Yager-Lawrence Watershed Analysis

Cumulative Watershed Effects

December 2009

Humboldt Redwood
COMPANY, LLC

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LIST OF ACRONYMS

ATM	Aquatic Trends Monitoring
CDEC	California Data Exchange Center
CAL FIRE	California Department of Forestry and Fire Protection
CBT	Coastal Belt Thrust
CDF	California Department of Forestry and Fire Protection (former name)
CDFG	California Department of Fish and Game
CEQA	California Environmental Quality Act
CFPR	California Forest Practice Rules
cfs	Cubic Feet per Second
CGU	Channel Geomorphic Unit
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
KM	Kilometers
LWD	Large Woody Debris
MMCA	Marbled Murrelet Conservation Area
MTJ	Mendocino Triple Junction
MWAT	Maximum Weekly Average Temperature
NC	Northern California
NCRWQCB	North Coast Regional Water Quality Control Board
NMFS	National Marine Fisheries Service
NOAA	National Oceanic & Atmospheric Administration
NRCS	Natural Resource Conservation Service
PALCO	The Pacific Lumber Company
PFC	Properly Functioning Condition
RCU	Riparian Condition Unit
RM	River Mile
THP	Timber Harvest Plan
TMDL	Total Maximum Daily Load
tons/mi^2/yr	Tons per square mile per year
WAU	Watershed Analysis Unit
WLPZ	Watercourse and Lake Protection Zone
WWII	World War II

1.0 ABSTRACT

Watershed analysis was conducted for the Yager-Lawrence watershed as required by the Pacific Lumber Company (PALCO) Habitat Conservation Plan (HCP) (PALCO, 1999) on lands now owned and managed by the Humboldt Redwood Company LLC (HRC). The HCP Watershed Analysis program is designed 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. 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 151-square-mile Yager-Lawrence Watershed Analysis Unit (WAU) is located in Humboldt County, California, approximately 20 miles southeast of Eureka. This WAU covers the basin of Yager Creek and its tributaries, including Lawrence Creek which is a 42-square-mile tributary entering Yager Creek nine miles upstream of its mouth. The Yager drains into the Van Duzen River, which empties into the Eel River 13.7 miles from its confluence with the Pacific Ocean. Elevations in the WAU range from 80 feet at the Yager Creek mouth to over 3,200 feet along the highest ridges. The portion of the Yager-Lawrence WAU within HRC ownership is comprised primarily of redwood and Douglas-fir plantations and young forest with mid- and late-successional forest found adjacent to streams and in established conservation areas. The primary land use is timber management. Oak-grassland communities are prevalent along ridges and higher elevations of the WAU beyond HRC ownership.

The predominant geology in the Yager-Lawrence WAU includes the Yager and Franciscan formations, with smaller portions including the undifferentiated Wildcat Group as well as mapped landslide deposits. The region is seismically and tectonically active, with frequent earthquakes due to the proximity of the area to the Mendocino triple junction, which is the intersection of three crustal plates, along with numerous earthquake faults. The topography of the Yager-Lawrence WAU is moderately rugged, with localized areas of steeper slopes adjacent to fish-bearing streams. Nearly half of the HCP land area has slope gradients less than 35 percent. Climate conditions are typical of coastal Northern California, marked by high levels of humidity throughout the year, a rainy season which runs from approximately

October through April, and an annual average precipitation depth of 45 to 60 inches with up to 70 inches per year occurring in the higher elevations of the WAU. The native forests of the Yager-Lawrence WAU are dominated by stands of coastal mixed conifer, primarily redwood (*Sequoia sempervirens*) and Douglas-fir (*Pseudotsuga menziesii*). Hardwood stands typically are dominated by tanoak (*Lithocarpus densiflorus*). A variety of understory herbaceous plants are present throughout the area.

Chinook (*Oncorhynchus tshawytscha*) and coho (*O. kisutch*) salmon, steelhead and resident rainbow trout (*O. mykiss*), and coastal cutthroat trout (*O. clarki clarki*) inhabit the WAU. The primary fish-producing tributary to Yager Creek is Lawrence Creek, with fish-bearing tributaries including Corner Creek, Shaw Creek, Fish Creek, Booths Run, and Bell Creek. Chinook and steelhead are the dominant salmonids in the WAU, while coho salmon have been found only in Shaw Creek and Lawrence Creek. Coastal cutthroat trout are found only in the upper reaches of Booths Run and the Middle Fork Yager Creek. Fish distribution is limited by natural barriers, primarily by steep channel gradients such as those found reaching into the headwaters of the smaller tributaries, and by bedrock falls. The Cooper Mill diversion dam is the only man-made structure that is a potential barrier in the WAU, but evaluation is required to determine its status with regard to fish passage as migration may be precluded for some species.

The annual sediment delivery was calculated at 3,791 tons/square mile for the sediment budget period of 1988 to 2003. The volume of sediment delivered was attributed to natural, legacy, or management associations, comprising 43, 11, or 45 percent of the total sediment delivery, respectively. Landslides accounted for an estimated 94 percent of the total sediment delivery from 1988 to 2003; 85 percent of the landslide sediment delivery during this period was from large landslides (larger than 3,000 cubic yards each). Sediment from mass wasting was predominantly produced by natural processes including prolonged periods of rainfall and resulting flood flows. Many of the large and very large slides have persisted through time without observable effects from management, although a portion of the sediment delivery has occurred in association with management activities. Historically, ground-based yarding appears to account for much of the total management-related landslide sediment delivery volume; however, landslide-related sediment delivery from cable yarding areas is slightly greater *per acre* harvested for the overall photo period as a result of this logging method being typically used more often on steeper, more landslide-prone slopes closer to streams. In addition to hillslope effects, tractor channels and mechanically filled tractor crossings, from historic logging operations, represent significant impacts to stream channels and contributed sediment. In recent years, bed sediment data suggest declining sediment loads in the streams. Also, bulk sediment data suggest that the percentage of fine particles is decreasing to levels that meet Properly Functioning Condition (PFC) targets.

Road-related sediment sources are an important source of management-related sediment. Ongoing sediment reduction efforts to address these sources include continual road system improvement and limitations on harvest activities on unstable areas and near streams. HCP upgrading and stormproofing measures conducted over the last 11 years have removed or prevented delivery of more than 65,000 cubic yards of sediment from entering watercourses in the Yager-Lawrence WAU.

Spawning-sized gravels are abundant in the mainstems of Yager Creek and Lawrence Creek, and commonly in lower reaches of the adjoining tributaries. Also, excellent adult rearing habitat in mainstem reaches is formed around rock outcrops and large boulder substrate. LWD frequency is low in many reaches, likely leading to mainstem pools being generally widely spaced; however, this condition is inherent in the Yager mainstem due to its larger watercourse size and seasonally high peak flows. Pool development is likely to improve as more LWD enters channels, providing grade control, and as sediment storage capacity improves with the exception of the Yager mainstem which is boulder dependent. Pool attributes of depth, frequency, and association with LWD currently do not typically meet PFCs; however, interpretations of the ‘key piece’ definition used in the survey methodology may be resulting in the reporting of less functional LWD than actually present.

Near and long-term LWD recruitment potential is in an advanced stage of recovery from historical streamside harvesting, with most riparian areas not meeting PFC matrix targets on track to do so within the life of the 50-year HCP. This trend toward increased LWD is facilitated, in part, by large remnants of late-seral (old growth redwood) forests, totaling over 6,000 acres, within several Marbled Murrelet Conservation Areas on HCP lands and within the Owl Creek Forest State Reserve. Improvement in LWD recruitment can be facilitated by management such as silvicultural prescriptions to promote streamside conifer growth, and by intentional falling of trees into streams, although regulatory interpretation of state law (AB 1986) associated with the HCP and Headwaters deal may inhibit such activities.

Water temperatures are cool and meet PFC objectives in most tributary streams, but become predictably warmer downstream in the larger streams where they fail to meet PFC targets. Overstream canopy closure has increased in nearly all sampled reaches and is abundant throughout the HCP area, thus moving streams toward cooler water temperatures except for the Yager Creek and Lawrence Creek mainstems where larger channel widths limit the extent of canopy development over the stream.

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 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 with shade canopy and LWD recruitment potential. 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 Yager mainstem 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 discussed for individual streams in Attachment 3 as presented in various modules (Appendices C, D, and E). Appendix E provides 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 to 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 species are derived from this discussion of current conditions and trends. These recommendations are then implemented through forest management measures relative to timber harvest operations, road upgrading prioritization, and in-stream habitat improvement.

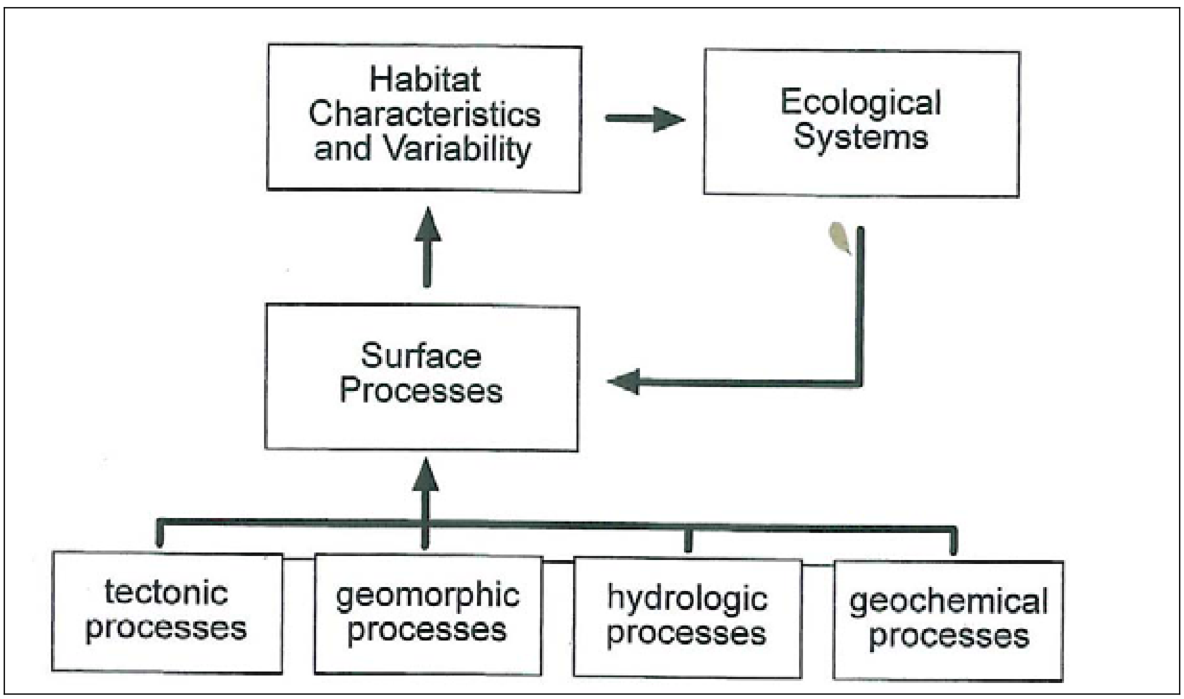
2.1 OVERVIEW OF WATERSHED ANALYSIS PROCESS

Watershed analysis is a systematic process for assessing the condition of water, wood, and sediment in a watershed relative to aquatic salmonid and/or amphibian and reptile habitat, and how land management affects this condition. It operates on the basic premise that hillslope (upland and riparian) processes influence 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 habitat conditions.

Watershed analysis involves evaluation of individual and cumulative management-related impacts to natural processes, which in turn affect 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 influence 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

Yager-Lawrence Watershed Analysis Unit (WAU), as described in the module reports (i.e., appendices) and listed in Table 2-1, to assess watershed condition and cumulative effects of land management and natural disturbances.

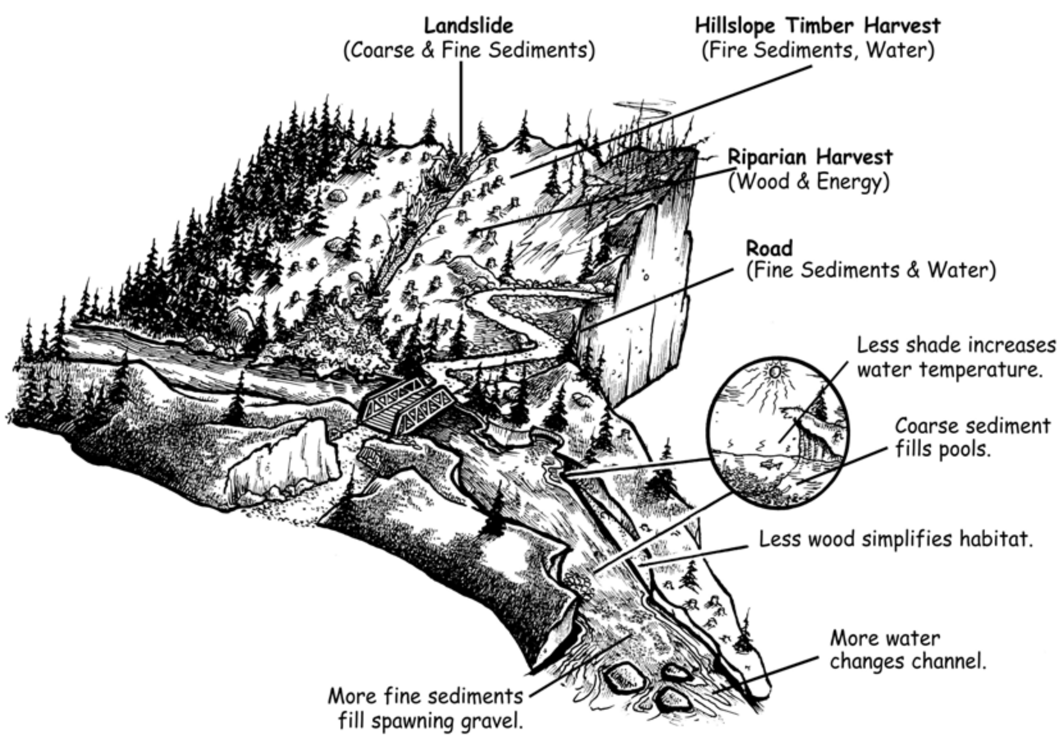
Table 2-1. Analysis and Data Collection for the Yager-Lawrence Watershed Analysis.

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 Yager Creek and Lawrence Creek	Appendix D
Analysis of channel width with respect to drainage area	Appendix D
Time series review of cross sections and channel longitudinal profile data surveyed since the late 1990s	Appendix D
Collection and analysis of bulk sediment distribution surface and subsurface streambed sediment samples	Appendices D and E
Measurement of 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 139,223 feet of stream for characterization of habitat features including pools	Appendix E
Review of historical aerial photographs of mainstem and tributary channels to understand major changes that have occurred to selected channels through land use and natural causes	Appendix D
Review of direct anthropogenic impacts to the channel network from historical aerial photographs	Appendix D
Review of previous fish surveys to determine upstream extent of fish distribution	Appendix E
Analysis of water temperature in streams	Appendix E
Review of previously collected data to assess occurrence of amphibians and reptiles	Appendix F

The key "currencies" of watersheds that are traded between a channel and its drainage basin are sediment, LWD, water, heat energy, and nutrients. River processes are driven by general physical relationships 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.

2.2 PURPOSE AND ORGANIZATION OF REPORT

This CWE Report presents a summary of the watershed setting and land use history in the Yager-Lawrence 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 Yager-Lawrence 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

A public meeting was held on July 26, 2006 for the purpose of identifying issues and receiving public input for the Yager-Lawrence WAU as the first step in conducting watershed analysis. This meeting was held at the Winema Theater in Scotia and provided a forum for input from the community for the Yager-Lawrence watershed analysis area. A total of 15 people attended including community members, PALCO staff, agencies, and analysts. Verbal comments were provided by four individuals; no written comments were received. Comments covered the following topics and were addressed as indicated:

- Concern over (non-PALCO) gravel extraction operations, particularly the danger of gravel hauling on Riverbar Road. Non-PALCO gravel operations are outside the scope of HCP watershed analysis.
- Concern over herbicide use. This comment is outside the scope of HCP watershed analysis; however, basic information is provided in the discussion on contemporary harvest (Section 4.3).
- Concern over changes in lower Yager Creek stream channel morphology; road-related landslides are believed to be responsible for reduction in pool depth. This comment is addressed through the Stream Channel Assessment (Appendix D).
- Concern over any reduction in riparian area protection or harvest of old growth from riparian areas. Revision of interim prescriptions will be based on findings of the watershed analysis. Modification of interim HCP prescriptions will be consistent with the HCP's conservation principles and objectives for streamside areas and based on the findings of the watershed analysis and commonly accepted scientific literature. In addition, the HRC policy of not harvesting large

old growth trees will provide protection for old-growth timber in riparian areas and elsewhere across the watershed.

- Curious as to how linkages between in-stream condition and hillslope processes are sorted out between on-PALCO property and off-PALCO property sources since the upper watershed is not owned by PALCO. These issues cannot be sorted out through this watershed analysis process, but analysis in the HCP area will involve documentation of stream conditions and linkages with sediment sources. Though not anticipated, any potentially significant issues upstream of the HCP area will be identified but not analyzed.
- Linkage of watershed analysis with the Total Maximum Daily Load (TMDL). The watershed analysis process uses the TMDL (USEPA, 1999) as existing information and compares TMDL sediment delivery estimates with those developed for watershed analysis, though the areas covered and methods used are not identical. The watershed analysis process is more intensive on HCP lands than the TMDL.
- Concern that previous watershed analyses have not been transparent. Data collection and involvement of the public continues for the Yager-Lawrence watershed analysis as has been the case for the past several watershed analyses. The invitation to participate in the field during the process of data collection continues to be open for watershed analysis.

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 subsequent watershed analysis.

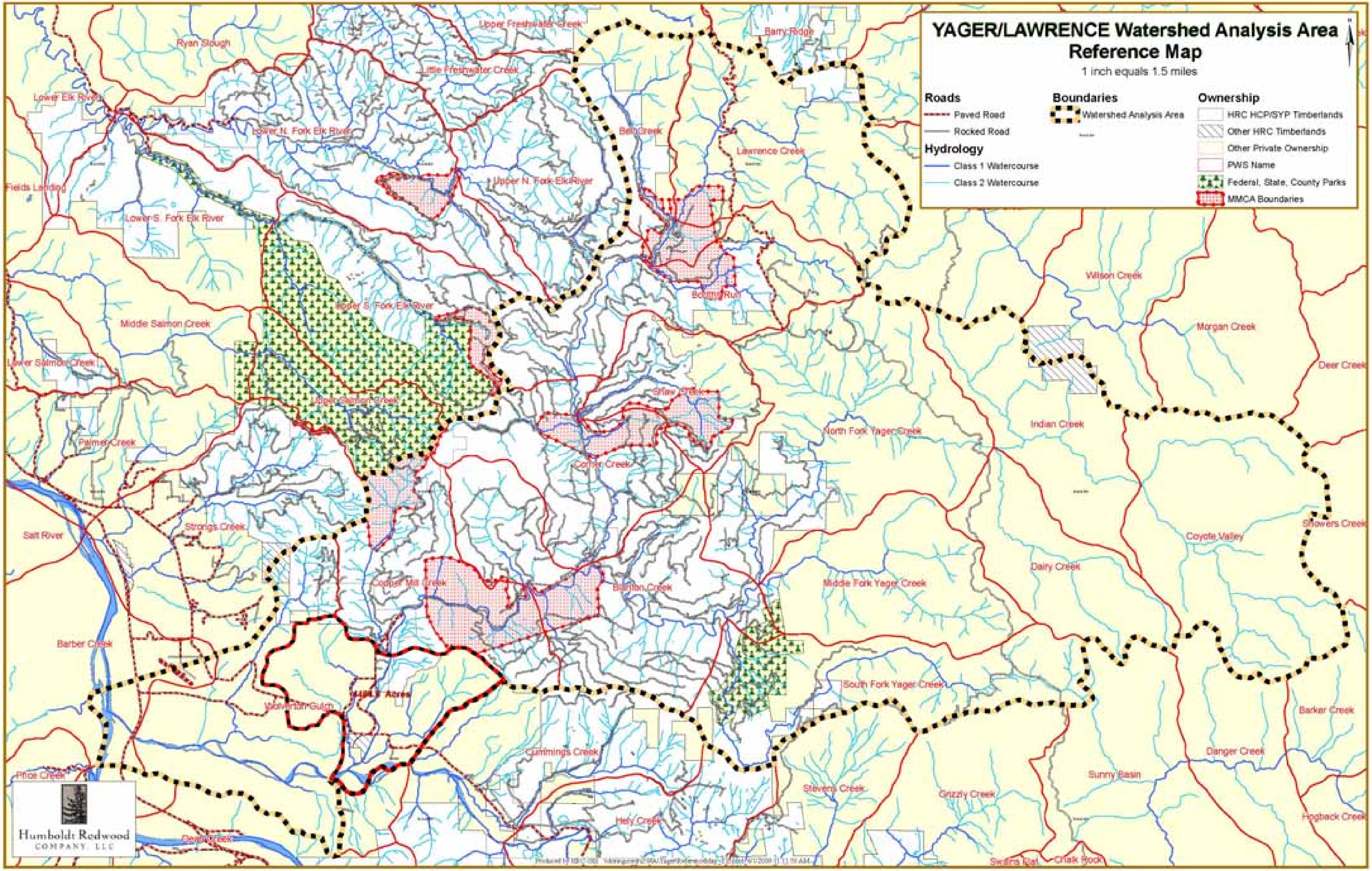
Development of a technical definition of cumulative watershed effects is an ongoing effort (U.C. Committee on Cumulative Watershed Effects, 2001). A standard definition of cumulative watershed effects, as defined in the Board of Forestry Practice Rules in reference to California Environmental Quality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

3.0 WATERSHED SUMMARY

This section provides a summary of the watershed setting, history, and key themes for the Yager-Lawrence WAU. 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 151-square-mile Yager-Lawrence WAU is located in California's north coast, northeast of the town of Carlotta and approximately 20 miles southeast of the city of Eureka. The Yager-Lawrence WAU covers the basin of Yager Creek and its tributaries, including Lawrence Creek – a 42-square-mile tributary of Yager Creek and a highly utilized anadromous fisheries stream which enters Yager Creek nine miles upstream of its mouth (Figure 3-1). The majority of the WAU is comprised of the Yager Creek drainage itself, but it also encompasses minor sub-basins adjacent to the Yager basin that drain directly into the Van Duzen River. The Yager basin drains into the Van Duzen River at River Mile 5.0, and the Van Duzen River empties into the Eel River 13.7 miles from its confluence with the Pacific Ocean.



YAGER/LAWRENCE Watershed Analysis Area
Reference Map
1 inch equals 1.5 miles
Roads
Paved Road
Rocked Road
Hydrology
Class 1 Watercourse
Class 2 Watercourse
Boundaries
Watershed Analysis Area
Ownership
HRC HCP/SYP Timberlands
Other HRC Timberlands
Other Private Ownership
PWS Name
Federal, State, County Parks
MMCA Boundaries
Ryan Slough
Upper Freshwater Creek
Barry Ridge
Little Freshwater Creek
Lower Elk River
Lower N. Fork Elk River
Bell Creek
Lawrence Creek
Upper N. Fork Elk River
Fields Landing
Lower S. Fork Elk River
Bouttie Run
Wilson Creek
Upper S. Fork Elk River
Middle Salmon Creek
Morgan Creek
Lower Salmon Creek
Deer Creek
Shaw Creek
Upper Salmon Creek
Indian Creek
North Fork Yager Creek
Palmer Creek
Corner Creek
Salt River
Strongs Creek
Showers Creek
Coyote Valley
Dairy Creek
Copper Mill Creek
Blanton Creek
Middle Fork Yager Creek
Barber Creek
South Fork Yager Creek
Wolverton Gulch
Barker Creek
Cummings Creek
Danger Creek
Price Creek
Sunny Basin
Stevens Creek
Grizzly Creek
Hely Creek
Hogback Creek
Swains Flat
Chalk Rock
Humboldt Redwood
COMPANY, LLC

Elevations in the Yager-Lawrence WAU range from 80 feet at the mouth of Yager Creek to over 3,200 feet along the highest ridges. Approximately 36 percent of the WAU is within HRC ownership, with 99 percent of the HRC ownership in this WAU managed under the HCP. Another 63 percent of the land is held by other private ownerships and 1 percent is under public ownership. The portion of the Yager-Lawrence WAU within HRC's ownership is comprised primarily of open and young forest with some mid- and late-successional forest, with the primary land use being timber management. Oak-grassland communities are prevalent along the ridges and higher elevations of the WAU beyond HRC ownership.

Stream flow is generally unimpeded and there are no stream gaging stations in the Yager-Lawrence WAU. A small diversion dam was established in Cooper Mill Creek for the previous owner SCOPAC's Yager fish hatchery, which operated from 1977 through 2000. Other small water diversions likely occur throughout the upper basin for domestic use, livestock watering, irrigation, and dust control (road watering). In the early to mid-1980s, a hydroelectric project was proposed on a private landholding on the North Fork Yager Creek, but was ultimately denied due to localized geologic instabilities.

The bulk of HRC ownership in the Yager-Lawrence WAU is concentrated in the tributary of Lawrence Creek and along the mainstem of Yager Creek, with HRC ownership extending only a short distance upstream from the downstream ends of the North Fork, Middle Fork, and South Fork Yager Creek. Within the 42-square-mile Lawrence Creek drainage, 56 percent of the land is owned by HRC and managed under the HCP. The primary subbasins in Lawrence Creek with HRC ownership include Corner Creek, Shaw Creek, Booths Run, and Bell Creek. Along the mainstem Yager, HRC owns 95 percent of the land area in the lowest Yager Creek subbasins of Cooper Mill Creek and Blanton Creek; conversely, in the North Fork Yager Creek and South Fork Yager Creek, HRC ownership encompasses only about 19 percent of the land area – all in the lowest portions of both the North Fork and South Fork subbasins. The majority of the remainder of HRC's ownership in the WAU is located in the headwaters of Wolverton Gulch. HRC has no ownership in the Barber Creek subbasin, or the upper North Fork Yager subbasins of Dairy Creek or Coyote Valley; HRC owns a small acreage in the Indian Creek sub-basin (upstream of the North Fork Yager Creek sub-basin) and manages the land outside of the HCP.

A summary of watershed parameters for the Yager-Lawrence WAU is provided in Table 3-1. The Yager-Lawrence WAU is divided into 15 CalWater Planning Units (Planning Watersheds), of which 11 include lands managed under the HCP as listed in Table 3-2 and shown in Figure 3-1. Attachment 1 provides data for the HCP-managed lands in the Yager-Lawrence WAU.

Table 3-1. Watershed Areas for the Yager-Lawrence WAU.

Parameter	Yager-Lawrence WAU
Total Basin WAU Area (mi^2)	151
Total Humboldt Redwood Company Ownership (mi^2)	54.2
Total HCP Area (mi^2)	53.4

Table 3-2. Humboldt Redwood Company (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)		
Bell Creek	1,966	-	1,725	3,691
Blanton Creek	8,326	-	378	8,703
Booths Run	4,644	-	2,136	6,780
Cooper Mill	6,015	-	31	6,047
Corner Creek	5,445	-	80	5,526
Coyote Valley	-	-	9,235	9,235
Dairy Creek	-	-	4,511	4,511
Eel Delta	-	-	1,028	1,028
Indian Creek	-	314	5,151	5,465
Lawrence Creek	685	-	6,801	7,486
Middle Fork Yager	104	-	5,886	5,989
North Fork Yager	2,118	-	8,781	10,899
Shaw Creek	2,287	-	1,162	3,449
South Fork Yager	1,285	-	5,544	6,829
Wolverton Gulch	1,306	188	9,341	10,835
GRAND TOTAL	**34,181**	**502**	**61,790**	**96,473**

[1] Non-HRC Ownership includes areas labeled “inholding” and “(blank)” in the PALCO database queried during 2007 for watershed analysis.

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), which is the intersection of three crustal plates – the North American, Pacific, and Gorda plates. The leading edge of the over-riding North American plate in the MTJ region consists of a series of accretionary wedges of the Mesozoic-Cenozoic age Franciscan Complex (Blake et al., 1985), in which “accretion” is the process by which material that has been scraped off the subducting plate is incorporated onto the overriding plate. The Franciscan Complex forms the basement rock throughout the region. Each accretionary wedge forms an elongate, highly deformed, northwest-trending belt. These belts increase in age and metamorphic grade in an inland direction.

There are three principal belts within the Franciscan Complex in the region (from southwest to northeast): the Coastal, Central, and Eastern belts. Within the Yager-Lawrence watershed, the Yager terrane, a subunit of the Coastal belt, is the dominant bedrock type (Table 3-3). In the eastern part of the watershed, the Yager terrane is in fault contact with mélange of the Central belt. The transition between the Yager and Central belt is characterized by a change in topography and vegetation, from forested, smoother topography (Yager) to “lumpy” prairies (mélange). This fault contact is referred to as the Coastal Belt Thrust (CBT) or Freshwater fault. The CBT is a northeast dipping, high angle reverse fault (Knudsen, 1993). Though the CBT is not considered active, bedrock on both sides of the fault is likely sheared and weakened from when the fault was active (mostly during the accretion of the Coastal belt).

There are numerous active seismic sources in the north coast region that are capable of generating moderate- to large-magnitude earthquakes. Historically, northwestern California has been the most seismically active region in the continental United States. More than 60 earthquakes have produced discernable damage in the region since the mid-1800s (Dengler et al., 1992). Most earthquakes in the region are capable of generating earthquakes with magnitudes on the order of 6.5 to 7.5. The Cascadia Subduction Zone (CSZ), however, is capable of significantly larger earthquakes that would be associated with significant regional impacts. The CSZ represents the most significant potential seismic source in the north coast region. A great subduction event may rupture as much as 1,000 kilometers (km) or more of the coast from Cape Mendocino to British Columbia, and may be as large as magnitude 9.5. The Sumatran earthquake of December 2004 is a reasonable estimate of what might be anticipated during a major CSZ earthquake.

Little Salmon fault is a northwest-trending, northeast-dipping reverse fault that crosses the southwestern section of the Yager-Lawrence WAU. Estimates of the amount of fault slip for individual earthquakes along the fault range from 15 to 23 feet (4.5 to 7 meters), and the average slip rate for the Little Salmon fault for the past 6,000 years is between 6 and 10 millimeters per year. The Yager fault, a northern splay of the Little Salmon fault, also passes through the study area as the contact between the Yager terrane and the Wildcat Group. No evidence has been found to indicate that the Yager fault is active; it defines the contact between units of the Wildcat Group or between the Wildcat Group and the Yager terrane.

