Bear River Watershed Analysis

Cumulative Watershed Effects

Public Review Draft

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Humboldt Redwood
COMPANY, LLC

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LIST OF ACRONYMS

ATM	Aquatic Trends Monitoring
CDEC	California Data Exchange Center
CDF	California Department of Forestry and Fire Protection
CDFG	California Department of Fish and Game
CEQA	California Environmental Quality Act
CFPR	California Forest Practice Rules
cfs	Cubic Feet per Second
CMZ	Channel Migration Zone
CSZ	Cascadia Subduction Zone
CWE	Cumulative Watershed Effects
cy	Cubic Yards
DBH	Diameter at Breast Height
HCP	Habitat Conservation Plan
HMD	Hardwood stand, small trees, moderate/dense canopy (RCU type)
HRC	Humboldt Redwood Company LLC
LSF	Little Salmon Fault
LWD	Large Woody Debris
MMD	Mixed conifer–hardwood stand, small trees, moderate/dense canopy (RCU type)
MTJ	Mendocino Triple Junction
NC	Northern California
NCRWQCB	North Coast Regional Water Quality Control Board
NMFS	National Marine Fisheries Service
NRCS	Natural Resource Conservation Service
PALCO	The Pacific Lumber Company
PFC	Properly Functioning Condition
RCU	Riparian Condition Unit
RM	River Mile
$tons/mi^2/yr$	Tons per square mile per year
WAU	Watershed Analysis Unit
WLPZ	Watercourse and Lake Protection Zones
WWII	World War II

1.0 ABSTRACT

Watershed analysis was conducted for the Bear River watershed per requirement of the Pacific Lumber Company (PALCO) Habitat Conservation Plan (HCP) (PALCO, 1999). The purpose of the HCP Watershed Analysis program is to characterize and monitor watershed conditions and trends, assess effects of historic and contemporary forest management, and identify management objectives and guidelines necessary to maintain or achieve, over time, properly functioning aquatic habitat for federal and state protected salmonids, amphibians, and reptiles. In the Bear River WAU, these HCP-covered species include the Northern California (NC) steelhead (*Oncorhynchus mykiss)*, Chinook salmon (*Oncorhynchus tshawytscha)*, coho salmon (*Oncorhynchus kisutch*), Northern red-legged frog (*Rana aurora aurora)*, Foothill yellow-legged frog (*Rana boylii)*, tailed frog (*Ascaphus truei)*, southern torrent salamander (*Rhyacotriton variegatus)*, and the Northwestern pond turtle (*Emys marmorata marmorata)*. The 84-square-mile Bear River watershed analysis unit (WAU) is located in Humboldt County, California, 20 miles south of the city of Eureka.

Bear River flows approximately 25 miles from its headwaters at an elevation of 3,600 feet to its mouth at the Pacific Ocean. Watershed geology includes Yager and Franciscan formations, with bedrock characterized by massive to highly sheared sandstone and shale, and areas of pervasively sheared mélange. The region is seismically and tectonically active, with more than 25 earthquakes of magnitude 6 or larger being recorded in historical times and rapid uplift rates estimated at nearly 3 meters per every 1,000 years at the Bear River mouth. Topography is generally characterized by steep valley walls and a narrow valley bottom. A coastal maritime climate, marked by high levels of humidity throughout the year, produces 77 inches of precipitation annually, most of which falls from October through April. Light to moderate snowfall occurs infrequently at higher elevations in the watershed. Vegetation consists of coniferous (primarily Douglas-fir, *Pseudotsuga menziesii*) and hardwood (primarily tanoak, *Lithocarpus densiflorus*) forest types along with open grasslands.

Approximately 26 square miles (16,537 acres) in the upper watershed are owned and managed by the Humboldt Redwood Company LLC (HRC) for timber production under the HCP; these lands were previously owned by PALCO until the Summer of 2008. This portion of the Bear River system is 'geared' towards sediment transport and generally not capable of storing excessive quantities of sediment for long periods due to moderate to steep channel gradients and the configuration of the valley bottom. Abundant steelhead and resident rainbow trout populations can be found on the ownership in the Bear

River mainstem and in lower reaches of larger tributaries. Among the fish-bearing tributaries, Harmonica Creek and Nelson Creek generally provide the most significant reaches of spawning and rearing habitat.

The upper watershed experienced a period of significant sediment delivery resulting from ground disturbance associated withextensive timber harvest (1948 – 1965) and two very large storm events (1955 and 1964) which combined to deliver 11 million cubic yards of harvested hillslope and road-related rock, soil, and organic material, primarily from steep streamside landslides, during this time period. Currently, forty years later, most stream channels have recovered from the aggraded situation caused by this spike in sediment delivery and are currently at or near bedrock, with evidence of active stream incision through alluvial deposits and gravel bars. However, lack of abundant in-stream large woody debris (LWD) and reduced riparian forest LWD recruitment due to historic logging may be limiting pool development in several tributaries including lower Harmonica Creek. Moderate to high levels of fines relative to spawning gravels were also observed locally in several tributaries, a condition potentially linked to contemporary road surface erosion. Modeled and inventory-based estimates of 1988-2003 surface erosion (i.e., rills, gullies, and sheet erosion) suggest roads are the primary management-associated source of this type of sediment delivery (141 tons/mi^2/yr) as compared to non-- road-related logging activities (i.e., log yarding and post harvest site preparation) (3 tons/mi^2/yr).

Stream temperatures in the mainstem Bear River typically remain below 18.9° C year-round and are suitable for steelhead and resident trout production. These cool temperatures are attributed to cool water influx from well-shaded tributary headwater streams, topographic shading, and overall close proximity to emergent groundwater. Large, older (late-seral) riparian forest types are rare as result of extensive mid-twentieth century logging operations, although moderate to densely canopied mid-seral (16- to 24-inch diameter at breast height [DBH]) riparian forest types are common. While riparian forest conditions currently provide only marginal in-stream functional large wood recruitment value, projected growth rates suggest this value will improve significantly over the next 40 years as average tree size increases to greater than 30 inches DBH. Surveys conducted in 2005 for anthropogenic fish barriers found only one - a culverted stream crossing on an unnamed tributary in the Happy Valley sub-basin. The culvert was replaced with a bridge in 2007 and the crossing now allows for fish passage.

Limiting forestry-related sediment delivery through continued road improvements and decommissioning, and harvest limitations on identified steep or unstable streamside slopes, along with maintaining and promoting larger tree size in riparian forests for the benefit of in-stream large woody debris recruitment were among management objectives identified by the watershed analysis.

2.0 INTRODUCTION

The goal of PALCO's Habitat Conservation Plan (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 the landowner's forest management activities. The purpose of the HCP watershed analysis process is to identify management objectives for protecting, restoring, and enhancing the aquatic habitat of specified salmonids, amphibians, and reptiles. These species include Northern California (NC) steelhead (*Oncorhynchus mykiss)*, Chinook salmon (*Oncorhynchus tshawytscha)*, coho salmon (*Oncorhynchus kisutch*), Northern red-legged frog (*Rana aurora aurora)*, Foothill yellow-legged frog (*Rana boylii)*, tailed frog (*Ascaphus truei)*, southern torrent salamander (*Rhyacotriton variegatus)*, and the Northwestern pond turtle (*Emys marmorata marmorata).*

Parameters for evaluating habitat conditions are identified by the National Marine Fisheries Service (NMFS) Properly Functioning Condition (PFC) matrix (hereafter PFC targets) and include targeted objectives for streambed (spawning gravel) and channel (rearing habitat) conditions, in-stream large woody debris (LWD) levels, water temperature, and streamside riparian forest conditions associated shade canopy and LWD recruitment potential. This report compares current habitat parameters in the Bear River Watershed Analysis Unit (WAU) with PFC targets for streams that are considered suitable salmonid habitat.

The habitat objectives in the PFC matrix are generally "one-size-fits-all" thresholds. In regard to in-stream channel conditions, the habitat objectives were derived from and created for streams with less than 3 percent gradient and channel widths ranging from 10 to 19 meters. While the upper Bear River and its larger tributaries include stream channel conditions consistent with those associated with the PFC matrix parameters, many of the smaller tributaries have steeper channel gradients and narrower channel widths. Because stream characteristics such as depth, pool spacing, LWD functional size, and shade potential are directly proportional to channel width (Bilby and Ward, 1989; Montgomery et al., 1995; Welty et al., 2002), it is important to keep in mind the differences in stream size when reviewing comparisons with PFC targets. Natural factors in this region may also influence the applicability of PFC criteria developed elsewhere in the Pacific Northwest. For example, local lithology will influence the sediment characteristics of the streambed due to the erodibility of the bedrock, and native forest vegetation will influence LWD volume and loading rates. Despite these limitations, PFC targets are useful 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). The stream gradient map produced from LIDAR digital elevation data, instream habitat and LWD inventory, electrofishing surveys (to determine upper extent of fish use), Aquatic Trends Monitoring (ATM) stations (that provide detailed streambed, habitat and temperature information over a period of recent years), and California Department of Fish and Game (CDFG) stream surveys provide an understanding of summer and winter instream habitat conditions in many of the streams on HCP-covered lands. The methods and intensity with which certain habitat conditions were measured are described in the Fish Habitat Assessment (Appendix E).

This Cumulative Watershed Effects (CWE) report presents information regarding current overall watershed-wide conditions as well as conditions found in individual sub-basins and compares these findings with PFC target conditions. Future trends are predicted based on current conditions and knowledge of biotic and abiotic processes, assuming forest management measures continue to be implemented for the protection of key resources. Recommendations for the protection, restoration, and enhancement of aquatic habitat based on the environmental needs of the eight target fish and wildlife species are derived from this discussion of current conditions and trends. Recommendations are then implemented through forest management measures relative to timber harvest operations, road upgrading prioritization, and in-stream habitat improvement.

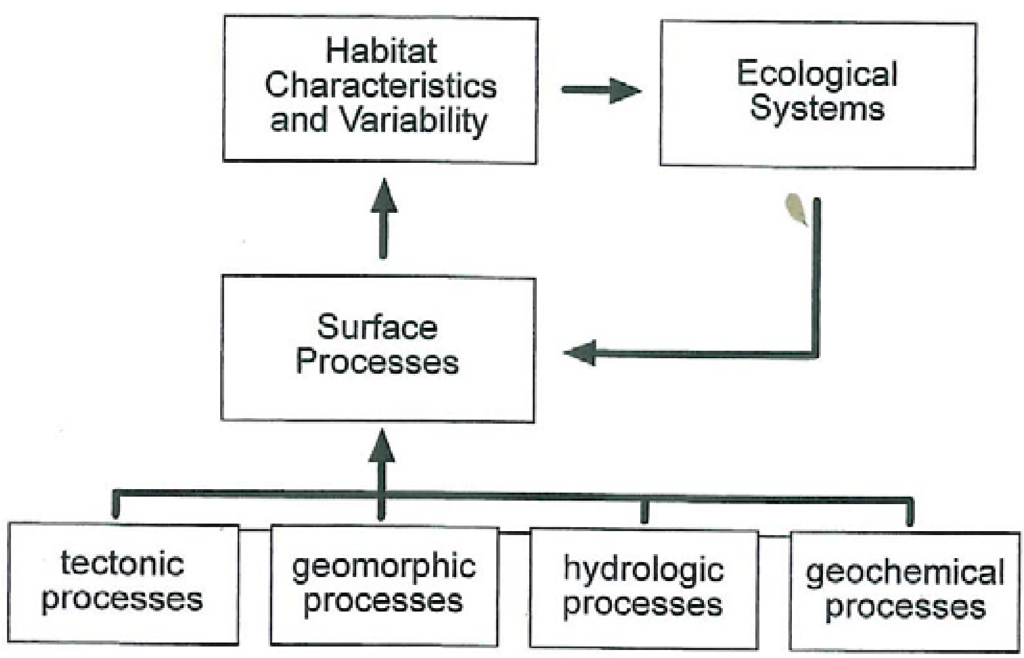
2.1 OVERVIEW OF WATERSHED ANALYSIS PROCESS

Watershed analysis is a systematic process for assessing the condition of water, wood, and sediment in a watershed relative to aquatic habitat, and how land management affects this condition. It 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 and reptile habitat conditions.

Watershed analysis involves evaluation of individual and cumulative management-related impacts to natural processes, which in turn affect aquatic habitat conditions. Natural "background" conditions of the watershed are important to the analysis given the unique geology, naturally occurring plant communities, water regimes, and other watershed variables, as these background conditions may affect any cause-and-effect relationship linked to forest management. Watershed analysis is conducted primarily to inform the application of watershed-specific forest management practices that achieve and/or maintain, over time, properly functioning aquatic habitat conditions for salmonids, reptiles, and amphibians.

The mechanisms determining the effect of forest practices on inputs of wood, sediment, water, or thermal energy are relatively well understood. Hypotheses regarding potential effects of forest management on streams include increased hillslope erosion and channel sedimentation, increases in peak stream flow during periods of storm runoff, reduced wood inputs to streams, and increases in the temperature of water caused by harvesting trees that shade the channel (Figure 2-1).

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).



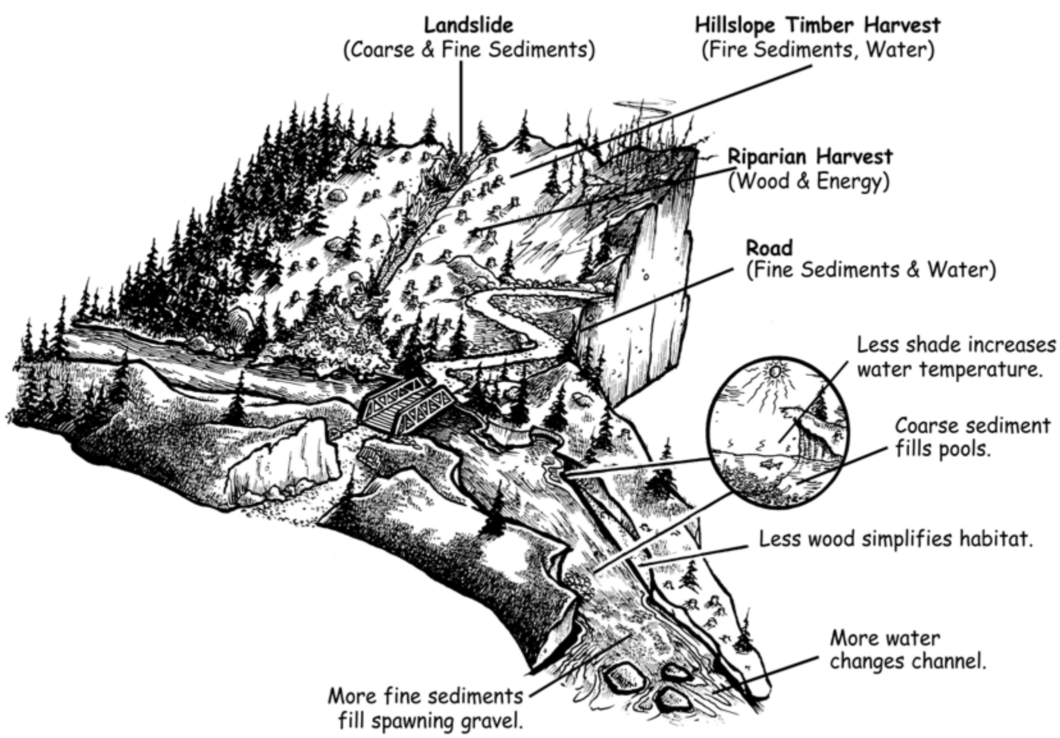
The guiding philosophy behind watershed analysis is that, although a landscape and its ecosystems are complex and probably impossible to understand or characterize completely, there is enough pattern to the linkages within and between physical and ecological systems that reasonable models of how they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

Table 2-1. Analysis and Data Collection for the Bear River 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 lower Harmonica Creek and upper mainstem Bear River	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 39,937 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
Fish surveys to determine upstream extent of fish distribution	Appendix E
Analysis of water temperature in streams	Appendix E
Species occurrence surveys, along with reviews of previously collected data for amphibians and reptiles	Appendix F

The key “currencies” of watersheds that are traded between a channel and its watershed are sediment, LWD, water, heat energy, and nutrients. 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). 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 despite 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.

Figure 2-2. Relationship between Hillslope Activities and Stream Effects through Changes in the Five Key Input Factors of Coarse Sediment, Fine Sediment, Wood, Water or Energy.



Changes in erosion processes or riparian functions may be relatively easy to observe and document in many cases. However, changes in runoff are more difficult to demonstrate but can be estimated by applying hydrologic principles. Changes in stream channel and aquatic habitat conditions may be easy to document in circumstances where the sources or causes (e.g., landslides or riparian forest harvest) are nearby and recent. However, stream channel or aquatic habitat conditions often must be assessed with respect to a range of watershed disturbances that occurred at distant points in the watershed over a period of decades. This is particularly true with respect to the sources of sediment that comprise the primary substrate upon which aquatic ecosystems are formed. Determinations regarding the strength of the linkage between observed or hypothesized changes in watershed processes (sources or "causes"), and observed or hypothesized effects on aquatic habitat are at the heart of both watershed analysis and assessment of cumulative watershed effects from the perspectives of management associations, legacy effects, and natural factors.

In summary, for watershed analysis to be able to make a determination of impact potential or risk, a link must be made between an aquatic resource and a management-related mechanism that can affect it. The watershed analysis procedure provides for this by: (1) defining resource vulnerability in terms of susceptibility to change in flows of wood, water, energy, and sediment; (2) evaluating how forest management affects these inputs, and (3) determining to what extent and in what locations these effects adversely impact aquatic habitat throughout the watershed.

While individual models exist for assessing individual watershed processes (e.g., sediment budgets), no "off-the shelf" or "one size fits all" method is available that comprehensively links the full range of hillslope processes to resource impacts at a watershed scale. This reflects the inherent complexity of the many processes at work in the forest landscape as well as the limitations of the tools associated with each scientific discipline involved. Because of these limitations, individual methods and models must often be linked in a less quantitative fashion, and the judgment and experience of resource professionals must be relied upon given their understanding of the watershed. Consequently, each watershed analysis typically utilizes unique elements and approaches to assess cumulative effects. In the end, the structural framework developed throughout the analysis provides for a rational, well-documented (transparent), science-based assessment of the linkage between land use and watershed conditions.

Photo 2-1. Geologist Gary Simpson Conducting Mass Wasting Field Assessment.

2.2 PURPOSE AND ORGANIZATION OF REPORT

This CWE Report presents a summary of the watershed setting and land use history in the Bear River WAU, followed by a cumulative watershed effects assessment. The watershed setting is summarized for the entire WAU, including non-HCP lands, as required for a Level 1 analysis on all lands within the WAU (PALCO, 2000). More detailed analysis conducted on HCP lands is also presented in this report, as required for a Level 2 analysis. The CWE assessment evaluates the effects of past, current, and future management practices on aquatic resources; provides pertinent information and justification supporting the delineation of areas and trends of particular ecological interest; and identifies specific management actions affecting aquatic resources. Conditions and trends are organized into the following four components: sediment, wood, shade and temperature, and fish habitat. Detailed methods, results, and information used in this assessment are provided primarily in the individual module reports (Appendices A-F).

The Bear River CWE Assessment fits within the adaptive management framework established under the HCP Incidental Take Permit and is designed to provide a level of site-specific information necessary for conducting informed forestry operations. The assessment also lays the foundation for future monitoring and assessment activities necessary to ensure that HCP Aquatic Conservation Plan goal of maintaining or achieving properly functioning aquatic habitat conditions are being met over the life of the HCP. The CWE assessment is the starting point in the adaptive management cycle; this assessment will be updated and improved as formal periodic re-visitation occurs.

2.3 ISSUES IDENTIFICATION

As required in the HCP, a public meeting was held on May 26, 2005 for the purpose of identifying issues and receiving public input for the Bear River WAU as the first step in conducting watershed analysis. This meeting was held at the Mattole Grange near Petrolia and provided a forum for input from the community for both the Mattole River and Bear River watershed analysis areas. While most of the focus in the well-attended meeting was on the Mattole River area, the North Coast Regional Water Quality Control Board (NCRWQCB) representative noted that Bear River is not on the 303(d) list for water quality impairment, but anyone with data supporting such a designation is asked to provide it to the NCRWQCB. Another individual mentioned he thought the Bear River watershed was as bad as, if not in worse condition than, the Mattole, but provided no specific details in support of the remark. A letter received from a lower Bear River landowner unable to attend the meeting noted that he had observed salmon carcasses along river banks in the spring and early summer in years past, but had seen none in the last 15 years - decline he attributed to ocean fishing.

2.4 DEFINITIONS

To aid review of this CWE assessment and accompanying module reports, definitions of key terminology used for watershed analysis are provided in Attachment 4, which is the glossary originally provided in the Watershed Analysis Methods for PALCO Lands (PALCO, 2000), with additional terms defined based on the current watershed analysis.

Development of a technical definition of cumulative watershed effects is an ongoing effort (U.C. Committee on Cumulative Watershed Effects, 2001). A standard definition of cumulative watershed effects, as defined in the Board of Forestry Practice Rules in reference to California Environmental

Quality Act (CEQA) guidelines (Section 14, CCR 15355), is often cited as a starting point. Paraphrased, this definition indicates that cumulative effects are defined as two or more individual effects, which when considered together, make a significant (usually adverse) change to some biological population, water quality, or other valued resource, or which compound or increase other environmental effects (Photos 2-2 and 2-3).

Photo 2-2. Nelson Creek Pool.

Photo 2-3. Nelson Creek.

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, fish use and habitat distribution, topography, stream class, geology and seismic regime, soils, climate and hydrology, forest ecology, and amphibian and reptile habitat. Attachment 1 provides specific watershed tabular information 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 84-square-mile Bear River WAU covers the entire Bear River basin (Figure 3-1), and is located generally 20 to 25 miles south of Eureka in Humboldt County, California. Bear River flows westerly approximately 25 miles from its headwaters near Happy Valley, at an elevation of 3,600 feet, to the Pacific Ocean which it enters near the historic town of Capetown. Bear River is believed to be a 4^{th} or 5^{th} order stream with Class I, II, III, and IV watercourses present. Significant tributaries within the HCP lands include Harmonica Creek, Pullen Creek, Nelson Creek, Brushy Creek, Gorge Creek, and Beer Bottle Creek. Numerous, smaller unnamed tributaries are also present. Stream flow is unimpeded by dams and there are no stream gaging stations on Bear River. However, small water diversions (less than one cubic foot per second) exist for domestic use. These water diversions are for livestock watering, irrigation, and dust control of unpaved roads.

Approximately 26 square miles (16,537 acres) of the Bear River WAU area are managed by Humboldt Redwood Company LLC (HRC) under the HCP (PALCO, 1999). These lands are located in the upper one-third of the basin, beginning at River Mile (RM) 18.3, and extending to the top of the divide. The bulk of the remaining acreage is in non-HRC private ownership (36,839 acres) or under ownership and management by the California Department of Parks and Recreation (161 acres).

A summary of watershed parameters for the Bear River WAU is provided in Table 3-1. The Bear River WAU is divided into six CalWater Planning Units (Planning Watersheds) – Beer Bottle Creek, Happy Valley, Johnson Gulch, Peaked Creek, South Fork Bear River, and West Side Creek (Figure 3-1). These Planning Watersheds are further sub-divided into a total of 15 sub-basins (generally smaller in area) to reflect variation in geologic types and to yield higher resolution for the larger Planning Watersheds located within HRC, formerly PALCO, ownership (Table 3-2). Attachment 1 provides data for the HCP-managed lands in the Bear River WAU.

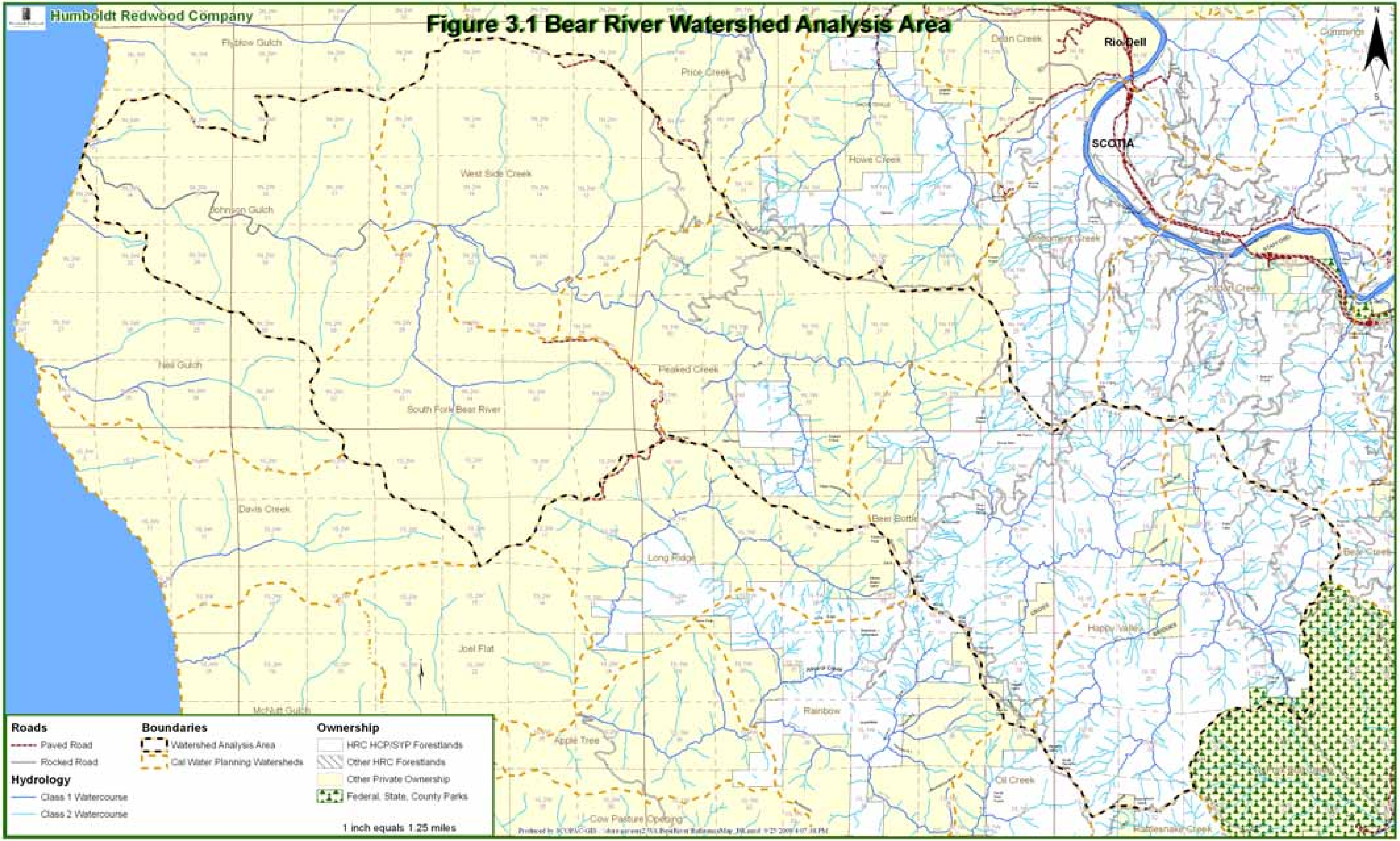
Table 3-1. Watershed Areas for the Bear River WAU.

Parameter	Bear River WAU
Total basin area (mi^2)	84
Total HRC ownership (mi^2)	25.8
Total HCP Area (mi^2)	25.8

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

Sub-basin	HRC Ownership		Non-HRC Ownership[1] (Acres)	Total (Acres)
	HCP Lands (Acres)	Non-HCP Lands (Acres)		
Beer Bottle Creek Complex	1,291	-	950	2,241
Brushy Creek	1,653	-	172	1,825
Chase Ranch Complex	1,569	-	225	1,793
Gorge Creek Complex	1,881	-	310	2,191
Happy Valley	1,235	-	87	1,322
Harmonica Creek	2,563	-	34	2,597
Johnson Gulch	-	-	7,915	7,915
Main Stem Bear River	1,338	-	428	1,766
Middle Bear Complex	25	-	6,118	6,143
Nelson Creek	1,894	-	167	2,062
Peaked Creek Complex	858	-	2,829	3,686
Pullen Creek	1,486	-	225	1,711
South Fork Bear River	-	-	8,272	8,272
Upper Bear River	744	-	66	810
West Side Creek	-	-	9,202	9,202
GRAND TOTAL	16,537	-	37,000	53,537

[1] Non-HRC Ownership includes areas labeled “inholding” and “(blank)” in the PALCO database queried during watershed analysis in 2005 and 2006.



Humboldt Redwood Company
Figure 3.1 Bear River Watershed Analysis Area
N
S
Rio Dell
SCOTIA
Cummings
Dean Creek
Fiddlow Gulch
Price Creek
Howe Creek
West Side Creek
Johnson Gulch
Monument Creek
Jordan Creek
Neil Gulch
Peaked Creek
South Fork Bear River
Davis Creek
Bear Bottle
Long Ridge
Bear Creek
Happy Valley
Joel Flat
McNutt Gulch
Rainbow
Apple Tree
Oil Creek
Cow Pasture Opening
Rattlesnake Creek
Roads
Paved Road
Rocked Road
Hydrology
Class 1 Watercourse
Class 2 Watercourse
Boundaries
Watershed Analysis Area
Cal Water Planning Watersheds
Ownership
HRC HCP/SYP Forestlands
Other HRC Forestlands
Other Private Ownership
Federal, State, County Parks
1 inch equals 1.25 miles

3.2 GEOLOGY AND SEISMIC REGIME

The coastal ranges of northern California reflect the history of sediment deposition and uplift related to convergent tectonics and the northward migration of the Mendocino Triple Junction (MTJ). The Bear River WAU is experiencing rapid uplift as the MTJ migrates northward (Clarke, 1992) (Map A-1). At the mouth of the Bear River, the uplift rate is estimated at nearly 3 meters per every 1,000 years. Late Mesozoic convergence resulted in a broad complex of highly deformed marine sediments along the western margin of the North American plate. These rocks now comprise the Franciscan Complex, which constitutes the basement of the North Coast region (Clarke, 1992). The Franciscan Complex has been divided into three (3) broad tectonic belts, the Eastern, Central and Coastal belts, based on composition, structure, and geographic location (Irwin, 1960). More recently, each of these belts have been subdivided into a number of fault-bounded tectonostratigraphic terranes (Blake et al., 1982), each having a distinct stratigraphy.

The geology of the Bear River WAU includes Yager and Franciscan formations. Approximately 84 percent of the HCP area is underlain by Coastal terrane bedrock (Table 3-3). Yager terrane underlies 12 percent of the HCP area, mainly in the Nelson Creek and Harmonica Creek sub-basins. Within the HCP area, the primary Franciscan Complex units consist of the Coastal and Yager terrane of the Coastal Belt, which comprises the largest aerial extent within the HCP area. Overlying these basement rocks are Quaternary age alluvial and colluvial deposits in a forearc region that was subsequently dismembered by uplifting and faulting (Nilsen and Clarke, 1987). The Late Cenozoic sediments are preserved in structural basins throughout coastal northern California and eroded from the uplifted areas between the basins (Nilsen and Clarke, 1987). Regionally, the bedrock is characterized by massive to highly sheared sandstone and shale, and areas of pervasively sheared mélange (McLaughlin et al., 2000; Spittler, 1984). A series of east-west trending high-angle shear zones (Russ shear zone, North Bear River shear zone, South Bear River shear zone), developed during the accretionary process, extend inland as bands of weak slide-prone bedrock.

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

Lithologic Unit	Area (acres)	Area (mi^2)	Percent of Area
Alluvium (Q)	136	0.2	<1%
Older terrace deposits (Qort)	12	<0.1	<1%
Terrace deposits (Qrt)	155	0.2	<1%
Franciscan Coastal Terrane (TKfs)	13,839	22	84%
Franciscan Coastal Belt-green stone (TKfs-gs)	0.5	<0.1	<1%
Franciscan Coastal Belt-sheared (TKfs-sz)	330	0.5	2%
Franciscan Coastal Belt-undifferentiated (TKfs-u)	2.7	<0.1	<1%
Yager Formation (Tky)	2,062	3.2	12%
Total for HCP Area	**16,537**	**26**	**100%**

The HCP area is situated in a seismically active region susceptible to frequent moderate to strong ground shaking. In the historical record, more than 25 earthquakes of magnitude 6 or greater have originated in or offshore from Humboldt County (Dengler et al., 1992) and faults in the vicinity of the Bear River WAU have potential to generate large to great earthquakes (Clarke and Carver, 1992). 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 Bear River WAU.

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, faults within the Mad River Fault Zone, and the Little Salmon Fault (Dengler et al., 1992). Seismic activity provides an important disturbance mechanism that can cause increased landslides, surface erosion, and other effects in the watershed. Most historical seismicity affecting the HCP area has originated from the Gorda Plate, which generates large (approximate M 7) events approximately every 12 years (McPherson, 1992; Dengler et al., 1992). The Mendocino Fault and the Mendocino Triple Junction have generated historical earthquakes ranging from M 5.6 to 6.9 (Dengler et al., 1992). The largest historical earthquake to affect the Bear River WAU was the M 8.3 San Andreas earthquake of 1906 (Toppozada and Parke, 1982).

The sources with the potential for generating the strongest ground motions in the study area are the Cascadia Subduction Zone (CSZ) and the Little Salmon Fault (LSF). The southernmost portion of the CSZ generated a M 7.1 event on April 25, 1992 (Dengler et al., 1992). Radiocarbon dates on earthquake-related deposits and Japanese tsunami records indicate a great earthquake originating from the CSZ on January 26, 1700 (Clague et al., 2000). The CSZ is estimated to have potential to generate earthquakes of M 8.4+ (Clarke and Carver, 1992).

Recurrence intervals for great (M 8+) earthquakes are estimated at 200 to 400 years for the San Andreas Fault (Prentice, 1989) and 300 to 600 years for the LSF/CSZ (Clarke and Carver, 1992). 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 (Clarke and Carver, 1992).

3.3 SOILS

Soil texture is largely controlled by underlying geology and topography. The Bear River WAU is dominated by rocks of the Franciscan and Yager formation. Within the HCP area, the primary Franciscan Complex units consist of the Coastal and Yager terrane of the Coastal Belt, which comprises the largest aerial extent within the HCP area. Yager terrane is found in the Nelson Creek and Harmonica Creek sub-basins. Soils in the Bear River WAU were mapped by the Soil Conservation Service (now called the Natural Resource Conservation Service, NRCS) and the University of California (McLaughlin and Harradine, 1965). The NRCS is currently updating soil maps for Humboldt County. Map B-1 shows the most recent (1970s) map of soils in the Bear River WAU; note the coverage does not extend to the full area of the WAU. Table 3-4 summarizes properties of soils in the HCP area according to soil depth, texture, drainage, permeability, and erosion hazard based on the NRCS database.

The HCP area is represented by three different soils series – Hugo, Kneeland, and Wilder. The Hugo series is the most common, occurring in two-thirds of the WAU area and within 85 percent of HCP lands. Hugo soil textures range from gravelly loam to stony clay loam, Wilder soils have a sandy loam/ gravelly sandy loam texture. Kneeland soils occur more commonly in grassland areas and are not as deep and have less gravels than the Hugo and Wilder soils.

3.4 TOPOGRAPHY

Bear River is predominantly a deeply incised, low gradient channel (Photo 3-1), characterized by steep, high valley walls, a relatively narrow valley bottom, and bedrock exposed at or near the channel bed. Wide, flat valleys exist in some areas where tributaries join the mainstem. Gentle slopes are present on grassed, south-facing areas and lands near the mouth of Bear River. On HRC lands, located in the upper, eastern portion of the drainage, most of the gently sloping ground is found in the Happy Valley sub-basin and along the mainstem Bear River in the Upper Bear River sub-basin. Within the HCP area, 25 percent of the slopes are less than 35 percent gradient (Table 3-5), based on the LIDAR-based slope analysis depicted on the slope gradient class map shown on Figure 3-2. Slopes steeper than 65 percent account for 28 percent of the HCP area. Approximately half of the land area in the HRC-owned portion of the Bear River WAU has slopes steeper than 50 percent gradient. The Gorge Creek Complex, Harmonica Creek, and Brushy Creek sub-basins collectively contain more than 40 percent of the HCP land area with slopes steeper than 65 percent gradient.

Table 3-4. Properties of Soils in HCP Area of the Bear River WAU.

Soil Series Name	Total HRC Acres	Percent of HRC Lands	Depth Range (inches)	Parent Material	Texture of Surface/ Subsurface	Drainage	Permeability
Hugo	13,995	85 %	30-60	Sandstone and shale	Gravelly loam/stony clay loam	Well[1]	Moderately rapid[1]
Wilder	1,426	9 %	26-50	Sandstone	Sandy loam/gravelly sandy loam	NA	NA
Kneeland	299	2 %	18-40	Sandstone and shale	Clay loam/ clay loam	NA	NA
Cahto	37	<1 %	6-25	Sandstone, hard	Loam/loam with rock fragments	NA	NA
Melbourne	38	<1 %	30-60	Sandstone and shale	Loam/clay loam	Well[1]	Moderate[1]
Orick	17	<1 %	40-70	Schistose sedimentary rocks	Loam/clay loam	NA	NA
McMahon	67	<1 %	30-60	Sandstone	Clay loam/ clay	Moderately well or somewhat poor (inferred)[1]	Slow (inferred)[1]
Laughlin	63	<1 %	16-36	Sandstone and shale	Loam/loam	Well[1]	Moderate[1]
Tatu	102	<1 %	30-60	Sandstone	Loam/loam	NA	NA
Maymen	13	<1 %	4-16	Sandstone and shale	Gravelly loam/gravelly loam	Somewhat excessively drained[1]	Moderate to moderately rapid[1]
Sheet Iron	12	<1 %	20-40	Schistose rock	Gravelly loam/gravelly loam	NA	NA
Bottom Land[2]	44	<1 %	64-70+	Sedimentary alluvium	Loam/Silt Loam	Moderately well to imperfectly[1]	Moderately rapid to slow[1]
Terraces[2]	389	2 %	64-70+	Sedimentary alluvium	Loam/Silt Loam	Moderately well to imperfectly[1]	Moderately rapid to slow[1]
Other[3]	35	<1 %	NA	NA	NA	NA	NA

1. 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/classification/osd/index.html".
2. Mapping units 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.
3. 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.

