of northern California, *in* Schymiczek, H. and Suchsland, R., eds., Tectonics, sedimentation and evolution of the Eel River and associated coastal basins of northern California, San Joaquin Geological Society Miscellaneous Publication, n. 37, p. 15-29.

Ogle, B.A. 1953. Geology of Eel River Valley area, Humboldt County, California: California Division of Mines and Geology Bulletin 164, 128 pp.

Pacific States Marine Fisheries Commission (PSMFC) and U.S. Fish and Wildlife Service (USFWS). 2004. Summary of the ninth Pacific coast steelhead management meeting. Prepared by the Pacific States Marine Fisheries Commission and U.S. Fish and Wildlife Service. March 9-11, 2004. Port Townsend, WA.

Pacific Watershed Associates (PWA), 1998a, Sediment source investigation and sediment reduction plan for the Bear Creek watershed, Humboldt County, California. Report prepared for The Pacific Lumber Company. Pacific Watershed Associates, Arcata, CA.

---. 1998b, Sediment source investigation and sediment reduction plan for the North Fork Elk River watershed, Humboldt County, California. Report prepared for The Pacific Lumber Company. Pacific Watershed Associates, Arcata, California.

PALCO. 1999. The Habitat Conservation Plan for the Properties of The Pacific Lumber Company, Scotia Pacific Company LLC, and Salmon Creek Corporation.

---. 2000. Watershed Assessment Methods for PALCO Lands, Scotia, California. April.

---. 2004. Elk River/Salmon Creek Watershed Analysis, Cumulative Watershed Effects Assessment. Scotia, California.

Pazzaglia, F. J., Gardner, T. W., and Merritts, D. J. 1999. “Bedrock fluvial incision and longitudinal profile development over geologic time scales determined by fluvial terraces,” in Rivers Over Rock: Fluvial processes in bedrock channels, *in* Tinkler and Wohl, eds., *American geophysical Union, Geophysical Monograph 107*, Washington, D. C.

Prentice, C.S. 1989. Earthquake geology of the northern San Andreas Fault near Point Arena, California, unpublished PhD thesis, California Institute of Technology, Pasadena, California, 235 pp.

Reeves, G.H., F.H. Everest, and J.D. Hall. 1987. Interactions between the redside shiner (*Richardsonius balteatus*) and the steelhead trout (*Salmo gairdneri*) in western Oregon: the influence of water temperature. Can. J. Fish. Aq. Sci. 44: 1603-1613

Sawyer, J. O., S. C. Sillett, et al. 2000. Characteristics of redwood forests. *The Redwood Forest: History, Ecology, and Conservation of the Coast Redwoods.* R. F. Noss. Washington, D.C., Island Press: 39-80. Spittler, T.E. 1983. Geologic and geomorphic maps from the California Geological Survey for the Bridgeville, Redcrest, Myers Flat, and Weott 7.5-minute quadrangles.

Spittler, T. E. 1983. Geology and Geomorphic Features Related to Landsliding, Redcrest 7.5' minute quadrangle, Humboldt County, California. California Division of Mines and Geology Open-file Report OFR 83-17, Scale 1:24,000.

Sullivan, K. 1986. Hydraulics and fish habitat in relation to channel morphology. PhD. Dissertation, The Johns Hopkins University, Baltimore, Md.

Sullivan, K., T.E. Lisle, C.A. Dolloff, G.E. Grant, and L.M. Reid. 1987. Stream channels: the link between forests and fishes. In: Salo, E.O. and T.W. Cundy. Streamside management: forestry and fishery interactions. Proc. Symposium Streamside Management: Forestry and Fishery Interactions. Held U. of Washington, Feb 12-14, 1986. Pg. 39-97.

Sullivan, K., J. Tooley, K. Doughty, J. E. Caldwell, and P. Knudsen. 1990. Evaluation of prediction models and characterization of stream temperature regimes in Washington. Timber/Fish/Wildlife Report No. TFW-WQ3-90-006. Washington Dept. Nat. Resources, Olympia, WA. 224 pp.

Sullivan, K., D. Martin, R. Cardwell, J.E. Toll, and S. Duke. 2000. An analysis of the effects of temperature on salmonids of the Pacific Northwest with implications for selecting temperature criteria. Sustainable Ecosystems Institute. Portland, OR.

Suttle, Kenwyn B., M.E. Power, J.M. Levine, and C. McNeely. 2004. How fine sediment in riverbeds impairs growth and survival of juvenile salmonids. Ecol. Applications 14(4): 969-974.

Taylor, R. and M. Love. 2003. Fish passage evaluation at stream crossings. Part IX in Flosi, G., Downie, S., Hopelain, J., Bird, M., Coey, R., and Collins, B. 1998. California Salmonid Stream Habitat Restoration Manual. Third Edition. Inland Fisheries Division, California Department of Fish and Game.

Theurer, F.D, K.A. Voos, and W.J. Miller. 1984. Instream water temperature model. Instream Flow Info. Paper No. 16. USDI Fish and Wildlife Service FWS/OBS-84/15.

Toppozada, T.R. and D.L. Parke. 1982. Areas damaged by California earthquakes 1900-1949, California Mines and Geology Open-File Report 82-17 SAC.

U.S. Army Corps of Engineers (US COE). 1999. Eel and Van Duzen Rivers general assessment of historical change in channel morphology. U.S. Army Corps of Engineers, San Francisco District.

U.S. Department of Agriculture Forest Service (USDA). 1995. Forest inventory and user's guide. USDA Forest Service Pacific Southwest Region 5. June 1995.

Wahle R. J., Pearson. 1987. A listing of Pacific Coast spawning streams and hatcheries producing Chinook and coho spawners. NOAA Tech. Memo. NMFS F/NWC-122, 32 p.

Washington Department of Natural Resources (WDNR). 1997. Standard Methodology for Conducting Watershed Analysis, Version 4.0. WDNR, Division of Forest Practices, Washington Forest Practices Board, Olympia.

Welsh, H.H. Jr., G.R. Hodgson, B.C. Harvey, and M.E. Roche. 2001. Distribution in juvenile coho salmon in relation to water temperatures in tributaries of the Mattole River, California, N. Am. J. Fish. Manage. 21: 464-470

Welty, J. J., T. Beechie, K. Sullivan, D.M. Hyink, R.E. Bilby, C. Andrus, and G. Pess. 2002. Riparian Aquatic Interaction Simulator (RAIS): a model of riparian forest dynamics for the generation of large woody debris and shade. For. Ecol. and Manage. 162(2002): 299-319.

Yarnell, S.M., J.F. Mount, and E.W. Larsen. 2006. The influence of relative sediment supply on riverine habitat heterogeneity. Geomorphology 80(2006): 310-324.

Appendix A

Mass Wasting Assessment Report

Appendix B

Surface Erosion Assessment Report

Appendix C

Riparian Function Assessment Report

Appendix D

Stream Channel Assessment Report

Appendix E

Fish Habitat Assessment Report

Appendix F

Amphibian and Reptile Assessment Report

Attachment 1

Sub-basin Data

<u>Information regarding Attachments 1A and 1B:</u>

Two spreadsheets summarizing basic environmental and cultural data for the Upper Eel WAU, with specific emphasis on HCP covered lands, are provided in Attachment One:

- The first (Attachment 1A) represents the best data available at the initiation of the analysis in early 2005. This data pre-dates the arrival of LIDAR technology and recent changes in ownership status. This data was used exclusively for all the analyses conducted in appendices A – F (watershed analysis modules), except in cases where the modules specifically state otherwise. Attachment 1A also provides, for quick reference, the results of the recent harvest history analysis (1988-2003) and the results of the riparian stand condition/LWD recruitment assessment.
- The second (Attachment 1b) represents the current best available data as of July 2006. Portions of this data (topography, stream density, and road density) are derived from recently acquired LIDAR technology. All of the data provided in this spreadsheet reflects recent changes in ownership (land sales) and the transition of previously non-HCP covered lands to HCP status as of July 2006.

UPPER EEL WATERSHED ANALYSIS AREA

Sub-Basin Data (Attachment 1A)

The information presented in this data sheet was the best available information at the initiation of the analysis. This information does not include LIDAR based data nor does it represent current ownership as lands were sold or transferred in and out of

	Balcom Creek Complex	Boulder Creek	Bridge Creek	Burr Creek	Butte Creek	Cameron Creek	Carson Creek Complex	Chris Creek	Decker Creek	Elk Creek	Kapple Creek Complex	Main Stem Larabee I	Main Stem Larabee II	McCann Creek Complex	McMahan Creek	Mid Larabee Creek Complex	Mill Creek	Newman Creek
OWNERSHIP (January 2005)																		
Total Sub-Basin Area (acres)	1259.23	1234.63	4288.68	6647.78	4177.74	13991.17	2012.48	1025.86	1834.84	7200.14	1845.71	2384.08	676.16	2571.67	8689.49	3341.33	15034.94	2208.23
Area of PALCO HCP ownership (acres)	1192.90	1105.47	377.07	0.00	33.22	496.45	1993.04	973.80	301.34	780.53	1550.04	1790.74	261.56	2320.96	0.00	1641.69	978.22	1878.14
Area of PALCO nonHCP ownership (acres)	0.00	0.00	785.98	0.00	0.00	506.32	0.00	0.00	0.00	812.60	149.10	0.00	0.00	0.00	0.00	0.00	0.00	236.23
Area of PALCO ownership (acres)	1192.90	1105.47	1163.05	0.00	33.22	1002.77	1993.04	973.80	301.34	1593.13	1699.13	1790.74	261.56	2320.96	0.00	1641.69	978.22	2114.37
Other Private Ownership (acres)	66.33	129.16	461.94	6647.78	4120.60	12988.41	19.44	52.06	593.64	4524.57	146.57	593.34	414.59	250.71	8689.49	1699.63	14056.72	93.87
Public Ownership (Parks)(acres)	0.00	0.00	2663.69	0.00	23.92	0.00	0.00	0.00	939.87	1082.43	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
GEOLOGY (HCP PALCO ONLY)																		
Geology - TKy (%)	3.8	77.3	100.0		92.2	60.9	63.6	0.0	100.0	100.0	34.8	54.6	0.0	92.8		100.0	0.0	72.5
Geology - KJfs (%)	0.0	10.0	0.0		0.0	36.8	0.0	0.0	0.0	0.0	0.0	3.0	80.5	0.0		0.0	87.6	0.0
Geology - fm/fm-ss/fm-bs/u (%)	0.0	12.7	0.0		0.0	1.2	0.0	0.0	0.0	0.0	0.0	0.8	13.6	0.0		0.0	0.0	0.0
Geology - QTwu (%)	96.1	0.0	0.0		0.0	0.0	34.8	79.8	0.0	0.0	54.7	16.9	0.0	0.0		0.0	0.0	11.4
Geology - Q/Qrt/Qf/Qsc(type, %)	0.0	0.0	0.0		7.8	0.1	0.3	2.4	0.0	0.0	5.9	21.5	5.9	7.2		0.0	0.3	11.6
Geology - QTsb (%)	0.0	0.0	0.0		0.0	0.0	1.3	17.8	0.0	0.0	0.0	0.0	0.0	0.0		0.0	0.0	0.0
Geology - Qort (%)	0.1	0.0	0.0		0.0	1.0	0.0	0.0	0.0	0.0	4.7	3.2	0.0	0.0		0.0	0.0	4.5
Geology - Unknown (%)	0.0	0.0	0.0		0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0		0.0	12.1	0.0
VEGETATION TYPE (HCP/NON PALCO ONLY)																		
Redwood (%)	42.6	0.0	34.1		0.0	0.1	61.5	57.5	60.5	0.0	55.1	30.7	0.0	10.1		0.0	0.0	48.0
Redwood/Doug-fir (%)	53.8	3.4	3.7		100.0	17.2	29.8	41.7	32.4	29.0	24.6	22.7	0.0	50.3		19.9	0.0	25.4
Redwood/Hardwood (%)	0.0	0.0	0.0		0.0	0.0	1.7	0.6	0.0	0.0	0.1	0.3	0.0	0.0		0.0	0.0	0.5
Doug-fir (%)	0.0	32.3	3.3		0.0	25.4	0.0	0.0	0.0	6.8	2.5	16.8	54.0	0.3		28.6	59.1	8.3
Doug-fir/Redwood (%)	3.4	0.1	31.0		0.0	12.4	1.6	0.0	0.1	14.3	4.5	0.0	0.0	13.7		27.3	0.0	0.5
Doug-fir/Hardwood (%)	0.0	20.0	0.0		0.0	2.2	0.3	0.0	0.0	0.0	0.0	6.6	35.8	0.5		11.9	14.4	0.9
Conifer/Hardwood (%)	0.0	12.2	10.6		0.0	4.0	0.0	0.0	0.0	45.9	1.4	0.0	0.0	16.6		1.4	0.0	1.0
Hardwood (%)	0.1	30.5	13.9		0.0	27.3	4.2	0.0	1.9	2.9	2.6	9.8	10.2	3.8		10.2	23.8	5.9
Non-timber (%)	0.1	1.4	3.5		0.0	11.5	0.9	0.2	5.1	1.0	9.3	12.9	0.0	4.7		0.7	2.6	9.4
HYDROLOGY(HCP PALCO ONLY)																		
Stream Miles, Class I (miles)	1.45	0.00	0.00		0.00	0.76	1.64	0.59	0.10	1.39	2.15	13.06	2.29	4.74		0.00	0.70	4.31
Stream Miles, Class II (miles)	5.25	7.06	1.15		0.00	2.96	10.00	5.76	1.11	4.28	7.11	6.80	1.34	10.02		10.88	8.11	7.47
Stream Miles, Class III (miles)	7.52	6.48	1.81		0.00	2.72	15.01	8.45	0.83	4.70	13.91	9.06	0.70	10.53		5.80	4.55	9.23
Stream Density, Class I (mile/sq mi)	0.78	0.00	0.00		0.00	0.98	0.53	0.39	0.21	1.14	0.89	4.67	5.61	1.31		0.00	0.46	1.47
Stream Density, Class II (mile/sq mi)	2.82	4.09	1.96		0.00	3.81	3.21	3.78	2.36	3.51	2.93	2.43	3.28	2.76		4.24	5.31	2.54
Stream Density, Class III (mile/sq mi)	4.03	3.75	3.08		0.00	3.51	4.82	5.55	1.77	3.85	5.75	3.24	1.72	2.90		2.26	2.98	3.14
TREATED ROADS (HCP PALCO ONLY)																		
Road Density (Rocked) (miles/sq mi)	0.92	0.63	0.00		0.00	0.00	2.03	0.50	0.00	0.00	1.19	0.85	0.00	0.00		1.27	0.00	2.01
Road Density (Native "Dirt") (miles/sq mi)	1.32	0.00	0.00		0.00	0.00	0.81	1.49	1.09	3.04	1.64	0.04	0.00	0.00		0.00	0.00	0.84
Road Density (Closed/Decomissioned) (miles/sq mi)	0.00	0.00	0.00		0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00		0.00	0.00	0.13
Road Density (Dirt Jeep Trail) (miles/sq mi)	0.00	0.00	0.00		0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00		0.00	0.00	0.09
UNTREATED ROADS (HCP PALCO ONLY)																		
Road Density (Rocked) (miles/sq mi)	0.82	0.12	0.00		0.00	0.53	0.68	0.80	0.00	0.00	0.09	1.34	0.00	0.99		1.40	0.29	0.70
Road Density (Native "Dirt") (miles/sq mi)	4.72	4.54	6.57		7.16	5.09	3.25	4.24	3.84	2.90	2.60	2.13	0.89	4.32		3.38	3.72	2.08
Road Density (Closed/Decomissioned) (miles/sq mi)	0.00	0.00	0.00		0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00		0.00	0.00	0.13
Road Density (Dirt Jeep Trail) (miles/sq mi)	0.00	0.00	0.00		0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00		0.00	0.00	0.00
Total Road Density by Sub-basin (miles/sq.mi.)	7.79	5.29	6.57		7.16	5.61	6.78	7.03	4.92	5.94	5.52	4.36	0.89	5.32		6.05	4.01	5.98
HARVEST HISTORY (HCP PALCO ONLY)																		
1988-2003 Harvest Clear Cut (acres)	587.50	200.00	0.00	0.00	0.00	97.60	797.10	441.40	91.10	129.20	477.30	449.00	33.20	25.40	0.00	285.60	283.70	565.10
1988-2003 Harvest Partial Cut (acres)	180.70	200.20	0.00	0.00	32.00	51.00	131.20	374.10	11.60	271.40	127.20	116.80	0.00	1.70	0.00	288.90	21.50	180.90
1988-2003 Harvest Tractor Yarding (acres)	216.60	298.50	0.00	0.00	32.00	92.10	419.30	134.60	102.80	400.60	221.00	335.40	0.00	27.00	0.00	315.50	175.40	300.00
1988-2003 Harvest Tractor/Cable Yarding (acres)	1.90	15.80	0.00	0.00	0.00	0.00	53.20	4.80	0.00	0.00	51.60	0.00	0.00	0.00	0.00	34.60	3.90	26.70
1988-2003 Harvest Cable Yarding (acres)	414.60	55.60	0.00	0.00	0.00	56.40	420.20	592.30	0.00	0.00	260.20	180.90	23.90	0.00	0.00	80.50	96.70	302.50
1988-2003 Harvest Helicopter Yarding (acres)	135.10	30.30	0.00	0.00	0.00	0.00	35.60	83.70	0.00	0.00	71.60	49.40	9.30	0.00	0.00	143.80	29.20	116.80
RIPARIAN FUNCTION (HCP PALCO ONLY)																		
Total RCU Acres (Class I & II)	138	151	21	0	0	87	244	140	28	112	199	337	67	302	0	242	192	258
LWD Recruitment, HIGH (%)	37.0	0.0	0.0	0.0	0.0	0.0	37.0	57.0	0.0	0.0	44.0	27.0	0.0	13.0	0.0	0.0	27.0	21.0
LWD Recruitment, MODERATE (%)	54.0	93.0	76.0	0.0	0.0	86.0	60.0	31.0	100.0	91.0	46.0	66.0	96.0	87.0	0.0	95.0	54.0	66.0
LWD Recruitment, LOW (%)	9.0	7.0	24.0	0.0	0.0	14.0	3.0	12.0	0.0	9.0	10.0	8.0	4.0	0.0	0.0	5.0	19.0	13.0
Over-Stream Canopy Cover, >85% (%)	98.0	99.0	79.0	0.0	0.0	100.0	98.0	95.0	100.0	87.0	84.0	41.0	56.0	80.0	0.0	100.0	96.0	90.0
Over-Stream Canopy Cover, 71-85% (%)	0.0	0.0	21.0	0.0	0.0	0.0	2.0	0.0	0.0	13.0	1.0	1.0	0.0	0.0	0.0	0.0	0.0	1.0
Over-Stream Canopy Cover, 41-70% (%)	0.0	1.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Over-Stream Canopy Cover, 21-40% (%)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	5.0	0.0	0.0	1.0	0.0	0.0	0.0	0.0	0.0	1.0	0.0
Over-Stream Canopy Cover, 0-20% (%)	2.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	13.0	58.0	44.0	20.0	0.0	0.0	3.0	9.0

UPPER EEL WATERSHED ANALYSIS A

Sub-Basin Data (Attachment 1A)

The information presented in this data sheet was the b

	No Name Creek Complex	Ohman Creek	Poison Oak Creek Complex	Scott Creek Complex	Smith Creek	Thompson Creek	Thurman Creek
OWNERSHIP (January 2005)							
Total Sub-Basin Area (acres)	1775.57	3130.82	3713.38	1918.69	1956.17	5531.26	8370.56
Area of PALCO HCP ownership (acres)	1773.81	152.24	2712.73	1918.69	1381.21	2333.13	0.00
Area of PALCO nonHCP ownership (acres)	0.00	1672.16	102.37	0.00	6.08	0.00	0.00
Area of PALCO ownership (acres)	1773.81	1824.39	2815.10	1918.69	1387.29	2333.13	0.00
Other Private Ownership (acres)	1.76	1051.88	690.74	0.00	568.87	3198.14	8370.56
Public Ownership (Parks)(acres)	0.00	254.54	207.54	0.00	0.00	0.00	0.00
GEOLOGY (HCP PALCO ONLY)							
Geology - TKy (%)	0.0	18.1	84.6	95.8	99.8	73.8	
Geology - KJfs (%)	92.4	55.6	0.0	0.0	0.0	0.0	
Geology - fm/fm-ss/fm-bs/u (%)	7.6	26.3	0.0	0.0	0.0	0.0	
Geology - QTwu (%)	0.0	0.0	0.0	4.2	0.0	19.9	
Geology - Q/Qrt/Qf/Qsc(type, %)	0.0	0.0	12.1	0.0	0.2	6.2	
Geology - QTsb (%)	0.0	0.0	0.0	0.0	0.0	0.0	
Geology - Qort (%)	0.0	0.0	3.3	0.0	0.0	0.1	
Geology - Unknown (%)	0.0	0.0	0.0	0.0	0.0	0.0	
VEGETATION TYPE (HCP/NON PALCO ONLY)							
Redwood (%)	0.0	0.0	36.1	6.9	16.3	6.5	
Redwood/Doug-fir (%)	0.0	0.0	34.2	57.7	41.0	34.2	
Redwood/Hardwood (%)	0.0	0.0	0.8	0.3	0.4	0.5	
Doug-fir (%)	63.9	44.3	1.0	3.4	15.0	15.4	
Doug-fir/Redwood (%)	0.0	0.0	7.6	23.9	6.5	6.9	
Doug-fir/Hardwood (%)	22.2	0.0	0.0	3.9	2.1	2.9	
Conifer/Hardwood (%)	0.0	0.0	14.1	1.3	0.0	6.4	
Hardwood (%)	11.9	46.7	1.0	2.4	9.9	12.2	
Non-timber (%)	1.9	9.0	5.4	0.3	8.8	14.9	
HYDROLOGY(HCP PALCO ONLY)							
Stream Miles, Class I (miles)	0.14	0.00	5.62	0.85	0.00	5.60	
Stream Miles, Class II (miles)	13.38	0.07	14.42	12.03	9.96	9.02	
Stream Miles, Class III (miles)	5.37	0.00	13.50	7.78	7.95	14.77	
Stream Density, Class I (mile/sq mi)	0.05	0.00	1.33	0.28	0.00	1.54	
Stream Density, Class II (mile/sq mi)	4.83	0.27	3.40	4.01	4.61	2.48	
Stream Density, Class III (mile/sq mi)	1.94	0.00	3.18	2.59	3.68	4.05	
TREATED ROADS (HCP PALCO ONLY)							
Road Density (Rocked) (miles/sq mi)	0.00	0.00	1.18	1.72	0.30	0.25	
Road Density (Native "Dirt") (miles/sq mi)	0.00	0.00	0.24	0.49	0.21	0.53	
Road Density (Closed/Decomissioned) (miles/sq mi)	0.00	0.00	0.00	0.00	0.00	0.00	
Road Density (Dirt Jeep Trail) (miles/sq mi)	0.00	0.00	0.00	0.03	0.00	0.00	
UNTREATED ROADS (HCP PALCO ONLY)							
Road Density (Rocked) (miles/sq mi)	1.59	0.00	0.35	1.44	1.03	0.00	
Road Density (Native "Dirt") (miles/sq mi)	4.86	3.18	2.56	3.76	3.80	4.96	
Road Density (Closed/Decomissioned) (miles/sq mi)	0.00	1.44	0.00	0.00	0.00	0.22	
Road Density (Dirt Jeep Trail) (miles/sq mi)	0.00	0.00	0.00	0.00	0.00	0.00	
Total Road Density by Sub-basin (miles/sq.mi.)	6.44	4.61	4.33	7.44	5.33	5.96	
HARVEST HISTORY (HCP PALCO ONLY)							
1988-2003 Harvest Clear Cut (acres)	371.30	23.00	489.10	789.30	428.00	361.50	0.00
1988-2003 Harvest Partial Cut (acres)	185.10	31.60	79.00	205.40	54.00	146.60	0.00
1988-2003 Harvest Tractor Yarding (acres)	192.20	54.60	347.70	515.00	263.70	220.50	0.00
1988-2003 Harvest Tractor/Cable Yarding (acres)	5.90	0.00	0.00	0.00	22.30	20.60	0.00
1988-2003 Harvest Cable Yarding (acres)	258.40	0.00	90.80	382.80	171.40	197.60	0.00
1988-2003 Harvest Helicopter Yarding (acres)	99.80	0.00	129.60	96.90	24.70	69.40	0.00
RIPARIAN FUNCTION (HCP PALCO ONLY)							
Total RCU Acres (Class I & II)	302	2	409	282	220	281	0
LWD Recruitment, HIGH (%)	9.0	0.0	22.0	25.0	33.0	7.0	0.0
LWD Recruitment, MODERATE (%)	75.0	0.0	75.0	69.0	64.0	65.0	0.0
LWD Recruitment, LOW (%)	16.0	100.0	3.0	6.0	3.0	28.0	0.0
Over-Stream Canopy Cover, >85% (%)	86.0	100.0	86.0	95.0	95.0	81.0	0.0
Over-Stream Canopy Cover, 71-85% (%)	8.0	0.0	0.0	3.0	3.0	7.0	0.0
Over-Stream Canopy Cover, 41-70% (%)	5.0	0.0	0.0	2.0	2.0	0.0	0.0
Over-Stream Canopy Cover, 21-40% (%)	1.0	0.0	0.0	0.0	0.0	0.0	0.0
Over-Stream Canopy Cover, 0-20% (%)	0.0	0.0	14.0	0.0	0.0	12.0	0.0