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

Lithologic Unit	Area (acres)	Area (mi^2)	Percent of Area
Alluvium (Qal)	263	0.41	<1%
Landslide Deposits (Qls)	3,991	6.24	12%
Wildcat Group (QTw)	4,466	6.98	13%
Non-marine Terrace Deposits (Qt)	669	1.05	2%
Yager Formation (Tky, y1)	18,232	28.49	53%
Central Belt Franciscan (includes Basaltic Rocks [bs]; Broken Formation [cb1]; Melange, Predominantly Argillite [cm1]; and Melange, Metasandstone and Argillite [cm2])	6,559	10.25	19%
Total for HCP Area	**34,180**	**53.41**	**100%**

3.3 SOILS

Soil texture is controlled largely by underlying geology and topography. The Yager-Lawrence WAU includes the following three geologic formations: undifferentiated sedimentary rocks of the Wildcat Group (13 percent of the HCP area, located at the downstream end), and two sub-units of the regional Franciscan Complex – the Yager formation (53 percent, located in the middle area) and the Central Belt Franciscan (19 percent, located in the northern and eastern portions of the HCP area). A detailed description of the geologic formations and history of the watershed is included in the Mass Wasting Assessment Report (Appendix A) for the Yager-Lawrence WAU. Map B-1 shows the most recent (1970s) map of soils in the portion of the Yager-Lawrence WAU in which HRC ownership is located.

Approximately 90 percent of the HCP area is represented by two soil series – Hugo and Larabee. The Hugo series is the most common, occurring in three-quarters of the HCP area. Hugo soil textures range from gravelly loam to stony clay loam, and Larabee soils have a loam/clay loam texture. Table 3-4 summarizes properties of soils in the HCP area according to soil depth, texture, drainage, permeability, and erosion hazard based on the National Resource Conservation Service (NRCS) database.

Table 3-4. Properties of Soils in HCP Area of the Yager-Lawrence WAU.

Soil Series Name	Total HCP Acres	Percent of HCP Lands	Depth Range (inches)	Parent Material	Texture of Surface/ Subsurface	Drainage[1]	Permeability[1]
Hugo	25,377	74%	30-60	Sandstone and shale	Gravelly loam/stony clay loam	Well	Moderately rapid
Larabee	5,195	15%	40-70	Soft sedimentary rock	Loam/clay loam	Moderate	Moderate
Bottom Land, Terraces, Farmland[2]	1,177	3%	64-70+	Sedimentary alluvium	Loam/silt Loam	Moderately well to imperfectly	Moderately rapid to slow
Melbourne	748	2%	30-60	Sandstone and shale	Loam/clay loam	Well	Moderate
Tonini	346	1%	20-40	Soft sandstone	Fine sandy loam/loamy fine sand	N.A.[4]	N.A.
Atwell	221	1%	36-72	Sheared sedimentary rock	Loam/gravelly clay loam	Moderately well or somewhat poor	Moderately slow surface; very slow below
Tatu	164	<1%	30-60	Sandstone	Loam/loam	N.A.	N.A.
Yorkville	160	<1%	30-60	Metamorphosed rock	Clay loam/ clay	Moderately well to well	Slow to very slow
Laughlin	126	<1%	16-36	Sandstone and shale	Loam/loam	Well	Moderate
Hugo Var.	48	<1%	30-60	Metamorphosed sedimentary rock	Gravelly loam/gravelly clay loam	Well	Moderately rapid
Tyson	19	<1%	18-48	Sandstone and shale	Gravelly loam/very gravelly loam	Well	Moderate
Boomer	12	<1%	26-60	Metamorphosed basic igneous rock	Gravelly loam/gravelly clay loam	Well	Moderately slow
Josephine	10	<1%	30-60	Sandstone and shale	Loam/clay loam	Moderate	Moderate
Kinman	10	<1%	40-72	Sandstone and shale	Clay loam/ clay	Moderately well or somewhat poor	Slow
Kneeland	4	<1%	18-40	Sandstone and shale	Clay loam/ clay loam	N.A.	N.A.
McMahon	3	<1%	30-60	Sandstone	Clay loam/ clay	Moderately well or somewhat poor (inferred)	Slow (inferred)
Comptche	2	<1%	30-60	Metamorphosed basic igneous rock	Gravelly clay loam/gravelly clay loam	N.A.	N.A.
Montara	1	<1%	6-18	Serpentine rock	Stony clay loam/ stony clay loam	N.A.	N.A.
Other[3]	557	2%	Varies	Varies	Varies	Varies	Varies

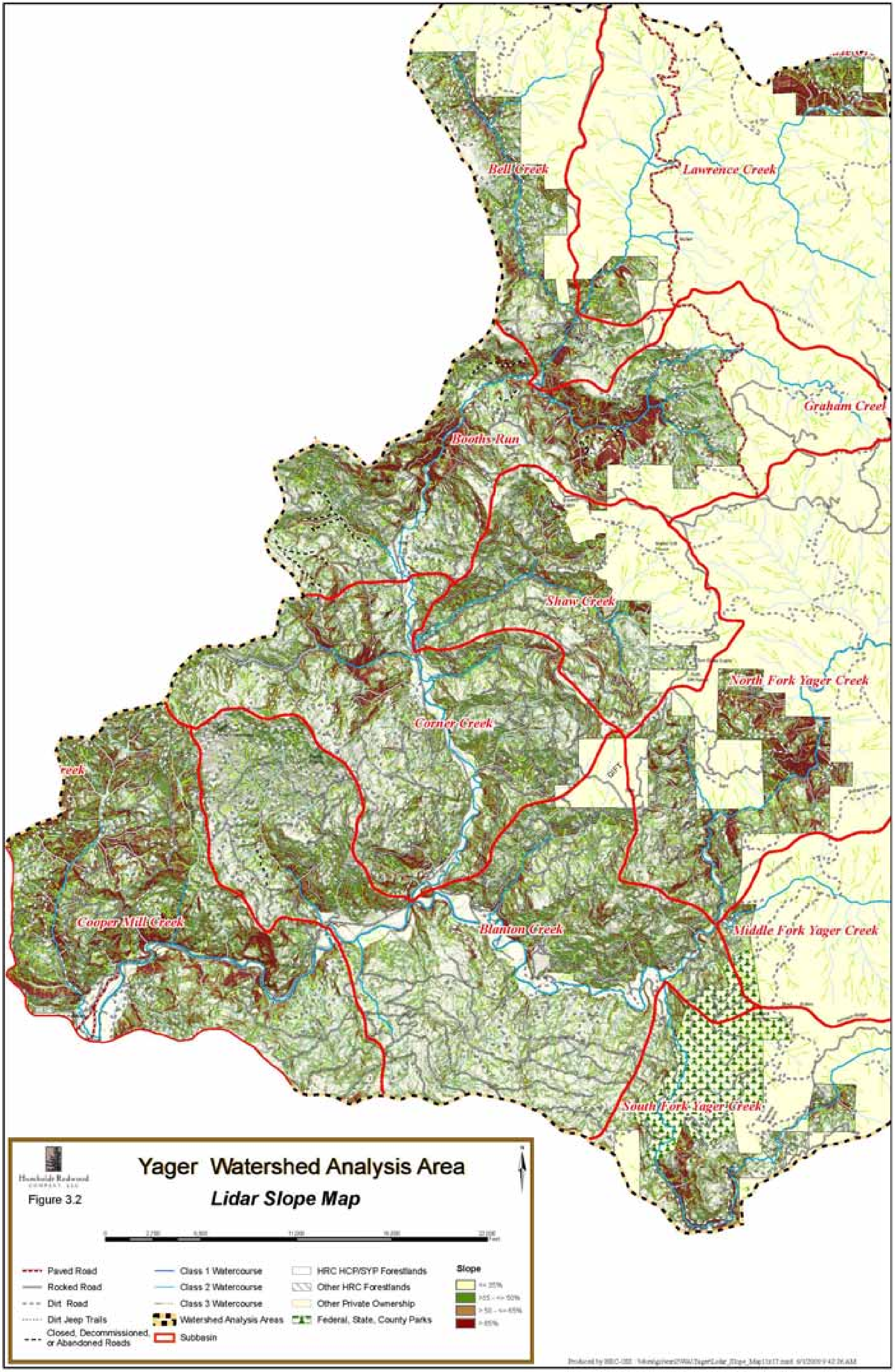
1. Information on soil drainage and permeability characteristics for these soils was obtained from the Soil Survey Staff, Natural Resources Conservation Service, United States Department of Agriculture. Official Soil Series Descriptions Available URL: "http://soils.usda.gov/technical/classification/osd/index.html".
2. Mapping units Bottomland, Terraces, and Farmland 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.
4. "N.A." indicates information not available from McLaughlin and Harradine (1965).

3.4 TOPOGRAPHY

The topography of the Yager-Lawrence WAU is generally moderately rugged, with slopes ranging from gentle to steep. Gentle slopes are present on floodplain areas of Yager Creek and Lawrence Creek mainstems and tributaries, with steeper slopes occurring throughout other portions of the HCP area as well as the non-timber lands in the eastern portion of the WAU. Soils on steeper slopes are more susceptible to erosion when disturbed than the same soil on lesser gradients. Approximately 24 percent of the land area in the HCP area of the Yager-Lawrence WAU has slopes steeper than 50 percent gradient, and only 10 percent of the land area has slopes steeper than 65 percent gradient (Table 3-5 and Figure 3-2). Of the HCP area occupied by these slopes steeper than 50 percent (8,150 acres), the Cooper Mill Creek and Booths Run sub-basins contain the largest acreage (1,987 and 1,345 acres, respectively), together accounting for 41 percent of the HCP area in which these slopes are located. Collectively, the Cooper Mill Creek, Booths Run, and North Fork Yager Creek sub-basins contain approximately 60 percent of the HCP land area in which slopes steeper than 65 percent gradient are located.

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

Sub-basin	0-35% (Acres)	35-50% (Acres)	50-65% (Acres)	>65% (Acres)	Total (Acres)
Bell Creek	1,033	525	252	157	1,966
Blanton Creek	5,345	2,086	707	189	8,326
Booths Run	2,055	1,244	634	712	4,644
Cooper Mill	2,134	1,894	1,205	782	6,015
Corner Creek	2,860	1,584	678	324	5,445
Lawrence Creek	169	187	137	192	685
Middle Fork Yager	44	44	12	3	104
North Fork Yager	675	631	378	434	2,118
Shaw Creek	980	735	406	166	2,286
South Fork Yager	637	319	187	141	1,285
Wolverton Gulch	462	388	303	153	1,305
Total for HCP Area	16,395	9,637	4,898	3,252	34,179
Percent of Total	48%	28%	14%	10%	100%
Cumulative Percent Total	48%	76%	90%	100%	-


Bell Creek
Lawrence Creek
Graham Creel
Booths Run
Shaw Creek
North Fork Yager Creek
Corner Creek
reek
Cooper Mill Creek
Blanton Creek
Middle Fork Yager Creek
South Fork Yager Creek
Yager Watershed Analysis Area
Lidar Slope Map
Figure 3.2
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
Slope

3.5 Stream Class

Stream classes are described in the California Forest Practice Rules (CFPRs) by water class characteristics or key indicator beneficial uses. Stream classes are defined as California Department of Forestry and Fire Protection (CAL FIRE, formerly known as CDF) Class I, II, III or IV streams. 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. 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. 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 Yager-Lawrence WAU. There are 382 miles of mapped stream channel in the HCP area; 58 miles are Class I, 117 miles are Class II, and 207 miles are Class III.

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

Sub-basin	Class I (Miles)	Class II (Miles)	Class III (Miles)	Total (Miles)
Bell Creek	5.3	4.9	15.4	25.6
Blanton Creek	11.2	23.0	46.9	81.1
Booths Run	8.9	12.8	32.5	54.2
Cooper Mill Creek	8.5	27.9	34.1	70.5
Corner Creek	7.4	19.9	30.1	57.4
Lawrence Creek	1.5	1.5	5.9	8.9
Middle Fork Yager Creek	0.6	0.7	0.5	1.8
North Fork Yager Creek	3.9	7.4	13.7	25.0
Shaw Creek	4.1	8.5	12.3	24.9
South Fork Yager Creek	4.4	1.4	6.1	11.9
Wolverton Gulch	2.5	8.8	9.4	20.7
Total for HCP Area	**58.3**	**116.8**	**206.9**	**382.0**

3.6 CLIMATE

The Yager-Lawrence WAU experiences climatic conditions typical of coastal Northern California. 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 approximately 90 percent of the annual precipitation occurs (Table 3-7, Figures 3-3 and 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). The Yager-Lawrence WAU receives an average of 50 to 60 inches of rain per year (Spatial Climate Analysis Service, 2007), with up to 70 inches per year occurring in the higher elevations of the WAU (PALCO, 2004). The majority of the precipitation falls as rain, and snow is uncommon in most of the basin with the exception of higher elevation areas in the eastern portion of the WAU beyond the extent of HCP-managed lands.

The dry season lasts from May through September. Average summer temperatures increase within the WAU with distance from the ocean. The western portion of the Yager-Lawrence WAU is within the coastal fog belt area, is dominated by redwood, and is generally somewhat cooler. During the dry season, morning low clouds and fog are common in the western portion of the WAU, often clearing by early afternoon and returning by evening; this pattern is less common in the eastern portion of the WAU where temperatures are generally warmer in the summer.

Table 3-7. Weather Stations for Climatic Data near the Yager-Lawrence WAU.

Station (ID#)	Latitude/ Longitude	Elevation (feet)	Data Obtained (may be missing values)
Grizzly Creek State Park (3647)	N 40° 29' W 123° 54'	410	Daily precipitation: 12/1/7–11/30/04 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 Yager-Lawrence WAU.

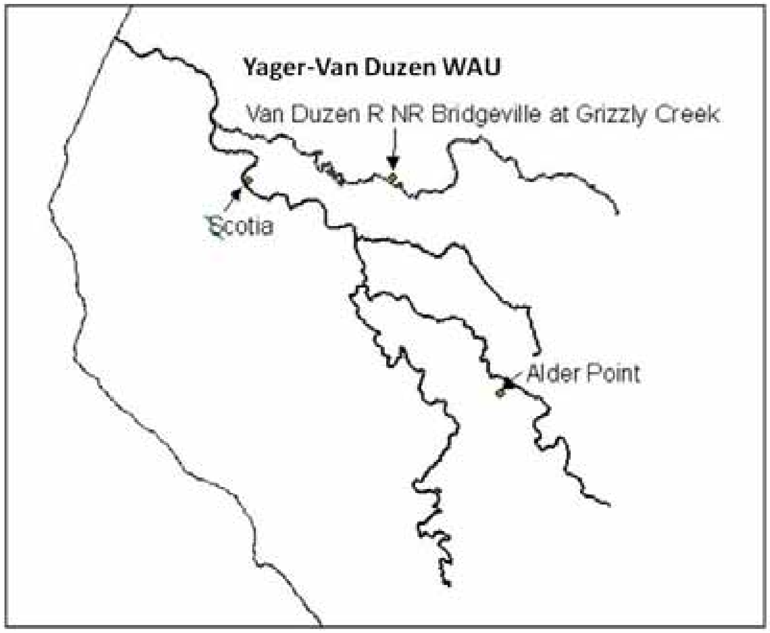
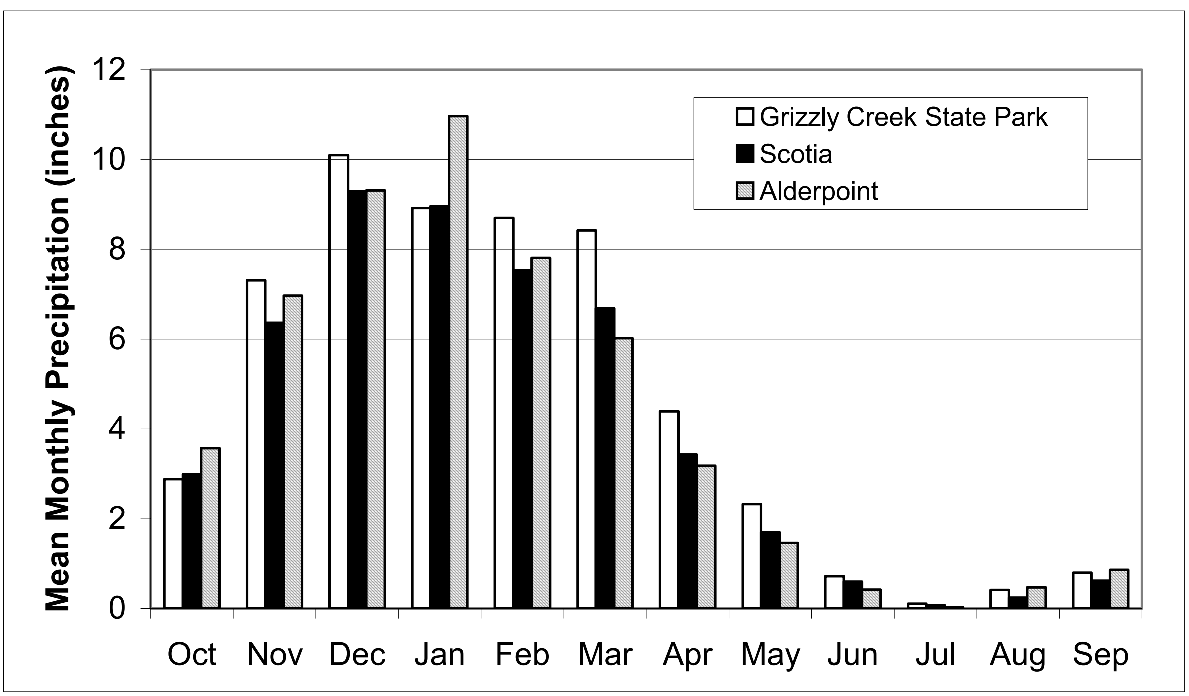


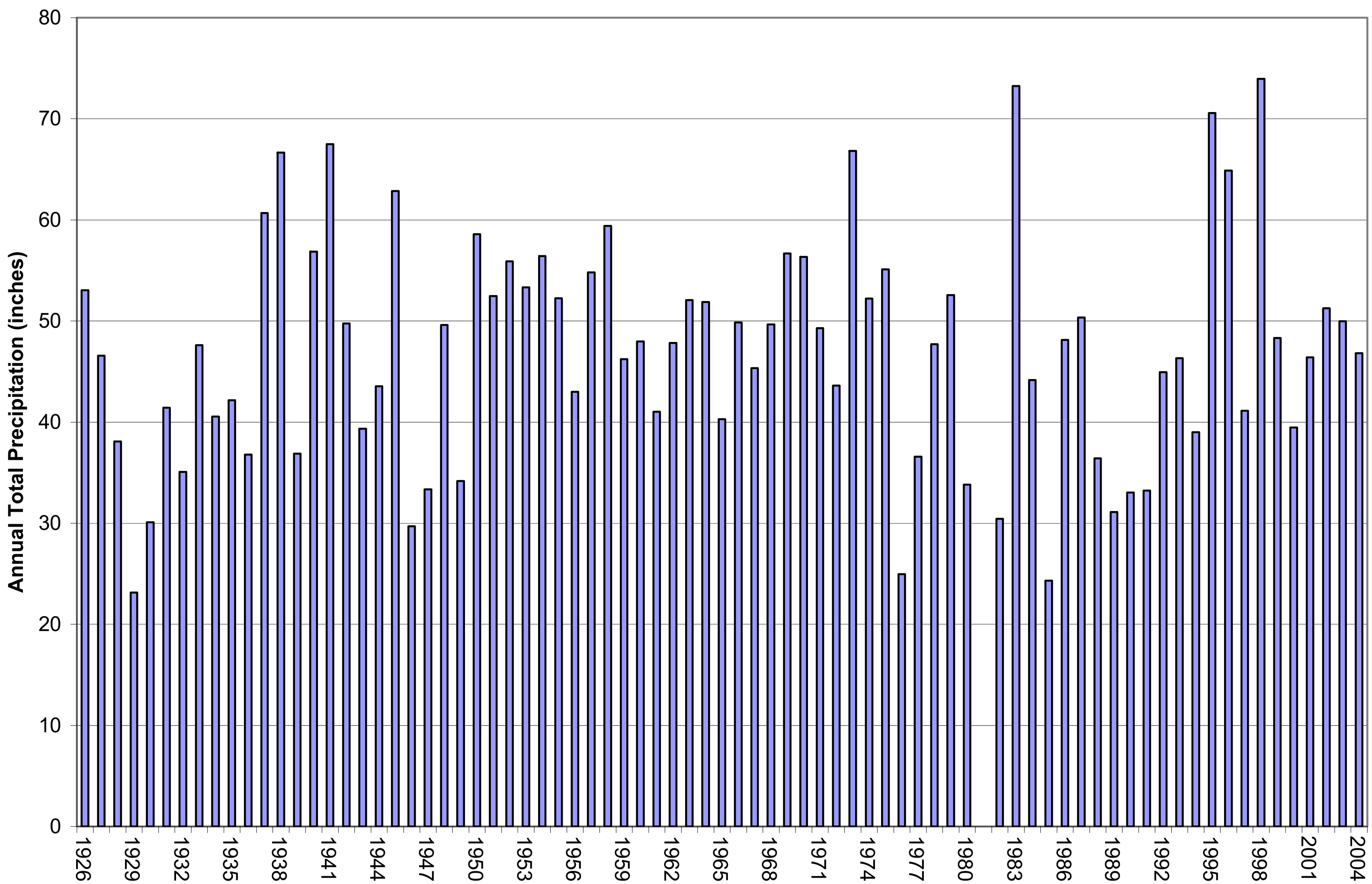
Figure 3-4. Mean Monthly Precipitation at Several Climate Stations in the Vicinity of the Yager-Lawrence WAU.



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 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 is 71 °F, and the summer temperatures in the Yager-Lawrence WAU can reach into the 80 to 90° F range in the higher elevations.

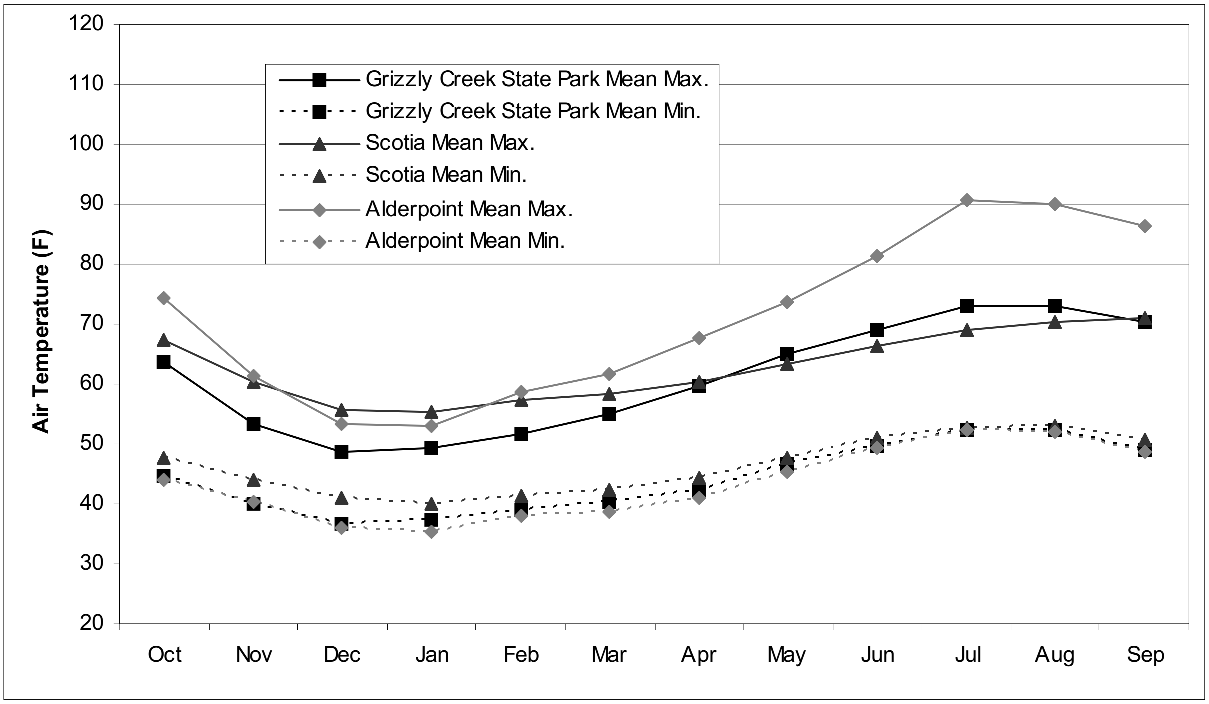
A search for snow pack information did not reveal data for any stations close to the analysis area. The Western Regional Climate Center lists no SNOTEL stations in the North Coast area in their station inventories and the NRCS lists no snow course sites. A search of the CDEC website revealed no climate 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 Yager-Lawrence WAU. However, though undocumented, significant snowfall depths of one foot or more can occur in the higher elevations of the WAU, generally outside of the HCP area, during significant cold-temperature winter storms.

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 Yager-Lawrence WAU.



3.7 HYDROLOGY

Hydrology is summarized in terms of flood history and calculated flood flows, with a discussion on channel morphology provided later in this report as part of the characterization of fish habitat (Section 5.1). No stream flow gage data are available for the Yager-Lawrence watershed. The primary tributaries feeding the mainstem of Yager Creek include the Lawrence Creek and the North Fork Yager Creek basins. To a much lesser extent, the smaller drainages of the South Fork Yager Creek and Middle Fork Yager Creek also enter in the upper mainstem region of Yager Creek.

A brief review of the flood history for the Yager-Lawrence 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 gaging has not been conducted in the Yager-Lawrence WAU, the area flooded in 1955 and 1964 with the 1964 flood causing more damage to floodplains and adjacent areas. Then, a record-breaking December 2002 storm 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 was larger than the 1964 and 1955 storms in this regard.

Peak flows were estimated for the Yager Creek and Lawrence Creek drainages, since there are no flow data available for the Yager-Lawrence WAU (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 Yager Creek, at the confluence with Cooper Mill Creek in the vicinity of the Yager Deck and Yager Camp, and for Lawrence Creek at the confluence with Yager Creek. Mean annual precipitation was set at 55 inches for the WAU, considering the precipitation is expected to annually range from 45 to 60 inches, with higher amounts in the highest elevations. The calculated peak flow rates for the 2-year and 100-year events at the downstream end of the Yager-Lawrence WAU, in Yager Creek, are 8,933 cubic feet per second (cfs) and 31,537 cfs, respectively (Table 3-8).

Table 3-8. Estimated Peak Flows for the Yager-Lawrence WAU.

Recurrence Interval	Yager Creek[1] Peak Flows at Confluence with Cooper Mill Creek (cfs)	Lawrence Creek[1] Peak Flows at Confluence with Yager Creek (cfs)	Regional Equation[2]
2 years	8,933	3,608	$3.52\ A^{0.90}p^{0.89}H^{-0.47}$
5 years	13,620	5,392	$5.04\ A^{0.89}p^{0.91}H^{-0.35}$
10 years	17,683	6,934	$6.21\ A^{0.88}p^{0.93}H^{-0.27}$
25 years	22,138	8,554	$7.64\ A^{0.87}p^{0.94}H^{-0.17}$
50 years	27,548	10,396	$8.57\ A^{0.87}p^{0.96}H^{-0.08}$
100 years	31,537	11,654	$9.23\ A^{0.87}p^{0.97}$

[1] Area of 132.2 square miles for the Yager Creek drainage (upstream of the confluence with Cooper Mill Creek) and 42.1 square miles for the Lawrence Creek drainage (upstream of the confluence with Yager Creek).
[2] From Waananen and Crippen, 1977 as presented by "California Salmonid Stream Habitat Restoration Manual" (Flosi et al., 1998)
Q is Peak Discharge (cubic feet per second)
A is drainage area (square miles)
P is mean annual precipitation (inches) = 55 inches
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; values of 1.3 and 1.0 were used for the Yager Creek and Lawrence Creek drainages, respectively.

3.8 FOREST ECOLOGY

The native forests of the Yager-Lawrence WAU are dominated by stands of coastal mixed conifer, including redwood (*Sequoia sempervirens*), Douglas-fir (*Pseudotsuga menziesii*), grand fir (*Abies grandis*), and western hemlock (*Tsuga heterophylla*). Many stands have a mixture of conifers, with redwood and Douglas-fir on the lower slopes, and western hemlock and grand fir coming in on the upper slopes and ridges. Hardwood species including tanoak (*Lithocarpus densiflorus*), Pacific madrone (*Arbutus menziesii*), California bay-laurel (*Umbellularia californica*), red alder (*Alnus rubra*), and big-leaf maple (*Acer macrophyllum*) are also commonly found in the riparian areas at varying levels. Understory herbaceous plants include sword fern (*Polystichum munitum*), chain fern (*Woodwardia fimbriata*), evergreen huckleberry (Vaccinium ovatum), red huckleberry (*Vaccinium parvifolium*), and poison oak (*Toxicodendron diversilobum*).

The western half of the WAU is generally located within the coastal fog belt where available soil moisture and cool, damp climatic conditions support typically redwood-dominated forests. The soils are relatively deep and well drained with high available water holding capacity. Flood deposits in alluvial floodplains and terraces further enhance the growth of redwood stands along the lower portions of Yager Creek. Old growth redwood forests are still found on HCP lands in the Yager Creek and Lawrence Creek drainages, typically occurring in Marbled Murrelet Conservation Areas (MMCAs), and on Park lands. Trees in predominantly redwood stands can reach heights of 360 ft (110 m) in the more sheltered, inland alluvial terraces.

The forests transition to more Douglas-fir and mixed Douglas-fir/hardwood inland to the east beyond the fog belt. This transition is marked by a warmer and drier inland climate and an increase in Franciscan bedrock material that weathers to soil with a high clay content and poor drainage, favoring Douglas-fir and hardwoods over redwood.

3.8.1 Historic Vegetation

Historically, redwood trees dominated riparian forests in the HCP area of the Yager-Lawrence WAU, with floods providing the primary mode of disturbance. During initial harvest of areas from the 1900s through the 1960s, replanting of harvested sites was uncommon and consequently succession was left to natural seeding or stump sprouting. Riparian habitat in the Yager-Lawrence WAU was most accessible and therefore was harvested first, resulting in direct deposition of logging debris and soil into the stream channels.