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

Sub-basin	0-35% (Acres)	35-50% (Acres)	50-65% (Acres)	>65% (Acres)	Total (Acres)
Beer Bottle Creek Complex	407	363	262	259	1,291
Brushy Creek	275	327	431	620	1,653
Chase Ranch Complex	373	399	376	420	1,569
Gorge Creek Complex	371	408	436	667	1,881
Happy Valley	396	351	282	206	1,235
Harmonica Creek	706	638	579	638	2,563
Main Stem Bear River	240	273	320	506	1,338
Middle Bear Complex	8	10	6	1	25
Nelson Creek	538	452	383	522	1,894
Peaked Creek Complex	190	181	187	301	858
Pullen Creek	263	338	410	474	1,486
Upper Bear River	339	201	135	69	744
Total for HCP Area	4,107	3,941	3,806	4,683	16,537
Percent of Total	25%	24%	23%	28%	100%
Cumulative Percent Total	25%	49%	72%	100%	-

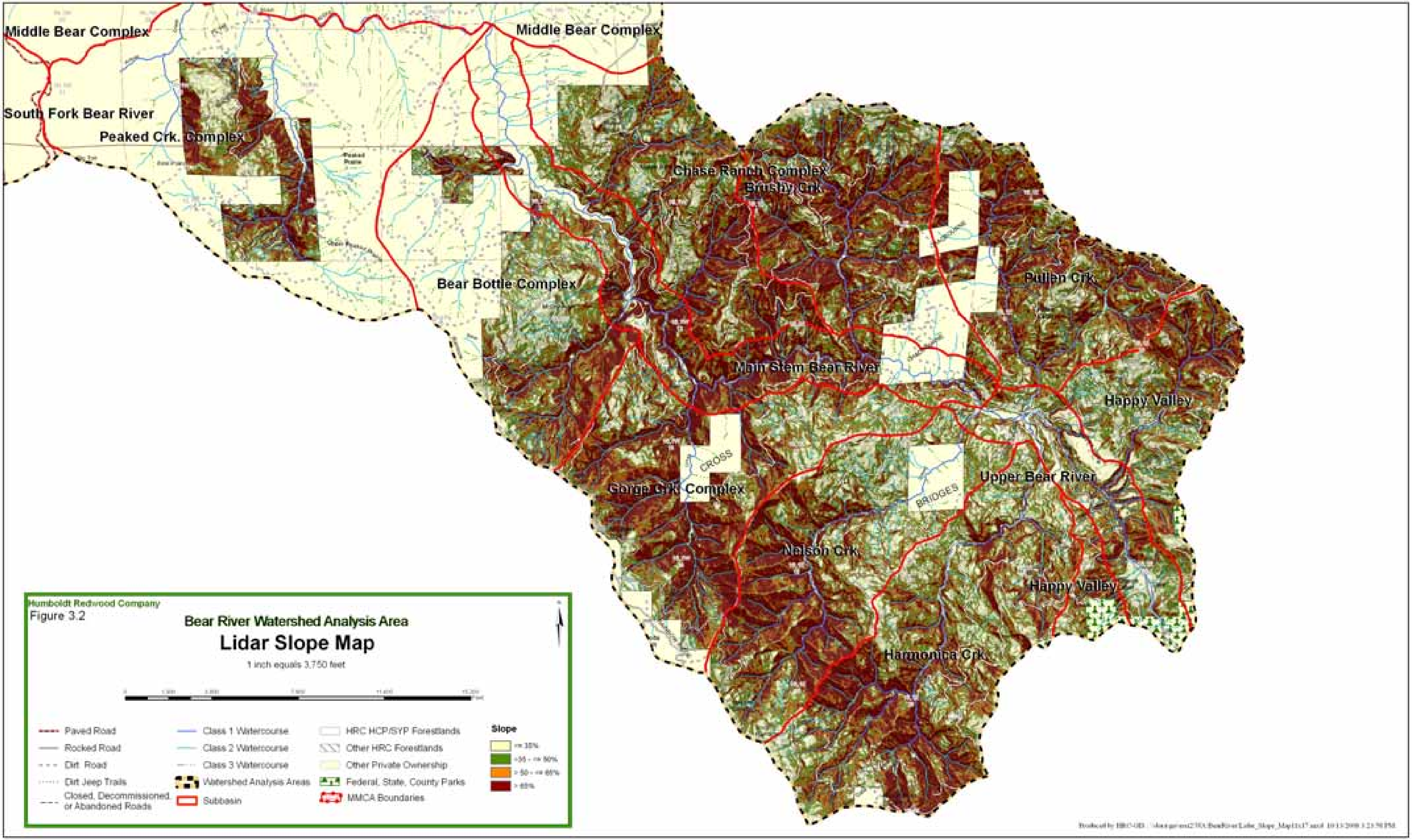

Middle Bear Complex
Middle Bear Complex
South Fork Bear River
Peaked Crk. Complex
Peaked Prairie
Chase Ranch Complex
Brushy Crk.
Bear Bottle Complex
Pullen Crk.
Main Stem Bear River
Happy Valley
CROSS
Gorge Crk. Complex
Upper Bear River
BRIDGES
Nelson Crk.
Happy Valley
Harmonica Crk.
Humboldt Redwood Company
Figure 3.2
Bear River Watershed Analysis Area
Lidar Slope Map
1 inch equals 3,750 feet
Paved Road
Rocked Road
Dirt Road
Dirt Jeep Trails
Closed, Decommissioned, or Abandoned Roads
Class 1 Watercourse
Class 2 Watercourse
Class 3 Watercourse
Watershed Analysis Areas
Subbasin
HRC HCP/SYP Forestlands
Other HRC Forestlands
Other Private Ownership
Federal, State, County Parks
MMCA Boundaries
Slope

Photo 3-1. Bear River Downstream from Gorge Creek.

3.5 STREAM CLASS

Stream classes are described in the California Forest Practice Rules (CFPR) by water class characteristics or key indicator beneficial uses. Stream classes are defined as CFPR Class I, II, III, or IV streams. CFPR 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. CFPR 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. CFPR 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, II, and III channel lengths by sub-basin in the HCP area of the Bear River WAU. There are 208 miles of known stream channel in the HCP area; 31 miles are Class I, 106 miles are Class II, and 71 miles are Class III.

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

Sub-basin	Class I (Miles)	Class II (Miles)	Class III (Miles)	Total (Miles)
Beer Bottle Creek Complex	<1	12.8	5.3	19
Brushy Creek	2.3	11.7	6.7	21
Chase Ranch Complex	1.3	10.5	6.2	18
Gorge Creek Complex	1.2	13.5	8.1	23
Happy Valley	1.6	8.9	4.0	15
Harmonica Creek	5.2	13.0	11.3	29
Main Stem Bear River	7.3	5.6	7.9	21
Middle Bear Complex	-	-	-	-
Nelson Creek	2.8	12.0	8.9	24
Peaked Creek Complex	2.0	5.7	3.2	11
Pullen Creek	2.7	7.5	6.6	17
Upper Bear River	4.5	4.9	2.7	12
Total for HCP Area	31	106	71	208

3.6 CLIMATE

The Bear River WAU has climatic conditions typical of coastal Northern California. Climate station locations in the vicinity are listed in Table 3-7 and shown in Figure 3-3. The Northern California coast has a 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 percent of the annual precipitation occurs (Figure 3-4). Annual total precipitation for Scotia, the nearest long-term reporting precipitation gauge, is presented in Figure 3-5 as obtained from the California Data Exchange Center (CDEC). Local precipitation data (not available from CDEC) was collected within the Bear River WAU during most years from 1954 to 1996 at the Lone Star Ranch, which is located in the approximate center of the Bear River watershed. Based on this data set, the Bear River watershed receives an average of 77 inches of rain per year (Western Timber Services and Best, 2001). Undocumented higher precipitation levels have been observed at higher elevations, near ridgelines, in the eastern portion of the WAU. Occasional snow also occurs in the eastern portion of the basin. No snowfall occurs in the lower river drainage area due to the climatic control of ocean temperatures.

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. The frequent coastal fog during the summer months is not as prolonged in the Bear River WAU area as compared to other portions of the coastal area in Humboldt County.

Table 3-7. Weather Stations for Climatic Data Near 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 3-3. Climate Stations in the Vicinity of the Bear River WAU

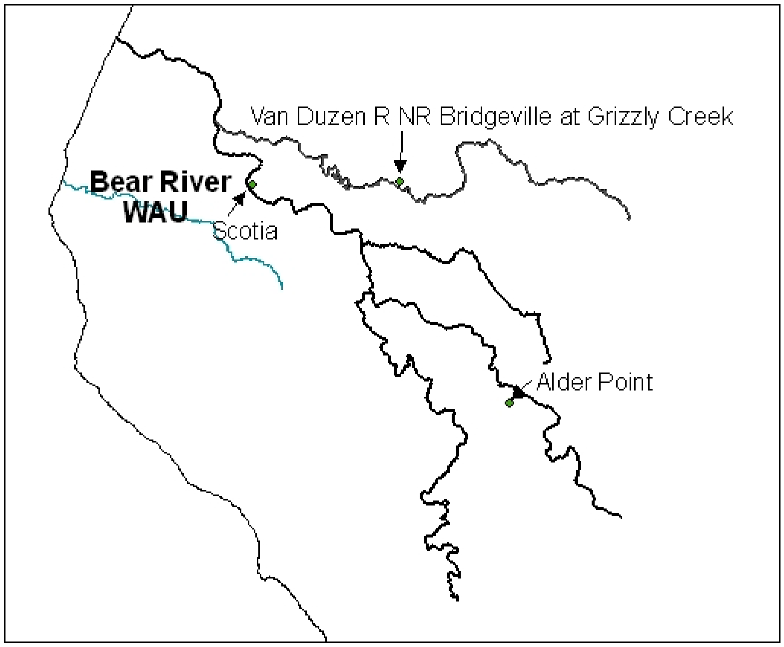
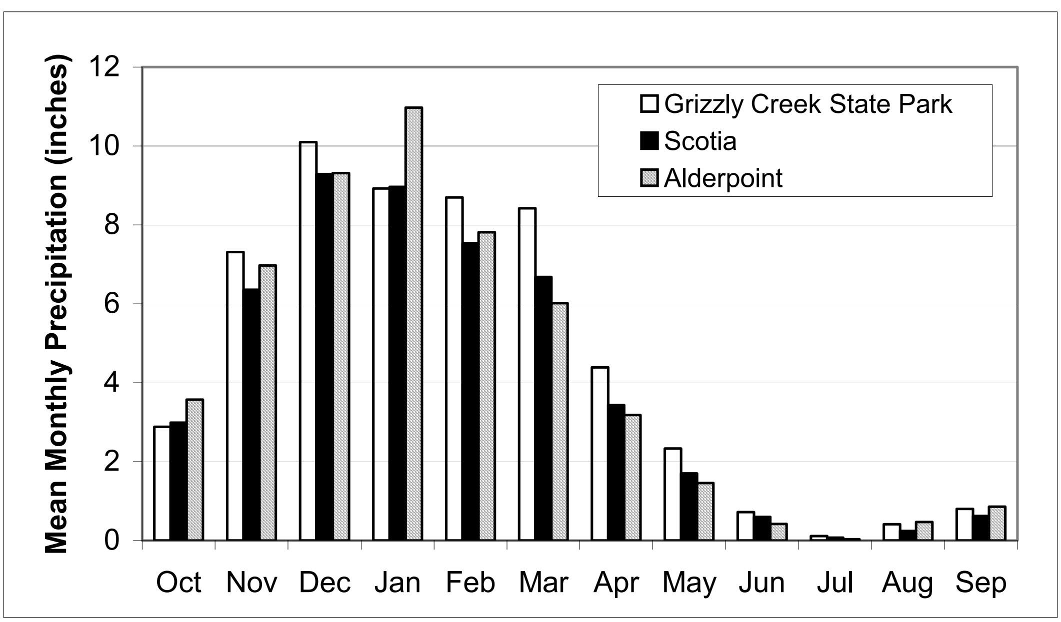


Figure 3-4. Mean Monthly Precipitation at Several Climate Stations in the Vicinity of the Bear River WAU.

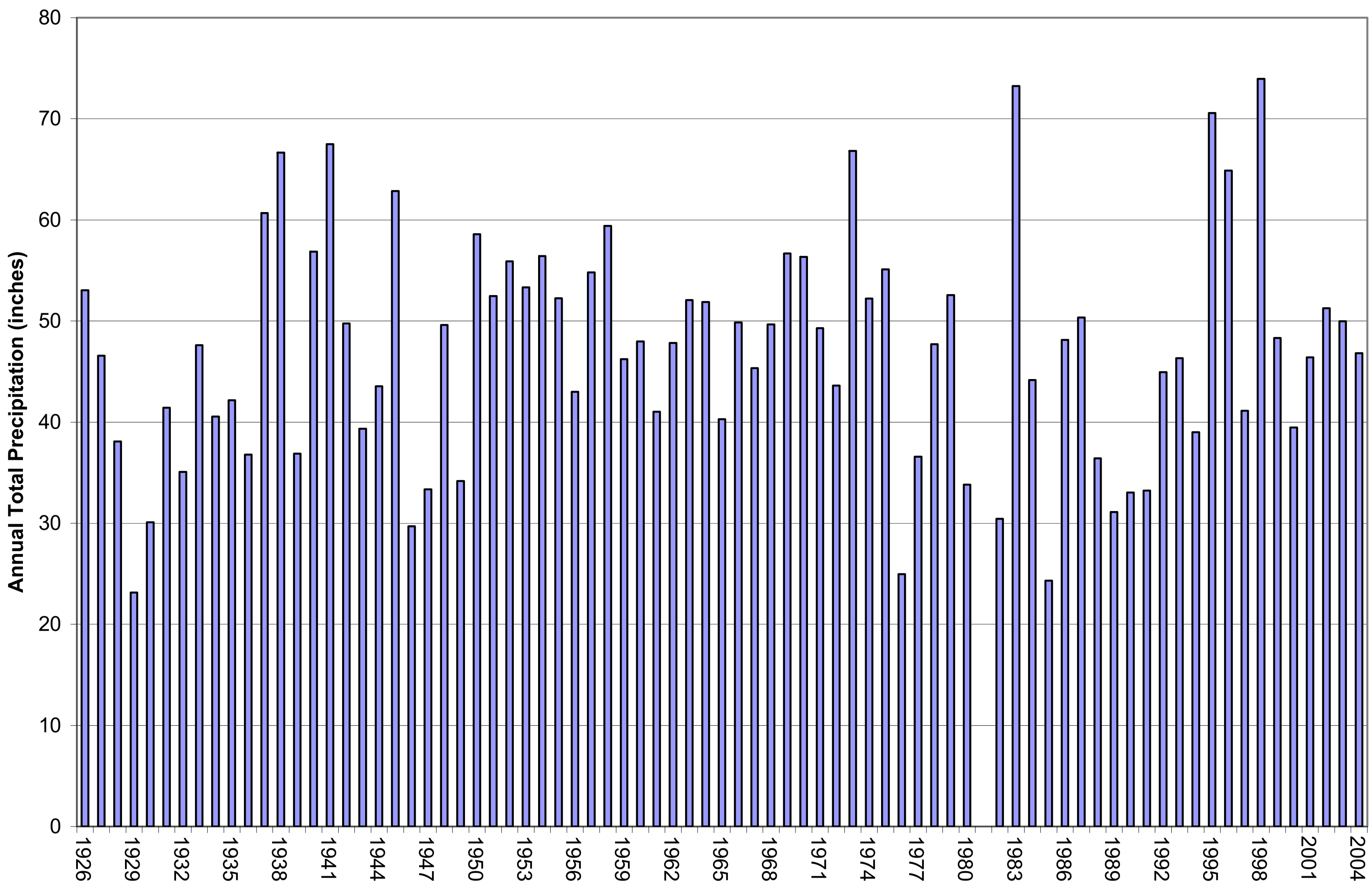


Air temperatures in the North Coast area are moderate and the annual fluctuation is one of the smallest in the conterminous United States (NOAA, 2000). Seasonal air temperature variation is small due to the close proximity to the Pacific Ocean, as the prevailing northwest winds cross with the cold upwelling waters usually present along the 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. The mean maximum temperature in Scotia for the month of September, the warmest month of the year, is 71 °F, whereas the summer temperatures over the ridge in the Bear River WAU typically reach into the 80 to 90° F range. High winds, including those in excess of 80 miles per hour, can occur at any time of the year (Western Timber Services and Best, 2001).

A search for snow pack information did not reveal data for any stations close to the analysis area. The Western Regional Climate Center lists no SNOTEL stations in the North Coast area in their station inventories and the NRCS lists no snow course sites. A search of the CDEC website revealed no climate stations in Humboldt County with snow pack or snow course information. Daily snowfall records are available for several stations in the vicinity of the analysis area (Table 3-7, Figure 3-3). Little snowfall occurs in Scotia, which is expected to be similar to lower elevations of the Bear River WAU. However, significant snowfall depths of one foot or more can occur in the higher elevations of the WAU during significant cold-temperature winter storms (Photo 3-2).

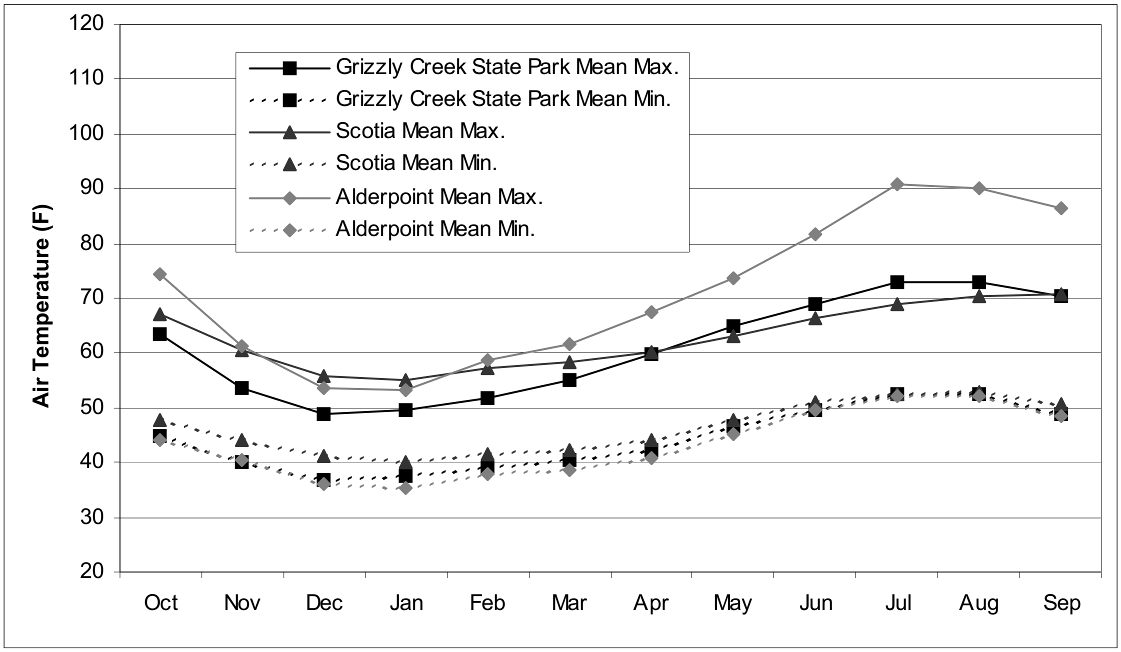
Photo 3-2. Monument Ridge near Headwaters of Brushy Creek.

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 Bear River WAU.

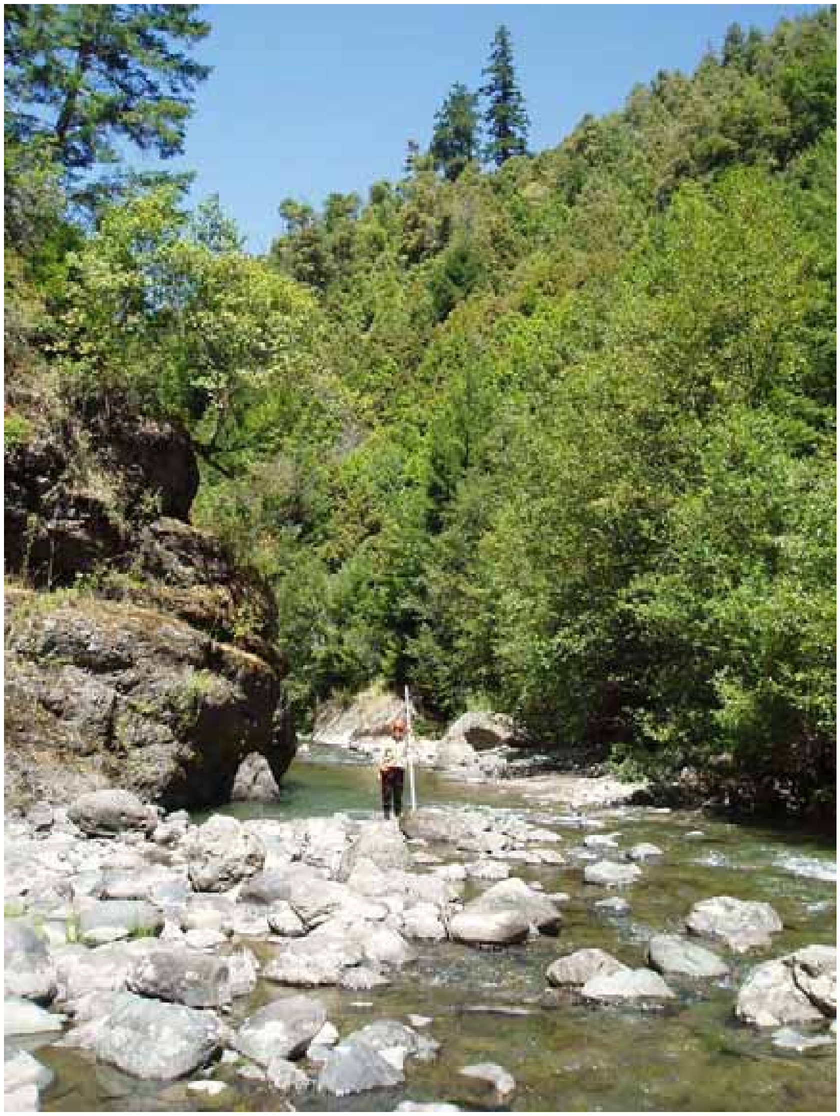


3.7 HYDROLOGY

Hydrology is summarized in terms of channel morphology, with a brief discussion on flood history and calculated flood flows. No data on stream flow are available for the Bear River watershed. The lower section of the river has a high degree of sinuosity, low gradient reaches, and deep pools. Channel topographic characteristics shift from lower to higher gradients further away from the coast. The estuary where Bear River enters the Pacific Ocean is roughly ¼ mile in length. There are six distinct channel morphologies for Bear River as depicted in Appendix D (Stream Channel) and described below from downstream to upstream reaches.

The first reach extends from the estuary to West Side Creek. The channel in this reach has a low gradient with large meanders and is shaded with less than 5 percent canopy cover. Stream temperatures in this segment may be relatively high in the summer. The second reach extends from West Side Creek to the lower boundary of the contiguous HRC property. Stream gradient increases and there is less meandering. Cobble substrate dominates and canopy cover increases, providing cooler stream temperatures. The third reach extends from the lower HRC property line to Beer Bottle Creek. The stream channel becomes narrow and gradients range between 2 to 4 percent. Large boulders are present in this stretch, indicating higher water velocities.

Photo 3-3. Confined Reach of Bear River between Beer Bottle and Nelson Creek.



Between Beer Bottle Creek and Nelson Creek (the fourth reach, Photo 3-3), the channel becomes more confined and gradients increase dramatically. Canopy cover also increases and the stream temperatures are cooler. Between Nelson and the confluence of the Bear River and Harmonica Creek (the fifth reach), the channel widens and alluvial deposits dominate the valley bottom. Gradients average between 1-3 percent and canopy cover decreases. Large woody debris is more abundant. Upstream of Harmonica

Creek (the sixth reach), the channel narrows with gradients between 2 and 4 percent and occasional jumps of up to 8 percent. Wood is present and helps to form pools in this morphology.

A brief review of the flood history for the Bear River WAU can provide an understanding of the role of flood events 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. Although stream gauging has not been conducted in the Bear River WAU, flooding occurred in the Bear River area and through coastal northern California in 1955 and 1964. The 1955 flood was reported as more significant and intense than the 1964 flood. The greater effects of the 1955 flood, as compared to the 1964 flood, may have been caused by the location where storms came on shore, antecedent moisture, and duration and intensity of rainfall. The 1955 flood caused severe damage, scouring, and altering of the stream channel – effects which are still apparent today (Western Timber Services and Best, 2001).

Peak flows were estimated for Bear River in this analysis, since there are no flow data available for the drainage area (Table 3-8). Regional regression equations, for the North Coast Region, were used to estimate flow (Waananen and Crippen, 1977). Peak flows for the 2-, 5-, 10-, 25-, 50-, and 100-year recurrence intervals were estimated for the Bear River WAU and for the HCP area (upstream portion of the WAU), separately. The Peaked Creek sub-basin was excluded from the estimate of flows for the HCP area, as it is not contiguous with the other HCP area sub-basins. Mean annual precipitation was set at 77 inches for the WAU (Western Timber Services and Best, 2001) and 100 inches for the HCP area, although the actual mean annual precipitation in the higher elevations has not been measured but is known to be larger than for lower elevations. The calculated peak flow rates for the 2-year and 100-year events at the downstream end of the Bear River WAU are 9,030 cubic feet per second (cfs) and 29,340 cfs, respectively. At the downstream end of the HCP area, excluding the Peaked Creek sub-basin, the calculated peak flow rates for the 2-year and 100-year events are 3,340 cfs and 13,000 cfs, respectively (Table 3-8).

Table 3-8. Estimated Peak Flows for the Bear River WAU and the HCP Area.

Recurrence Interval	Bear River- Peak Flows at the mouth (cfs)	HCP Area [2]- Peak Flows (cfs)	Regional Equation [3]
2 years	9,026	3,336	$3.52A^{0.90}p^{0.89}H^{-0.47}$
5 years	13,487	5,235	$5.04A^{0.89}p^{0.91}H^{-0.35}$
10 years	17,341	6,995	$6.21A^{0.88}p^{0.93}H^{-0.27}$
25 years	21,316	8,960	$7.64A^{0.87}p^{0.94}H^{-0.17}$
50 years	26,081	11,283	$8.57A^{0.87}p^{0.96}H^{-0.08}$
100 years	29,337	12,995	$9.23A^{0.87}p^{0.97}$

[1] Area of 83.6 square miles for entire Bear River WAU.
[2] Excluding Peaked Creek sub-basin, includes 24.5 square miles of HCP area.
[3] From Waananen and Crippen (1977) as presented by "California Salmonid Stream Habitat Restoration Manual", April 2003

Q is Peak Discharge (cfs)
A is drainage area (sqmi)
P is mean annual precipitation (inches) = 77 inches (WAU), 100 inches (HCP area)
H is the altitude index, which is the average of altitudes in thousands of feet along the main channel at 10% and 85% of the distances from the site to the divide. North Coast Region, uses minimum value of 1.0.

3.8 FOREST ECOLOGY

Douglas-fir (*Pseudotsuga menziesii*) and tanoak (*Lithocarpus densiflorus*), occurring in either relatively pure or mixed stand conditions, are the most common tree species in the Bear River WAU (Photo 3-4). In addition to Douglas-fir, other conifers found in the watershed include grand fir (*Abies grandis*), Sitka spruce (*Picea sitchensis*), and to a limited extent coastal redwood (*Sequoia sempervirens*). Sitka spruce and grand fir are typically found lower in the drainage near the mouth of the river, while Douglas-fir exists throughout the watershed. Coastal redwood is uncommon, but can be found in moist, shaded draws, and is also being planted on various ownerships following timber harvest operations on sites considered suitable for the species. In addition to tanoak, other hardwood species found in the watershed include Pacific madrone (*Arbutus menziesii*), red alder (*Alnus rubra*), willow (*Salix spp.*), big-leaf maple (*Acer macrophyllum*), and California bay-laurel (*Umbellularia californica*). The lower portion of the watershed includes large expanses of grasslands, while in the upper watershed grasslands are more limited and constrained to smaller openings.

Photo 3-4. Overlook of Upper Bear River Forest Condition.

3.8.1 Historic Vegetation

Prior to the 1940s, conifer forests, typically Douglas-fir dominated, were more expansive and older in stand age, containing trees in excess of 100 years old and 160 feet in height. Wildfire, either intentionally set by natives or resulting from lightning strikes, and earthquake and flood induced mass-wasting, were the primary modes of large scale mortality and succession, in addition to the more constant mechanisms of windthrow, heart-rot, and insect attack. Aerial photographs from 1948 show sections of riparian habitat dominated by hardwoods and other early succession species suggesting channel migration was another form of localized disturbance.

A reduction of this once more expansive Douglas-fir dominated forest type occurred following the initial industrial logging boom of the mid-twentieth century as hardwood forests occasionally regenerated in place of conifer forests following harvest. The extent, in terms of overall area, to which this conversion occurred has not been documented. In recent years, localized conversion from hardwood back to conifer dominance has been the objective of numerous "rehabilitation" harvest efforts with hardwood sites being logged or otherwise treated and the area replanted with conifers, primarily Douglas-fir, but occasionally redwood as well.

3.8.2 The Role of Fire

The Bear River Indians, also called the Nī'ekeni', are a group of Native Americans that lived in the Bear River basin for hundreds of years prior to European settlement in the 19th century. Fire was an important component of their culture as it allowed for vegetation management to maintain willow thickets and clear the ground around oak trees to make acorn collection easier. As hunting and gathering of plant and animal resources occurred throughout the basin so did these intentionally set fires. During and subsequent to European settlement, fire was used for maintenance of grasslands for ranching purposes and, in the mid and later twentieth century, following harvest operations to reduce logging slash.

Fire records have been maintained for lands in the Bear River WAU since the 1950s (California Department of Forestry and Fire Protection [CDF], 2006). Most of the natural, lightning strike caused fires in this recent period of record occurred in the 1950s, and all of them occurred in the eastern or southern fringes of the WAU. During the 1950s, three major fires (Pacific Lumber Co. Fire, Bear River Lumber Co. Fire, and Ed Lewis #3 Fire) occurred in portions of the Upper Bear River and Happy Valley sub-basins, covering 215 acres, 412 acres, and 292 acres, respectively. Later, in 1990, the Rainbow Fire burned primarily to the south of the Bear River WAU, moving over the ridge into the Harmonica Creek sub-basin to burn approximately 250 acres. No other major fires have been recorded for HCP lands in the Bear River WAU.

3.9 Fish Species Composition and Distribution

The Bear River WAU currently supports Chinook salmon (*Oncorhynchus tshawytscha*) (Photo 3-5), steelhead trout (*O. mykiss*) (Photo 3-6), and resident rainbow trout. A search of historical records did not substantiate the existence of coho (*O. kisutch*) in the watershed, although potential habitat exists. While Chinook are relatively few in number and distribution is constrained to the lower reach of the river by channel conditions, steelhead and resident rainbow trout are abundant throughout the watershed area including HRC lands. With the 2007 replacement of a previously culverted stream crossing with a bridge in the Happy Valley area, the current extent of fish distribution on HRC ownership is limited only by natural barriers and channel conditions as described in Appendix E.

Photo 3-5. Chinook Salmon, *Oncorhynchus tshawytscha.*

Photo 3-6. Steelhead, *O. mykiss.*

The Bear River watershed contains several non-salmonid fish species. Native resident fish include the Pacific lamprey (*Lampetra tridentata*), prickly sculpin (*Cottus asper*), coast range sculpin (*C. aleuticus*), Sacramento sucker (*Catostomas occidentalis*), and the three-spine stickleback (*Gasterosteous aculeatus*). Marine species, which typically utilize estuaries along the northcoast, consist of surf smelt (*Hypomesus pretiosus*), redtail surf perch (*Amphistichus rhodoterus*), shiner perch (*Cymatogaster aggregata*), walleye surf perch (*Hyperprosopon argenteum*), Pacific staghorn sculpin (*Leptocottus armatus*), speckled sanddab (*Citharichthys stigmeus*), and starry flounder (*Platichthys stellatus*).

Channel topographic characteristics shift from lower to higher gradient at reaches further away from the coast, favoring Chinook salmon (*Oncorhynchus twshawytscha*) near the mouth and steelhead and resident rainbow trout (*O. mykiss*) further upstream. Winter-run steelhead are the most abundant anadromous salmonid species found within Bear River watershed, capable of utilizing the smaller tributaries with steeper gradients as well as the lower gradient mainstem. The point where Bear River enters the Pacific Ocean (Photo 3-7) is periodically blocked by a temporary sand bar during summer low flow. Subsequent fall rains and high surf erode the bar allowing access for upstream migrating anadromous salmonids. The estuary, where fresh water blends with ocean water, is roughly one-quarter of a mile in length. Above the estuary, the stream channel breaks out into six distinct morphologies that help to separate Chinook and steelhead populations according to individual life histories and habitat preferences.

Photo 3-7. Mouth of Bear River at Pacific Ocean.

The lowest reach extends from the estuary to West Side Creek; a distance of approximately 9.5 river miles. The channel in this reach is of a low gradient (approximately 0.5%) alluvial nature with large meanders and point/alternate bars (Photo 3-8). The channel has a high width to depth ratio and is shaded with less than 5 percent canopy. Stream temperatures may be relatively high in the summer in this section of the stream particularly moving away from the ocean's marine influence. The channel bed is highly aggraded and consists mainly of extensive gravel deposits. Very little LWD is present in this reach due to the channel width and magnitude of winter flows. The majority of suitable Chinook spawning and rearing habitat occurs in this reach. Although there has been no documentation of coho in the basin, this lower reach may provide suitable habitat due to its high degree of sinuosity, low gradient, and deep pools.

Photo 3-8. Low Gradient Meander Near Mouth of Bear River

The second distinctive reach extends from West Side Creek to the lower boundary of the contiguous portion of HRC's property. In this reach, the stream gradient increases and the channel becomes more confined, with less meandering and smaller alluvial deposits. The substrate is cobble dominated with heavily armored bars. The streamside canopy increases in this reach and topographic shading helps maintain cooler stream temperatures. The stream characteristics in this reach appear to transition from those favored by Chinook salmon to those preferred by steelhead and resident rainbow trout. One record from 1954 reports seeing Chinook spawning in this reach approximately 10 river miles from the mouth. This is the maximum upstream extent for Chinook reported in the basin.

The third reach extends from the lower HRC property line up to Beer Bottle Creek (Photo 3-9). Within this reach the stream channels narrows and becomes moderately entrenched with occasional small point bars. The stream channel gradient ranges from 2 to 4 percent. There are five 200-foot long, 4 to 8 percent gradient steps within this reach. The substrate coarsens and periodic large boulder fields are present, which indicate high winter water velocities occur within this reach. Large logs are infrequent but present throughout the stream segment. Winter rearing habitat is limited to edgewaters, inundated point bar surfaces, and under or behind large substrate. This reach contains suitable summer rearing habitat for steelhead and resident rainbow trout.

Photo 3-9. Bear River near Beer Bottle Creek.

Photo 3-10. Bear River Gradient Step below Nelson Creek.

The Bear River reach between Beer Bottle Creek and Nelson Creek (the fourth reach) becomes more confined and has low amplitude meanders. This reach is dominated by large substrate with some bedrock outcroppings (Photo 3-10). The average stream gradient is 2 to 4 percent, but five steps in gradient also occur throughout this section of the river. The gradient at two of these jumps is between 4 and 8 percent and three are between 8 and 12 percent gradient. Stream canopy increases and water temperatures are cooler than downstream. Steelhead summer rearing habitat appears to be in good condition in this reach. Winter habitat exists in the mouths of tributaries and behind or under large substrate.

Between Nelson Creek and the confluence of Bear River and Harmonica Creek (the fifth reach), the channel widens and alluvial deposits dominate the valley bottom. The stream gradient averages between 1 and 3 percent and the substrate size becomes smaller, consisting mainly of gravel and small cobble. Stream canopy decreases while LWD is more abundant although still relatively infrequent. Summer rearing habitat is present throughout the low flow channel. Winter rearing habitat is primarily found in the edgewaters and on gravel bar surfaces.

The Bear River reach upstream of Harmonica Creek (the sixth reach) once again narrows and becomes moderately entrenched with occasional small point bars. The stream channel gradient ranges between 2 and 4 percent with occasional jumps of 4 to 8 percent for the first mile. Wood is present and helps form about half the pools. However, the pools are short and shallow (Photo 3-11). Good spawning and rearing habitat is present. Winter habitat can be found associated with LWD, undercut banks, and bar surfaces.

Photo 3-11. Bear River Upstream of Harmonica Creek.

The tributary streams are generally 2 to 4 percent gradient in the lower quarter to third of the drainages. Pool frequencies are good although depths are somewhat shallow. Spawning habitat is available to varying degrees. Water temperatures are generally low and suitable for steelhead. LWD loads are generally low to moderate with the exception of Pullen Creek (Photos 3-12 through 3-14). The higher gradient reaches are typically boulder dominated with frequent high gradient riffles and cascades. Spawning habitat is present in small pockets. Winter rearing habitat is provided by substrate and LWD. Juvenile steelhead and resident trout were observed in 2005 as present and abundant in most tributaries.