UPPER EEL WATERSHED ANALYSIS AREA

Sub-Basin Data (Attachment 1B)

This spreadsheet was updated 7/31/2006 using environmental and cultural conditions derived from LIDAR technology. Also sub-basin acreage was revised as a result of a recent land sales (changes in ownership) and transfers of PALCO n

	Balcom Creek Complex	Boulder Creek	Bridge Creek	Burr Creek	Butte Creek	Cameron Creek	Carson Creek Complex	Chris Creek	Decker Creek	Elk Creek	Kapple Creek Complex	Main Stem Larabee I	Main Stem Larabee II	McCann Creek Complex	McMahan Creek
OWNERSHIP															
Total Sub-Basin Area (acres)	1259.23	1234.63	4288.68	6647.78	4177.74	13991.17	2012.48	1025.86	1834.84	7200.14	1845.71	2384.08	676.16	2571.67	8689.49
Area of PALCO HCP ownership (acres)	1192.90	1105.47	1163.05	0.00	0.00	562.35	1993.04	973.80	301.34	838.65	1699.13	1790.74	261.56	2320.96	0.00
Area of PALCO nonHCP ownership (acres)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Area of PALCO ownership (acres)	1192.90	1105.47	1163.05	0.00	0.00	562.35	1993.04	973.80	301.34	838.65	1699.13	1790.74	261.56	2320.96	0.00
Other Private Ownership (acres)	66.33	129.16	461.94	6647.78	4153.82	13428.83	19.44	52.06	593.64	5279.05	146.57	593.34	414.59	250.71	8689.49
Public Ownership (Parks)(acres)	0.00	0.00	2663.69	0.00	23.92	0.00	0.00	0.00	939.87	1082.43	0.00	0.00	0.00	0.00	0.00
LIDAR BASED TOPOGRAPHY (HCP PALCO ONLY)															
LIDAR Topography, <35% (%)	30.0	38.0	46.0		0.0	34.0	45.0	26.0	64.0	60.0	36.0	42.0	20.0	29.0	
LIDAR Topography, 36-50% (%)	36.0	28.0	30.0		0.0	29.0	32.0	29.0	24.0	22.0	27.0	17.0	24.0	21.0	
LIDAR Topography, 51-65% (%)	24.0	19.0	18.0		0.0	19.0	14.0	30.0	9.0	12.0	23.0	16.0	27.0	24.0	
LIDAR Topography, >65% (%)	10.0	15.0	6.0		0.0	17.0	9.0	14.0	2.0	5.0	14.0	26.0	29.0	25.0	
GEOLOGY (HCP PALCO ONLY)															
Geology - TKy (%)	3.8	77.3	0.0		0.0	65.5	63.6	0.0	100.0	100.0	40.0	54.6	0.0	92.8	
Geology - KJfs (%)	0.0	10.0	0.0		0.0	32.4	0.0	0.0	0.0	0.0	0.0	3.0	80.5	0.0	
Geology - fm/fm-ss/fm-bs/u (%)	0.0	12.7	0.0		0.0	1.1	0.0	0.0	0.0	0.0	0.0	0.8	13.6	0.0	
Geology - QTwu (%)	96.1	0.0	96.6		0.0	0.0	34.8	79.8	0.0	0.0	50.4	16.9	0.0	0.0	
Geology - Q/Qrt/Qf/Qsc(type, %)	0.0	0.0	0.0		0.0	0.1	0.3	2.4	0.0	0.0	5.4	21.5	5.9	7.2	
Geology - QTsb (%)	0.0	0.0	3.4		0.0	0.0	1.3	17.8	0.0	0.0	0.0	0.0	0.0	0.0	
Geology - Qort (%)	0.1	0.0	0.0		0.0	0.9	0.0	0.0	0.0	0.0	4.2	3.2	0.0	0.0	
Geology - Unknown (%)	0.0	0.0	0.0		0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	
VEGETATION TYPE (HCP/NON PALCO ONLY)															
Redwood (%)	44.1	0.0	80.2		0.0	7.6	61.6	57.7	60.5	0.5	51.5	30.7	2.6	14.4	
Redwood/Doug-fir (%)	53.0	3.4	2.7		0.0	23.2	29.8	41.7	32.6	30.4	28.9	22.7	0.0	48.3	
Redwood/Hardwood (%)	0.0	0.0	2.5		0.0	0.0	1.7	0.4	0.0	0.0	0.1	0.3	0.0	0.0	
Doug-fir (%)	0.0	32.3	0.0		0.0	18.1	0.0	0.0	0.0	6.8	2.3	16.8	51.4	0.2	
Doug-fir/Redwood (%)	2.7	0.1	0.0		0.0	14.1	1.6	0.0	0.0	13.0	4.1	0.0	0.0	13.3	
Doug-fir/Hardwood (%)	0.0	20.0	0.0		0.0	2.0	0.3	0.0	0.0	0.0	0.0	6.6	35.8	0.3	
Conifer/Hardwood (%)	0.0	12.2	0.0		0.0	3.3	0.0	0.0	0.0	42.4	1.3	0.0	0.0	15.4	
Hardwood (%)	0.1	30.5	0.0		0.0	21.6	4.2	0.0	1.9	6.3	2.4	9.8	10.2	3.7	
Non-timber (%)	0.1	1.4	14.6		0.0	10.1	0.9	0.2	5.1	0.6	9.4	12.9	0.0	4.4	
HYDROLOGY(HCP PALCO ONLY)															
Stream Miles, Class I (miles)	0.00	0.04	0.50			1.09	0.34	0.63	0.12	1.09	1.43	10.41	1.59	2.39	
Stream Miles, Class II (miles)	7.49	6.86	7.88			3.30	11.92	6.23	1.09	3.50	9.07	7.04	1.45	11.71	
Stream Density, Class I (mile/sq mi)	0.00	0.03	0.28			1.23	0.11	0.41	0.26	0.83	0.54	3.72	3.88	0.66	
Stream Density, Class II (mile/sq mi)	4.02	3.97	4.33			3.75	3.82	4.10	2.31	2.67	3.42	2.51	3.55	3.24	
TREATED ROADS (HCP PALCO ONLY)															
Road Density (Rocked) (miles/sq mi)	1.05	0.75	0.00			0.00	2.08	1.31	0.00	0.00	1.28	0.85	0.00	0.22	
Road Density (Native "Dirt") (miles/sq mi)	3.68	1.41	0.00			0.20	1.10	0.79	1.04	3.36	2.24	0.45	1.00	0.85	
Road Density (Closed/Decomissioned) (miles/sq mi)	0.09	0.00	0.00			0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	
Road Density (Dirt Jeep Trail) (miles/sq mi)	0.00	0.00	0.00			0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	
UNTREATED ROADS (HCP PALCO ONLY)															
Road Density (Rocked) (miles/sq mi)	0.69	0.00	0.00			1.10	0.68	0.80	0.00	0.00	0.04	1.34	0.00	0.99	
Road Density (Native "Dirt") (miles/sq mi)	2.47	3.20	6.84			5.02	3.00	4.31	3.92	2.67	2.15	1.72	0.00	3.58	
Road Density (Closed/Decomissioned) (miles/sq mi)	0.00	0.00	0.00			0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	
Road Density (Dirt Jeep Trail) (miles/sq mi)	0.00	0.00	0.00			0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	
Total Road Density by Sub-basin	7.98	5.36	6.84			6.32	6.86	7.21	4.96	6.03	5.71	4.37	1.00	5.65	

UPPER EEL WATERSHED ANALYSIS
Sub-Basin Data (Attachment 1B)

This spreadsheet was updated 7/31/2006 using envion-HCP land into PALCO

	Mid Larabee Creek Complex	Mill Creek	Newman Creek	No Name Creek Complex	Ohman Creek	Poison Oak Creek Complex	Scott Creek Complex	Smith Creek	Thompson Creek	Thurman Creek
OWNERSHIP										
Total Sub-Basin Area (acres)	3341.33	15034.94	2208.23	1775.57	3130.82	3713.38	1918.69	1956.17	5531.26	8370.56
Area of PALCO HCP ownership (acres)	1641.69	978.22	2114.37	1773.81	0.00	2815.10	1918.69	1387.29	2154.07	0.00
Area of PALCO nonHCP ownership (acres)	0.00	0.00	0.00	0.00	152.24	0.00	0.00	0.00	179.06	0.00
Area of PALCO ownership (acres)	1641.69	978.22	2114.37	1773.81	152.24	2815.10	1918.69	1387.29	2333.13	0.00
Other Private Ownership (acres)	1699.63	14056.72	93.87	1.76	2724.04	690.74	0.00	568.87	3198.14	8370.56
Public Ownership (Parks)(acres)	0.00	0.00	0.00	0.00	254.54	207.54	0.00	0.00	0.00	0.00
LIDAR BASED TOPOGRAPHY (HCP PALCO ONLY)										
LIDAR Topography, <35% (%)	40.0	23.0	35.0	23.0	0.0	33.0	32.0	49.0	34.0	
LIDAR Topography, 36-50% (%)	28.0	21.0	25.0	25.0	0.0	21.0	27.0	34.0	30.0	
LIDAR Topography, 51-65% (%)	20.0	22.0	24.0	21.0	0.0	23.0	22.0	14.0	20.0	
LIDAR Topography, >65% (%)	12.0	34.0	16.0	31.0	0.0	23.0	18.0	4.0	16.0	
GEOLOGY (HCP PALCO ONLY)										
Geology - TKy (%)	100.0	0.0	75.6	0.0	0.0	84.2	95.8	99.8	79.9	
Geology - KJfs (%)	0.0	87.6	0.0	92.4	0.0	0.0	0.0	0.0	0.0	
Geology - fm/fm-ss/fm-bs/u (%)	0.0	0.0	0.0	7.6	0.0	0.0	0.0	0.0	0.0	
Geology - QTwu (%)	0.0	0.0	10.1	0.0	0.0	0.0	4.2	0.0	15.1	
Geology - Q/Qrt/Qf/Qsc(type, %)	0.0	0.3	10.3	0.0	0.0	11.7	0.0	0.2	4.9	
Geology - QTsb (%)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	
Geology - Qort (%)	0.0	0.0	4.0	0.0	0.0	4.1	0.0	0.0	0.1	
Geology - Unknown (%)	0.0	12.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	
VEGETATION TYPE (HCP/NON PALCO ONLY)										
Redwood (%)	0.0	0.2	43.2	0.5	0.0	35.6	9.6	16.2	4.1	
Redwood/Doug-fir (%)	19.9	0.0	31.3	0.0	0.0	36.1	54.7	40.9	36.3	
Redwood/Hardwood (%)	0.0	0.0	0.4	0.0	0.0	0.8	0.3	0.4	0.5	
Doug-fir (%)	28.6	58.7	7.6	63.3	0.0	1.1	3.5	15.3	16.5	
Doug-fir/Redwood (%)	27.3	0.0	0.3	0.0	0.0	6.7	24.1	6.4	4.6	
Doug-fir/Hardwood (%)	11.9	14.4	0.8	22.2	0.0	0.0	3.9	2.0	3.2	
Conifer/Hardwood (%)	1.4	0.0	1.7	0.0	0.0	13.6	1.3	0.0	7.0	
Hardwood (%)	10.2	24.1	5.8	12.1	0.0	0.9	2.4	10.0	13.2	
Non-timber (%)	0.7	2.6	8.8	1.9	0.0	5.2	0.2	8.8	14.6	
HYDROLOGY(HCP PALCO ONLY)										
Stream Miles, Class I (miles)	0.26	0.69	3.28	0.13		2.35	0.15	0.00	3.10	
Stream Miles, Class II (miles)	12.45	8.16	10.33	15.36		17.51	13.50	9.67	10.53	
Stream Density, Class I (mile/sq mi)	0.10	0.45	0.99	0.05		0.53	0.05	0.00	0.92	
Stream Density, Class II (mile/sq mi)	4.85	5.34	3.12	5.58		3.98	4.50	4.46	3.13	
TREATED ROADS (HCP PALCO ONLY)										
Road Density (Rocked) (miles/sq mi)	1.46	0.06	2.41	1.64		1.17	1.76	0.35	0.27	
Road Density (Native "Dirt") (miles/sq mi)	0.39	1.28	1.38	3.28		0.31	0.76	0.62	1.40	
Road Density (Closed/Decomissioned) (miles/sq mi)	0.00	0.00	0.18	0.00		0.00	0.00	0.00	0.00	
Road Density (Dirt Jeep Trail) (miles/sq mi)	0.00	0.00	0.01	0.00		0.00	0.00	0.00	0.00	
UNTREATED ROADS (HCP PALCO ONLY)										
Road Density (Rocked) (miles/sq mi)	1.21	0.14	0.10	0.00		0.32	1.46	0.95	0.00	
Road Density (Native "Dirt") (miles/sq mi)	3.03	2.51	1.91	1.84		2.48	3.48	3.39	4.00	
Road Density (Closed/Decomissioned) (miles/sq mi)	0.00	0.00	0.04	0.00		0.00	0.00	0.00	0.23	
Road Density (Dirt Jeep Trail) (miles/sq mi)	0.00	0.00	0.00	0.00		0.00	0.00	0.00	0.00	
Total Road Density by Sub-basin	6.09	3.99	6.04	6.76		4.29	7.46	5.31	5.90	

Attachment 2

Sediment Budget

Upper Eel Watershed Analysis

Sediment Budget (Tons/square mile/yr)

1988-2003	7/18/2006		Module	Balcom Creek Complex	Boulder Creek	Bridge Creek	Burr Creek	Butte Creek	Cameron Creek	Carson Creek Complex	Chris Creek	Decker Creek	Elk Creek	Kapple Creek Complex	Main Stem Larabee I	Main Stem Larabee II	McCann Creek Complex	McMahan Creek	Mid Larabee Creek Complex
NATURAL	Landslides	Deep Seated	MW	0.0	0.0	0.0	0.0	0.0	97.0	0.0	0.0	0.0	0.0	109.2	0.0	0.0	0.0	0.0	0.0
		Shallow Seated	MW	0.0	76.4	0.0	0.0	0.0	0.0	211.7	0.0	0.0	29.7	177.2	1266.7	0.0	65.9	0.0	19.4
		Small Streamside	MW	216.3	274.5	131.3	0.0	0.0	290.1	233.9	267.5	165.8	275.0	209.9	189.4	284.5	204.1	0.0	284.7
	Surface Erosion	Soil Creep	SE	65.8	67.6	43.4	0.0	0.0	71.6	73.8	83.8	37.4	73.3	82.5	89.1	91.5	60.1	0.0	56.1
	Stream Channel Erosion	Bank Erosion	SC	19.7	45.5	28.4	0.0	0.0	51.2	41.9	23.6	27.9	37.3	38.2	34.6	65.1	44.8	0.0	46.1
LEGACY	Landslides	"Untreated" Abandoned roads	MW	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	107.0	0.0	0.0	9.6
		Tractor Harvest 15-30yrs (PC)	MW	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
		Tractor Harvest 20-30yrs (CC)	MW	0.0	54.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1311.1	0.0	0.0	0.0
		Small Streamside	MW	28.8	36.6	17.5	0.0	0.0	38.7	31.2	35.7	22.1	36.7	28.0	25.3	37.9	27.2	0.0	38.0
	Surface Erosion	"Untreated" Abandoned Roads	SE	3.5	91.9	86.0	0.0	0.0	132.1	36.5	0.0	241.1	217.9	27.3	198.4	601.9	155.4	0.0	128.3
	Stream Channel Erosion	Bank Erosion	SC	9.2	10.7	5.3	0.0	0.0	12.1	9.8	11.0	6.5	11.6	9.0	8.1	12.2	8.4	0.0	10.8
		Channel Incision	SC	4.2	6.1	3.0	0.0	0.0	5.8	4.8	5.6	3.5	5.2	4.4	3.7	4.9	4.1	0.0	6.3
MGMT	Landslides	HCP Roads	MW	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	24.3	317.7	0.0	196.4	0.0	8.3
		Partial Cut <15 yrs	MW	7.1	0.0	0.0	0.0	0.0	0.0	0.0	892.7	0.0	0.0	26.9	1608.4	0.0	0.0	0.0	35.4
		Clearcut <20 yrs	MW	6.3	104.2	0.0	0.0	0.0	4.1	159.7	11.9	0.0	87.2	63.2	110.4	0.0	0.0	0.0	0.0
		Small Streamside	MW	43.2	54.9	26.3	0.0	0.0	58.0	46.8	53.5	33.1	55.0	42.0	37.9	57.0	40.8	0.0	56.9
	Surface Erosion	Harvest Unit (1988-2003)	SE	7.6	2.8	0.0	0.0	0.0	3.7	5.2	11.6	0.7	5.0	5.3	4.1	0.1	0.0	0.0	2.3
		Road - Surface	SE	84.2	28.7	17.7	0.0	0.0	31.6	59.0	104.0	13.0	36.0	41.9	60.4	1.7	38.1	0.0	21.4
		Road - Gullies/Washouts	SE	85.1	475.8	269.3	0.0	0.0	697.8	354.9	55.6	240.9	573.6	165.4	407.4	143.2	608.1	0.0	459.2
	Stream Channel Erosion	Bank Erosion	SC	32.7	14.9	1.8	0.0	0.0	16.9	13.7	39.0	9.3	28.7	12.6	11.3	4.1	2.8	0.0	15.1
		Channel Incision	SC	4.2	6.1	3.0	0.0	0.0	5.8	4.8	5.6	3.5	5.2	4.4	3.7	4.9	4.1	0.0	6.3
				618	1351	633	0	0	1516	1288	1601	805	1477	1072	4377	2727	1460	0	1204

Upper Eel Watershed Analysis

Sediment Budget (Tons/square mile/yr)

1988-2003	7/18/2006		Module	Mill Creek	Newman Creek	No Name Creek Complex	Ohman Creek	Poison Oak Creek Complex	Scott Creek Complex	Smith Creek	Thompson Creek	Thurman Creek
NATURAL	Landslides	Deep Seated	MW	0.0	0.0	0.0	0.0	0.0	0.0	42.5	0.0	0.0
		Shallow Seated	MW	0.0	104.0	0.0	46.3	364.6	41.9	41.8	32.8	0.0
		Small Streamside	MW	365.3	209.0	325.9	18.4	253.1	279.4	309.8	206.5	0.0
	Surface Erosion	Soil Creep	SE	75.4	61.7	58.8	2.4	68.2	59.4	71.5	69.5	0.0
	Stream Channel Erosion	Bank Erosion	SC	60.1	29.0	52.4	2.9	44.7	46.5	51.0	39.2	0.0
LEGACY	Landslides	"Untreated" Abandoned roads	MW	0.0	0.0	0.0	0.0	162.5	0.0	34.2	13.4	0.0
		Tractor Harvest 15-30yrs (PC)	MW	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
		Tractor Harvest 20-30yrs (CC)	MW	182.1	0.0	3.0	0.0	0.0	0.0	0.0	31.3	0.0
		Small Streamside	MW	48.7	27.9	43.4	2.6	33.8	37.2	41.3	27.5	0.0
	Surface Erosion	"Untreated" Abandoned Roads	SE	3.4	3.8	20.4	229.5	127.5	39.9	114.2	54.8	0.0
	Stream Channel Erosion	Bank Erosion	SC	14.1	9.1	12.3	0.7	10.5	10.9	12.0	9.2	0.0
		Channel Incision	SC	7.9	3.8	7.2	0.4	5.0	6.0	6.9	3.7	0.0
MGMT	Landslides	HCP Roads	MW	0.0	182.4	596.8	57.4	44.2	0.0	0.0	15.2	0.0
		Partial Cut <15 yrs	MW	0.0	22.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0
		Clearcut <20 yrs	MW	22.9	9.4	264.5	0.0	0.0	2.7	0.0	84.6	0.0
		Small Streamside	MW	73.0	41.8	65.2	3.7	50.6	55.9	62.0	41.3	0.0
	Surface Erosion	Harvest Unit (1988-2003)	SE	4.0	3.6	2.7	0.2	0.9	7.6	3.8	1.7	0.0
		Road - Surface	SE	10.1	29.4	20.9	0.0	26.2	45.0	21.5	41.7	0.0
		Road - Gullies/Washouts	SE	334.3	261.0	455.2	334.8	449.6	533.3	459.9	359.9	0.0
	Stream Channel Erosion	Bank Erosion	SC	19.7	22.4	17.2	1.1	14.7	15.2	16.7	12.9	0.0
		Channel Incision	SC	7.9	3.8	7.2	0.4	5.0	6.0	6.9	3.7	0.0
				1229	1024	1953	701	1661	1187	1296	1049	0

Attachment 3

Sub-basin Summaries

Attachment 3

PALCO
Upper Eel Watershed Analysis

Sub-basin Summaries

Attachment 3

Upper Eel Watershed Analysis

Sub-basin Summaries

A summary of conditions for each sub-basin is presented in this attachment based on data provided in the watershed analysis modules (Appendices A-F). Four sub-headings are included for each sub-basin: introduction; HCP species; stream channel and riparian conditions; and hillslope conditions. In the introduction, the location of the sub-basin, general characteristics of the terrain and vegetation, roads, and general harvest history are discussed. The discussion on HCP species summarizes the presence or absence of fish, amphibian, and reptile species. Also, fish barriers are mentioned along with the occurrence of suitable habitat for amphibians and reptiles. Stream channel and riparian conditions are summarized in terms of fish access, spawning and rearing habitat, and riparian conditions. Factors limiting fish distribution, along with streambed, pool, and stream temperature conditions, are discussed. Riparian conditions are characterized from module information on canopy cover, average tree size, and large woody debris recruitment data. Hillslope conditions are summarized in terms of sediment sources quantified in the sediment budget. Types of sediment sources are categorized as natural, legacy, and management-associated. The discussion includes identification of causes or associations for significant volumes in the sediment budget. The complete sediment budget is presented in detail in Attachment 2, which includes a definition of types, timelines, and attribution/association of sediment sources to potential or observed causes. Also, the design, structure, and process for constructing the sediment budget is provided in Attachment 2. It is important to note that the sediment budget is derived from several different types of analysis, each with its own level of accuracy, including air photo inventories, sample surveys, calculations based on unit rates, and modeling. If data were collected through a sample survey, then this information was applied to other unsurveyed areas based on attributes available on a WAU-wide basis. Calculation methods and unit rates were utilized, as necessary, based on the best available literature or sample surveys. Time periods were set to cover available data (e.g., air photo years) and to represent the major periods in which management changes occurred, including recent management (1988-2003), legacy (1972-1987), and historic (pre-1972) periods.