Logging within riparian forests removed conifers and directly deposited debris and soil into stream channels. Furthermore, stream courses represented the least path of resistance for moving logs from the hillside to the mill. In-stream skid trails were commonplace during this period as they were less steep, and allowed easier negotiation of the terrain. The 1955 and 1964 floods significantly altered stream and riparian conditions in the Yager-Lawrence WAU on a broad scale, associated with the landscape as a whole and not only anthropogenic influences. Degraded by skid trails and road construction, and denuded by timber harvest, the Yager-Lawrence WAU responded to the heavy rains and flash floods with episodic mass wasting events that deposited tremendous amounts of sediment into the tributaries and mainstem channels of the basin. The result was stream channel scour and aggradation, which led to chronic floodplain bank erosion and reactivation of earth flows that lasted many years to decades.

3.8.2 The Role of Fire

Important differences exist between the fire regimes of redwood and Douglas-fir/hardwood, which changes the frequency, role, and nature of fire throughout the WAU. Redwood forests are generally able to resist effects of most but the most intense wildfires (Agee, 1993); most fires are low and moderate in severity with only local effects. Windthrow generally contributes to redwood losses more than fire. Douglas-fir/hardwood forests are drier and subject to lightning occurrence, which is a common ignition source for these forests. Effects of fire in the drier Douglas-fir/hardwood forests can be severe and widespread, although a range of severity is typical for these forests (Agee, 1993).

Pre-European peoples regularly burned portions of the watershed resulting in significant disturbance to the landscape. Fire was an important component of the pre-European 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 Yager-Lawrence WAU since the 1950s by the California Department of Forestry and Fire Protection (CAL FIRE, 2008), with fire data collected state-wide by other agencies dating back as early as 1878 for fires 10 acres and greater. Two natural fires were recorded by CAL FIRE for the WAU in this recent period of record – one in 1950 and another in 1952. The causes of these two fires are unknown. In August 1950, a 1,654-acre wildfire (C.W. Syphers #3) occurred in the South Fork Yager Creek sub-basin, outside of HRC ownership, and the Grizzly Creek drainage which is part of the Van Duzen WAU (to the south, over the ridge). Then, in September 1952, a 1,184-acre wildfire (L. Sibley) occurred in the Booths Run sub-basin bordering the HRC ownership. No other major natural fires have been recorded in the Yager-Lawrence WAU.

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

3.9 Fish Species Composition and Distribution

The Yager-Lawrence WAU currently supports Chinook (*Oncorhynchus tshawytscha*) and coho (*O. kisutch*) salmon, steelhead and resident rainbow trout (*O. mykiss*), and coastal cutthroat trout (*O. clarki clarki*). The primary fish-producing tributary to Yager Creek is Lawrence Creek, which enters 9 miles upstream from the mouth of Yager Creek. Fish-bearing tributaries to Lawrence Creek include Corner Creek, Shaw Creek, Fish Creek, Booths Run, and Bell Creek. Chinook and steelhead are the dominant salmonids in the WAU, while coho salmon have been found only in Shaw Creek and Lawrence Creek. Coastal cutthroat trout are found only in the upper reaches of Booths Run and the Middle Fork Yager Creek.

The Yager-Lawrence WAU also 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 three-spine stickleback (*Gasterosteous aculeatus*). The California roach (*Lavinia ssymmetricus*), speckled dace (*Rhinichthys osculus*), brown bullhead (*Ictalurus nebulosus*), largemouth bass (*Micropterus salmoides*), Sacramento pikeminnow (*Ptychocheilus grandis*), and green sunfish (*Lepomis cyanellus*) represent non-native fish species introduced into the Van Duzen watershed, some of which likely inhabit Yager Creek. The Sacramento pikeminnow is a predatory threat to all salmonid species of concern where they are co-located. However, the species was not introduced to the area through forestry-related activities.

The topographic nature between the mouth and the headwaters creates changing channel attributes which influence instream habitat characteristics, particularly with respect to anadromy. Instream habitat transitions in an upstream direction from the lower gradients preferred by Chinook and coho salmon to somewhat higher gradient reaches primarily occupied by steelhead. These changing conditions have a distinct bearing on the distribution and habitat suitability for each of these species.

A notable feature of HRC ownership in the Yager-Lawrence WAU is the large amount of mainstem and low gradient channel accessible to salmonids. The mainstem of Yager Creek along with the lower five miles of Lawrence Creek (totaling 22.5 miles) are wholly dominated by gradients less than 3 percent, with 67 percent of these stream miles at gradients of less than 1 percent. In contrast, the remainder of the stream miles (totaling 52.4 miles) with stream gradients less than 8 percent are divided evenly between reaches with less than 3 percent gradient and those with gradients from 3 to 8 percent. Once off the mainstem, it is not uncommon for the smaller tributary watersheds to have an impassable gradient barrier to anadromy, such as an 8 percent gradient boulder falls, nestled within a reach of lower gradient stream channel. These barriers effectively reduce the total stream miles accessible to anadromous fish.

Due to the Mediterranean climate of the north coast where little rainfall occurs from late spring to late fall, the point where the Yager Creek enters the Van Duzen River may be periodically blocked by a temporary sand and gravel bar during the summer low-flow period, particularly during dry years. This sort of seasonal blockage is not uncommon at the confluence of the Van Duzen with the Eel River as well. Access for upstream migrating anadromous salmonids becomes reestablished once fall rains raise the streamflow to a level to breach these seasonal barriers.

A reach-by-reach discussion, by channel geomorphic unit (CGU), focused on channel characteristics and the quality and abundance of fish habitat is provided later in this report (Section 5.1). Further detail regarding fish and habitat distribution on HCP-covered lands can be found in Sections 3.1 and 3.2 of Appendix E.

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 Yager-Lawrence WAU including HCP-covered lands. 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*]). All five species have been documented on HCP lands. The Amphibian and Reptile Assessment report (Appendix F) provides detailed information regarding the habitat requirements and distribution of each species.

4.0 LAND USE

This section presents a summary of land use in the Yager-Lawrence WAU, as well as a description of pre-historic 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 road construction and use.

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

4.1 PREHISTORIC LAND USE

Among the earliest settlers of the Van Duzen watershed, within which the Yager-Lawrence WAU is located, were the Lassik and the Nongatl sub-tribes of the Athabascan peoples of the Pacific North Coast. Of these native groups, the Lassik inhabited the upper portions of the Van Duzen River watershed; the Nongatl lived in and around Grizzly Creek, Yager Creek, and Larabee Creek (DWR, 1976). Native American land use practices included hunting and gathering, as well as some controlled burning in the low grassland areas.

One important characteristic of these peoples was their seasonal land use pattern. In the winter, they typically 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.

The arrival of Europeans in the mid-nineteenth century marked significant changes in land use practices throughout the Van Duzen River watershed (Tetra Tech, 2002). Though these pioneers typically sought gold upon their arrival, they soon found the fertile lowlands and floodplain of the Van Duzen River basin more reliably profitable. Sheep grazing dominated the higher elevation areas in the eastern portion of the

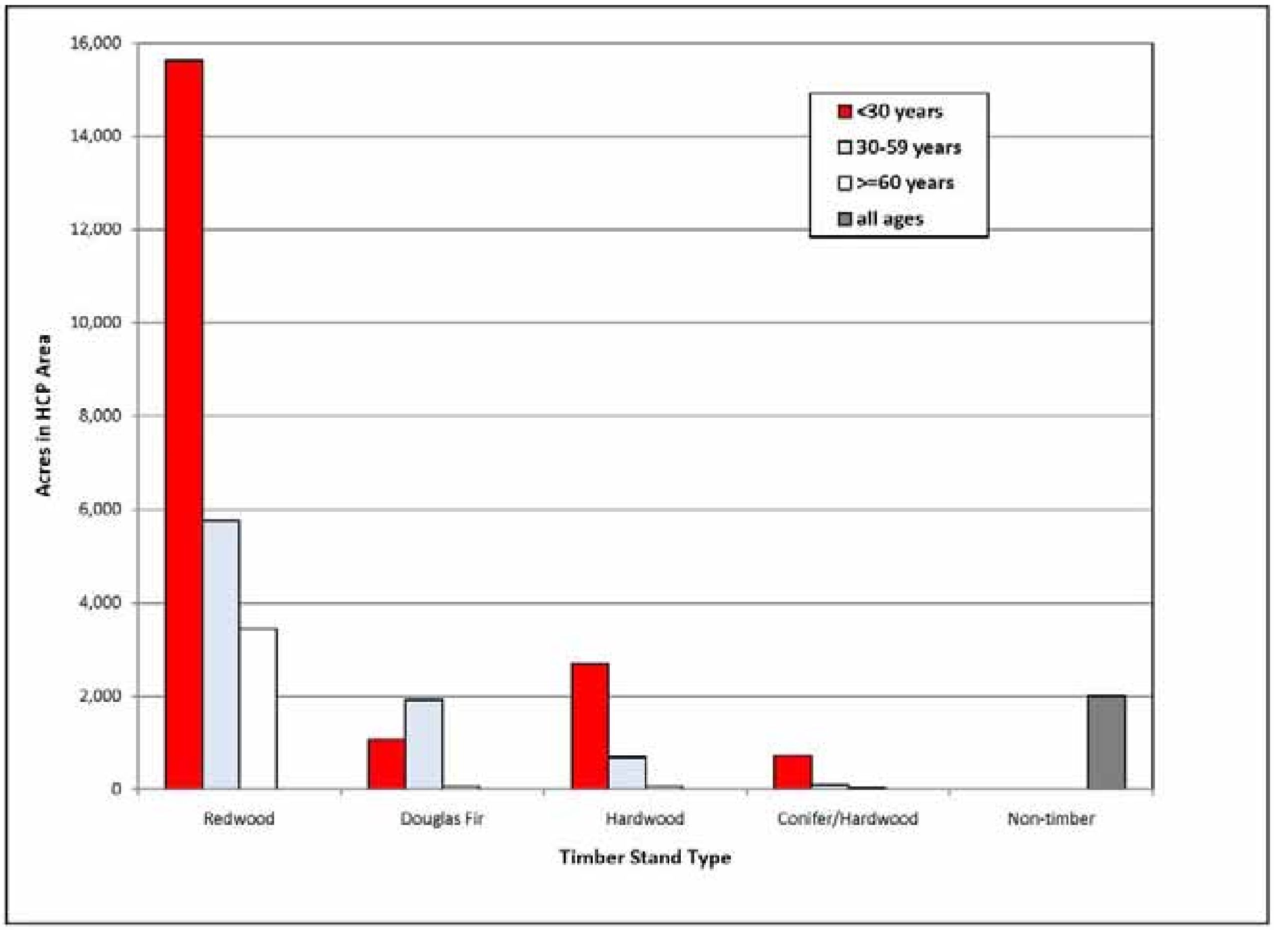
WAU, with herd sizes numbering in the thousands. Sheep grazing remained dominant until the 1930s when cattle ranching became more common (Moore, 1999). Also, with the addition of the railroad in the early 1900s, lumbering of large redwoods became more accessible and was intensified in this period.

Table 4-1. Timber Stand Acres by Type and Age (as of 2007) in HCP Area.

Sub-basin	Redwood			Douglas-fir			Hardwood			Conifer/Hardwood			Non-timber (all ages)	Total
	<30 yrs	30-59 yrs	>=60 yrs	<30 yrs	30-59 yrs	>=60 yrs	<30 yrs	30-59 yrs	>=60 yrs	<30 yrs	30-59 yrs	>=60 yrs		
Bell Creek	385	13	289	95	34	3	636	0	0	307	0	0	204	1,966
Blanton Creek	4,396	2,383	370	57	537	7	178	42	0	60	12	0	282	8,326
Booths Run	2,349	176	220	251	338	45	845	131	6	50	4	0	231	4,644
Cooper Mill Creek	1,859	1,557	1,144	36	591	0	202	315	0	0	0	1	310	6,015
Corner Creek	3,187	794	201	21	333	0	138	170	0	291	78	0	232	5,445
Lawrence Creek	0	0	255	58	0	<1	197	0	54	0	0	0	119	685
Middle Fork Yager Creek	56	0	0	0	0	0	0	0	0	0	0	0	47	104
North Fork Yager Creek	251	630	35	526	33	0	205	14	0	9	0	0	414	2,118
Shaw Creek	1,573	96	412	10	0	0	163	0	0	0	0	0	32	2,286
South Fork Yager Creek	981	44	52	5	58	5	108	18	0	0	0	0	13	1,285
Wolverton Gulch	590	59	469	0	1	0	23	3	5	0	0	27	129	1,305
Grand Total	15,627	5,752	3,447	1,061	1,924	61	2,695	694	66	717	94	28	2,013	34,179

Notes:
1. "Redwood" category includes Redwood, Redwood/Douglas-fir, and Redwood/Hardwood.
2. "Douglas-fir" category includes Douglas-fir, Douglas-fir/Redwood, and Douglas-fir/Hardwood

Figure 4-1. Timber Stand Type and Age Classes (as of 2007) for HCP Area of the Yager-Lawrence WAU.



4.2 HARVEST HISTORY (1890-1988)

Early timber extraction in the upper elevations (eastern portion) of the Yager-Lawrence WAU began with ranchers hiring loggers to clear their lands to provide additional grazing and agricultural land; few landowners made use of the timber resources on their lands as the tools/machinery and lack of transport infrastructure made timber extraction prohibitively expensive. It wasn't until accessibility was well established in the early 1900s that large-scale timber operations in the lower portions of the basin were established (Tetra Tech, 2002).

The first recorded harvest activity in the HCP area of the Yager-Lawrence WAU began, on a limited basis, in the Corner Creek sub-basin in the late 1890s to early 1900s. The 1910s through 1920s saw a significant increase in harvest in the Cooper Mill Creek and Wolverton Gulch sub-basins, starting in the stream areas and progressing to higher elevations during this period in these two sub-basins. Forests were typically clearcut, or harvested in a modified seed tree step that met the ad-valorum tax laws, with no riparian protections. Early yarding systems involved moving logs to landings by donkey skidder cable ways or with oxen. Steam donkey and early tractor roads tended to use watercourse channels and draws as skid trails for dragging logs to landings. Table 4-2 presents first entry harvest acreages by sub-basin and decade.

The use of log trucks and ground-based tractor yarding in the 1940s initiated a period of extensive road building and skid trail use which extended into the 1980s. During the early part of this period, railroad and early truck haul routes were commonly located near, or sometimes even within, the stream channels. The combination of the early railroad and other pre-1970s logging practices had a profound impact on the watercourses of the WAU, with most of this focus in the HCP area because of its abundant stands of redwood and accessibility by traversing within or along streams from the mouth of Yager Creek. The large-scale industrial timber operations that commenced in the late 1940s continued to access more timberland, progressing upstream through the Cooper Mill Creek, Blanton Creek, and Corner Creek sub-basins. Beginning in the 1960s, more distant areas were harvested for the first time, including the Bell Creek, Booths Run, and Shaw Creek sub-basins. By the end of the 1980s, old-growth forest stands remained in portions of the HCP area, primarily protected as MMCAs on HCP-covered lands and within the Owl Creek Forest State Reserve located in the South Fork Yager Creek sub-basin.

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
Bell Creek	0	0	0	0	<1	69	0	182	1,101	455	40	118	1,966
Blanton Creek	<1	0	10	0	14	2,298	1,659	1,897	562	436	137	1,313	8,326
Booths Run	0	0	8	0	0	0	850	295	1,255	1,131	93	1,009	4,642
Cooper Mill Creek	0	0	401	886	0	1,503	1,482	732	54	1	48	908	6,015
Corner Creek	41	0	10	0	0	944	932	1,816	492	991	77	143	5,445
Lawrence Creek	0	0	0	0	0	0	0	0	18	28	10	237	293
Middle Fork Yager Creek	0	0	0	0	0	0	0	0	0	95	9	0	104
North Fork Yager Creek	0	0	6	0	0	0	0	837	760	417	3	94	2,118
Shaw Creek	0	0	0	0	0	0	131	237	400	838	288	390	2,283
South Fork Yager Creek	0	0	0	0	0	47	145	41	547	234	188	82	1,285
Wolverton Gulch	0	0	971	279	0	23	<1	28	0	0	0	4	1,305
Totals	41	0	1,407	1,164	14	4,884	5,199	6,065	5,189	4,625	894	4,300	33,783

Note: "All Other Categories" includes:
- Acquired (904 acres)
- Old Growth (1,671 acres)
- Prairie (195 acres)
- Unlabeled/unassigned (1,528 acres)

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, 'seed trees' were occasionally retained individually or in patches to facilitate stand regeneration, with mixed success. Logs were 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.

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 lower Yager Creek drainage responded to the regional heavy rains and flash floods with significant mass wasting. This period of flooding resulted in the largest total volume of delivery than the other photo-analysis periods (see Appendix A), delivering over 2.6 million cubic yards (cy) of sediment 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.

In common with other timberlands on the North Coast, land management measures in this WAU have evolved over time – particularly those that prevent and minimize sediment delivery and protect riparian areas. Historic logging including road construction, downhill yarding, and using creeks as skid roads have result in massive soil movement and direct filling of channels and valley bottoms for use as skid roads. Riparian forests were completely removed until the Z'berg-Nejedly Forest Practices Act was passed and the California Forest Practice Rules (CFPRs) subsequently established in 1973. Prior to 1973, relatively few protective practices were used or required when working around streams; the CFPRs governed sediment control strategies on land owned and managed by PALCO (now HRC lands) for the subsequent 25 years. Among other things, the CFPRs provided protection for water quality and riparian areas in the form of watercourse and lake protection zones (WLPZ) within which ground disturbance was minimized and timber removal limited. Reforestation requirements were also established. In general, the CFPRs became more protective with time, so that practices in the late 1990s were superior to those of the 1970s or 1980s. Equipment operations were excluded from stream channels during this period, and riparian buffers were expanded in width along fish-bearing streams.

4.3 CONTEMPORARY HARVEST (1988-2003)

Contemporary timber harvest operations conducted by PALCO from 1988 through 2003 primarily involved the harvest of second-growth redwood timber in individual 10- to 40-acre clearcut or selective harvest units, 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, with most of the acreage occurring in the Blanton Creek, Booths Run, Cooper Mill Creek, and Corner Creek sub-basins. Along with total acres harvested each year, Figure 4-3 depicts yarding systems used from 1988 through 2003, and Figure 4-4 shows silviculture methods used during the same period with the majority of acres under partial cut silviculture. Tractor yarding was the primary method for moving logs from the harvest setting to the landing. Cable high-lead or skyline yarding operations also occurred but not as commonly. During this period, yarding systems shifted from a predominance of tractor-based yarding (through 1992, including the years with the largest acreages harvested) to a greater proportion of yarding by cable in the years thereafter (coinciding with years of less harvest). Helicopter yarding, starting in 1998, was utilized most commonly in the years 1998 through 2000, declining significantly since then.

HRC acquired ownership of PALCO 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.

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. 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

Figure 4-2. Acres Harvested in HCP Area, by Sub-basin, from 1988–2003.

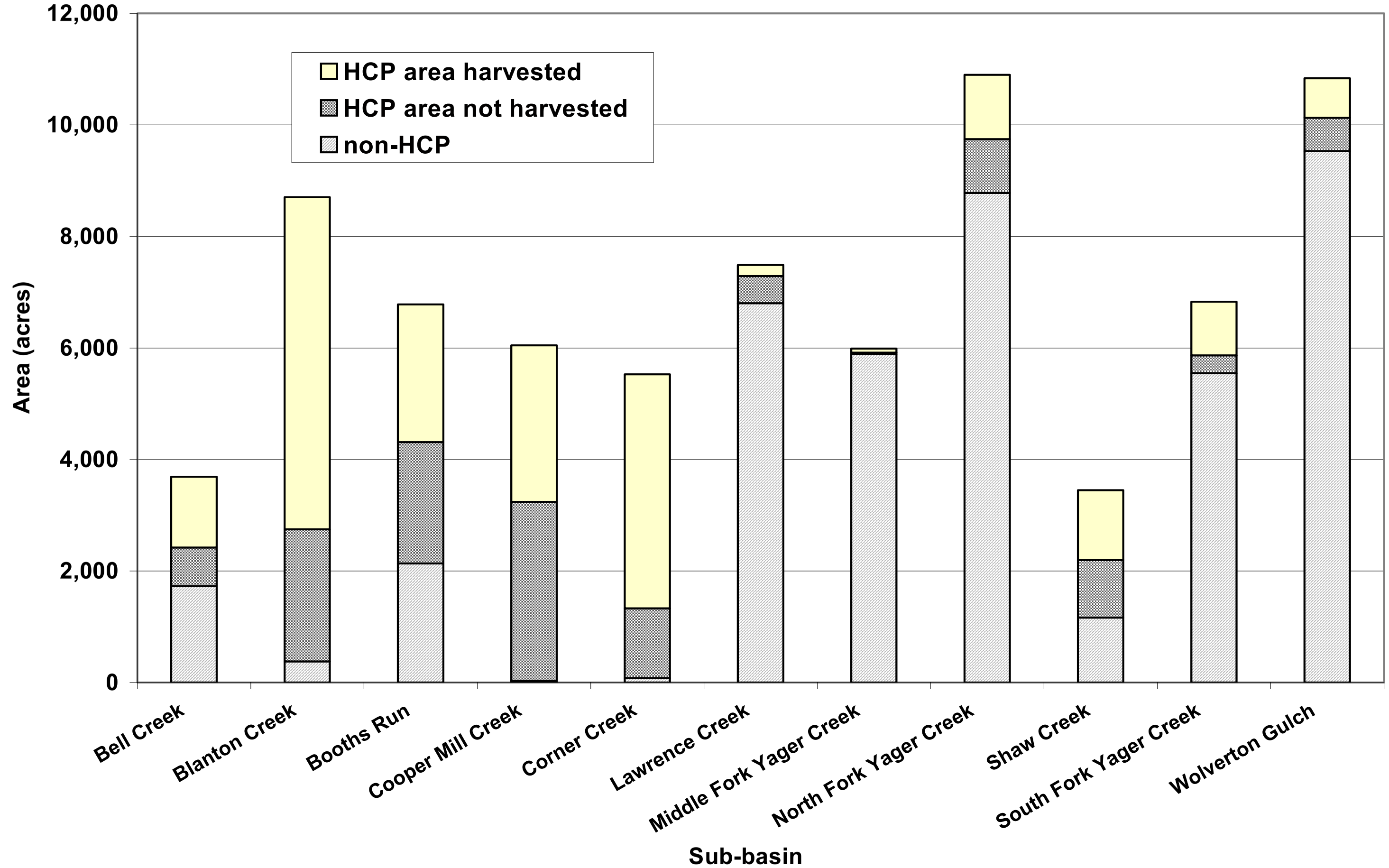


Figure 4-3. Acres Harvested in HCP Area by Yarding System from 1988–2003.

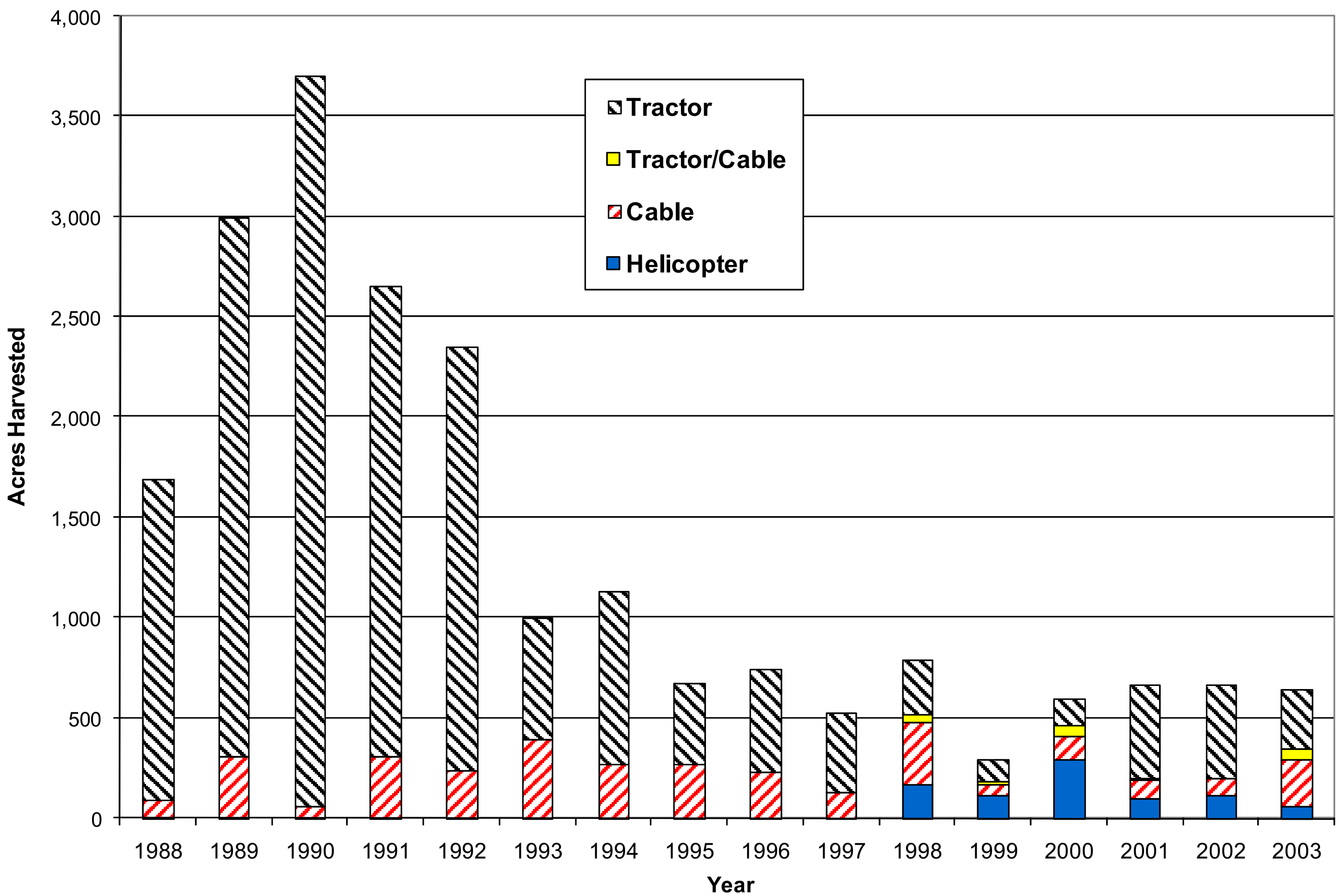
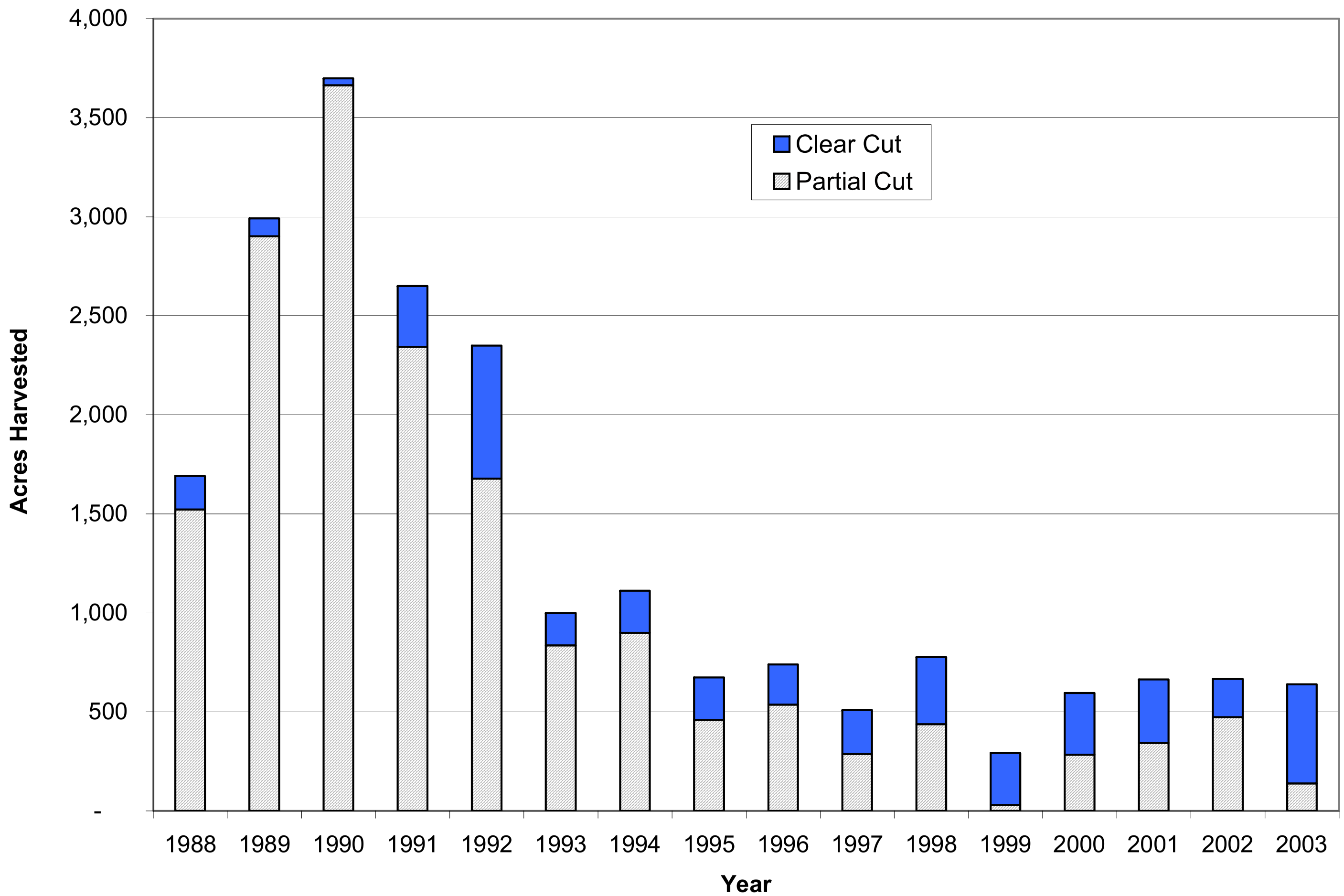


Figure 4-4. Acres Harvested in HCP Area by Silviculture Method from 1988–2003.



other half involves mechanical site preparation. Herbicides are used on an as-needed basis only, in accordance with applicable county, state, and federal laws, for controlling unwanted herbaceous and woody species in order to promote desired conifer forest regeneration and growth. The following herbicides are used by HRC: Chopper (active ingredient - imazapyr), Garlon (active ingredient - triclopyr), and Arsenal (active ingredient - imazapyr). Importantly, HRC's shift from even-age management to all-age selection management will result in less herbicide 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. Along with changes in management practices, the HCP led to the initiation of scientific studies designed to improve the understanding of stream conditions on lands owned and managed by PALCO (now HRC lands). The Aquatic Trends Monitoring Program measures the effects of recent management practices. The stream monitoring program implemented as part of the HCP provided much of the data reviewed as part of this 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 involve 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 ensure a well-drained condition, installation of additional waterbreaks, and the rocking or otherwise 'treating' of road surfaces.