Further detail regarding habitat distribution on HCP-covered lands can be found in Section 4.2 of Appendix E.

Photo 3-12. Pullen Creek.

Photo 3-13. West Fork Pullen Creek.

Photo 3-14. Pullen Creek Plunge Pool.

3.10 AMPHIBIAN AND REPTILE SPECIES COMPOSITION AND DISTRIBUTION

Habitat for all five of the amphibian and reptile HCP species of concern exists in the Bear River watershed including HCP-covered lands (Photo 3-15). The five HCP-covered amphibian and reptile species include two headwater species (southern torrent salamander [*Rhyacotriton variegates*] and tailed frog [*Ascaphus truei*]), and three lowland species (foothill yellow-legged frog [*Rana boylii*], northern red-legged frog [*Rana aurora aurora*], and Northwestern pond turtle [*Emys marmorata marmorata*]). Southern torrent salamander, tailed frog, and Foothill yellow-legged frog have been documented on HCP lands, whereas, despite the presence of habitat, the northern red-legged frog and the northwestern pond turtle have not been observed. The Amphibian and Reptile Assessment report (Appendix F) provides detailed information regarding the habitat requirements and distribution of each species.

Photo 3-15. Typical Suitable Habitat for Amphibians and Reptiles in Bear River Watershed.

4.0 LAND USE

This section presents a summary of land use in the Bear River WAU, as well as a description of prehistoric land use, forest management from the early days of human settlement to the late twentieth century, and recent harvest and road construction. Harvest, yarding, and hauling methods and locations are discussed, along with rates of harvest and road construction over the years.

Commercial timber production activities and grazing of rangelands occur on lands in the WAU not owned by HRC. Most of the areas in the Bear River have not been developed for residential or commercial use. There are only a few private residences located near the Bear River mainstem, downstream of HRC ownership. Distribution of major land cover within HCP lands in the Bear River WAU is listed in Table 4-1 and illustrated in Figure 4-1.

Europeans settled the area beginning in 1855. Initial land uses included ranching, timbering, and some grazing. Many of these same land uses continue to this day (Western Timber Services and Best, 2001).

4.1 PREHISTORIC LAND USE

Prior to settlement by Europeans, along Bear River a group of Indians lived for whom no suitable native name was preserved. These Indians were referred to as "Bear River Indians" and were also called Nī'ekeni', a name they applied to themselves and to the Mattole Indians (Access Genealogy, 2006). The Bear River Indians belonged to the Athabascan linguistic family, and were most closely connected with the Mattole, Sinkyone, and Nongatl tribes to the south and east. All of these tribes experienced a significant decline in population as non-native settlement increased (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, whereas, 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.

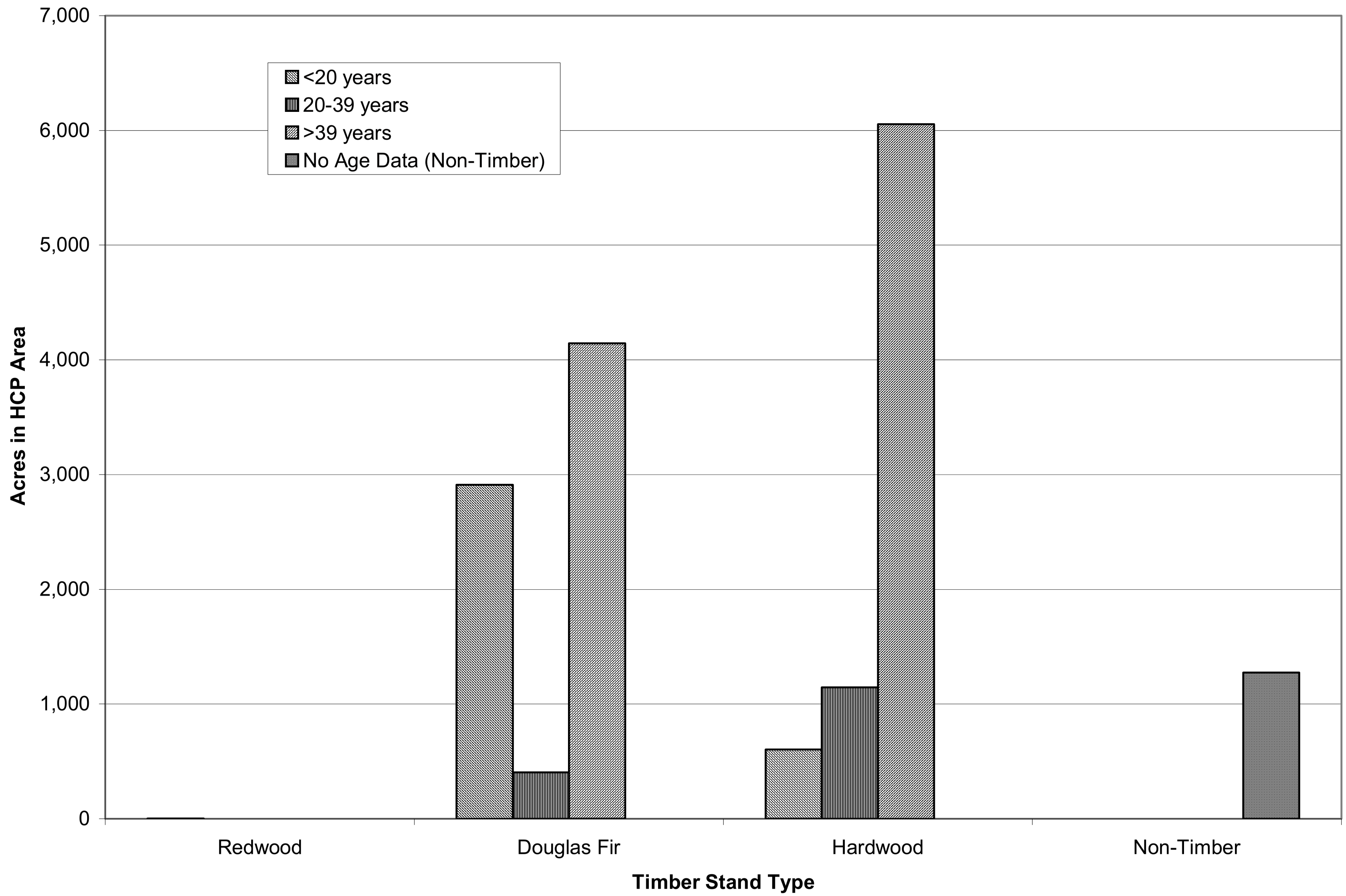
Table 4-1. Timber Stand Acres by Type and Age (as of 2005) in HCP Area.

Sub-basin	Redwood		Douglas Fir			Hardwood			Non-Timber (no age)	Totals
	<20 years	>20 years	<20 years	20-39 years	40 - 150 years	<20 years	20-39 years	40 - 150 years		
Beer Bottle Creek Complex	-	-	540	-	428	35	8	130	151	1,291
Brushy Creek	<1	-	254	34	351	11	215	636	152	1,653
Chase Ranch Complex	<1	-	216	71	251	57	28	511	435	1,569
Gorge Creek Complex	-	-	214	33	396	44	95	1,022	77	1,881
Happy Valley	-	-	218	30	382	92	68	386	59	1,235
Harmonica Creek	-	-	455	11	647	202	217	958	73	2,563
Main Stem Bear River	-	-	71	22	318	66	43	725	93	1,338
Middle Bear Complex	<1	-	22	<1	-	-	-	-	3	25
Nelson Creek	-	-	325	71	363	12	214	850	59	1,894
Peaked Creek Complex	-	-	225	117	245	-	174	84	13	858
Pullen Creek	-	-	214	7	408	40	31	679	106	1,486
Upper Bear River	-	-	155	7	357	45	51	76	54	744
Totals	<1	-	2,910	404	4,145	604	1,146	6,055	1,274	16,537

Notes:

1. "Redwood" category includes Redwood and Redwood-Doug Fir
2. "Douglas Fir" category includes Douglas Fir, Douglas Fir-Hardwood, and Douglas Fir-Redwood

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



4.2 HARVEST HISTORY (1900-1988)

HCP-covered lands in the Bear River WAU, now currently under one ownership, were under numerous separate ownerships at the start of the 20th century. The first recorded harvest activity in the upper Bear River watershed began on a few discrete properties in the headwaters of Gorge Creek, Harmonica Creek, Brushy Creek, and the very upper extent of the Bear River mainstem. These harvest activities (early 1900s) were conducted by man and animal power with the lumber and tannin used locally for construction of homes, barns, a dairy, and a schoolhouse, among other things, at locations such as Happy Valley and McDonough Prairie which were originally early settlement homesteads. Table 4-2 presents first entry harvest acreages by sub-basin and decade.

Large scale industrial timber operations commenced in the late 1940s starting in the Happy Valley area along the Bear River mainstem and on slopes adjacent to the lower reaches of several tributaries including Brushy, Pullen, Harmonica, and Nelson Creeks. Pullen Creek in particular was reported to have had some very high quality large diameter Douglas-fir timber, and even pockets of redwood. Harvesting progressed both upstream and downstream of Happy Valley in the 1950s with logging occurring at and downstream of the mouth of Gorge Creek and in the vicinity of Chase Ranch, as well as upslope to the east of Happy Valley. By the mid 1960s, much of the headwaters of Gorge Creek, Nelson Creek, Harmonica Creek, and Pullen Creek were harvested. By the end of the 1960s, over 90 percent of HRC's current Bear River ownership had been initially harvested, much of it in contiguous large blocks. Remaining old-growth forest stands were limited to very steep slopes, mostly inaccessible to the ground-based tractor yarding operations of the time.

The management style for this early logging was similar to most areas of the North Coast at the time. Practices included substantial ground disturbance, little protection of stream channels and riparian zones, extensive road construction, and little or no recognition of the potential adverse influence to slope stability caused by harvesting on inner gorge slopes. While the majority of growing timber was harvested at each logging site, Douglas-fir 'seed trees' were occasionally retained individually or in patches to facilitate stand regeneration, with mixed success. Logging was conducted almost entirely by diesel-powered bulldozers and tractors, with logs typically yarded downhill to landings and haul roads located at or near the bottom of the harvest setting. Where they constituted the least steep, easiest to negotiate terrain, watercourses were often used as skid trails during this process. This practice, along with unmitigated upslope cut and fill skid trail construction, resulted in the filling of many stream channel segments with soil and logging debris. At landings, the logs were placed on trucks and hauled either to the north, up and over Monument Ridge to the Scotia Mill via the Hampton Road (now known as the J-line) located along the ridge west of Brushy Creek, or over the southeastern watershed divide into the Bull Creek watershed where two lumber mills were also active at the time. The era of railroad logging pre-dated the initial Bear River harvest cycle and rails and trains were never used in the Bear River watershed.

The 1955 and 1964 floods drastically altered stream and riparian conditions in the basin. Disturbed by skid trail and road construction, and often denuded by extensive timber harvest, streamside slopes in the Bear River drainage responded to the heavy rains and flash floods with catastrophic mass wasting delivering 11 million cubic yards (cy) of harvested hillslope and road-related sediment during this period alone into the tributaries and mainstem channels of the basin. The major flood flows caused significant stream channel scour destroying riparian vegetation and transporting sediment downstream, with the larger sediment and gravel depositing and leaving aggraded channel conditions resulting in an over-simplified hydraulic condition (i.e., loss of aquatic habitat diversity). Elevated aggraded channel beds led to chronic floodplain bank erosion and the reactivation of earth flows during subsequent high winter stream flows, causing locally persistent aggradation in years subsequent to these initial flood events. Removal of much of the large timber which historically constrained mass wasting processes and sediment delivery, and contributed to aquatic habitat diversity when delivered to stream channels, compounded the adverse effect.

Growing concern over water quality and aquatic habitat in the late 1960s and 1970s led to scrutiny of timber harvest activities, and in 1973 the Z'berg-Nejedly Forest Practices Act was passed and the CFPRs subsequently established. These rules, among other things, provided protection for water quality and riparian areas in the form of watercourse and lake protection zones (WLPZ), within which ground disturbance was and is minimized and timber removal limited. Reforestation requirements were also established.

Harvest rates declined significantly in the watershed in the 1970s and 80s, before second growth harvesting began to increase in the late 1990s.

Table 4-2. First Harvest Entry Acres in HCP Area.

Sub-basin	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
Beer Bottle Creek Complex	-	-	-	-	-	-	173	25	-	126	90	877	1,291
Brushy Creek	-	-	-	-	-	411	900	-	-	-	<1	342	1,653
Chase Ranch Complex	18	27	9	-	-	97	882	-	-	-	-	536	1,569
Gorge Creek Complex	-	-	-	-	-	500	541	473	-	-	1	365	1,881
Happy Valley	-	-	-	-	-	70	891	39	-	-	6	229	1,235
Harmonica Creek	-	-	182	-	-	1,297	<1	645	43	-	-	395	2,563
Main Stem Bear River	-	-	-	-	-	407	654	18	-	-	4	255	1,338
Middle Bear Complex	<1	-	-	-	-	2	20	-	-	-	-	4	25
Nelson Creek	-	-	72	-	-	874	20	677	-	-	7	244	1,894
Peaked Creek Complex	-	-	-	-	-	-	535	-	-	-	-	323	858
Pullen Creek	-	-	-	-	-	341	271	545	-	-	5	325	1,486
Upper Bear River	-	-	-	-	-	399	102	-	-	-	-	243	744
Totals	18	27	264	-	-	4,399	4,987	2,422	43	126	113	4,138	16,537

*Note: "All Other Categories" include:

Two unlabeled categories (7 acres)
Old growth (1,777 acres)
Unknown (41 acres)
Acquired (836 acres)
Prairie (1,477 acres)

4.3 CONTEMPORARY HARVEST (1988-2003)

Contemporary timber harvest operations conducted by PALCO from 1988 through 2003 primarily involved the harvest of second growth Douglas-fir timber in individual 10-40 acre clearcut or selective harvest units blocks, along with the conversion of hardwood dominated stands to conifer. Harvest acres by sub-basin during this time period are shown on Figure 4-2. Along with total acres harvested each year, Figure 4-3 depicts yarding systems used from 1988-2003, and Figure 4-4 shows silviculture methods used during the same period. Tractor yarding was the primary method for moving logs from the harvest setting to the landing. Cable high-lead or skyline yarding operations were also common. Helicopter logging, with its ability to access otherwise difficult or inaccessible harvest settings with little to no ground disturbance, but at a substantially higher cost, came onto the scene in 1999. Due to economic and silvicultural efficiencies, clearcutting (including the "rehabilitation of understocked areas") was applied to more acres than partial cutting silvicultural systems.

Harvest-related ground disturbances continue to be associated with yarding activities and post-harvest site treatment in preparation for planting, although heightened concerns over erosion and water quality resulted in practices less disturbing than those of the previous logging boom era, particularly in riparian areas and on steep slopes (Photo 4-1). Over the past decade, site preparation has been performed on approximately half of the clearcut 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.

The 1999 implementation of the HCP provided additional watershed protection beyond the CFPRs. This additional mitigation included wider stream buffers, green tree retention measures, and greater restrictions regarding timber operations on steep and/or unstable slopes, subject to further refinement upon completion of watershed analysis. Also as part of the HCP, a policy precluding hauling and heavy equipment use of roads during wet weather was implemented to reduce road sediment generation and delivery to streams. 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 significant rain. Road storm-proofing, reconstruction, and upgrading have occurred on a significant portion of HCP roads effectively reducing sediment inputs to streams. Road improvements include replacement or decommissioning of failing or undersized culverts as well as ‘Humboldt’ and fill-only stream crossings, removal of ‘perched’ fill material, reconfiguration of road prisms to insure a well-drained condition, installation of additional waterbreaks, and the rocking or otherwise ‘treating’ of road surfaces.

As of 2005, the PALCO GIS database showed a total of 124 miles of existing or proposed (not constructed yet) roads on HCP lands in the Bear River WAU (Table 4-3). Main-line rocked haul roads used to access large tracts of land account for slightly less than 30 miles of the existing road system. There are approximately 80 miles of dirt, primarily native-surfaced roads, many of which are ‘spur roads’ not used for year-round traffic. Overall road density on HRC lands of the Bear River WAU is 4.8 miles of road per square mile of land area (Table 4-3). Road densities are highest in the Upper Bear River (7.4 miles per square mile) and Happy Valley (6.2 miles per square mile) sub-basins.

HRC acquired ownership of HCP-covered lands in 2008. HRC silvicultural philosophies preclude the use of traditional clearcutting and suggest future harvesting on the ownership will be selective in nature where stand conditions permit. ‘Variable retention’ and ‘Rehabilitation of Understocked Area’ silvicultural approaches will be used to promote long-term sustained yield of commercial conifer species where mixed conifer/hardwood or pure hardwood stand conditions currently preclude selection harvest.

Figure 4-2. Acres Harvested by Sub-basin from 1988–2003.

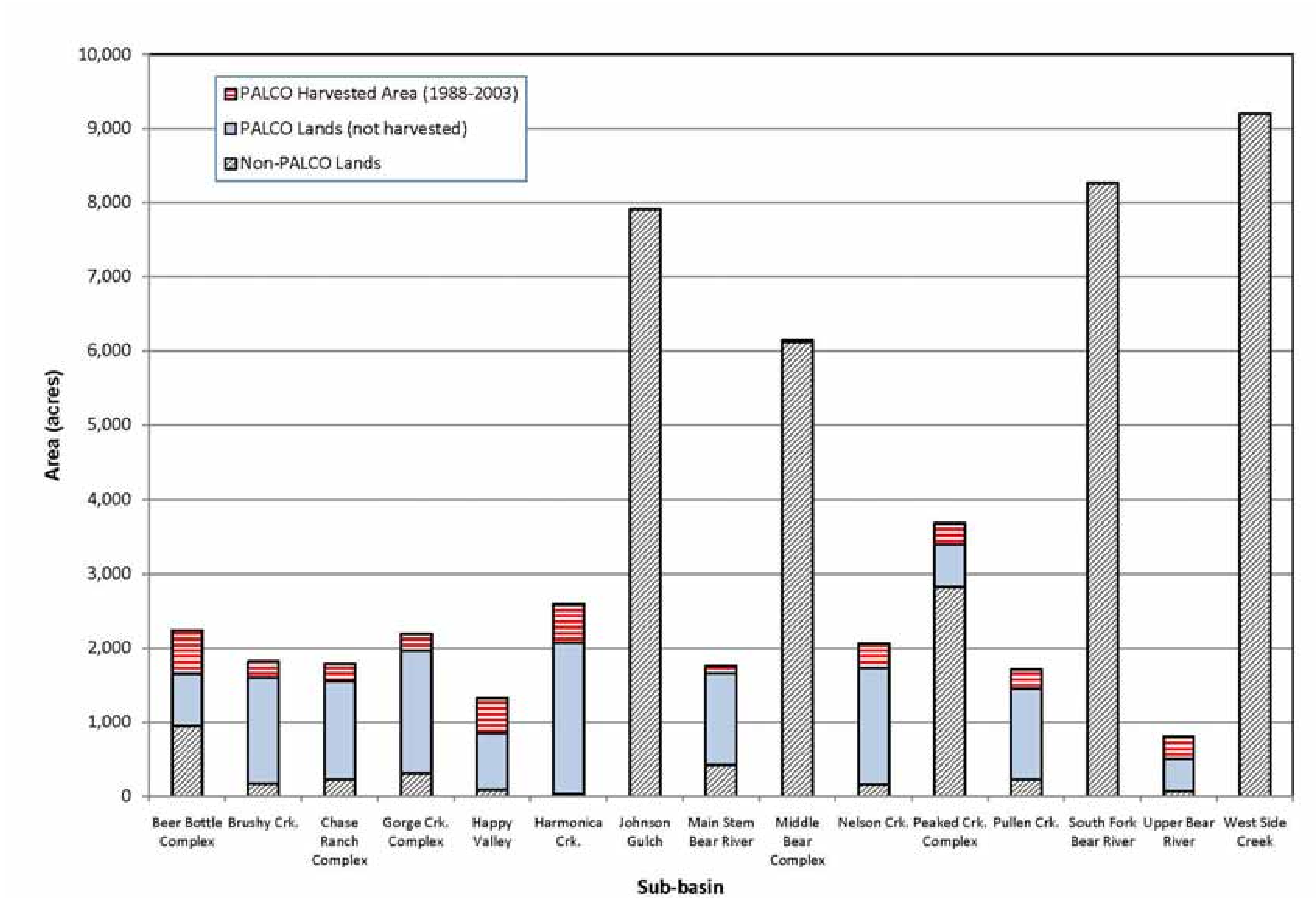


Figure 4-3. Acres Harvested in HCP Area by Yarding System from 1988–2003.

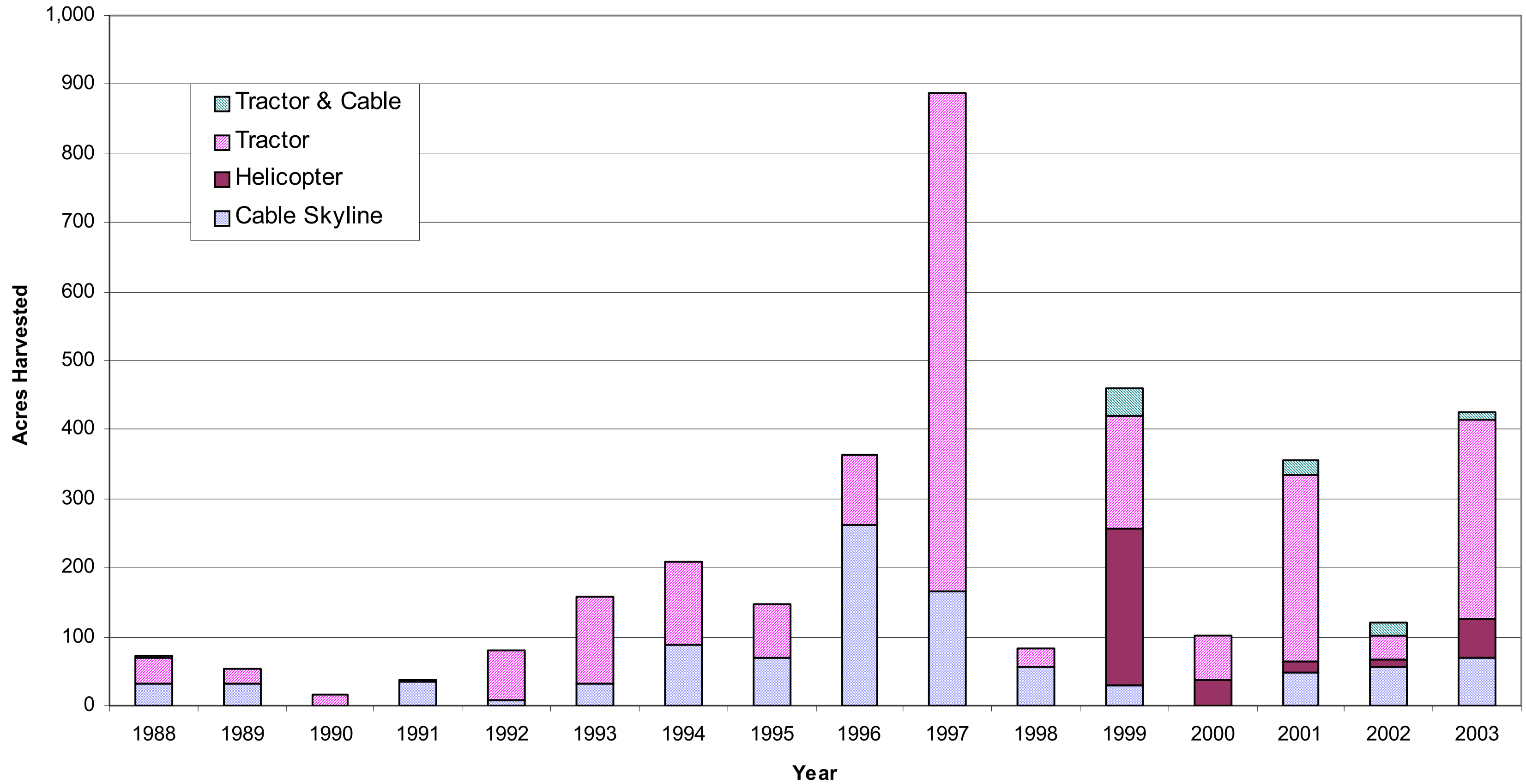


Figure 4-4. Acres Harvested in HCP Area by Silviculture Method from 1988–2003.

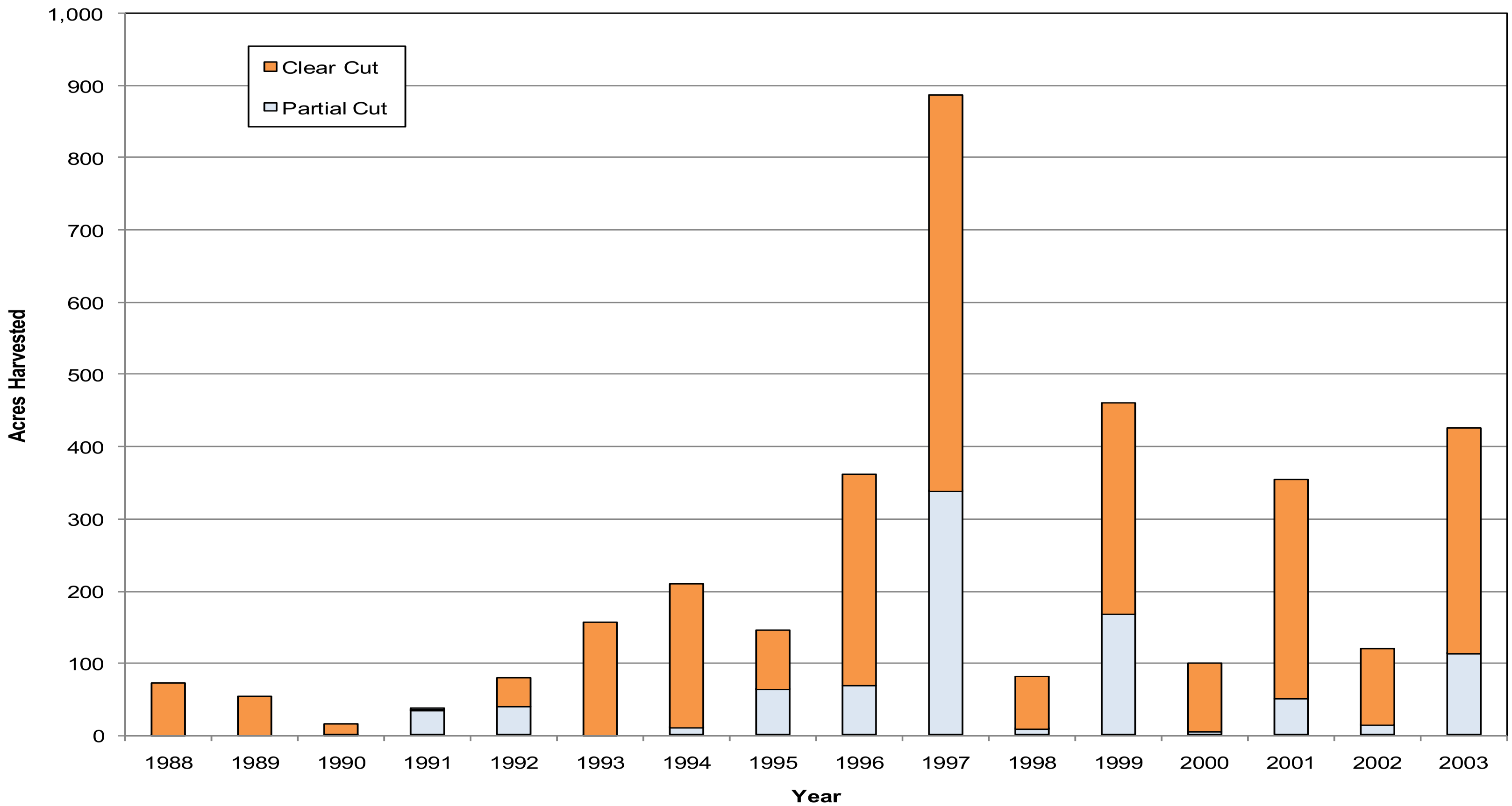


Photo 4-1. Clear Cut, Cable Yarded, No Burn Unit Harvested in 2004--Chase Ranch Complex Sub-basin

Table 4-3. Roads by Sub-basin in HCP Area (based on PALCO GIS Data).

Sub-basin	Regular Miles		Upgraded Only Miles		Stormproofed Miles [1]			Stormproofed and Decomissioned	Total Miles	PALCO Road Density (miles/sqmi)
	Gravel	Dirt	Gravel	Dirt	Gravel	Dirt	Proposed	Grassed Native		
Beer Bottle Complex	<1	7	3	<1	<1	-	1	-	**11**	**5.3**
Brushy Creek	1	7	1	-	1	2	1	-	**13**	**4.9**
Chase Ranch Complex	1	8	2	-	-	1	1	-	**13**	**5.3**
Gorge Creek Complex	1	8	3	<1	-	-	3	-	**14**	**4.8**
Happy Valley	2	4	2	-	3	<1	1	-	**12**	**6.2**
Harmonica Creek	-	13	<1	-	<1	2	3	-	**19**	**4.7**
Main Stem Bear River	<1	6	2	<1	-	-	1	-	**8**	**3.7**
Middle Bear Complex	<1	<1	-	-	-	-	<1	-	**<1**	**-** [2]
Nelson Creek	<1	6	1	-	-	2	2	-	**11**	**3.9**
Peaked Creek Complex	-	3	-	-	-	-	-	-	**3**	**2.5**
Pullen Creek	<1	5	1	-	2	<1	2	<1	**11**	**4.9**
Upper Bear River	<1	3	2	2	-	<1	<1	-	**9**	**7.4**
Total for HCP Area	**7**	**70**	**16**	**2**	**7**	**8**	**15**	**<1**	**124**	**4.8**

1. All new road construction is done to "stormproofed" standards.
2. Road density is not calculated due to exceptionally small area of PALCO ownership in sub-basin.

5.0 CUMULATIVE EFFECTS OF TIMBER OPERATIONS AND WATERSHED PROCESSES ON AQUATIC HABITAT CONDITIONS

The premise behind the study of 'cumulative' watershed effects is that althoughindividual management effects (e.g. one road failure) may not, individually, result in a significant change to water quality and aquatic habitat; when considered cumulatively across space and over time, these effects can in fact alter watershed processes and habitat conditions to the extent that entire biological populations are adversely affected.

In this section, key findings of Appendices A through F are presented and discussed in order to identify and spatially locate activities and areas where historic and contemporary adverse effects associated with forest management have, or could, occur; and to describe the extent to which these adverse effects cumulatively prevail upon current and future watershed processes and aquatic habitat conditions. In the light of these current conditions and trends, recommendations for future forest and watershed management are made in order to accomplish HCP objectives of maintaining or achieving, over time, properly functioning aquatic habitat conditions for HCP-covered species. Current stream conditions in specific locations within the WAU are discussed with reference to habitat (i.e., PFC) targets (Photo 5-1).

Potential management-related adverse effects of interest include diminished hydraulic complexity, loss of pool habitat, plugging or burying of streambed gravel (i.e., spawning substrate), and increases in water temperature.

Photo 5-1. Harmonica Creek.

5.1 SEDIMENT INPUT

Sediment is an important and vital component of aquatic ecosystems. In an active streambed, gravel, cobble, boulders, and organic debris that form critical components of fish habitat must be continuously replenished from upland or near stream sources since they are transient and move through the stream system during high flows (CDFG, 1998). 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:

- 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.

Human activities such as those described above usually disturb the natural supply rate of sediment which, depending upon extent, can in turn affect stream channel conditions and aquatic habitat. Increased sediment yield, if not scoured by seasonal flows, can result in streambed aggradation which leads the widening of stream channels, stream shallowing, severe bank instability, and loss of pool habitat and overall hydraulic diversity. Widening of stream channels, along with loss of stream depth and pools, in turn makes streams more vulnerable to solar heating and increased water temperatures. Excessive input of inorganic fines can reduce egg and embryo survival rates and impede fry emergence. These changes in stream conditions can cause adverse impacts in aquatic habitat suitability, species composition, and aquatic biomass production.

As part of the Bear River watershed analysis, a sediment budget was prepared as a quantitative accounting of estimated sediment delivery to streams for the period from 1988 through 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 Bear River 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 5-1 shows the annual sediment delivery 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 CFPRs in 1974. These legacy practices are no longer used and include many 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 1988-2003 Bear River sediment budget is designed to assist in identifying significant sources of past sediment delivery and to assess the extent to which these sources were associated with land use. Where management-associated delivery is found to be significant, relative to background (i.e., natural), 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 erosion control management 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; and Bank erosion.	Landslides from untreated abandoned roads; Hillslope landslides from older tractor yarded units (15-30 year old partial cut) and 20-30 year old clearcut); Small streamside landslides; Surface erosion from untreated abandoned roads; and Bank erosion.	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; and Bank erosion.

Figure 5-1. Annual sediment budget for sub-basins in the Bear River WAU for the period 1988-2003.

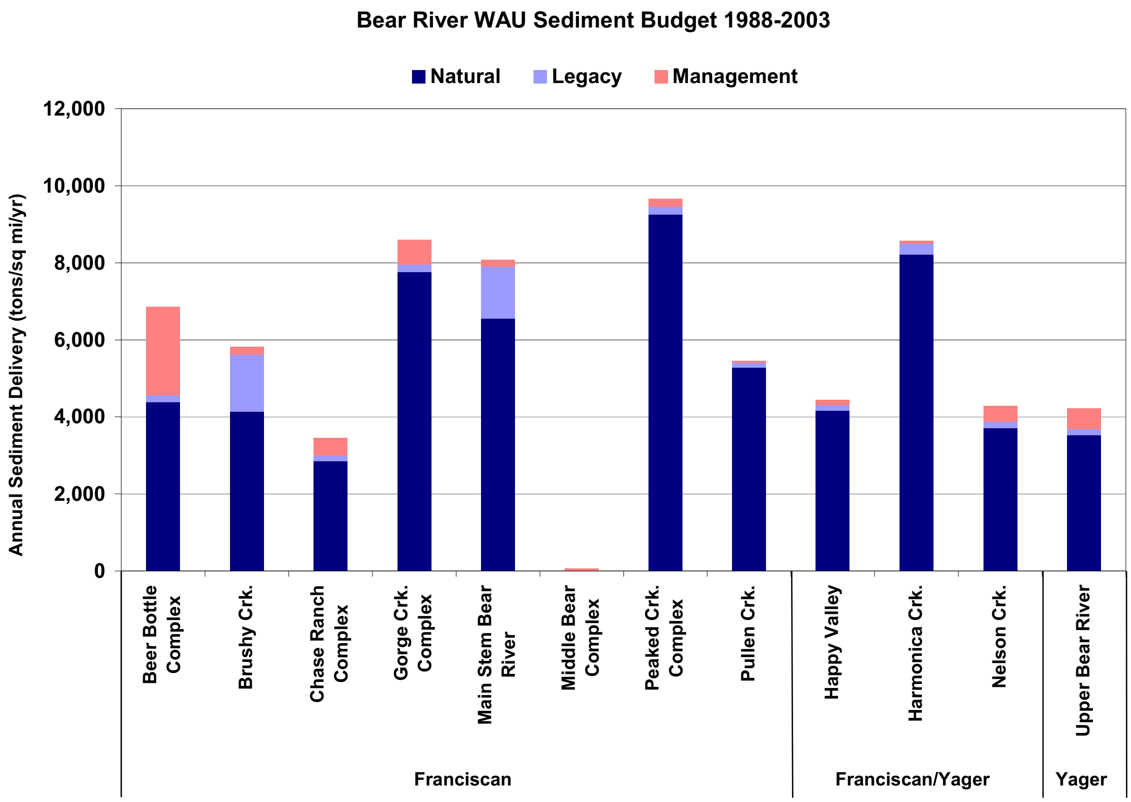
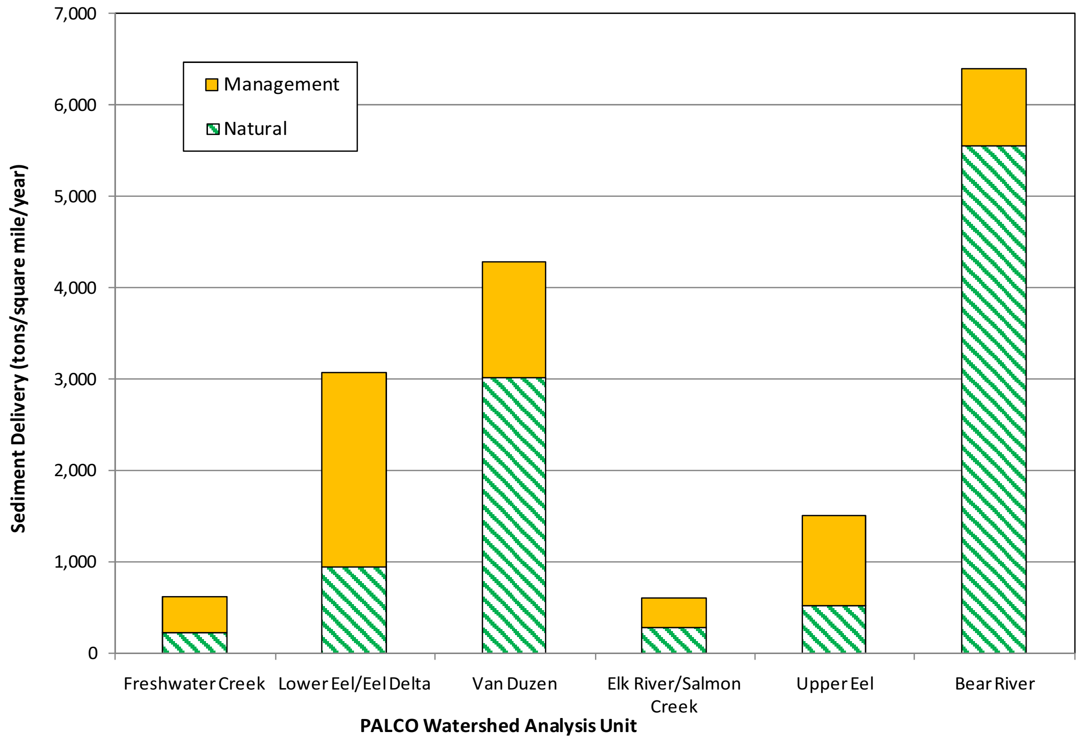


Figure 5-1 illustrates the extent to which 'natural' sources control sediment input to the Upper Bear River watershed, as well as the proportion to which contemporary delivery originates from lingering legacy effects versus more recent management activities. For comparison, Figure 5-2 shows HCP watershed analysis-derived sediment delivery rates for portions of other watersheds owned and managed by PALCO for the same or similar time period. Different rates are a result of these watersheds varying from one another with regard to composition of the bedrock, proximity to faults and earthquake zones, topography, precipitation and climate, and harvest history. In general, the results show substantially higher contributions from the Bear River area as compared to other watersheds, with notably larger contributions from natural sources. This observation is expected based on the significance of contributions from large landslides in the Bear River HCP area, which account for the vast majority of the total sediment delivery volume from all sources in the 1988-2003 sediment budget.