1.0 BALCOM CREEK COMPLEX SUB-BASIN

The Balcom Creek Complex sub-basin is located in the Larabee Creek drainage upstream from the confluence of Larabee Creek and the main stem Eel River. HCP lands comprise 95 percent of this 2-square-mile sub-basin. This sub-basin includes lands to the south of Larabee Creek and includes two major Class I tributaries – Balcom Creek and Dauphiny Creek. The terrain is rugged with elevations ranging from 2,800 feet at the ridge top to 260 feet at the boundary with the Main Stem Larabee I sub-basin. Based on recent LIDAR data, more than half of the HCP area has slope gradients of less than 35 percent, and 10 percent of the area has slopes steeper than 65 percent. The predominant geologic formation in the Balcom Creek sub-basin is Wildcat group, undifferentiated.

Redwood/Douglas fir is the dominant vegetation type for the Balcom Creek Complex sub-basin, covering 54 percent of the HCP area, with another 43 percent of the redwood vegetation type. The vegetation community is relatively stable in terms of vegetation type, with no significant changes expected in the future.

Presently, the Balcom Creek Complex sub-basin has a road density of 8.3 miles/square mile for all HCP and non-HCP roads in the HCP area. The majority of these roads are regular dirt and are used seasonally. In addition to these seasonal roads, the Sockeye Road is a rocked main route that provides access to HCP lands between Larabee Creek and the main stem Eel River.

The Balcom Creek Complex sub-basin is one of the areas of the Upper Eel WAU in which harvest has increased since the late 1980s. Second-cycle logging activities have been ongoing for the past several decades; first harvest occurred from the 1910s through 1930s. In the period from 1988 through 2003, a total of 768 acres were harvested. Of this total, 76 percent of the harvested acres were clear cut. Yarding was most commonly done by cable for the harvested acres (54 percent); 26 percent of the clear cut acres were yarded by tractor.

1.1 HCP SPECIES

The information utilized in this sub-section is presented in Appendix E (Section 4.2.3.4 and 4.2.3.5, Tables E-7 and E-8); and Appendix F (Section 4.6, Table F-10).

Surveys completed in 2004 and 2005, along with earlier surveys conducted by DFG in 1963 and 1981, show that no fish are present in Balcom Creek. Fish cannot populate this drainage due to a natural barrier comprised of a series of bedrock cascades, starting 75 feet above its confluence with Larabee Creek. The lower reach of Dauphiny Creek is fishbearing, as observed in both 2004 and 2005, and extends approximately 3,700 feet upstream from its confluence with Larabee Creek. At this point, a 1.8-meter high bedrock step barrier prevents further upstream fish access. Beyond this barrier, the channel gradient rapidly increases.

The western pond turtle and yellow-legged frog were observed in the Balcom Creek Complex sub-basin, with habitat in the gentle gradient reaches of its streams and its interface with the Main Stem Larabee I sub-basin. Red-legged frog breeding and pond turtles have been confirmed in the Balcom Creek Pond, which provides important habitat for pond turtles. The other amphibian and reptile species of concern, tailed frog and torrent salamander, were not observed in this sub-basin.

1.2 STREAM CHANNEL AND RIPARIAN CONDITIONS

The information utilized in this sub-section is presented in Appendix C (Section 6.1.1, Figures C-5 and C-8); and Appendix E (Sections 3.2, 4.2.3.4 and 4.2.3.5, Tables E-1, E-7, E-8, and E-14).

Fish access is precluded 75 feet upstream from the mouth of Balcom Creek because of a natural barrier. Likewise, in Dauphiny Creek a natural bedrock barrier 3,700 ft from the mouth precludes fish migration upstream from this point.

Balcom Creek and Dauphiny Creek, as well as other smaller tributaries in this sub-basin, are generally underlain by easily erodible Wildcat bedrock which can result in deposits of fine sediments on the streambed of gentle gradient reaches. Pools in Balcom Creek and Dauphiny Creek are abundant but there are not many deep pools – average residual pool depth does not meet the PFC target, possibly because of sediment filling. However, as discussed in the Fish Habitat Assessment (Appendix E), it is important to recognize that channel size and contributing basin area play a role in determining channel dimensions. The pool depth criterion is unlikely to be achievable for this sub-basin because of its small drainage area.

Water temperatures are cool and near optimum (below PFC criteria) for salmonid growth in Balcom Creek; no temperature data were available for Dauphiny Creek. Over-stream canopy cover in Balcom Creek and Dauphiny Creek is greater than 85 percent for 98 percent of the stream length, providing good cover for temperature protection. Riparian forests consist of medium- to large-sized trees, ranging from 12-inch to greater than 24-inch at dbh. Redwood is the dominant species found in these stands, and the canopy closure is mostly dense.

A significant percentage (37 and 54 percent, respectively) of riparian stands in the Balcom Creek Complex have moderate or high LWD recruitment potential on Class I streams. LWD recruitment rates are generally highest in the low and moderate gradient reaches in Wildcat terrain due to the prevalence of bank erosion in these channels. Additionally, moderate gradient channels are down-cutting into the Wildcat formation occasionally resulting in the destabilization of the toes of the streamside hillslope, causing small failures that often deliver LWD. Total LWD amounts appear to be increasing in low and moderate gradient channels in Wildcat terrain due to these recruitment processes, as well as through ongoing channel incision exposing buried logs. The percentage of pools recorded in 2005 associated with LWD (wood scour pools or key piece associations) was generally much greater in channels in Wildcat terrain compared to other geologies. In Dauphiny Creek, LWD pieces are infrequent (does not meet the PFC targets for volume/100 feet and number per channel width), although key pieces are of good size; approximately 22 percent of the creek is made up of pools, with 30 percent of those associated with LWD. In Balcom Creek, instream LWD size meets PFC criteria but pieces are not occurring frequently enough to meet the PFC target for number per 100 feet. Approximately 45 percent of Balcom Creek is made up of pools, with 48 percent of those associated with LWD.

1.3 HILLSLOPE CONDITIONS

The information utilized in this sub-section is presented in the Sediment Budget, Appendix A, and Appendix B.

The Balcom Creek Complex sub-basin has the lowest total sediment delivery rate (per square mile) for HCP lands in the Upper Eel WAU. At a total of 618 tons/mi^2/year, 49 percent is associated with natural processes, 7 percent with legacy effects, and 44 percent with management. Naturally-occurring small streamside landslides deliver the largest amount of sediment (216 tons/mi^2/year or 35 percent of the total), and road surface erosion and road gullies and stream crossing washouts account for 27 percent (169 tons/mi^2/year) of sediment delivery in this sub-basin. The road surface erosion rate in this sub-basin is high, compared with other sub-basins, and can be attributed to the high road density and the small percentage of roads that were stormproofed or upgraded at the time of the surface erosion assessment. Of the 84 tons/mi^2/year total delivery from road surface erosion, the gravel-surfaced Sockeye Road yields 24 percent and primary, secondary, and spur dirt roads yield another 69 percent. Sixty-two percent of the road surface erosion delivery occurs from roads not yet treated to HCP stormproofing and/or upgrading standards. However, significant sediment reduction has already occurred on roads in the Balcom Creek Complex sub-basin by implementing road outsloping measures and wet weather use restrictions. As more road miles are stormproofed and upgraded, the sediment contribution from roads is expected to decrease.

2.0 BOULDER CREEK SUB-BASIN

The Boulder Creek sub-basin is located in the Larabee Creek drainage, bordering the upstream portion of the Main Stem Larabee I sub-basin. HCP lands comprise 89 percent of this 1.9-square-mile sub-basin. This sub-basin includes lands to the south of Larabee Creek and includes one Class I stream – Boulder Creek. The terrain is rugged with elevations ranging from 3,500 feet at the ridge top to approximately 900 feet at the boundary with the Main Stem Larabee I sub-basin. Based on recent LIDAR data, more than half of the HCP area has slope gradients of less than 35 percent, and 15 percent of the area has slopes steeper than 65 percent. The predominant geologic formation is Yager, with Franciscan mélange and Franciscan sandstone lithologies in the eastern portion of the sub-basin.

Douglas fir and hardwood, along with Douglas fir/hardwood, are the dominant vegetation types for the Boulder Creek sub-basin, covering 82 percent of the HCP area, with another 12 percent of the conifer/hardwood vegetation type. .

Presently, the Boulder Creek sub-basin has a road density of 6.4 miles/square mile for all HCP and non-HCP roads in the HCP area. The vast majority of these roads are regular dirt and are used seasonally.

The Boulder Creek sub-basin is one of several areas in the Upper Eel WAU in which harvest has increased since the late 1980s. Previously, first harvest was initiated in the 1950s and continued at increasing rates until it was completed in the 1970s. Later, second-cycle logging in the period from 1988 through 2003 involved harvest on 400 acres, with 80 percent of this acreage harvested in 1998. Half of the harvest in this period was clear cut and included the rehabilitation (conversion to conifer) of understocked, hardwood dominated areas. Yarding was most commonly done by tractor (75 percent); 66 percent of the clear cut acres were yarded by tractor.

2.1 HCP SPECIES

The information utilized in this sub-section is presented in Appendix E (Section 4.2.3.6); and Appendix F (Section 4.6, Table F-10).

Resident rainbow trout are present for a short distance upstream from a natural anadromous barrier (falls/cascades/bedrock steps) located near the mouth of Boulder Creek. The existence of these resident trout is highly unusual since the natural barrier is completely insurmountable by salmonids. All age classes of rainbow trout were represented during surveys, suggesting a significant resident population; none of the fish shocked during surveys indicated signs of smoltification. It is suspected these fish were planted from the top of the drainage or at road crossings during the initial logging entry, escaped from upstream ponds, or occur as a result of the steep barriers at their confluences with Larabee Creek that are thought to be a product of geological uplift over time.

The yellow-legged frog and tailed frog were observed in the Boulder Creek sub-basin, although there were no observations of red-legged frog and torrent salamander. The Boulder Creek sub-basin has high gradient streams with consolidated Yager and Franciscan geologies, providing good habitat for both tailed frogs and torrent salamander. Yellow-legged frog habitat occurs along the interface with the Main Stem Larabee I sub-basin. This sub-basin has north-facing slopes and the over-stream canopy cover is greater than 85 percent, so micro-climate conditions are generally good for headwater species except in the upper reaches where the riparian vegetation is more prone to drying.

2.2 STREAM CHANNEL AND RIPARIAN CONDITIONS

The information utilized in this sub-section is presented in Appendix C (Section 6.1.2, Figures C-5 and C-8); and Appendix E (Sections 3.2 and 4.2.3.6, Table E-1).

Fish access from Larabee Creek into Boulder Creek is precluded because of natural bedrock/boulder falls; a 5.9-foot barrier on Boulder Creek is located 1,363 feet upstream from the mouth. However, salmonids living upstream of these anadromous barriers were probably planted there many years ago, as discussed above. Further data collection to assess aquatic PFCs was not conducted in this sub-basin. However, riparian function was assessed for Boulder Creek. Data show that over-stream canopy cover is greater than 85 percent for 99 percent of the stream length. Also, 93 percent of the stands have moderate LWD recruitment, indicating a trend of increasing LWD recruitment potential. Stands are primarily dense and comprised of medium-sized Douglas fir or a conifer/hardwood mix, mostly ranging from 12 to 24-inch dbh.

2.3 HILLSLOPE CONDITIONS

The total sediment delivery rate (per square mile) for the Boulder Creek sub-basin is near the median relative to the other sub-basins in the Upper Eel WAU. At a total of 1,351 tons/mi^2/year, 34 percent is associated with natural processes, 15 percent with legacy effects, and 51 percent with management. It is estimated that management-related road gullies and stream crossing washouts have delivered the largest amount of sediment over the last 18 years (estimated at 476 tons/mi^2/year or 35 percent of the total), and that naturally-occurring small streamside landslides have accounted for 20 percent (275 tons/mi^2/year) of sediment delivery in this sub-basin. Sediment delivery from road gullies and stream crossing washouts is high in this sub-basin for two reasons: (1) a small percentage of roads have been stormproofed or upgraded, and (2) significant road lengths are located in middle and lower hillslope positions on hard geology, which is a combination that yields high rates of road gullying and crossing washouts. As more roads are stormproofed or upgraded, thus providing improved drainage and stability especially at stream crossings, sediment delivery from road gullies and stream crossing washouts is expected to decrease especially for roads in middle and lower hillslope positions on hard geology.

3.0 BRIDGE CREEK SUB-BASIN

The Bridge Creek sub-basin is located in the South Fork Eel River drainage, bordering the Decker Creek, Poison Oak Creek Complex, and McCann Creek Complex sub-basins. HCP lands comprise 27 percent of this 6.7-square-mile sub-basin, up from 9 percent of the area prior to recent changes in ownership. This sub-basin includes lands in the headwaters of Bridge Creek, located generally to the east of the South Fork Eel River. The terrain is rugged with elevations ranging from 2,400 feet at the ridge top to 200 feet at the river. HCP lands in this sub-basin include only Class II and III watercourses; there are no Class I streams on HCP lands. Based on recent LIDAR data, approximately 46 percent of the HCP area has slope gradients of less than 35 percent, and 6 percent of the area has slopes steeper than 65 percent. The geologic formation in the HCP area of this sub-basin is Yager.

Redwood is the dominant vegetation type for the Bridge Creek sub-basin, covering 80 percent of the HCP area, with another 15 percent in non-timber.

Presently, the Bridge Creek sub-basin has a road density of 8.7 miles/square mile for all HCP and non-HCP roads in the HCP area. These roads are regular dirt and are used seasonally.

During the analysis period of 1988 through 2003, no timber harvest occurred in the HCP area of the Bridge Creek sub-basin. First harvest occurred in the HCP area during the 1960s and 1970s.

3.1 HCP SPECIES

The information utilized in this sub-section is presented in Appendix F (Section 4.6, Table F-10).

Fish distribution and habitat data were not collected in the HCP area of the Bridge Creek sub-basin during watershed analysis activities as no fish-bearing streams are present.

The Bridge Creek sub-basin has a mix of low and high gradient watercourses with consolidated Yager geology. Yellow-legged frogs have been located in this sub-basin, and it also has potential habitat for the headwater species. This sub-basin has primarily south-facing slopes but the over-stream canopy cover is greater than 85 percent, so micro-climate conditions for the headwater species are likely to be suitable.

3.2 STREAM CHANNEL AND RIPARIAN CONDITIONS

The information utilized in this sub-section is presented in Appendix C (Section 5.4, Figures C-5 and C-8).

Riparian function was assessed for the HCP area of the Bridge Creek sub-basin. Data show that over-stream canopy cover is greater than 85 percent for 79 percent of the stream length, and 71 to 85 percent for the remainder of the stream length. Seventy-six percent of the stands have dense stand conditions comprised of mixed conifer and redwood, mostly ranging from 12- to 24-inch dbh, with moderate LWD recruitment potential, while the remainder is dominated by small hardwoods providing low LWD recruitment potential.

3.3 HILLSLOPE CONDITIONS

The total sediment delivery rate (per square mile) for the Bridge Creek sub-basin is nearly the lowest relative to the other sub-basins in the Upper Eel WAU. At a total of 633 tons/mi^2/year, 32 percent is associated with natural processes, 18 percent with legacy effects, and 50 percent with management. It is estimated that management-related road gullies and stream crossing washouts have delivered the largest amount of sediment over the last 18 years (269 tons/mi^2/year or 43 percent of the total), and that naturally-occurring small streamside landslides have accounted for 21 percent (131 tons/mi^2/year) of sediment delivery in this sub-basin. Sediment delivery from road gullies and stream crossing washouts is high in this sub-basin because all of the HCP roads are located on hard geology, which yields the highest rates of road gullying and crossing washouts. In the future, as roads are stormproofed or upgraded, improved drainage and stability especially at stream crossings will result in less sediment delivery from road gullies and stream crossing washouts.

4.0 BURR CREEK SUB-BASIN

The Burr Creek sub-basin is located in the Larabee Creek drainage, bordering the Main Stem Larabee II sub-basin (on the main stem Larabee Creek). There are no HCP lands in this 10.4-square-mile sub-basin. No data were collected to characterize stream channel, riparian, and hillslope conditions. Similarly, fish distribution and habitat data were not collected or evaluated for the Burr Creek sub-basin during watershed analysis activities.

However, PALCO wildlife personnel have detected presence of both red-legged and yellow-legged frogs in the Burr Creek sub-basin (no HCP area), primarily on the interface with the Main Stem Larabee II sub-basin. In the Burr Creek sub-basin (no HCP area), there are higher gradient streams with consolidated geologies, which indicates potential habitat for headwater species. Slopes are primarily south or east-facing, are in the region of Douglas fir and hardwood dominated stands, and are further inland where ambient temperatures are higher in the summer months. Thus, micro-climate conditions for the headwater species may be less than optimal.

5.0 BUTTE CREEK SUB-BASIN

The Butte Creek sub-basin is located in the South Fork Eel River drainage, near the main stem South Fork Eel River. There are no HCP lands in this 6.5-square-mile sub-basin, based on recent changes in ownership.

6.0 CAMERON CREEK SUB-BASIN

The Cameron Creek sub-basin is located in the Eel River drainage, immediately upstream from the Thompson Creek and McCann Creek Complex sub-basins. HCP lands comprise 4 percent of this 22-square-mile sub-basin. The terrain is rugged with elevations ranging from 2,400 feet at the ridge top to approximately 160 feet at the Eel River valley bottom. The HCP area of this sub-basin includes lands and watercourses draining to the main stem Eel River or to Sonoma Creek which flows into the Eel River.

HCP lands in this sub-basin include Class I, II, and III streams. Based on recent LIDAR data, approximately 34 percent of the HCP area has slope gradients of less than 35 percent, and 17 percent of the area has slopes steeper than 65 percent. The Yager formation covers 66 percent of the HCP area, and Central Belt Franciscan Complex covers most of the remainder of the HCP area.

Hardwood and redwood/Douglas fir are the dominant vegetation types in the Cameron Creek sub-basin, covering 45 percent of the HCP area, with another 32 percent of the Douglas fir and Douglas fir/redwood vegetation types.

Presently, the Cameron Creek sub-basin has a road density of 7.6 miles/square mile for all HCP and non-HCP roads in the HCP area. These roads are primarily regular dirt and are used seasonally.

During the analysis period of 1988 through 2003, harvest occurred on a total of 149 acres (30 percent) of the HCP area. Approximately two-thirds of the harvest was clear cut, with a similar proportion yarded by tractor. Otherwise, harvest was by partial cut with yarding by cable. First harvest occurred in the HCP area during the 1890s, 1910s, 1960s, and 1980s.

6.1 HCP SPECIES

The information utilized in this sub-section is presented in Appendix F (Section 4.6, Table F-10).

Fish distribution and habitat data were not collected in the Cameron Creek sub-basin during watershed analysis activities.

The presence of red-legged and yellow-legged frogs was detected in the Cameron Creek sub-basin, although most of this sub-basin is comprised of non-HCP lands. Available data indicates that there are primarily consolidated Yager and Franciscan geologies, with higher gradient streams, and thus relatively high potential habitat for the headwater species as well. Information for PALCO lands includes north and east facing slopes with high percent over-stream canopy cover for the Cameron Creek sub-basin, such that micro-climate conditions for headwater species may be generally suitable.

6.2 STREAM CHANNEL AND RIPARIAN CONDITIONS

The information utilized in this sub-section is presented in Appendix C (Section 6.4, Figures C-5 and C-8).

Based on its location in the watershed analysis area, conditions in the Cameron Creek sub-basin favor species that are tolerant of warmer temperatures and drier soils. For the small acreage of riparian stands analyzed in the Cameron Creek sub-basin, riparian stand composition is primarily Douglas fir and mixed conifer/hardwood dominant with a small amount of hardwood species. Canopy closure is rated as mostly dense, with a small acreage given a moderate canopy closure rating. Data show that over-stream canopy cover is greater than 85 percent for all of the assessed stream length. Also, 86 percent of the riparian stands have moderate LWD recruitment, and the remainder has low LWD recruitment because of the small diameter and/or sparsely stocked hardwood dominated or Douglas fir/hardwood mixed stands.

6.3 HILLSLOPE CONDITIONS

The total sediment delivery rate (per square mile) for the Cameron Creek sub-basin is exceeded by only several of the other sub-basins in the Upper Eel WAU. At a total of 1,516 tons/mi^2/year, 34 percent is associated with natural processes, 12 percent with legacy effects, and 54 percent with management. It is estimated that management-related road gullies and stream crossing washouts have delivered the largest amount of sediment over the last 18 years (698 tons/mi^2/year or 46 percent of the total), and that naturally-occurring small streamside landslides have accounted for 19 percent (290 tons/mi^2/year) of sediment delivery in the sub-basin. Legacy-related gullies and stream crossing washouts on abandoned roads are estimated to have accounted for 9 percent (132 tons/mi^2/year) of sediment delivery. Sediment delivery from road gullies and stream crossing washouts is high in this sub-basin because most of the HCP roads are located on hard geology at middle or lower hillslope positions, thus yielding the highest rates of road gullies and stream crossing washouts. As roads are stormproofed or upgraded, improved drainage and stability especially at stream crossings will result in less sediment delivery from road gullies and stream crossing washouts.

7.0 CARSON CREEK COMPLEX SUB-BASIN

The Carson Creek Complex sub-basin is located in the Larabee Creek drainage upstream from the confluence of Larabee Creek with the main stem Eel River. HCP lands comprise 99 percent of this 3.1-square-mile sub-basin. This sub-basin includes lands to the north of Larabee Creek and includes one major Class I tributary – Carson Creek. The terrain is rugged with elevations ranging from] 2,500 feet at the ridge top to approximately 260 feet at the boundary with the Main Stem Larabee I sub-basin. Based on recent LIDAR data, approximately 45 percent of the area has slope gradients of less than 35 percent, and 9 percent of the area has slopes steeper than 65 percent. The geologic formation in approximately two-thirds of this sub-basin is Yager, in the area east of the main stem of Carson Creek, and most of the remaining area is Wildcat group, undifferentiated, in the area west of Carson Creek.

Redwood is the dominant vegetation type for the Carson Creek Complex sub-basin, covering 62 percent of the HCP area, with another 30 percent of the redwood/Douglas fir vegetation type.

Presently, the Carson Creek Complex sub-basin has a road density of 7.7 miles/square mile for all HCP and non-HCP roads in the HCP area. The majority of the HCP roads are regular dirt and are used seasonally.

The Carson Creek Complex sub-basin is one of the areas of the Upper Eel WAU in which harvest has increased since the late 1980s. Second-cycle logging activities have been ongoing for the past several decades; first harvest occurred primarily from the 1910s through the 1920s. In the period from 1988 through 2003, a total of 928 acres (47 percent of the HCP area) were harvested. Of this total, 86 percent of the harvested acres were clear cut, with 44 percent of the clear cut acres yarded by tractor. Yarding was evenly split for all harvested areas between cable and tractor at 45 percent each.

7.1 HCP SPECIES

The information utilized in this sub-section is presented in Appendix E (Section 4.2.3.3, Table E-6); and Appendix F (Section 4.6, Table F-10).

Carson Creek is a Chinook salmon spawning stream, and coho salmon may inhabit this stream as well. In addition, rainbow trout have been observed in Carson Creek. Fish occur in Carson Creek for about 3,000 feet upstream from the confluence with Larabee Creek, at which there is a natural barrier in the form of falls and cascades.

The Carson Creek Complex contains habitat for all of the amphibian and reptile species of concern. Four of the 5 species have been detected, including the southern torrent salamander, red-legged frog, yellow-legged frog, and pond turtle. The yellow-legged frog and pond turtle locations are on the Main Stem Larabee I interface with this sub-basin. Although the slopes are primarily south-facing, the over-stream canopy cover is greater than 85 percent, and micro-climate conditions for the headwater species appear generally suitable.

7.2 STREAM CHANNEL AND RIPARIAN CONDITIONS

The information utilized in this sub-section is presented in Appendix C (Sections 5.4 and 6.1.3, Figures C-5 and C-8); and Appendix E (Sections 3.2 and 4.2.3.3, Tables E-1, E-6, and E-14).