As of 2007, the PALCO GIS database showed a total of 324 miles of existing roads on HCP lands in the Yager-Lawrence WAU (Table 4-3). Rocked haul roads used to access large tracts of land account for approximately 185 miles of the existing road system. There are approximately 130 miles of dirt, primarily native-surfaced roads, many which are 'spur roads' not used for year-round traffic. Overall road density on HCP lands of the Yager-Lawrence WAU is 6.1 miles of road per square mile of land area (Table 4-3). Road densities are highest in the South Fork Yager Creek (7.2 miles per square mile) and Bell Creek (6.7 miles per square mile) sub-basins.

Table 4-3. Roads by Sub-basin in HCP Area (based on PALCO GIS Data [2007]).

Sub-basin	Regular			Upgraded Only			Stormproofed			Stormproofed and Decomissioned	Total Miles	HCP Area Road Density (miles/sqmi)
	Paved	Gravel	Dirt	Paved	Gravel	Dirt	Paved	Gravel	Dirt	Grassed Native		
Bell Creek	-	8	12	-	-	-	-	<1	<1	<1	21	**6.7**
Blanton Creek	-	25	24	-	8	-	-	21	4	<1	83	**6.4**
Booths Run	<1	5	11	-	-	1	-	20	4	6	47	**6.5**
Cooper Mill Creek	<1	11	20	<1	6	1	<1	9	4	-	54	**5.7**
Corner Creek	-	14	16	-	9	-	-	12	-	<1	51	**6.0**
Lawrence Creek	-	2	2	-	-	-	-	-	-	-	4	**3.6**
Middle Fork Yager Creek	-	<1	<1	-	-	-	-	-	-	-	1	**6.4**
North Fork Yager Creek	-	9	7	-	1	-	-	-	<1	-	17	**5.3**
Shaw Creek	-	3	4	-	-	-	-	11	<1	2	20	**5.6**
South Fork Yager Creek	-	4	9	-	<1	-	-	<1	<1	-	14	**7.2**
Wolverton Gulch	<1	3	5	<1	-	1	-	2	1	-	12	**6.1**
Total for HCP Area	**<1**	**83**	**110**	**1**	**26**	**4**	**<1**	**76**	**16**	**8**	**324**	**6.1**

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 although individual 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. By considering 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.

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.

5.1 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 22.5 miles of stream including the mainstem of Yager Creek along with the lower five miles of Lawrence Creek are dominated by gradients less than 3 percent, with the majority of these stream miles at gradients of less than 1 percent.

The 2005 aquatic habitat stream surveys, conducted for watershed analysis using a modified version of the CDFG (Flosi et al., 1998) protocols (see Appendix E), focused primarily on stream reaches with gradients ranging from 0 to approximately 4 percent but often continued into steeper reaches especially if prior data noted salmonid presence. These 0 to 4 percent gradient reaches can be considered “response reaches” as defined by Montgomery and Buffington (1993). ATM stations in the Yager-Lawrence WAU are likewise located in “response reaches”; these ATM stations provide detailed streambed, habitat, wood, and temperature data collected over a period of recent years at established locations. 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.

In addition to assessment of fish habitat through stream surveys and ATM data, the Riparian Function Assessment (Appendix C) characterizes existing riparian key habitat elements and compares results to Properly Functioning Condition (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. The riparian assessment involved delineating conditions in riparian areas through air photo interpretation and field observations.

Overall recent average trends in channel characteristics at the watershed scale within Yager Creek and Lawrence Creek are summarized below, followed by a summary of fish habitat, including riparian condition, on the basis of geomorphic units. Data collected from the ATM stations are utilized in the discussions that follow primarily for assessment of temporal trends, whereas, aquatic habitat stream survey data collected in 2005 (Table 5-1) are utilized primarily in the Fish Habitat Assessment (Appendix E) to evaluate conditions relative to PFCs at that time. Locations of the surveyed reaches and the ATM stations are shown on Map E-3. Also, locations of the various types of riparian condition units along with results for LWD recruitment and overstream canopy cover are presented on Maps C-1 through C-3, respectively.

Observations for ATM stations are not always directly comparable to results from 2005 surveys due to differences in the length and representativeness of the monitored stream reaches and differences in the methods used. However, it is important to the assessment of fish habitat that both ATM data and 2005

Table 5-1. Summaries of Most Recent Habitat and Channel Conditions

Stream[1]	Yager Mainstem (to Middle Fk Confluence)	Cooper Mill Creek	Blanton Creek (2006)	Straw-berry Creek (1998)	South Fork Yager Creek	Middle Fork Yager Creek	North Fork Yager Creek	Lawrence Creek	Corner Creek	Shaw Creek	Fish Creek	Bell Creek	East Fork Bell Creek
Survey Length (ft)	64,859	5,863	4,571	3,420	3,832	2,984	9,312	24,157	1,085	7,948	2,752	15,478	953
Average of Bankfull Measured Widths (ft)	123	23	23	(ATM 163) 13 *	42	39	85	73	19	25	16	33	21
Gradient (%)	0 - 3	0 - 8	1 - 12+	1-12+	1 - 8+	1 - 8+	0 - 4	0 - 8+	1-12+	0 - 8+	1 - 8+	1-12+	1-12+
# Pools in survey	61	41	37	54	13	9	17	59	4	53	8	98	4
Pool Frequency (channel widths/pool)	5.45	3.04	4.00	3.52	5.34	8.55	4.04	3.48	10.85	3.25	12.92	2.77	6.53
% Pools by Length	18	33	24	28	19	12	25	29	9	31	8	36	15
% Pool Area	19	38	42	29	29	13	26	34	16	42	8	48	14
% Pools Associated with LWD	26	44	NA	20	15	44	0	42	0	55	38	26	0
% Pools >= 3 ft Deep	98	27	20	0	46	33	94	83	0	30	0	48	0
Pool: Riffle: Flatwater %	18: 26: 56	33:34:33	24:30:43	28: 43: 27	19:38:43	12:45:43	25:25:50	29: 29: 42	9: 50: 41	31: 27: 42	8:73:19	36:25:39	15:35:50
Pieces LWD / 100 ft >1 ft dia. & > 6 ft long	2.7	1.9	NA	(ATM 163) 6.1 *	(ATM 68) 4.5 *	(ATM 10) 2.7 *	(ATM 11) 2.6 *	1.2	1.8	(ATM 40) 6.5 *	1.3	2.8	2.0
Volume LWD / 100 ft.	234	113	NA	403 *	201 *	290 *	435 *	171	232	328 *	67	326	65
Mean LWD piece volume (ft³)	27	71	NA	19 *	17 *	38 *	42 *	145	126	26 *	51	118	33
# Key Pieces / 100 ft	0.03	0.20	NA	NA	0.16	0.17	0	0.19	0.65	0.30	0	0.23	0.10
Ave. Key LWD Piece Volume (ft³)	726	203	NA	NA	581	557	0	298	181	654	0	469	1,979
Key LWD Pieces / Channel Width	0.03	0.05	NA	NA	0.07	0.07	0	0.14	0.12	0.08	0	0.07	0.02
Canopy closure %	33	92	88	90	91	67	33	63	90	99	94	93	93

[1] Summaries are from the 2005 aquatic habitat stream survey, unless noted.

* LWD Data reported from the ATM stations for the average of 2006, 2003, 2000, and 1999 inventories; otherwise from 2005 survey.

Note: LWD key piece counts may be biased low due to subjectivity inherent in the key piece definition (e.g., all log scour pools were not included in the key piece tallies since the logs may not have had the potential to hold back other pieces of LWD even though they were stable and forming pools). Also, Tally & Volumes of LWD do not include rootwads.

aquatic habitat stream survey data be utilized to provide a picture of conditions in the watershed more completely than if only one or the other source was used.

Methods and detailed data utilized in support of the following discussion are presented and discussed in the Stream Channel Assessment (Appendix D) or, for 2005 aquatic habitat stream surveys, in the Fish Habitat Assessment (Appendix E). Likewise, the Riparian Function Assessment (Appendix C) presents methods and results for the riparian characterization. The PFCs for each surveyed stream reach are presented in the habitat and channel conditions tables of the Fish Habitat Assessment (Appendix E, Tables E-3 through E-15). Changes in various stream channel characteristics, based on ATM data, are depicted on Figure 5-1, along with a listing of channel parameters in Yager Creek and Lawrence Creek, over time, in Table 5-2. A summary of watershed average trends in channel characteristics, based on ATM data, is provided in Table 5-3.

There have already been significant changes in a few parameters, and others are projected to be significant if current trends continue in future years. The trend in many of the channel parameters varies by watershed, usually in the magnitude of the change and often in the direction of change.

A strong trend of decreasing subsurface bed sediment median particle size was evident in both watersheds. In Yager Creek, this fining of the subsurface median particle size was accompanied by a tendency for decreasing the proportion of fine sediments of either 0.85 mm or 6.35 mm in the bed, indicating a coarsening of the streambed on average. The average median particle size of the bed surface has not changed appreciably in either watershed. The bed sediment ratio D_{50}* has clearly increased in Lawrence Creek, but shows no strong trend in Yager Creek.

Residual pool depth has not changed appreciably in either watershed.

Average total pieces of wood in the channel has remained the same in Lawrence Creek, and declined in Yager Creek. The diameter and length of wood pieces has slightly declined in both watersheds. At the same time, pool spacing has remained the same in Lawrence Creek and declined in Yager Creek. This suggests that the trends in watershed averages are consistent with the expected relationship between these two parameters.

Figure 5-1. Summary of Recent Trends in Various Stream Channel Characteristics.

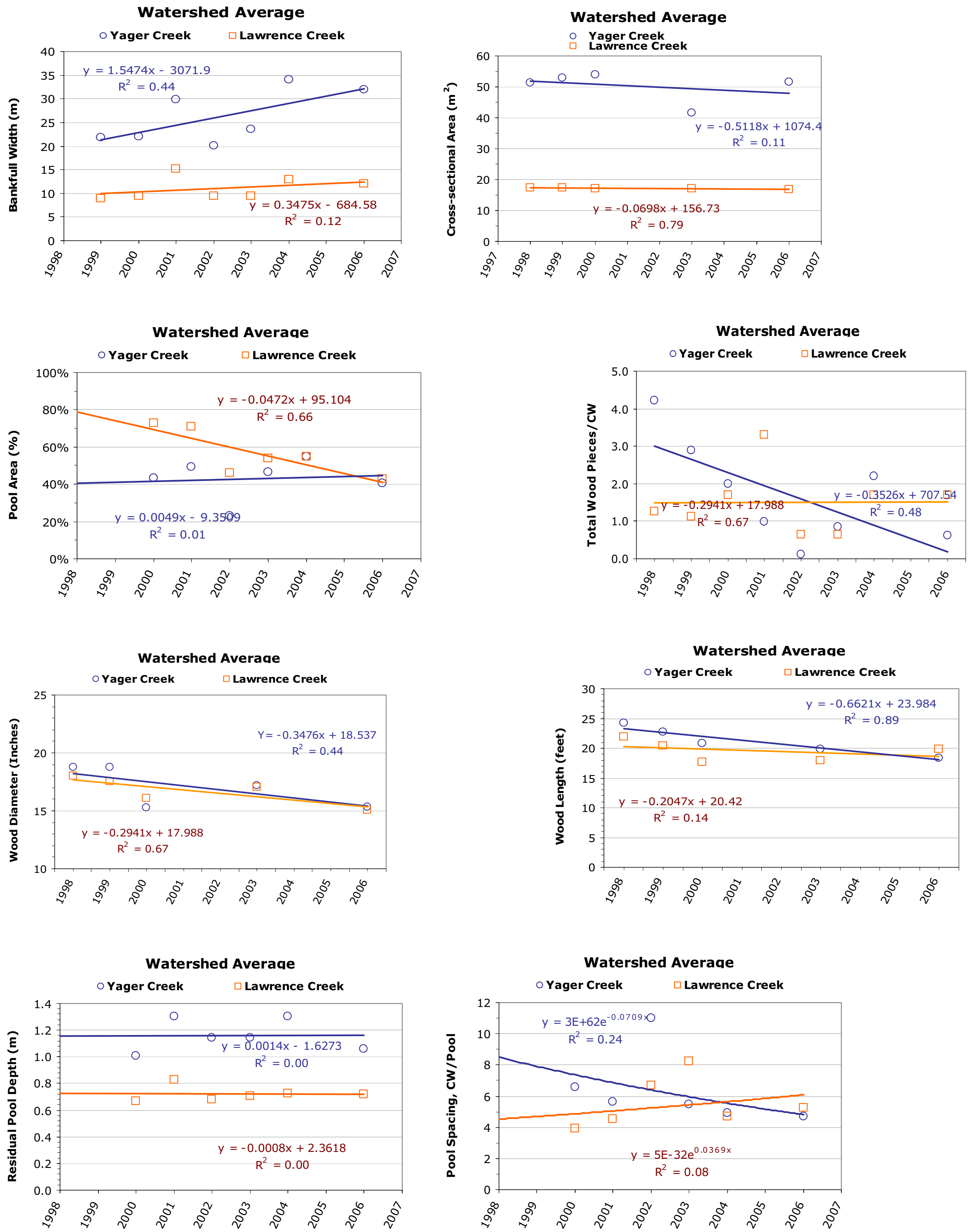


Figure 5-1, continued.

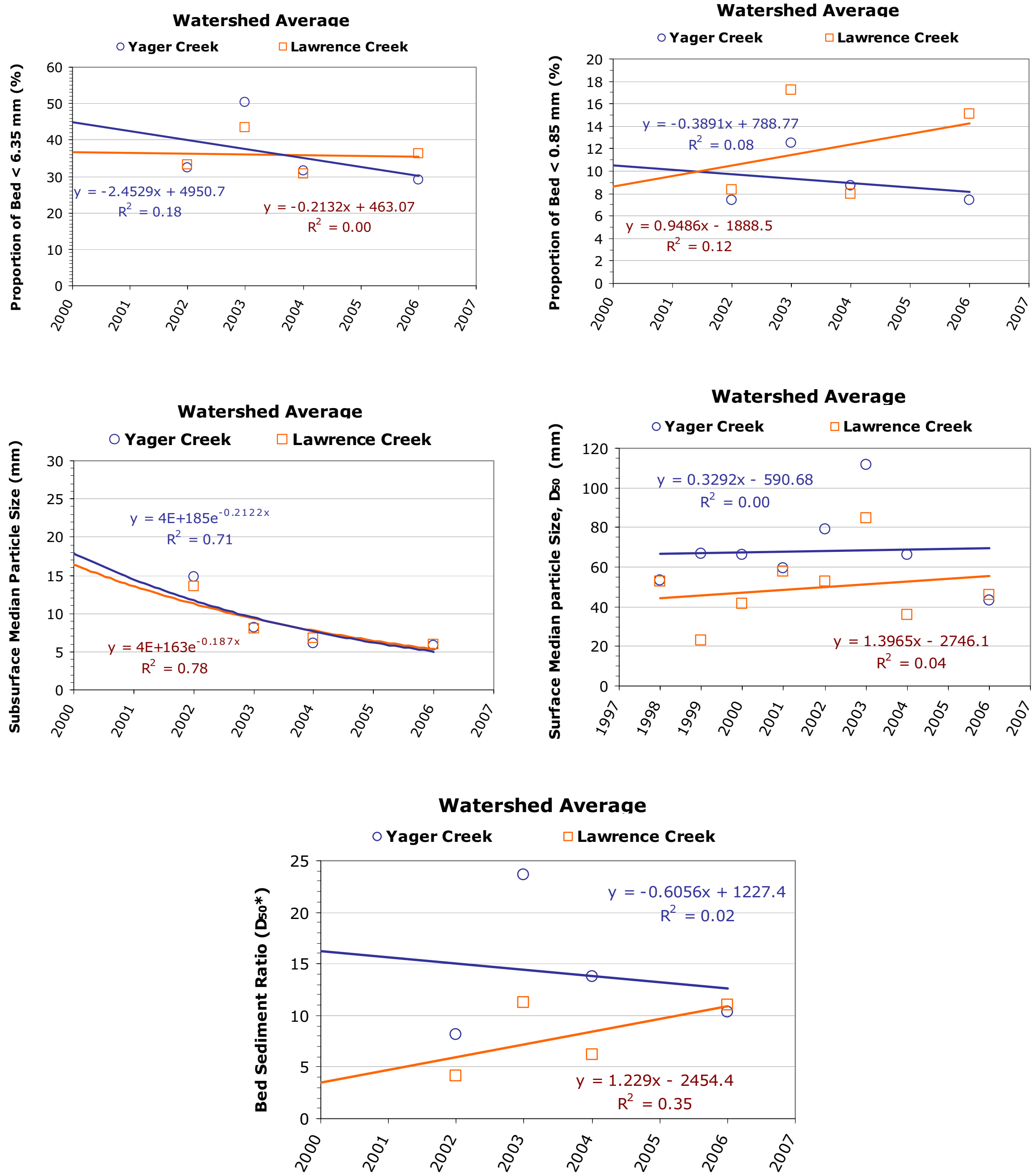


Table 5-2. Watershed Average of Stream Channel Parameters. Yager Creek includes ATM stations 164, 5, 46, and 7. Lawrence Creek includes ATM stations 9, 49, and 40.

The regression slope is used to project the change in parameter in the period of record for that parameter. The percent change is the estimated change in the period divided by the initial value of the observed parameter. A change of 15% of more was interpreted as a change sufficient to report. No estimates of change are made for canopy closure since this parameter has not been measured since 2000.

	1998	1999	2000	2001	2002	2003	2004	2005	2006	□□ Parameter in yrs of record based on regression	Estimated Change from Initial Value	Current Direction of Change
Bankfull Width (m)												
Yager Creek		21.9	21.9	29.8	20.1	23.6	34.1		31.9	10.83	49%	Increase
Lawrence Creek		8.9	9.5	15.2	9.5	9.5	13.0		12.1	2.43	27%	Increase
Cross-section Area (m^2)												
Yager Creek	51.2	52.8	53.9			41.6			51.7	4.61	9%	No change
Lawrence Creek	17.3	17.4	17.0			17.1			16.8	0.63	4%	No change
Surface D_{50} (mm)												
Yager Creek	53.0	67.0	66.0	59.3	79.1	111.7	66.4		42.9	2.96	6%	No change
Lawrence Creek	52.7	23.0	41.3	57.7	52.7	84.7	36.1		46.2	12.57	24%	Increase
Subsurface Geometric Mean Diameter (mm)												
Yager Creek					14.85	8.09	6.02		5.88	4.34	29%	Decrease
Lawrence Creek					13.56	7.97	6.81		5.92	3.48	26%	Decrease
Proportion <0.85 mm												
Yager Creek					7.40	12.53	8.72		7.45	1.95	26%	Decrease
Lawrence Creek					8.36	17.26	8.01		15.05	4.74	57%	Increase
Proportion <6.35 mm												
Yager Creek					32.42	50.37	31.41		28.98	12.26	38%	Decrease
Lawrence Creek					33.20	43.52	30.57		36.10	1.07	3%	No change
Bed Sediment Ratio D_{50}*												
Yager Creek					8.13	23.57	13.79		10.29	3.03	37%	Decrease
Lawrence Creek					4.14	11.24	6.18		11.06	6.15	148%	Increase
Pool Spacing (CW/Pool)												
Yager Creek			6.6	5.6	11.0	5.5	4.9		4.7	1.00	15%	Decrease
Lawrence Creek			3.9	4.5	6.7	8.2	4.7		5.2	0.75	19%	Increase
Residual Pool Depth (m)												
Yager Creek			1.01	1.30	1.14	1.14	1.30		1.06	0.01	1%	No change
Lawrence Creek			0.67	0.83	0.68	0.71	0.72		0.72	0.06	8%	No change
Pool Area (% Wetted Channel Surface Area)												
Yager Creek			44%	49%	23%	47%	55%		41%	3%	8%	No change
Lawrence Creek			73%	71%	46%	54%	55%		43%	33%	45%	Decrease
Wood Loading (Total Pieces/CW)												
Yager Creek	4.23	2.89	2.00	0.98	0.12	0.85	2.20		0.63	3.17	75%	Decrease
Lawrence Creek	1.25	1.12	1.70	3.30	0.63	0.63	1.70		1.69	0.04	4%	No change
Wood Diameter (Inches)												
Yager Creek	18.8	18.8	15.3			17.2			15.4	3.13	17%	Decrease
Lawrence Creek	18.0	17.6	16.1			17.0			15.1	2.65	15%	Decrease
Wood Length (Feet)												
Yager Creek	24.2	22.8	20.8			19.9			18.4	5.96	25%	Decrease
Lawrence Creek	22.0	20.4	17.7			18.0			19.8	1.84	8%	No change
Canopy Closure (%)												
Yager Creek	45.1	35.0	27.5									
Lawrence Creek	71.8	51.2	57.4									

Table 5-3. Summary of Watershed Average Trends in Channel Characteristics.

	Yager Creek	Lawrence Creek
Clearly Evident in Observed Values	• Increase in bankfull width • Decrease in pool spacing • Decrease in wood loading • Decrease in subsurface median particle size • Decrease in proportion of bed <0.85 mm	• Increase in bankfull width • Increase in pool spacing • Decrease in pool area • Decrease in subsurface median particle size • Increase in bed sediment ratio (D_{50}*)
Possible Trend based on regression equations extended over the period	• Decrease in proportion of the bed <6.35 mm • Decrease in bed sediment ratio (D_{50}*) • Decreased wood diameter • Decreased wood length	• Increase in proportion of bed <0.85 mm • Increase in bed surface particle size D_{50} • Decreased wood diameter
No Trend	• Cross-section area • Bed surface D_{50} • Residual pool depth • Pool area	• Cross-section area • Proportion of the bed <6.35 mm • Residual pool depth • Wood loading • Wood length

Although there are watershed patterns in time and space, analysis of the data identified many differences in channel behavior by channel geomorphic units (CGUs). The identification of CGUs used for this discussion is provided in Table 5-4. This summary will focus on the CGUs that are substantially within HRC ownership, with the exception of the lower mainstem Yager alluvial valley that receives the sediment from HRC ownership upstream. This includes the mainstem of Lawrence Creek up to ATM 47, the mainstem of Yager Creek upstream to ATM 11, and the tributaries Shaw Creek, Strawberry Creek, Corner Creek and South Fork Yager Creek that all occur in the Yager Formation group. Bell Creek is the only tributary formed on the Franciscan Central Belt Formation that lies substantially within HRC ownership. ATM sites that monitor watersheds lying mostly out of HRC ownership are ATM 47 in upper Lawrence Creek, and ATM 11 and 10 on the North Fork and Middle ForkYager Creek. These 3 stations were discontinued from measurement after 2004. Several important streams within the WAU that are not covered by ATM monitoring data are Blanton Creek and Booths Run (Yager Formation) and Cooper Mill Creek (Wildcat Formation). These streams are discussed in the Fish Habitat Assessment (Appendix E), along with any data available from CDFG surveys.

The summaries in the following discussion are brief and emphasize important findings for each CGU. Historical impacts are qualitatively determined from review of local knowledge and pertinent literature (as was also done for other watershed analyses conducted on HRC [formerly SCOPAC] ownership), a review of recent and historic aerial photographs, and inferences made from direct field observations in the context of those typically observed for areas with similar land use history. We review the watershed findings moving from the lower watershed upstream to headwaters tributaries, including temporal trends identified from ATM data as presented in the Stream Channel Assessment (Appendix D).

Table 5-4. Summary of CGUs Developed for Analysis of Patterns and Trends in Channel Morphology in the Yager-Lawrence WAU.

Channel Geomorphic Unit Name	Streams Included	Basis of Class	Represented by Data
Lower Yager Alluvial Floodplain	Yager Creek mainstem from mouth to RM 2.0	Unconstrained alluvial mainstem response reach	ATM 164
Yager Mainstem Canyon	Yager Creek mainstem from RM 2.0 to RM 4.4	Yager Formation; Tightly constrained valley mainstem response reach	ATM 5
Yager Mainstem Constrained Valley Alluvium	Yager Creek RM 4.4 to RM 8.8	Yager Formation, Moderately constrained valley mainstem response reach	ATM 46 ATM 7
Lawrence Mainstem Constrained Valley Alluvium	Lawrence Creek mainstem from mouth to gorge	Yager Formation; moderately constrained valley mainstem response reach	ATM 9 ATM 49
Yager Tributaries	Blanton Creek Corner Creek Shaw Creek Strawberry Creek Owl Creek; Fish Creek South Fork Yager Creek	Yager Formation; smaller watersheds; response reaches	ATM 88 ATM 40 ATM 68 ATM 163
Wildcat Formation Tributaries	Cooper Mill Creek Allen Creek	Wildcat Formation; smaller watersheds; response reaches	CDFG 1996 data
Franciscan Formation Tributaries	Bell Creek E. Fork Lawrence Creek North and Middle Forks of Yager Creek from confluence to headwaters	Franciscan; smaller watersheds; response reaches, moderately to tightly constrained valley response reach	ATM 117, 47 ATM 11 ATM 10 CDFG 2003 data

5.1.1 *Lower Yager Alluvial Valley*

<u>Geology/Geomorphology.</u> The lower mainstem of Yager Creek lies entirely within the wide floodplain of the Van Duzen River to which it is tributary. On geologic maps it is identified as Quaternary Alluvium (Qal). Alluvial deposits consist of well-rounded boulders, cobbles, gravel, sand, and clay (Ristau, 1979). Stream bed sediment consists of the same materials.

The Lower Yager Alluvial Floodplain CGU is delineated as the stream length from the confluence of Yager Creek with the Van Duzen River 4.6 km (2.86 miles) upstream to the general area of Yager Camp

(Photo 5-1). The entire unit is unconfined between valley walls, and the unit widens significantly as the stream exits the narrow valley constrained by the forested mountainous terrain.

Photo 5-1. Lower Yager Alluvial Floodplain Delineation (photo from Google Earth).

Note: The overall channel gradient of Yager Creek through this reach is 0.5%.

Cooper Mill Creek is a major tributary that drains to Yager Creek just downstream from the Yager logging camp within this CGU. Cooper Mill Creek is the only tributary formed within the Wildcat geologic formation within this WAU. The stream is utilized by chinook, steelhead, and possibly coho salmon. This stream is described in greater detail in the Fish Habitat Assessment (Appendix E.)

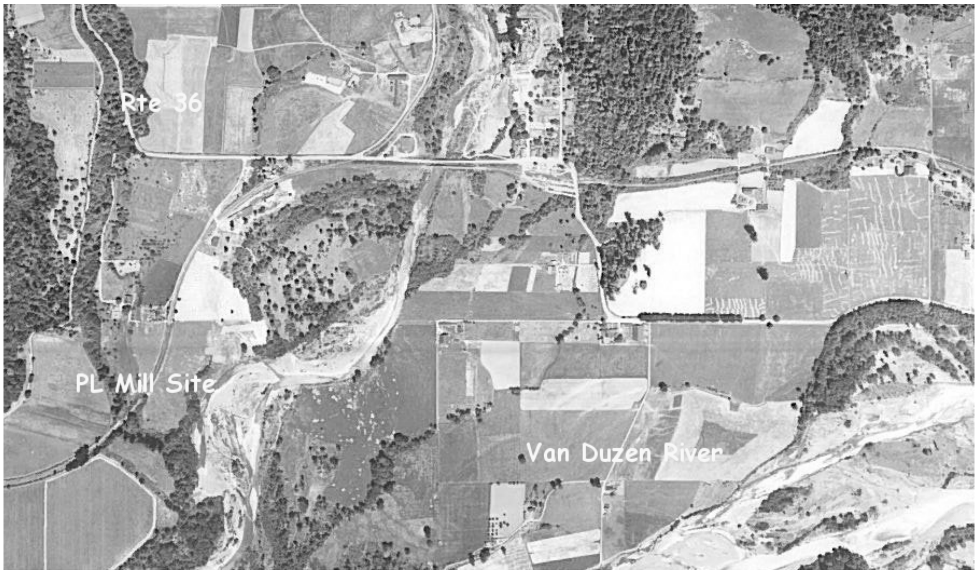
Yager Creek has relatively low sinuosity through the lower reach. The current sinuosity is 1.016 (meander length/valley length). This is not a high sinuosity and indicates a nearly straight channel. In 1948 aerial photos, the sinuosity was 1.033. The channel has straightened by approximately 152 meters (approximately 500 ft) or 3 percent of the length through this reach since the earliest aerial photos.

This is a sediment deposition reach and the channel should be responsive to changes in sediment supply and factors controlling bank stability. The stream is low gradient, and it is unclear how large woody debris may play a role in fish habitat formation, although it is likely that woody debris jams have existed prior to European settlement and played some role in pool formation or channel migration.

Channel Migration Zone. The channel has migrated within the floodplain over the past 60 years within a fairly well defined migration corridor that varies from about 150 meters (465 feet) at its narrowest to 450 meters (about 1500 feet) at its widest. The migration zone averages about 280 meters (930 feet) in width through much of the reach. The channel is generally single threaded, but is multi-threaded in a few locations.

Anthropogenic Disturbances. The wide floodplain that borders the lower reach of Yager Creek was settled early in the post-European history of the region. The primary land use along the reach is agriculture. The lower floodplain is crossed by State Highway 36 near Carlotta. A lumber mill was built near the confluence of Yager Creek and the Van Duzen River in the 1950s. Yager Creek was actively migrating across its valley in the 1948 air photo (Photos 5-2 and 5-3). The PL saw mill was built at the site shown in Photo 5-2 a few years later than this photograph. This actively migrating river segment in this lower portion of the valley stabilized to a straight channel after construction of the mill. HRC timberlands are just at the upstream of the upper boundary of this Channel Migration Zone (CMZ) at the location of the Yager Camp (Photo 5-3). Changes to sediment and LWD input would be expected to affect this CGU.