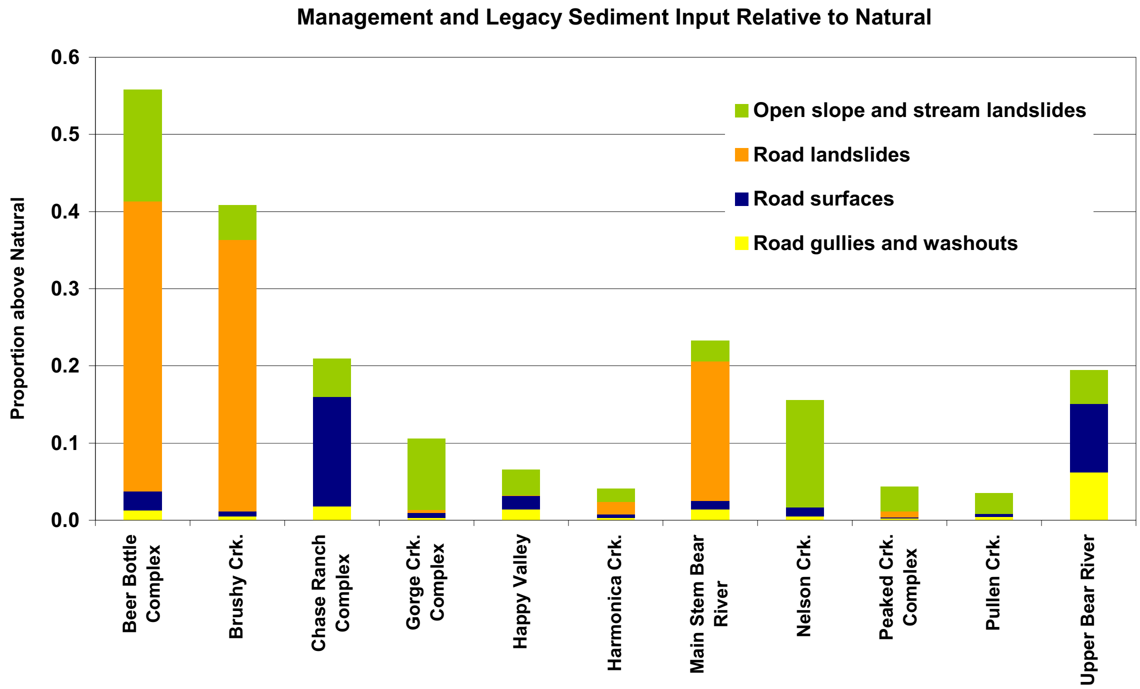
Figure 5-2. Annual Sediment Delivery for HCP Lands Analyzed within the PALCO Watershed Analysis Units



Note: Sediment delivery from older (legacy) sources are included in the management category shown.

Figure 5-3 shows management and legacy-related sediment sources expressed as a proportion above ‘background’ or ‘natural’ sources. (A value of one indicates that management plus legacy sediment is the same magnitude as the estimated natural baseline rate.) This figure facilitates comparison of the relative level and management associations of excess sediment among the Bear River sub-basins (HCP lands only).

Figure 5-3. Relative importance of management-related and legacy sediment sources by sub-basin in the Bear River WAU (HCP lands).

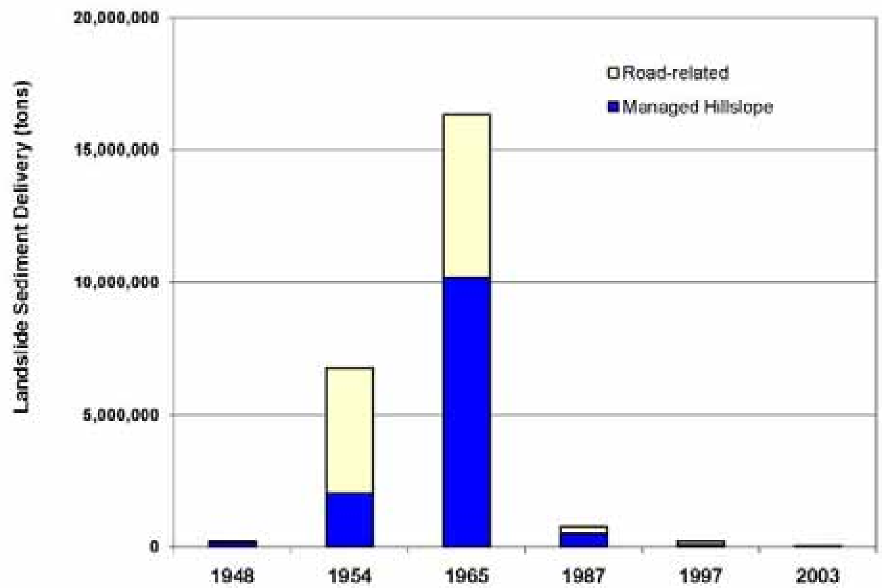


Seven out of the eleven sub-basins analyzed were reported to have an overall management- and legacy-associated sediment delivery rate of less than 20 percent over background for the 1988-2003 time period. Beer Bottle exceeds 50 percent and Brushy Creek 40 percent. With the exception of the Nelson Creek and Gorge Creek Complex sub-basins, roads were identified as the primary management-related sediment source for all sub-basins. Another key finding is that regardless of road or harvest area association, large to very large landslides, rather than numerous small ones or surface erosion, are responsible for the vast majority of sediment delivery linked to forestry operations. Four large road-associated landslides drive the sediment delivery shown for the Beer Bottle, Brushy Creek, and Mainstem Bear River sub-basins, with the largest of these slides delivering an estimated 36,000 cubic yards in the 1988 to 1997 photo analysis period. A similar situation exists with the open-slope, harvest related landslides, with two landslides in the Beer Bottle Complex, two in the Gorge Creek Complex, and one in Nelson Creek responsible for the vast majority of sediment delivery in this category. Relative to the other sub-basins, fine sediment delivery from road surfaces is high in the Chase Ranch Complex and Upper Bear River sub-basins. For the Chase Ranch Complex sub-basin, this results from the fact the Bear River mainline runs through the sub-basin and, therefore, road use is very high. While the mainline is a rocked road, there are numerous Class II and III stream crossings, increasing the likelihood for delivery. In the case of the Upper Bear River sub-basin, the road system is primarily native surfaced, with a portion of it used nearly year-round by inholding landowners who have deeded access pre-dating the HCP, in addition to mostly seasonal use for forest management operations. Again, numerous stream crossings and sections of road adjacent to Class I watercourses, including the upper Bear River, increase the potential for sediment delivery to streams. Significant sediment delivery from road surfaces or failing crossings has the highest potential for occurrence on roads that have not yet been fully upgraded, storm-proofed, or decommissioned, but even after this work is done, routine inspections and maintenance are required to minimize sediment delivery (Photo 5-2).

Photo 5-2. Mainline Road Approaching Bear River Bridge.

Landslides, particularly large landslides, have historically been a dominant source of sediment in the Bear River watershed. The watershed experienced an especially large influx of sediment from landslides in response to intensive early post-World War II (WWII) logging operations and the large, geomorphically-significant storms of 1955 and 1964 (Figure 5-4). Additional discussion related to harvest history and historic logging practices contributing to this ‘spike’ in delivery is provided in Section 4.0.

Figure 5-4. History of Landslide Sediment Delivery on Bear River HCP Lands by Photoperiod and General Land Use Association.



Harvested hillslope and road-related landslides were a major contributor of sediment in the 1954 and 1965 air photoperiods, but have since declined significantly (Figure 5-4). During the 1965 photoperiod, landslides with management (and legacy) associations delivered 11 million cy of sediment input (89% of total sediment delivery for the 1965 photoperiod) (Photo 5-3). Subsequently, during the sediment budget period (1988-2003), management contributions dropped to less than 150,000 cy (17% of the total sediment delivery for this period).

Photo 5-3. Bear River and Exposed Bedrock from mid-1960s Landslide Downstream of Gorge Creek.

The decrease in the overall landslide delivery rates may reflect less impacting management practices after adoption of the CFPRs and the HCP (PALCO, 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 important to note despite the record-breaking December 2002 storm which established the largest single day rainfall (6.8 inches) measured in the 118 years of record at Eureka and broke 9 of 17 rainfall records reported by the National Weather Service for Eureka, including maximum 12-hour, 24-hour, 5-day, and 1-month rainfall depths (Sullivan and Dhakal, 2005). This storm far exceeded rainfall thresholds expected to trigger landslides, and was larger than the 1964 and 1955 storms in this regard. In contrast to the large volume of landslide delivery from the 1955 and 1964 storms, the small sediment delivery response from the 2002 storm indicates significant benefits from implementing improved management practices.

Inner gorges (regardless of slope) are by far the most susceptible landform in the assessment area, accounting for 92 percent of the landslide sediment delivered to streams. The topographic setting of the watershed is characterized by deeply incised, narrow stream canyons, so inner gorge slopes are common within the assessment area. Debris sliding is the most common landslide mechanism, representing up to 99 percent of documented mass wasting. The strong correlation between debris slides on inner gorge slopes with sediment delivering mass wasting features results from the highly incised topography caused by high rates of tectonic uplift (Merritts et al., 1992); the inner gorge slopes can extend several hundred feet upslope from stream channels, with significant sediment contributions originating from farther than 400 feet from streams (Photo 5-4).

Road-related mass wasting associations are relatively few in terms of frequency in part because steep topography constrains much of the road network to ridge top settings with low failure and limited sediment delivery potential. However, as noted above, some of these road failures have delivered significant volumes of sediment, particularly in the Beer Bottle Complex, Brushy Creek, and Main Stem Bear River sub-basins.

The mass wasting analysis indicates significant landslide delivery in the sub-basins of Harmonica Creek (30% of the total for the 1988-2003 sediment budget period), the Gorge Creek Complex (18% of the total), and the Main Stem Bear River (13% of the total). The other sub-basins exhibit a relatively even, lower distribution of landslide volumes delivering to streams. Most of the landslide delivery in the Harmonica Creek sub-basin results from large, natural landslides on inner gorge slopes, occurring primarily on Coastal terrane bedrock and Yager terrane.

Photo 5-4. Large 1997 Landslide Downstream of Beer Bottle Creek.

5.2 RIPARIAN FORESTS

Riparian areas are transition zones between terrestrial and aquatic ecosystems and provide important ecological functions, including temperature regulation and input of LWD, organic matter, and nutrients (Gregory et al., 1987). 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. These processes may be lost or degraded as riparian vegetation is altered in size, density, or species composition (USDA, 1995).

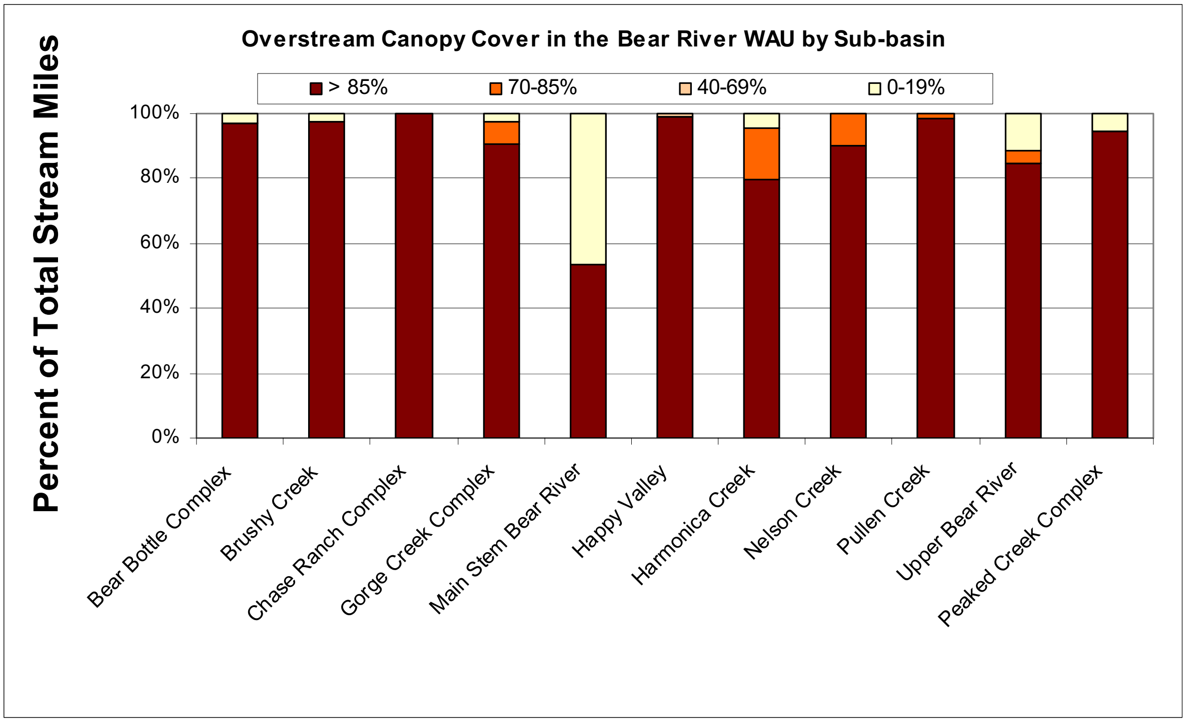
The Riparian Function Assessment for HCP lands in the Bear River WAU (Appendix C) characterizes existing riparian key habitat elements and compares results to PFC targets. The assessment focuses on LWD and canopy shade function, but also acknowledges other criteria that define PFCs. The greatest constraints on riparian forest management will likely be imposed by the need to provide LWD to both the stream channel and the forest floor. The maintenance or achievement of PFCs for the purpose of aquatic and terrestrial LWD recruitment are assumed to provide adequately for these other criteria as well, such as a cool micro-climate, bank stability, sediment filtration, and terrestrial riparian habitat diversity.

To determine the current and future LWD recruitment functionality and micro-climate value of riparian areas in the HCP lands, the stand type (based on predominant tree species), tree size, canopy closure, and overstream canopy cover were assessed using field-verified air-photo analysis (see Appendix C for detailed methodology, Figure 5-5 for overstream canopy cover results by sub-basin). The assessment area included 100 feet on each side of the bankfull channel, or channel migration zone (CMZ) if present, of Class I and II streams, but did not include isolated seeps and springs or ephemeral Class III watercourses. The Bear River HCP lands contain approximately 2,915 acres of riparian forest within 100 feet of Class I and II watercourses. Segments with similar characteristics are termed riparian condition units (RCUs). In the Bear River HCP area, the RCUs ranged from 500 to 4,000 feet in length. Field verification of RCU classifications was conducted on randomly selected groups of RCUs totaling approximately 13 percent of the RCU acres. Field verification included qualitative assessments and quantitative standard forest mensuration measurements (see Appendix C for methods and variables measured).

Retention and promotion of stream side and overstream shade canopy is a vital aspect of riparian forest management necessary for controlling stream temperatures, providing litter and invertebrate fall, and maintaining streambank cohesion. Current ***overstream*** canopy cover conditions on HCP-covered lands are presented in Figure 5-5. In general all but the largest streams (Bear River [Photo 5-5] and lower Harmonica Creek) are well shaded.

Photo 5-5. Exposed Reach of Bear River Upstream of Mainline Bridge.

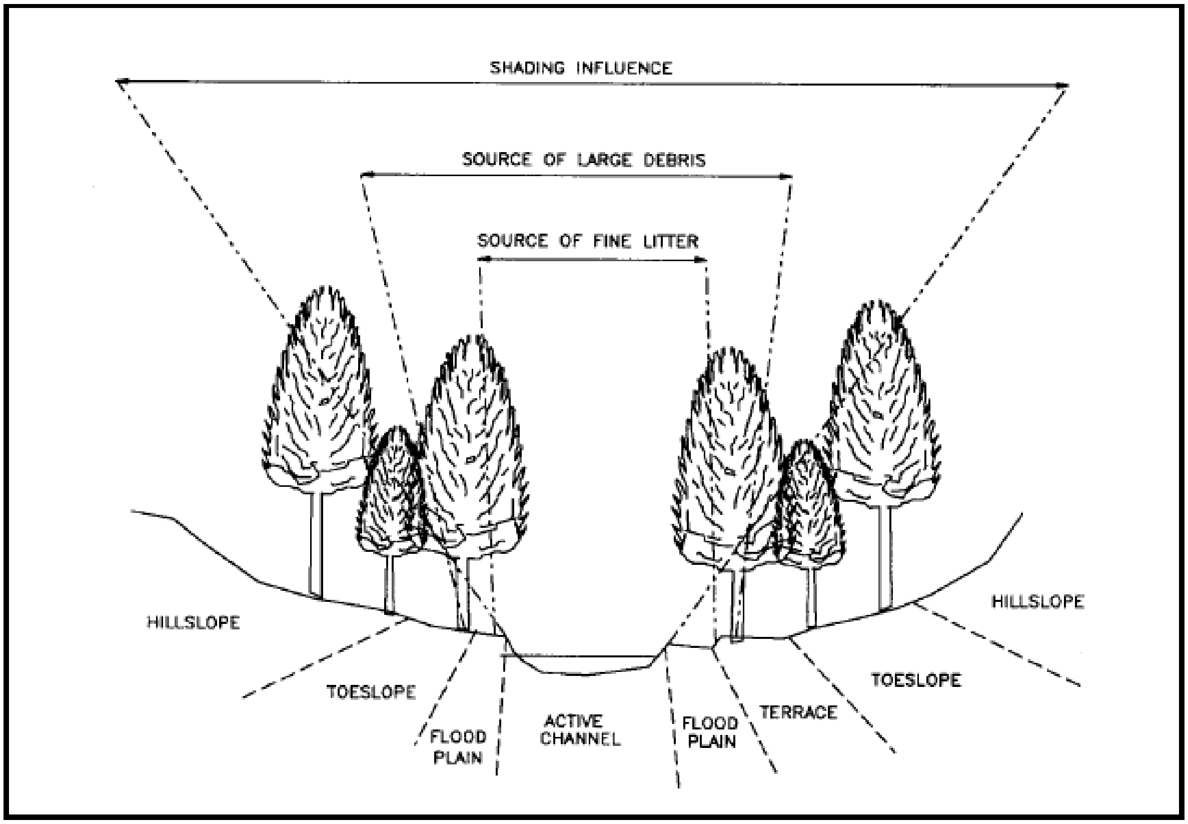
Figure 5-5. Overstream Canopy Cover by Sub-Basin



Source: Figure C-7, Riparian Function module.

Ongoing recruitment of LWD to stream channels is an important function of riparian forests (Gregory et al., 1987). Trees growing near the stream die through natural mortality processes, and some that fall will enter the channel where they direct flow and create hydraulic diversity within the channel, thus improving fish habitat (Figure 5-6). The probability of a tree falling into the channel diminishes with distance from the channel with most woody debris recruitment from tree fall originating within 20 meters of the stream channel (Murphy and Koski, 1989; Robison and Beschta, 1990; McDade et al., 1990; Reid and Hilton, 1998). In addition to LWD recruitment from mortality processes or wind effects, other LWD is delivered from landsliding adjacent to streams and bank erosion (Photo 5-6).

Figure 5-6. Functional Roles of Riparian Zones



(Source: Lamberti and Gregory, 1989)

For trees to affect habitat within streams, they must be large enough relative to channel dimensions to significantly deflect stream flow (Bilby and Ward, 1989). Ongoing recruitment from the adjacent forests is required through time since woody debris is also transported out of a stream reach through fluvial processes and decay. Conifer species are generally preferred, because they tend to be larger and have significantly greater longevity within the stream (Grette, 1985). The goal of riparian area management is to maintain forests that naturally sustain LWD of sufficiently sized wood within the channel through time. The characteristics of forest stands within the riparian area will determine the type, size, and rate at which LWD may be replenished (Murphy and Koski, 1989; Benda et al., 2002; Welty et al., 2002).

Photo 5-6. Bank Erosion with Delivered LWD and Sediment

Conifer-dominated forests of large size and high stand density are capable of recruiting LWD through natural mortality in the short term. Stands of this nature are likely to perpetuate through time with old growth stand dynamics eventually dominated by individual tree replacement of widely spaced trees (approximately 30 per acre, PALCO, 2004). Large woody debris recruitment is potentially greatest in even-aged conifer stands of approximately 60 to 120 years of age, when trees are relatively large and stands are naturally self-thinning resulting in mortality (Lindquist and Palley, 1967). Conversely, hardwood-dominated stands have low recruitment potential in the near and long-term future.

Though the transition of a hardwood-dominated stand to a conifer-dominated stand may eventually occur, LWD recruitment to adjacent streams may ultimately be impaired for several hundred years (Murphy and

Koski, 1989; Welty et al., 2002). Mixed hardwood–conifer stands may transition to conifer-dominated stands if understory growth of conifers beneath the hardwood overstory is sufficient. In this case, adequate LWD recruitment may occur, but will require a fairly lengthy time frame. Examination of mixed hardwood–conifer stands is necessary to determine whether there is sufficient conifer undergrowth for conversion to a conifer-dominated stand to occur naturally over time. If species conversion is desired where such understory conditions do not exist, species manipulation is required.

Large woody debris recruitment potential was categorized as high, moderate, or low based on RCU stand type (dominant tree species), tree size class, and stand canopy closure (Table 5-2) and assigned one of the three categories to all RCU acres in the Bear River HCP area. High LWD recruitment potential was assigned to RCU areas that met PFC matrix targets for canopy closure (moderate to dense), stand type (conifer- or mixed conifer–hardwood-dominated), and tree size class (mean tree DBH >24 inches). Moderate LWD recruitment potential was assigned to RCU areas that currently did not meet those PFC targets, but had some current LWD delivery potential trending toward, and likely to achieve, the desired PFC condition within the 50-year life of the HCP. Low LWD recruitment potential was assigned to RCU areas that did not meet PFC targets and, due to hardwood dominance and/or low stocking levels, are not likely to reach PFC target conditions within the 50-year life of the HCP.

Table 5-2. LWD Recruitment Potential Categories (H = High; M = Moderate; L = Low) as defined by RCU Stand Type, Tree Size Class, and Canopy Closure.

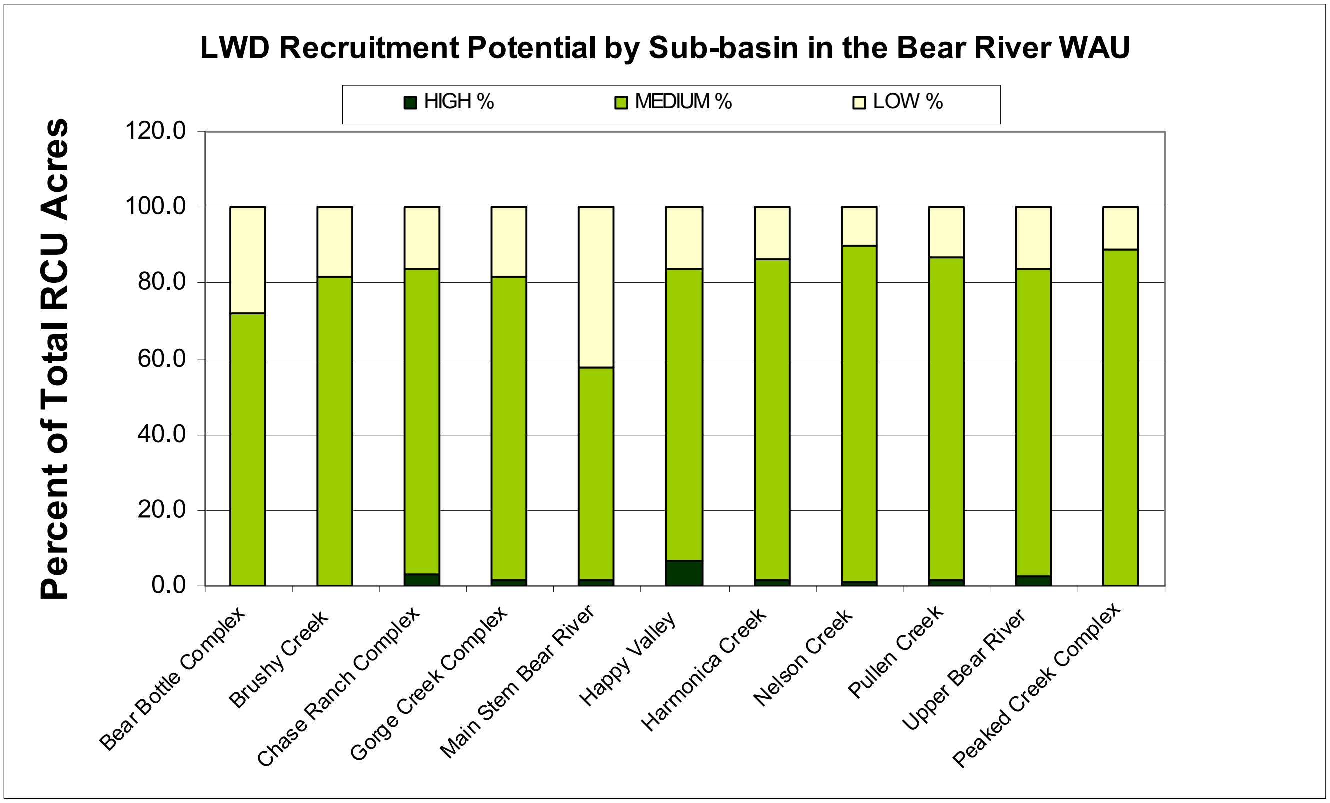
Stand Type	Medium to Large Trees		Small Trees		Sapling/Pole Trees	
	Dense Canopy	Sparse Canopy	Dense Canopy	Sparse Canopy	Dense Canopy	Sparse Canopy
Hardwood	M	L	L	L	L	L
Conifer	**H**	M	M	L	M	L
Mixed Hardwood–Conifer	**H**	L	M	L	M	L

Riparian habitat on HCP-covered lands typically consists of relatively evenly mixed conifer–hardwood stands (72% of total riparian acres). Hardwood-dominated stands with little conifer component account for approximately 18 percent of riparian acres, while pure conifer stands (mainly Douglas-fir) with little hardwood component account for only about 10 percent. Regardless of species composition, most of these stands are populated by trees with DBH ranging from 11 to 24 inches. Stands where the average tree diameter exceeds 24 inches occupy less than 10 percent of the total riparian assessment area. Over 90 percent of Class I and II riparian stands within the Bear River HCP area have moderate to dense canopy closure, with the remainder of the acres classified as sparse, mainly due to the presence of naturally-occurring prairies in several of the higher Class II reaches or sparsely vegetated inner gorge slopes along Class I streams.

The RCU type MMD (mixed conifer–hardwood stand, small trees, moderate/dense canopy) represented over 63 percent of all riparian habitat on Bear River HCP lands (Photo 5-7), and no other RCU type represented more than 12 percent (hardwood stand, small trees, moderate/dense canopy [HMD]) of total riparian habitat.

Less than 2 percent of Bear River HCP RCU acres were classified as currently meeting PFC targets and having high-value LWD recruitment potential (Figure 5-7); the sub-basins with the highest proportions of high LWD recruitment potential are Happy Valley, Chase Ranch Complex, and Upper Bear River. Nearly 80 percent of the RCU acres were classified as moderate, that is not currently meeting PFC targets but trending towards and likely to achieve the targeted riparian condition within the next 40 years as trees continue to grow (Table 5-3, Photo 5-8). The remaining 18 percent of RCU acres were classified as having low LWD recruitment potential; the sub-basins with the highest proportions of low LWD recruitment potential are Main Stem Bear River, Beer Bottle Complex, and Brushy Creek. A similar distribution of LWD recruitment categories was found by stream class (Table 5-3), planning watershed (Appendix C, Figure C-3) and by sub-basin (Appendix C, Figure C-4).

Figure 5-7. Percent of LWD Recruitment by Sub-basin in the Bear River WAU



Source: Figure C-4, Riparian Function module.

Table 5-3. Number of Class I and Class II Stream RCU acres by LWD Recruitment Potential Category, Bear River HCP Lands.

Recruitment Potential	Class I	Class II	Total
Low	125	419	544
Moderate	602	1,713	2,314
High	6	44	50
Total	733	2,175	2,908

Photo 5-7. Common Douglas-Fir/Tanoak Streamside Forest Type.

Photo 5-8. Stocked but Undersized Riparian Forest Type.

5.3 CHANNEL RESPONSE

A total of approximately 18 miles of stream channel with less than 4 percent gradient were delineated on HCP-covered lands in the Bear River watershed. These low gradient 'response' reaches contain the highest quality fish habitat and are located along the Bear River mainstem and in the lower reaches of major tributaries such as Harmonica Creek, Nelson Creek, and Pullen Creek. Historical aerial photographs suggest that channel migration is generally limited to the lower gradient reaches of these major tributaries, and the mainstem Bear River where the valley bottom width significantly exceeds channel width (Map D-3). Outside of these mapped reaches, the upper Bear River system is generally not capable of storing excessive quantities of sediment for long periods due to moderate to steep channel gradients and/or narrow bedrock configuration of valley bottoms – in other words, the channel network is geared towards sediment transport. These transport reaches were observed to be at bedrock or actively incising through alluvial material and frequently exposing bedrock.

Unconfined, low-gradient reaches can respond quickly to changes in sediment, wood, and water, with channel migration occurring relatively quickly on the order of several years. Significant changes in pool characteristics can occur within a single year, in response to storm events and associated peak flows. In smaller basins, pools are often associated with LWD, where (based on field observation) bank erosion and streamside landsliding are the primary sources of LWD key piece delivery. Wider channels (in larger basins) lack LWD in general as wood can easily be transported during high flows; a simple relationship was observed whereby LWD appears to decrease logarithmically with increasing drainage area.

Bear River and Harmonica Creek (Photo 5-9) have been actively flushing sediment (net loss of stored sediment) as a general trend over the last 20 years (1984-2003). There has been relatively little change in total channel length over this time period for three specific reaches studied using historical aerial photographs, with a small amount of channel lengthening observed in the mainstem and a slight reduction in channel length of the studied reach in Harmonica Creek. Channel lengthening typically occurs in response to increases in sediment supply, while shortening occurs when supply decreases (Pazzaglia et al., 1999). This relative balancing is consistent with the findings of the Mass Wasting Assessment (Appendix A) showing significant declines in sediment delivery following the large spike of the 1950s and 60s.

Despite an overall net loss (mobilization and downstream transport) of an estimated 5,500 cubic yards of sediment in Harmonica Creek from 1984 to 2003, ATM data for 2003-2004 indicate a period of recent localized aggradation at the ATM site. The sediment budget, as depicted in Figure 5-1, shows Harmonica Creek with one of the higher annual sediment delivery rates for the 1988-2003 period (8,000 tons/mi^2/yr), the vast majority which was contributed from 'natural' landslides (i.e., not linked to roads or contemporary harvest activities) (Photo 5-10). Incision through this aggraded reach is occurring and it is likely the condition is temporary in nature (Photo 5-11).

No significant differences were observed relative to Yager versus Franciscan bedrock with respect to their resistance to fluvial erosion. Details regarding conditions and processes relative to sediment storage and transport are provided in Appendix D.

Photo 5-9. Harmonica Creek, 2 to 4 Percent Gradient.

Photo 5-10. Streamside Mass Wasting along Harmonica Creek.

Photo 5-11. Harmonica Creek Gravel Bar with Evidence of Incision and Recent Transport.

5.4 FISH HABITAT

Instream fish habitat conditions naturally vary throughout a watershed dependent upon basin size, geology, LWD load, and stream gradient. Channel gradient is a useful basis for delineating streams to assess response to watershed inputs such as sediment and wood, and the general condition of fish habitat (Montgomery and Buffington, 1993). The 2005 aquatic habitat surveys focused primarily on stream reaches with gradients ranging from 0 to approximately 4 percent. These reaches can be considered "response reaches" as defined by Montgomery and Buffington (1993). ATM stations are likewise located in "response reaches". While it is known that salmonid species do occupy streams steeper than 4 percent (termed transport reaches by Montgomery and Buffington [1993]), the lower gradient reaches are the locations where sediment and wood accumulate to form the best and most abundant habitats for spawning and rearing. The condition of the response reaches in natal tributaries is crucial to the general viability of a population of anadromous salmon during their freshwater life history phase.

Analysis of the in-stream habitat and LWD inventory (2005 modified CDFG stream habitat surveys), 2005 electro-fishing ("Last Fish") surveys, multi-year ATM stations, and past 1996 CDFG stream surveys provides some understanding of summer and winter in-stream habitat conditions on HCP-covered lands relative to the NOAA Fisheries Preferred Functioning Conditions (PFC) matrix. Detailed data from these field studies are tabulated in the Stream Channel Assessment (Appendix D) and the Fish Habitat Assessment (Appendix E).

5.4.1 Spawning Habitat

Chinook typically conduct their spawning migration in late summer to late fall utilizing low gradient floodplain reaches where the channel is of an alluvial nature and typically unconfined by valley walls. This constrains their spawning habitat to reaches downstream of HCP-covered lands, primarily from the mouth of Bear River (Photo 5-12) to the mouth of West Side Creek, including larger tributaries such as the South Fork Bear River. Extensive gravel deposits associated with an aggraded stream channel condition provide spawning opportunity in these lower reaches.

Photo 5-12. Lower Bear River near the Pacific Ocean.

Further upstream, HCP-covered lands provide abundant spawning size gravels for winter-run steelhead and resident rainbow trout (Photos 5-13 and 5-14). While steelhead spawn in late winter in the mainstem and lower reaches of larger tributaries such as Harmonica Creek, Nelson Creek, and Pullen Creek, resident rainbow trout are essentially spring spawners (mid-April to late June) and utilize smaller gravel sizes and smaller tributaries as well as the headwaters of the mainstem.

CDFG stream surveys conducted from 1996 to 2000 on HCP lands reported fair to good spawning habitat conditions for the mainstem and all tributaries surveyed except for Nelson Creek, Brushy Creek, and an unnamed tributary. More recent surveys found similar results. While much of the spawning substrate in the mainstem Bear River near ATM station 1 (RM 20-21.4) was highly embedded, well-sorted gravel pockets suitable for steelhead spawning were found to exist trapped behind larger substrate (i.e. boulders and cobbles). Further upstream (RM 25.2-26.6) in the vicinity of ATM station 97, ample high quality spawning habitat with abundant appropriately sized gravel exists. Bulk substrate samples taken at ATM station 97 showed the substrate to be not embedded and, therefore, in a condition which allows for a relatively high egg-through-emergence survival rate. Steelhead and resident rainbow trout were observed in abundance in this area. Spawning gravels were abundant and of ideal size for steelhead in Harmonica Creek and Pullen Creek, with the majority of spawning substrate sampled at ATM stations found to be unembedded as well.

Photo 5-13. Upper Bear River on HRC Ownership.

Tributaries where spawning habitat conditions were less optimal include Nelson Creek, Brushy Creek, and Gorge Creek. While suitable spawning gravel exists in Nelson Creek, substrate size in general was often found to be too large and/or embedded, thus limiting spawning opportunities. Gorge Creek was similar in that most substrate is simply too large (Photo 5-15), as smaller substrate material is quickly transported downstream out of the tributary due to its incised and steep gradient nature. The pockets of smaller gravel that do exist in Gorge Creek are more suited to resident rainbow trout. Brushy Creek has an abundance of appropriately sized spawning gravels but they are highly embedded with fine sediment. The current condition in Brushy Creek is likely linked to a very large landslide which occurred in its headwaters in 1997 (Photo 5-16).

Photo 5-14. Pool Tail-Out and Suitable Spawning Habitat.

Photo 5-15. Gorge Creek.

Photo 5-16. Landslide Deposition in Lower Brushy Creek.

Another factor potentially limiting the distribution of suitable spawning substrate is the amount of in-stream LWD in certain tributaries, as spawning substrate is often captured behind key-piece formations. However, an overall abundance of spawning habitat is available for fish use in the Bear River watershed. Continued road maintenance and reduction of fine sediment delivery, particularly from the contemporary road system, is important for maximizing the value of this spawning habitat.