A potential anadromous barrier exists about 850 feet up from the mouth of the creek. This is a 6-foot vertical drop over a large redwood log which, at least, makes upstream migration difficult, potentially blocking access to 2,200 feet of potential anadromous habitat. Notching this log could be a simple solution to improving upstream migration for anadromous fish. Further upstream, approximately 3,000 feet from the confluence with Larabee Creek, a series of vertical drops and cascades ends fish use.

Carson Creek streambed characteristics include mixed gravels and cobbles suitable for spawning. Pools are abundant but there are not many deep pools and average residual pool depth does not meet the PFC target. Approximately 25 percent of the creek length is comprised of pools, with 66 percent of those associated with LWD. As discussed in the Fish Habitat Assessment (Appendix E), it is important to recognize that channel size and contributing basin area play a role in determining channel dimensions. The pool depth criterion is unlikely to be achievable for this sub-basin because of its small drainage area.

Water temperatures are cool and near optimum (below PFC criteria) for salmonid growth in Carson Creek. Over-stream canopy cover is greater than 85 percent for 98 percent of the stream length, providing good cover for temperature protection.

Although Carson Creek was logged extensively in the past 100 years, the current conditions of the Carson Creek riparian stands suggest that this basin is in recovery. The riparian stands within the Carson Creek Complex sub-basin are predominantly medium to large redwoods, greater than 12-inch dbh, with dense canopy cover. A significant percentage (37 and 60 percent, respectively) of riparian stands in the Carson Creek Complex have high or moderate LWD recruitment potential on Class I streams.

7.3 HILLSLOPE CONDITIONS

The total sediment delivery rate (per square mile) for the Carson Creek Complex sub-basin is near the median relative to the other sub-basins in the Upper Eel WAU. At a total of 1,288 tons/mi^2/year, 44 percent is associated with natural processes, 6 percent with legacy effects, and 50 percent with management. It is estimated that management-related road gullies and stream crossing washouts have delivered the largest amount of sediment over the last 18 years (355 tons/mi^2/year or 28 percent of the total), and that naturally-occurring small streamside landslides have accounted for 18 percent (234 tons/mi^2/year) of sediment delivery in the sub-basin. Naturallyoccurring shallow-seated landslides account for 16 percent (212 tons/mi^2/year) of sediment delivery in this sub-basin. Another 12 percent (160 tons/mi^2/year) of sediment is produced through landslides that originate on partial cut areas less than 15 years after harvest. Although the largest individual sediment delivery source type is road gullies and stream crossing washouts, the percentage contribution of this source relative to the total sediment delivery is less than for other sub-basins because a significant portion of the road system has been stormproofed or upgraded, although most of the HCP roads are located on hard geology, thus yielding higher rates of road gullies and stream crossing washouts. The large contribution of sediment from landslides occurring in partial cut areas less than 15 years after harvest results from a large volume of landslides occurring in inner gorge areas.

8.0 CHRIS CREEK SUB-BASIN

The Chris Creek sub-basin is located in the Larabee Creek drainage upstream from the confluence of Larabee Creek with the main stem Eel River. HCP lands comprise 95 percent of this 1.6-square-mile sub-basin. This sub-basin includes lands to the north of Larabee Creek and includes one major Class I tributary – Chris Creek. Elevation ranges from from 1,600 feet at the ridge top to approximately 200 feet at the boundary with the Main Stem Larabee I sub-basin. Based on recent LIDAR data, approximately 26 percent of the area has slope gradients of less than 35 percent, and 14 percent of the area has slopes steeper than 65 percent. The geologic formation in approximately 80 percent of this sub-basin is Wildcat group, undifferentiated. Another 18 percent of the HCP area is Scotia Bluffs sandstone in the far western portion of this sub-basin.

Redwood and redwood/Douglas fir are the dominant forest types for the Chris Creek sub-basin, covering 58 and 42 percent of the HCP area, respectively.

Presently, the Chris Creek sub-basin has a road density of 6.9 miles/square mile for all HCP and non-HCP roads in the HCP area. Most of the HCP road miles are regular dirt and are used seasonally.

The Chris Creek sub-basin is one of the areas of the Upper Eel WAU in which harvest has increased since the late 1980s. Second-cycle logging activities have been ongoing for the past several decades; first harvest occurred primarily from the 1910s through the 1920s. In the period from 1988 through 2003, a total of 816 acres (84 percent of the HCP area) were harvested. Of this total, 54 percent of the harvested acres were clear cut, with 57 percent of the clear cut acres yarded by cable. Yarding was done by cable for 73 percent of the harvested acres in this period.

8.1 HCP SPECIES

The information utilized in this sub-section is presented in Appendix E (Section 4.2.3.2, Table E-5); and Appendix F (Section 4.6, Table F-10).

Chris Creek has habitat available for anadromous fish in its extensive low gradient reach near Larabee Creek, but there were no fish found in this reach because of a culvert blocking upstream migration beyond the Larabee Ranch. Chris Creek has roughly a mile of potentially good salmonid habitat above the culvert.

Red-legged and yellow-legged frogs have been observed in the Chris Creek sub-basin, particularly in the lower gradient reaches near the Main Stem Larabee I interface. Although the Wildcat formation is considered an unconsolidated geology, and thus may provide less suitable substrate for the headwater species, potential habitat may exist where inclusions of consolidated substrates may be found. Although the slopes are primarily south-facing, the over-stream canopy cover is more than 85 percent, thus providing adequate shading and micro-climate conditions.

8.2 STREAM CHANNEL AND RIPARIAN CONDITIONS

The information utilized in this sub-section is presented in Appendix C (Sections 5.4 and 6.1.4, Figures C-5 and C-8); and Appendix E (Sections 3.2 and 4.2.3.2, Tables E-1, E-5, and E-14).

Chris Creek provides an excellent opportunity for restoration. Near the downstream end of Chris Creek, prior to its confluence with Larabee Creek, a culvert blocks upstream migration. This culvert prevents fish access to an extensive one-mile-long low gradient reach, with habitat available for anadromous fish, specifically juvenile coho salmon. A second hindrance to migration exists a few hundred feet upstream of the property line where the stream drops about 6 feet over a redwood log. The blocking culvert could be backwatered and the log could be notched to allow unimpeded upstream migration.

The 2- to 4-percent gradient reaches of the creek have suitable size gravel for spawning. Although gravel size is generally good, there are deposits of fines on channel margins and in some pools. Pools are abundant but there are not many deep pools – average residual pool depth does not meet the PFC target, possibly because of sediment filling. Approximately 38 percent of the creek length is comprised of pools, with 61 percent of those associated with LWD. As discussed in the Fish Habitat Assessment (Appendix E), it is important to recognize that channel size and contributing basin area play a role in determining channel dimensions. The pool depth criterion is unlikely to be achievable for this sub-basin because of its small drainage area.

Temperatures are cool and within PFC criteria, as would be expected based on overstory canopy cover and temperatures measured in nearby streams with similar canopy characteristics. Canopy cover over the stream exceeds 85 percent for 95 percent of its length, providing good cover for temperature protection.

Although the Chris Creek sub-basin was logged extensively in the past 100 years, including railroad placement in the channel, current conditions of the Chris Creek riparian stands suggest that this basin is in recovery. Riparian stands within Chris Creek have large to medium sized redwoods with moderate to dense canopy cover. A significant percentage (57 and 31 percent, respectively) of riparian stands in Chris Creek have high or moderate LWD recruitment potential.

Wood is fairly abundant within the reach, including larger size pieces, although PFC criteria for key piece distribution are still not met within the low gradient portion of the stream. Also, riparian vegetation is not present where Chris Creek drains into Larabee Creek, after leaving PALCO property, and flows through the Larabee Ranch. The lower portion of Chris Creek on the Larabee Ranch also has relatively lower shade.

8.3 HILLSLOPE CONDITIONS

The total sediment delivery rate (per square mile) for the Chris Creek sub-basin is one of the higher rates relative to the other sub-basins in the Upper Eel WAU. At a total of 1,601 tons/mi^2/year, 23 percent is associated with natural processes, 3 percent with legacy effects, and 73 percent with management. Management-related landslides originating from partial cut areas less than 15 years after harvest deliver the largest amount of sediment (893 tons/mi^2/year or 56 percent of the total) and naturally-occurring small streamside landslides account for 17 percent (268 tons/mi^2/year) of sediment delivery. The large contribution of sediment from landslides occurring in partial cut areas less than 15 years after harvest results from a large volume of landslides occurring in inner gorge areas.

9.0 DECKER CREEK SUB-BASIN

The Decker Creek sub-basin is located in the South Fork Eel River drainage, bordering the Bridge Creek and Poison Oak Creek Complex sub-basins. HCP lands comprise 16 percent of this 2.9-square-mile sub-basin. This sub-basin includes lands in the headwaters of three small tributaries to the South Fork Eel River – Feese Creek, Robinson Creek, and an unnamed tributary. HCP lands in this sub-basin include Class I, II, and III watercourses; only a short distance (0.1 mile) of Feese Creek is a Class I stream located on HCP lands. The terrain is rugged with elevations in the HCP area ranging from 1,800 feet at the ridge top to 800 feet. Based on recent LIDAR data, approximately 64 percent of the HCP area has slope gradients of less than 35 percent, and 2 percent of the area has slopes steeper than 65 percent. The geologic formation in the HCP area of this sub-basin is Yager.

Redwood and redwood/Douglas fir are the dominant vegetation types for the Decker Creek sub-basin, covering 93 percent of the HCP area.

Presently, the Decker Creek sub-basin has a road density of 10.0 miles/square mile for all HCP and non-HCP roads in the HCP area; HCP roads comprise approximately half of the total roads. Roads in the HCP area of the sub-basin are accessed from the Poison Oak Creek Complex sub-basin, located to the north; state park lands are located downstream from this area. The approximately 2 miles of road in this sub-basin are regular dirt and are used seasonally.

During the analysis period of 1988 through 2003, harvest occurred on a total of 103 acres (34 percent) of the HCP area. Approximately 89 percent of the harvest was clear cut; all of the harvested acres in this period were yarded by tractor. First harvest occurred in the HCP area during the 1930s (a small amount) and the 1970s.

9.1 HCP SPECIES

The information utilized in this sub-section is presented in Appendix F (Section 4.6, Table F-10).

Fish distribution and habitat data were not collected in the HCP area of the Decker Creek sub-basin during watershed analysis activities.

There is little data on the Decker Creek sub-basin, as most of the sub-basin is non-PALCO property. Based on geology and other similar sub-basins, suitable habitat for the headwater species may be found in the higher gradient reaches of the watercourses within the HCP area of this sub-basin.

9.2 STREAM CHANNEL AND RIPARIAN CONDITIONS

The information utilized in this sub-section is presented in Appendix C (Section 6.7, Figures C-5 and C-8).

Riparian function was assessed for the HCP area of the Decker Creek sub-basin, with only a limited amount of riparian acreage occurring along the upper portions of Feese Creek, Robinson Creek, and an unnamed tributary. Data show that over-stream canopy cover is greater than 85 percent for all of the stream lengths. Also, all of the stands have moderate LWD recruitment. Riparian stands are primarily conifer dominated riparian stands, primarily redwood, with a small amount of mixed conifer/hardwood composition. The riparian stands contain small trees, with a moderately dense to totally dense canopy closure rating.

9.3 HILLSLOPE CONDITIONS

The total sediment delivery rate (per square mile) for the Decker Creek sub-basin is one of the lower rates relative to the other sub-basins in the Upper Eel WAU. At a total of 805 tons/mi^2/year, 29 percent is associated with natural processes, 34 percent with legacy effects, and 37 percent with management. Management-related road gullies and stream crossing washouts and legacy-related gullies and stream crossing washouts on abandoned roads each account for 30 percent (241 tons/ mi^2/year) for a combined total of 60 percent of all sediment delivery on HCP lands in this sub-basin. All of the road gullies and stream crossing washouts occurred on hard geology, thus yielding the highest rates of sediment delivery from this source type. This high percentage of contribution to the total sediment delivery signifies the importance of addressing stream crossings and erosion control on roads, although abandoned roads may continue to deliver sediment to streams unless also addressed.

10.0 ELK CREEK SUB-BASIN

The Elk Creek sub-basin is located in the South Fork Eel River drainage upstream from the confluence of Bridge Creek and the South Fork Eel River. HCP lands comprise 11 percent of this 11-square-mile sub-basin. This sub-basin includes one major Class I tributary, Elk Creek, along with Class II and III watercourses. The terrain is rugged with elevations ranging from 1,700 feet at the ridge top to 400 feet along the main stem of Elk Creek. Based on recent LIDAR data, approximately 60 percent of the area has slope gradients of less than 35 percent, and 5 percent of the area has slopes steeper than 65 percent. The geologic formation in the HCP area of this sub-basin is Yager.

Conifer/hardwood comprises 42 percent of the HCP area within the Elk Creek sub-basin, with another 30 percent of the HCP area as redwood/Douglas fir.

Presently, the Elk Creek sub-basin has a road density of 8.3 miles/square mile for all HCP and non-HCP roads in the HCP area. The HCP roads in this sub-basin are regular dirt and are used seasonally.

A total of 401 acres (51 percent of the HCP area) were harvested in the HCP area of the Elk Creek sub-basin in the period from 1988 through 2003. Of this total, 32 percent of the harvested acres were clear cut; all of the harvested acres in this period were yarded by tractor.

10.1 HCP SPECIES

The information utilized in this sub-section is presented in Appendix E (Section 4.2.3.13, Tables E-2 and E-14); and Appendix F (Section 4.6, Table F-10).

Elk Creek has excellent habitat for fish and has been known to contain coho, Chinook, and steelhead. Chinook salmon typically utilize the low gradient floodplain reach of Elk Creek where the channel is of an alluvial nature and is typically unconfined within the valley. In 1990, DFG observed spawning Chinook in Elk Creek. Previously, in 1987, one coho female carcass was observed by the California Conservation Corps.

There is little amphibian and reptile species data in the Elk Creek sub-basin because most of the land area is non-PALCO property. However, red-legged frogs were detected in this area. The majority of over-stream canopy cover is greater than 85 percent, so micro-climate conditions are generally good for headwater species except in the upper reaches where the riparian vegetation is more prone to drying.

10.2 STREAM CHANNEL AND RIPARIAN CONDITIONS

The information utilized in this sub-section is presented in Appendix C (Section 6.8, Figures C-5 and C-8); and Appendix E (Section 3.2 and 4.2.3.13, Tables E-1, E-2, and E-14).

No barriers to fish access were identified in the Fish Habitat Assessment (Appendix E) for the Elk Creek sub-basin. Stream channel and riparian data were available only for pool frequency, percent pool area and association with LWD, percent pools deeper than 3 feet, percent canopy closure, and LWD recruitment. Streambed gravel, water temperature, and LWD key piece data were not available for the Elk Creek sub-basin. Therefore, this summary of stream channel and riparian conditions focuses on the limited pool data, along with canopy cover and riparian stand information.

Pools are abundant but there are not many deep pools, as indicated by this sub-basin not meeting the PFC for the percent of pools deeper than 3 feet. Based on a 1992 DFG stream inventory report, approximately 19.5 percent of Elk Creek (length) was made up of pools with 57 percent of those associated with LWD. As discussed in the Fish Habitat Assessment (Appendix E), it is important to recognize that channel size and contributing basin area play a role in determining channel dimensions. The pool depth criterion is unlikely to be achievable for this sub-basin because of its small drainage area.

Temperature protection is provided for much of Elk Creek because the canopy cover over the stream exceeds 85 percent for 87 percent of its length. Riparian stands are primarily comprised of coniferous species, namely redwood and mixed conifer/hardwood, with the remaining riparian stands comprised of Douglas fir and hardwood. The riparian stands contain medium sized trees, between 12- to 24-inch dbh, with dense to moderately dense canopy closure. A significant percentage (91 percent) of riparian stands in Elk Creek have moderate LWD recruitment potential.

10.3 HILLSLOPE CONDITIONS

The total sediment delivery rate (per square mile) for the Elk Creek sub-basin is more than the median rate for sub-basins in the Upper Eel WAU. At a total of 1,477 tons/mi^2/year, 28 percent is associated with natural processes, 18 percent with legacy effects, and 54 percent with management. Management-related road gullies and stream crossing washouts account for 39 percent (574 tons/mi^2/year) of sediment delivery and naturally-occurring small streamside landslides account for another 19 percent (275 tons/mi^2/year). In addition, legacy-related gullies and stream crossing washouts on abandoned roads account for 15 percent (218 tons/ mi^2/year) of sediment delivery. The large sediment contribution from management-related road gullies and stream crossing washouts results from all of the HCP roads located on hard geology, thus yielding the highest rates of road gullies and stream crossing washouts.

11.0 KAPPLE CREEK COMPLEX SUB-BASIN

The Kapple Creek Complex sub-basin is located in the Eel River drainage, immediately upstream from the Newman Creek sub-basin. HCP lands comprise 92 percent of this 2.9-square-mile sub-basin, including lands that were recently added to the HCP designation. The HCP area of this sub-basin includes lands and watercourses draining to the main stem Eel River. HCP lands in this sub-basin are located to the north of Eel River and include Class I, II, and III streams – Kapple Creek and a short length of an unnamed creek comprise the Class I reaches that are tributaries to the main stem Eel River. The terrain is rugged with elevations ranging from 2,800 feet at the ridge top to approximately 110 feet at the Eel River. Based on recent LIDAR data, approximately 36 percent of the HCP area has slope gradients of less than 35 percent, and 14 percent of the area has slopes steeper than 65 percent. The geologic formation in approximately 50 percent of this sub-basin is Wildcat group, undifferentiated. Another 40 percent of the HCP area is Yager formation in the northern, headwaters portion of this sub-basin.

Redwood and redwood/Douglas fir are the dominant vegetation types in the Kapple Creek Complex sub-basin, covering 80 percent of the HCP area.

Presently, the Kapple Creek Complex sub-basin has a road density of 6.8 miles/square mile for all HCP and non-HCP roads in the HCP area. Many of the HCP roads in this sub-basin are regular dirt and used seasonally; nearly one-quarter of the HCP roads are rocked.

During the analysis period of 1988 through 2003, harvest occurred on a total of 605 acres (39 percent) of the HCP area. Approximately 79 percent of the harvest in this period was clear cut, with 46 percent of the clear cut acreage yarded by cable, 34 percent yarded by tractor, and 12 percent yarded by helicopter. Of the 127 acres harvested by partial cut, 45 percent of the acreage was yarded by tractor, 33 percent by cable, and 11 percent by helicopter. First harvest occurred in the HCP area during the 1920s through the 1950s, and also in the 1970s with a small amount in the 1980s.

11.1 HCP SPECIES

The information utilized in this sub-section is presented in Appendix E (Section 4.2.3.8); and Appendix F (Section 4.6, Table F-10).

Fish distribution and habitat data were not collected in the Kapple Creek Complex sub-basin during watershed analysis activities. However, steelhead/rainbow trout have been observed in this creek up to a natural 6.5-foot step barrier about 3,600 feet upstream from the mouth.

Yellow-legged frogs have been detected along the lower stream reaches in the Kapple Creek Complex sub-basin. Suitable pond turtle habitat also occurs in these areas. Potential habitat for the headwater species occurs in the high gradient watercourse reaches where consolidated substrate may be found. Although slopes are primarily south-facing, the over-stream canopy cover is greater than 85 percent, thus providing adequate shading and micro-climate conditions.

11.2 STREAM CHANNEL AND RIPARIAN CONDITIONS

The information utilized in this sub-section is presented in Appendix C (Section 6.10.1, Figures C-5 and C-8); and Appendix E (Section 3.2 and 4.2.3.8, Table E-1).

Fish access up Kapple Creek is precluded 3,600 feet upstream from its mouth because of a 6.5-foot high rock/log barrier. Only limited information to assess stream and riparian conditions was available for Kapple Creek. In general, Kapple Creek has relatively poor quality spawning habitat. Approximately 14 percent of the stream length is comprised of pools which account for 22 percent of the stream's surface area. The average residual pool depth is 1.5 feet, well below the PFC of 3 feet.

Water temperatures in the 13-16 ^{o}C range were recorded with a handheld thermometer during watershed analysis field reviews in Kapple Creek during late-June through mid-August 2005. These spot data indicate relatively cool temperatures in this sub-basin.

Canopy cover over the stream exceeds 85 percent for 84 percent of its length, although another 13 percent of the stream length has canopy cover of less than 20 percent. Also, 46 percent of the stands have moderate LWD recruitment, while another 44 percent have high LWD recruitment. The riparian stands in the Kapple Creek Complex sub-basin are predominantly redwood, with Douglas fir as the co-dominant species. Significant amounts of riparian forest in this sub-basin are medium to large sized, with dense canopy cover.

11.3 HILLSLOPE CONDITIONS

The total sediment delivery rate (per square mile) for the Kapple Creek Complex sub-basin is lower than the median rate for sub-basins in the Upper Eel WAU. At a total of 1,072 tons/mi^{2}/year, 58 percent is associated with natural processes, 6 percent with legacy effects, and 36 percent with management. Naturally-occurring small streamside landslides account for 20 percent (210 tons/mi^{2}/year) of sediment delivery, and another 17 percent (177 tons/mi^{2}/year) is contributed by naturally-occurring shallow-seated landslides. Management-related road gullies and stream crossing washouts account for another 15 percent (165 tons/mi^2/year) of sediment delivery. With most sediment delivery originating from natural sources, addressing management-related road gullies and washouts can result in reduced sediment but cannot address most of the non-management sources that will continue.

12.0 MAIN STEM LARABEE I SUB-BASIN

The Main Stem Larabee I sub-basin is located in the Larabee Creek drainage and encompasses the main stem of Larabee Creek from its confluence with the Eel River and upstream to the Main Stem Larabee II sub-basin. HCP lands comprise 75 percent of this 3.7-square-mile sub-basin. This sub-basin includes a significant length of Larabee Creek, a Class I stream, as well as the downstream ends of the following Class I tributary streams within the HCP area: Chris Creek, Carson Creek, Smith Creek, Balcom Creek, Dauphiny Creek, Scott Creek, and two unnamed creeks in the Mid Larabee Creek Complex sub-basin.

This sub-basin is dominated by Larabee Creek and the hillslopes and tributaries within a short distance from the main channel. Based on recent LIDAR data, approximately 42 percent of the area has slope gradients of less than 35 percent, and 26 percent of the area has slopes steeper than 65 percent. The geologic formation in the eastern half of this sub-basin is Yager; the predominant formation in the western portion of the sub-basin, in upland areas, is Wildcat group, undifferentiated. Stream channel and terrace formations are common along the channel, accounting for 22 percent of the HCP area in this sub-basin; these formations are abundant where the creek is surrounded by Wildcat group, undifferentiated. Larabee Creek is generally constrained between valley walls with increasing alluvial deposition in the lower several miles. The lowermost creek mile is bordered by privately owned ranch land.

Redwood and redwood/Douglas fir are the dominant vegetation types for the Main Stem Larabee I sub-basin, covering 53 percent of the HCP area, with another 17 percent of the Douglas fir vegetation type.

Presently, the Main Stem Larabee I sub-basin has a road density of 6.5 miles/square mile for all HCP and non-HCP roads in the HCP area. Over half of the HCP roads in this sub-basin are rocked; the others are primarily regular dirt and are used seasonally.

Portions of the Main Stem Larabee I sub-basin have been harvested recently, including 566 acres (32 percent) of the HCP area in the period from 1988 through 2003. Of this total, 79 percent of the harvested acres were clear cut, with 56 percent of the clear cut acres yarded by tractor. Overall, tractor yarding was used for 59 percent of the harvested acres for this period, whereas, helicopter yarding was used for 9 percent of the harvested acres. First harvest has occurred during most decades, since the 1910s, throughout this sub-basin.

12.1 HCP SPECIES

The information utilized in this sub-section is presented in Appendix E (Sections 3.0, 4.2.3.1, and 5.3, Table E-3); and Appendix F (Section 4.6, Table F-10).

Chinook salmon are known to occur in Larabee Creek at least up to Smith Creek where a mile-long series of falls and cascades may preclude further distribution. Spawning surveys by DFG have reported spawning Chinook in Larabee Creek. Steelhead are distributed throughout the sub-basin up to natural anadromous barriers. Coho salmon seasonally inhabit Larabee Creek during migration periods, although they are relatively uncommon.