Photo 5-2. Lower Yager Creek Immediately Upstream of the Confluence with the Van Duzen River in 1948.



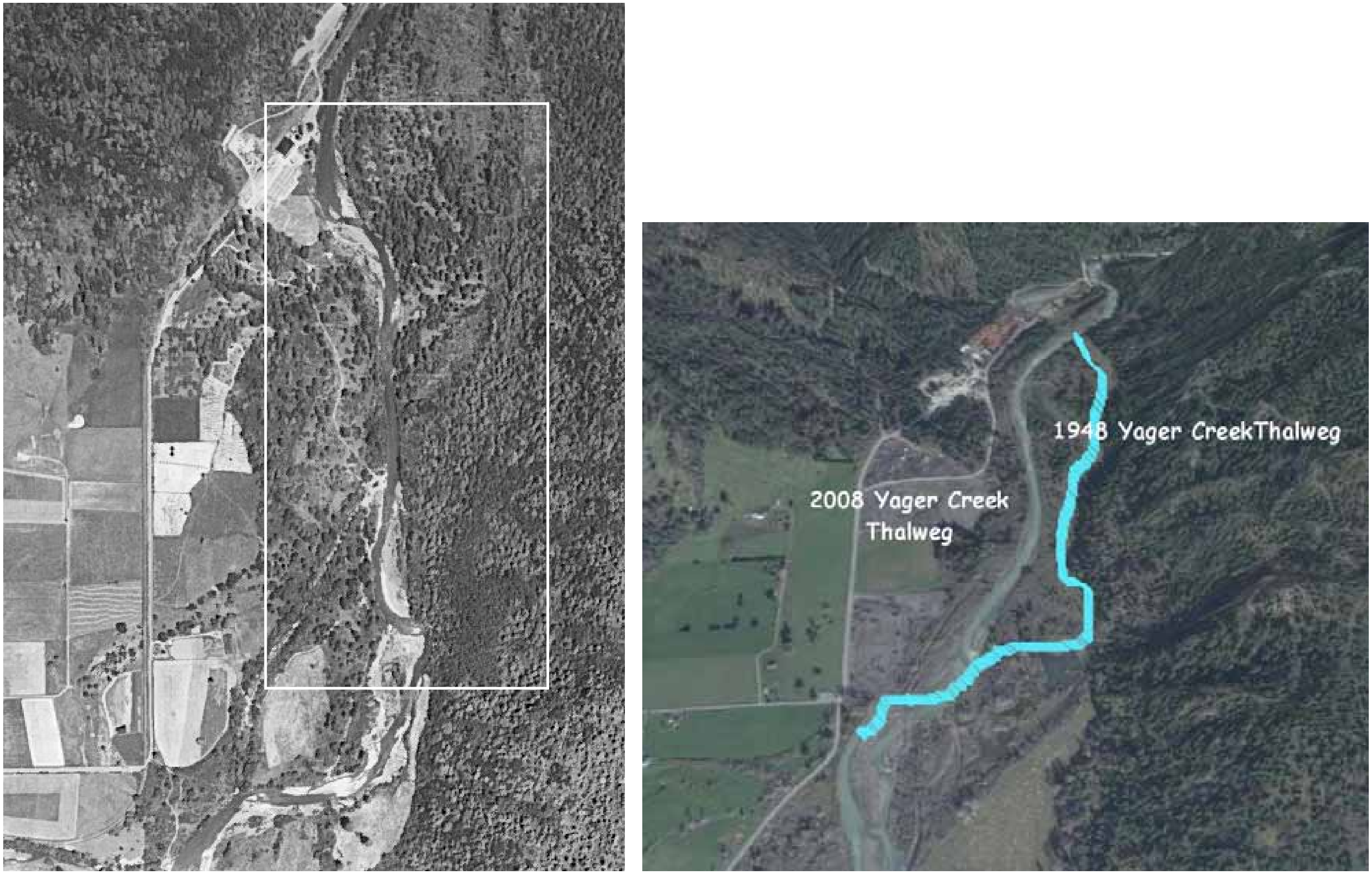
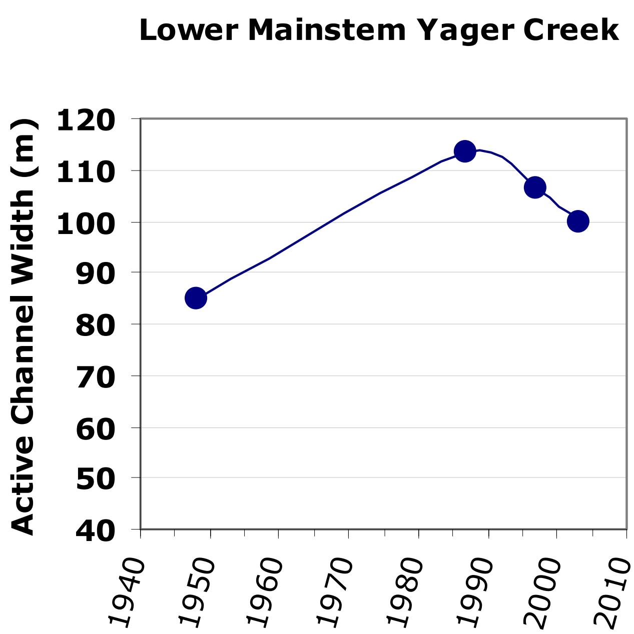


Photo 5-3. Upper Segment of Yager Creek in the Alluvial Valley in 1948 photo (left) and in 2008 (right).

Note: Current thalweg is evident in 2008 photo, with sketch of thalweg in 1948 is shown in blue.

Evidence of Channel Disturbance and Adjustment. The upper segment of Yager Creek within the lower mainstem CGU is shown in Photo 5-3, which includes the 1948 aerial photo and a 3-dimensional 2008 photo view. Even within this relatively straight section of the valley bordered by a hillslope visible on the right side of the 2008 photograph (Photo 5-3), the channel has migrated across the CMZ since 1948. In the 1948 photo, the thalweg was close to the east side of the valley (left in the photo). In the 1987 photos, the thalweg had migrated to the west side in its current position. This migration likely occurred in the 1964 storm event. Yager Creek has remained in a similar location since the 1987 photos. Selecting one reference point along Yager Creek in one of the wider portions of the CMZ near the right angle road corner (lower left corner of Photo 5-3), we measured the visible active channel width on the aerial photographs. The active channel width widened from 85 to 115 meters (280 to 372 ft) after 1948, probably largely during the 1964 flood event (Figure 5-2). The channel has been narrowing progressively since the mid-1980s. This finding is consistent with narrowing of channel width observed at ATM 164.

Figure 5-2. Active Channel Width of Reference Location on Yager Creek within the Alluvial CGU.



It is likely that, prior to European settlement, the channel was bordered by a robust conifer forest with a generally single-threaded channel that was possibly multi-threaded in the widest reaches.

The riparian vegetation along Yager Creek has been severely disturbed. The 1948 aerial photos show virtually no riparian canopy cover over the stream, and that condition persists today. Much of this riparian area is classified in the HSS Riparian Condition Unit (RCU) which represents hardwoods such as willows, of sapling and pole size (less than 12-inch diameter at breast height [DBH]), and with sparse stand density (less than 40 percent) as presented in the Riparian Function Assessment (Appendix C, Map C-1). Smaller portions of this reach, in the Yager Camp area, have mixed or conifer stands at less than 24-inch DBH, with stand densities ranging from sparse to dense. The riparian forest, such as it is, typically has low LWD recruitment potential (Photo 5-4), with some areas with moderate LWD recruitment potential located in the Yager Camp area (Map C-2).

Photo 5-4. Mainstem Yager Creek within the Lower Alluvial Channel Geomoprhic Unit.

Recent Trends in Stream Channel Conditions. The primary consequences of channel and riparian disturbance appear to be channel widening, loss of stable large woody debris, loss of overstream canopy cover, and sediment input. Channel characteristics within the lower mainstem alluvial CGU are characterized by ATM station 164 for this discussion and are also represented, on a longer reach scale, by the 2005 aquatic habitat stream survey data for the Yager mainstem reach (Table 5-1). This reach of Yager Creek has been actively changing channel characteristics in the nearly 10 years of measurement since 1998.

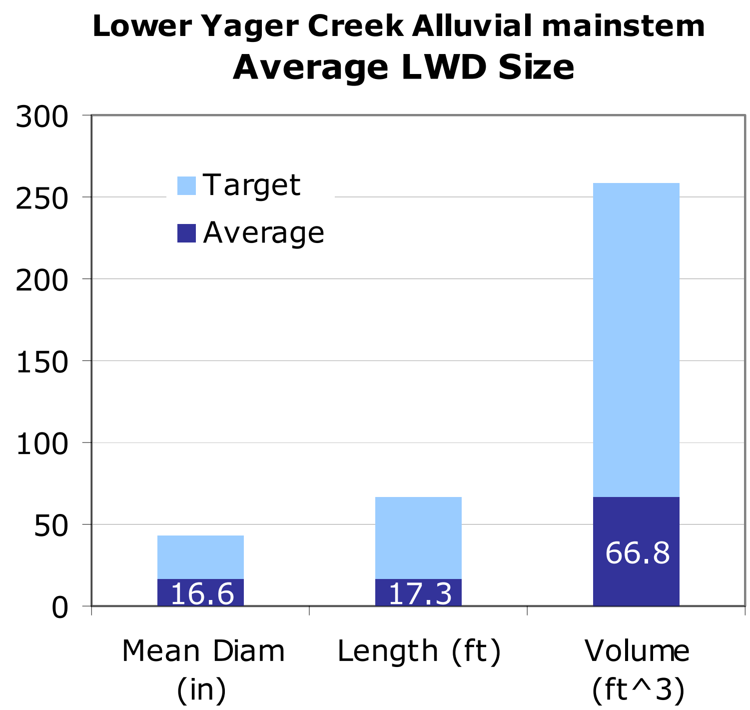
The active channel has widened in the past and has been narrowing for at least the past 20 years. Bankfull width of the channel has also narrowed at ATM 164 within the reach since 1998. Bankfull width is still somewhat higher than expected relative to watershed trend in bankfull width suggesting further narrowing of possibly 5 percent to 45 meters. Cross-sectional area has also decreased 6 percent since 1998.

Despite the large volume of sediment input to this reach from the watershed above, the channel substrate is quite coarse (D_{50} =110 mm in 2004) and has coarsened from 50 mm since 2000 (Photo 5-4). The portion of sediment less than 0.85 mm is 10 percent while the portion of sediment less than 6.35 mm is 35 percent. The finer fraction meets but the larger fraction does not meet the PFC targets. Neither subsurface fraction has shown a trend since 2002. The bed sediment ratio (D_{50}*) has increased significantly since 2002, largely due to the coarsening of the surface sediment.

Pools have increased in frequency and in residual depth, while pool area has remained at about 50 percent the wetted channel. Pool spacing is currently about 5 CW/pool, which meets the PFC target of less than 6 CW/pool, although spacing varies widely from year to year. Pool depth has increased from about 0.6 m (2 ft) consistently in each year of measurement to 1.0 m (3.3 ft) in 2006, which meets the PFC target for average residual pool depth of greater than 3 feet.

Large woody debris has declined in the reach since 1998. Initial loading of total pieces was as high as 13 pieces/CW in 1998 and has declined to only 0.4 pieces/CW in 2006, which does not meet the PFC target of 1.77 pieces/CW. It is likely that woody debris floated into the reach during the 1996 storm and probably accumulated in jams. This wood is clearly not stable and is washed out easily. The average size of wood pieces is shown in Figure 5-3 (note the figure is in English units). The average length of piece is only 17.3 feet in length (5.27 meters). Given that the channel is 165 feet wide (50 meters), this length is clearly too small to have any stability. The average size of wood has not changed since 1998. This CGU would benefit from recruitment of large wood from adjacent riparian stands with rootwads intact. Although channel gradient is low, stable large woody debris would likely create local scour zones and provide improved habitat within the mainstem of Yager Creek. It would also help to form and stabilize logjams.

Figure 5-3. Average Size of Wood Pieces at ATM 164 in the Lower Mainstem Alluvial CGU.



Note: Figure is in English Units.

Canopy closure is quite low along Yager Creek (e.g., Photo 5-4). We estimate that canopy closure could improve to about 30 percent overhead cover in old growth conifer stand conditions, and could possibly decrease the annual maximum water temperatures (MWAT) about 2°C from current annual maxima of about 22°C.

Additional Comments and Observations. The coarsening of bed sediments within this CGU in time and relative to the upstream watershed is probably the most unusual observed trend in this alluvial reach. In a stream with this low gradient, sediment deposition of fines would be expected, especially given that there is a relatively high sediment load delivered to this CGU from the watershed above.

Although the mainstem of Yager flows through agriculturally managed land, most of the channel migration zone is not disturbed by active management within it. This has been true throughout the 60 years of aerial photographic record. The channel has migrated within this zone, but failed to re-establish a riparian forest. This channel reach would benefit from riparian restoration which is not expected to conflict with land use activities.

Further information regarding this CGU, which is part of the larger Mainstem Yager Creek listed in Table 5-1 and evaluated from 2005 aquatic habitat stream survey data in the Fish Habitat Assessment, is provided in Section 4.2.3.1 of Appendix E.

5.1.2 *Yager Mainstem Canyon*

Geology and Geomorphology. Upstream of the alluvial reach, the mainstem of Yager Creek encounters the Yager Formation. The mainstem has carved through this fairly resistant rock to form a deep canyon that tightly constrains the mainstem between the valley walls. This reach is about 2.7 miles (4.5 km) in length. No major fish-bearing tributaries join Yager Creek within this CGU. A few very small tributaries join Yager Creek within the CGU at very steep gradients.

Figure 5-4. Yager Mainstem Canyon CGU Located on Geologic Map of the Watershed.
Note: CGU boundaries are delineated with black line. Stream gradient is 0-2% where red, 2-4% where blue and >4% where yellow.

Although the canyon constrains the channel, the average channel gradient is 1 percent, just marginally steeper than the completely unconstrained reach downstream. Figure 5-4 shows the gradient class determined from Lidar DEM through the reach. Most of the reach is 1 percent gradient. There are local short reaches with gradient between 2-4 percent. There are no barriers to salmon migration.

The channel is varied through the reach but reflects the very high stream power imposed by the valley constraint. There are large boulder fields left as lag from the weathering of the bedrock. Photo 5-5 shows the stream near the first bridge crossing during an approximate bankfull event and the deposits left following the event. The series of three photographs are taken from the 1st bridge looking upstream and downstream. These photographs illustrate the varying nature of channel morphology through the CGU. Sediments similar to the composition of the bedload deposit locally around obstructions and resemble the sediment deposits in other alluvial locations within the WAU. In other locations, the bed is essentially devoid of alluvium bedforms and composed of boulders left behind resembling cascade type bedforms, although the channel is too low gradient to formally classify as this channel type. The intense scour forms deep pools almost exclusively associated with rock outcrops.

Photo 5-5. Stream Channel Characteristic of the Yager Mainstem Canyon.

Note: The photographs on the top row are taken from the 1st bridge looking downstream and bottom left is looking upstream. There is localized deposition of sediment around obstructions such as the bridge and rock outcrops, creating gravel deposits similar in size to the bed load.

The Yager Mainstem Canyon CGU is responsive to sediment input. Sediment input from the upstream watershed may be important for maintaining sediment of cobble sized and smaller within the reach due to the high stream power within this unit; the channel is not expected to be responsive to bank destabilization or to wood loading.

Channel Migration Zone. There is no channel migration zone along Yager Creek within this CGU. There is almost no stored alluvium wider than the active channel.

Anthropenic Disturbances. HRC's mainline haul road closely follows the stream channel through most of the length of the canyon, alternating between the north and south sides of the channel. The haul road further constrains the valley in some locations and is a persistent disturbance factor.

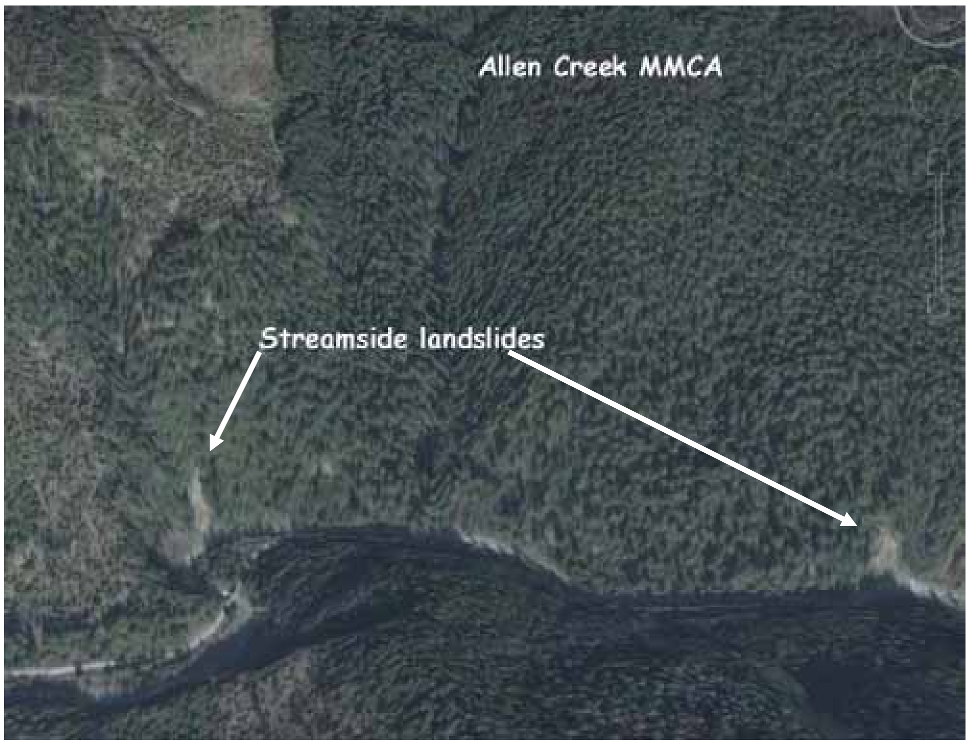
The aerial photo from 1948 (Photo 5-6) shows that logging had occurred by this time along much of the south side of Yager Creek, working up the mainstem. Portions of the steep canyon walls were left and are now within the Allen Creek Marbled Murrelet Conservation Area. Some of these stands of old growth redwood that were on the most difficult to access hillslopes were never logged (mostly north side of river), while others were selectively logged (e.g., south side of river).

There is no known history of stream cleaning within the reach, but it seems likely that this occurred with construction of the road near the channel. However, it is also possible that LWD has never been very stable within this high stream power reach and that wood loading has never been high.

Photo 5-6. Yager Mainstem Canyon CGU Reach (1948 aerial photograph).

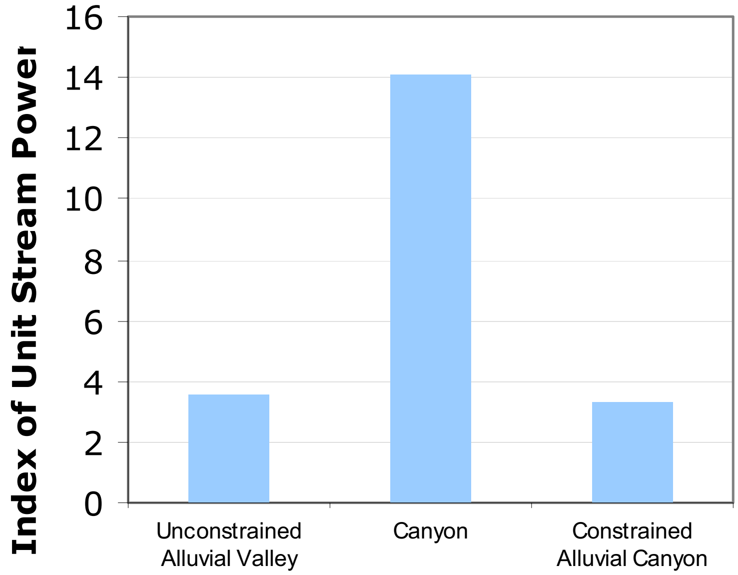
Evidence of Channel Disturbance and Adjustment. There has been no alteration of channel location during the 60 years of photographic record. The channel is subject to streamside landslides as the river works on the canyon walls (Photo 5-7). Large and small landslides occur along the channel and lower slopes throughout the CGU. Most of these are likely natural slides resulting from streamflow destabilizing the lower slopes, especially at river bends. The large landslides evident today were also evident in the 1948 photos (Photo 5-6).

Photo 5-7. Streamside Landslides along Yager Mainstem Canyon Reach.



Recent Trends in Stream Channel Conditions. The tight constraint of the valley walls has a significant effect on the channel dimensions within the CGU. The mainstem Yager Creek within the reach is significantly narrower and deeper than the basin trend in these characteristics. This CGU is represented by ATM Station 5. The residual pool depth is over 2 times deeper than pools in the downstream alluvial zone. Cross-sectional area is also significantly smaller. This contributes to the high scour power as velocity is forced through the relatively small channel area. The index of unit stream power introduced in the discussion of bed sediment characteristics (Sections 5.2.4 and 5.2.5 of Appendix D) is shown for the Yager mainstem CGUs, including the alluvial, canyon, and the constrained alluvial valley reaches (Figure 5-5). The index of unit stream power increases significantly within the canyon, compared to the alluvial reaches above and below. Although narrowly constrained within the valley, the channel width has widened and channel cross-sectional area has increased a small amount in recent years.

Figure 5-5. Index of Unit Stream Power (Basin Area x Slope/Bankful Width) for the Yager Mainstem Channel Geomorphic Units.



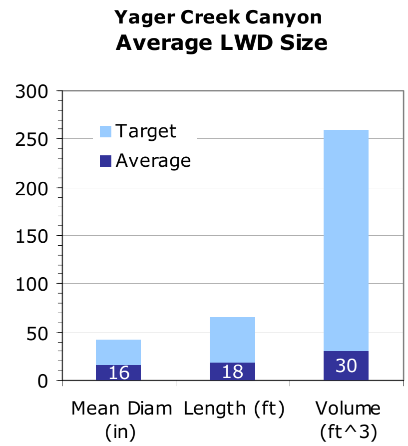
The streambed sediment characteristics sampled within the ATM stations do not appear to reflect the high stream power in the reach. This probably is a result of the sampling methods. Surveyors do not include the boulders in surface particle counts, and they are certainly not included in the shovel samples of the streambed. Thus, the large rocks that create very high relative roughness within the channel are ignored in the bed sampling. However, this sediment should be indicative of the sediment load from the watershed above. The sediment in transport drops as the flow recedes, leaving the patchy alluvium in the pools and between the boulders that is sampled in the ATM survey. It is likely that the bed sediment is completely mobilized in every major storm.

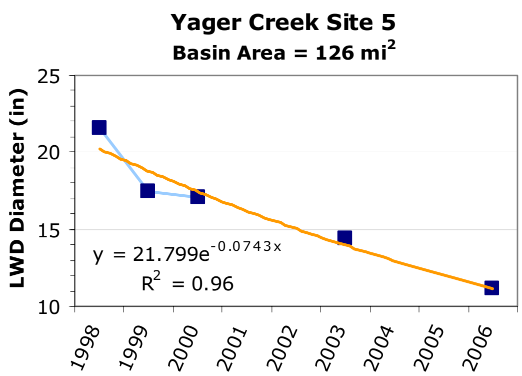
The surface particle size reported from the ATM station is relatively small (D_{50} of 55mm in 2004) compared to the basin trend, and oscillates widely from year to year. The portion of sediment less than 0.85 mm is 9 percent while the portion of sediment less than 6.35 mm is 38 percent, neither meeting the PFC targets of 11-16 percent and less than 30 percent, respectively. The finer fraction meets the PFC target but the larger fraction exceeds the PFC target. It should be noted that this reach is probably not good spawning habitat due to the high mobility of the bed. Nevertheless, the proportion of fines in the bed has tended to decline since 2002.

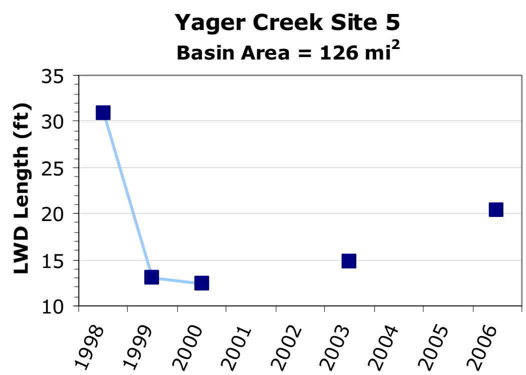
Pools tend to form only around the bedrock outcrops. Pool area tends to be low, the pools are widely spaced, but those that form are quite deep. There have been no recent trends for any pool characteristics within the reach.

Approximately half of the riparian forest area in this CGU is classified as the CLD RCU (Appendix C, Map C-1), which is conifer, large size (DBH greater than 24 inches), and moderate to dense (greater than 40 percent canopy closure) stand density, with other areas in mixed conifer/hardwood stands and smaller conifer stands. LWD is virtually non-existent within the Yager Mainstem Canyon and there has been no recent trend of increasing the occurrence of LWD in this reach, although this CGU includes high LWD recruitment potential for approximately half of the riparian forest, with low and moderate potential for the other areas (Appendix C, Map C-2). Piece count is very low relative to PFC target conditions (Figure 5-6). When measurements began in 1998, the average diameter and length of LWD was significantly greater than it is now. This was probably wood delivered to the reach during the large storm of 1996. There was no increase in wood amount or size following the 2002 storm. LWD diameter has continued to decline throughout the measurement period, but LWD length is tending to increase in recent years.

Figure 5-6. Average LWD Dimensions and Recent Trends within the Yager Canyon CGU.







It is likely that the road in a few locations as well as logging have reduced canopy closure from potential levels along Yager Creek within the canyon. Canopy closure above the stream is rather low (30 percent at ATM 5) given the relatively narrow stream, and does not meet the PFC target of greater than 85 percent. The MWAT currently exceeds 21°C, exceeding the PFC target of 16.8°C. Topographic shading by the canyon walls is significant when the stream flows east to west, but this direction also exposes the water to sunlight longer during the day, somewhat ameliorating the benefit of the topography (Photo 5-8). Note the riparian buffer in the recently logged area on the north side of Yager Creek in Photo 5-8. The stream cover along most of the stream reach has not changed substantially from that evident in the 1948 aerial photo (Photo 5-6). An increase in canopy closure to potential (perhaps as high as 50 percent) could probably improve water temperature by 3°C.

Photo 5-8. Segment of Yager Creek within the Yager Canyon CGU (topographic and riparian shading).

Additional Comments and Observations. The high stream power within this reach makes it difficult to predict how channel characteristics will respond to changes in wood or sediment input from the watershed. Sediment is transient within the reach, and sediment supply reduction could actually shrink the size of pools. Wood will have to be very large to stabilize within this reach. If significant debris dams ever formed they could lead to destructive dam break floods.

Despite, or perhaps because of, the high stream power, this reach of stream provides excellent adult holding habitat for chinook, steelhead, and coho that move through to the upper reaches of the watershed. The deep pools scoured at the bedrock outcrops provide excellent holding habitat for even the largest fish.

Further information regarding this CGU, which is part of the larger Mainstem Yager Creek listed in Table 5-1 and evaluated from 2005 aquatic habitat stream survey data in the Fish Habitat Assessment, is provided in Section 4.2.3.1 of Appendix E.

5.1.3 *Yager Mainstem Constrained Valley Alluvium*

Geology and Geomorphology. Upstream of the canyon, the Yager Creek Valley widens somewhat, allowing deposition of alluvial sediments. The mainstem is alternatively loosely to moderately constrained within the valley walls, and the alluvium varies accordingly. The CGU begins where the mapped alluvium begins approximately where Blanton Creek joins Yager Creek from the northwest. The alluvium is mapped as green on the geologic map. The hillslopes adjacent to the stream are Yager Formation. Note that the channel is impinged on by large old dormant landslide features from the south. Near ATM 7, the valley alluvium is very narrow and local channel gradient steepens.

Figure 5-7. Location of the Yager Mainstem Constrained Valley Alluvium CGU on the Standard Geologic Map of the Watershed (from Map D-1).

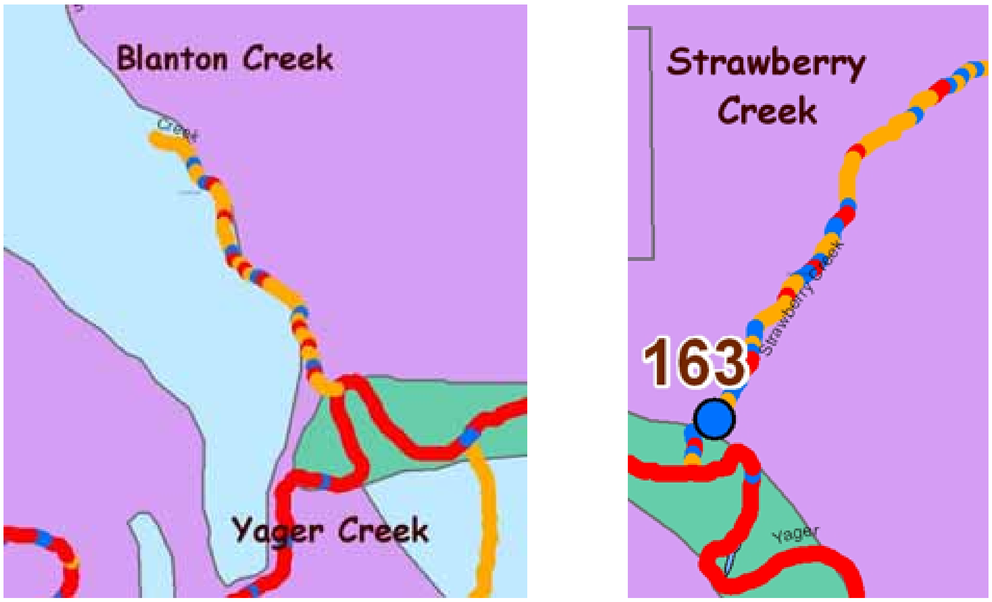
Purple is the Yager Formation (yf), blue is Qls, and blue green is Qtw. Franciscan is bright green (cb); right side at stations 10 and 11. Channel gradient classes: red 0-2%, blue 2-4%, orange >4%.

