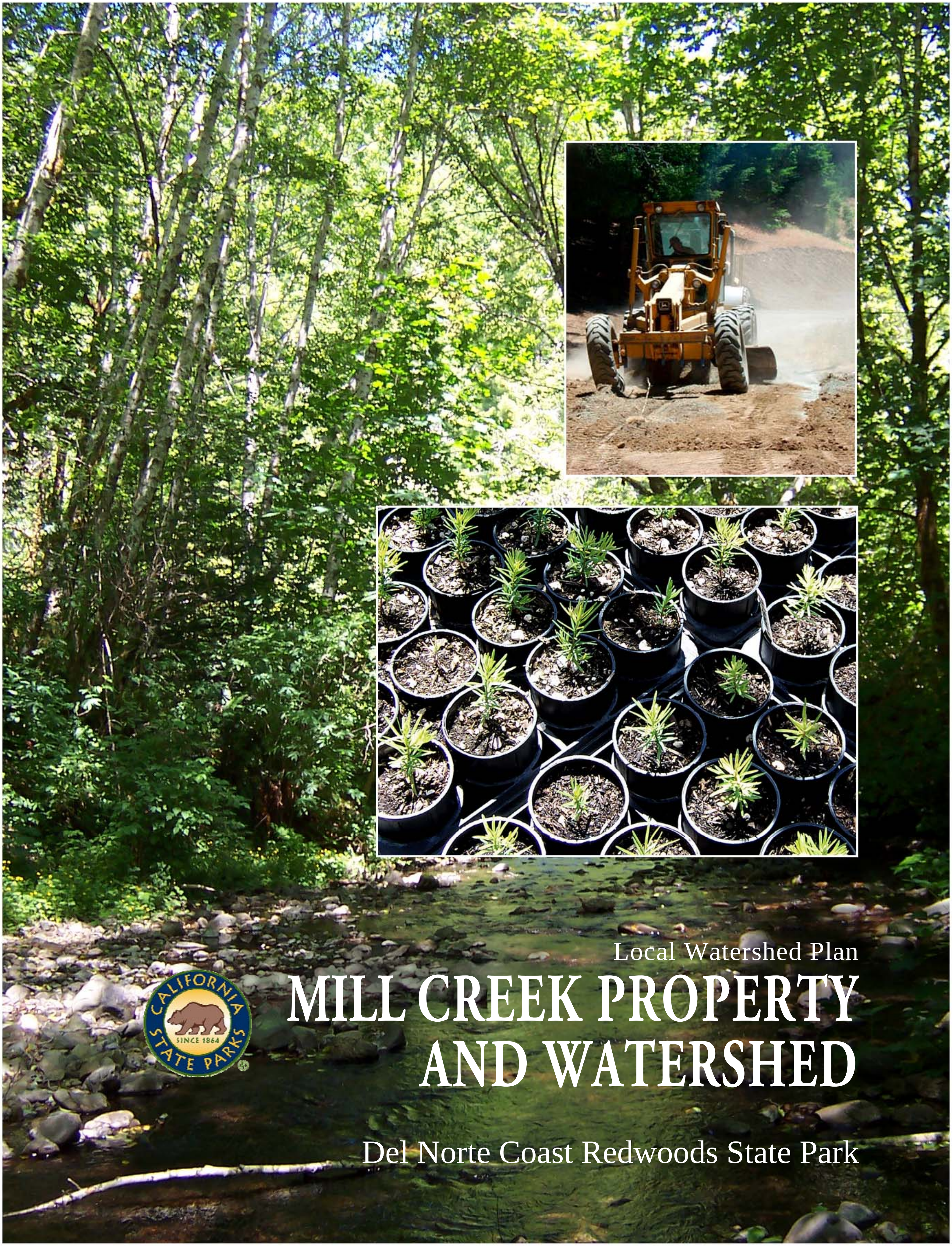
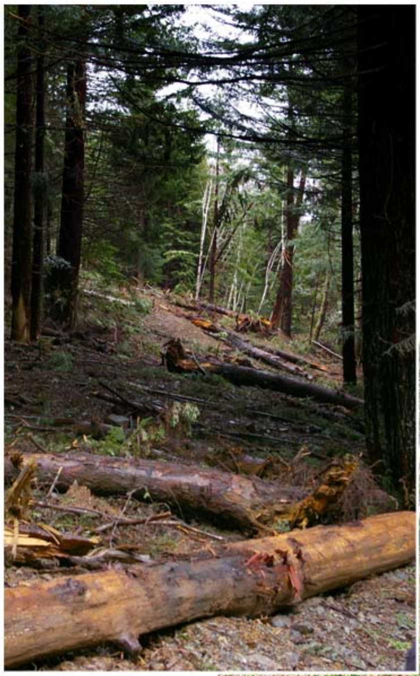
Local Watershed Plan



MILL CREEK PROPERTY AND WATERSHED

Del Norte Coast Redwoods State Park



MILL CREEK PROPERTY AND WATERSHED

Del Norte Coast Redwoods State Park

California Department of Parks and Recreation

P 07110066.01

Funding for this project has been provided in full or in part through an agreement with the State Water Resources Control Board. The contents of this document do not necessarily reflect the views and policies of the State Water Resources Control Board, nor does mention of trade names or commercial products constitute endorsement of recommendation for user.