The Main Stem Larabee I sub-basin has suitable habitat for pond turtles and yellow-legged frogs, and both species have been detected in this sub-basin. The higher gradient reaches of the streams draining directly into this sub-basin can also have potential habitat for the headwater species. For example, tailed frogs have been located near the mouth of Arnold Creek, which is located within the Chris Creek Complex sub-basin. However, Larabee Creek has low over-stream canopy cover and water temperatures that can be unsuitable for headwater species.

12.2 STREAM CHANNEL AND RIPARIAN CONDITIONS

The information utilized in this sub-section is presented in Appendix C (Section 6.1.5, Figures C-5 and C-8); and Appendix E (Section 4.2.3.1, Tables E-3 and E-14).

A mile-long series of falls and cascades comprise a natural barrier to fish passage in Larabee Creek upstream of its confluence with Smith Creek. Steelhead are distributed throughout this sub-basin up to natural anadromous barriers.

The broadly alluvial channel in PALCO ownership above the Larabee Ranch has a gravel bedded channel with widely spaced pools and little wood. Within the main stem there are deep pools scoured around lag boulder deposits. The substrate is gravel to cobble size; particle sizes of the streambed are at or within criteria indicating favorable conditions for spawning and incubation. Upstream of its confluence with Carson Creek, the main stem Larabee is relatively steep where it intersects the Yager geology and is constrained within valley walls. However, the average residual pool depth is greater than 3 feet, and pools are reasonably frequent. PFCs related to pool frequency, area, LWD association, and depth are met in the Main Stem Larabee I sub-basin; no data were collected for percent pools greater than 3 feet deep.Water temperatures in the main stem Larabee Creek exceed stressful thresholds for salmonids. Coho rearing may be impeded in Larabee Creek, while steelhead appear to be doing well during the summer. The MWATs consistently exceed the PFC target in Larabee Creek, although the PFC target is exceeded upstream of the Upper Eel WAU. The temperature data presented in the Fish Habitat Assessment (Appendix E) show a general increase in MWAT values over the period of record (1999-2004).

Larabee Creek is unaffected by riparian shade and reach equilibrium with air temperature at approximately 23 °C. Due to natural influences including distance from divide, air temperature, reduced effectiveness of riparian shade, channel width, and other factors, the PFC target for MWAT may not be applicable for Larabee Creek. However, it is also feasible that temperatures could be lowered in Larabee Creek by as much as 3-4 °C with achievement of mature conifer riparian forests. Though still above optimal temperatures, this would make the main stem Larabee more conducive for summer rearing of anadromous salmonids. Mature riparian canopies have been removed as first cycle logging advanced in this sub-basin since the early 20th century.

A notable characteristic of the Main Stem Larabee I sub-basin is the general lack of canopy cover, which exceeds 85 percent for only 41 percent of the stream length. Another 58 percent of the stream length has canopy cover of less than 20 percent.

The main stem Larabee channel is generally deficient in LWD for which pieces are small in size and probably fairly transient given the size of the stream. Riparian data show that 66 percent of the stands have moderate LWD recruitment, while another 27 percent have high LWD recruitment. The riparian stands in the Main Stem Larabee I sub-basin are comprised of primarily medium to large trees, ranging from 12- to more than 24-inch dbh. Coniferous species dominate these stands, with a large redwood component, followed by Douglas fir. The remaining riparian forests include stands containing mixed conifer/hardwood species. Densities within these stands range from highly concentrated to moderately spaced stems, with the occasional sparse riparian area interspersed.

12.3 HILLSLOPE CONDITIONS

The total sediment delivery rate (per square mile) for the Main Stem Larabee I sub-basin is the highest of all the sub-basins in the Upper Eel WAU. At a total of 4,377 tons/mi^2/year, 36 percent is associated with natural processes, 5 percent with legacy effects, and 59 percent with management. Naturally-occurring shallow-seated landslides account for 29 percent (1,267 tons/mi^2/year) of sediment delivery, and another 37 percent (1,608 tons/mi^2/year) are attributed to management-related landslides occurring in partial cut areas harvested within the last 15 years. Management-related road gullies and stream crossing washouts account for another 9 percent (407 tons/mi^2/year) of sediment delivery, and 7 percent (318 tons/mi^2/yr) from road-related landslides. The large amount of delivery from natural shallow-seated landslides occurs in inner gorge areas, as is also the case for the large contribution from landslides occurring in partial cut areas.

13.0 MAIN STEM LARABEE II SUB-BASIN

The Main Stem Larabee II sub-basin is located in the Larabee Creek drainage and encompasses the main stem of Larabee Creek from the upstream boundary of the Main Stem Larabee II sub-basin to the Mill Creek sub-basin. HCP lands comprise 39 percent of this 1.1-square-mile sub-basin. Class I streams in this sub-basin include Larabee Creek and the downstream ends of No Name Creek and three other unnamed streams in the No Name Creek Complex sub-basin.

This sub-basin is dominated by Larabee Creek and the hillslopes and tributaries within a short distance from the main channel. Based on recent LIDAR data, approximately 20 percent of the area has slope gradients of less than 35 percent, and 29 percent of the area has slopes steeper than 65 percent. The geologic formation is predominantly Central Belt Franciscan Complex, sedimentary rocks throughout this sub-basin, with Franciscan mélange occurring in the area surrounding the downstream end of No Name Creek. Stream channel and terrace formations are located to a limited extent along the Larabee.

Douglas fir and Douglas fir/hardwood are the dominant vegetation types for the Main Stem Larabee II sub-basin, covering 90 percent of the HCP area.

Presently, the Main Stem Larabee II sub-basin has a road density of 4.7 miles/square mile for all HCP and non-HCP roads in the HCP area. The short length of HCP road is regular dirt and is located at the end of spur roads originating in the No Name Creek Complex sub-basin.

A total of only 33 acres of the Main Stem Larabee II sub-basin were harvested in the period from 1988 through 2003. All of the harvest was clear cut; 72 percent was cable yarded, and the remainder was helicopter yarded. First harvest occurred during the 1960s and 1970s throughout this sub-basin.

13.1 HCP SPECIES

The information utilized in this sub-section is presented in Appendix E (Sections 3.0, 4.2.3.1, and 5.3, Table E-3); and Appendix F (Section 4.6, Table F-10).

The Main Stem Larabee II sub-basin has suitable habitat for pond turtles and yellow-legged frogs. Detections of yellow-legged and red-legged frogs have been noted in this sub-basin. The higher gradient reaches of the streams draining directly into this sub-basin can also have potential habitat for the headwater species. Larabee Creek has low over-stream canopy cover and water temperatures that can be unsuitable for headwater species.

13.2 STREAM CHANNEL AND RIPARIAN CONDITIONS

The information utilized in this sub-section is presented in Appendix C (Section 6.3, Figures C-5 and C-8); and Appendix E (Section 4.2.3.1, Tables E-3 and E-14).

The Main Stem Larabee II sub-basin does not provide anadromous access as it is located upstream of a natural barrier. The barrier is located within the Main Stem Larabee I sub-basin just upstream from the confluence of Larabee Creek and Smith Creek.

Within the main stem there are deep pools scoured around lag boulder deposits. The substrate is generally gravel to cobble size. Streambed PFCs for sediment size are not all met for this sub-basin, as there is an abundance of particles tending toward the finer (but not the finest) fraction. The main stem Larabee is relatively steep in this sub-basin and constrained within valley walls. The average residual pool depth is greater than 3 feet, and pools are reasonably frequent. PFCs related to pool frequency, area, and depth are met in the Main Stem Larabee II sub-basin; PFCs are not met for percent pools associated with LWD.

Water temperatures in the main stem Larabee Creek exceed stressful thresholds for salmonids. The MWATs consistently exceed the PFC target in Larabee Creek, although the PFC target is exceeded upstream of the Upper Eel WAU. The temperature data presented in the Fish Habitat Assessment (Appendix E) show a general increase in MWAT values over the period of record (1999-2004).

Larabee Creek is unaffected by riparian shade and reach equilibrium with air temperature at approximately 23 ^{o}C. Due to natural influences including distance from divide, air temperature, reduced effectiveness of riparian shade, channel width, and other factors, the PFC target for MWAT may not be applicable for Larabee Creek. However, it is also feasible that temperatures could be lowered in Larabee Creek by as much as 3-4 ^{o}C with achievement of mature conifer riparian forests.

A notable characteristic of the Main Stem Larabee II sub-basin is the general lack of canopy cover, which exceeds 85 percent for only 56 percent of the stream length. The remaining 44 percent of the stream length has canopy cover of less than 20 percent.

The main stem Larabee channel is generally deficient in LWD for which pieces are small in size and probably fairly transient given the size of the stream. Riparian data show that 96 percent of the stands have moderate LWD recruitment. The remaining 4 percent of the stands have low LWD recruitment; there are no stands with high LWD recruitment potential.

The riparian stands in the Main Stem Larabee II sub-basin are comprised of primarily Douglas fir and mixed conifer/hardwood, with a minimal amount of predominantly hardwood stands. Canopy closure is mostly dense to moderately dense, with a minimal amount of sparse/open stands.

13.3 HILLSLOPE CONDITIONS

The total sediment delivery rate (per square mile) for the Main Stem Larabee II sub-basin is the second highest of all the sub-basins in the Upper Eel WAU. At a total of 2,727 tons/mi^2/year, 16 percent is associated with natural processes, 76 percent with legacy effects, and 8 percent with management. Legacy-related landslides originating on tractor-yarded hillslopes harvested 20 to 30 years ago account for 48 percent (1,311 tons/mi^2/year) of sediment delivery in this sub-basin. Another 22 percent (602 tons/mi^2/year) is attributed to legacy-related gullies and stream crossing washouts on abandoned roads. With most sediment delivery originating from legacy-related sources, addressing management-related sources may result in reduced sediment but cannot address most of the non-management sources that will continue.

14.0 MCCANN CREEK COMPLEX SUB-BASIN

The McCann Creek Complex sub-basin is located in the Eel River drainage, on the north-facing slopes and drainages that flow into the Eel River immediately upstream its confluence with Thompson Creek. HCP lands comprise 90 percent of this 4.0-square-mile sub-basin. The HCP area of this sub-basin includes lands and watercourses draining to the main stem Eel River.

HCP lands in this sub-basin include the following streams with Class I, II, and III reaches – Bell Creek, McCann Creek, Devil's Elbow Creek, and an unnamed tributary in the eastern portion of the HCP area. Each of these creeks flows directly into the main stem Eel River. The terrain is rugged with elevations ranging from 2,400 feet at the ridge top to approximately 150 feet at the downstream end of sub-basin on Eel River. Based on recent LIDAR data, approximately 29 percent of the HCP area has slope gradients of less than 35 percent, and 25 percent of the area has slopes steeper than 65 percent. The Yager geologic formation occurs in approximately 93 percent of the HCP area in this sub-basin, with stream channel and terrace deposits along the main stem Eel River comprising the rest of the area.

Redwood/Douglas fir is the dominant vegetation type in the McCann Creek Complex sub-basin, covering 48 percent of the HCP area; redwood, conifer/hardwood, and Douglas fir/redwood comprise most of the other vegetation types.

Presently, the Kapple Creek Complex sub-basin has a road density of 7.3 miles/square mile for all HCP and non-HCP roads in the HCP area. Approximately one-quarter of the HCP roads are rocked, and the others are regular dirt and are used seasonally.

During the analysis period of 1988 through 2003, harvest occurred on a total of 27 acres (1 percent) of the HCP area. Approximately 94 percent of the harvest in this period was clear cut and tractor yarding was used for all of the harvested acres. First harvest occurred in the HCP area during the 1960s and 1970s, with a small amount in the 1990s.

14.1 HCP SPECIES

The information utilized in this sub-section is presented in Appendix E (Section 4.2.3.12); and Appendix F (Section 4.6, Table F-10).

No fish were observed in Class I reaches of streams in the HCP area of the McCann Creek Complex sub-basin because of significant barriers near the mouths of these streams. There is a substantial restoration potential if man-made barriers, such as culverts, are removed.

The amphibian and reptile species of concern are present in this sub-basin, with the pond turtle occurring on the main stem Eel River. Tailed frogs and torrent salamanders occur in the higher gradient watercourse reaches. Slopes tend to be north-facing and canopy closure is high (greater than 85 percent), so micro-climate conditions are generally favorable for these species. Although past impacts in these sub-basins were adverse and relatively recent, it appears that recovery of the stream habitat is progressing well.

14.2 STREAM CHANNEL AND RIPARIAN CONDITIONS

The information utilized in this sub-section is presented in Appendix C (Section 6.11.1, Figures C-5 and C-8); and Appendix E (Sections 3.2 and 4.2.3.12, Table E-1).

Bell Creek, McCann Creek, and Devil's Elbow Creek each provide an excellent opportunity for restoration. Near the downstream end of each of these streams, prior to flowing into the Eel River, there are barriers to fish access. Bell Creek has a railroad culvert, at a height of 5 feet, located 523 feet from its mouth, and a naturally steepened channel gradient of 20 to 30 percent another 1,000 feet beyond the culvert. McCann Creek has a culvert, at a height of 3 feet, on a county road located 476 feet upstream from its mouth. Devil's Elbow Creek has a natural boulder, at a height of 5.3 feet, located 701 feet from its mouth. According to the Fish Habitat Assessment (Appendix E), restorable salmonid habitat for Bell Creek and McCann Creek are approximately 2,000 and 825 feet, respectively.

There has been significant recovery of riparian habitat since the days of first harvest logging practices, conducted in the 1960s and 1970s, in which stream corridors were utilized as a means for log transportation. Evidence of remnant railroad systems is still present within many of these riparian stands, including fully intact sections of track that parallel the stream, and even trestles that span over them.

Canopy closure is high with more than 85 percent canopy over 80 percent of the stream lengths, although another 20 percent of the stream length has canopy cover of less than 20 percent. Also, 87 percent of the stands have moderate LWD recruitment, while the other stands have high LWD recruitment. The riparian stands in the McCann Creek Complex sub-basin are predominantly medium-sized redwoods that form dense canopy cover over low lying areas of the riparian forest.

14.3 HILLSLOPE CONDITIONS

The total sediment delivery rate (per square mile) for the McCann Creek Complex sub-basin is above the median for the sub-basins in the Upper Eel WAU. At a total of 1,460 tons/mi^2/year, 26 percent is associated with natural processes, 13 percent with legacy effects, and 61 percent with management. Management-related road gullies and stream crossing washouts account for 42 percent (608 tons/mi^2/year) of sediment delivery in this sub-basin. Naturally-occurring small streamside landslides account for 14 percent (204 tons/mi^2/year) of sediment delivery, road-related landslides account for 13 percent (196 tons/mi^2/year), and another 11 percent (155 tons/mi^2/year) are attributed to legacy-related road gullies and washouts on abandoned roads. Sediment delivery from road gullies and stream crossing washouts is high in this sub-basin because the vast majority of road lengths are located in middle and lower hillslope positions on hard geology, which is a combination that yields high rates of road gullying and crossing washouts. As roads are stormproofed or upgraded, thus providing improved drainage and stability especially at stream crossings, sediment delivery from road gullies and stream crossing washouts is expected to decrease especially for roads in middle and lower hillslope positions on hard geology.

15.0 MCMAHAN CREEK SUB-BASIN

The McMahan Creek sub-basin is located in the headwaters of the Larabee Creek drainage. There are no HCP lands in this 13.6-square-mile sub-basin. Fish distribution and habitat data were not collected or evaluated for the McMahan Creek sub-basin during watershed analysis activities. Similarly, data on species distribution were not collected or evaluated for this sub-basin.

16.0 MID LARABEE CREEK COMPLEX SUB-BASIN

The Mid Larabee Creek Complex sub-basin is located in the Larabee Creek drainage, spanning the upstream portion of the Main Stem Larabee I sub-basin. HCP lands comprise approximately half of this 5.2-square-mile sub-basin. The HCP area of this sub-basin consists of primarily north-facing slopes and drainages located to the south of the Main Stem Larabee I sub-basin. This sub-basin includes one Class I stream – Pond Creek. The terrain is rugged with elevations ranging from 3,000 feet at the ridge top to approximately 1,000 feet at the boundary with the Main Stem Larabee I sub-basin. Based on recent LIDAR data, approximately 40 percent of the HCP area has slope gradients of less than 35 percent, and 12 percent of the area has slopes steeper than 65 percent. The geologic formation in this sub-basin is Yager.

Douglas fir and Douglas fir/redwood are the dominant vegetation types for the Mid Larabee Creek Complex sub-basin, covering 56 percent of the HCP area, with another 20 percent of the redwood/Douglas fir vegetation type.

Presently, the Mid Larabee Creek Complex sub-basin has a road density of 7.8 miles/square mile for all HCP and non-HCP roads in the HCP area. Approximately half of the HCP roads are rocked, and the others are regular dirt and are used seasonally.

The Mid Larabee Creek Complex sub-basin is a part of the Upper Eel WAU in which a significant amount of harvest occurred over the past several decades. Previously, first harvest was initiated in the 1950s and continued to a peak in 1970s, followed by a small amount in the 1980s. Later, second-cycle logging in the period from 1988 through 2003 involved harvest on 575 acres, with half of this acreage harvested by clear cut. Yarding was most commonly done by tractor (55 percent) followed by helicopter (25 percent).

16.1 HCP SPECIES

The information utilized in this sub-section is presented in Appendix E (Section 3.1 and 4.2.3.6); and Appendix F (Section 4.6, Table F-10).

Resident rainbow trout are present for a short distance upstream from a natural anadromous barrier (falls/cascades/bedrock steps) located near the mouth of Pond Creek. The existence of these resident trout is highly unusual since the natural barrier is completely insurmountable by salmonids. All age classes of rainbow trout were represented during surveys, suggesting a significant resident population; none of the fish shocked during surveys indicated signs of smoltification. It is suspected these fish were planted from the top of the drainage or at road crossings during the initial logging entry, escaped from upstream ponds, or occur as a result of the steep barriers at their confluences with Larabee Creek that are thought to be a product of geological uplift over time.

The western pond turtle, yellow-legged frog, and tailed frog were detected in the Mid Larabee Creek Complex sub-basin. Similar to the Boulder Creek sub-basin, the Mid Larabee Creek Complex has high gradient streams with consolidated Yager geology, providing good habitat for both tailed frogs and torrent salamander. Yellow-legged frog and pond turtle habitat occurs along the interface with the Main Stem Larabee I sub-basin. This sub-basin also has north-facing slopes and greater than 85 percent over-stream canopy cover, so micro-climate conditions are generally good for headwater species here as well.

16.2 STREAM CHANNEL AND RIPARIAN CONDITIONS

The information utilized in this sub-section is presented in Appendix C (Section 6.1.6, Figures C-5 and C-8); and Appendix E (Sections 3.2 and 4.2.3.6, Table E-1).

Fish access from Larabee Creek into Pond Creek is precluded because of natural bedrock/boulder falls; a 5-foot barrier on Pond Creek is located 2,454 feet upstream from the mouth. However, salmonids living upstream of these anadromous barriers were probably planted there many years ago, as discussed above.

Data collected during the electro-fishing surveys suggested that the distribution of these resident trout is contracting. Fish did not persist in the flatter reaches of Pond Creek. These relatively low gradient (4-12%) reaches contain significantly more gravel than the transport reaches and had no surface flow even following the wet spring of 2005. In addition, the first and second order headwater streams upstream of these relatively flat reaches are often dry by the end of summer. Therefore, it appears that the upstream extent of the resident stock's distribution is progressing further downstream with each successive drought.

Data show that over-stream canopy cover is greater than 85 percent for all of the stream length. Also, 95 percent of the stands have moderate LWD recruitment, indicating a trend of increasing LWD. Stands are dense to moderately dense, with mainly medium sized trees ranging from 12- to 24-inch dbh. Canopy composition is coniferous, but trees are small.

16.3 HILLSLOPE CONDITIONS

The total sediment delivery rate (per square mile) for the Mid Larabee Creek Complex sub-basin is near the median for the sub-basins in the Upper Eel WAU. At a total of 1,204 tons/mi^2/year, 34 percent is associated with natural processes, 16 percent with legacy effects, and 50 percent with management. Management-related road gullies and stream crossing washouts account for 38 percent (459 tons/mi^2/year) of sediment delivery in this sub-basin. Naturally-occurring small streamside landslides account for 24 percent (285 tons/mi^2/year) of sediment delivery, and another 11 percent (128 tons/mi^2/year) are attributed to legacy-related road gullies and washouts on abandoned roads. Sediment delivery from road gullies and stream crossing washouts is high in this sub-basin because all of the roads are located on hard geology, thus yielding high rates of road gullying and crossing washouts. As more roads are stormproofed or upgraded, thus providing improved drainage and stability especially at stream crossings, sediment delivery from road gullies and stream crossing washouts is expected to decrease.

17.0 MILL CREEK SUB-BASIN

The Mill Creek sub-basin is the sub-basin located farthest upstream in the Larabee Creek drainage. HCP lands are located to the southwest of Larabee Creek and comprise 7 percent of this 23-square-mile sub-basin. The HCP area of this sub-basin includes lands and watercourses draining to Larabee Creek.

HCP lands in this sub-basin include a short segment of Larabee Creek, along with two unnamed streams with short Class I segments. The terrain is rugged with elevations ranging from 3,100 feet at the ridge top to approximately 900 feetat Larabee Creek. Based on recent LIDAR data, approximately 23 percent of the HCP area has slope gradients of less than 35 percent, and 34 percent of the area has slopes steeper than 65 percent. The geology in the HCP area of this sub-basin is Central Belt Franciscan Complex.

Douglas fir and hardwood are the dominant vegetation types in the Mill Creek sub-basin, covering 83 percent of the HCP area, with another 14 percent of the Douglas fir/hardwood vegetation types.

Presently, the Mill Creek sub-basin has a road density of 4.2 miles/square mile for all HCP and non-HCP roads in the HCP area. These roads are primarily dirt and are used seasonally.

During the analysis period of 1988 through 2003, harvest occurred on a total of 305 acres (31 percent) of the HCP area. Approximately 93 percent of the harvest was clear cut, with 58 percent of the harvested acres yarded by tractor and 32 percent by cable. First harvest started in the HCP area primarily during the 1970s and continued into the 1980s. During the 1980s, first harvest occurred on 40 percent of the HCP area.

17.1 HCP SPECIES

The information utilized in this sub-section is presented in Appendix F (Section 4.6).

Fish distribution and habitat data were not collected in the HCP area of the Mill Creek sub-basin during watershed analysis activities.

There is little amphibian and reptile data on the Mill Creek sub-basin. Based on geology and other similar sub-basins, suitable habitat for the headwater species may be found in the higher gradient reaches of the watercourses within the HCP area of this sub-basin. However, this sub-basin has primarily Douglas fir and hardwood dominated stands and is further inland where ambient temperatures are higher in the summer months. Thus, micro-climate conditions for the headwater species may be less than optimal.

17.2 STREAM CHANNEL AND RIPARIAN CONDITIONS

The information utilized in this sub-section is presented in Appendix C (Section 6.2, Figures C-5 and C-8).

Riparian function was assessed for the HCP area of the Mill Creek sub-basin. Data show that over-stream canopy cover is greater than 85 percent for 96 percent of the stream lengths. Also, 54 percent of the stands have moderate LWD recruitment, and another 27 percent have high LWD recruitment.

Riparian stands in the Mill Creek sub-basin are comprised primarily of Douglas fir and mixed conifer/hardwood, with a few hardwood and redwood dominated acres. Most of the riparian areas contain small or sapling trees, while the remaining areas are comprised of medium to large size trees. The canopy in this sub-basin is dense to moderately dense in 75 percent of the riparian areas, and sparse in the rest of the areas.