The channel gradient of Yager Creek varies from 0.6 percent at the downstream end of the unit to 1 percent at the upstream end. The gradient throughout is less than 2 percent (red in Figure 5-7) for nearly the entire length except for a few short reaches of 2-4 percent gradient (blue in Figure 5-7).

Chinook salmon heavily use the mainstem Yager throughout the length of the CGU. Steelhead also use the mainstem and tributaries to Yager Creek within this CGU. Major tributaries that join Yager Creek within the WAU are Lawrence Creek, Blanton Creek, and Strawberry Creek that drain from the north, and the South Fork Yager Creek and Middle Fork Yager Creek that join from the south and east. Upstream of the junction of the Middle Fork Yager Creek with the mainstem, Yager Creek is called the North Fork Yager Creek. The three forks of Yager Creek roughly coincide with the transition to the Franciscan Central Belt formation geologic type (light green and on far right of Figure 5-7). We draw the upper boundary of the CGU at ATM station 11 (Figure 5-7), although the valley bottom alluvium disappears above the confluence of South Fork Yager Creek with the mainstem of Yager Creek. As has been observed in other WAUs on HRC property, tributary streams that form on the Yager Formation tend to join the mainstem at fairly steep gradients with little development of low gradient response reaches.

For example, the stream gradient map of Strawberry Creek and Blanton Creek is shown in Figure 5-8. These streams are suitable for steelhead spawning and rearing but barriers to chinook and coho. They have little response gradient anywhere within their length.

Figure 5-8. Channel Gradient Map of Strawberry Creek and Blanton Creek.



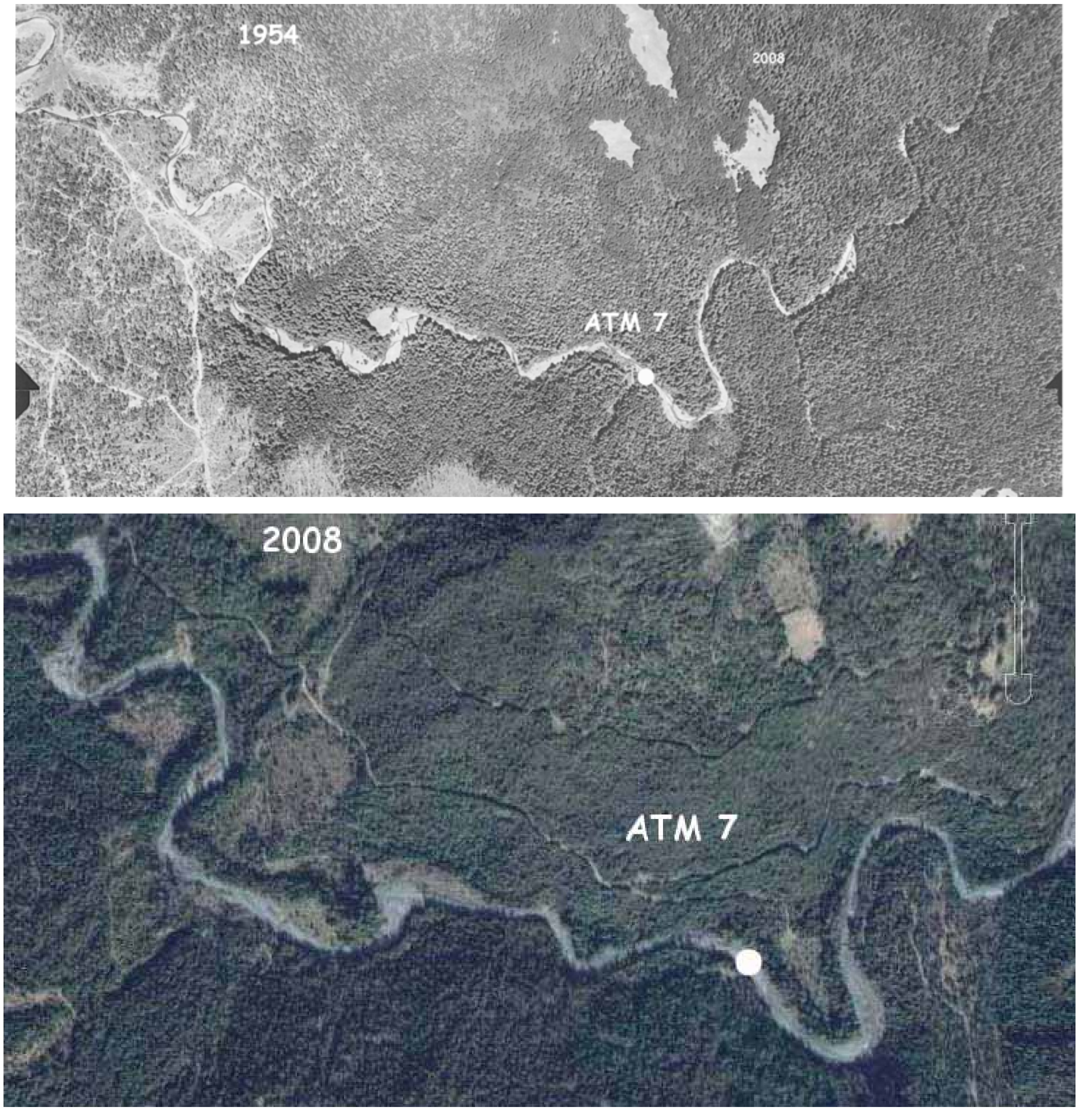
Note: Channel gradient in red <2%, blue 2-4%, yellow >4%. Geology colors are Yager: purple, Alluvium Qts: green, Qls: light blue.

This CGU lies entirely within the Yager Formation, although it is fed sediment from the Franciscan Belt Formation by the North Fork and Middle Fork Yager Creek. The North Fork Yager above ATM station 11 has a watershed area of 121 km^2 (46.7 mi^2) which is still much larger than the tributaries within the WAU. Thus, the sediment load imposed from the upper watershed is likely to have a strong influence on channel characteristics within the Yager Mainstem Constrained Alluvial Valley CGU. HRC owns only a small portion of the watershed area above ATM 11, and very little in the Middle Fork and South Fork of Yager Creek.

The channel characteristics of the Yager Mainstem Constrained Alluvial Valley CGU are represented by ATM stations 46 in the lower end and 7 at the upper end (Figure 5-7).

Channel Migration Zone. There is a well developed channel migration zone that varies in width with the alluvium. It can be generally mapped coincident with the Qtw geologic map unit shown as dark green in Figure 5-7.

Photo 5-9. Aerial Photo View of the Yager Constrained Valley Alluvium CGU in 1954 and 2008.



<u>Anthropenic Disturbances.</u> Photo 5-9 shows roughly the same reach of Yager Creek within the Constrained Alluvial Valley CGU in 1954 and recently. The mainstem of Yager Creek was progressively logged upstream several miles as early as 1948. However, as late as 1954, most of the CGU on the easterly side had not been logged. Riparian forests were clearcut in many locations from the period 1949 to 1997, but residual stands were left in some locations. By 1997, the majority of the CGU had been clearcut logged at least once, or harvested in a series of selection cuts. There was no direct disturbance to Yager Creek locally from log hauling. The haul roads do not impinge on Yager Creek within this CGU although there are several bridge crossings.

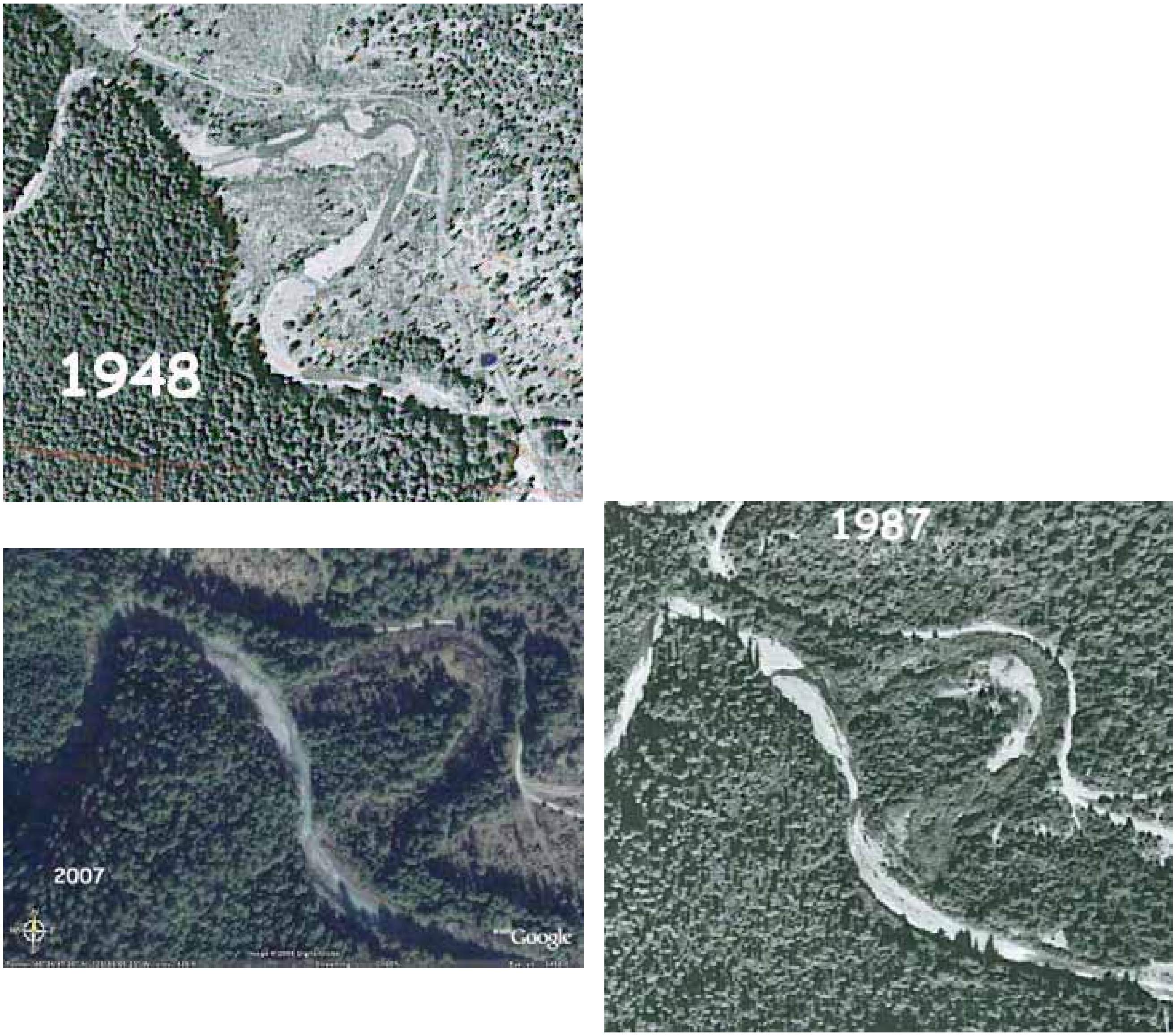
One of the main purposes of Photo 5-9 is to show the Yager Creek channel prior to logging. Note that the channel is clearly visible in 1954 photos (as well as on 1948 photos, not shown). The reaches that were naturally wide in 1954, mostly between ATM 7 and ATM 46) are still open and wide today. If anything, there appears to be some reestablishment of vegetation within the active zone of the meander bends in recent photos that was not visible in the 1954 photo.

Evidence of Channel Disturbance and Adjustment. Photo 5-9 shows that the active channel has been relatively wide since prior to logging old growth in this portion of the watershed. The channel thalweg actively migrates within the active channel zone. The most dramatic channel adjustment occurred on the west side of the CGU near the confluence of Yager Creek and Lawrence Creek. A sequence of photos of a meander cutoff of one of the large meander loops within the alluvial valley is shown in Photo 5-10. In 1948, the thalweg was at the widest point in the meander. By 1987, the channel straightened and cut the meander off. This probably occurred during the 1964 storm, given that the abandoned meander was already well vegetated in 1987. The stream channel continues to occupy the new channel pathway. The old channel pathway was approximately 3,100 feet long, and the new pathway is 930 ft. This meander cutoff reduced the total length of Yager Creek within the CGU by about 10 percent.

Recent Trends in Stream Channel Conditions. It is unclear based on aerial photography what direct and observable effects that management has had on the channel conditions of the mainstem Yager within this CGU. Channels were already fairly wide and open by 1948 before most of the logging had occurred (Photo 5-10). This was especially true in the mid-section of the reach at the meander bends. Higher in the watershed above ATM 7, the channel was narrow and the overstory covered the channel in aerial photographs. Widening, or at least loss of overstory cover, was more evident after logging. There is also some visual evidence of increased bar size in the more recent photos of 1997 and 2003 than in the earliest photos. There is no apparent difference in the active channels between the 1997 and 2003 photos.

The channel characteristics of the Yager Mainstem Constrained Alluvial Valley CGU are represented by ATM stations 46 in the lower end and 7 at the upper end (Figure 5-7).

Photo 5-10. Meander Bend Cutoff of Yager Creek Upstream from Confluence with Lawrence Creek (photos are from 1948, 1987, and 2007).



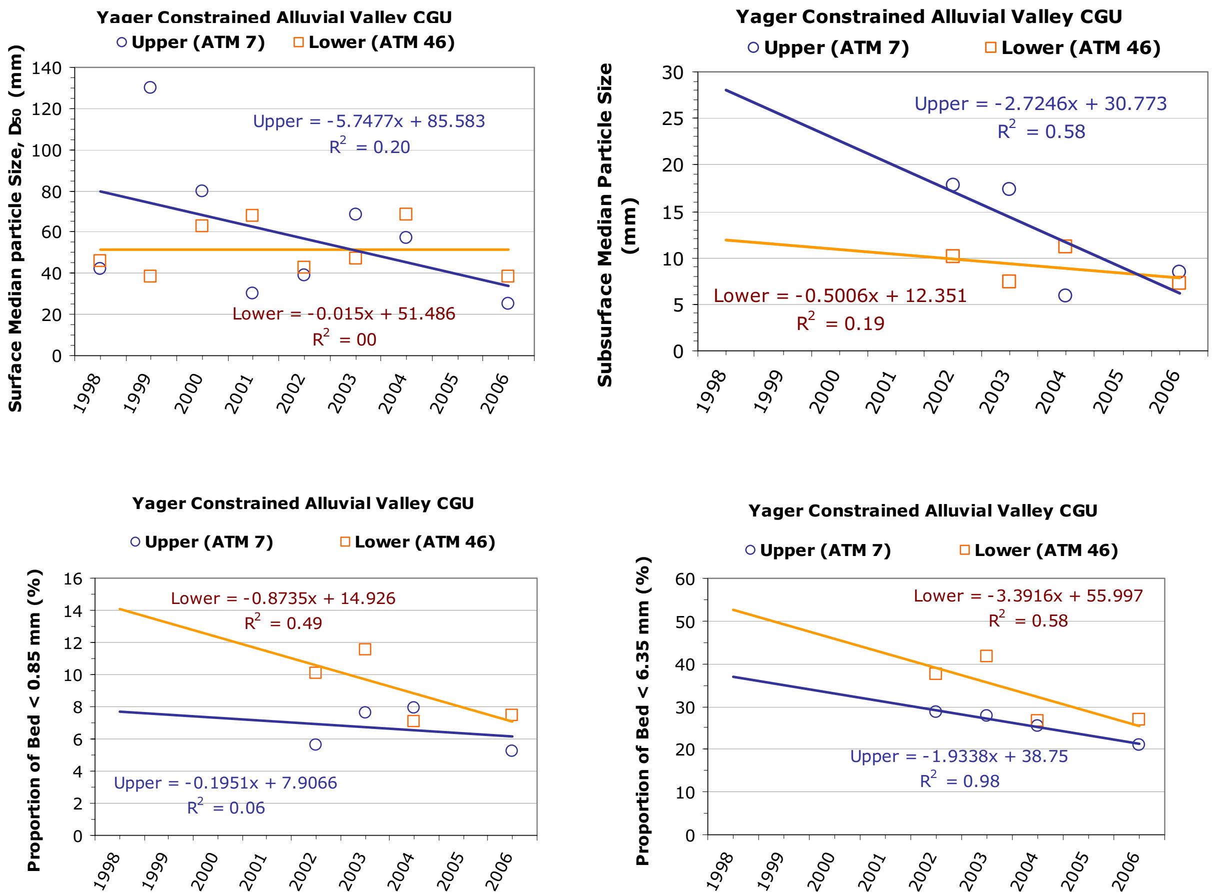
At the upper end of the CGU, the channel width of Yager Creek is significantly wider than the basin trend. Channel width has widened and cross-sectional channel area increased significantly in the 2006 measurement. If channel width from earlier years had been used in the basin relationships, channel width would have been more consistent with the basin trend. This suggests that widening is a response to some change in watershed processes. Importantly, channel parameters at the upper and lower end of the CGU generally have the same trend and direction of change during recent monitoring, although the values of parameters having a strong basin trend differ. The most noteworthy characteristics are highlighted here.

Importantly, the bed surface D_{50} in the upper end of the CGU has declined to only 25 mm in 2006, a significant reduction from values of 80 to 120 in 1998 and 1999 (Figure 5-9) compared to the PFC target for D_{50} of surface particles of 64 to 96 mm. Note however, that there is wide scatter in surface D_{50} at the upstream site. Bed surface D_{50} at the lower end of the CGU has been steady at about 50 mm during this time. Similarly, the bed subsurface D_{50} at the upper site was relatively coarse in 2002 and has trended sharply down. The subsurface D_{50} has been significantly finer at the lower station throughout the period.

What appears to be occurring is that the sediment size is becoming more even throughout the Yager Creek reach in this CGU. The upstream reach was coarser at the onset of measurement and the bed sediment of the lower reach was fine. Bed sediment in the upper reach has fined towards the conditions observed in the lower reach throughout the period and at this time they are similar. The bed sediment ratio (D_{50}*) at the upper station was about 3 at the last measurement in 2006. This is nearing the lower limit of the parameter and suggests high sediment loads relative to stream power capacity. The trends in these parameters suggest that sediment load has increased in recent years. However, we will feel more confident in this interpretation when a longer record of measurement has been achieved.

At the same time that the particle size metrics suggest that the streambed is fining, the metrics of fine sediment proportion within the gravels have been coarsening. The fine sediment content less than 0.85 mm and less than 6.35 mm have declined at both sites in the CGU. Sediment content less than 0.85 mm has met the PFC targets in all years. Values are actually approaching the minimum of 6 percent in recent years. The lower site in the CGU has had particularly high content of particles less than 6.35 mm in 2002, which has declined to near 25 percent in recent years, now meeting the PFC target of less than 30 percent. We would surmise that the subsurface bed measures should trend in the same direction.

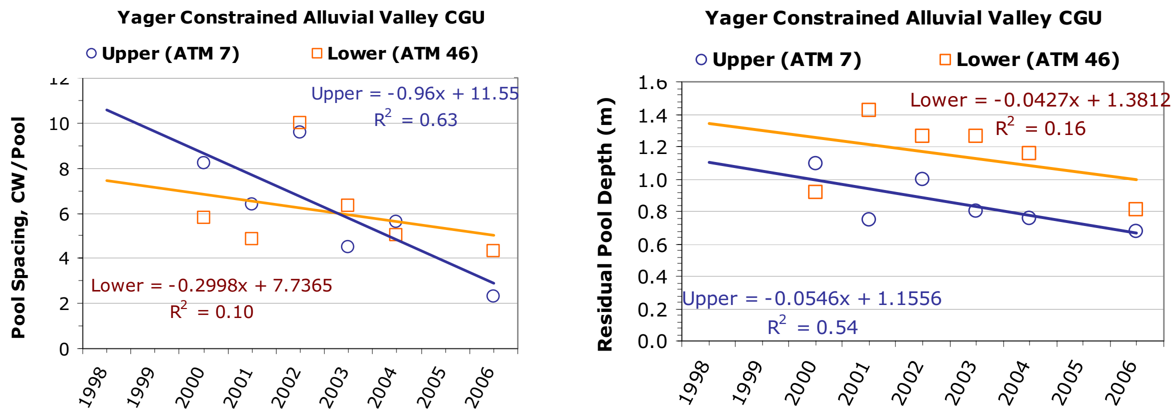
Figure 5-9. Trends in Bed Sediment Characteristics within the Yager Mainstem Constrained Valley Alluvium CGU.



Pool frequency has tended to increase in both the upper and lower end of the CGU and pool area has increased slightly as well (Figure 5-10). On the negative side, residual pool depth has declined significantly from high values that meet the PFC target of 0.9 meters (3 ft) to about 0.75 meters (2.5 ft) in recent years for these specific ATM stations. This could suggest pool filling with sediment consistent with the hypothesis of increased load.

Approximately half of the riparian forest area in this CGU is classified as the CLD RCU (Appendix C, Map C-1), which is conifer, large size (DBH greater than 24 inches), and moderate to dense (greater than 40 percent canopy closure) stand density, with other areas in mixed conifer/hardwood stands and smaller conifer stands. There have been no trends in LWD loading since 1998, although this CGU includes large areas of high and moderate LWD recruitment potential, with low potential for the other areas (Appendix C, Map C-2). Wood diameter has been decreasing at the upper site and increasing at the lower site. In 2006, both sites were nearly the same in wood diameter. Wood length has also tended to decline.

Figure 5-10. Trends in Pool Characteristics within the Yager Mainstem Constrained Valley Alluvium CGU.



Canopy closure is low over Yager Creek in much of the upper portion of the CGU, but is somewhat higher in the lower reach. The canopy closure measured in 2000 ranged from 25-55 percent at the lower station (left in Photo 5-11) and from 0-20 percent in the upstream reach (right in Photo 5-11). We hypothesize that this portion of the stream could have significantly greater canopy closure (+30 to 40 percent) over much of the stream. If this canopy closure could be achieved, we estimate that water temperature could improve at least 3°C from the current summer maxima (MWAT) of about 21°C.

Photo 5-11. Yager Creek in the Lower Gradient Reach in the Downstream End of the CGU and the More Constrained Reach in the Upstream Portion of the CGU.

<u>General Comments and Observations</u>. We find it interesting that the trend in channel and stream bed sediment characteristics are reasonably consistent between the two stations in the upper and lower portion of the CGU. This gives some confidence that measurement of the channel parameters may be interpretative of watershed processes.

The earliest aerial photographs of the watershed prior to logging of the area show the channel of Yager Creek to be relatively wide and open through much of the reach, although it appears that the channel has widened to some extent since logging. The extent to which the channel is naturally wide will determine the extent that water temperature can be improved.

Further information regarding this CGU, which is part of the larger Mainstem Yager Creek listed in Table 5-1 and evaluated from 2005 aquatic habitat stream survey data in the Fish Habitat Assessment, is provided in Section 4.2.3.1 of Appendix E.

5.1.4 *Lawrence Mainstem Constrained Valley Alluvium*

<u>Geology and Geomorphology.</u> This CGU contains the mainstem of Lawrence Creek from its confluence upstream to the steep canyon known as “the gorge”, which forms the boundary between the Yager Formation and the Franciscan Central Belt Formation. This distance is approximately 7 km (4.1 miles). The Lawrence Creek watershed is much smaller than the Yager Creek watershed above the confluence of Yager and Lawrence Creeks; the drainage area of Lawrence Creek is 108 km^2 (41.7 mi^2) while Yager Creek is 178 km^2 (68.7 mi^2). Valley morphometry is similar between the two mainstems. The mainstem of Lawrence Creek is alternatively loosely to moderately constrained within the valley walls, and the alluvium varies accordingly. However, the alluvial zones occupy a much smaller proportion of the CGU mainstem. The channel is primarily straight with little floodplain along its length (Figure 5-11).

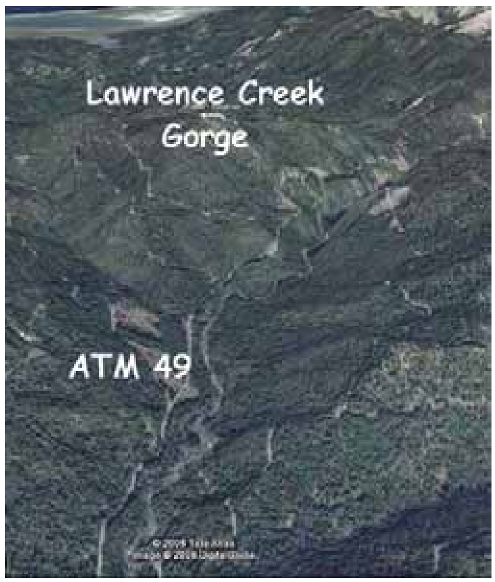
Figure 5-11. Location of the Lawrence Creek Mainstem Constrained Valley Alluvium CGU on the Standard Geologic Map of the Watershed (from Map D-1).

Note: Purple is the Yager Formation (yf), blue is Qls, and blue green is Qtw; Franciscan is light green (cb). Channel gradient classes are red 0-2%, blue 2-4%, orange >4%.

The alluvium is mapped as blue-green on the geologic map. There are significant alluvial deposits along the mainstem of Lawrence Creek only at the downstream end of the CGU at the confluence with Yager Creek (represented by ATM 9) and near the top at the confluence of Shaw Creek, Corner Creek, and Fish Creek (represented by ATM 49). The upper extent of the Lawrence Mainstem CGU is shown on Photo 5-12. The hillslopes adjacent to the stream are Yager Formation. Note that old dormant landslide features impinge on the channel in several locations.

Channel gradient throughout the reach is generally less than 2 percent. Gradient in the downstream alluvium at ATM station 9 is 0.5 percent and in the upstream alluvium is 1.1 percent. This range in gradient is similar to that observed in the Yager Mainstream Constrained Valley Alluvium CGU. Lawrence Creek and its tributaries are utilized by coho salmon, chinook salmon, and steelhead. The boulder roughs that occur within the gorge area block coho and chinook migration, but steelhead continue upstream. The channel morphology is riffle/pool, but glides make up a substantial stream area. Lawrence Creek should be sensitive to sediment loads from the watershed and LWD.

Photo 5-12. Upper Extent of Lawerence Mainstem CGU.



Channel Migration Zone. The channel migration zone is limited within this CGU. The channel meanders more within the alluvium, but is contained within the valley walls for much of its length. The channel migration zone in these reaches is limited to the active channel area.

Anthropenic Disturbances. The mainstem of Lawrence Creek was progressively logged upstream several miles as early as 1948 (Photos 5-13 and 5-14). By 1997, the majority of the CGU had been clearcut logged at least once, or harvested in a series of selection cuts (Photo 5-14).

Photo 5-13. 1954 Aerial Photo of Logging along Lawrence Creek (arrow is a common reference point in the two photos).

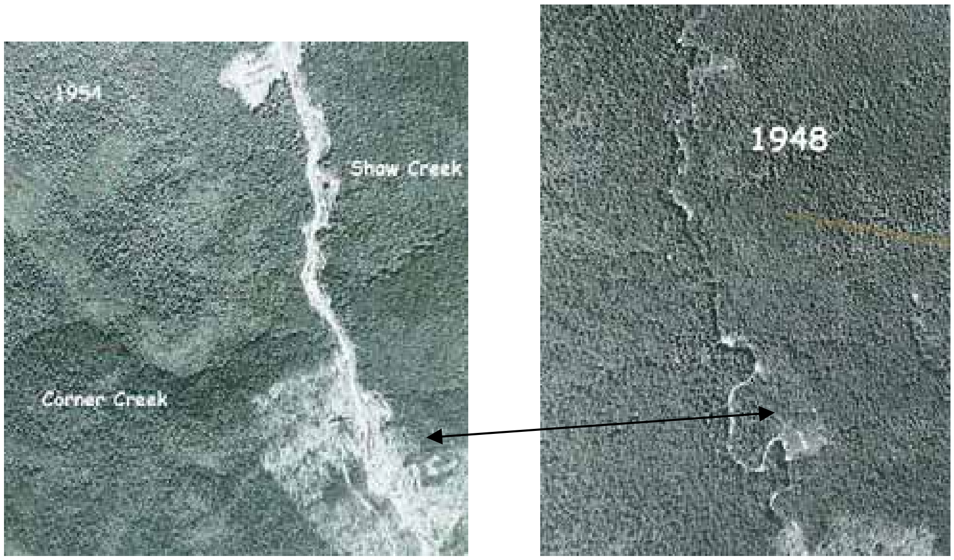
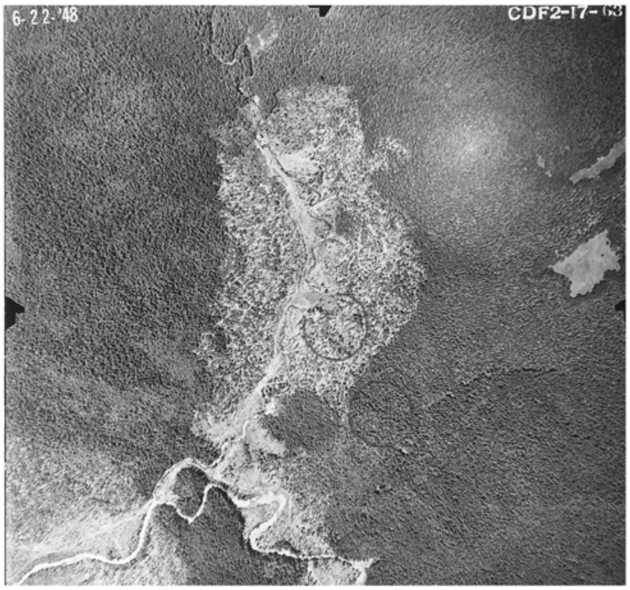


Photo 5-13 shows logging progressing up the Lawrence Creek valley as of 1954 (left). Cat logging was used around the channel on both sides while the mainline haul road was punched upstream along the channel. Direct channel disturbance would have occurred during logging in this area as logs were yarded across the stream. The same location is shown in 1948 prior to logging and road construction. The canopy is densely closed and the channel is not generally visible. Note that this section is within the portion of the valley with relatively broad alluvial floodplain and that the channel meanders within it. However, the unlogged channels are not open as observed in the larger Yager Creek (e.g., Photo 5-9).

Photo 5-14. Early Logging around the Lawrence Creek Channel (the right image is a 3-d view of the area shown in the left aerial photograph).