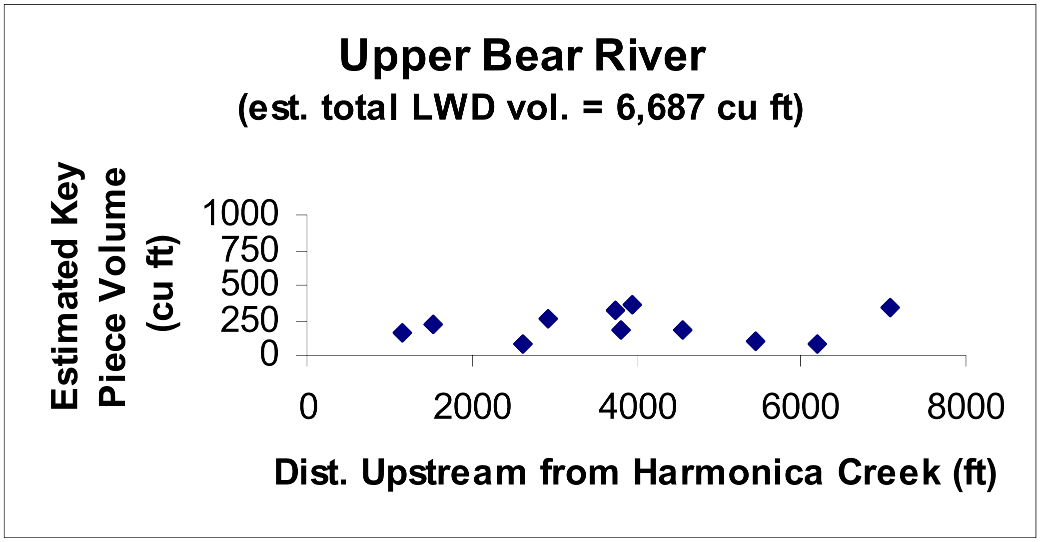
5.4.2 Large Woody Debris

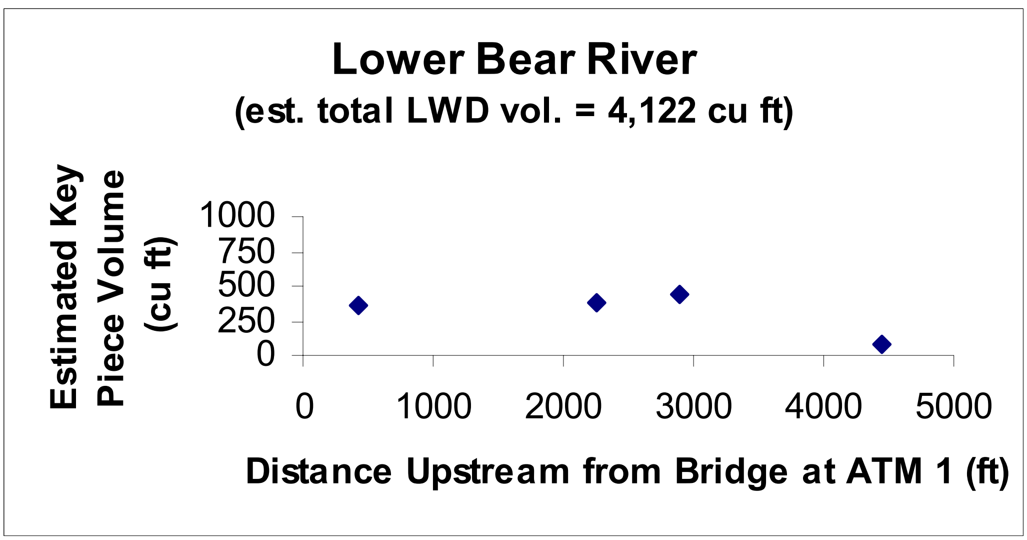
Large woody debris is scarce in the Bear River mainstem downstream of the mouth of Brushy Creek, but increases significantly moving upstream as channel width and basin area decrease. The recruitment of woody material from hillslopes and riparian areas is critical to pool development and quality. The formation of independently stable (key) pieces capable of capturing other woody debris is a function not only of the availability of wood material but also the suitability of the channel to store this material. In the case of wide channels with high peak flows, key piece formation can be problematic. In Bear River, where bankfull channel width is relatively great (such as a lower Bear River width of 44 ft), it is unlikely that woody debris will form key pieces that in turn can contribute to pool formation. So, while LWD recruitment in low order tributary drainages may be high, little LWD is likely to be stored in the mainstem (Photo 5-17).

Photo 5-17. Bear River Approximately 20 Miles from the Mouth.

Figure 5-8 illustrates the key LWD piece volume and location in the main channel of two discrete 2005 Bear River survey reaches (Appendix E; map E-15 for survey locations). The upper Bear River reach surveyed appears to contain nearly double the number of key pieces and greater than 50 percent more LWD volumetrically (Photo 5-18) than the lower Bear River reach. Overall, wood volumes are low in the mainstem when compared with most tributaries. ATM data indicate that, while fluctuating from year to year, LWD density decreases moving downstream (Figure 5-9), consistent with the findings of the 2005 stream surveys.

Figure 5-8. Bear River Estimated Key Piece Volume Distribution Along Survey Reaches.

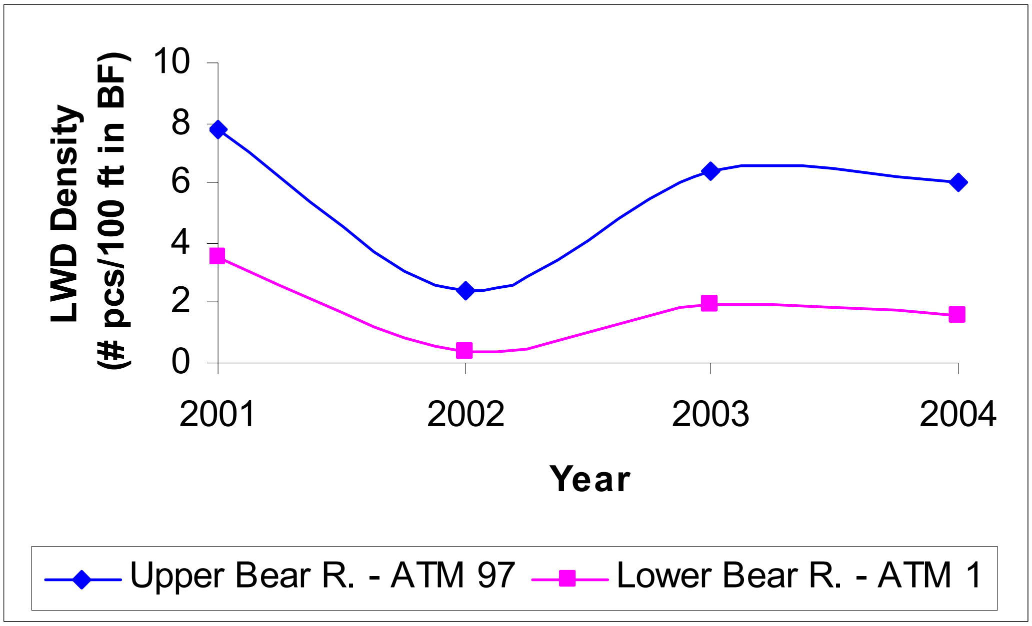




Source: Figure D-7, Stream Channel module.

Photo 5-18. Bear River Approximately 26 Miles from Mouth.

Figure 5-9. LWD Density from Bear River ATM Station Data.



Source: Figure D-8, Stream Channel module.

LWD is generally lower in the Bear River mainstem relative to its tributaries due to greater channel width, higher flows, and a general lack of alluvial sediments. These factors combine to inhibit LWD from forming key pieces in the mainstem, instead resulting in flushing of LWD downstream.

Trends in LWD density suggest that fluctuations can be large from year to year in response to peak flows associated with storm events mobilizing wood. The decrease in LWD density from 2001 to 2002, however, is not due to flushing from the 2002 storm because that storm would register in the 2003 data. Conversely, the increase in LWD density from 2002 to 2003 may be due to the 2002 storm event, an inference that is supported by LWD density data for tributary channels, indicating transport from upstream reaches and recruitment from hillslopes resulting in higher LWD density.

Large woody debris recruitment rates are expected to be highest in steep and moderate gradient reaches (tributary streams) due to the prevalence of bank erosion and landslides that deliver sediment and wood to these channels in response to large storm events. Based on field observations, streamside landslides appear to be the primary source of LWD. Primary LWD source areas likely include riparian timber stands and steep (inner gorge) slopes (>65%) with direct delivery potential to a watercourse.

Channel confinement in smaller basins undoubtedly contributes to the formation of key pieces and accumulation of fine sediment behind these obstructions to flow. As wood becomes lodged against bedrock constrictions or spans the bankfull width of the channel, it is capable of trapping sediment and other LWD, and forming pools. In addition, greater quantities (volume and density) of LWD could contribute to an increase of fine particles in stored sediment as was observed in some channels such as Pullen Creek (e.g., at ATM station 134 from 2002 to 2004). Greater LWD density in Pullen Creek relative to Harmonica Creek during the 2002 to 2004 period may also explain the higher absolute values of fine particles observed in Pullen Creek over the same time period. The relative absence of LWD in the largest tributary, Harmonica Creek, is due to processes similar to those described for the mainstem – high winter peak flows capable of flushing LWD in combination with a wide valley bottom that tends to prevent LWD from spanning the channel or lodging into banks. Mid-twentieth century logging, which removed the majority of large trees adjacent to streams, has also reduced LWD recruitment as large timber which historically would have provided greater and longer lasting in-stream function is currently less available. The lack of LWD in Harmonica Creek is also consistent with recent survey data showing incision and mobilization in that system from the substantial hydraulic power of the stream.

The rate of landsliding and sediment delivery to channels in the HCP area has decreased dramatically over the last 30 years (see Appendix A) perhaps resulting in lower levels of LWD recruitment more recently. While natural landsliding processes will continue to serve as an ongoing source of LWD, future recruitment of pieces from landsliding may be less if the trend towards lower rates of mass wasting continues. However, piece size should increase as forestry prescriptions favor the retention and promotion of streamside forest growth.

Similar to mainstem Bear River data, sharp and synchronous increases in LWD density in Harmonica and Pullen Creeks suggest a 2002 storm origin. Peak flows likely mobilize and transport existing in-stream LWD as well as influence hillslope processes leading to new recruitment. The gradual post-storm decrease in LWD density further suggests that the storm-related influx of LWD has a short residence time in the system (on the order of 3 years).

The key piece volume average surpassed the PFC targets in all seven stream reaches surveyed by SCOPAC in 2005, with the exception of Harmonica Creek; however, all reaches failed to meet the PFC targets for number of 'key pieces per 100 feet' or 'key piece per channel width' targets[1]. None of the response reaches surveyed met the PFC target for the number of pools associated with wood. At 43 percent, the upper reach of the mainstem Bear River was the closest to the PFC target (>50%), while the lower Bear River reach survey recorded no pools (0%) associated with LWD. ATM station data, in contrast with the reach-length 2005 stream survey data, cover much shorter stream reaches and depict a large number of Harmonica Creek and Pullen Creek pools associated with LWD (meets PFC matrix) for the two reaches monitored, similar to the proximal upper Bear River reach, suggesting that LWD is important for pool development as stream size decreases. Field observations made by the fisheries biologist and stream channel analyst conducting the fish habitat and stream channel assessments support the general finding that there is not an abundance of wood in the upper Bear River or most of its tributaries, but what is there and recorded under current methodologies functions to create pools and entrap sediments including spawning habitat substrates (Photo 5-19).

As mentioned previously, in addition to channel geomorphology, this condition of apparent sub-optimal LWD loading is attributed in part to the extensive streamside harvesting that occurred in the late 1940s through the 1960s. Little harvesting occurred on the ownership in the 1970s and 1980s, and new state-regulated forestry practices limiting streamside harvest were in place when timber operations increased in the 1990s from the earlier low levels.

While the riparian function assessment (Appendix C) reports few riparian stands currently with high value LWD recruitment potential as a result of earlier land use, most riparian stands are currently well-stocked with moderate-sized trees (12- to 24-inch DBH) including a significant conifer component; reliable growth projections suggest these stands will attain properly functioning LWD recruitment values in 20 to 40 years. While pool frequency and overall area is at or near PFC matrix objectives for most streams despite sub-optimal LWD loading, opportunity for improved LWD-associated pool habitat certainly exists

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[1] It is important to note that LWD key piece counts may be biased low in these surveys due to the key piece definition used in the survey methodology. The PFC criterion, adopted for the survey methodology, states that all pieces must be 'independently stable'. This effectively eliminated the recording of any piece of wood partially buried in the banks of the channel. This can amount to a significant reduction in the total key piece count particularly in the Bear River drainage where the geology is weak and the bank slopes are oversteepened due to tectonic activity. This leads to mass wasting events causing the majority of wood to be recruited into the channel by landslides. Much of this LWD may still be partially buried, but providing significant hydraulic function. In addition, LWD volumes were reported lower than actual due to field measurement errors on rootwads.

and may occur as forests mature and LWD is recruited. Current HCP forestry practices promote expediting Class I riparian forest growth through thinning from below silvicultural methods, and preclude harvest of streamside trees exhibiting LWD recruitment value.

Photo 5-19. Nelson Creek Plunge Pool.

Harmonica Creek, Pullen Creek, Nelson Creek, Brushy Creek, and Peaked Creek, as well as several unnamed tributaries and the upper Bear River mainstem (RM 25.2 to 26.6), were all identified in Appendix E as containing response reaches where fish habitat would benefit now from additional in-stream LWD. Harmonica Creek is considered a priority stream for future LWD-associated fish habitat enhancement projects.

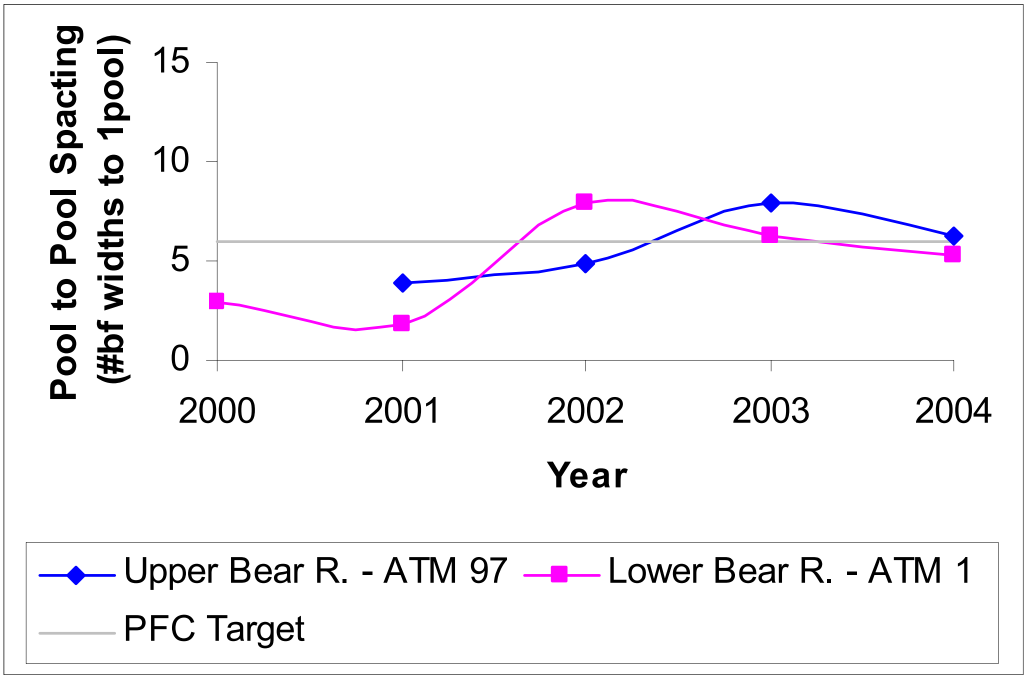
5.4.3 Pool Habitat

Lack of pool habitat does not appear to be a problem for the mainstem Bear River (Photo 5-20) nor most of the primary fish-bearing tributaries with the potential exception of Harmonica Creek. In-stream habitat data reveal that in the lower Bear River reach (RM 20-21.4), while individual pools are fewer in number, they make up a greater percentage of overall stream habitat (i.e., they are larger) and are deeper than those found in the upper reach (RM 25.2-26.6). The lower Bear River channel is nearly double the bankfull width as compared with that of the upper reach and, consequently, for reasons noted above, pools in the lower reach are seldom associated with LWD.

Figure 5-10 presents pool to pool spacing data collected from Bear River ATM stations over a five-year time period. ATM data suggest that distance between pools has increased subsequent to 2001, a trend that may have been affected by a change in survey methodology implemented in 2002 (see Appendix D for details). Prior to 2002, pools range between roughly 2 and 5 bankfull widths apart, well within the PFC target. After 2001, pools are farther apart, ranging between approximately 5 and 7 bankfull widths, and currently approximate the PFC target.

Photo 5-20. Long Pool in Bear River Downstream of Gorge Creek.

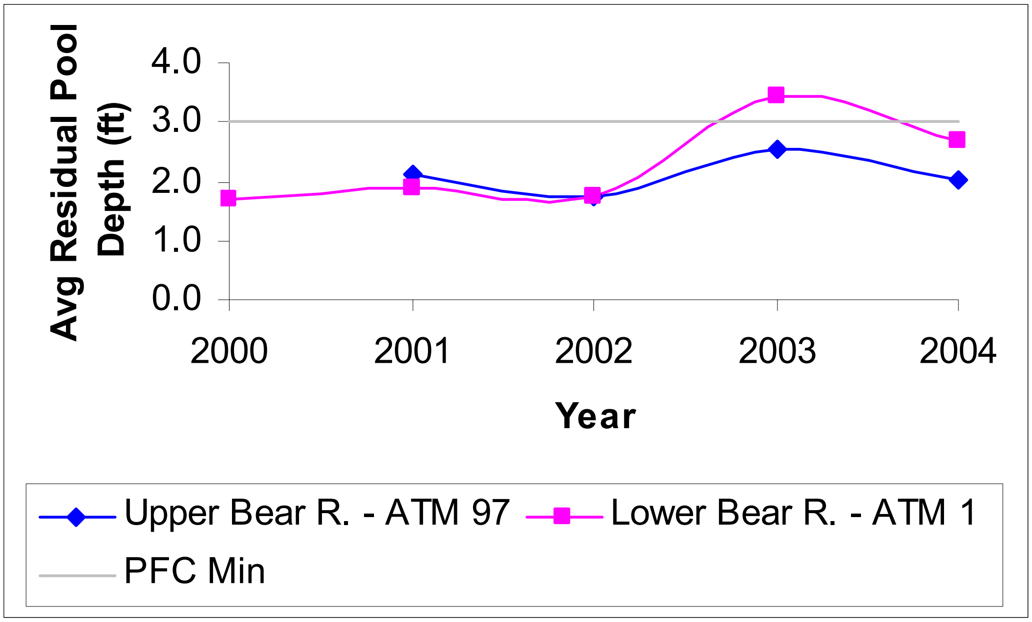
Figure 5-10. Number of Pools in Relation to Bankfull Width Developed from Bear River ATM Station Data.



Source: Figure D-9, Stream Channel module.

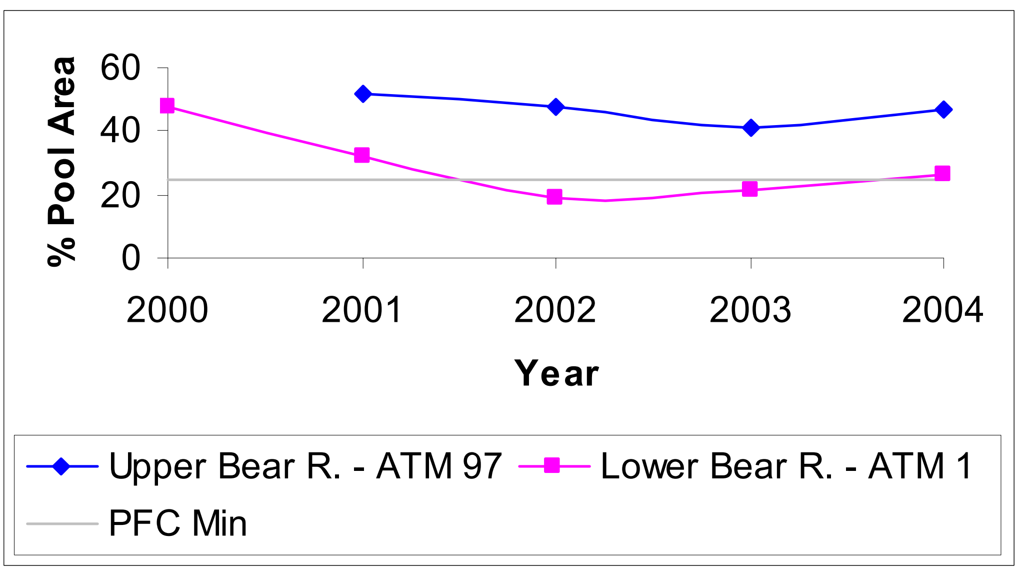
Residual pool depths appear to vary from approximately 2 to 3 feet, the latter which is the pool depth PFC target (Figure 5-11). The lower Bear River ATM station has deeper pools than the upper Bear River ATM station, a predictable finding considering the significant increase in drainage area, and consistent with the stream survey data which reported most of the lower Bear River pools having depths greater than 3 feet. Pool depths change synchronously at the upper and lower Bear River ATM reaches, indicating the flashiness and overall powerful sediment transport capabilities of the Bear River in response to significant storm events. During the same period, pool areas in these two ATM reaches (Figure 5-12) varied widely between 20 and 60 percent with the upper Bear River station (ATM station 97) exhibiting more pool habitat area than the lower ATM station, a finding that is inconsistent with 2005 stream survey data (which covered greater stream length), but perhaps due to more LWD present locally at the upper Bear River ATM station. As with pool depth, changes in pool area appear to vary synchronously at the two ATM stations.

Figure 5-11. Residual Pool Depths and Pool Areas Developed from Bear River ATM Station Data.



Source: Figure D-10, Stream Channel module.

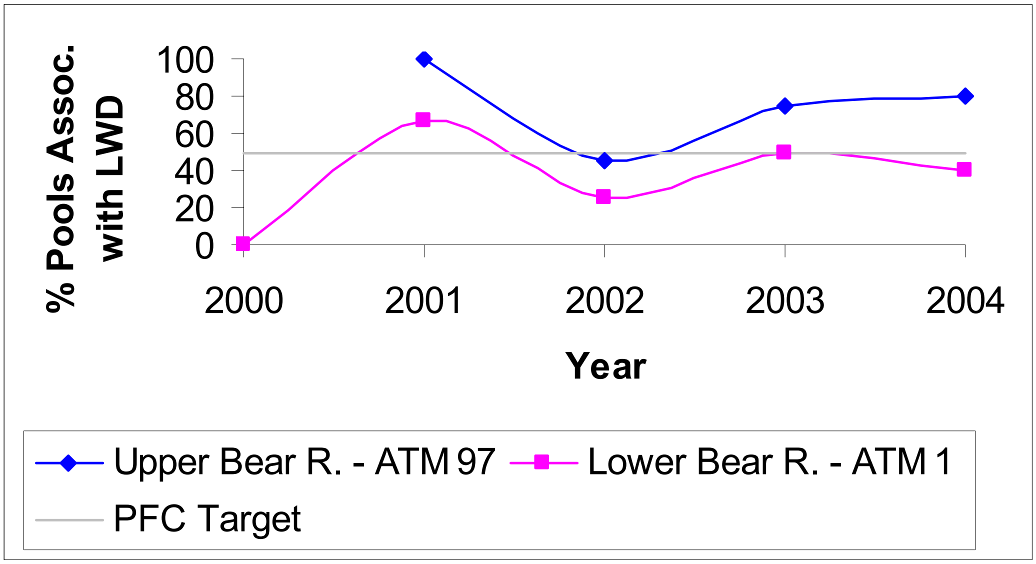
Figure 5-12. Pool Area as a Percentage of Total Surface Area of Reach Developed from Bear River ATM Station Data.



Source: Figure D-11, Stream Channel module.

Consistent with 2005 stream survey data, ATM station data (Figure 5-13) show that LWD plays a less significant role in pool formation farther downstream as both channel width and flow increase. The percentage of pools associated with LWD varies considerably over the monitoring period but varies synchronously between the upper and lower Bear River ATM stations. For the period from 2001 through 2004, the lowest percentage of pools associated with LWD occurred in 2002 concurrent with an overall decrease in LWD density.

Figure 5-13. Percentage of Pools Associated with LWD Developed from Bear River ATM Station Data.

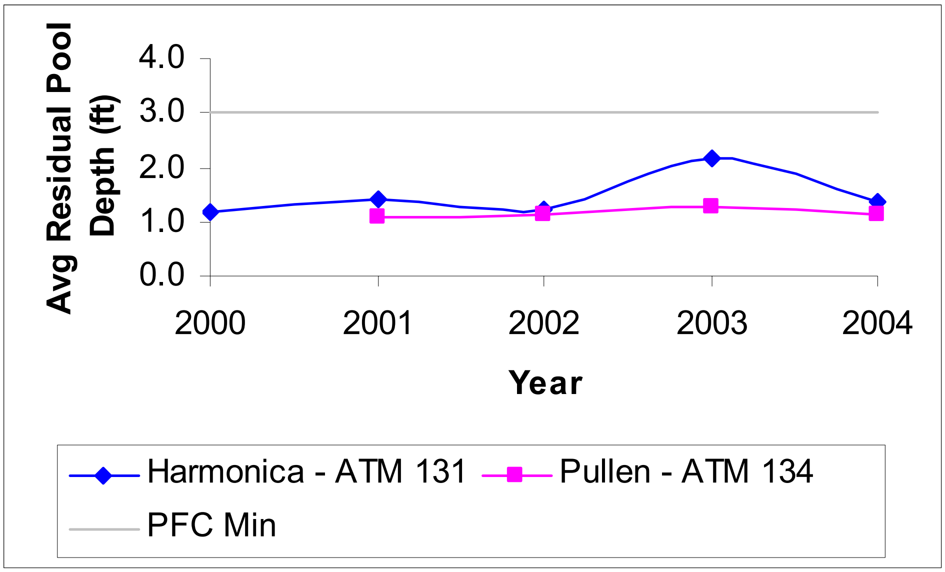


Source: Figure D-12, Stream Channel module.

Pool habitat within the Bear River mainstem survey reaches appear to change rapidly, synchronously, and at similar magnitudes. These rapid changes can in part be explained as responses to peak flows caused by large storm events, such as the 2002 storm. However, some apparent inconsistencies in the various data suggest that changes in pool characteristics are complex and at times difficult to attribute to a single causal factor.

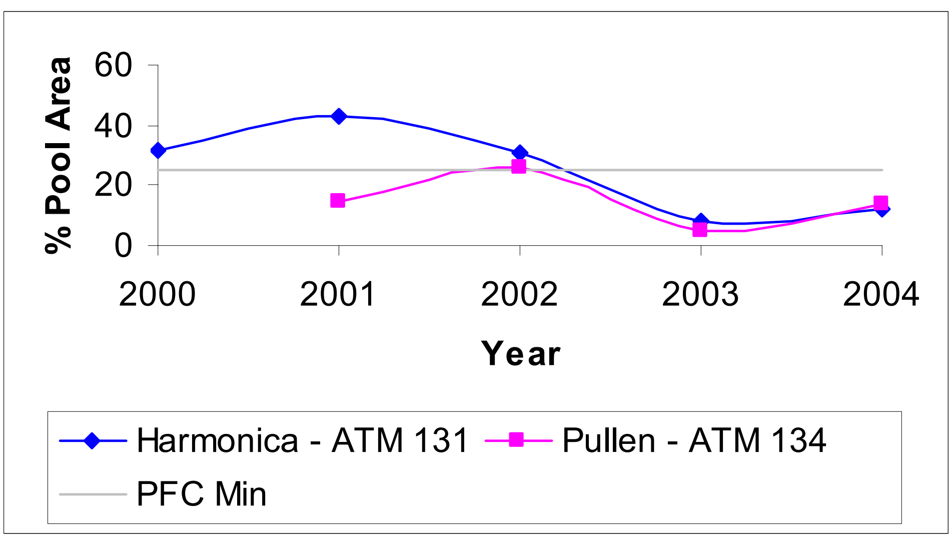
Average residual pool depths measured at the Pullen and Harmonica Creek ATM stations appear to be unchanging and shallow relative to mainstem pools and PFC target minimums (Figure 5-14). At the same ATM stations, pool areas attained PFC targets in 2002, then decreased in 2003 following the large 2002 storm event, and remained below the PFC target in 2004 (Figure 5-15). These changes are commensurate with a sharp increase in distance between pools (Figure 5-16). Pullen Creek and Harmonica Creek appear generally synchronous with respect to changes in pool area and spacing.

Figure 5-14. Average Residual Pool Depth Developed from Harmonica and Pullen Creek ATM Station Data.



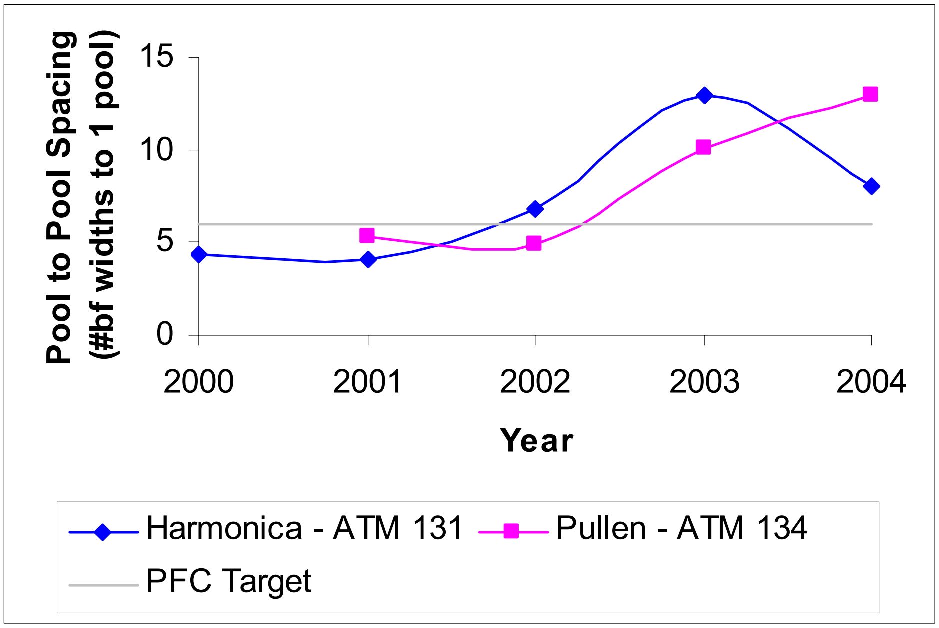
Source: Figure D-22, Stream Channel module.

Figure 5-15. Pool Area Developed from Harmonica and Pullen Creek ATM Station Data.



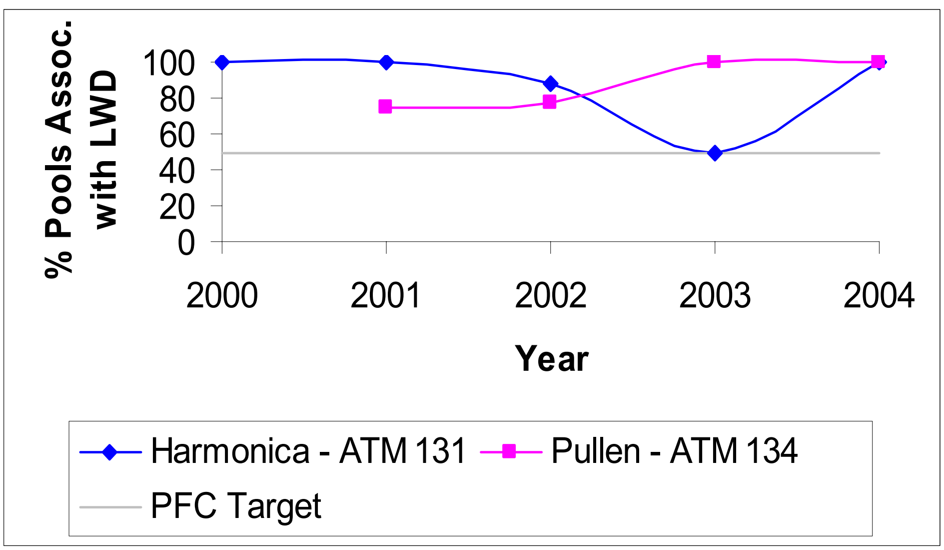
Source: Figure D-23, Stream Channel module.

Figure 5-16. Pool to Pool Spacing Developed from Harmonica and Pullen Creek ATM Station Data.



Source: Figure D-24, Stream Channel module.

Figure 5-17. Percentage Pools Associated with LWD Developed from Harmonica and Pullen Creek ATM Station Data.



Source: Figure D-25, Stream Channel module.

Rapid decreases in pool area and corresponding increases in pool depth and pool spacing, after the 2002 storm event at these monitoring stations, suggest that pool development is greatly affected by peak flows and scour associated with such events, and that LWD is often rapidly transported and/or buried during these events. ATM station data depict a high number of the pools in the monitored Harmonica and Pullen Creek reaches as associated with LWD (Figure 5-17), a finding similar to the proximal upper Bear River reaches, suggesting that LWD is more important to pool development as stream size decreases.

The 2005 aquatic habitat surveys, which cover significantly more stream length than the ATM stations, report the quantity of pool habitat met the PFC criteria (channel widths per pool) in four of the five tributary response reaches surveyed and in both surveyed reaches of Bear River (Figure 5-18). Two of the creeks (Unnamed Tributary #7 and Peaked Creek), using the earlier 1996 CDFG stream inventories, did not have sufficient data to make this determination. The PFC criterion relating to pool area as a percentage of channel area was achieved in four of the six tributary response reaches (includes Peaked Creek and Unnamed Tributary 7 from 1996 CDFG stream surveys) and both reaches of Bear River. The only stream segment to meet the PFC criterion for pools greater than three feet deep was the lower segment of Bear River (Figure 5-19). The PFC criterion for pool depth does not take into account basin area or channel confinement when designating the requirement for pools to be greater than three feet in depth, limiting its meaningfulness with regard to defining a PFC for pool depth in smaller streams.

In general, pool depths are expected to be relatively shallow in the typically bedrock-dominated Bear River channel. Pool scour and peak flows associated with significant storm events affect pool geometry, but the effect is muted by the prevalence of bedrock exposed in the channel bed and relatively limited amounts of channel alluvium that are available to help form deep pools (Photo 5-21). Despite the low contemporary landslide rates, similar in magnitude to those in the pre-industrial logging era (Appendix A), aggraded pool conditions were observed in 2005 in several tributaries including Harmonica Creek, Pullen Creek, and Brushy Creek, as well as in the upper Bear River mainstem in the Happy Valley area. In these tributaries and the upper Bear River, existing alluvium can best be manipulated to increase pool depth through increased LWD recruitment (Photo 5-22).

Figure 5-18. Pool Frequency From 2005 Stream Survey Data.

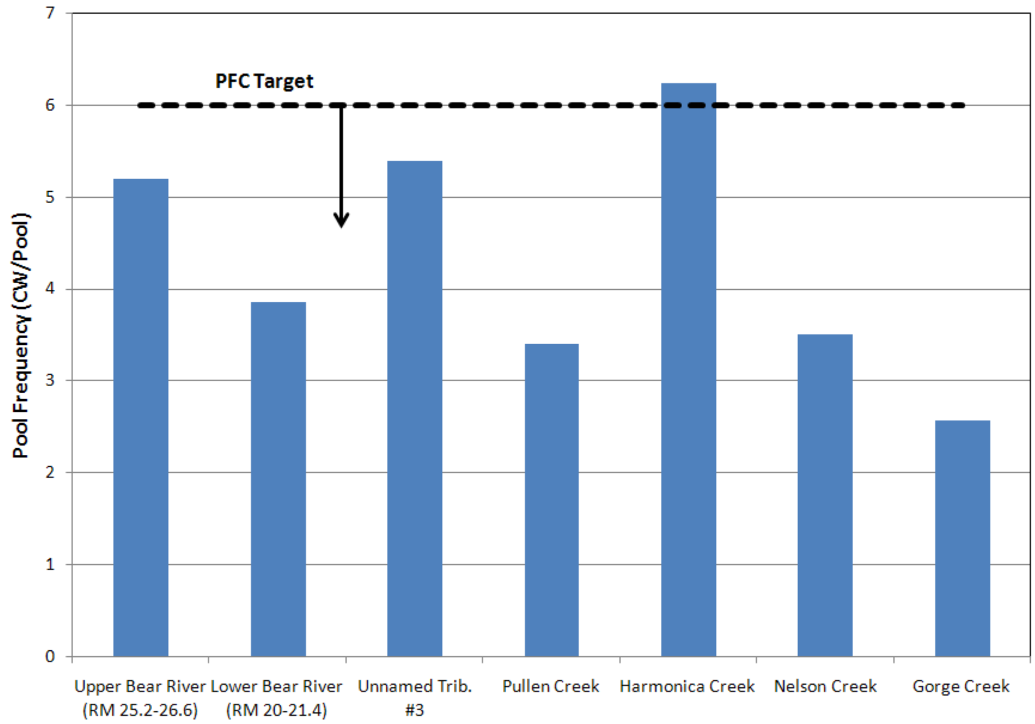


Figure 5-19. Percent Pools > 3 Feet Deep From 2005 Stream Survey Data.