17.3 HILLSLOPE CONDITIONS

The total sediment delivery rate (per square mile) for the Mill Creek sub-basin is near the median relative to the other sub-basins in the Upper Eel WAU. At a total of 1,229 tons/mi^2/year, 41 percent is associated with natural processes, 21 percent with legacy effects, and 38 percent with management. Naturally-occurring small streamside landslides deliver the largest amount of sediment (365 tons/mi^2/year or 30 percent of the total), and management-related road gullies and stream crossing washouts contribute another 27 percent (334 tons/mi^2/year) of sediment delivery in this sub-basin. Sediment delivery from legacy-related landslides originating on tractor-yarded hillslopes clear cut harvested 20 to 30 years ago account for 15 percent (182 tons/mi^2/year) of sediment delivery. Sediment delivery from road gullies and stream crossing washouts is high in this sub-basin because all road lengths are located on hard geology, thus yielding high rates of road gullying and crossing washouts. As more roads are stormproofed or upgraded, thus providing improved drainage and stability especially at stream crossings, sediment delivery from road gullies and stream crossing washouts is expected to decrease.

18.0 NEWMAN CREEK SUB-BASIN

The Newman Creek sub-basin is located in the Eel River drainage just upstream from where the South Fork Eel River joins the main stem Eel River. HCP lands comprise 96 percent of this 3.5-square-mile sub-basin. This sub-basin includes lands to the north of Eel River and includes one major Class I tributary – Newman Creek. The terrain is rugged with elevations ranging from 3,000 feet at the ridge top to approximately 100 feet at the confluence of Newman Creek and the Eel River. Based on recent LIDAR data, approximately 35 percent of the area has slope gradients of less than 35 percent, and 16 percent of the area has slopes steeper than 65 percent. The geologic formation in 76 percent of this sub-basin is Yager, in the area to the west and north of the main stem of Newman Creek. The remaining area has Wildcat group, undifferentiated, or terrace deposit formations.

Redwood and redwood/Douglas fir are the dominant vegetation types for the Newman Creek sub-basin, covering 74 percent of the HCP area, with another 8 percent of the Douglas fir vegetation type.

Presently, the Newman Creek sub-basin has a road density of 6.5 miles/square mile for all HCP and non-HCP roads in the HCP area. Approximately half of the HCP roads are rocked, and the remainder are regular dirt and are used seasonally; some of the dirt roads have been stormproofed or upgraded.

Second-cycle logging activities have been ongoing for the past several decades; first harvest occurred primarily from the 1920s through the 1960s. In the period from 1988 through 2003, a total of 746 acres (40 percent of the HCP area) were harvested. Of this total, 76 percent of the harvested acres were clear cut, with 45 percent of the clear cut acres yarded by cable and 33 percent by tractor. In this period, yarding was done by helicopter on 16 percent on the harvested acres.

18.1 HCP SPECIES

The information utilized in this sub-section is presented in Appendix E (Sections 3.1 and 4.2.3.7, Table E-9); and Appendix F (Section 4.6, Table F-10).

Chinook salmon typically utilize the low gradient reaches of Newman Creek where the channel is of an alluvial nature and is unconfined within the valley. Coho salmon may inhabit Newman Creek, but were not observed recently although they were observed in the lower half-mile of Newman Creek by the DFG in 1963. All three species of salmonids have been observed in this creek in the past.

The Newman Creek sub-basin has primarily consolidated Yager geology, with some Wildcat, and also Quarternary deposits in the lower reaches and near the Eel River. Yellow-legged frogs have been found in this sub-basin, and there is suitable pond turtle habitat along the Eel River. The higher gradient reaches contain potential habitat for the headwater species. Slopes are primarily southwest-facing, and the over-stream canopy closure is greater than 85 percent with moderate water temperature and micro-climate.

18.2 STREAM CHANNEL AND RIPARIAN CONDITIONS

The information utilized in this sub-section is presented in Appendix C (Section 6.10.2, Figures C-5 and C-8); and Appendix E (Sections 3.2 and 4.2.3.7, Tables E-1, E-9, and E-14).

Natural barriers to fish access are located in upstream areas of Newman Creek, just upstream of the confluence of the West Fork and East Fork Newman Creek, limiting fish utilization of these upper stream reaches. These barriers consist of high gradient cascades which are natural, permanent, and unrestorable barriers to fish migration. Cumulatively, these cascades restrict upstream passage.

The low gradient portion of the main stem Newman Creek contains excellent habitat for juvenile coho salmon and suitable size gravel for spawning, meeting the PFC criteria for percent less than 0.85 and 6.34 mm. Channels are plane bed through much of the surveyed reach, and bed particle size characteristics are suitable for salmonid spawning and incubation. Pools are frequently spaced, but relatively shallow. Average residual pool depth does not meet the PFC target, possibly because of sediment filling. Approximately 33 percent of the creek length is made up of pools with 55 percent of those associated with LWD. As discussed in the Fish Habitat Assessment (Appendix E), it is important to recognize that channel size and contributing basin area play a role in determining channel dimensions. The pool depth criterion is unlikely to be achievable for this sub-basin because of its small drainage area.

Water temperatures are slightly above optimum for salmonid growth in Newman Creek, and exceeded PFC criteria in 2004. Over-stream canopy cover in Newman Creek is greater than 85 percent for 90 percent of the stream length, providing good cover for temperature protection. LWD key pieces are relatively large, meeting PFC criteria for LWD volume, but these pieces occur infrequently. LWD density is below PFC criteria, but larger pieces are beginning to accumulate in the channel and have formed several temporary barriers immediately above the “last fish” observed.

Newman Creek riparian stands are comprised of mainly medium to large size redwoods and other coniferous species, greater than 12-inch dbh, with dense canopy cover that produce high percentages of canopy cover. A significant percentage (21 and 66 percent, respectively) of riparian stands in the Newman Creek sub-basin have high or moderate LWD recruitment potential on Class I stream reaches.

18.3 HILLSLOPE CONDITIONS

The total sediment delivery rate (per square mile) for the Newman Creek sub-basin is less than the median for the sub-basins in the Upper Eel WAU. At a total of 1,024 tons/mi^2/year, 39 percent is associated with natural processes, 4 percent with legacy effects, and 56 percent with management. Management-related road gullies and stream crossing washouts account for 25 percent (261 tons/mi^2/year) of sediment delivery in this sub-basin. Naturally-occurring small streamside landslides account for 20 percent (209 tons/mi^2/year) of sediment delivery, and another 18 percent (182 tons/mi^2/year) is attributed to road-related landslides. The large amount of delivery from management-related road gullies and stream crossing washouts is a result of the significant road miles located on hard geology, thus yielding higher rates of sediment delivery from this source type. The significant contribution from road-related landslides is also related to the hard geology and, specifically, originates in inner gorge areas.

19.0 NO NAME CREEK COMPLEX SUB-BASIN

The No Name Creek Complex sub-basin is the sub-basin located near the upstream extent of HCP lands in the Larabee Creek drainage, immediately to the west of the Mill Creek sub-basin. HCP lands comprise 99.9 percent of this 2.8-square-mile sub-basin. This sub-basin includes lands and watercourses that flow through the Main Stem Larabee II sub-basin to Larabee Creek.

HCP lands in this sub-basin include approximately four unnamed streams and No Name Creek, none which have Class I segments in this sub-basin. An additional unnamed stream has a short Class I segment. The terrain is rugged with elevations ranging from 3,100 feet at the ridge top to approximately 1,000 feetat Larabee Creek. Based on recent LIDAR data, approximately 23 percent of the HCP area has slope gradients of less than 35 percent, and 31 percent of the area has slopes steeper than 65 percent. The geologic formation is predominantly Central Belt Franciscan Complex, sedimentary rocks throughout this sub-basin, with Franciscan mélange occurring in the area surrounding the downstream portion of No Name Creek.

Douglas fir and Douglas fir/hardwood are the dominant vegetation types in the No Name Creek Complex sub-basin, covering 86 percent of the HCP area, with another 12 percent of the hardwood vegetation type.

Presently, the No Name Creek Complex sub-basin has a road density of 7.0 miles/square mile for all HCP and non-HCP roads in the HCP area. These roads are primarily regular dirt and are used seasonally.

During the analysis period of 1988 through 2003, harvest occurred on a total of 556 acres (31 percent) of the HCP area. Approximately 67 percent of the harvest was clear cut, with 46 percent of the harvested acres yarded by cable and 35 percent by tractor. First harvest started in the HCP area during the 1960s and continued into the 1980s. During the 1980s, first harvest occurred on 41 percent of the HCP area.

19.1 HCP SPECIES

The information utilized in this sub-section is presented in Appendix F (Section 4.6, Table F-10).

Fish distribution and habitat data were not collected in the HCP area of the No Name Creek Complex sub-basin during watershed analysis activities.

Southern torrent salamanders have been located at higher elevations in this sub-basin, and both red and yellow-legged frogs at lower elevations and near the Main Stem Larabee II sub-basin interface. The main stem gradient may be too steep for pond turtles to use effectively. This sub-basin has steep incised north-facing slopes with greater than 85 percent over-stream canopy closure. Conditions for headwater species are generally favorable.

19.2 STREAM CHANNEL AND RIPARIAN CONDITIONS

The information utilized in this sub-section is presented in Appendix C (Section 6.3, Figures C-5 and C-8); and Appendix E (Section 3.2, Table E-1).

A natural barrier to fish access is located in the downstream portion of No Name Creek – 294 feet from the mouth. The barrier consists of bedrock at a height of 6.3 feet on a 90-percent-gradient stream reach. Streambed sediment and water temperature data were not collected in this sub-basin. However, over-stream canopy cover is greater than 85 percent for 86 percent of the stream length, indicating good cover for temperature protection. A significant percentage (75 and 16 percent, respectively) of riparian stands in the No Name Creek Complex sub-basin have moderate or low LWD recruitment potential. The riparian stands in No Name Creek, like many other riparian forests in this area, contain remnants of old logging operations, including numerous abandoned machines that were probably used during the early to mid 1900s.

19.3 HILLSLOPE CONDITIONS

The total sediment delivery rate (per square mile) for the No Name Creek Complex sub-basin is higher than the rates for most of the other sub-basins in the Upper Eel WAU. At a total of 1,953 tons/mi^2/year, 22 percent is associated with natural processes, 4 percent with legacy effects, and 73 percent with management. Road-related landslides are the largest individual source, accounting for 31 percent (597 tons/mi^2/year) of sediment delivery in this sub-basin. Management-related road gullies and stream crossing washouts account for 23 percent (455 tons/mi^2/year) of sediment delivery in this sub-basin. Naturally-occurring small streamside landslides account for 17 percent (326 tons/mi^2/year) of sediment delivery, and another 14 percent (265 tons/mi^2/year) is attributed to management-related landslides occurring in areas of clear cut that were harvested less than 20 years ago. The large delivery from roads and/or clear cut areas results from landslides occurring in inner gorge and swale areas. The significant contribution from management-related road gullies and stream crossing washouts results from all of the road lengths located on hard geology, thus yielding higher rates of delivery from this source type.

20.0 OHMAN CREEK SUB-BASIN

The Ohman Creek sub-basin is the sub-basin located near the upstream extent of former HCP lands in the South Fork Eel River drainage, immediately to the northeast of the Butte Creek sub-basin. HCP lands are no longer present in this sub-basin, due to recent land management designation changes; previously, during much of the Upper Eel WAU assessment, HCP lands comprised approximately 5 percent of this 4.9-square-mile sub-basin. This sub-basin includes lands and watercourses draining to Ohman Creek and, subsequently, to the South Fork Eel River.

21.0 POISON OAK CREEK COMPLEX SUB-BASIN

The Poison Oak Creek Complex sub-basin is located in the Eel River drainage just upstream from the confluence of the South Fork Eel with the main stem Eel River. HCP lands comprise 76 percent of this 6-square-mile sub-basin. This sub-basin includes lands to the south of the main stem Eel River and includes three major Class I tributaries – Poison Oak Creek, Pipeline Creek, and Bloyd Creek. The terrain is rugged with elevations ranging from 2,400 feet at the ridge top to approximately 100 feet at the Eel River. Based on recent LIDAR data, approximately 33 percent of the HCP area has slope gradients of less than 35 percent, and 23 percent of the area has slopes steeper than 65 percent. The Yager formation accounts for approximately 84 percent of the geology in the Poison Oak Creek Complex sub-basin, with the remaining geology comprised of terrace deposits along the main stem Eel River.

Redwood and redwood/Douglas fir are the dominant vegetation types for the Poison Oak Creek Complex sub-basin, covering 72 percent of the HCP area, with another 14 percent of the conifer/hardwood vegetation type.

Presently, the Poison Oak Creek Complex sub-basin has a road density of 6.2 miles/square mile for all HCP and non-HCP roads in the HCP area. Approximately one-quarter of the HCP roads are rocked, approximately half of the roads are regular dirt and used seasonally, and the remainder are paved (County Road) or stormproofed or upgraded.

During the analysis period of 1988 through 2003, harvest occurred on a total of 568 acres (21 percent) of the HCP area. Approximately 86 percent of the harvest was clear cut, with 61 percent of the harvested acres yarded by tractor and 23 percent by helicopter. First harvest in the HCP area occurred during the 1920s and 1930s, then in the 1960s through 1990s peaking with a first harvest of 800 acres in the 1970s.

21.1 HCP SPECIES

The information utilized in this sub-section is presented in Appendix E (Sections 3.2, 4.2.3.10, 4.2.3.11, and 4.2.3.12, Tables E-1, E-11, E-12, and E-13); and Appendix F (Section 4.6, Table F-10).

Fish were not observed in Pipeline Creek and Bloyd Creek because of migration barriers near the mouths of these streams; other barriers exist upstream as well. However, Coho salmon are known to currently exist in Poison Oak Creek where they were sampled in 2005 in the presence/absence surveys.

All amphibian and reptile species of concern are present in the Poison Oak Creek Complex sub-basin, with the pond turtle occurring on the main stem Eel River. Tailed frogs and torrent salamanders occur in the higher gradient watercourse reaches. Slopes tend to be north-facing and canopy closure is high (greater than 85 percent), so micro-climate conditions are generally favorable for these species. Although past impacts in these sub-basins were adverse and relatively recent temporally, it appears that recovery of the stream habitat is proceeding well.

21.2 STREAM CHANNEL AND RIPARIAN CONDITIONS

The information utilized in this sub-section is presented in Appendix C (Section 6.10.3, Figures C-5 and C-8); and Appendix E (Sections 3.2, 4.2.3.10, 4.2.3.11, and 4.2.3.12, Tables E-1, E-11, E-12, E-13, and E-14).

Pipeline Creek and Bloyd Creek provide excellent opportunities for restoration due to the presence of railroad culvert barriers located 2,800 and 3,388 feet, respectively, upstream from the mouths – near the boundary of the HCP area. Natural barriers are also located farther upstream, at distances of 4,315 and 3,980 feet, respectively, upstream from the mouths. These upstream natural bedrock or boulder barriers provide further restrictions, if fish were to attempt access, at heights of 10 and 7 feet, respectively, for these two streams. On Poison Oak Creek, a natural bedrock falls barrier exists 8,784 feet upstream from its mouth, preventing further upstream migration by salmonids.

There are no data on streambed sediment characteristics for the major streams in this sub-basin. However, channel aggradation has caused flow-limiting barriers upstream of logjams or landslide deposits; this was observed on Poison Oak Creek and Pipeline Creek downstream from HCP lands. These types of barriers are common where a tributary channel crosses a main stem river floodplain. Salmonids that spawn in these reaches or further upstream, are forced to hold in the main stem until flows increase enough to allow passage. In Poison Oak Creek, the channel incises and contains some excellent salmonid habitat upstream of the County road.

Channels in the three Class I streams are plane bed and would likely have improved pool habitat if LWD were present; LWD pieces are large, but they do not occur with sufficient frequency. Pools also are relatively infrequent, but meet the PFC criterion for frequency in Poison Oak Creek and Pipeline Creek. Most of the LWD-associated pools are located upstream of the County road. There are not many deep pools – average residual pool depth does not meet the PFC target, possibly because of sediment filling. As discussed in the Fish Habitat Assessment (Appendix E), it is important to recognize that channel size and contributing basin area play a role in determining channel dimensions. The pool depth criterion is unlikely to be achievable for this sub-basin because of its small drainage area.

Water temperatures were evaluated only in Poison Oak Creek for which water temperatures are cool and near optimum (below PFC criteria) for salmonid growth. Canopy cover over Poison Oak Creek exceeds 85 percent for 86 percent of its length, thus providing good cover for temperature protection.

The riparian forests that are currently found in the Poison Oak Creek sub-basin are primarily redwood of moderate to large size. A significant percentage (22 and 75 percent, respectively) of riparian stands in the Poison Oak Creek Complex have high or moderate LWD recruitment potential on Class I streams.

21.3 HILLSLOPE CONDITIONS

The total sediment delivery rate (per square mile) for the Poison Oak Creek Complex sub-basin is higher than the rates for most of the other sub-basins in the Upper Eel WAU. At a total of 1,661 tons/mi^2/year, 44 percent is associated with natural processes, 20 percent with legacy effects, and 36 percent with management. Management-related road gullies and stream crossing washouts are the largest individual source, accounting for 27 percent (450 tons/mi^2/year) of sediment delivery in this sub-basin. Naturally-occurring shallow-seated landslides account for 22 percent (365 tons/mi^2/year) of sediment delivery, and another 15 percent (253 tons/mi^2/year) is attributed to naturally-occurring small streamside landslides. The significant contribution from management-related road gullies and stream crossing washouts occurs because most roads are located on hard geology, with a significant portion of these roads located in the lower hillslope position, thus yielding the highest rates of delivery from this source type. This contribution should decrease significantly as more roads are upgraded or stormproofed.

22.0 SCOTT CREEK COMPLEX SUB-BASIN

The Scott Creek Complex sub-basin is the sub-basin located near the downstream end of Larabee Creek, between the Balcom Creek Complex and Mid Larabee Creek Complex sub-basins. This entire 3-square-mile sub-basin is comprised of HCP lands, and includes lands and watercourses draining to the main stem Larabee Creek. This sub-basin includes Scott Creek, a Class I stream, Arnold Creek, and smaller watercourses that drain the north-facing slopes located to the south of Larabee Creek. The terrain is rugged with elevations ranging from 3,000 feet at the ridge top to approximately 400 feet at the boundary of the Main Stem Larabee I sub-basin. Based on recent LIDAR data, approximately 32 percent of the HCP area has slope gradients of less than 35 percent, and 18 percent of the area has slopes steeper than 65 percent. The geologic formation is predominantly Yager formation, with a small portion of the western area of this sub-basin in Wildcat group, undifferentiated geology.

Redwood/Douglas fir and Douglas fir/redwood vegetation types comprise 79 percent of the HCP area of the Scott Creek Complex sub-basin.

Presently, the Scott Creek Complex sub-basin has a road density of 8.0 miles/square mile for all HCP and non-HCP roads in the HCP area. Approximately half of the HCP roads are regular dirt and used seasonally, and the remainder are rocked, stormproofed, or upgraded.

During the analysis period of 1988 through 2003, harvest occurred on a total of 995 acres (52 percent) of the sub-basin. Approximately 79 percent of the harvest was clear cut, with 52 percent of the harvested acres yarded by tractor and another 38 percent yarded by cable. First harvest in the sub-basin occurred primarily in the decades of the 1910s, 1920s, 1950s, and 1970s.

22.1 HCP SPECIES

The information utilized in this sub-section is presented in Appendix E (Section 3.1 and 4.2.3.6); and Appendix F (Section 4.6, Table F-10).

Resident rainbow trout are present for a short distance upstream from a natural anadromous barrier (falls/cascades/bedrock steps) located near the mouth of Scott Creek. The existence of these resident trout is highly unusual since the natural barrier is completely insurmountable by salmonids. All age classes of rainbow trout were represented during surveys, suggesting a significant resident population; none of the fish shocked during surveys indicated signs of smoltification. It is suspected these fish were planted from the top of the drainage or at road crossings during the initial logging entry, escaped from upstream ponds, or occur as a result of the steep barriers at their confluences with Larabee Creek that are thought to be a product of geological uplift over time.

Tailed frogs, torrent salamanders, red-legged frogs, and yellow-legged frogs were found in the Scott Creek Complex sub-basin. This sub-basin contains consolidated geology (primarily Yager formation), and a diversity of habitats that supports all four amphibian species of concern. Watercourses have very good habitat for the headwater species, and there is pond habitat near the head of Scott Creek. The canopy closure over most streams in the sub-basin is greater than 85 percent and slopes are north-facing, thus providing good micro-climate conditions for the amphibian species.

22.2 STREAM CHANNEL AND RIPARIAN CONDITIONS

The information utilized in this sub-section is presented in Appendix C (Section 6.1.7, Figures C-5 and C-8); and Appendix E (Sections 3.2 and 4.2.3.6, Table E-1).

Fish access from Larabee Creek into Scott Creek is precluded because of natural bedrock/boulder falls; a 10-foot barrier on Scott Creek is located 228 feet upstream from the mouth, along with a natural cascade barrier of 90 feet on a 20 to 30 percent gradient stream reach located approximately 1,981 feet from the mouth. However, salmonids living upstream of these anadromous barriers were probably planted there many years ago, as discussed above. Further data collection to assess aquatic PFCs was not conducted in this sub-basin. However, riparian function was assessed for Scott Creek. Data show that over-stream canopy cover is greater than 85 percent for 95 percent of the stream length. Also, 69 percent of the stands have moderate LWD recruitment, indicating a trend of increasing LWD; another 25 percent of the stands have high LWD recruitment. The riparian stands in the Scott Creek Complex sub-basin exhibit a strong conifer component, predominantly redwood. The riparian stands are dense with primarily medium sized trees, with a fair amount of larger trees interspersed.

22.3 HILLSLOPE CONDITIONS

The total sediment delivery rate (per square mile) for the Scott Creek Complex sub-basin is near the median for sub-basins in the Upper Eel WAU. At a total of 1,187 tons/mi^2/year, 36 percent is associated with natural processes, 8 percent with legacy effects, and 56 percent with management. Management-related road gullies and stream crossing washouts are the largest individual source, accounting for 45 percent (533 tons/mi^2/year) of sediment delivery in this sub-basin. Naturally-occurring small streamside landslides account for another 24 percent (279 tons/mi^2/year) of sediment delivery. The significant contribution from management-related road gullies and stream crossing washouts occurs because most roads are located on hard geology, thus yielding higher rates of delivery from this source type. This contribution should decrease significantly as more roads are upgraded or stormproofed.

23.0 SMITH CREEK SUB-BASIN

The Smith Creek sub-basin is located north of Larabee Creek, between the Carson Creek Complex and Mid Larabee Creek Complex sub-basins. Approximately 71 percent of this 3-square-mile sub-basin is comprised of HCP lands, and includes lands and watercourses draining to the main stem Larabee Creek. There are no Class I streams in this sub-basin. The terrain is rugged with elevations ranging from 3,000 feet at the ridge top to approximately 600 feet at the boundary of the Main Stem Larabee I sub-basin. Based on recent LIDAR data, approximately 49 percent of the HCP area has slope gradients of less than 35 percent, and 4 percent of the area has slopes steeper than 65 percent. The geologic formation in this sub-basin is Yager.

The redwood/Douglas fir and redwood vegetation types comprise 57 percent of the HCP area of the Smith Creek sub-basin, with another 15 percent in the Douglas fir vegetation type.

Presently, the Smith Creek sub-basin has a road density of 7.1 miles/square mile for all HCP and non-HCP roads in the HCP area. Most of the HCP roads are regular dirt and are used seasonally, and a small portion of the roads are rocked.

During the analysis period of 1988 through 2003, harvest occurred on a total of 482 acres (35 percent) of the HCP area. Approximately 89 percent of the harvest was clear cut, with 55 percent of the harvested acres yarded by tractor and another 36 percent yarded by cable. First harvest in the HCP area of the Smith Creek sub-basin occurred primarily in the 1920s, with later first harvest in smaller acreages occurring from the 1950s through the 1990s.

23.1 HCP SPECIES

The information utilized in this sub-section is presented in Appendix E (Section 4.2.3.6); and Appendix F (Table F-10).

Fish distribution and habitat data were not collected in the HCP area of the Smith Creek sub-basin during watershed analysis activities. Likewise, amphibian data were not collected.