<u>Evidence of Channel Disturbance and Adjustment</u>. The aerial photos provide evidence of direct channel disturbance during early logging practices. However, there has been no obvious channel adjustment of channel position within the valley during the 60 years of the aerial photo record. Today, the riparian forest is largely composed of hardwood, classified as the "Hardwood stand, small trees, moderate/dense canopy" (HMD) Riparian Condition Unit (RCU) (Appendix C, Map C-1) with 12-24 inches DBH and moderate to dense stands; the channel is open to the sky for much of its length (Photo 5-15). Several large slides that introduce sediment to the streams are also evident in the photo. The channel width appears somewhat wider than it did in the photos prior to logging (Photo 5-13). We expect that this channel is depauperate of wood and that stream temperature has increased post logging.

Photo 5-15. Section of Lawrence Creek Downstream from Shaw Creek.

<u>Recent Trends in Stream Channel Conditions</u>. ATM stations are located on the upper end of Lawrence Creek in this CGU (ATM 49) and the lower end near the mouth of Lawrence Creek (ATM 9). Channel dimensions have not changed significantly since 1998 although there is a slight trend of increasing cross-sectional area at the upper end of the CGU.

Bed sediment characteristics in the lower reach are significantly fining in both surface and subsurface particle size (Figure 5-12). This CGU is experiencing a significant fining of the bed sediment in the lower reach. Surface particle size is fine in the lower reach (less than 60 mm), and widely variable in the upper reach (ranging from 10 to 130 mm). Given this variability it is difficult to identify trends in surface particle size at this location. However, the subsurface median sediment size has declined significantly throughout the CGU since 2002. The portion of the bed with sediment size less than 0.85 mm and less than 6.35 mm oscillates over a wide range from year to year in the lower reach and can be very high in some years. Conversely, these parameters are low, at or near PFC targets, and vary little from year to year in the upper reach. It appears as if sediment is depositing in the lower end of this CGU, and winnowing from the upper reach. The bed sediment deposits throughout the CGU are quite varied in texture (Photo 5-16).

The trend towards decreasing sub-surface sediment size is consistent between Yager and Lawrence Creeks. The trends in other bed sediment less than 0.85 mm and less than 6.35 mm are opposite in the two watersheds. Lawrence Creek is tending to fine while Yager Creek is tending to coarsen.

Pool area has declined throughout the CGU since 2000 (Figure 5-13). Initial estimates of pool area were very high (80 percent) and have declined to approximately 40 percent throughout the CGU, still meeting the PFC target of greater than 25 percent. CDFG surveys also identify a high portion of glides in Lawrence Creek. These were probably included with pools in early surveys. Pool spacing is wide, and has increased in the lower reach. Pool depth has also increased slightly in the lower reach and remained the same in the upper reach.

Figure 5-12. Trends in Bed Sediment Characteristics within the Lawrence Mainstem Constrained Valley Alluvium CGU.

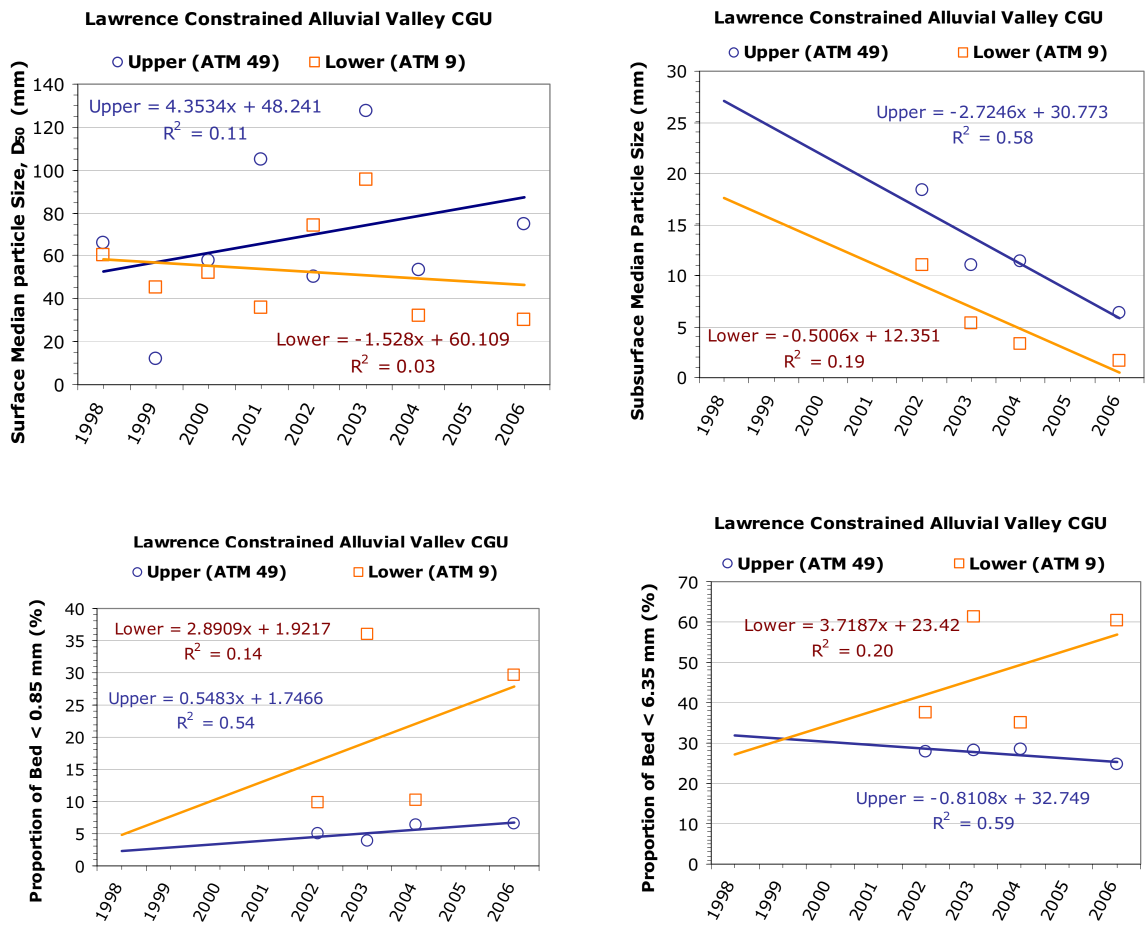
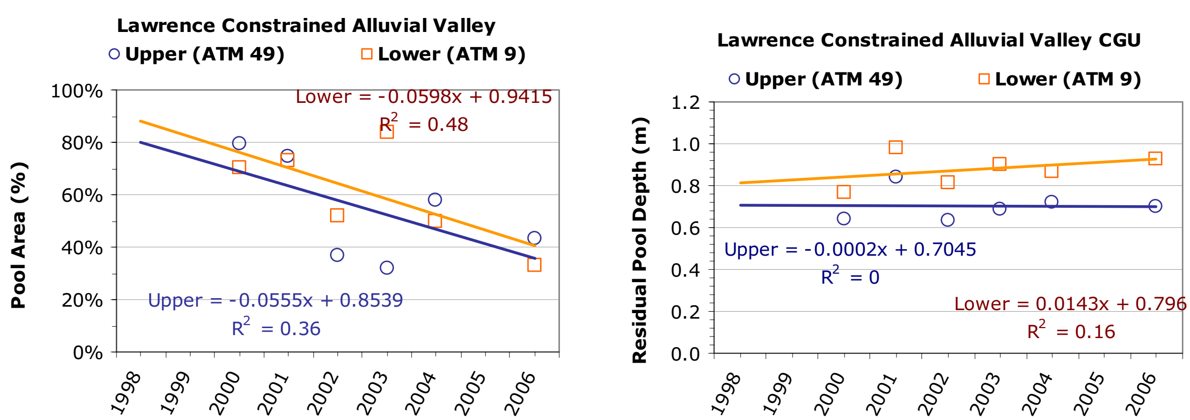
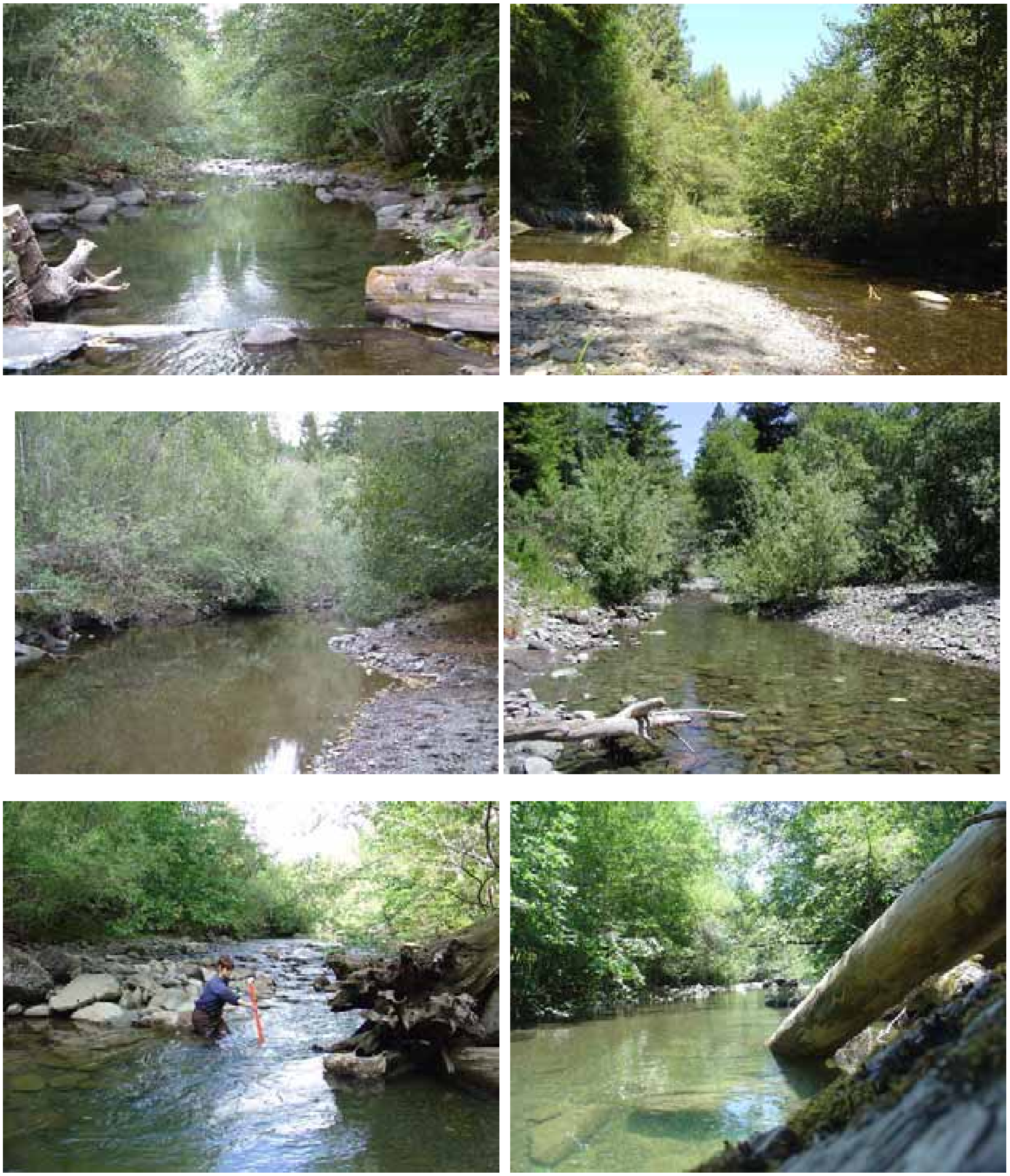


Figure 5-13. Trends in pool characteristics within the Lawrence Mainstem Constrained Valley Alluvium CGU.



Channel morphology and sediment deposits vary through the CGU. Photo 5-16 shows Lawrence Creek at various points along its length.

Photo 5-16. Lawrence Creek at: Top row – lower Lawrence Creek at Rd. 9 and ATM 9; Middle row – mid Lawrence Creek at Rd. 50 just downstream from Shaw Creek; Lower row – upper Lawrence Creek at ATM 49.



Throughout the CGU, the riparian forest is primarily composed of hardwood (Appendix C, Map C-1), some of which is mature and some of which is not. The channel is fairly open to the sky. Canopy cover over the stream is about 20 percent in the lower reach and about 35 percent in the upper reach, neither meeting the PFC target for canopy closure of greater than 85 percent. We estimate that canopy closure could be as high as about 80 percent under a fully mature conifer forest. This does not seem unreasonable based on the pre-logging aerial photograph shown in Photo 5-13. We estimate that this could reduce annual maximum temperatures (MWAT) from approximately 18^{o}C to approximately 14^{o}C. This would be a substantial improvement for coho salmon in particular who do use Lawrence Creek for spawning and rearing.

LWD is low for most of the reach, and this CGU includes large areas of low LWD recruitment potential, with other areas having moderate potential and only a few areas with high LWD recruitment potential (Appendix C, Map C-2). Installed habitat structures perform well in creating pools (see Photo 5-16), suggesting that Lawrence Creek would be responsive to LWD despite its relatively low gradient.

General Comments and Observations. Further information regarding this CGU, which comprises most of the Lawrence Creek reach listed in Table 5-1 and evaluated from 2005 aquatic habitat stream survey data in the Fish Habitat Assessment, is provided in Section 4.2.3.8 of Appendix E.

5.1.5 *Tributaries*

The characteristics of tributary streams, especially from a fish utilization and habitat quality perspective, are discussed for each major tributary in the WAU in the Fish Habitat Assessment (Appendix E). The reader is referred to this source for a comprehensive discussion of recent channel conditions for a large number of tributaries in the Yager-Lawrence WAU. The discussion, below, focuses on channel conditions and habitat trends in tributaries for which temporal trends have been assessed from ATM station monitoring data.

Some channel information is available from ATM stations in Shaw Creek, Strawberry Creek, Corner Creek, and the Yager mainstem forks. Most of these stations were discontinued after 2004 because the watersheds draining to them did not have major SCOPAC (now HRC) ownership. Current HRC information on habitat conditions extends only to Shaw Creek, although water temperature continues to be monitored at these locations each year. This data was used to determine basin trends in parameters. In addition, other watershed analyses on HRC (formerly SCOPAC) lands have identified some trends in parameters with underlying geology. For example, the Upper Eel Watershed Analysis found that some pool characteristics and LWD characteristics appeared to vary by geology (PALCO, 2007). In the Stream Channel Assessment (Appendix D), the major tributaries were grouped by their bedrock association (Table 5-5). Relationships of stream characteristics to geology were explored in Section 5 of the Stream Channel Assessment (Appendix D). The primary comparisons were between the Yager Formation and the Franciscan Central Belt Formation because these are the dominant geologic types in this WAU. Only one tributary (Cooper Mill Creek) is formed on the Wildcat Formation and no data were available for that stream.

Table 5-5. Major Tributaries in the Yager-Lawrence WAU (streams in bold have significant HRC ownership).

Watershed	Yager Formation	Franciscan Formation	Wildcat Formation
Yager Creek	**Blanton Creek** **Strawberry Creek** **South Fork Yager Creek**	North Fork Yager mainstem Middle Fork Yager Creek	**Cooper Mill Creek**
Lawrence Creek	**Corner Creek** **Shaw Creek** **Fish Creek**	**Bell Creek** Upper Lawrence Booths Run	

Here we briefly summarize findings for all tributaries.

Geomorphology. Stream channels developed on the Yager Formation tend to steeply descend to stream channels with relatively little response reach. An example of tributary gradients of stream channel formed on Yager Formation in Lawrence Creek is shown in Figure 5-14. The larger tributaries have greater lengths of low gradient reaches near their mouths, and are more suitable for coho salmon. Shaw Creek is one of the few streams used by coho in the WAU.

Figure 5-14. Channel Gradient Map of Tributary Streams to Lawrence Creek.

Note: Purple background is the Yager Formation (yf), blue is Qls, and blue green is Qtw. Franciscan is light green (cb). Channel gradient classes are red 0-2%, blue 2-4%, orange >4%.

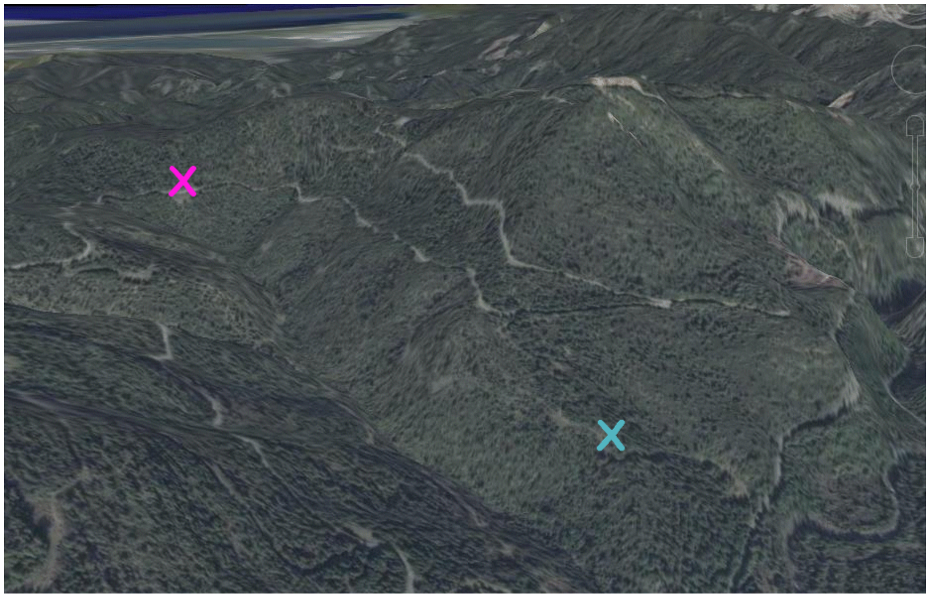
Channel migration zones. Streams are small and tend to be somewhat incised. Channel migration zones are limited in all tributaries, including the larger Yager tributaries. Hillslopes constrain migration to the active channel area within the immediate area of the stream. Lower reaches near the confluences with Yager or Lawrence Creeks may have lengths formed on the alluvial zones associated with those streams. The Rosgen method of flood prone width of 2 times the Bankfull depth will generally define the channel migration zone of the Class 1 portion tributary streams adequately.

Evidence of Channel Disturbance and Adjustment and Anthropogenic Effects. Most of these tributaries have been clearcut and tractor-logged one or more times during the history of forest management in the watershed. Riparian forests were logged, and most areas today have a second growth conifer forest of various ages depending on logging history.

Tractor logging was extensive. The mainstems and lower reaches of tributaries may have been used as tractor roads and could have been filled with sediment. Tractoring through channels was banned in the 1980s, but many lower reaches were impacted prior to this time. Most of that sediment has probably washed out but riparian areas and local floodplains may still show signs of disturbance. Tractor-logging outside of riparian areas has still had an impact on small streams and hillslopes. An example of a dense network of tractor skid trails in Fish Creek is shown in Photo 5-17.

All tributary channels, regardless of geology, are likely to be highly responsive to sediment and wood inputs from the watershed. The majority of the fish-bearing length of these streams is in the gradient class of 2-4 percent, the forced pool type of Montgomery and Buffington (1993). Stream temperature should be highly responsive to canopy cover.

Photo 5-17. Fish Creek as an Example of Dense Skid Trails.



Note: At left is a 3-D view of Fish Creek in 2007. At right is the aerial photo image of the area in 1987. The two colored x's are reference point. Riparian areas are in place and have been avoided by tractors. However, hillslopes are covered with a dense network of skid trails.

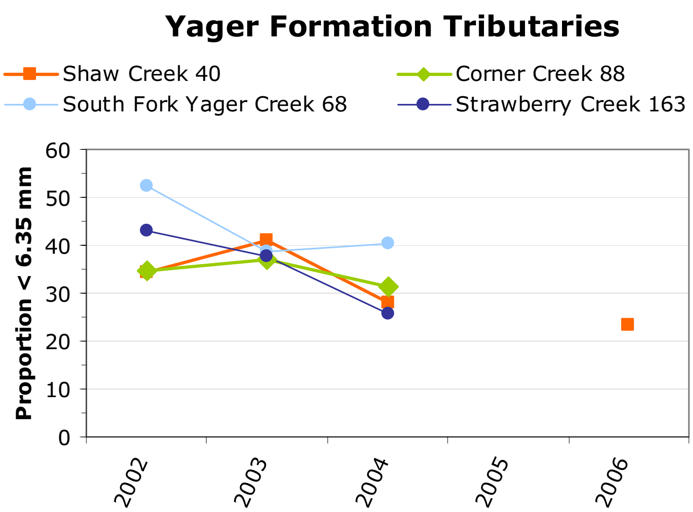
Recent Trends in Stream Channel Conditions. We briefly summarize recent trends in channel conditions in Table 5-6.

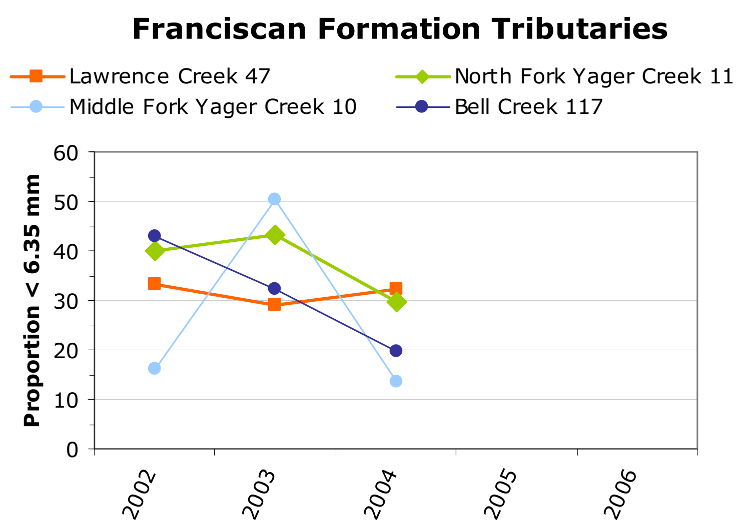
Table 5-6. Summary of Trends in Channel Conditions for Tributary Streams in the Yager-Lawerence WAU.

	Parameter	Yager Formation	Franciscan Formation
Streams		Shaw Creek Blanton Creek Corner Creek Fish Creek Strawberry Creek South Fork Yager Creek	Bell Creek Upper Lawrence Creek
Channel Dimension	Width	In line with basin trend Tending to increase slightly	In line with basin trend Tending to increase slightly
	Cross-sectional Area	In line with basin trend Tending to increase slightly	In line with basin trend Tending to increase slightly
Bed Sediment	Surface particle size (D_{50}) mm	Significantly smaller than Franciscan (30 mm) Widely variable among streams **All sites recently fined significantly **Shaw Creek particularly small (34 mm in 2006)	Larger (50 mm) Widely variable among streams and year to year Bell Creek particularly small (35 mm in 2004)
	Subsurface particle size (geomean) mm	Same between geologies All sites possibly fining since 2002	Same between geologies Bell Creek possibly fining since 2002 Middle Fork Yager unusually coarse
	Proportion < 0.85 mm (%)	Meets PFC criteria No recent trends	Meets PFC criteria No recent trends
	Proportion < 6.35 mm (%)	Tend to be higher than Franciscan All declining from high levels to lower levels Shaw Creek currently at target of less than 25%	Tend to be lower than Yager All sites declining since 2002
	Bed sediment ratio (D_{50}*)	Low values all tribs except South Fork Yager	Low values all tribs Upper Lawrence increasing
Pools	Area	Tends to vary more by watershed than geology—Lawrence Creek tribs higher Shaw Creek has high pool area relative to others	Tends to vary more by watershed than geology—Lawrence Creek tribs higher
	Spacing	Widely spaced pools Variability among tributaries Shaw Creek pool spacing narrowing in recent years	Widely spaced pools Variability among tributaries No trend among tributaries
	Residual Depth	No difference by geology No trends	No difference by geology No trends
LWD	Total Pieces/CW	No difference by geology Tends to be low in all streams No trends Except Strawberry Creek increasing	No difference by geology Tends to be low in all streams Upper Lawrence very high in wood count No trends

At this time, the most important trends in channel characteristics of the tributary streams appear to be changes in bed sediment characteristics. Refer to Figure 5-15 to illustrate changes in the portion of the bed less than 6.35 mm.

Figure 5-15. Trends in Streambed Composition <6.35 mm at ATM Sites in the Yager Formation Tributaries and the Franciscan Formation CGUs from 2002 to 2006.

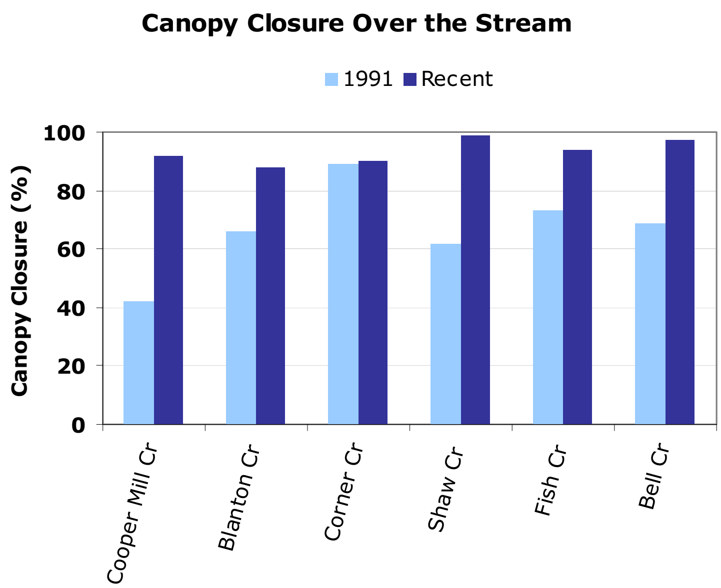




LWD in tributary streams is generally below the PFC target of about 2 pieces per channel width, with the exception of Upper Lawrence Creek which has a very high amount of LWD (about 5 pieces/CW). There are no strong trends in wood loading, with typically moderate LWD recruitment potential in the tributaries but including areas of low and high potential as well (Appendix C, Map C-2).

Canopy cover is high in all tributaries and temperatures are less than 16.8°C. Canopy cover is shown in Figure 5-16. Canopy closure has improved significantly in the past 15 years, and all streams are at their estimated potential, meeting the PFC target of greater than 85 percent.

Figure 5-16. Canopy Cover Over the Stream of Tributaries in 1991 and Recently.



Further information regarding this CGU, which includes tributaries listed in Table 5-1 and evaluated from 2005 aquatic habitat stream survey data in the Fish Habitat Assessment, is provided in Sections 4.2.3.5 (Cooper Mill Creek), 4.2.3.6 (Blanton Creek), 4.2.3.9 (Corner Creek), 4.2.3.10 (Shaw Creek), 4.2.3.11 (Fish Creek), and 4.2.3.13 (Bell Creek) of Appendix E. Other tributaries are also discussed in Appendix E.

5.2 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 Yager-Lawrence WAU (see Appendix F for additional detail). 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 Yager-Lawrence WAU (Photo 5-18). Currently, there are several records on HCP lands in the Yager-Lawrence WAU for all five species. Other species commonly detected in the WAU are the Pacific giant salamander, Pacific tree frog, Northwestern salamander, and rough-skinned newt.

Photo 5-18. Northern Pacific Pond Turtles (*Actinemys marmorata marmorata*) Basking on Lower Yager Creek.

Streams and riparian zones have had varying amounts of recovery time since initial harvest impacted watersheds adversely, but habitat conditions in all sub-basins appear to be improving following the implementation of the CFPRs and HCP. Factors contributing to the generally good habitat conditions include: primarily consolidated geologic types, high gradient transport reach streams with gravel and cobble substrates and cool water temperatures, relatively high canopy closure in upland areas, instream pool habitat in lowland areas, and pond habitat. For the amphibian and reptile species of concern, any changes in management practices should be designed to allow for continued recovery, including maintenance and enhancement of riparian canopy cover, prevention of large sediment influx, and retention or improvement of instream pools and pond habitats.

5.3 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 (Flosi et al., 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 to 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 Yager-Lawrence watershed analysis, a sediment budget was prepared as a quantitative accounting of estimated sediment delivery to streams for the period from 1988 through 2003, with sediment delivery on HCP lands during this period estimated at 3,791 tons/sq mi/yr. 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 Yager-Lawrence 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. Table 5-7 lists the sediment sources included in the sediment budget, and the summarized sediment budget in Figure 5-17 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.

The 1988-2003 Yager-Lawrence 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 5-7. 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 (included in streamside landslides).	Landslides from untreated abandoned roads; Hillslope landslides from 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 (included in streamside landslides).	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 (included in streamside landslides).

Figure 5-17. Annual Sediment Budget for the Yager-Lawrence WAU for the Period 1988 to 2003.