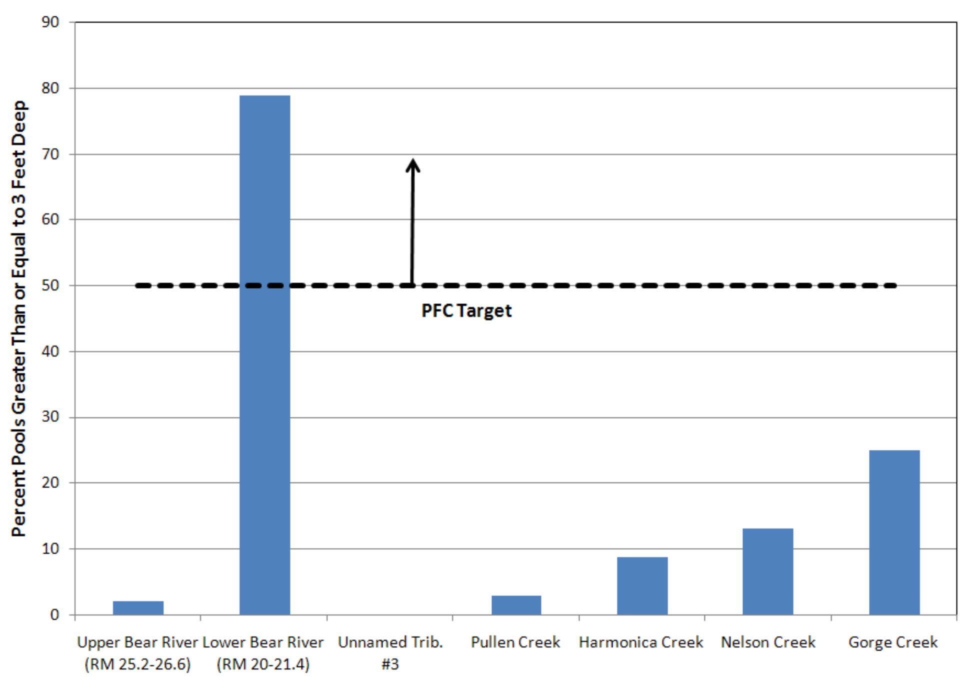


Photo 5-21. Boulder-Formed Step Pool in Gorge Creek.

Photo 5-22. Reach of Harmonica Creek Standing to Benefit from LWD Recruitment.

In addition to reducing sediment inputs through ongoing road storm-proofing and maintenance activities, along with restriction of timber operations on potentially unstable streamside slopes, forestry prescriptions promoting Class I riparian forest growth (i.e., thinning from below) and precluding harvest of trees with LWD recruitment value are of utmost importance as they will ensure large trees become available for in-stream recruitment. The introduction of additional LWD to these smaller fish-bearing streams is essential for maximizing pool habitat and overall aquatic habitat diversity.

Methodologies, results, and more detailed discussion of in-stream habitat conditions and trends are presented in both the Stream Channel and Fish Habitat Assessments (Appendices D and E, respectively).

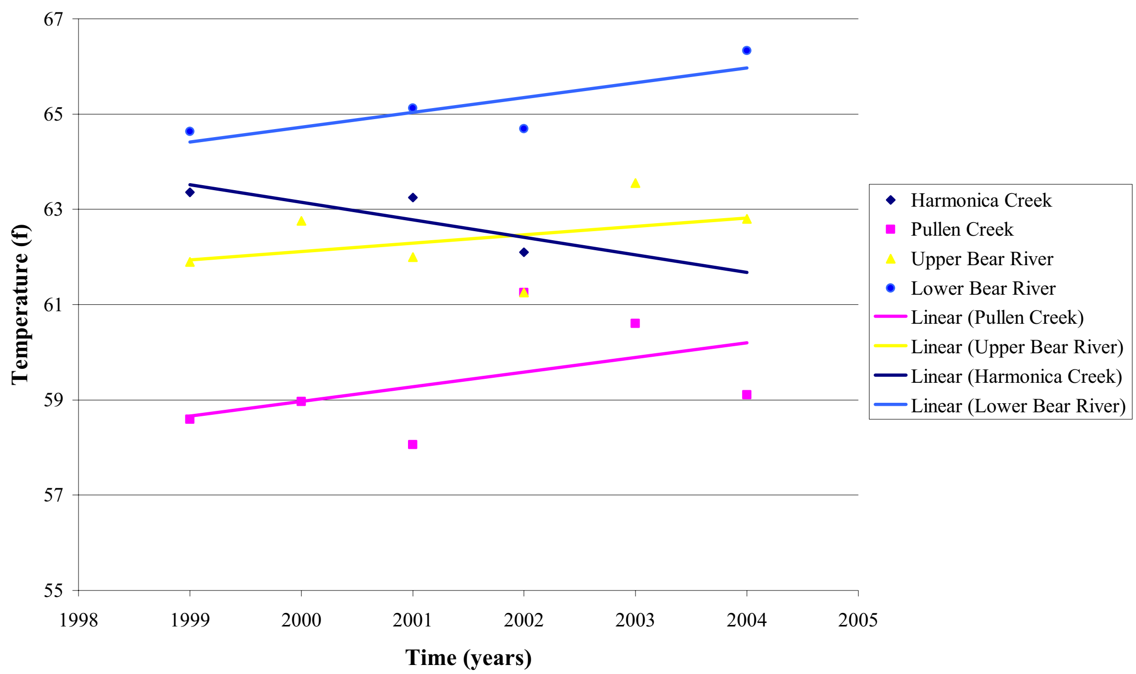
5.4.4 Water Temperature

Water temperature is a critical component to the survival and growth of juvenile salmonids. Different species of salmonids have different tolerances to stream temperature, with steelhead having greater tolerance than Chinook or coho. The phenomenon in which water temperatures typically increase as streams grow larger further from the watershed divide (Lewis et al., 2000; Zwieniecki and Newton, 1999; Sullivan et al., 1990) has been documented well in the scientific literature; this has also been documented when channels widen (Bartholow, 1989; Beschta et al., 1987) and elevation decreases (Sullivan et al., 1990). There are a number of factors that control water temperature including: air temperature, solar radiation input, topographic shading, vegetative shading, aquifer inflow, evaporative energy loss, relative humidity, and wind speed (Adams and Sullivan, 1999; Bartholow, 1989; Lewis et al., 2000). While experiencing a recent warming trend, as described below, stream temperatures in the Bear River watershed remain generally cool and favorable to salmonid production, especially steelhead which is the primary fish species inhabiting the system.

The PFC matrix states the indicator range for water temperatures is 11.6°C – 14.5°C (52.9° to 58°F) with an MWAT target of 16.8°C (62.2°F), based on the optimal preferences of coho salmon. MWAT values have exceeded the PFC targets at the Harmonica Creek, upper Bear River, and lower Bear River ATM stations at least once over the period of record (Figure 5-20). The only creek to stay under the MWAT target over the entire period of record was Pullen Creek.

As noted, MWAT standards were developed for the protection of coho, which has the most restrictive optimal preferred temperature range. MWAT temperatures do not become a problem until fish are actively avoiding an area for prolonged periods of time. Steelhead do not actively avoid an area until temperatures exceed 18.9°C (66°F) (Moyle, 1976). Water temperatures within HCP-covered lands exceeded the 18.9°C (66°F) threshold only one time (2004) at the lower Bear River ATM station (Figure 5-20).

Figure 5-20. MWAT Trend for Four Locations in Bear River Drainage

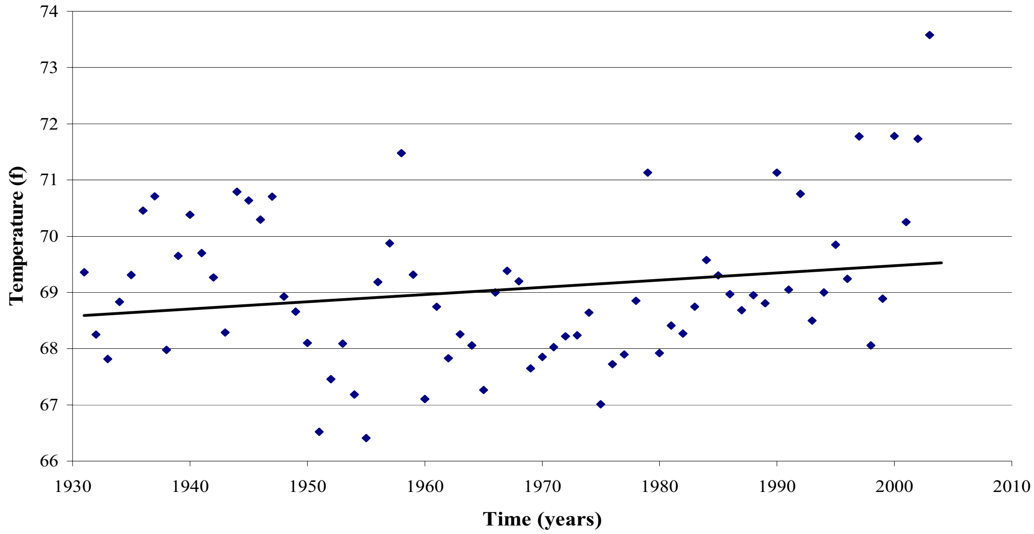


Source: Figure E-7, Fish Habitat module.

Water temperature has been directly correlated to ambient air temperature (Anderson, 2000). Water temperatures increased over time during the ATM station period of record (1999-2004). Air temperature data collected from the USGS Temperature Web Site were analyzed for changes within the Bear River Drainage from 1931-2004 (Figure 5-21). Air temperature data were also gathered from a gauging site in Scotia, California. The Scotia data were collected because this was the closest site and deemed to be the most representative of the temperature in the upper Bear River drainage. These data indicate the average maximum air temperatures during the summer months have increased over time and much more dramatically over the past fifteen years. The water temperature increases in the Bear River drainage directly correspond to ambient temperature increases over the period of record (Figure 5-22). Since 1999, all maximum air temperatures have been above the average of 70.6°F (21.4°C). In 2003, the maximum average air temperature was 4.2°F warmer than the average. These averages were taken for the months of August and September when the air temperatures were the warmest and also correspond with the time when the MWATs were derived from the monitoring data. The MWATs within the Bear River drainage have increased at three of the four sample sites over the past seven years steadily (Figure 5-20). Data were incomplete for the fourth site (Harmonica Creek) and the sample size is too small to adequately ascertain a trend. Ignoring Harmonica Creek, the three trend lines for water temperature are almost identical to each other and are slightly less steep than the trend for air temperature over the same period. The difference is slight and likely a result of water's high heat capacity relative to air's heat capacity.

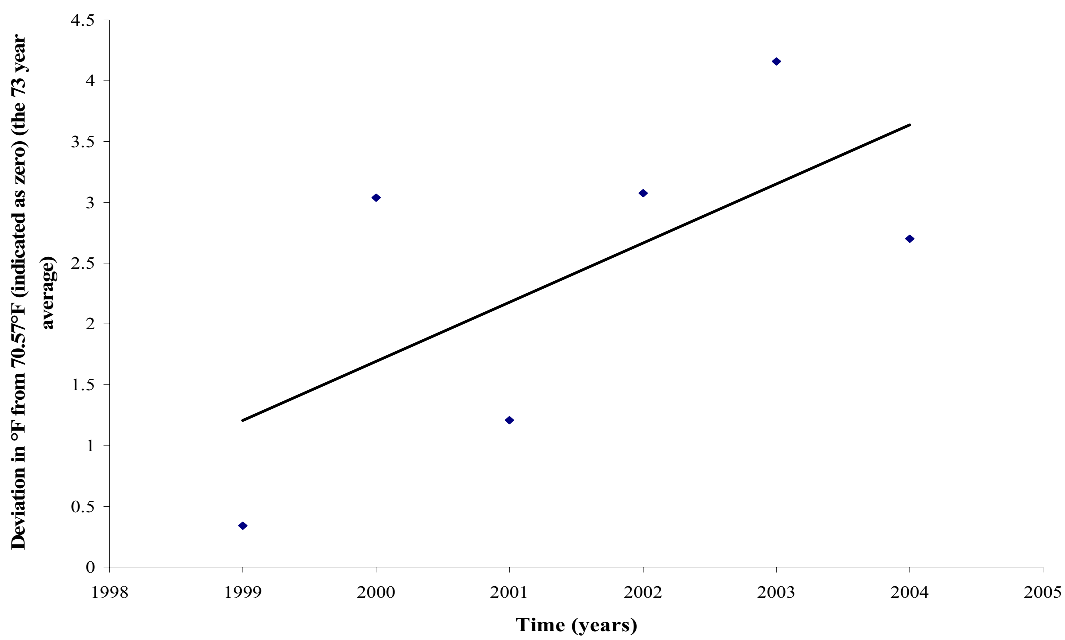
While air temperature increases may present significant challenges to fisheries, stream shading and maintenance and enhancement of warm water escape opportunities (i.e., pools and cool water influx) can be managed locally through conscientious forest management. As noted previously, riparian stand conditions continue to recover from mid-twentieth century streamside harvest. Nearly 90 percent of the Class I and II watercourses on HCP-covered lands currently have overstream canopy cover in excess of 85 percent (Appendix C) (Photos 5-23 and 5-24). These include tributary fish-bearing streams as well as non-fish bearing headwater streams, both of which provide important cool water influx to larger fish-bearing streams including the Bear River mainstem and Harmonica and Nelson Creeks. As increased solar radiation at a site is the major factor driving summer stream warming (Moore et al., 2005), maintenance and promotion of shade canopy is essential. Current HCP forest practices preclude streamside shade canopy removal and promote riparian forest growth through thinning operations.

Figure 5-21. Average Maximum Air Temperature for June – September from 1931- 2004 at Scotia (Source: USGS)



Source: Figure E-5, Fish Habitat module.

Figure 5-22. Maximum Air Temperature Deviation from a 73-year Average for Scotia



Source: Figure E-6, Fish Habitat module.

Future forestry will continue these riparian management practices and will, therefore, maintain and likely increase shade canopy value over time. Pool depth is often restricted in smaller streams by bedrock and low summer flow. However, previously described forest management activities aimed at limiting management-related sediment inputs and maximizing in-stream LWD recruitment, should continue to increase or maximize pool habitat and associated cool water escape opportunities.

Photo 5-23. Overstream Canopy Cover in Upper Bear River.

Photo 5-24. Overstream Canopy Cover in Nelson Creek

5.4.5 Barriers to Upstream Fish Migration

Upstream migration barriers on HCP-covered lands were identified during CDFG stream surveys and during the SCOPAC presence/absence surveys described above. This information was used to identify potential fish passage restoration opportunities and to determine the likely upper extent of fish distribution. Eleven headwater streams were visited during the 2005 presence/absence surveys, and many barriers reported in the historic CDFG records were reassessed. Barrier surveys did not encompass entire stream lengths, but relied upon LIDAR stream channel gradient data and surveys performed by CDFG to focus field efforts on areas of known concern and areas of likely uppermost fish distribution. Only one anthropogenic fish migration barrier was found on HCP-covered lands within the watershed (Unnamed Tributary #3 to Bear River). This barrier consisted of culverted haul road stream crossing which was upgraded to a bridge in 2007 and now allows fish passage (Photo 5-25).

Examples of natural barriers are shown in Photos 5-26 and 5-27. A detailed description of the types and location of barriers encountered during these presence/absence surveys can be found in Section 3.2.3 of the Fish Habitat Assessment (Appendix E).

Photo 5-25. Stream Crossing Fish Barrier Before and After Bridge Installation.

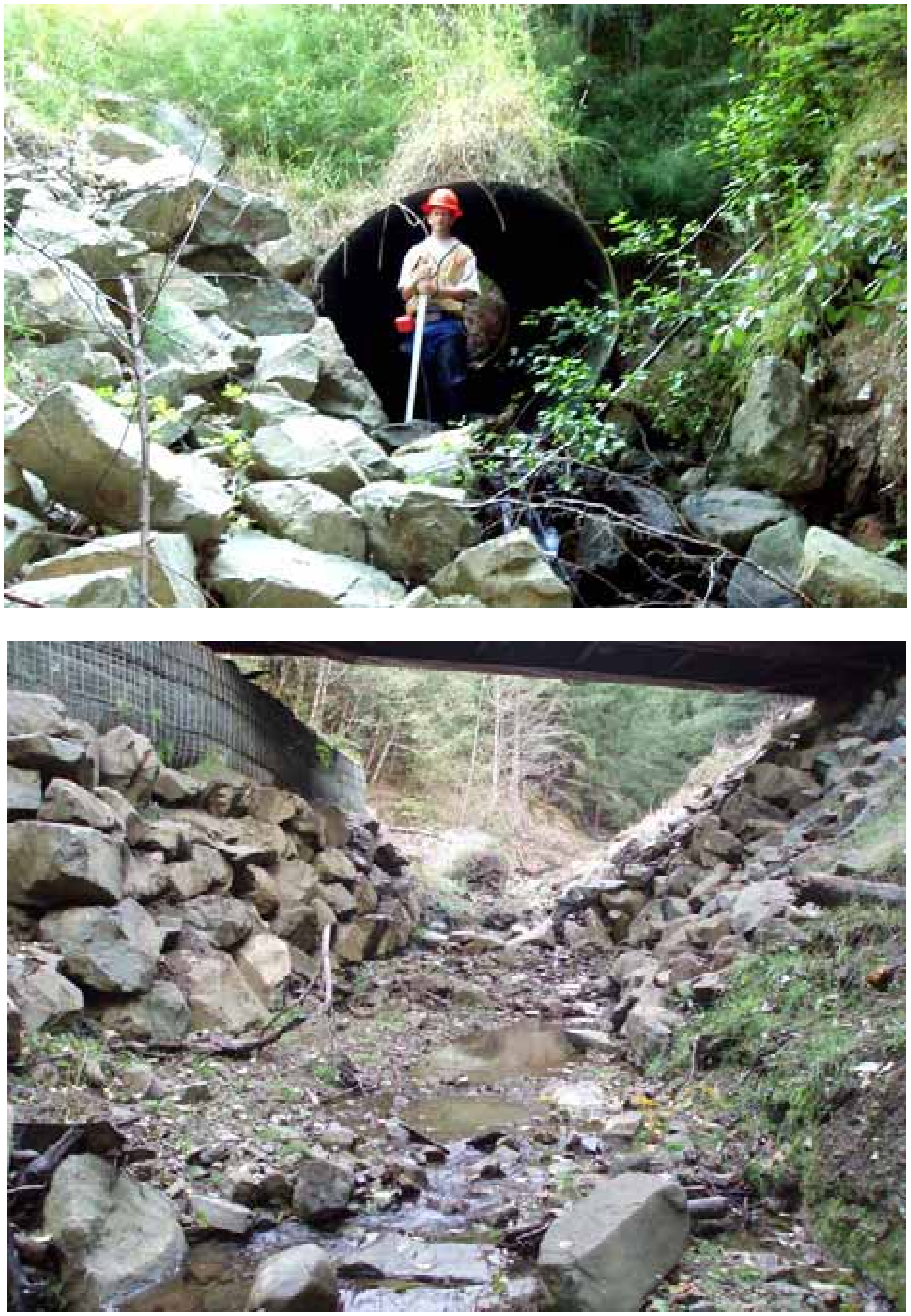


Photo 5-26. Hidden Falls, Upper Bear River Watershed.

Photo 5-27. A 7.7-foot High Bedrock/Boulder Fish Barrier in Beer Bottle Creek.

5.5 AMPHIBIAN AND REPTILE HABITAT

Using the Watershed Analysis Methods guidelines developed cooperatively between the Wildlife Agencies and PALCO (2000), existing data and new data collected during the watershed analysis period were utilized to assess the occurrence and habitat of four amphibians and one reptile species of concern on HCP lands within the Bear River Watershed Analysis Unit (WAU). The five HCP-covered amphibian and reptile species include two headwater species (southern torrent salamander [*Rhyacotriton variegates*] and tailed frog [*Ascaphus truei*]), and three lowland species (foothill yellow-legged frog [*Rana boylii*], northern red-legged frog [*Rana aurora aurora*] and Northwestern pond turtle [*Emys marmorata marmorata*]). Habitat for all five of these species exists in the Bear River watershed (Photo 5-28). Southern torrent salamander, tailed frog, and foothill yellow legged frog have been documented on HCP-covered lands, whereas, despite the presence of habitat the northern red legged frog and the Northwestern pond turtle have not been observed.

Streams and riparian zones have had varying amounts of recovery since the post-WWII logging boom combined with two significant storm events in the mid-twentieth century to adversely impact watercourses of all sizes with excessive sedimentation and removal of riparian forest canopy. The HCP-covered lands analyzed in this watershed analysis appear to be in an improving condition relative to amphibian and reptile habitat. The steep decline in harvest activity in the 1970s, coupled with significant improvements in forestry operations associated with inception of the CFPRs and later the HCP, has resulted in this trend towards recovery. Factors contributing to the generally suitable amphibian and reptile habitat conditions currently found in the watershed 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. For the amphibian and reptile species of concern, management practices should be designed to allow for continued recovery, including maintenance of riparian canopy cover, prevention of large sediment influx, and retention or improvement of instream pools and pond habitat.

Please refer to Appendix F for a detailed discussion of habitat requirements, condition, and distribution.

Photo 5-28. Class II Watercourse, Upper Bear River Watershed.

6.0 MANAGEMENT RECOMMENDATIONS

The results of this first round of HCP watershed analysis indicate the Bear River watershed experienced a period of significant disturbance in the 1950s and 1960s. As described throughout this CWE assessment, this watershed-wide disturbance was brought about by the early post-WWII housing and lumber production boom which accelerated logging operations throughout much of the Pacific Northwest. In the Bear River watershed, these activities resulted in concentrated and substantial ground disturbance and canopy removal, often on steep streamside slopes already prone to significant mass wasting in response to earthquakes and large storm events. In 1955, and again in 1964, two geomorphically significant storm events struck the region. Disturbed by skid trail and road construction, and often denuded by extensive timber harvest, the steep Bear River hillslopes responded to these heavy rains and flash floods by delivering 11 million cy of harvested hillslope and road-related sediment to tributaries and the Bear River mainstem, scouring what riparian vegetation remained and developing severely aggraded conditions in the stream channels.

In subsequent decades, landslide rates decreased significantly. This occurred as logging operations were reduced in size and management practices causing less ground disturbance were adopted, particularly in riparian areas and on steep unstable slopes. As well, these decades did not see storm events rivaling those of 1955 and 1964 (except until very recently). This decline appears to have provided the opportunity for the watershed to transport much of the sediment delivered during the 1950s and 60s through its system and out to sea. While both natural and management-associated mass wasting events continue to occur in response to large storm events, such as those occurring recently in 1997 and 2002, they do so at geomorphic rates generally commensurate with in-stream sediment transport. This more balanced condition is evidenced by the upper Bear River channel profile being at or near bedrock in most channel reaches and with a net loss of stored sediment in study reaches. Developing and implementing strategies that continue to minimize the effect of management on landslide delivery rates is important to the promotion of healthy aquatic habitat processes and conditions.

Riparian conditions also have recovered significantly from this mid-twentieth century disturbance. While not yet fully mature, current overstream shade canopy and riparian forest cover appear to be essentially adequate for the present and future maintenance of cool stream temperatures and microclimate conditions. However, a number of years are still required for the development of larger riparian forests that can function consistently to contribute large wood to aquatic systems and thereby diversify hydraulic processes and aquatic habitat conditions. Strategies that promote individual tree growth, particularly of conifers outside of the immediate hardwood-dominated riparian zone, for long-term benefits of LWD recruitment and micro-climate while also maintaining existing shade and LWD recruitment values, should drive development of riparian forestry prescriptions.

Road systems have been the focus of significant economic investment and improvement over the last decade. However, roads remain the primary management-associated source of sediment delivery, particularly fine sediments; therefore, continued emphasis should be placed on storm-proofing, decommissioning, and maintenance of roads.

In summary, this CWE assessment has found the HCP-covered lands of the Bear River WAU to be generally trending towards a properly functioning aquatic habitat condition; this is expected to continue as forest management operations remain vigilant with this as a goal. The Bear River has demonstrated a resiliency to cumulative adverse impacts with its present day consistent production of steelhead and resident rainbow trout, and many miles of useable Chinook and potential coho habitat. And yet the assessment also documents room for improvement through further reductions of fine sediment delivery from roads, further avoidance of linkages between forestry and mass wasting, and emphasis on the management of riparian areas for the promotion of larger trees and increased LWD recruitment value.

Specific management and monitoring recommendations to address these and other goals are presented in the remainder of this section.

6.1 HILLSLOPE

- ***Minimize slope disturbance and retain forest canopy on inner gorge slopes and near streams along the bottom of other landslide prone slopes for root strength retention, rainfall interception, and minimization of logging-related ground disturbance; as well as to facilitate large woody debris recruitment and sediment entrapment in the event of slope failure.*** While the Bear River watershed appears to be positioned for sediment transport in line with its naturally high sediment delivery rate, and recent 1988-2003 delivery appears on par with pre-1948 delivery rates, recognizing and mitigating timber operations on inherently unstable terrain such as inner gorge slopes remains vital to continued reduction of management-related sediment delivery and insuring large wood is available for in-stream recruitment in the event of slope failure. The Harmonica Creek and Gorge Creek sub-basins and the Bear River mainstem have naturally high landslide delivery rates relative to other sub-basins, and special considerations regarding the potential effect of harvest on slope stability in these sub-basins is warranted. In general, slopes adjacent to fish-bearing (Class I) streams, and with gradients steeper than 65 percent, are better correlated with higher rates of landslide delivery than slopes leading to smaller watercourses or having less steep gradients.

- ***Continue road upgrading/storm-proofing efforts along the upper mainstem Bear River (Upper Bear River Sub-basin).*** While this area has benefited from recent road improvements subsequent to preparation of the road surface erosion analyses in Appendix B (Surface Erosion Module), continual upgrading and maintenance, particularly in the form of rocking or otherwise winterizing watercourse crossings, are necessary to address potential erosion from road use on the F-line. In addition to providing periodic, mostly summer management access for the upper portion of the watershed, this road system also provides needed year-round access to a number of in-holdings. Model results from SEDMODL suggest roads in the Upper Bear River sub-basin may deliver as much as 30 tons of sediment per road mile annually whereas the rate for the HCP lands, collectively, is 12 tons per road mile per year. While this estimate is likely high due to modeling limitations discussed in Appendix B, year-round road use, numerous watercourse crossings, and the presence of important spawning and rearing habitat in the Bear River mainstem, as well as in the lower reaches of Harmonica and Nelson Creek, combine to warrant special attention. The installation of locked gates along the F-line limiting in-holding access to their deeded right-of-way and preventing trespass onto branching seasonal (native surface) road systems should be considered.

- ***Review, identify, and schedule treatment for highest priority roadwork reported in the 2005 PWA watershed-wide storm-proofing inventory.*** A sampling of the HCP road system in the Bear River watershed conducted as part of this watershed analysis prior to the completion of the PWA inventory suggested landslides associated with legacy (no longer used and not properly abandoned) roads may have been the leading contributor of land use associated sediment delivery for the 1988-2003 sediment budget period. A 2005 watershed-wide inventory of active or potential future road-related delivery sources was completed subsequent to this initial sampling and should be used in prioritizing and scheduling future roadwork.

- ***Periodically update landslide inventory per established protocol and with focused assessment of roads and harvest areas (following large storm events if feasible) to assess "effectiveness" of forestry activities relative to avoiding mass wasting associations. Provide findings to HRC staff***

and HCP Agencies following each inventory, with comprehensive analysis provided as part of WA re-visitation.

6.2 RIPARIAN

- ***Retain existing large trees with the highest probability of recruitment to Class I streams (e.g., within 20 meters of stream channel; leaning towards stream channel; dead or dying; within areas prone to mass wasting).*** Despite observance of an abundant young steelhead population, Harmonica Creek in particular was noted as lacking in-stream LWD which, in combination with recent aggradation, may have led to a decline in pool depth, frequency, and overall aquatic habitat and hydraulic complexity relative to pre-European settlement conditions. Directional felling or placement of large timber, rootwads, or logs into Harmonica Creek would likely benefit pool development and habitat diversity.
- ***In moderate to dense conifer-dominated and mixed conifer–hardwood riparian stands situated along Class I watercourses, implement silvicultural strategies that maintain or increase average stand stem diameter and promote increased growth rates and multiple canopy layers post-harvest.***
- ***In hardwood-dominated riparian stands along Class II watercourses implement silvicultural strategies that increase conifer occupation for long-term promotion of multiple canopy layer, shade-rich forest characteristics and reduce watershed risk of widespread Sudden Oak Death (Phytophtora ramorum) infestation.***

6.3 STREAM CHANNEL

- ***Maintain existing ATM station locations and continue monitoring program providing comprehensive reporting as part of WA re-visitation.***
- ***Repeat CDFG methodology stream channel surveys of low-gradient fish-bearing streams prior to watershed analysis re-visitation.*** While permanent ATM stations provide valuable long-term monitoring data, both resource managers and scientists involved in the stream channel and fish habitat assessments commented on the value of performing periodic stream reach surveys to characterize fish habitat conditions more widely throughout the watershed. Periodic fish counts and spawner surveys

are also encouraged to track population changes over time in order to document localized use and to provide a more complete larger, region-wide perspective on anadromous fish trends.

- ***During future Aquatic Trends Monitoring and stream surveys, record 'key piece' in-stream LWD using a revised definition.*** The current definition found in the PFC Matrix tables defines a "key piece" as:

  "… a log and/or rootwad that:

  a. is independently stable in the stream bankfull width (not functionally held by another factor, i.e. pinned by another log, buried, trapped against a rock or bedform, etc.) and
  b. is retaining (or has the potential to retain) other pieces of organic debris. Without this "key piece", the retained organic debris will likely become mobilized in a high flow (approximately an ≥ 10-year event) (Fox, 1994).

  This current definition precludes the recording of many functional (i.e., pool forming/sediment entrapping) pieces of LWD because the wood has either become partially buried in the stream channel or adjacent stream bank, or is part of a larger log jam (i.e., not necessarily independently stable). The definition should be modified to drop the "(not functionally held by another factor i.e. pinned by another log, buried, trapped against a rock or bedform, etc.)"; and should instead focus on the active function or functional capacity of the LWD to form pools and entrap other organic debris, gravel, and/or other sediment.
- ***Continue searches of suitable habitat for Red-Legged Frogs and Northwestern Pond Turtles in order to determine presence/absence in the upper watershed.***

Photo 6-1. Upper Bear River Watershed, 2006.

Photo 6-2. Bear River Downstream of Beer Bottle Creek.

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Attachment 1

Bear River Watershed Analysis

Sub-basin Data

BEAR RIVER WATERSHED ANALYSIS AREA (HCP) - ATTACHMENT 1

Sub-Basin Data - November 3, 2006

	Beer Bottle Complex	Brushy Crk.	Chase Ranch Complex	Gorge Crk. Complex	Happy Valley	Harmonica Crk.	Johnson Gulch	Main Stem Bear River	Middle Bear Complex	Nelson Crk.	Peaked Crk. Complex	Pullen Crk.	South Fork Bear River	Upper Bear River	West Side Creek
OWNERSHIP															
Total Sub-Basin Area (acres)	2241	1825	1793	2191	1322	2597	7915	1766	6143	2062	3686	1711	8272	810	9202
Area of Humboldt Redwood Company HCP ownership (acres)	1291	1653	1569	1881	1235	2563	0	1338	25	1894	858	1486	0	744	0
Area of HRC nonHCP ownership (acres)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Area of HRC ownership (acres)	1291	1653	1569	1881	1235	2563	0	1338	25	1894	858	1486	0	744	0
Other Private Ownership (acres)	950	172	225	310	0	27	7915	428	6118	167	2829	225	8272	0	9202
Public Ownership (Parks)(acres)	0	0	0	0	87	8	0	0	0	0	0	0	0	66	0
LIDAR BASED TOPOGRAPHY (HCP Humboldt Redwood Company ONLY)															
LIDAR Topography, <35% (acres)	374	215	330	318	350	613		175	7	477	164	206		306	
LIDAR Topography, 36-50% (acres)	350	283	371	378	338	598		245	11	432	165	298		205	
LIDAR Topography, 51-65% (acres)	266	420	374	425	306	607		321	6	379	178	415		153	
LIDAR Topography, >65% (acres)	302	736	493	760	241	744		596	1	605	351	567		80	
LIDAR BASED TOPOGRAPHY (HCP Humboldt Redwood Company ONLY)															
LIDAR Topography, <35% (% of area)	29	13	21	17	28	24		13	28	25	19	14		41	
LIDAR Topography, 36-50% (% of area)	27	17	24	20	27	23		18	43	23	19	20		28	
LIDAR Topography, 51-65% (% of area)	21	25	24	23	25	24		24	25	20	21	28		21	
LIDAR Topography, >65% (% of area)	23	45	31	40	20	29		45	4	32	41	38		11	
GEOLOGY (HCP Humboldt Redwood Company ONLY)															
Geology - TKfs-sz/TKfs-ls/TKfs-u (% of area)	0.0	0.0	20.7	0.0	0.0	0.0		0.6	0.0	0.0	0.0	0.0		0.0	
Geology - TKfs/TKfs-ss/Fm-ss/TKfs-gs (% of area)	100.0	99.8	79.3	100.0	65.3	61.2		94.5	100.0	89.7	98.6	100.0		10.3	
Geology - TKy (% of area)	0.0	0.0	0.0	0.0	32.7	37.7		0.0	0.0	10.0	0.0	0.0		67.3	
Geology - Qort/Qrt (% of area)	0.0	0.0	0.0	0.0	2.0	0.2		1.9	0.0	0.0	1.4	0.0		13.4	
Geology - Q/Qsc(% of area)	0.0	0.2	0.0	0.0	0.0	0.8		2.9	0.0	0.3	0.0	0.0		9.0	
Geology - QTwu (% of area)	0.0	0.0	0.0	0.0	0.0	0.0		0.0	0.0	0.0	0.0	0.0		0.0	
Geology - Qf (% of area)	0.0	0.0	0.0	0.0	0.0	0.0		0.0	0.0	0.0	0.0	0.0		0.0	
Geology - Qal (% of area)	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 Humboldt Redwood Company ONLY)															
Redwood (% of area)	0.0	0.0	0.0	0.0	0.0	0.0		0.0	0.8	0.0	0.0	0.0		0.0	
Redwood/Doug-fir (% of area)	0.0	0.0	0.0	0.0	0.0	0.0		0.0	0.0	0.0	0.0	0.0		0.0	
Redwood/Hardwood (% of area)	0.0	0.0	0.0	0.0	0.0	0.0		0.0	0.0	0.0	0.0	0.0		0.0	
Doug-fir (% of area)	71.1	33.1	32.9	32.6	42.5	37.3		25.4	86.6	35.7	62.9	33.6		63.8	
Doug-fir/Redwood (% of area)	0.0	0.0	0.0	0.0	0.0	0.0		0.0	2.5	0.0	0.0	0.0		0.0	
Doug-fir/Hardwood (% of area)	3.9	5.5	1.4	1.6	8.4	6.1		5.3	0.0	4.3	5.5	8.7		5.9	
Conifer/Hardwood (% of area)	0.0	0.0	0.0	0.0	0.0	0.0		0.0	0.0	0.0	0.0	0.0		0.0	
Hardwood (% of area)	13.3	52.1	38.0	61.7	44.2	53.7		62.3	0.0	56.8	30.1	50.5		23.1	
Non-timber (% of area)	11.7	9.2	27.7	4.1	4.8	2.8		6.9	10.1	3.1	1.5	7.1		7.2	
LIDAR-BASED HYDROLOGY post WA Last Fish Assessment (HCP Humboldt Redwood Co. ONLY)															
Stream Miles, Class I (miles)	0.0	2.4	0.6	0.4	1.6	4.8		7.3		3.0	1.6	2.2		4.6	
Stream Miles, Class II (miles)	13.6	11.8	11.8	15.1	8.9	13.9		6.1		12.8	6.2	7.6		5.2	
Stream Miles, Class III (miles)	5.2	5.4	5.6	6.7	4.2	12.2		8.6		8.5	3.2	6.2		2.7	
Stream Density, Class I (mile/sq mi)	0.00	0.94	0.22	0.14	0.82	1.19		3.48		1.02	1.18	0.93		3.91	
Stream Density, Class II (mile/sq mi)	6.72	4.55	4.82	5.14	4.63	3.46		2.93		4.34	4.61	3.25		4.44	
Stream Density, Class III (mile/sq mi)	2.59	2.08	2.28	2.26	2.17	3.05		4.09		2.87	2.42	2.67		2.32	
USGS/DEM-BASED HYDROLOGY as of October 2005 (HCP Humboldt Redwood Company ONLY)															
Stream Miles, Class I (miles)	0.5	2.3	1.3	1.2	1.6	5.2		7.3		2.8	2.0	2.7		4.5	
Stream Miles, Class II (miles)	12.8	11.7	10.5	13.5	8.9	13.0		5.6		12.0	5.7	7.5		4.9	
Stream Miles, Class III (miles)	5.3	6.7	6.2	8.1	4.0	11.3		7.9		8.9	3.2	6.6		2.7	
Stream Density, Class I (mile/sq mi)	0.23	0.90	0.53	0.39	0.84	1.31		3.50		0.96	1.47	1.16		3.84	
Stream Density, Class II (mile/sq mi)	6.33	4.53	4.29	4.58	4.60	3.24		2.67		4.07	4.27	3.22		4.23	
Stream Density, Class III (mile/sq mi)	2.63	2.57	2.53	2.75	2.08	2.81		3.77		2.99	2.36	2.84		2.34	
TREATED ROADS as of October 2005 (HCP Humboldt Redwood Company ONLY)															
Road Density (Rocked) (miles/sq mi)	1.39	0.81	0.81	0.90	2.28	0.21		0.76	0.00	0.33	0.00	1.38		1.96	
Road Density (Native "Dirt") (miles/sq mi)	0.06	0.76	0.29	0.01	0.19	0.50		0.04	0.00	0.64	0.00	0.20		1.97	