23.2 STREAM CHANNEL AND RIPARIAN CONDITIONS

The information utilized in this sub-section is presented in Appendix C (Section 6.1.8, Figures C-5 and C-8); and Appendix E (Sections 3.2 and 4.2.3.6, Table E-1).

Fish access from Larabee Creek into Smith Creek is precluded because of high gradient stream cascades, at a height of 47 feet on a 43 percent gradient, located at the mouth. Further data collection to assess aquatic PFCs was not conducted in this sub-basin. However, riparian function was assessed for Smith Creek. Data show that over-stream canopy cover is greater than 85 percent for 95 percent of the stream length. Also, 64 percent of the stands have moderate LWD recruitment, indicating a trend of increasing LWD; another 33 percent of the stands have high LWD recruitment. The riparian stands in Smith Creek are conifer dominated, mostly medium to large size redwood and Douglas fir with dense canopy cover.

23.3 HILLSLOPE CONDITIONS

The total sediment delivery rate (per square mile) for the Smith Creek sub-basin is near the median for sub-basins in the Upper Eel WAU. At a total of 1,296 tons/mi^2/year, 40 percent is associated with natural processes, 16 percent with legacy effects, and 44 percent with management. Management-related road gullies and stream crossing washouts are the largest individual source, accounting for 35 percent (460 tons/mi^2/year) of sediment delivery in this sub-basin. Naturally-occurring small streamside landslides account for another 24 percent (310 tons/mi^2/year) of sediment delivery. The significant contribution from management-related road gullies and stream crossing washouts occurs because all roads are located on hard geology, thus yielding higher rates of delivery from this source type. This contribution should decrease significantly as more roads are upgraded or stormproofed.

24.0 THOMPSON CREEK SUB-BASIN

The Thompson Creek sub-basin is located in the Eel River drainage just upstream from the Kapple Creek Complex sub-basin. This sub-basin is located to the north of the Eel River main stem. HCP lands comprise 39 percent of this 8.6-square-mile sub-basin. This sub-basin includes the Class I tributary Thompson Creek which also has two Class I forks – the North Fork Thompson Creek and South Fork Thompson Creek. The terrain is rugged with elevations ranging from 3,200 feet at the ridge top to approximately 150 feet at the confluence of Thompson Creek and the Eel River. Based on recent LIDAR data, approximately 34 percent of the HCP area has slope gradients of less than 35 percent, and 16 percent of the area has slopes steeper than 65 percent. The geologic formation in 80 percent of the HCP area of this sub-basin is Yager, in the area generally upstream of the confluence of the North Fork and South Fork Thompson Creek. The remaining area has Wildcat group, undifferentiated, or terrace deposit formations.

Redwood/Douglas fir and Douglas fir are the dominant vegetation types for the HCP area of the Thompson Creek sub-basin, covering 53 percent of the HCP area, with another 13 percent of the hardwood vegetation type.

Presently, the Thompson Creek sub-basin has a road density of 7.0 miles/square mile for all HCP and non-HCP roads in the HCP area. The majority of the HCP roads are regular dirt and are used seasonally.

Second-cycle logging activities have been ongoing for the past several decades; first harvest occurred primarily from the 1950s through the 1970s, with most of this first harvest occurring in the 1970s. In the period from 1988 through 2003, a total of 508 acres (22 percent of the HCP area) were harvested. Of this total, 71 percent of the harvested acres were clear cut. In this period, 43 percent of the harvested acres were yarded by tractor, with another 39 percent by cable.

24.1 HCP SPECIES

The information utilized in this sub-section is presented in Appendix E (Sections 3.2 and 4.2.3.9); and Appendix F (Section 4.6, Table F-10).

The moderate gradient Yager section of Thompson Creek is used by steelhead for spawning and rearing. Yellow-legged frogs have been located along the lower stream reaches of Thompson Creek. Suitable pond turtle habitat also occurs in these areas. Potential habitat for the headwater species occurs in the high gradient watercourse reaches where consolidated substrate may be found. Although slopes are primarily south-facing, the over-stream canopy cover is greater than 85 percent, thus providing adequate shading and micro-climate conditions.

24.2 STREAM CHANNEL AND RIPARIAN CONDITIONS

The information utilized in this sub-section is presented in Appendix C (Section 6.11 and 6.11.2, Figures C-5 and C-8); and Appendix E (Section 3.2 and 4.2.3.9, Tables E-1, E10, and E-14).

The fishbearing portion of the North Fork Thompson Creek extends to a 9.5-foot waterfall that is approximately 5,300 feet upstream of its confluence with SF Thompson. The fishbearing reach of South Fork Thompson Creek may extend up to 5,500 feet from its mouth, but further data collection is needed to determine the actual fish distribution.

Thompson Creek contains suitable size gravel for anadromous spawning, meeting the PFC criterion for percent less than 0.85 mm. This stream has a plane bed channel with few, widely spaced, shallow pools. Average residual pool depth does not meet the PFC target, possibly because of sediment filling. Approximately 18 percent of the creek length is made up of pools with none of those associated with LWD. An increase in LWD would likely improve pool frequency and depth. However, as discussed in the Fish Habitat Assessment (Appendix E), it is important to recognize that channel size and contributing basin area play a role in determining channel dimensions. The pool depth criterion is unlikely to be achievable for this sub-basin because of its small drainage area.

Water temperatures are slightly above optimum for salmonid growth in Thompson Creek, and exceeded or met PFC criteria at various times over the monitoring period. Over-stream canopy cover in Thompson Creek is greater than 85 percent for 81 percent of the stream length, with less than 20 percent cover for 12 percent of its length. LWD key pieces are relatively large, meeting PFC criteria for LWD volume, but these pieces occur infrequently and LWD density is below PFC criteria.

Thompson Creek has reaches where the conifer canopy is sparse and overall canopy is made up of a larger hardwood component. The riparian stands of Thompson Creek are dominated by medium sized trees, with a prevailing species composition of mixed conifer and hardwood, with occasional stands that contain mostly Douglas fir. A significant percentage (65 and 28 percent, respectively) of riparian stands in the Thompson Creek sub-basin have moderate or low LWD recruitment potential on Class I stream reaches. Riparian stands in Thompson Creek would likely benefit from restoration silvicultural practices to enhance conifer forests.

24.3 HILLSLOPE CONDITIONS

The total sediment delivery rate (per square mile) for the Thompson Creek sub-basin is less than the median for sub-basins in the Upper Eel WAU. At a total of 1,049 tons/mi^2/year, 33 percent is associated with natural processes, 13 percent with legacy effects, and 53 percent with management. Management-related road gullies and stream crossing washouts are the largest individual source, accounting for 34 percent (360 tons/mi^2/year) of sediment delivery in this sub-basin. Naturally-occurring small streamside landslides account for another 20 percent (207 tons/mi^2/year) of sediment delivery. The significant contribution from management-related road gullies and stream crossing washouts occurs because most roads are located on hard geology, thus yielding higher rates of delivery from this source type. This contribution should decrease significantly as more roads are upgraded or stormproofed.

25.0 THURMAN CREEK SUB-BASIN

The Thurman Creek sub-basin is located in the upper portion of the Larabee Creek drainage, and is situated between the McMahan Creek and Mill Creek sub-basins. There are no HCP lands in this 13-square-mile sub-basin. Fish distribution and habitat data were not collected or evaluated for the Thurman Creek sub-basin during watershed analysis activities. Similarly, data on species distribution were not collected or evaluated for this sub-basin.

Attachment 4

Glossary

Attachment 4

PALCO
Upper Eel Watershed Analysis

Glossary

Derived from April 2000 Watershed Analysis Methods

with additional terms

TERMS IN ALPHABETICAL ORDER

active channel – A portion of the stream channel within the limits of the bankfull channel characterized by mobile sediment deposits or frequent submergence; the portion of the channel occupied by flow during winter baseflow conditions.

active riparian recruitment – Large woody debris (LWD) from riparian forest stands is entering the stream channel under current stand conditions; as distinct from LWD in stream channels that originated as debris from old-growth stands no longer present or as logging debris.

aerial (air) photo – A photograph of the earth's surface taken from the air. It is usually a vertical view, and one of a series of photos taken from an aircraft flying a systematic pattern at a given altitude in order to obtain continuous photo coverage for mapping purposes.

aerial photo interpretation – The identification of specific earth surface features and conditions by recognition of the patterns displayed on aerial photographs.

aggradation – An accumulation, often gradual, of sediment on a streambed that increases bed elevation and reduces channel capacity.

alluvial fan – A fan-shaped deposit of fluvial sand and gravel, usually located at the mouth of a tributary valley; a type of flood plain.

alluvial plain – A plain underlain by fluvial deposits, including alluvial (fluvial) fans and lacustrine deposits (stream-transported materials that have accumulated in lakes). See flood plain.

alluvium – Sediment deposits laid down by streams; usually refers to sand and gravel in channel deposits, but includes flood-plain deposits.

armor layer – Surface layer of material in a channel that is coarser than the underlying sediment.

bank erosion – The erosion of streambanks by a combination of processes, including undercutting of the bank during periods of peak streamflow and seepage erosion of sediment comprising the bank. This process may occur either rapidly or slowly.

bankfull channel – The portion of the channel that the stream normally occupies during regular high-water periods, which occur about every 0.5 to 2.0 years. There is often confusion regarding the distinction to be made between the "bankfull" criteria stated above and the literal "top of bank" criterion that often represents the channel dimension at a rare, extreme flood stage, or even a level of flow that is not likely to be reached under existing climatic conditions owing to past channel incision, tectonic uplift, or climate change.

bar – A sediment accumulation within the stream channel, which can specifically be located inside meander bends, on topographic high points within the channel, in the active channel parallel to the banks, or upstream of obstructions within the channel.

base level – A downstream elevation control on a stream channel. This may be either sea level, a lake, or a valley floor.

baseline – A quantitative level or value from which data and observations are referenced; data collected to establish the state of a system, process, or activity before the initiation of actions that may result in change.

basemap – The map (usually a topographic map) to which terrain mapping is added, either by drafting directly onto the basemap, or by drafting onto a transparent overlay.

bed load – Material transported in a stream that rolls, slides, and "hops" (saltates) downstream and is partly supported by the streambed; this in contrast with material carried in suspension or solution.

bedform – A gravel bar or sand dune in a stream channel.

bedrock – Solid rock, usually older than Quaternary (except rock formed by cooling of lava), either exposed at the land surface or underlying surficial deposits or regolith of varying thickness.

bimodal – A characteristic of a histogram or frequency distribution where there are two peaks or modes.

braided channel – A stream reach characterized by multiple channel threads.

break-in-slope - Major change in the gradient of a topographic surface.

broadcast burning – a controlled burn, where the fire is intentionally ignited and allowed to proceed over a designated area within well-defined boundaries. It reduces fuel hazard after logging or is used for site preparation before planting. Also called slash burning.

buffer zone – a strip of land (often including undisturbed vegetation) where disturbance is not allowed or is closely monitored to preserve or enhance aesthetic and other qualities along or adjacent to roads, trails, watercourses, and recreation sites. In forest practices, riparian buffer zones are often retained to preserve riparian vegetation and habitat values and to act as a sediment trap to capture sediment from upland sources before it reaches a watercourse.

canopy – The overhanging cover formed by leaves, needles, and branches of vegetation.

canopy closure – Vegetation projecting over waters, including crown cover (generally more than 1 m above the water surface) and overhead cover (less than 1 m above the water surface).

canopy cover – The proportion of an area covered by tree crowns.

centroid - Mid-point between the landslide headscarp and base of landslide erosional void.

channel geometry – Physical channel characteristics that are typically used to determine channel flow capacity or hydraulic parameters; slope, width, depth, flow velocity.

channel migration zone (CMZ) – The boundary generally corresponds to the modern flood plain, but may also include river terraces that are subject to significant bank erosion; the area adjacent to watercourses constructed by the river in the present climate and inundated during periods of high flow. The CMZ corresponds to the 100-year floodplain adjacent to Rosgen channel types C, D, and E.

channel order – Refers to a system of channel classification in which a channel with no tributaries is called first-order; below the confluence with two first-order streams is a second-order stream, and so on.

channel response matrix – A table of data used to approximate sediment transport and response characteristics expected for channel segments defined through assessment using primarily map and aerial photo data.

channel roughness – Flow resistance; elements of the channel bed and shape that essentially slow the flow velocity.

channel segment – The basic stream mapping unit representing a part of the stream with unique characteristics.

channel sensitivity – Degree of potential physical channel change to a change in watershed inputs.

channel stability – Refers to the channel's ability to resist change in shape or position, whether attacked by flood or ice flows.

Class I, II, III streams – Stream classes as defined in the California Forest Practice Rules. Class I streams supply domestic water, or fish are always or seasonally present. Class II streams have fish present 1,000 ft downstream and/or provide aquatic habitat for nonfish species. Class III streams have no aquatic life present but have evidence of being capable of sediment transport to Class I or II waters.

clay – A rock or mineral fragment of any composition having a diameter less than 1/256 mm (4 micrometres) (Wentworth scale); a finely crystalline hydrous silicate of aluminum, iron, manganese, magnesium, and other metals belonging to the phyllosilicate group, such as kaolinite, montmorillonite, bentonite, and vermiculite—known as clay minerals.

clinometer – A device used to measure slope designed primarily for measurement of large angles; commonly used by foresters to determine tree height.

coarse sediment – Sediment particles greater than or equal to 2 mm in diameter.

Glossary

coarse-grained – Rock particles or sediment that are easily seen by the naked eye and have an average diameter greater than 2 mm (0.08 inches).

cobbles – A rock fragment between 64 and 256 mm intermediate diameter (Wentworth scale); rounded and sub-rounded rock fragments between 62 and 256 mm.

cohesion – Shear strength of a rock or particle not related to interparticle friction; the capacity of particles to stick or adhere together.

colluvial fan – A fan-shaped mass of sediments deposited by colluvial processes, most commonly debris flows.

colluvial processes – See slope processes and mass movement.

colluvium – Materials that have reached their present positions as a result of direct, gravity-induced mass movements. No agent of transportation such as water or ice is involved, although the moving material may have contained water or ice (in some definitions includes deposits resulting from slope wash). Includes talus, landslide debris, and debris-flow deposits. Usually distinguished from alluvium by the abundance of silt and clay.

compaction – A physical change in soil properties that results in an increase in soil bulk density and a decrease in porosity; the packing together of soil particles by forces exerted at the soil surface, resulting in increased soil density.

composite terrain polygon (unit) – A polygon (unit) that includes two or three types of basic elements, usually occurring repetitiously.

cone – A mountain, hill, or other landform shaped like a cone, having relatively steep slopes and a pointed top; a sector of a cone with a straight or concave long profile and slopes generally steeper than 15° (26%)—includes talus cones and avalanche cones .

confinement – The degree to which a stream channel is laterally constrained by hillslopes or terraces.

contacts (stratigraphic) – The surfaces that separate a stratigraphic unit from overlying and underlying units. May be sharp or gradational, horizontal or inclined, planar or wavy.

creep – The imperceptibly slow, more or less continuous downhill movement of soil or rock on slopes. The movement is essentially flow of a highly viscous medium under shear stresses sufficient to produce deformation but too small to produce shear failure as in a landslide.

critical shear stress – The threshold of value of shear stress that is sufficient to entrain a sediment particle or a representative grain size for a patch of streambed. See shear stress.

cross-drain culvert – A culvert used to carry ditch water from one side of the road to the other.

crown – The live branches and foliage of a tree.

crown closure – Synonymous with canopy closure.

crowned road – A road that is graded with the centerline of the road higher than the edges of the road. As a result, water drains from center of roadway toward both edges of road.

cutslope – The face of the excavated bank along the uphill side of a road.

dam-break flood – Similar to a debris torrent; a localized flood event generated by breaching of a debris dam formed by a landslide event.

debris flow – The downslope movement of unconsolidated, matrix-supported, water-laden materials that are capable of scour and deposition.

delta – An accumulation of stream-transported sediments deposited where a stream enters a body of water. The landform is flat or very gently sloping, triangular or fan-shaped in plan, and consists of fluvial (alluvial) gravel, sand, silt, and/or clay.

deposit – An accumulation of earth material resulting from naturally occurring physical, chemical, or organic processes.

depression – A circular or irregular enclosed hollow separated from the surrounding area by a distinct slope break.

derivative (interpretive) maps – Maps derived from information contained on a terrain map or in a terrain database, but displaying information relevant only to some specific theme or application. Examples include slope-stability maps, urban capability maps, and maps of granular resources.

desynchronization – To affect the timing of two or more activities so as to make them less likely to occur simultaneously.

digital terrain data – Topographic data stored in computer files.

discharge – Rate of streamflow.

distortion (on aerial photos) – Distortion is caused by several effects, of which the two most relevant to aerial photo interpretation are as follows: Radial distortion occurs because the camera is not vertically above every point on the photograph—features near the edges appear to lean outward. Topographic distortion results from differences in scale related to topography—scale is larger where topography is high and camera-to-ground distance is least, and vice versa.

downcutting – The active incising by a stream of a streambed or valley due to erosion of sediment or bedrock.

drainage area – Upstream contributing watershed area to a point of interest.

drainage basin – See watershed.

dry ravel – Downslope movement of dry, noncohesive soil or rock particles under the influence of gravity; a form of soil creep.

duff – The layer of partially and fully decomposed organic materials lying below the litter and immediately above the mineral soil. It corresponds to the fermentation (F) and humus (H) layers of the forest floor. When moss is present, the top of the duff is just below the green portion of the moss.

earth – Any or a mixture of soil, surficial materials, and weathered rock.

effective height for LWD – Effective height is the height of the tree where the stem diameter is equal to the minimum qualifying LWD diameter (i.e., 4 inches). This height is computed from a tree taper function.

entrainment –Initiation of movement of sediment on a streambed by streamflow.

entrenchment – The degree to which a stream channel is inset in the valley floor.

erosion – The removal of rock and soil from the land surface by a variety of processes: by gravitational stress, through mass wasting; or by the movement of a medium (e.g., water, in solution or by overland flow or channel flow).

erosional regime – A set of watershed conditions associated with a characteristic degree of erosion at the watershed scale.

escarpment – A steep slope that is usually of great lateral extent compared to its height, such as the risers of river terraces and steep faces associated with stratified rocks.

evapotranspiration – The combined processes by which water is transferred from the earth surface to the atmosphere; evaporation of liquid or solid water plus transpiration from plants. Evapotranspiration occurs through evaporation of water from the surface, evaporation from the capillary fringe of the groundwater table, and the transpiration of groundwater by plants (phreatophytes) whose roots tap the capillary fringe of the groundwater table. The sum of evaporation plus transpiration.

exceedance interval – The average number of years between the occurrence of an event (in this case, flood event) of a given magnitude and one that is more extreme.

fan – An accumulation of detrital material in the shape of a low-angle cone, usually at the point where a stream emerges from a canyon onto a plain; a sector of a cone with gradient not steeper than 15°. See alluvial fan, colluvial fan.

felling – The process of cutting down standing timber and then cutting it into specific lengths for yarding and hauling.

field-check (verification) – Refers to the observations and written description of conditions at a particular site in a terrain polygon. Used to assess correctness of aerial photo interpretation and to collect information that cannot be obtained by aerial photo interpretation.

fillslope – The face of an embankment required to raise the desired road profile above the natural ground line (on downhill side of road tread).

fine sediment – Sediment particles less than 2 mm in diameter.

fine-grained – Rock particles or sediment that have an average diameter smaller than 2 mm (0.08 inches).

flight line – The succession of overlapping aerial photos (about 250) on one roll of film and identified by specific index numbers and letters; the succession of overlapping aerial photos taken along a single straight segment of the flight path of the aircraft.

flood hydrograph – A graphic depiction of the discharge of a stream over time.

flood plain – Level or very gently sloping surface bordering a river that has been formed by river erosion and deposition. It is usually subject to flooding and is underlain by fluvial sediments. Similar to alluvial plain.

flood-frequency curve – Graph showing the relationship between recurrence interval (or exceedence probability) and peak discharge (volume flux of water per unit time).

flood-plain width – Width of the area on both sides of a stream, which is subject to flooding.

flow regime – A set of hydrologic and watershed conditions that determine a watershed's characteristic hydrograph; e.g. snow-melt runoff regime versus storm runoff regime.

fluvial – Pertaining to streams and rivers. Similar to alluvial.

fluvial geomorphology – The branch of geomorphology devoted to the study of stream channels.

fluvial terraces – See river terraces.

fog drip – Occurs when fog droplets encounter an obstruction, coalesce, and fall to the ground. Fog drip occurs primarily near ridge crests during cool periods when temperatures are less than 50°F.

gentle slope – A planar surface sloping at 3 to 15°.

geological processes – Geomorphological processes; including those dynamic actions or events that take place below the earth's surface, and result in effects such as earthquakes and volcanism, as well as geomorphological processes.

geological structure – The three-dimensional arrangement of geological contacts and discontinuities, such as bedding, stratification, joints, faults, dykes, plutons, folds.

geomorphic regime – A set of geologic, hydrologic, and watershed conditions that determine a watershed's characteristic geomorphology; e.g., debris-flow-dominated landscapes.

geomorphic unit – An area encompassing portions of the channel network that are representative of similar fluvial processes.

geomorphological history – The evolution of landforms and landscapes, surface materials, and changes with time in geomorphological processes.

geomorphological processes – Dynamic actions or events that occur at the earth's surface due to application of natural forces resulting from gravity, temperature changes, freezing and thawing, chemical reactions, seismic shaking, and the agencies of wind and moving water, ice, and snow. Where and when a force exceeds the strength of the earth material, the material is changed by deformation, translocation, or chemical reactions.

geomorphology – The study of the origin of landforms, the processes whereby they are formed, and the materials of which they consist.

glacial till – Unsorted sediment transported by glaciers and deposited as they melt.

gradient – Channel slope or hillslope expressed as units of rise over units of run.

grading – An engineering term pertaining to the degree of sorting by size of particles in a clastic sediment or sedimentary rock. Sandy and gravelly materials with a wide range of particle sizes are termed “well graded”; material with a small range of sizes is “poorly graded.” (Note that these terms are the reverse of the geological expressions “well sorted” and “poorly sorted.”

grain roughness – Flow resistance in a channel caused by sediment grains on the bed.

gravel – A loose accumulation of rock fragments greater than 2 mm in diameter; pertaining to stream gravel: a rounded rock particle with a median diameter between 2 mm and 64 mm.

gravel pavement – Similar to channel armor, but regarded as less likely to be entrained by flow, and more permanent.

ground-checking – Fieldwork carried out to assess the correctness of aerial photo interpretation or other sources of information. See also field-check.

gully – A small valley or ravine, longer than wide, and typically from a few meters to a few tens of meters across.

gully erosion – Advanced stage of surface erosion in which rills are formed in soil or soft rock by a variety of processes, including erosion by running water; erosion as a result of weathering and the impact of falling rocks, debris slides, debris flows, and other types of mass movement; and erosion by snow avalanches.

HCP – Habitat Conservation Plan for the Properties of The Pacific Lumber Company, Scotia Pacific Company LLC, and Salmon Creek Corporation, February 1999.

headwall swale - Concave depression, with convergent slopes typically of 65% or greater, that is connected to waters via a continuous linear depression. A linear depression interrupted by a landslide deposit is considered to be continuous for purposes of this definition.

hillslope geomorphology – The study of hillslope processes (e.g., landslide and surface erosion processes), and how these processes affect the earth's surface.

historical condition – A description of the riparian condition (species composition, stand density, tree size, etc.) occurring within an area over time, beginning with pre-European settlement and extending up to the present.

hummocks – Steep-sided hillocks and hollows, nonlinear and chaotically arranged, and with rounded or irregular cross-profiles. Slopes are between 15 and 35° (26-70%) on surficial materials and between 15 and 90° (more than 26%) on bedrock.

hydraulic geometry – See channel geometry. Hydraulic geometry refers to a systematic analysis of the changes in the width, depth, and velocity of flow with changing streamflow or at different locations in a watershed under similar flow conditions.

hydraulic sorting – The process by which the variation in flow velocity at different locations acting on the bed creates patches of different-sized sediment particles on the streambed.

hydrograph – A graphic representation or plot of changes in streamflow or in the water level elevation plotted against time. A graph showing stage, flow, velocity, or other hydraulic properties of water with respect to time for a particular point on a stream.