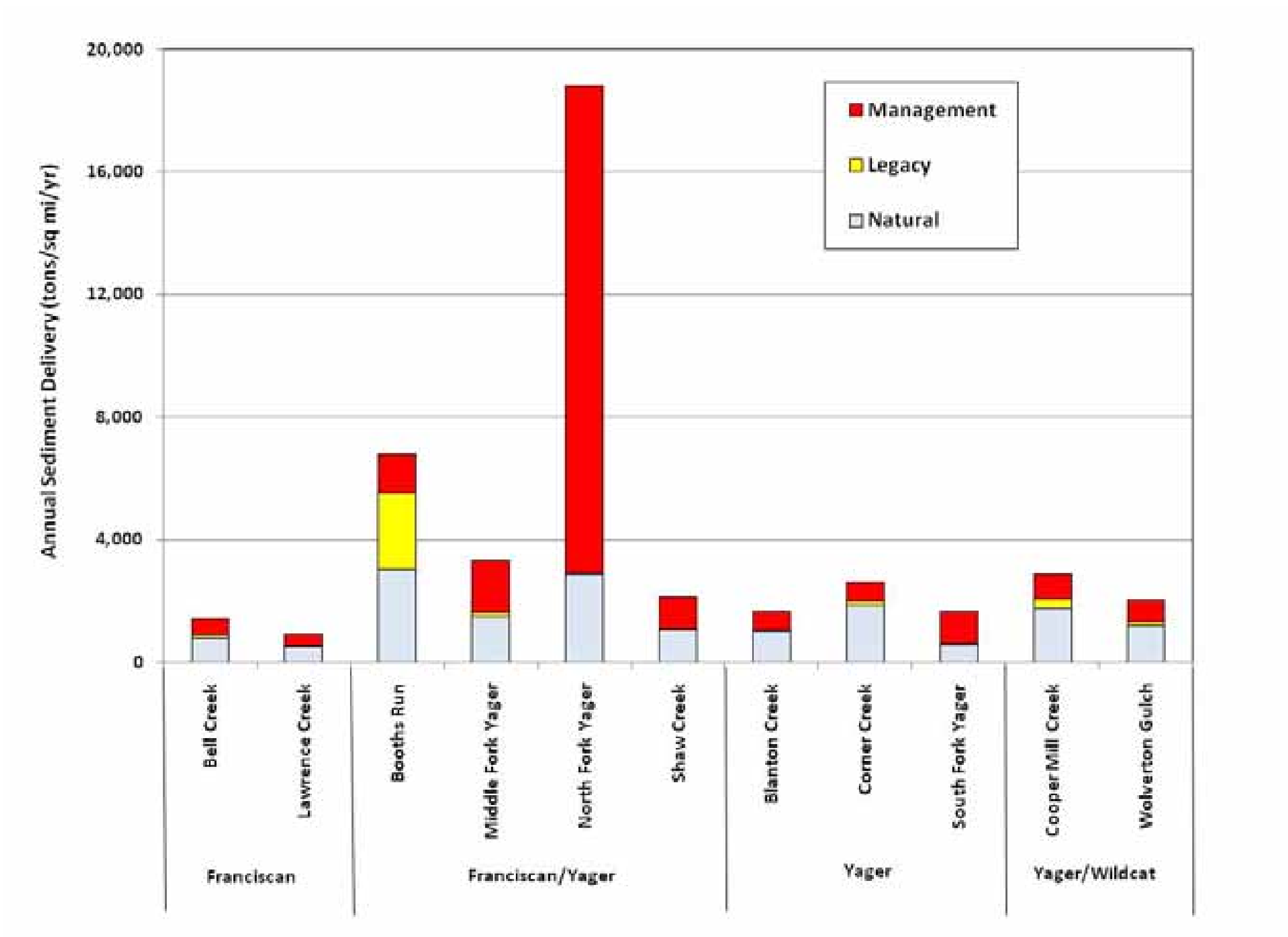


Figure 5-17 illustrates the extent to which 'management' sources are associated with sediment input in the North Fork Yager Creek sub-basin, as well as the proportion to which contemporary delivery originates from lingering legacy effects versus more recent management activities. Management and/or legacy sources were significant contributors of sediment in the North Fork Yager Creek and Booths Run sub-basins. Also, sub-basins that include both Franciscan and Yager lithologies generally yielded the highest rates of sediment delivery.

For comparison with other watersheds, Figure 5-18 shows HCP watershed analysis-derived sediment delivery rates for portions of other watersheds managed under the HCP 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 are similar to those for the Van Duzen and Lower

Eel/Eel Delta WAUs – both in the vicinity of the Yager-Lawrence WAU. In comparison, as expected the sediment budget prepared by Kelsey (1980) for the Van Duzen River, extending far upstream from the Yager-Lawrence WAU with lands highly susceptible to significant landslide delivery, shows larger deliver volumes of 5,000 to 7,335 tons/sq mi/yr for the period from 1941 to 1975 for conditions without and with the 1964 flood, respectively. This estimated delivery volume was larger than the estimated 1,257 cy/sq mi/yr (2,212 tons/sq mi/yr) developed by PWA (1999) for the Van Duzen Total Maximum Daily Load (TMDL) study (1955 to 1999). The TMDL estimate (USEPA, 1999) also was lower than the Yager-Lawrence WAU (HCP lands only) sediment budget of 3,791 tons/sq mi/yr, in part, because the TMDL did not include soil creep, streamside landslides, and surface erosion sediment sources.

Figure 5-18. Annual Sediment Delivery for HCP Lands Analyzed within the Watershed Analysis Units.

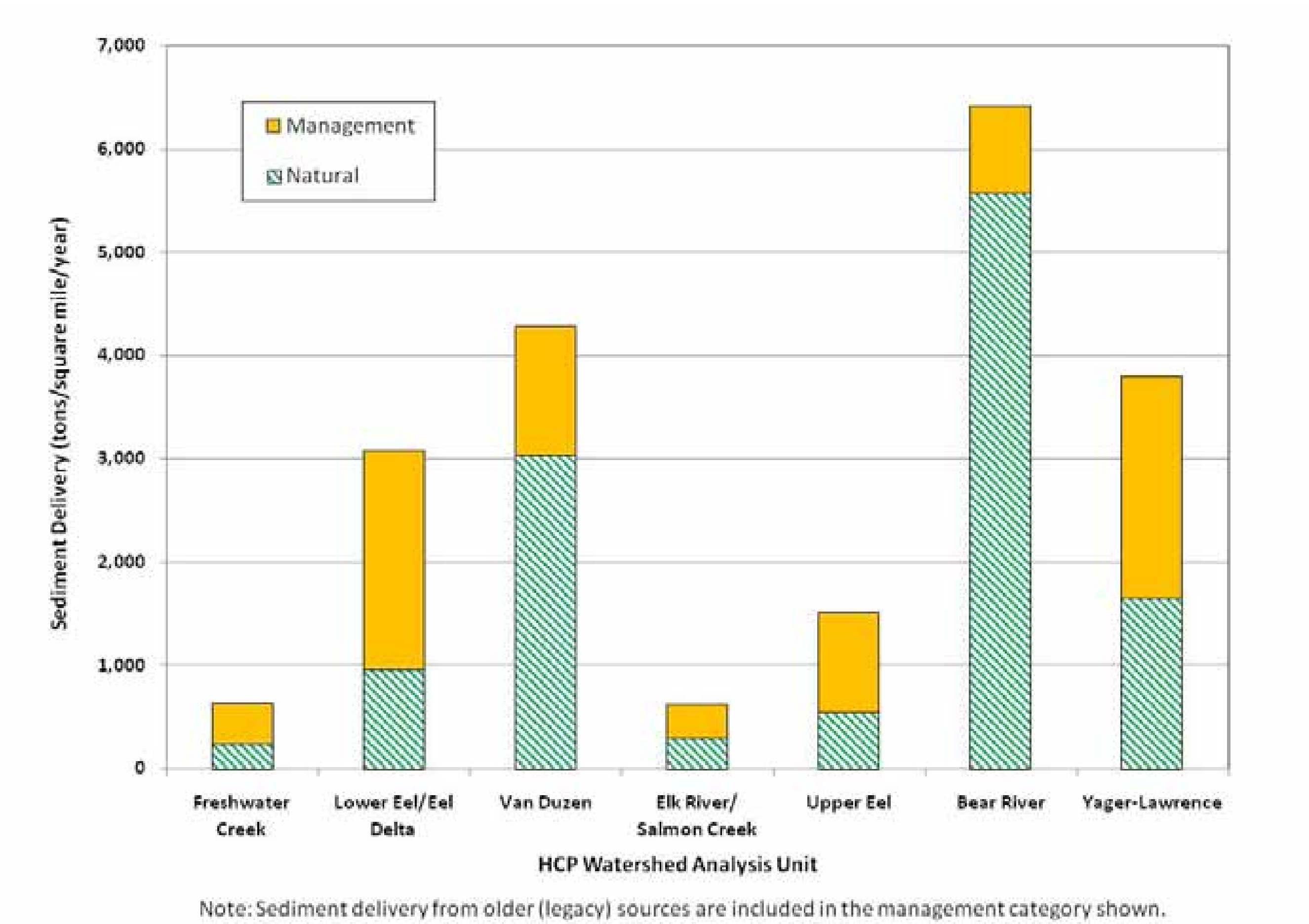
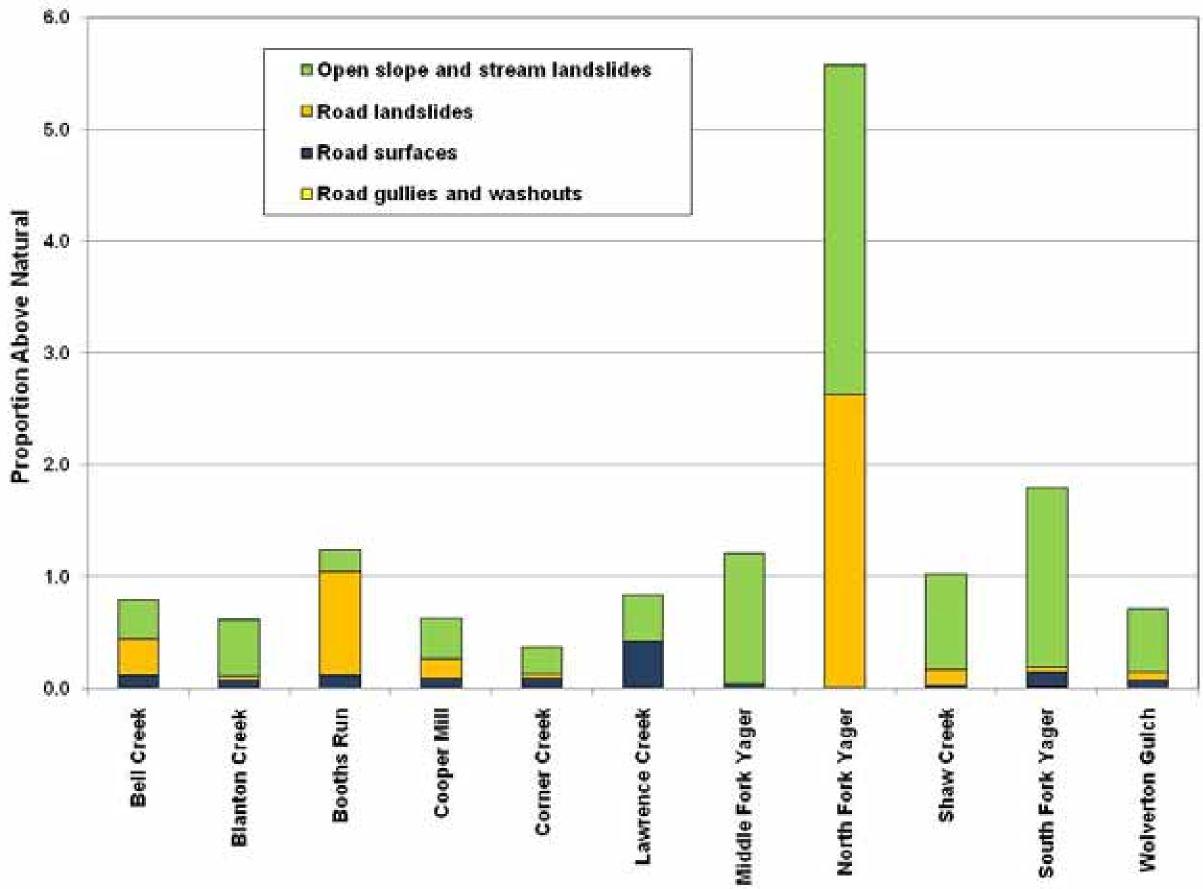


Figure 5-19 shows management and legacy-related sediment sources expressed as a proportion above 'background' or 'natural' sources. (A value of one indicates that management plus legacy sediment is the same magnitude as the estimated natural baseline rate.) This figure facilitates comparison of the relative level and management associations of excess sediment among the Yager-Lawrence WAU sub-basins (HCP lands only). The proportion of the high sediment delivery rate (see Figure 5-17) for the North Fork Yager Creek sub-basin attributed to management- and legacy-associated sources is significant due to the open slope and stream landslides, along with road-related landslides. In this sub-basin, the elevated sediment delivery, relative to the other sub-basins, results from a small number of very large landslides.

Figure 5-19. Relative Importance of Management-Related and Legacy Sediment Sources by Sub-basin in the Yager-Lawrence WAU.



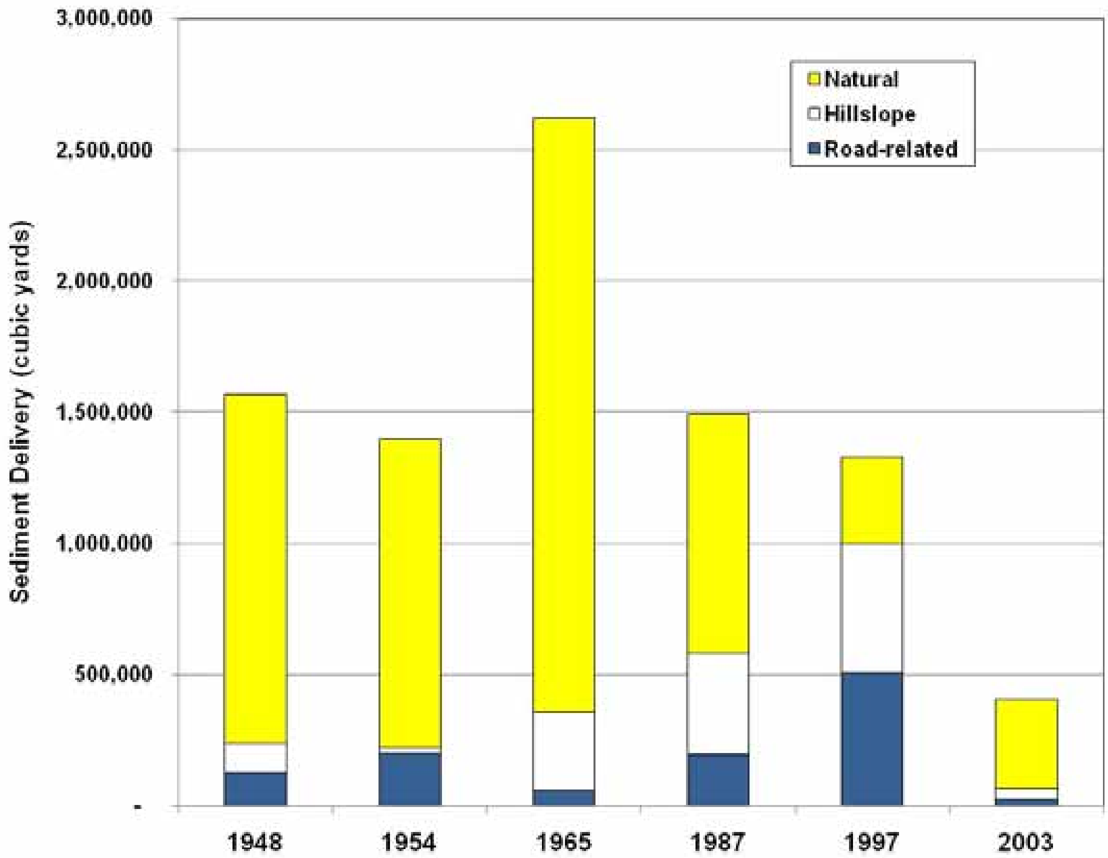
Other sub-basins with significant management- and/or legacy-associated contributions include the South Fork Yager Creek, Middle Fork Yager Creek, and Shaw Creek sub-basins with large volumes of open slope and stream landslides; and the Booths Run sub-basin with large volumes of road-related landslides. In general, regardless of road or harvest area association, a small number of 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.

Large landslides drive the highest sediment delivery rates shown in Figures 5-17 and 5-19. For example, nearly two-thirds of the management-associated delivery volume for the North Fork Yager Creek sub-basin is from two landslides – one is road-related and the other is on a partial cut hillslope. Similarly, almost all of the legacy-associated sediment delivery in the Booths Run sub-basin is from one landslide associated with an abandoned road.

Relative to the other sub-basins, fine sediment delivery rates from road surfaces are highest in the Booths Run sub-basin because of the location of the main road adjacent to, and crossing, Lawrence Creek. This results in a higher proportion of the road surface contributing fine sediment to the adjacent stream. While the mainline is a rocked road, there are numerous stream crossings, increasing the likelihood for delivery.

Landslides, particularly large landslides, have historically been a dominant source of sediment in the Yager-Lawrence WAU area. The watershed experienced an especially large influx of sediment from landslides in response to primarily natural conditions combined with the large, geomorphically-significant storms of 1955 and 1964, with effects from both storms captured in the 1965 air photoperiod (Figure 5-20). Some landslide contributions during this period can also be attributed to intensive early post-World War II (WWII) logging operations; additional discussion related to harvest history and historic logging practices contributing to the management- and legacy-associated sediment delivery is provided in Section 4 of this report.

Figure 5-20. History of Landslide Delivered Sediment on Yager-Lawrence HCP Lands by Photoperiod and General Land Use Association.



Landslides were a major contributor of sediment in the 1965 air photoperiod, declining significantly since then particularly in the 2003 air photoperiod (Figure 5-20). During the 1965 air photoperiod, the vast majority of landslide delivery was from natural landslides, with a relatively small contribution from hillslope and road-related (management and legacy) landslides. The management- and legacy-associated landslide contributions continued at similar levels in the 1987 and 1997 air photoperiods, followed by a significant decline in the 2003 air photoperiod. Through these same periods, a significant decline occurred in sediment delivery from natural landslides.

The nearly constant management- and legacy-associated landslide sediment delivery continued, from the 1965 through 1997 air photoperiods, despite implementation of less impacting management practices after adoption of the CFPRs in the 1970s. These continued landslides delivery amounts reflect the ongoing high rate of harvest along with associated road use that occurred into the early 1990s. Many of these harvest-related areas were clearcut and located close to streams in sub-basins such as Booths Run.

The large amount of delivery between 1987 and 1997 may be related to the increase in management, particularly tractor yarding, in this period. The large amount of sediment delivery in the 1997 air photoperiod is coincident with a period of intense management prior to 1997 (about 1,700 acres per year between 1988 and 1997 compared to about 600 acres per year between 1997 and 2003). Results from 1997 appear to show that slides may occur in areas managed several years prior to the slide, particularly if the management period is followed by a wet winter such as occurred in 1996-97. Road-related management follows a slightly different pattern, with sediment increasing between 1948 and 1954, dropping off in 1965 and 1987, increasing in 1997, and decreasing by 2003.

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. Since 1998, Timber Harvest Plans (THPs) on HCP lands have required sediment reduction measures to offset potential sediment production resulting from timber harvest. During the 11 years from 1998 through 2008, sediment reduction measures have prevented more than 65,000 cubic yards of sediment from delivering to watercourses in the Yager-Lawrence WAU. This type of sediment reduction is continuing outside of the watershed analysis process, specifically as required by the CFPRs.

The 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. This significant decrease (from management) occurred from the 1997 to 2003 air photoperiods despite the relatively unchanged contribution from natural landslides in the same period (Figure 5-20).

The mass wasting analysis indicates significant landslide delivery in the sub-basins of North Fork Yager Creek (31 percent of the total for the 1988-2003 sediment budget period), Booths Run (23 percent of the total), and the Cooper Mill Creek (12 percent of the total). The other sub-basins exhibit a lower distribution of landslide volumes delivering to streams. As indicated previously, the majority of the landslide delivery in the North Fork Yager Creek sub-basin, during the 1988-2003 sediment budget period, results from two large complex landslides (one road-related and the other on a partial cut hillslope) – both occurring on inner gorge slopes on Broken Formation (cb1) of the Central belt Franciscan lithology. The majority of landslide delivery in the Booths Run sub-basin during this period results from one large legacy-related (abandoned) road debris slide slope landslide occurring on inner gorge slopes on the Yager Formation lithology.

6.0 FUTURE FOREST/WATERSHED MANAGEMENT

The Humboldt Redwood Company (HRC) was founded with a vision to sustain the long-term ecological, social, and economic vitality of a large block of productive forestland by managing with high standards of environmental stewardship while operating a successful business.

A detailed, comprehensive Management Plan has been carefully crafted and is being implemented for the purpose of realizing this vision. The Plan includes an abundance of information pertaining to forest inventory, silviculture, landscape planning, habitat conservation, watershed analysis, cultural and biological resources, employees, business goals, forest certification, and related policies and practices. This Management Plan can be found on the HRC website (www.hrcllc.com) and provides an overview of HRC's forest management approach along with information specific to the Yager and Lawrence forest inventories.

Many of these property-wide forestry practices are beneficial to watershed health and restoration including, but not limited to:

- Reduced harvest and transition to uneven-aged (selective harvest) management benefits habitat for threatened and endangered species;
- Protection of large old-growth trees and other key forest elements, such as snags, culls, and wildlife trees, improves wildlife habitat and increases large woody debris (LWD) recruitment that is critical to maintaining complexity and diversity in a forested environment; and
- Continued road upgrading and storm-proofing efforts reduce sediment production and delivery to streams.

As an important part of implementing the Plan, watershed analysis provides foresters and other resource managers with detailed, localized scientific understanding of conditions, processes, and trends affecting aquatic habitat from which informed watershed-specific forest management practices can be established and restoration decisions made.

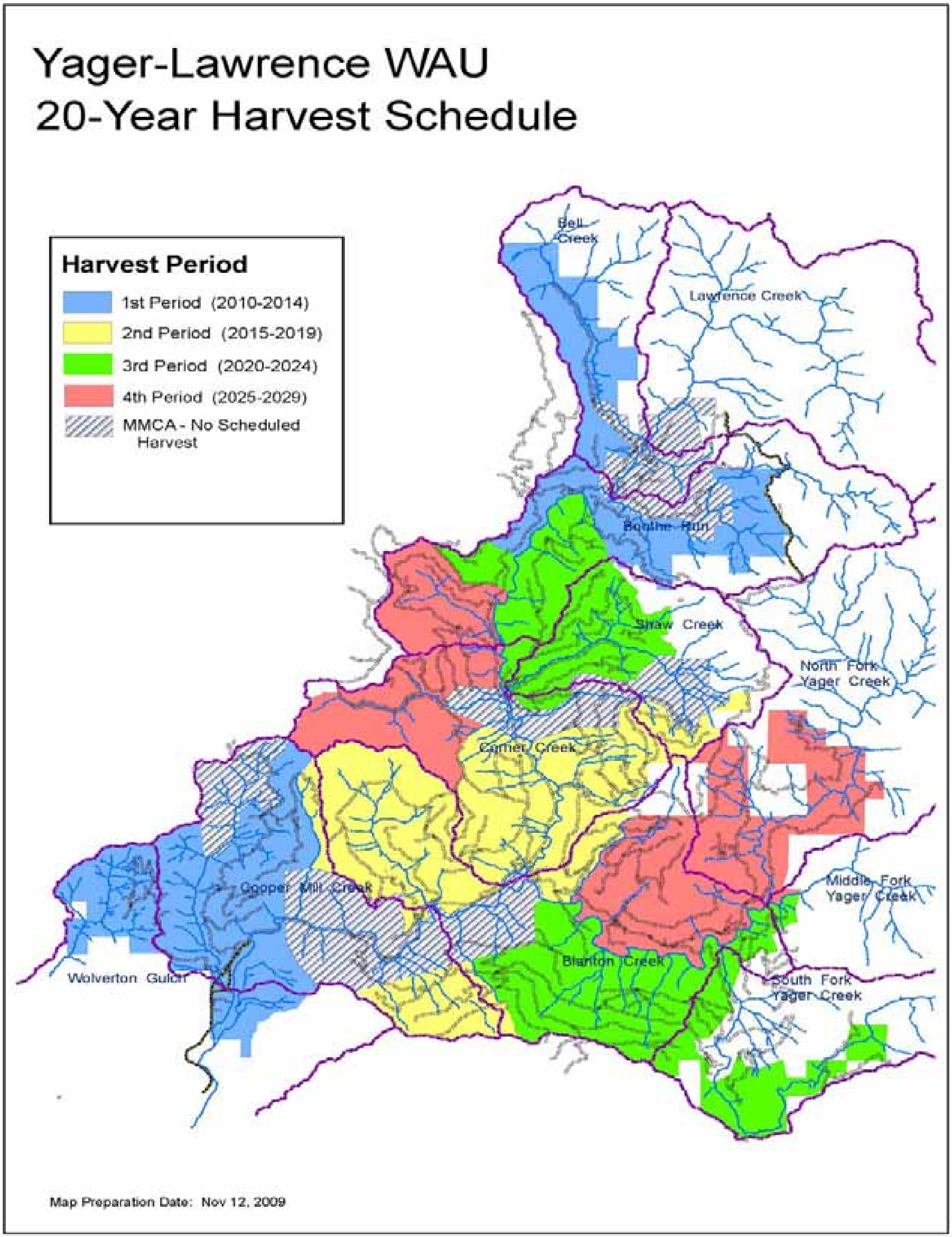
The Yager-Lawrence watershed contains some of the highest quality habitat found on the HRC ownership for Chinook, steelhead, and Coho, along with other species such as the northwestern pond turtle. However, current habitat conditions show adverse impacts from past human activities. Adverse effects include increased stream temperatures, reduction of in-stream LWD, and the compounding reduction of future LWD recruitment potential. These conditions, potentially temporal in nature, result from the extensive riparian forest harvest that occurred throughout much of the watershed in the mid- to late-twentieth century. Historical photographs show that extensive mid-twentieth century tractor logging operations and road construction, particularly along smaller tributary streams, disturbed riparian areas and resulted in significant sediment delivery. While recent field observations confirm this history of disturbance and adverse impact, much of the sediment introduced by these past practices has been washed out of the system, and disturbed ground has stabilized through forest re-vegetation. More recent management-related sediment sources include streamside landslides associated with logging and road construction, and road surface erosion. Impacts to stream temperatures and LWD recruitment have been significantly reduced in recent times through the application of riparian buffers along watercourses.

Forestry prescriptions designed to achieve, over time, or maintain a properly functioning aquatic habitat condition (i.e., essential habitat elements) have been developed by HRC in consultation with the HCP wildlife agencies as part of the Yager-Lawrence Watershed Analysis (HCP 6.3.2.2). The prescriptions are included as Attachment 5 of this Cumulative Watershed Effects report and affect the following elements of the HCP Aquatics Conservation Plan: hillslope management (HCP 6.3.3.7), channel migration and riparian management zones (HCP 6.3.4.1), disturbance index (HCP 6.3.4.3), and monitoring (HCP 6.3.5). These prescriptions may be further modified through adaptive management or future watershed analysis re-visitation.

The watershed analysis forestry prescriptions, in combination with other aspects of HRC policy (see Management Plan, identified above), current California Forest Practice Rules, CDFG Code, and North Coast Regional Water Quality Control Board (NCRWQCB) requirements, work to eliminate or reduce the potential for adverse effects from past, present, and future forestry operations by addressing management-related sediment delivery, LWD recruitment, and stream temperature.

A 20-year harvest schedule has been developed for the Yager and Lawrence Sustainability Units (Figure 6-1). Figure 6-1 illustrates the timing and spatial/area constraint of harvest throughout the WAU over the next two decades. While modifications to the schedule may occur, no more than approximately 25 percent of the WAU area will be available for harvest during any 5-year period. Current stand conditions and environmental constraints suggest actual harvest area will typically be much less than 25 percent for each 5-year period (e.g., 10 to 15 percent). As young harvest stands age to harvestable size,

Figure 6-1. Yager-Lawrence 20-Year Harvest Schedule



this percentage will increase. This area constraint not only works towards the goal of long-term sustainable harvest but also sets limits on watershed-wide harvest-related disturbance.

The HCP requires all roads in the watershed be upgraded to meet a 'storm-proofed' standard by 2019 (HCP 6.3.3.2). The scheduling of road work is typically based on harvest scheduling and current road conditions. State regulations and the HCP require that controllable sediment sources be addressed for roads associated with timber harvesting activities during the 3- to 5-year life of the THP. The HCP also requires that the worst road-related sediment sources be prioritized for treatment to the extent feasible. Current road conditions (i.e., priority for need of repair) were considered during the design and scheduling of the harvest areas shown in Figure 6-1. For the purposes of watershed analysis, road-related sediment delivery is categorized as resulting from one of two categories: road surface erosion and road gullies/washouts. Watershed analysis (Surface Erosion module, Appendix B) has identified the sub-basins that exceed average watershed-wide road-related sediment delivery rates via surface erosion (Table 6-1) and gully/washouts (Table 6-2). This information, in combination with site-specific road inventories and harvest scheduling will be used to prioritize future road storm-proofing activities. Storm-proofing activities are planned and implemented on an annual basis with a property-wide roadwork plan available for review by May 1st of each year.

The timing and amount of road improvement activities conducted each year is affected by seasonal restrictions associated with the four Marbled Murrelet Conservation Areas (MMCA) located in the WAU. HRC will likely continue to seek some relief from these restrictions in order to meet road stormproofing goals. It is also recommended that future watershed management activities include further assessment of the opportunity for in-stream and riparian restoration projects along the lower mainstem of Yager Creek, both on and off HRC property. Appendices D and E (Stream Channel Assessment and Fish Habitat Assessment modules, respectively) note this reach as important for fish habitat but impaired by past land use activities (i.e., loss of habitat complexity, shade canopy, and long-term LWD recruitment potential).

For further information regarding HRC forest operations and watershed restoration efforts please contact the Yager-Lawrence Area Manager.

Table 6-1. Largest Contributing Sub-basins, Surface Erosion-Related Sediment Delivery

Sub-basin[1]	Total Road Miles (excluding decommissioned roads)[2]	Delivery Rate (tons/road mile/year)[3]	Estimated Total Delivery (tons/year)[3]
Lawrence Creek	4	16.5	64
Booths Run	41	10.9	447
Cooper Mill Creek	54	7.2	386
Middle Fork Yager	1	6.9	7
Wolverton Gulch	12	6.9	86
Corner Creek	50	6.5	331

[1] This listing includes only the sub-basins with road surface erosion-related sediment delivery above the watershed-wide average of 6.1 tons/road mile/yr, which is similar in magnitude to the Upper Eel and Elk River WAUs but significantly lower than for the Van Duzen WAU.
[2] Road Miles are from Table B-14 of the Surface Erosion module (Appendix B), with "stormproofed and decommissioned" roads excluded; the only sub-basin significantly affected by this adjustment is Booths Run (of 47 total road miles, 6 miles are decommissioned and are excluded from this table).
[3] Delivery Rate values are from Table B-16 (Appendix B) and represent conditions with the HCP implemented; Estimated Total Delivery values are from Table B-16, except for Booths Run which was re-calculated to exclude the 6 miles of decommissioned road.

Table 6-2. Largest Contributing Sub-basins, Gully/Washout Road-Related Sediment Delivery

Sub-basin[1]	Total Road Miles (excluding decommissioned roads)[2]	Sediment Delivery (tons/square mile of HCP area/year)[2]
Middle Fork Yager	1	23
South Fork Yager	14	20
Bell Creek	21	19
Blanton Creek	71	17
Cooper Mill Creek	47	17
Corner Creek	50	17
North Fork Yager	17	17

[1] This listing includes only the sub-basins with gully/washout road-related sediment delivery above the watershed-wide average 16 tons/square mile/yr, which is significantly lower than for the Upper Eel and Elk River WAUs.
[2] Data are from Table B-20 of the Surface Erosion module (Appendix B) for the analysis period of 1988-2003.

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