BEAR RIVER WATERSHED ANALYSIS AREA (HCP) - ATTACHMENT 1

Sub-Basin Data - November 3, 2006

	Beer Bottle Complex	Brushy Crk.	Chase Ranch Complex	Gorge Crk. Complex	Happy Valley	Harmonica Crk.	Johnson Gulch	Main Stem Bear River	Middle Bear Complex	Nelson Crk.	Peaked Crk. Complex	Pullen Crk.	South Fork Bear River	Upper Bear River	West Side Creek
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	0.07		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 as of October 2005 (HCP Humboldt Redwood Company ONLY)															
Road Density (Rocked) (miles/sq mi)	0.14	0.51	0.49	0.21	1.06	0.00		0.02	8.43	0.07	0.00	0.18		0.22	
Road Density (Native "Dirt") (miles/sq mi)	3.23	2.53	3.22	2.60	2.19	3.22		2.65	1.40	2.13	2.54	2.32		2.91	
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	
LAND USE HISTORY/ROADS (HCP Humboldt Redwood Company ONLY)															
1988-2003 Harvest Clear Cut (acres)	437.1	207.4	186.3	199.7	287.7	367.1		94.2	18.2	254.4	240.1	212.3		143.4	
1988-2003 Harvest Partial Cut (acres)	151.5	16.0	51.7	23.9	182.0	160.0		12.3	0.0	70.6	52.3	45.0		157.6	
1988-2003 Harvest Tractor Yarding (acres)	333.4	72.1	158.1	118.1	286.7	437.3		12.5	10.2	216.5	123.5	86.0		289.6	
1988-2003 Harvest Tractor/Cable Yarding (acres)	2.3	6.6	0.6	6.6	12.4	19.2		0.5	0.1	21.4	21.0	4.3		0.0	
1988-2003 Harvest Cable Yarding (acres)	158.1	144.6	70.0	87.8	122.7	70.6		74.2	7.9	87.2	72.4	75.7		11.3	
1988-2003 Harvest Helicopter Yarding (acres)	94.8	0.0	9.2	11.0	47.9	0.0		19.3	0.0	0.0	75.5	91.2		0.0	
RIPARIAN FUNCTION (HCP Humboldt Redwood Company ONLY)															
LWD Recruitment, HIGH (% of RCU area)	0.0	0.2	2.9	1.4	6.7	1.8		1.5		1.2	0.0	1.3		5.0	
LWD Recruitment, MODERATE (% of RCU area)	71.9	80.8	79.1	80.4	76.9	84.7		56.4		88.5	89.1	85.6		79.0	
LWD Recruitment, LOW (% of RCU area)	28.1	19.0	18.1	18.2	16.4	13.5		42.1		10.3	10.9	13.1		15.9	
Canopy Cover, >85% (% of stream length)	96.9	97.4	100.0	90.7	100.0	79.2		53.3		89.9	94.4	98.4		84.8	
Canopy Cover, 70-85% (% of stream length)	0.0	0.0	0.0	7.0	0.0	15.7		0.0		10.1	0.0	1.6		3.7	
Canopy Cover, 40-69% (% of stream length)	0.0	0.0	0.0	0.0	0.0	0.7		0.0		0.0	0.0	0.0		0.0	
Canopy Cover, 20-39% (% of stream length)	0.0	0.0	0.0	0.0	0.0	0.0		0.0		0.0	0.0	0.0		0.0	
Canopy Cover, 0-19% (% of stream length)	3.1	2.6	0.0	2.3	0.0	4.4		46.7		0.0	5.6	0.0		11.5	

Attachment 2

Bear River Watershed Analysis

Sediment Budget

Bear River Watershed Analysis

Sediment Budget (Tons/square mile/yr)

1988-2003	1/6/2007		Module	Beer Bottle Complex	Brushy Crk.	Chase Ranch Complex	Gorge Crk. Complex	Happy Valley	Harmonica Crk.	Johnson Gulch	Main Stem Bear River	Middle Bear Complex	Nelson Crk.	Peaked Crk. Complex	Pullen Crk.	South Fork Bear River	Upper Bear River	West Side Creek	TOTAL	% OF TOTAL
NATURAL	Landslides	Deep Seated	MW	0	0	0	0	0	1513		0	0	0	0	1236		0		345	5.4%
		Shallow Seated	MW	1069	1244	102	4821	1564	3964		3108	0	681	6489	1304		491		2302	36%
		Streamside (typically channel related	MW	3239	2822	2687	2881	2539	2677		3358	0	2960	2694	2670		2947		2845	44%
	Surface Erosion	Soil Creep	SE	79	69	63	67	65	63		86	0	69	70	62		90		69	1.1%
	Stream Channel Erosion	Bank Erosion (incl in streamside LS)		0	0	0	0	0	0		0	0	0	0	0		0		0	0%
LEGACY	Landslides	"Untreated" Abandoned roads	MW	0	1335	0	29	0	136		1185	0	0	72	0		0		257	4.0%
		Tractor Harvest 15-30yrs (PC)	MW	0	0	0	1.7	0	0		0	0	0	0	0		0		0	0.0%
		Tractor Harvest 20-30yrs (CC)	MW	0	0	0	0	0	0		0	0	0	0	0		0		0	0.0%
		Streamside (typically channel related	MW	170	149	141	152	134	141		177	0	156	142	141		155		150	2.3%
	Surface Erosion	"Untreated" Abandoned Roads	SE	0	0	0	0	0	0		0	0	0	0	0		0		0	0%
	Stream Channel Erosion	Bank Erosion (incl in streamside LS)		0	0	0	0	0	0		0	0	0	0	0		0		0	0%
		Channel Incision - no data		0	0	0	0	0	0		0	0	0	0	0		0		0	0%
MGMT	Landslides	HCP Roads	MW	1647	118	0	0	1.4	0		0	0	0	0	0		0		141	2.2%
		Partial Cut <15 yrs	MW	0	0	0	564	0	0		0	0	0	0	0		0		64	1.0%
		Clearcut <20 yrs	MW	466	39	0	0	6.2	0		0	0	360	158	1.5		0		90	1.4%
		Streamside (typically channel related	MW	0	0	0	0	0	0		0	0	0	0	0		0		0	0%
	Surface Erosion	Harvest Unit (1988-2003)	SE	12	2.1	2.0	1.5	3.9	2.2		0.4	0.1	1.9	2.3	1.7		7.1		3	0.0%
		Road - Surface	SE	109	27	405	49	72	36		76	0	42	9.9	20		312		93	1.5%
		Road - Gullies/Washouts	SE	56	21	52	23	60	25		89	55	20	23	22		219		45	0.7%
	Stream Channel Erosion	Bank Erosion (incl in streamside LS)		0	0	0	0	0	0		0	0	0	0	0		0		0	0%
		Channel Incision - no data		0	0	0	0	0	0		0	0	0	0	0		0		0	0%
				6848	5826	3453	8588	4444	8558		8078	55	4289	9661	5458		4221		6406	100%
SUMMARY																				
	Natural	Landslides		4309	4066	2789	7702	4102	8154		6466	0	3641	9183	5210		3438		5493	86%
		Surface Erosion		79	69	63	67	65	63		86	0	69	70	62		90		69	1%
		Stream Channel		0	0	0	0	0	0		0	0	0	0	0		0		0	0%
	Legacy	Landslides		170	1483	141	182	134	277		1361	0	156	214	141		155		407	6%
		Surface Erosion		0	0	0	0	0	0		0	0	0	0	0		0		0	0%
		Stream Channel		0	0	0	0	0	0		0	0	0	0	0		0		0	0%
	Management	Landslides		2113	157	0	564	8	0		0	0	360	158	2		0		295	5%
		Surface Erosion		177	50	459	74	135	63		165	55	63	36	43		538		141	2%
		Stream Channel		0	0	0	0	0	0		0	0	0	0	0		0		0	0%
Annual Sediment Yield		**Natural**		4388	4135	2853	7769	4167	8218		6551	0	3710	9253	5272		3528		5562	87%
	tons/mi²/yr	**Legacy**		170	1483	141	182	134	277		1361	0	156	214	141		155		407	6%
		Management		2290	207	459	637	143	63		165	55	423	194	45		538		436	7%
Annual Sediment Yield		**Natural**		64%	71%	83%	90%	94%	96%		81%	0%	87%	96%	97%		84%		87%	
	% of sub-basin total	**Legacy**		2%	25%	4%	2%	3%	3%		17%	0%	4%	2%	3%		4%		6%	
	tons/mi²/yr	**Management**		33%	4%	13%	7%	3%	1%		2%	100%	10%	2%	1%		13%		7%	
		Total		6848	5826	3453	8588	4444	8558		8078	55	4289	9661	5458		4221		6406	
		Disturbance Index		0.56	0.41	0.21	0.11	0.07	0.04		0.23		0.16	0.04	0.04		0.20			
																			HCP total	
		Total (tons/yr)		13818	15047	8463	25236	8573	34268	0	16891	2	12694	12951	12671	0	4908	0	165522	

Bear River Watershed Analysis

			Module	Definition
NATURAL	Landslides	Deep Seated	MW	Includes composite, earthflow, rock topple, and rock fall landslide types
		Shallow Seated	MW	Includes debris flow, debris slide, and debris torrent landslide types
		Streamside (typically channel related	MW	Streamside landslides identified by field surveys - not identified by air photo analysis; no observable management association
	Surface Erosion	Soil Creep	SE	Gravitational movement of solid soil particles dislodged by processes such as raindrop splash, wind, frost action, animal movement - eventually delivered to stream by bank erosion
	Stream Channel Erosion	Bank Erosion (incl in streamside LS)		Distinct streamside bank erosion features (>10 yds3), with no observed mgmt. association
LEGACY	Landslides	"Untreated" Abandoned roads	MW	Landslides associated with pre-1975 constructed roads that are no longer used, typically revegetated, and have not been "treated" (e.g. HCP decommissioned, abandoned, closed)
		Tractor Harvest 15-30yrs (PC)	MW	Landslides originating from slopes where last harvest occurred between 15 and 30 years ago; harvest removed <50% canopy and utilized ground-based yarding methods (e.g. tractors)
		Tractor Harvest 20-30yrs (CC)	MW	Landslides originating from slopes where last harvest occurred between 20 and 30 years ago; harvest removed >50% canopy and utilized ground-based yarding methods (e.g. tractors)
		Streamside (typically channel related	MW	Streamside landslides identified by field surveys - not identified by air photo analysis; associated with "untreated" abandoned roads or pre-1975 logging operations
	Surface Erosion	"Untreated" Abandoned Roads	SE	Stream crossing washouts or other road fill erosion from "untreated" abandoned roads
	Stream Channel Erosion	Bank Erosion (incl in streamside LS)		Distinct streamside bank erosion features associated with "untreated" abandoned roads or pre-1975 logging operations
		Channel Incision - no data		Streambed erosion of sediment delivered to the watercourse by pre-1975 logging activities including tractor, railroad, steam "donkey", and animal yarding operations
MGMT	Landslides	HCP Roads	MW	Landslides associated with HCP maintained, decommissioned, abandoned, or closed roads
		Partial Cut <15 yrs	MW	Landslides originating from slopes where last harvest occurred <15 yrs ago and harvest removed <50% canopy; includes skid road associated landslides
		Clearcut <20 yrs	MW	Landslides originating from slopes where last harvest occurred <20 yrs ago and harvest removed >50% canopy; includes skid road associated landslides
		Streamside (typically channel related	MW	Streamside landslides identified by field surveys - not identified by air photo analysis; associated with recent timber harvest operations or HCP roads
	Surface Erosion	Harvest Unit (1988-2003)	SE	Sheet or rill erosion resulting from harvesting induced ground disturbance
		Road - Surface	SE	Sheet or rill erosion coming off of road surfaces
		Road - Gullies/Washouts	SE	Stream crossing washouts or other road fill erosion from HCP roads
	Stream Channel Erosion	Bank Erosion (incl in streamside LS)		Distinct streamside bank erosion features associated with recent timber harvest operations or HCP roads; includes effects of timber harvest associated peak flow increases
		Channel Incision - no data		streambed erosion associated with recent timber harvest operations or HCP roads resulting in concentrated or increased peak flows

			Module	Module	Method
NATURAL	Landslides	Deep Seated	MW	mass wasting	SHN Air Photo Landslide Inventory
		Shallow Seated	MW	mass wasting	SHN Air Photo Landslide Inventory
		Streamside (typically channel related	MW	mass wasting	SHN Streamside Landslide Surveys (unit rates applied based on sub-basin stream miles)
	Surface Erosion	Soil Creep	SE	surface erosio	SHN calculation based on annual rate x soil depth x 2 stream banks x sub-basin stream miles
	Stream Channel Erosion	Bank Erosion (incl in streamside LS)			SHN Streamside Landslide Surveys (insignificant bank erosion observed)
LEGACY	Landslides	"Untreated" Abandoned roads	MW	mass wasting	SHN Air Photo Landslide Inventory
		Tractor Harvest 15-30yrs (PC)	MW	mass wasting	SHN Air Photo Landslide Inventory
		Tractor Harvest 20-30yrs (CC)	MW	mass wasting	SHN Air Photo Landslide Inventory
		Streamside (typically channel related	MW	mass wasting	SHN Streamside Landslide Surveys (unit rates applied based on sub-basin stream miles)
	Surface Erosion	"Untreated" Abandoned Roads	SE	surface erosio	PWA past road erosion calculations from data collection in Bear River WAU
	Stream Channel Erosion	Bank Erosion (incl in streamside LS)			SHN Streamside Landslide Surveys (insignificant bank erosion observed)
		Channel Incision - no data			
MGMT	Landslides	HCP Roads	MW	mass wasting	SHN Air Photo Landslide Inventory
		Partial Cut <15 yrs	MW	mass wasting	SHN Air Photo Landslide Inventory
		Clearcut <20 yrs	MW	mass wasting	SHN Air Photo Landslide Inventory
		Streamside (typically channel related	MW	mass wasting	SHN Streamside Landslide Surveys (unit rates applied based on sub-basin stream miles)
	Surface Erosion	Harvest Unit (1988-2003)	SE	surface erosio	SHN - WEPP Model (run by Scopac GIS)
		Road - Surface	SE	surface erosio	SHN - SEDMODL (run by Scopac GIS)
		Road - Gullies/Washouts	SE	surface erosio	PWA past road erosion calculations from data collection in Bear River WAU
	Stream Channel Erosion	Bank Erosion (incl in streamside LS)			SHN Streamside Landslide Surveys (insignificant bank erosion observed)
		Channel Incision - no data			

Attachment 3

Bear River Watershed Analysis

Sub-basin Summaries

ATTACHMENT 3

BEAR RIVER WATERSHED ANALYSIS SUB-BASIN SUMMARIES

Conditions for each sub-basin are summarized in this attachment based on data presented in the six watershed analysis modules (Appendices A–F). Four sections are included for each sub-basin: introduction; Habitat Conservation Plan (HCP) species; stream channel and riparian conditions; and hillslope conditions. The introduction describes the location of the sub-basin, general characteristics of the terrain and vegetation, roads, and general harvest history. The HCP species section summarizes results of fish, amphibian, and reptile surveys (primarily presence or absence in sub-basin), provides estimates of the quantity and quality of suitable habitat within the sub-basin, and describes physical barriers to upstream fish migration. The stream channel and riparian condition section describes the quality and quantity of fish spawning and rearing habitat based on streambed, pool, and stream temperature conditions. Riparian conditions are characterized from module information on canopy cover, tree size, and large woody debris recruitment. Hillslope conditions are summarized in terms of sediment sources as 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 analyses, 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 watershed analysis unit (WAU)-wide basis. Calculation methods and unit rates were used, 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.

BEER BOTTLE CREEK COMPLEX SUB-BASIN

The 3.5 mi^2 Beer Bottle Complex sub-basin is located on the western edge of the Bear River WAU south of Bear River and contains mainly the Class II Beer Bottle Creek and its tributaries along with a very short Class I segment of Beer Bottle Creek at the boundary with the mainstem Bear River sub-basin. HCP lands comprise 58% of the sub-basin. Elevation ranges from 920 feet to 3,160 feet. Based on recent LIDAR data, 29% of the HCP area has slope gradients of less than 35%, and 23% of the area has slopes steeper than 65%. The entire Beer Bottle Complex sub-basin is within the Franciscan Coastal Terrane geologic formation.

Douglas-fir is the dominant vegetation type in the Beer Bottle Complex sub-basin, covering 71% of the HCP area. Hardwood forest comprises 13% of the HCP area, and the remainder of the HCP area is typed as non-timber (12%) and Douglas-fir/Hardwood (4%). The sub-basin has a road density of 5.3 mi/mi^2 for all Humboldt Redwood Company (HRC) HCP and non-HCP lands. The majority of these are regular dirt roads that are used seasonally.

First harvest in the Beer Bottle Complex sub-basin occurred in the 1950s and second-cycle logging activities have been ongoing for the past several decades. During the analysis period of 1988 through 2003, harvest occurred on a total of 589 acres, or 46% of the total HCP area. Of this total, 74% of the harvested acres were clear cut and tractor yarding was the most common method of harvest (57% of total harvested acres). Cable yarding was used on 27% of the total harvested acres.

HCP Species

Steelhead trout and resident rainbow trout are abundant near the confluence with the Bear River, but the fish-bearing reach is limited to the lower 982 feet of the stream due to a boulder and a gradient barrier. Likewise, spawning habitat is limited to the lower reaches. Despite the high amount of fine sediment observed during 2005 stream surveys, this sub-basin contains some of the best salmonid rearing habitat in the Bear River WAU.

Due to the Franciscan geology, generally northern aspect, and dense canopy cover, this sub-basin appears ideal for headwaters amphibian species (southern torrent salamanders [*Rhyacotriton variegates*] and tailed frogs [*Ascaphus truei*]), and both species have been found in stream segments with low (10–11 °C) water temperature. Foothill yellow-legged frogs (*Rana boylii*) have been observed in the lower gradient portions of Beer Bottle Creek only. There are no recorded observations of northwestern pond turtles (*Actinemys marmorata marmorata*) or northern red-legged frogs (*Rana aurora aurora*) in the sub-basin. This was expected because the sub-basin contains no suitable habitat for either species.

For details see Appendix E (Section 4.2.3.17; Photo E-22; Map E-10) and Appendix F (Section 4.6; Tables F-1 to F-11; Figures F-1 and F-2; Photo F-2; Maps F-1 to F-5).

Stream Channel and Riparian Conditions

The fish-bearing reach of Beer Bottle Creek has an 889-acre drainage area, and is contained in a steep (4–25% gradient), confined channel with abundant large woody debris (LWD). Approximately 17% of the survey length was comprised of pools, with the remainder of the creek being high gradient cascades and riffles. Pool depth exceeded two feet in depth and contained complex LWD and boulder cover, which provides over-winter habitat. While no landslides were observed in the survey reach, fine sediment (silt and sand) was prevalent in the pools. Stream temperatures are suitable for salmonids due to dense canopy cover of Douglas-fir and tanoak combined with north aspects. Two barriers to fish migration exist within the surveyed portion of Beer Bottle Creek. The first barrier is a 7.7-foot vertical step over boulder with a 2.3-foot jump pool at its base, located approximately 982 feet upstream of the confluence with Bear River. Immediately upstream of the step is a 48% gradient cascade that extends for 103 feet; these barriers prevent fish passage upstream of this point.

For details see Appendix C (Section 6.1; Figure C-4; Tables C-14 to C-16; Photo C-12) and Appendix E (Sections 3.2, 4.2.3.17; Tables E-3, E-4, E-12; Photo E-22; Map E-10).

Hillslope Conditions

The total sediment delivery rate estimated for the Beer Bottle Complex sub-basin is 6848 tons/mi^2/year, with 64% associated with natural processes, 33% management-related, and 2% due to legacy effects. Naturally-occurring small streamside landslides deliver the largest amount of sediment (3239 tons/mi^2/year or 47% of the total), followed by road-related landslides (1647 tons/mi^2/year or 24% of the total) and shallow seated natural landslides (1069 tons/mi^2/year or 16% of the total). Overall, landslides account for 6592 tons/mi^2/year or 96% of the total delivered sediment per year. An estimated 147 tons of sediment are deposited each year by road surface erosion in this sub-basin. Gravel-surfaced primary roads contribute an estimated 76 tons/year (52% of total sediment deposited) followed by spur dirt roads at 46 tons/year (31% of total). This sub-basin has the highest percentage of sediment contributed by gravel primary roads than any other sub-basin in the Bear River WAU. Even though dirt spur roads ranked second for this sub-basin at 31% of total sediment from road erosion, it has the lowest percentage for any sub-basin for that type of road (Upper Bear River sub-basin is a close second at 32%).

For details see Appendix A, Appendix B, and the Sediment Budget.

BRUSHY CREEK SUB-BASIN

The 2.9 mi^2 Brushy Creek sub-basin is in the north central portion of the Bear River WAU and includes the Class I Brushy Creek and its Class II tributaries; the lower reaches of two tributaries are Class I watercourses. HCP lands comprise 91% of the sub-basin. Elevation ranges from 1,320 feet to 3,160 feet. Based on recent LIDAR data, only 13% of the HCP area has slope gradients of less than 35%, but 45% of the area has slopes steeper than 65%. Nearly the entire Brushy Creek sub-basin (99.8%) is within the Franciscan Coastal Terrane geologic formation. A very small portion (0.2%) of the sub-basin is composed of Quaternary alluvium deposits.

Hardwood forest is the dominant vegetation type in the Brushy Creek sub-basin, covering 52% of the HCP area. Douglas-fir forest comprises 33% of the HCP area, and the remainder of the HCP area is typed as non-timber (9%) and Douglas-fir/Hardwood (6%). The sub-basin has a road density of 4.9 mi/mi^2 for all HRC HCP and non-HCP lands. The majority of these are regular dirt roads that are used seasonally.

First harvest in the Brushy Creek sub-basin occurred in the 1940s and second-cycle logging activities have been ongoing for the past several decades. During the analysis period of 1988 through 2003, harvest occurred on a total of 223 acres, or 13% of the total HCP area. Of this total, 93% of the harvested acres were clear cut and cable yarding was the most common method of harvest (65% of total harvested acres). Tractor yarding was used on 32% of the total harvested acres.

HCP Species

Steelhead trout were observed in Brushy Creek during 2005 stream inventories. Spawning habitat within the sub-basin is abundant but highly embedded with fine sediment. While steelhead trout production is good, a reduction of sediment and addition of LWD and deeper pools could greatly improve steelhead trout production. Due to topographic variability and vegetation along the channel banks, overwintering habitat is present on wide floodplains in the valley bottoms.

Brushy Creek contains habitat elements suitable for headwater amphibians such as the southern torrent salamander; however, none of the 4 amphibian and 1 reptile HCP species has been observed in the sub-basin. There is potential habitat for the foothill yellow-legged frog in the mainstem of Brushy Creek where the gradient is less than 18% and over-stream canopy closure is less than 19%. The sub-basin contains no suitable habitat for northern red-legged frogs or northwestern pond turtles.

For details see Appendix E (Section 4.2.3.10; Photo E-16; Map E-6) and Appendix F (Section 4.6; Tables F-1 to F-11; Figures F-1 and F-2; Maps F-1 to F-5).

Stream Channel and Riparian Conditions

Brushy Creek has a watershed area of 1,642 acres, and tends to be moderately confined at the mouth, becoming less confined by mid-basin with periodic bedrock constrictions. Slopes within the sub-basin tend to be south facing with over-stream canopy closure exceeding 85%. Upper reaches of Brushy Creek tend to be steep while the remaining reaches tend to be moderate to low gradient. Fish habitat within Brushy Creek appears to have been heavily impacted by landslide(s) that occurred 15–20 years ago, as evidence by floodplain deposits 7–8 feet above the low flow water surface with 15–20 year old Douglas-fir growing on it. Vertical and horizontal down cutting through landslide deposits has resulted in an unstable thalweg. The streambed substrate is mainly composed of heavily embedded gravel.

LWD is abundant but restricted to channel constriction points and the base of landslides. Similarly, pool habitat is also limited and restricted to reaches with channel constrictions. Canopy closure is provided by hardwoods and is low in the valley bottoms but is higher in constricted areas.

For details see Appendix C (Section 6.1; Figures C-4, C-11; Tables C-7 to C-10, C-14, C-17; Photo C-5) and Appendix E (Sections 3.2, 4.2.3.10 to 4.2.3.13; Tables E-3, E-4, E-12; Photos E-16 to E-19; Map E-6).

Hillslope Conditions

The total sediment delivery rate estimated for the Brushy Creek sub-basin is 5826 tons/mi^2/year, with 71% associated with natural processes, 25% due to legacy effects, and 4% management-related. Naturally-occurring small streamside landslides deliver the largest amount of sediment (2822 tons/mi^2/year or 48% of the total), followed by landslides associated with "untreated" abandoned (legacy) roads (1335 tons/mi^2/year or 23% of the total) and shallow seated natural landslides (1244 tons/mi^2/year or 21% of the total). Overall, landslides account for 5707 tons/mi^2/year or 98% of the total delivered sediment per year. An estimated 61 tons of sediment are deposited each year by road surface erosion in this sub-basin. Spur dirt roads contribute an estimated 27 tons/year (44% of total sediment deposited) followed by gravel-surfaced primary roads at 23 tons/year (38% of total). This sub-basin has the second highest percentage of sediment contributed by gravel primary roads (second only to the Beer Bottle Complex sub-basin). Abandoned dirt roads contribute an estimated 10 tons/year (16% of total), which is the greatest proportion contributed by this road type for any sub-basin in the Bear River WAU. The percent contribution of road surface erosion attributed to the different road types is similar to the Main Stem Bear River sub-basin.

For details see Appendix A, Appendix B, and the Sediment Budget.

Chase Ranch Complex Sub-Basin

The 2.8 mi^2 Chase Ranch Complex sub-basin is in the northwestern portion of the Bear River WAU and includes two Class I watercourses and their Class II tributaries. The sub-basin also includes the upper reaches of several Class II streams that drain directly into the Bear River. HCP lands comprise 88% of the sub-basin. Elevation ranges from 1,040 feet to 3,160 feet. Based on recent LIDAR data, 21% of the HCP area has slope gradients of less than 35%, and 31% of the area has slopes steeper than 65%. The entire Chase Ranch Complex sub-basin is within the Franciscan Coastal Terrane geologic formation.

Hardwood forest and Douglas-fir forest are the dominant vegetation types in the Chase Ranch Complex sub-basin, covering 38% and 33% of the HCP area, respectively. The remainder of the HCP area is typed as non-timber (28%) and Douglas-fir/Hardwood (1%). The sub-basin has a road density of 5.3 mi/mi^2 for all HRC HCP and non-HCP lands. The majority of these are regular dirt roads that are used seasonally.

First harvest in the Chase Ranch Complex sub-basin occurred in the 1890s and second-cycle logging activities have been ongoing for the past several decades. Other than the Middle Bear Complex sub-basin (where less than one acre was harvested in the 1890s and no additional harvest occurred until the 1940s) the Chase Ranch Complex sub-basin is the only sub-basin within the Bear River WAU that was first harvested prior to 1910. Further, this sub-basin is one of only three (Harmonica Creek and Nelson Creek are the other two) with first harvest acres between 1910 and 1940. During the analysis period of 1988 through 2003, harvest occurred on a total of 238 acres, or 15% of the total HCP area. Of this total, 78% of the harvested acres were clear cut and tractor yarding was the most common method of harvest (66% of total harvested acres). Cable yarding was used on 29% of the total harvested acres.

<u>HCP Species</u>

Habitat features within the Chase Ranch sub-basin are suitable for amphibian headwater species. To date, southern torrent salamanders, but not tailed frogs, have been observed in the sub-basin. The salamanders were found in cold (8–12 °C) stream segments only. There are records of foothill yellow-legged frogs in the lower reaches of this sub-basin; however, northern red-legged frogs and northwestern pond turtles are absent perhaps due to a lack of suitable habitat. Anadromous fish data are not available for this sub-basin.

For details see Appendix F (Section 4.6; Tables F-1 to F-11; Figures F-1 and F-2; Maps F-1 to F-5).

<u>Stream Channel and Riparian Conditions</u>

Sub-basin geology is primarily (80% of the HCP area) Franciscan Coastal Terrain (TKfs), with Franciscan Coastal Belt-sheared (TKfs-sz) covering the remaining 20% of the HCP area. Slopes within the sub-basin tend to be moderate to steep and south facing, with an over stream canopy closure that is greater than 85%.

For details see Appendix C (Section 6.1; Figures C-2, C-4, C-11; Tables C-7 to C-10, C-14, C-18; Photo C-3).

Hillslope Conditions

The total sediment delivery rate estimated for the Chase Ranch Complex sub-basin is 3453 tons/mi^2/year (the lowest rate for any Bear River WAU sub-basin), with 83% associated with natural processes, 13% management-related, and 4% due to legacy effects. Naturally-occurring small streamside landslides deliver the largest amount of sediment (2687 tons/mi^2/year or 78% of the total), followed by surface erosion from roads (405 tons/mi^2/year or 12% of the total) and legacy-related small streamside landslides (141 tons/mi^2/year or 4% of the total). Overall, landslides account for 2903 tons/mi^2/year or 85% of the total delivered sediment per year. An estimated 262 tons of sediment are deposited each year by road surface erosion in this sub-basin, which is the highest amount estimated for any sub-basin in the Bear River WAU (Upper Bear River sub-basin is a close second at 257 tons/year). Spur dirt roads and gravel main haul roads each contribute an estimated 86 tons/year (33% of total sediment deposited for each; 66% combined contribution) followed by gravel-surfaced primary roads at 55 tons/year (21% of total). This sub-basin has the second highest percentage (13%) of sediment contributed by abandoned dirt roads (second only to the Brushy Creek sub-basin at 16%).

For details see Appendix A, Appendix B, and the Sediment Budget.

GORGE CREEK COMPLEX SUB-BASIN

The 3.4 mi^2 Gorge Creek Complex sub-basin is in the south central portion of the Bear River WAU and includes the Class I Gorge Creek and its Class II tributaries. The sub-basin also includes a short reach of an unnamed Class I watercourse that drains into the Bear River upstream from its confluence with Gorge Creek. The sub-basin also includes the upper reaches of several Class II streams that drain directly into the Bear River. HCP lands comprise 86% of the sub-basin. Elevation ranges from 1,120 feet to 3,480 feet. Based on recent LIDAR data, only 17% of the HCP area has slope gradients of less than 35%, but 40% of the area has slopes steeper than 65%. The entire Gorge Creek Complex sub-basin is within the Franciscan Coastal Terrane geologic formation.

Hardwood forest is the dominant vegetation type in the Brushy Creek sub-basin, covering 62% of the HCP area. Douglas-fir forest comprises 33% of the HCP area, and the remainder of the HCP area is typed as non-timber (4%) and Douglas-fir/Hardwood (<2%). The sub-basin has a road density of 4.8 mi/mi^2 for all HRC HCP and non-HCP lands. The majority of these are regular dirt roads that are used seasonally.

First harvest in the Gorge Creek Complex sub-basin occurred in the 1940s and second-cycle logging activities have been ongoing for the past several decades. During the analysis period of 1988 through 2003, harvest occurred on a total of 224 acres, or 12% of the total HCP area. Of this total, 89% of the harvested acres were clear cut and tractor yarding was the most common method of harvest (53% of total harvested acres). Cable yarding was used on 39% of the total harvested acres.

HCP Species

During 2005 surveys, steelhead trout and resident rainbow trout were abundant within the first 583 feet from the confluence with the Bear River. Spawning habitat is poor quality due to large size substrate (boulders). Rearing habitat within the sub-basin appears favorable with 39% of the channel consisting of pools. Over-wintering habitat was limited to areas under or behind large substrate. No barriers to migration were found during the 2005 survey.

Habitat conditions appear ideal for headwater amphibians, but no occurrence records exist for either southern torrent salamanders or tailed frogs. Lower gradient reaches of Gorge Creek appear suitable for foothill yellow-legged frogs, but none were found during surveys. No northern red-legged frogs or northwestern pond turtles were detected during surveys, but no suitable habitat for either species exists in the sub-basin.

For details see Appendix E (Section 4.2.3.14; Table E-11; Photo E-20; Map E-7) and Appendix F (Section 4.6; Tables F-1 to F-11; Figures F-1 and F-2; Maps F-1 to F-5).

Stream Channel and Riparian Conditions

Gorge Creek drains a 1,471-acre watershed comprised of Franciscan geology. Gorge Creek is moderately steep (4–16%), and generally flows in a northerly aspect with moderate (70–85%) to dense (greater than 85%) over stream canopy. Because of the northerly aspect of Gorge Creek, full sun reaches the stream, however canopy closure was 76%. Approximately 39% of the stream contained pools, and 9 of the 12 pools were greater than two feet deep. Spawning habitat was associated with pool tailouts and was in poor condition consisting of embedded boulders. LWD abundance was moderate, but pieces were generally small, and large key pieces were infrequent.

For details see Appendix C (Section 6.1; Figures C-4, C-13; Tables C-7 to C-10, C-14, C-19; Photos C-4, C-7) and Appendix E (Sections 3.2, 4.2.3.14; Tables E-11, E-12; Photo E-20; Map E-7).

Hillslope Conditions

The total sediment delivery rate estimated for the Gorge Creek Complex sub-basin is 8588 tons/mi^2/year, with 90% associated with natural processes, 7% management-related, and 2% due to legacy effects. The sediment delivery rate for this sub-basin is the second highest of any sub-basin in the Bear River WAU (the Peaked Creek Complex sub-basin has the highest at 9661 tons/mi^2/year). Shallow seated natural landslides deliver the largest amount of sediment (4821 tons/mi^2/year or 56% of the total), followed by naturally-occurring small streamside landslides (2881 tons/mi^2/year or 34% of the total) and partial cut (<15 years) management-related landslides (564 tons/mi^2/year or 7% of the total). Overall, landslides account for 8066 tons/mi^2/year or 94% of the total delivered sediment per year. An estimated 140 tons of sediment are deposited each year by road surface erosion in this sub-basin. Spur dirt roads contribute an estimated 107 tons/year (76% of total sediment deposited) followed by gravel-surfaced primary roads at 23 tons/year (16% of total). Abandoned dirt roads contribute an estimated 8 tons/year (6% of total).

For details see Appendix A, Appendix B, and the Sediment Budget.

HAPPY VALLEY SUB-BASIN

The 2 mi^2 Happy Valley sub-basin forms the eastern edge of the Bear River WAU and includes the Class I Tributary #3 of the Upper Bear River Gorge Creek and its Class II tributaries. The sub-basin also includes a short Class I reach of Tributary #1 of the Upper Bear River, and the upper reaches of several Class II tributaries of the Bear River. HCP lands comprise 93% of the sub-basin. Elevation ranges from 1,480 feet to 2,960 feet. Based on recent LIDAR data, 28% of the HCP area has slope gradients of less than 35%, and 20% of the area has slopes steeper than 65%. The northern two-thirds (65%) of the Happy Valley sub-basin is within the Franciscan Coastal Terrane geologic formation and the southern one-third (33%) is within the Yager Formation. The remainder of the sub-basin (2%) is composed of Quaternary river terrace deposits.

Hardwood forest and Douglas-fir forest are the dominant vegetation types in the Happy Valley sub-basin, covering 44% and 43% of the HCP area, respectively. The remainder of the HCP area is typed as non-timber (5%) and Douglas-fir/Hardwood (8%). The sub-basin has a road density of 6.2 mi/mi^2 for all HRC HCP and non-HCP lands. Approximately one-half of the roads are regular dirt roads that are used seasonally and the other half are rocked roads.

First harvest in the Happy Valley sub-basin occurred in the 1940s and second-cycle logging activities have been ongoing for the past several decades. During the analysis period of 1988 through 2003, harvest occurred on a total of 470 acres, or 38% of the total HCP area. Of this total, 61% of the harvested acres were clear cut (39% of acres were partial cut) and tractor yarding was the most common method of harvest (61% of total harvested acres). Cable yarding was used on 26% of the total harvested acres.

<u>HCP Species</u>

Historic records within the sub-basin include southern torrent salamanders, but not tailed frogs. There is habitat for foothill yellow-legged frogs in the lower reaches of Pullen Creek and in a few of the other large watercourses in this sub-basin. However, the high (greater than 85%) canopy closure may limit the distribution and abundance of foothill yellow-legged frogs in these areas. There are no records, and habitat is limited, for northern red-legged frogs and northwestern pond turtles in the sub-basin. Anadromous fish data are not available for this sub-basin.

For details see Appendix F (Section 4.6; Table F-7).

Stream Channel and Riparian Conditions

Happy Valley is greater than 65% Franciscan geology with the remaining area comprised of various mélanges of Franciscan. The Happy Valley sub-basin runs due south and is typically moderate to low gradient, except where headwalls in the upper reaches slope to over 20% gradient.

Canopy closure within the Happy Valley sub-basin is estimated to be moderate (70–85%) to high (greater than 85%) throughout. High canopy closure is important for maintaining a suitable microclimate for headwater amphibians in high gradient stream segments.

For details see Appendix C (Section 6.2; Figures C-4, C-15, C-16; Tables C-7 to C-10, C-21 to C-23; Photo C-17).

Hillslope Conditions

The total sediment delivery rate estimated for the Happy Valley sub-basin is 4444 tons/mi^2/year, with 94% associated with natural processes, 3% management-related, and 3% due to legacy effects. Naturally-occurring small streamside landslides deliver the largest amount of sediment (2539 tons/mi^2/year or 57% of the total), followed by shallow seated natural landslides (1564 tons/mi^2/year or 35% of the total) and legacy-related small streamside landslides (134 tons/mi^2/year or 3% of the total). Overall, landslides account for 4244 tons/mi^2/year or 95% of the total delivered sediment per year. An estimated 108 tons of sediment are deposited each year by road surface erosion in this sub-basin. Spur dirt roads contribute an estimated 45 tons/year (41% of total sediment deposited) followed by dirt-surfaced primary roads at 34 tons/year (31% of total). This sub-basin is second only to the Upper Bear River sub-basin (at 50%) in the percentage of road surface erosion attributed to dirt-surfaced primary roads. Gravel-surfaced primary roads contribute an estimated 14 tons/year (13% of total) in this sub-basin.