Hydrologic Analysis Unit – Area within a watershed that has been delineated as having distinct hydrologic properties.

hydrologic cycle – The circuit of water movement from the atmosphere to the earth and return to the atmosphere through various stages or processes such as precipitation, interception, runoff, infiltration, percolation, storage, evaporation, and transportation.

hydrologic maturity – Condition of the forest stand in which hydrologic processes operate as they do in a mature or old-growth forest. In particular, snow accumulation is typically lower in thick, dense forest (at middle and lower elevations) than in openings, due to interstorm melting of snow caught in the canopy; snow-melt is slower, due to increased wind-aided flux of sensible and latent heat.

hydrology – The scientific study of the distribution and characteristics of water at and close to the earth's surface.

imbrication – See gravel pavement. A pattern of overlapping grain-to-grain contact that tends to make the bed resistant to mobilization by streamflow.

infiltration – The flow of a fluid into a solid substance through pores or small openings; specifically, the movement of water into soil or porous rock.

infiltration rate – Rate of downward movement or flow of water from the surface into the soil; the rate at which infiltration takes place, expressed in depth of water per unit time, usually in inches per hour.

inner gorge slope - Geomorphic feature formed by coalescing scars originating from landsliding and erosional processes caused by active stream erosion that begins immediately adjacent to the stream channel below the first break in slope. For the purposes of the air photo landslide analysis, all slopes >65% leading directly to a stream and located below the last major break-in-slope were considered "inner gorge slopes".

input variables – For watershed analysis, regarded as sediment, wood, water, and thermal energy inputs to streams.

insloping – Shaping the road surface to direct water onto the cutslope (uphill) side of the road. Water is then carried in a ditch parallel to the road.

interception – The process of storing rain or snow on leaves and branches, with eventual evaporation back to the air. Interception equals the precipitation on the vegetation minus stemflow and throughfall.

key piece LWD – Defined in the Properly Functioning Condition Matrix, National Marine Fisheries Service, March 20, 1997 Attachment C. Based on Bilby and Ward 1989 and Fox 1994.

lacustrine deposit – Sediment deposited at the bottom of a lake; typically very fine-grained.

landform – Any physical, recognizable form or feature of the earth's surface, having a characteristic shape, and produced by natural processes.

landing – An area modified by equipment that is designed for accumulating logs before they are transported.

landscape – A particular part of the earth's surface, such as can be seen from a vantage point or examined on an aerial photo, and the various landforms and other physical features that together make up the field of view.

landslide – A general term for the downslope movement of large masses of earth material and the resulting landforms.

landslide headscarp – The relatively steep slope, commonly arcuate in plan, that forms the upper part of a landslide scar.

landslide headwall – See landslide headscarp.

landslide scar – The part of a slope exposed or visibly modified by detachment and downslope movement of a landslide. Usually lies upslope from the displaced landslide material. Commonly a steep, concave slope.

large woody debris (LWD) – Any large piece of woody material whose smallest diameter is >10 cm and whose length is >1 m.

large-scale map – Maps on which earth surface features appear relatively large; e.g., 1:10,000.

late successional – Forest stands that possess characteristics defined in the Properly Functioning Criteria Matrix (NMFS 1997) for riparian forest buffer.

lays – A spot designated for a large tree to fall after being cut during timber harvest. Lays for large trees are often constructed by piling duff, soil, branches, etc., to make the landing of a falling tree softer so that the tree does not split.

lithology – The characteristics of a rock. Commonly used to refer to rock type.

LWD – Large woody debris in and around channels.

macropore – Structural openings in the soil matrix, through which the movement of water is not affected by capillary action.

marginal information – Information such as scale, map legend, notes, magnetic declination, etc. that appears in the margin of a large map.

marginal notes – Text placed in the margin of a map or diagram.

marine materials – Sediments deposited in the ocean by settling from suspension and by submarine gravity flows, and sediments accumulated in the littoral zone due to wave action.

mass movement – A general term for downslope gravitational movement of earth materials by processes such as rockfall and debris slides.

mass wasting – A general term for the dislodgement and downslope transport of soil and rock under the direct application of gravitational stress (i.e., without major action of water, wind, or ice), a process that effects reduction of slopes and lowering of the land surface. See mass movement.

mass wasting – The generalized term for downslope movement of rock, soil, or debris; landslides.

matrix – The groundmass of smaller grains in which larger particles are supported.

meander bend – A curved portion of channel in an alluvial valley. It is implied that the position of the bend changes slowly over time, moving in the direction of the outside (convex) edge of the bend.

meandering channel – See meander bend. A reach of channel characterized by a series of meander bends.

median grain size – The sediment grain diameter in a distribution of sizes for a deposit of interest for which half of the grains are smaller and half of the grains are larger.

micropore – Openings in the soil matrix, through which the movement of water is subject to capillary action.

moderate slope – A planar surface sloping at 16 to 26° (28 to 50%).

moderately steep slope – A planar surface sloping at between 27 and 35° (51 to 70%).

morphology – The three-dimensional shape or geometry of a landform or other feature; shape or form of stream channels

Mylar – A semitransparent medium onto which maps are photographed and/or drafted; can be used to reproduce black- or blue-line copies of maps and diagrams; also used for overlays on aerial photos.

orographic effects – The effects of orography and mountains upon the passing flow of an air mass; precipitation that results from the lifting of moist air over a topographic barrier such as a mountain range. The precipitation may occur some distance upwind and a short distance downwind, as well as on the barrier feature.

orphan roads – Roads that are no longer used, often blocked to traffic, but that have not been decommissioned. These roads usually still have culverts and other drainage structures in place, but are no longer maintained.

outlet – Point where water exits from a stream, river, lake, reservoir, tidewater, or artificial drain. The mouth of a river where it flows into a larger body of water.

outslope – To shape the road surface to direct water away from the cutslope side of the road.

overbank deposit – A sediment deposit outside of the bankfull channel; a flood-plain deposit.

overbank flooding – Flood flows that exceed the capacity of the active channel, overtop the channel banks, and occupy areas of the flood plain.

overland flow – Surface runoff produced as the result of (1) rainfall intensity exceeding the infiltration capacity of the land surface, or (2) the rise of the shallow water table to the land surface.

particle size analysis – Determination of the grain size composition of a sediment by laboratory analysis.

peak flow – The maximum instantaneous discharge of a stream or river at a given location. It usually occurs at or near the time of maximum stage.

pebble – A rock fragment between 2 and 64 mm intermediate diameter (Wentworth scale); a rounded rock fragment between 2 and 64 mm diameter.

pedologist – A scientist who studies the soil.

pedology – The science of the soil.

permeability – The capacity of porous rock, sediment, or soil for transmitting a fluid.

physiography – Pertains to the factors that influence the development of landforms or a landscape, such as relief and topography, bedrock geology and structure, and geomorphological history.

pipeflow – The flow of water in a soil pipe. Soil pipes are interconnected large soil macropores (voids in the soil larger than 2 cm in diameter) that form shallow underground flow pathways.

plain – A level or very gently sloping planar surface with gradient up to 3° (5%)—local relief is less than 1 m; an extensive region of comparatively smooth and level or gently undulating land, having few or no prominent surface irregularities, and usually at a low elevation with reference to surrounding areas.

Pleistocene – An epoch of the Quaternary Period, after the Pliocene and before the Holocene, characterized by repeated glacial and nonglacial intervals; the corresponding worldwide series of rocks.

polygon boundary lines – The lines that delineate polygons on a terrain map or other map. Solid, dashed, and dotted lines are used to represent definite, indefinite, and assumed boundaries, respectively.

precipitation – The process by which atmospheric water becomes surface or subsurface water. The term “precipitation” is also commonly used to designate the quantity of water that is precipitated. Forms of precipitation include drizzle, rainfall, glaze, sleet, snow, graupel, small hail, and hail.

presentation map – The completed map in its final form.

presentation scale – The scale of the presentation map.

pretyping – The process of preliminary terrain mapping on aerial photos prior to fieldwork.

quadratic mean diameter (QMD) – Mean stem diameter of trees within a sample group. The formula for QMD is d_q= SQW 1/N N3*I*=1 di^2 (where d is the diameter of the woody stems and N is the number of stems in the sample). Only stems >5 inches dbh are included in the calculation.

Quaternary deposits (materials) – Sediments deposited during the Quaternary Period. Similar to surficial materials.

Quaternary Period – The most recent geological time period, subdivided into the Pleistocene and Holocene (Recent) Epochs. Currently defined as beginning about 1.6 million years ago.

rain-on-snow (ROS) zone – Area (generally defined as an elevation zone) where it is common for snow packs to be partially or completely melted during rainstorms several times during the winter.

raised delta – A delta now standing above the level of the water body into which is was deposited. Commonly resembles a terrace, with the terrace top marking the former water level.

rapid mass movement – Rapid downslope movement of earth material by falling, rolling, sliding or flowing. Includes rockfall, debris flows, and rapid landslides.

recurrence interval – The average time interval, usually in years, between the occurrence of a flood or other hydrologic event of a given magnitude or larger. The reciprocal, or inverse, of the recurrence interval is the probability (chance) of occurrence, in any year, of a flood equaling or exceeding a specified magnitude. For example, a flood that would be equaled or exceeded on the average of once in 100 years would have a recurrence interval of 100 years and a 0.01 probability, or 1 percent chance of occurring or being exceeded in any year.

regolith – The mantle of loose material that overlies bedrock. Includes weathered rock, soil, and surficial materials.

remote sensing – Data collection methods using interpretation of aerial photography or satellite imagery.

residual pool depth – The depth of a pool in a stream for which the depth of the pool outlet is subtracted; a standardized method of measuring pool depth independent of streamflow.

response potential – Likelihood of significant channel changes in reaction to changes in input variables.

response rating – In the WDNR method, the low, medium, or high sensitivity of a channel geomorphic unit to a changed input variable.

response reach – The segment of a stream where gradient is less than 3%; the segment of a stream that is effected most by sediment supply.

response variables – Characteristics of stream channel bed, banks, form, or flood plain that change in response to input variables.

response zones – Areas surrounding and including response reaches.

rheology – The study of the behavior of materials under stress. In geomorphology, the term refers to the composition and flow characteristics of debris flows and other sediment-laden flows.

ridges – Elongate hillocks with slopes dominantly between 15 and 35° (26 and 70%) on unconsolidated materials and steeper on bedrock. Local relief is greater than 1 m.

riffle – A shallow portion of a streambed where the flow is turbulent as it passes over a typically gravel–cobble deposit; typically located at the outlet of a pool.

rill erosion – Development of many closely spaced channels, caused by the removal of soil by concentrated overland flow; a form of surface erosion, intermediate between sheet erosion and gullying.

riparian – An area of land adjacent to a stream, river, lake or wetland that contains vegetation which, due to the presence of water, is distinctly different from the vegetation of adjacent upland areas.

Riparian Channel Unit (RCU) – The smallest length unit of stream distance distinguished when characterizing riparian condition for watershed analysis (not applicable to Timber Harvest Plans). Riparian species composition, tree density, and size regimes are similar within this length of riparian habitat. The width of the RCU is defined by the stream class and associated RMZ width identified in the Aquatic Conservation Plan.

river terrace – A more or less flat surface bounded downslope by a scarp and resulting from fluvial erosion and deposition. Same as fluvial terraces and alluvial terraces.

road crossing – The location and means by which a road crosses over a stream.

road cutslope – The face of an excavated bank required to lower the natural ground line to the desired road profile.

road drainage system – A system designed to control the flow of water within a road prism.

road prism – The area of the ground containing the road surface, cutslope, and fillslope.

rolling – Elongate hillocks with slopes dominantly between 3 and 15° (5 and 26%) with local relief greater than 1 m.

roughness – See channel roughness.

routing – The derivation of an outflow hydrograph of a stream from known values of upstream inflow, using the wave velocity and/or the storage equation; a technique used to compute the effect of channel storage and translation on the shape and movement of a flood wave through a river reach.

runout area – The portion of a stream channel where a debris flow or debris torrent is deposited; for example, an alluvial fan.

sand – A detrital particle having a diameter in the range of 1/16 to 2 mm.

scarification – A method of seedbed preparation that consists of exposing patches of mineral soil through mechanical action.

scarp – See escarpment.

scour – The excavation of streambed material by elevated streamflow.

scour depth – The depth of excavation of streambed scour.

sediment budget – Accounting of the sources, movement, storage, and disposition of sediment produced by a variety of erosion processes, from its origin to its exit from a basin. The Upper Eel sediment budget identifies sources and provides estimated volumes of sediment delivery for the time period of 1988 – 2003.

sediment loading – The magnitude of sediment abundance or deposition.

sediment production – Occurs when sediment, colluvium, or bedrock is transported from hillslope to stream.

sediment regime – See erosional regime.

sediment supply – The availability of sediment transported from upstream to a point of interest.

sediment yield – The total sediment outflow from a catchment over some unit of time.

seepage zone – An area where soil is saturated due to emerging groundwater.

segment clustering – The process by which stream segments are grouped together into strata that represent significantly different channel morphology and/or response potential.

seismic – Pertaining to earthquakes.

seismic aonation – Broad subdivision of a province or country into regions of similar susceptibility to earthquakes; subdivision of an area according to types of surface materials and their properties with regard to seismic shaking, location of faults, etc. Commonly termed micro-zonation.

shear resistance – The force produced by surface-layer deposits that is exerted on the water flowing over them.

shear stress – The downslope component of force of the fluid weight exerted on the streambed.

sheet erosion – Removal (more or less evenly) of surface material from sloping land, by the action of broad sheets of overland flow; a form of surface erosion.

side-channel – A portion of the stream channel separate from the main flow path of the stream.

silt – A detrital particle having a diameter in the range of 0.004 to 0.0625 mm.

silviculture – The art and science of controlling the establishment, growth, composition, health, and quality of forests and woodlands. Silviculture entails the manipulation of forest and woodland vegetation in stands and on landscapes to meet the diverse needs and values of landowners and society on a sustainable basis.

simple terrain unit/polygon – A terrain polygon consisting of a single type of basic element; a single type of terrain (e.g., “colluvial veneer”).

sinuosity – The ratio of channel length to valley length.

skid trails – A pathway traveled by ground skidding equipment while moving trees or logs to a landing. The tractor or rubber-tired skidder generally drags the cut trees behind it to the landing. A skid trail differs from a skid road in that stumps are cut very low and the ground surface is mainly untouched by the blades of earth-moving machines.

slash – the residual cut vegetation (tree limbs, etc.) left on the ground as a result of forest and other vegetation being altered by forest practices or other land use activities.

slope break – The point on a slope where gradient changes rather abruptly.

slope failure – Rupture and collapse, or flow, of surficial materials, soil, or bedrock due to shear stress exceeding the shear strength of the material.

slope processes – Mass movement processes, such as debris slides, and surface wash whereby fine sediments are transported downslope by overland flow.

slope stability – Pertains to the susceptibility of slope to landslides and the likelihood of slope failure.

slope wash – Fine sediments, on or at the foot of hillsides, that have been moved downslope by overland flow.

slow mass movement – Slow, usually imperceptible, downslope movement of masses of surficial material or bedrock by creeping, flowing, or sliding; slow slope failure.

slumping – The downslope movement of earth materials along a curved failure plane.

small-scale maps – Maps on which earth surface features appear relatively small; e.g., 1:250,000.

snow pack – A field of naturally packed snow that ordinarily melts slowly during the early summer months.

snow-water equivalent (SWE) – Amount of liquid water (expressed as depth) derived by a melting snow pack.

soil – The natural medium for growth of land plants; the result of the combined effects of physical, chemical, and biological processes.

soil creep – The gradual, steady downhill movement of soil and loose rock material on a slope.

soil drainage – Refers to the rapidity and extent of water removal from the soil in relation to additions, especially by surface runoff and by percolation downward through the soil.

soil horizon – A zone in the soil that is generally parallel to the land surface and distinguished from zones above and below by characteristic physical properties, such as color, structure and texture, and soil chemistry.

soil moisture – The water content of the soil in its natural state.

soil pipes – Generally synonymous with macropores.

soil pit – A pit excavated for the purpose of examining the soil. Most commonly dug by hand using shovels, and usually less than 1 m deep.

soil surveys – Mapping the distribution of soil types (requires aerial photo interpretation and fieldwork by pedologists); assessing the engineering properties of surficial materials, such as bearing strength and plasticity, at a site or in an area where construction is proposed; collecting soil or surficial material samples for geochemical analysis for the purposes of mineral exploration.

sorting – A geological term pertaining to the variability of particle sizes in a clastic sediment or sedimentary rock. Materials with a wide range of particle sizes are termed “poorly sorted”; material with a small range of sizes is “well sorted.” (Note that these terms are the reverse of the engineering expressions “well graded” and “poorly graded.”)

source reach – The segment of a stream where gradient is greater than 20%; the segment of a stream where the majority of colluvium is stored.

steep slope – A planar surface steeper than about 35° (70%).

stereopair – Two adjacent photos from a flight line. Can be viewed simultaneously under a stereoscope to obtain a three-dimensional image.

stereoscope – An instrument used for obtaining a three-dimensional view of overlapping pairs of aerial photos.

stereoscopic field of view – The overlapping parts of a stereopair that can be seen in three dimensions under a stereoscope.

stream channel - Streambed and banks formed by fluvial processes. Landslides located in stream channels typically occur in headwaters of steep class 3 streams.

streambed material – Generally the sediment stored in the channel bed.

streamside slope - Hillslopes between 50% and 64% and located below the last major break-in-slope leading to a watercourse.

subsurface flow – Water that infiltrates the soil surface and moves laterally through the upper soil layers until it enters a channel.

surface erosion – Movement of soil particles down or across a slope, as a result of exposure to gravity and a moving medium such as rain or wind. The transport rate of sediment depends on the steepness of the slope, the texture and cohesion of the soil particles, and the activity of rainsplash, sheetwash, gullying, and dry ravel processes.

surface expression – Refers to small topographic features and landforms that are not usually shown adequately on a topographic map, and to the relation of a surficial material to the underlying surface.

surface runoff – That part of the runoff which travels over the soil surface to the nearest stream channel; that part of the runoff of a drainage basin that has not passed beneath the surface since precipitation. Also applies to snow-melt or irrigation water in excess of what can infiltrate the soil surface and be stored in small surface depressions.

surficial deposits (materials) – Relatively young, nonlithified sediments, usually of Quaternary age. Usually classified as to their genesis; hence fluvial sediments, colluvium, glaciolacustrine sediments, etc.

surficial geology – Geology of surficial deposits.

survey intensity (level) – Expresses the relation between map scale and the amount of field-verifying carried out during preparation of a terrain map.

Sustained Yield Plan – refers to the “Final Environmental Impact Statement/Environmental Impact Report and Habitat Conservation Plan/Sustained Yield Plan for the Headwaters Forest Project” January 1999.

swale - An unchanneled hillslope with concave topographic form where subsurface flow is concentrated. Swales are often sites of colluvium accumulation.

tension cracks – Open fissures in bedrock or surficial materials resulting from tensile stress. Typically located at or near the crest of a steep slope, and indicative of potential slope failure.

terrace – Any relatively level or gently inclined surface, generally less broad than a plain, and bounded along one side by a steeper descending slope or scarp and along the other by a steeper ascending slope or scarp.

terraced – Either one or several step-like forms, each consisting of a scarp face and a horizontal or gently inclined tread upslope.

terrain – A comprehensive term to describe a tract of landscape being studied with respect to its natural features; pertains to maps showing surficial materials, material texture, surface expression, present-day geomorphological (geological) processes, and related features.

Terrain Classification System – A classification of surficial materials, their texture, surface expression, present-day geomorphological (geological) processes, and other features, used for mapping.

terrain database – Terrain map information and related additional information stored in digital form. May also apply to information on maps and in notebooks.

terrain features – Landforms and related phenomena, such as striations, gravel pits, and fossil sites, shown on a terrain map by on-site symbols.

terrain legend – The legend of a terrain map. Usually the symbols for surficial materials, their texture, surface expression, present-day geomorphological (geological) processes, and other features are defined individually.

terrain map – A map showing surficial materials, their texture, surface expression, present-day geomorphological (geological) processes, and other features.

terrain polygon – The area enclosed by a boundary line on a terrain map; the basic mapping unit.

terrain stability – See slope stability.

terrain unit – See terrain polygon.

texture of sediments – Pertains to the grain sizes, shape, and arrangement of particles in a sedimentary unit.

transport capacity – In fluvial geomorphology, this refers to potential sediment transport by fluvial processes in a given stream reach, segment, or cross section.

transport reach – The segment of a stream where gradient is between 3% and 20%; the segment of a stream that rapidly transports sediment downstream.

traverse – A survey line. Applied to various kinds of surveys, including topographic, geological, soil, and biological surveys.

tree throw – Trees uprooted and toppled by the wind.

turbidity – A condition in which suspended matter causes water to become cloudy or opaque.

undulating – Gently sloping hillocks and hollows with multidirectional slopes generally up to 15° (26%). Local relief is greater than 1 m.

Unified Soil Classification System – Soil classification used by engineers. Based on particle size of coarse materials and consistency of fines (silt/clay mixtures).

UTM – Universal Transverse Mercator grid. Present on most topographic maps and used for quantitative description of locations.

valley slope – The gradient of slope along the axis of a valley floor as distinguished from the channel slope, which is generally less than the valley slope.

veneer – A thin mantle of surficial material that does not mask the topographic irregularities of the surface upon which it rests. Ranges in thickness from 10 cm to about 1 m.

wash load – The part of the total stream load that is carried for a considerable time in suspension, free from contact with the stream bed. It consists mainly of clay and silt.

water table – The upper surface of the zone of groundwater saturation in permeable rocks or surficial materials.

water yield – Runoff, including groundwater outflow that appears in the stream, plus groundwater outflow that leaves the basin underground. Water yield is the precipitation minus the evapotranspiration.

waterbar – A shallow ditch excavated across a road at an angle to prevent excess surface-water flow down the road surface and subsequent erosion of road surface materials; a small excavation across a road to collect and divert roadway surface-water flow.

watershed – All lands enclosed by a continuous hydrologic drainage divide and lying upslope from a specified point on a stream. Also referred to as the drainage basin.

weathered bedrock – Bedrock that has decomposed or disintegrated in situ due to mechanical and/or chemical weathering.

Wentworth particle size scale – A logarithmic scale for size classification of sediment particles. Defines terms such as silt, pebbles, and boulders.

wood loading – The magnitude of LWD abundance or deposition.

yarding – in logging, the hauling of felled timber to the landing or temporary storage site from where trucks (usually) transport it to the mill site. Yarding methods include cable yarding, ground skidding, and aerial methods such as helicopter and balloon yarding.

yarding systems – Methods for moving timber from the sites where the trees are felled to sites where they are loaded onto logging trucks. Includes high lead, skyline, ground skidding, and so on.

BIBLIOGRAPHY

Bilby, R.E., and J.W. Ward. 1989. Changes in characteristics and function of woody debris with increasing size of streams in western Washington. Transactions of the American Fisheries Society 118:368-378.

Davis, L.S., and K.N. Johnson. 1987. Forest management. McGraw-Hill. New York.

Howes, D.E., and E. Kenk (contributing editors). 1997. Terrain classification system for British Columbia (Version 2). BC Ministry of Environment, Recreational Fisheries Branch, and BC Ministry of Crown Lands, Surveys and Resource Mapping Branch, Victoria, BC.

Plum Creek Timber. 1999. Plum Creek native fish habitat conservation Plan. Technical Report No. 7, Plum Creek Timber, Seattle, Washington.

Resources Inventory Committee. 1995. Guidelines and standards for terrain mapping in British Columbia. Government of British Columbia. Victoria, BC. (Source for mass wasting terms.

These are terms commonly used by Quaternary geomorphologists and geologists, and terms used in the BC Terrain Classification System [Howes and Kenk 1997]).

WDNR (Washington Department of Natural Resources). 1997. Standard methodology for conducting watershed analysis, version 4.0. WDNR, Division of Forest Practices, Washington Forest Practice Board, Olympia.