For details see Appendix A, Appendix B, and the Sediment Budget.

HARMONICA CREEK SUB-BASIN

The 4 mi^2 Harmonica Creek sub-basin forms the southeastern corner of the Bear River WAU and includes the Class I Harmonica and its Class I and II tributaries. This is the only sub-basin within HCP lands of the Bear River WAU that includes other tributaries (besides Harmonica Creek) of the Bear River. HCP lands comprise 98.7% of the sub-basin. Elevation ranges from 1,320 feet to 3,600 feet. Based on recent LIDAR data, 24% of the HCP area has slope gradients of less than 35%, and 29% of the area has slopes steeper than 65%. The southern two-thirds (61%) of the Harmonica Creek sub-basin is within the Franciscan Coastal Terrane geologic formation and the northern one-third (38%) is within the Yager Formation. The remainder of the sub-basin (1%) is composed of Quaternary river terrace and channel deposits, and alluvium.

Hardwood forest is the dominant vegetation type in the Harmonica Creek sub-basin, covering 54% of the HCP area. Douglas-fir forest comprises 37% of the HCP area, and the remainder of the HCP area is typed as Douglas-fir/Hardwood (6%) and non-timber (3%). The sub-basin has a road density of 4.7 mi/mi^2 for all HRC HCP and non-HCP lands. The majority of these are regular dirt roads that are used seasonally.

First harvest in the Harmonica Creek sub-basin occurred in the 1910s and second-cycle logging activities have been ongoing for the past several decades. This sub-basin is one of only three (Chase Ranch Complex and Nelson Creek are the other two) with first harvest acres between 1910 and 1940. In addition, from 1940 to 1949 this sub-basin had the greatest number of first harvest acres (1,297 acres) of any sub-basin in the Bear River WAU during any decade since harvest began in the 1890s. During the analysis period of 1988 through 2003, harvest occurred on a total of 527 acres, or 21% of the total HCP area. Of this total, 70% of the harvested acres were clear cut and tractor yarding was the most common method of harvest (83% of total harvested acres). Cable yarding was used on 13% of the total harvested acres.

<u>HCP Species</u>

Steelhead trout and resident rainbow trout are abundant in Harmonica Creek. Furthermore, recent data collected over several years at ATM station 131, near the confluence with Bear River, indicate that Harmonica Creek supports a stable, high-density population. Topographic complexity within the wide floodplains creates abundant over-wintering habitat. Spawning gravels at the ATM station are unembedded, abundant, and ideal for steelhead trout.

The relatively open canopy and subsequent warmer temperatures taken near ATM station 131 likely explain the lack of detections of headwater amphibian species. However, in small seeps and springs where canopy closure is more dense, there are records of southern torrent salamanders. During aquatic trend surveys, foothill yellow-legged frogs were detected along the mainstem of Harmonica Creek and some of the lower tributaries. No records exist for northern red-legged frogs or northwestern pond turtles, and habitat is non-existent or extremely limited in the sub-basin.

For details see Appendix E (Section 4.2.3.6; Photos E-9 and E-10; Table E-8; Map E-3) and Appendix F (Section 4.6; Tables F-1 to F-11; Figures F-1 and F-2; Photos F-1 and F-2; Maps F-1 to F-5).

Stream Channel and Riparian Conditions

Harmonica Creek is the largest tributary within the SCOPAC Bear River WAU ownership and is a low gradient, unconfined channel with a drainage area of 6,593 acres (10.3 square miles). Approximately 65% of the HCP area of Harmonica Creek has Franciscan Coastal Terrane (TKfs) geology with the remaining area comprised primarily of the Yager Formation (Tky). The lower reach is a pool/riffle morphology with a 0–2% gradient, changing to a plane bed channel morphology with a 4–6% gradient in the mid-basin. Streamside landslides are abundant resulting in a heavily aggraded channel with a wide cross-section, short and shallow pools, and low canopy closure. LWD is very limited within the channel; the quality of instream habitat would be greatly improved with a reduction of sediment and increased LWD recruitment. Using the LIDAR map, a gradient barrier was detected in the headwaters of the left bank tributary (T1S, R1E, S29, NW ¼) to Harmonica Creek. A gradient exceeding 20% on average for over 200 feet on the east fork of the tributary is likely a barrier to salmonid migration. Furthermore, another potential barrier was detected on the west fork of the same tributary where the channel gradient exceeded 30% for over 200 feet. The channel of Harmonica Creek is open and receives direct sunlight in the summer. While recent stream temperature data are not available, MWAT taken at ATM station 131 in 1999 and 2001–2001 ranged from 16–18° C.

For details see Appendix C (Section 6.2; Figures C-2, C-4, C-17; Tables C-7 to C-11, C-21, C-24; Photos C-18, C-19) and Appendix E (Sections 3.2, 4.2.3.6; Tables E-8, E-12, E-14; Photos E-9, E-10; Map E-3).

Hillslope Conditions

The total sediment delivery rate estimated for the Harmonica Creek sub-basin is 8558 tons/mi^2/year, with 96% associated with natural processes, 3% due to legacy effects, and 1% management-related. The sediment delivery rate for this sub-basin is very similar (only 30 tons/mi^2/year lower) to the Gorge Creek Complex sub-basin, which has the second highest delivery rate of any sub-basin in the Bear River WAU (the Peaked Creek Complex sub-basin has the highest at 9661 tons/mi^2/year). Shallow seated natural landslides deliver the largest amount of sediment (3964 tons/mi^2/year or 46% of the total), followed by naturally-occurring small streamside landslides (2677 tons/mi^2/year or 31% of the total) and deep seated natural landslides (1513 tons/mi^2/year or 18% of the total). Overall, landslides account for 8431 tons/mi^2/year or 99% of the total delivered sediment per year. An estimated 152 tons of sediment are deposited each year by road surface erosion in this sub-basin. Spur dirt roads contribute the vast majority of sediment with an estimated 134 tons/year (88% of total sediment deposited) followed by abandoned dirt roads at 13 tons/year (9% of total). This sub-basin is second only to the Nelson Creek sub-basin (at 96%) in the percentage of road surface erosion attributed to dirt-surfaced spur roads (all road surface erosion in the Peaked Creek Complex is from dirt-surfaced spur roads, but HRC-owned HCP lands account for only 23% of that sub-basin compared with 99% for this sub-basin).

For details see Appendix A, Appendix B, and the Sediment Budget.

JOHNSON GULCH SUB-BASIN

The 12 mi^2 Johnson Gulch sub-basin includes the lowest reach of the Bear River and includes its estuary. There are no HCP lands or HRC-owned lands within the sub-basin. Fish distribution and habitat data were not collected or evaluated for the Johnson Gulch sub-basin during watershed analysis activities. Similarly, data on species distribution were not collected or evaluated for this sub-basin. Johnson Gulch consists of agricultural lands and open prairies, therefore lacking habitat for southern torrent salamanders and tailed frogs. However, habitat for the foothill yellow-legged frog and potential habitat for the northern red-legged frog and northwestern pond turtle exists along the mainstem of the Bear River. Anadromous fish data are not available for this sub-basin. Hillslope, stream channel and riparian condition data are also not available.

MAIN STEM BEAR RIVER SUB-BASIN

The 2.8 mi^2 Main Stem Bear River sub-basin follows the mainstem Bear River west from the Nelson Creek confluence to the western edge of the Bear River WAU. The sub-basin includes the mainstem Bear River and the lower reaches of all of its Class I and II tributaries from Nelson Creek downstream to the western edge of the Bear River WAU where the Bear River begins flowing west. HCP lands comprise 76% of the sub-basin. Elevation ranges from 720 feet to 1,880 feet. Based on recent LIDAR data, only 13% of the HCP area has slope gradients of less than 35%, but 45% of the area has slopes steeper than 65%. The predominant (95%) geologic formation in the Main Stem Bear River sub-basin is the Franciscan Coastal Terrane. The remainder of the sub-basin is composed of Quaternary river terrace and channel deposits, and alluvium.

Hardwood forest is the dominant vegetation type in the Main Stem Bear River sub-basin, covering 62% of the HCP area. Douglas-fir forest comprises 25% of the HCP area, and the remainder of the HCP area is typed as non-timber (7%) and Douglas-fir/Hardwood (5%). The sub-basin has a road density of 3.7 mi/mi^2 for all HRC HCP and non-HCP lands. The majority of these are regular dirt roads that are used seasonally.

First harvest in the Main Stem Bear River sub-basin occurred in the 1940s and second-cycle logging activities have been ongoing for the past several decades. During the analysis period of 1988 through 2003, harvest occurred on a total of 106 acres, or 8% of the total HCP area. Of this total, 89% of the harvested acres were clear cut and cable yarding was the most common method of harvest (70% of total harvested acres). Helicopter yarding was used on 18% of the total harvested acres.

HCP Species

This sub-basin contains the most steelhead trout habitat on HCP lands within the Bear River watershed. High quality habitat may be due to the size of the drainage area (14,744 acres) and the mostly confined valley through which the river flows. High velocity winter flows, combined with mostly confined river morphology and a large drainage area, result in pool scouring and sorting of spawning gravels. Large resident rainbow trout (12–14 inches) are present in large deep pools with steelhead trout and smaller resident fish occupying all other habitat types. Over wintering habitat is restricted to point bars, tributary mouths, and areas under or behind large substrate. No barriers to fish migration were observed in this segment of the Bear River mainstem.

Channel gradients along this stretch of the Bear River are low (0–4%) with low (<20%) canopy closure along the mainstem. In contrast, canopy closure along the tributaries is dense and there are records of southern torrent salamanders in these cooler areas. Despite relatively high (>16.3 °C) water temperatures in the mainstem, foothill yellow-legged frogs have been found at several sites. Although there were no confirmed records of northern red-legged frogs or northwestern pond turtles, sparse habitat may exist for these species, especially along the lower reaches of the mainstem of the Bear River and at Chisum Pond.

For details see Appendix E (Section 4.2.3.1; Table E-5; Photo E-2) and Appendix F (Section 4.6; Tables F-1 to F-11; Figures F-1 and F-2; Maps F-1 to F-5).

Stream Channel and Riparian Conditions

Approximately 7,257 feet of river was surveyed (within RM 20 to 21.4), although river morphology was similar and extended beyond the extent of the survey up to RM 24.6. The large drainage area (14,744 acres) and mostly confined river morphology results in high velocity winter flows that scours pools and sorts spawning gravel. Pools tend to be long and formed through scour processes occurring along exposed bedrock outcroppings of Franciscan geology. Furthermore, while pool depths do not meet PFC targets, it appears that pool length and depth have increased between 2000 DFG surveys and 2005 SCOPAC surveys. Pools made up 19% of the channel length during 2000 surveys, while that percentage increased to 27% in 2005. Furthermore, pool depth of greater than 3 feet deep was noted for 28% of the pools, while in 2005, 79% of the pools were greater than 3 feet.

LWD is very limited in the channel. Streamside timber harvests in the 1950s and 1960s reduced LWD recruitment rates, and winter flows likely flushed the majority of remaining LWD down river. Substrate in this section of the river is cobble sized or larger. Spawning habitat is limited to gravel pockets behind large substrate in the lower reach but the majority of spawning substrate sampled is highly embedded. While canopy closure is low (44%), young hardwoods make up the majority of the streamside canopy. Tributary inflow, stream aspect, and topographic shading help keep stream temperatures relatively low, although further reduction of stream temperature would be beneficial.

For details see Appendix C (Section 6.1; Figures C-4, C-9, C-10, C-14; Tables C-15, C-16, C-20; Photos C-12, C-13, C-15, C-16) and Appendix E (Sections 3.2, 4.2.3.1; Tables E-5, E-12; Photos E-2, E-3).

Hillslope Conditions

The total sediment delivery rate estimated for the Main Stem Bear River sub-basin is 8078 tons/mi^2/year, with 81% associated with natural processes, 17% due to legacy effects, and 2% management-related. Naturally-occurring small streamside landslides deliver the largest amount of sediment (3358 tons/mi^2/year or 42% of the total), followed by shallow seated natural landslides (3108 tons/mi^2/year or 38% of the total) and landslides associated with "untreated" abandoned (legacy) roads (1185 tons/mi^2/year or 15% of the total). Overall, landslides account for 7827 tons/mi^2/year or 97% of the total delivered sediment per year. An estimated 113 tons of sediment are deposited each year by road surface erosion in this sub-basin. Spur dirt roads contribute an estimated 61 tons/year (54% of total sediment deposited) followed by gravel-surfaced primary roads at 42 tons/year (37% of total). This sub-basin has the third highest percentage of sediment contributed by gravel-surfaced primary roads (second only to the Beer Bottle Complex and Brushy Creek sub-basins). Abandoned dirt roads contribute an estimated 8 tons/year (7% of total). The percent contribution of road surface erosion attributed to the different road types is similar to the Brushy Creek sub-basin.

For details see Appendix A, Appendix B, and the Sediment Budget.

MIDDLE BEAR COMPLEX SUB-BASIN

The 9.6 mi^2 Middle Bear Complex sub-basin includes only a very small amount (0.04 mi^2 or 25.4 acres) of HRC HCP lands and no HRC non-HCP lands. Fish distribution and habitat data were not collected or evaluated for the Middle Bear Complex sub-basin during watershed analysis activities. Similarly, data on species distribution were not collected or evaluated for this sub-basin. The primary geologic type is Franciscan, and this sub-basin is very similar to the Johnson Gulch sub-basin. This area is primarily foraging for cattle and agriculture, and some timber production occurs. Anadromous fish data are not available for this sub-basin. Hillslope, stream channel and riparian condition data are also not available. First harvest in the Middle Bear Complex sub-basin occurred in the 1890s (<1 acre harvested) with very few first entry acres (24 acres) harvested during the next century. The total sediment delivery rate estimated for the Middle Bear Complex sub-basin is 55 tons/mi^2/year, all of which is management related (road gullies and washouts). An estimated 43 tons of sediment are deposited each year by road surface erosion in this sub-basin, all from gravel-surfaced main haul roads.

NELSON CREEK SUB-BASIN

The 3.2 mi^2 Nelson Creek sub-basin is south of the Bear River and west of Harmonica Creek and includes the Class I Nelson Creek and its Class I and II tributaries. The sub-basin contains a short segment of only a single Bear River tributary (i.e., other than Nelson Creek). HCP lands comprise 92% of the sub-basin. Elevation ranges from 1,320 feet to 3,560 feet. Based on recent LIDAR data, 25% of the HCP area has slope gradients of less than 35%, and 32% of the area has slopes steeper than 65%. The predominant (90%)

geologic formation in the Nelson Creek sub-basin is the Franciscan Coastal Terrane. The remainder of the sub-basin is within the Yager Formation (10%) and Quaternary river channel deposits and alluvium.

Hardwood forest is the dominant vegetation type in the Nelson Creek sub-basin, covering 57% of the HCP area. Douglas-fir forest comprises 36% of the HCP area, and the remainder of the HCP area is typed as Douglas-fir/Hardwood (4%) and non-timber (3%). The sub-basin has a road density of 3.9 mi/mi^2 for all HRC HCP and non-HCP lands. The majority of these are regular dirt roads that are used seasonally.

First harvest in the Nelson Creek sub-basin occurred in the 1910s and second-cycle logging activities have been ongoing for the past several decades. This sub-basin is one of only three (Chase Ranch Complex and Harmonica Creek are the other two) with first harvest acres between 1910 and 1940. During the analysis period of 1988 through 2003, harvest occurred on a total of 325 acres, or 17% of the total HCP area. Of this total, 78% of the harvested acres were clear cut and tractor yarding was the most common method of harvest (67% of total harvested acres). Cable yarding was used on 27% of the total harvested acres.

HCP Species

During the 2005 stream survey, SCOPAC crews reported seeing steelhead trout and resident rainbow trout in nearly every habitat unit sampled but did not provide fish abundance estimates. In 1997, DFG stream inventory reported steelhead trout densities of 2.88 fish/m^2 with fish extending 17,560 feet from the confluence with the Bear River. The upper extent of fish distribution likely ends at the headwaters fork where stream gradient is >20%. LIDAR mapping suggests another gradient barrier within the left bank tributary where the stream gradient is above 20% for more than 200 feet. Stream substrate tends to be cobble sized or larger, and spawning habitat appears to be in poor condition with the majority of pool tailouts being embedded cobble. Instream, over-winter habitat is provided by large substrate, edgewater, streamside vegetation, and bar surfaces.

Habitat exists for the headwater amphibian species in this sub-basin's headwater stream reaches. In the lower gradient (0–8%) stream reaches of mainstem Nelson Creek, habitat for foothill yellow-legged frogs exists where canopy closure is moderate (less than 85%). No records exist for northern red-legged frogs and northwestern pond turtles within Nelson Creek, nor does habitat appear appropriate within the creek or sub-basin to support these species.

For details see Appendix E (Section 4.2.3.9; Photos E-14 and E-15; Table E-10; Map E-5) and Appendix F (Section 4.6; Tables F-1 to F-11).

Stream Channel and Riparian Conditions

Nelson Creek has a drainage area of 5,612 acres, which is second in size only to Harmonica Creek within the HCP area of the Bear River WAU. Nelson Creek is composed primarily of Coastal Terrane (TKfs) geology with a small amount (10%) of Yager Formation (Tky). Stream gradient in the lower reaches of Nelson Creek are 0–4%, increasing to 6–8% near mid-basin. In-stream habitat is dominated by riffles and flatwaters, which constitute 48% and 24% of the channel length, respectively. Large woody debris is very limited and is most often associated with prevalent stream side landslides resulting in short and shallow pools. Stream substrate tends to be cobble sized or larger and spawning habitat appears to be in poor condition with the majority of pool tailouts being embedded cobble. In-stream, over-winter habitat is provided by large substrate, edgewater, streamside vegetation, and bar surfaces. While long-term stream temperature data are not available, the channel is open and receives direct sunlight; water temperature taken on July 21, 2005 during a SCOPAC stream survey showed the creek to be at 17 °C at noon when the air temperature was 27 °C. It is likely temperatures increased later in the day, and also as summer progressed and flow decreased. In turn, stream temperatures in Nelson Creek may be problematic for salmonids. Reduction of sediment, increases in LWD recruitment, and deeper pools would improve habitat for steelhead trout in Nelson Creek.

For details see Appendix C (Section 6.2; Figures C-4, C-18; Tables C-7 to C-10, C-21, C-25; Photos C-6, C-8 to C-10, C-20) and Appendix E (Sections 3.2, 4.2.3.9; Tables E-4, E-10, E-12; Photo E-14; Map E-5).

Hillslope Conditions

The total sediment delivery rate estimated for the Nelson Creek sub-basin is 4289 tons/mi^2/year, with 87% associated with natural processes, 10% management-related, and 4% due to legacy effects. Naturally-occurring small streamside landslides deliver the largest amount of sediment (2960 tons/mi^2/year or 69% of the total), followed by shallow seated natural landslides (681 tons/mi^2/year or 16% of the total) and clearcut (<20 years) management-related landslides (360 tons/mi^2/year or 8% of the total). Overall, landslides account for 4157 tons/mi^2/year or 97% of the total delivered sediment per year. An estimated 140 tons of sediment are deposited each year by road surface erosion in this sub-basin. Spur dirt roads contribute the vast majority of sediment with an estimated 135 tons/year (96% of total sediment deposited) followed by gravel-surfaced primary roads at only 5 tons/year (3% of total). This sub-basin has the highest percentage of road surface erosion attributed to dirt-surfaced spur roads of any sub-basin in the Bear River WAU.

For details see Appendix A, Appendix B, and the Sediment Budget.

PEAKED CREEK COMPLEX SUB-BASIN

The 5.8 mi^2 Peaked Creek Complex sub-basin is west of the core of HRC-owned lands within the Bear River watershed and includes the mainstem Bear River and numerous of its tributaries including Class I Antone and

Peaked Creeks and their Class II tributaries. HCP lands comprise only 23% of the sub-basin, but all of the HRC-owned lands within the sub-basin. Elevation ranges from 600 feet to 2,640 feet. Based on recent LIDAR data, 19% of the HCP area has slope gradients of less than 35%, and 41% of the area has slopes steeper than 65%. The predominant (99%) geologic formation in the Peaked Creek Complex sub-basin is the Franciscan Coastal Terrane. The remainder of the sub-basin is composed of Quaternary river terrace deposits.

Douglas-fir is the dominant vegetation type in the Peaked Creek Complex sub-basin, covering 63% of the HCP area. Hardwood forest comprises 30% of the HCP area, and the remainder of the HCP area is typed as Douglas-fir/Hardwood (6%) and non-timber (<2%). The sub-basin has a road density of 2.5 mi/mi^2 for all HRC HCP and non-HCP lands, which is the lowest road density for any sub-basin within the Bear River WAU (road density for all Bear River WAU sub-basins combined is 4.8 mi/mi^2). The majority of these are regular dirt roads that are used seasonally.

First harvest in the Peaked Creek Complex sub-basin occurred in the 1950s, with no additional first harvest acres in subsequent decades. Second-cycle logging activities have been ongoing for the past several decades. During the analysis period of 1988 through 2003, harvest occurred on a total of 292 acres, or 34% of the total HCP area. Of this total, 82% of the harvested acres were clear cut and tractor yarding was the most common method of harvest (42% of total harvested acres). Helicopter yarding and cable yarding were each used on about 25% of the total harvested acres.

HCP Species

Steelhead trout and resident rainbow trout were present to the first temporary barrier located approximately 358 feet upstream from the confluence with Bear River.

There are records of both southern torrent salamanders and tailed frogs within the Peaked Creek sub-basin where water temperatures ranged from 11 to 12 °C. Habitat is suitable throughout the sub-basin to support populations of these species. However, despite suitable habitat within the mainstem Peaked Creek for foothill yellow-legged frogs, there are no observation records for this species. Furthermore, there are no records for northern red-legged frogs and northwestern pond turtles but some potential habitat exists in man-made stock ponds and in stream pools.

For details see Appendix E (Section 4.2.3.20; Table E-12; Map E-12) and Appendix F (Section 4.6; Tables F-1 to F-11; Figures F-1 and F-2; Maps F-1 to F-5).

Stream Channel and Riparian Conditions

The confluence of Peaked Creek is located approximately 3 miles downstream from the majority of the SCOPAC ownership block. Peaked Creek runs due north to Bear River at the Middle Bear Complex sub basin and runs from low gradient along mainstem Peaked Creek to high gradient reaches in its tributaries. The Peaked Creek sub-basin drains a 1,856-acre area, of which part is owned by SCOPAC and managed under the HCP. A 9,606-foot long survey was completed by DFG in 1996. Peaked Creek is mostly Franciscan Coastal Terrane (TKfs) geology and is dominated by step runs (65%), mid-channel pools (14%), and low and high gradient riffles. According to the DFG, 24% of the pools were greater than two feet deep. Overall, the concentration of fine sediment appeared to be low, with 41% of the pool tails being less than 25% embedded. Canopy closure in Peaked Creek is 75% and stream temperature data collected between June 26 and October 23, 1996 was warmest for the week of July 24–30 (MWAT) at approximately 16 °C. Two temporary barriers to upstream migration were identified: the first occurred 358 feet upstream from the confluence was a log jam with a 7-foot drop; the second was located on SCOPAC property and was 9,606 feet upstream from the confluence. The second logjam, which has a gradient break that can be seen on LIDAR maps, has a 12-foot drop with no fish for at least 500 feet upstream of the barrier.

For details see Appendix C (Section 6.3; Figure C-4; Tables C-7 to C-10, C-28; Photo C-22) and Appendix E (Section 4.2.3.20; Tables E-4, E-12; Map E-12).

<u>Hillslope Conditions</u>

The total sediment delivery rate estimated for the Peaked Creek Complex sub-basin is 9661 tons/mi^2/year, with 96% associated with natural processes, 2% management-related, and 2% due to legacy effects. The sediment delivery rate for this sub-basin is the highest of any sub-basin in the Bear River WAU. Shallow seated natural landslides deliver the largest amount of sediment (6489 tons/mi^2/year or 67% of the total), followed by naturally-occurring small streamside landslides (2694 tons/mi^2/year or 28% of the total) and clearcut (<20 years) management-related landslides (158 tons/mi^2/year or <2% of the total). Overall, landslides account for 8066 tons/mi^2/year or 99% of the total delivered sediment per year. An estimated 13 tons of sediment are deposited each year by road surface erosion in this sub-basin; all attributed to dirt spur roads. However, only 23% of the sub-basin is within HRC HCP lands and the amount of sediment deposited by roads on the remaining 77% of the sub-basin is unknown.

For details see Appendix A, Appendix B, and the Sediment Budget.

PULLEN CREEK SUB-BASIN

The 2.7 mi^2 Pullen Creek sub-basin is located in the northeastern portion of the Bear River WAU and includes the Class I Pullen Creek and its Class I "Left Bank" tributary along with their Class II tributaries. The sub-basin also includes the upper reaches of several Class II watercourses that drain directly into the Bear River. HCP lands comprise 87% of the sub-basin. Elevation ranges from 1,360 feet to 3,080 feet. Based on recent

LIDAR data, only 14% of the HCP area has slope gradients of less than 35%, and 38% of the area has slopes steeper than 65%. The entire Pullen Creek sub-basin is within the Franciscan Coastal Terrane geologic formation.

Hardwood forest is the dominant vegetation type in the Pullen Creek sub-basin, covering 51% of the HCP area. Douglas-fir forest comprises 34% of the HCP area, and the remainder of the HCP area is typed as Douglas-fir/Hardwood (9%) and non-timber (7%). The sub-basin has a road density of 4.9 mi/mi^2 for all HRC HCP and non-HCP lands. The majority of these are regular dirt roads that are used seasonally.

First harvest in the Pullen Creek sub-basin occurred in the 1940s and second-cycle logging activities have been ongoing for the past several decades. During the analysis period of 1988 through 2003, harvest occurred on a total of 257 acres, or 17% of the total HCP area. Of this total, 83% of the harvested acres were clear cut and helicopter yarding was the most common method of harvest (35% of total harvested acres). Tractor yarding was used on 33% of the total harvested acres and cable yarding was used on 29% of the total harvested acres.

HCP Species

Young-of-the-year to age 2+ steelhead trout are abundant throughout Pullen Creek. A large logjam may hinder fish migration beyond 1,450 feet from the mouth. Steelhead trout abundance may be related to high egg-through-emergence survival rates due to relatively unembedded spawning gravel and relatively high quality winter rearing habitat. Abundant topographic relief and woody debris complexity on an extensive and wide floodplain create quality over-wintering habitat for steelhead trout in Pullen Creek. Conversely, summer rearing habitat appears to be limited by shallow pool depths.

Within the Pullen Creek sub-basin, no observation records exist for the four HCP amphibians and one reptile species. However, habitat exists for the headwater species and the foothill yellow-legged frog, although, near ATM station 134, water temperatures may be too high to support southern torrent salamanders. Current habitat conditions within the sub-basin do not appear suitable for northern red-legged frogs or northwestern pond turtles.

For details see Appendix E (Section 4.2.3.7; Table E-9; Figures F1 and F2; Photos E-11 and E-12; Map E-4) and Appendix F (Section 4.6; Tables F-1 to F-11).

Stream Channel and Riparian Conditions

The HCP area of the Pullen Creek watershed covers approximately 1,742 acres and is comprised of Franciscan Coastal Terrane (TKFs) geology. The lower reach of Pullen Creek is characterized as unconfined with large point bars vegetated with young hardwoods. LWD loading is low and pools tend to be aggraded with fine sediment; coarse sediment delivery from landslides results in channel aggradation. Approximately 2,350 feet from the confluence, Pullen creek tends to be more confined and steeper, and LWD becomes more abundant. In Pullen Creek, LWD criteria are met for volume per 100 feet and individual key pieces, but are low for pieces per channel width. Periodically, benches are encountered resulting from the creek cutting through the toes of inner gorge landslides. In addition, log jams trap sediment and reduce channel gradient for short distances. Similar to the lower reach, mid- to upper Pullen Creek continues to exhibit aggraded conditions with short and shallow pools. Canopy closure is high (greater than 85%) and stream temperature ranges from 14.4–16.0 °C at ATM station 134, which does not appear to be problematic for steelhead trout. A large log debris accumulation with substantial trapped sediment may be a potential barrier approximately 1,450 feet from the confluence, although a side channel may allow for passage at peak flows.

For details see Appendix C (Section 6.2; Figures C-2, C-4, C-19; Tables C-7 to C-11, C-21, C-26; Photo C-21) and Appendix E (Sections 3.2, 4.2.3.9, 4.2.3.8; Tables E-3, E-4, E-9, E-12, E-14; Photos E-11, E-13; Map E-4).

Hillslope Conditions

The total sediment delivery rate estimated for the Pullen Creek sub-basin is 5458 tons/mi^2/year, with 97% associated with natural processes, 3% due to legacy effects, and 1% management-related. Naturally-occurring small streamside landslides deliver the largest amount of sediment (2670 tons/mi^2/year or 48% of the total) followed by shallow seated natural landslides (1304 tons/mi^2/year or 24% of the total) and deep seated natural landslides (1236 tons/mi^2/year or 23% of the total). Overall, landslides account for 5353 tons/mi^2/year or 98% of the total delivered sediment per year. An estimated 44 tons of sediment are deposited each year by road surface erosion in this sub-basin. Spur dirt roads contribute an estimated 29 tons/year (65% of total sediment deposited) followed by gravel-surfaced main haul roads and dirt-surfaced secondary roads each at 6 tons/year (13% of total for each; 26% combined total for sub-basin). This sub-basin has the highest percentage of sediment contributed by dirt-surfaced secondary roads for any sub-basin in the Bear River WAU. Gravel-surfaced secondary roads contribute an estimated 4 tons/year (9% of total), which is the greatest proportion contributed by this road type for any sub-basin in the Bear River WAU. This sub-basin and the Upper Bear River sub-basin are the only two within the Bear River WAU where secondary roads contribute more than 1% of the total sediment input from road surface erosion (Pullen Creek sub-basin = 22%; Upper Bear River sub-basin = 15%).

For details see Appendix A, Appendix B, and the Sediment Budget.

SOUTH FORK BEAR RIVER SUB-BASIN

The 12.9 mi^2 South Fork Bear River sub-basin is located in the lower reaches of the Bear River watershed to the west of HRC-owned lands within the watershed. HRC has no land holdings within this sub-basin, and there is limited information about this sub-basin. It is unknown what geologic and stream gradient conditions exist for the headwaters species in this sub-basin. Foothill yellow-legged frog habitat does exist along the entire length of the South Fork Bear River in this sub-basin. Potential habitat, in the form of man-made structures for watering and irrigation, may exist for northern red-legged frogs and npond turtles. Additionally, pond turtle habitat may exist along the mainstem of the South Fork Bear River due to its increased size and pooling. Anadromous fish data are not available for this sub-basin. Hillslope, stream channel and riparian condition data are also not available.

UPPER BEAR RIVER SUB-BASIN

The 1.3 mi^2 Upper Bear River sub-basin is located in the eastern portion of the Bear River WAU and includes the upper reaches of the Class I Bear River to its headwaters as well as the lower reaches of several of its Class I and II tributaries downstream to the confluence with Nelson Creek. HCP lands comprise 92% of the sub-basin. Elevation ranges from 1,280 feet to 2,120 feet. Based on recent LIDAR data, 41% of the HCP area has slope gradients of less than 35%, and only 11% of the area has slopes steeper than 65%; 69% of the HCP area has slope gradients that are ≤ 50%. The majority (67%) of the Upper Bear River sub-basin is located within the Franciscan Coastal Terrane geologic formation. This sub-basin contains the greatest proportion (22%) of Quaternary river terrace and channel deposits, and alluvium of any sub-basin in the Bear River WAU. The remainder (10%) of the sub-basin is within the Yager Formation.

Douglas-fir is the dominant vegetation type in the Upper Bear River sub-basin, covering 63% of the HCP area. Hardwood forest comprises 23% of the HCP area, and the remainder of the HCP area is typed as non-timber (7%) and Douglas-fir/Hardwood (6%). The sub-basin has a road density of 7.4 mi/mi^2 for all HRC HCP and non-HCP lands, which is the highest road density for any sub-basin within the Bear River WAU (road density for all Bear River WAU sub-basins combined is 4.8 mi/mi^2). The majority of these are regular dirt roads that are used seasonally. However, over two miles of rocked road also occurs within the sub-basin.

First harvest in the Upper Bear River sub-basin occurred in the 1940s and second-cycle logging activities have been ongoing for the past several decades. During the analysis period of 1988 through 2003, harvest occurred on a total of 301 acres, or 40% of the total HCP area. Of this total, 52% of the harvested acres were partial cut (48% were clear cut) and tractor yarding was the most common method of harvest (96% of total harvested acres). Cable yarding was used on only 4% of the total harvested acres.

HCP Species

Steelhead trout and resident rainbow trout were abundant in the surveyed section of the Upper Bear River, which extended 7,338 feet upstream beyond the confluence with Harmonica Creek. Spawning gravels in this reach are high quality and abundant and bulk substrate samples at the ATM site show that spawning substrate is not embedded, which likely allows for relatively high survival of the life stages from egg through emergence. Furthermore, wide floodplains with high levels of complexity provide extensive over-wintering habitat.

The Main Stem and Upper Bear River sub-basin amphibian and reptile information is combined; overall, the total length of mainstem stream through these two sub-basins extends for more than 7 miles. This portion of Bear River flows to the northwest, starting at Chisum Pond, which is suitable habitat for northern red-legged frogs and northwestern pond turtles. The open (less than 20%) over story canopy attributed to the river's wide flood plain provides suitable habitat for foothill yellow-legged frog occurrences in the mainstem stream. In contrast to the mainstem, the canopy closure above the tributaries is dense (greater than 85%). Southern torrent salamander records occur in this sub-basin, as well as habitat to support this and other headwater species. Temperatures in this sub-basin are too high based on ATM stations 97 and 1 (16.3–19.1 °C) to support southern torrent salamanders. Furthermore, temperatures may be too high to support tailed frogs and northern red-legged frogs.

For details see Appendix E (Section 4.2.3.2; Table E-6; Photos E-4 to E-6; Map E-1) and Appendix F (Section 4.6; Tables F-1 to F-11; Figures F-1 and F-2; Photos F-1, F-3, and F-5; Maps F-1 to F-5).

Stream Channel and Riparian Conditions

Upper Bear River has an unconfined channel and is relatively low gradient (less than 2%) with a drainage area of approximately 2,000 acres. LWD is limited in the channel but very large pieces exist within log jams. Furthermore, log jams are actively trapping sediment on the upstream side as well as reducing stream gradient for short distances. In general, the channel appears to be aggraded probably due to sediment input from landslides and bank failures. Pools tend to be short and shallow and comprise 19% of the channel length, with an average residual pool depth of 1.3 feet. Canopy closure is high and stream temperatures remain very cool.

For details see Appendix C (Section 6.2; Figures C-2, C-4, C-20; Tables C-7 to C-11, C-14, C-21, C-27; Photo C-13) and Appendix E (Section 4.2.3.2; Tables E-4, E-6, E-12, E-14; Photos E-4 to E-6).

Hillslope Conditions

The total sediment delivery rate estimated for the Upper Bear River sub-basin is 4221 tons/mi^2/year, with 84% associated with natural processes, 13% management-related, and 4% due to legacy effects. Naturally-occurring small streamside landslides deliver the largest amount of sediment (2947 tons/mi^2/year or 70% of the total), followed by shallow seated natural landslides (491 tons/mi^2/year or 12% of the total) and surface erosion from roads (312 tons/mi^2/year or 7% of the total). Overall, landslides account for 3593 tons/mi^2/year or 85% of the total delivered sediment per year. An estimated 257 tons of sediment are deposited each year by road surface erosion in this sub-basin, which is the second highest amount estimated for any sub-basin in the Bear River WAU (Upper Bear River sub-basin is the highest at 262 tons/year). Dirt-surfaced primary roads contribute an estimated 129 tons/year (50% of total sediment deposited) followed by dirt spur roads at 82 tons/year (32% of total). This sub-basin has the highest percentage (50%) of sediment contributed by dirt-surfaced primary roads. This sub-basin and the Pullen Creek Complex sub-basin are the only two within the Bear River WAU where secondary roads contribute more than 1% of the total sediment input from road surface erosion (Pullen Creek sub-basin = 22%; Upper Bear River sub-basin = 15%).

For details see Appendix A, Appendix B, and the Sediment Budget.

WEST SIDE CREEK SUB-BASIN

The 14.4 mi^2 West Side Creek sub-basin is located in the lower reaches of the Bear River watershed to the west of HRC-owned lands within the watershed. HRC has no land holdings within this sub-basin, and there is limited information about this sub-basin. It is unknown what geologic and stream gradient conditions exist for the headwaters species in this sub-basin. Foothill yellow-legged frog habitat does exist along the entire length of the mainstem Bear River and the Class I segment of West Side Creek. Potential habitat, in the form of man-made structures for watering and irrigation, may exist for northern red-legged frogs and northwestern pond turtles. Anadromous fish data are not available for this sub-basin. Hillslope, stream channel and riparian condition data are also not available.

Attachment 4

Bear River Watershed Analysis

Glossary

From April 2000 Methods for Watershed Analysis

along 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.

Glossary

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 subrounded 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 – Steep (generally greater than 50 percent), concave slopes at or near the heads of steep swales, gullies and Class II and Class III waters.

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.

Glossary

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 – Hillslopes greater than or equal to 65% and located below the last major break-in-slope leading to a watercourse.

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.

Glossary

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.

Glossary

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. Includes sediment types, amounts, and routing to specific locations of analysis.

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 accumulation of colluvium.

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.

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