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ACRONYMS AND ABBREVIATIONS

ac	acres
AGR	Agricultural Supply
AQUA	Aquaculture
BA	basal area
Basin Plan	Water Quality Control Plan for the North Coast Region
CCR	California Code of Regulations
CDFG	California Department of Fish and Game
CEQA	California Environmental Quality Act
CFR	Code of Federal Regulations
cfs	cubic feet per second
cms	cubic meters per second
COLD	Cold Freshwater Habitat
COMM	Commercial and Sport Fishing
CUL	Native American Culture
CV	coefficient of variation
D50	median particle size
DARR2.0	Darroch Analysis
DEM	digital elevation model
DOB	Date of Birth
DOQ	digital orthophoto quadrangle
EST	Estuarine Habitat
ESU	Evolutionarily Significant Unit
FERPP	Forest Ecosystem Restoration and Protection Plan
FRSH	Freshwater Replenishment
ft	feet
GIS	geographic information system
GMP/GP	General Management Plan/General Plan
GPA	General Plan Amendment
GPS	global positioning system
GWR	Groundwater Recharge
ha	hectare

HA	hydrologic area
HSA	hydrologic subarea
HU	Hydrologic Unit
IMAP	Inventory Monitoring and Assessment Program
in/yr	inch per year
IND	Industrial Supply
JHA	Job Hazard Analysis
km	kilometer
km^2	square kilometer
LiDAR	Light Detection and Ranging
LSEP	Landscape Stabilization and Erosion Prevention Plan
m	meter
m^2	square meter
m^3	cubic meter
MAR	Marine Habitat
MCA	Mill Creek Addition
MCFMP	Mill Creek Fisheries Monitoring Program
mg/L	milligrams per liter
mi	mile
mi^2	square mile
MIGR	Migration of Aquatic Organisms
mm	millimeter
mm/yr	millimeters per year
MUN	Municipal Water Supply
MWAT	Maximum Weekly Average Temperature
NAV	Navigation
NCRWQCB	North Coast Regional Water Quality Control Board
NMFS	National Marine Fisheries Service
NRCS	Natural Resources Conservation Service
NTU	Nephelometric Turbidity Unit
P95	95th percentile return height
PIT	passive integrated transponder
PNW	Pacific Northwest Research Station

POW	Hydropower Generation
PRO	Industrial Process Supply
PVC	polyvinyl chloride
QMD	quadratic mean diameter
RARE	Rare, Threatened or Endangered Species
REC-1	Water Contact Recreation
REC-2	Non-Contact Water Recreation
RNP	Redwood National Park
RNSP	Redwood National and State Parks
SDI	stand density index
SHDI	Shannon's Diversity Index
SHELL	Shellfish Harvesting
SONCC	southern Oregon/northern California coast
SPWN	Spawning, Reproduction, and/or Early Development
SR	state route
State CEQA Guidelines	California Environmental Quality Act Guidelines
State Parks	California Department of Parks and Recreation
Stimson	Stimson Lumber Company
SWAMP	Surface Water Ambient Monitoring Program
TMDL	Total Maximum Daily Load
tonnes/km	tonnes per kilometer
$tonnes/km^2/yr$	tonnes per square kilometer
tpa	trees per acre
tph	trees per hectare
USGS	U.S. Geological Survey
V*	V-star
WILD	Wildlife Habitat
WMP	watershed management plan
WY	water year
yds^3	cubic yard

1 INTRODUCTION

View from Child's Hill. Source: Photograph taken by AECOM in 2010.

The Mill Creek Addition (MCA), consisting primarily of substantial portions of the Mill Creek and Rock Creek watersheds, has one of the most productive coho salmon (*Oncorhynchus kisutch*) fisheries in the Pacific Northwest. Before ownership of the MCA was transferred to the California Department of Parks and Recreation (State Parks) in 2003, substantial timber harvest and related road construction were conducted over much of the property. Sedimentation associated with this period of timber management has the potential to threaten the fishery. Forest recovery toward late-seral conditions, the goal for MCA managers, will be hindered without management intervention. Although the water quality of Mill Creek and Rock Creek and their receiving stream, the Smith River, is not listed by state or federal agencies as being impaired, the previous intensive land management requires measures to ensure that good water quality and other natural resource values are maintained or enhanced under park management.

The Mill Creek General Plan Amendment (GPA) (State Parks 2010), which helps to guide this document, requires the preparation of additional management plans to enable the commitment of resources toward specific activities. This Watershed Management Plan (WMP) outlines methods and measures to maintain existing conditions where they are desirable, enables restoration of impaired land where needed, provides a scientifically based method to assess project progress, and briefly identifies watershed management planning links as they affect future management plans.

1.1 DOCUMENT STRUCTURE AND CONTENTS

This WMP has two distinct parts: the body of the plan and an appendix that provides supporting detail for certain sections of the plan. The general content of this document is as follows:

- **Chapter 1, "Introduction."** This chapter presents the report rationale, purpose and goals, site characteristics, restoration work to date, sources of information and expertise, and public outreach efforts.
- **Chapter 2, "Problem Statement."** This chapter presents applicable water quality standards and characterizes aquatic species, sediment and forestry problems, and other water quality conditions.
- **Chapter 3, "Sediment."** This chapter outlines study methods, addresses upland sediment sources and instream sediment delivery, presents a sediment source analysis and target reductions, and develops treatment methods and priorities.
- **Chapter 4, "Forest Recovery."** This chapter outlines study methods, recommends forest treatment prioritization methods, estimates forest trajectories, addresses and summarizes the forest stand analysis, and develops forest recovery treatment methods and priorities.
- **Chapter 5, "Monitoring."** This chapter addresses types of monitoring, the criteria for assessing load reductions, and data management.
- **Chapter 6, "Economic Analysis."** This chapter addresses project cost estimates, sources of funding, and project interim milestones.
- **Chapter 7, "References."** This chapter presents information on the references used to prepare this WMP, including personal communications.
- **Chapter 8, "List of Preparers."** This chapter presents a complete list of the authors and reviewers for this plan and those involved in report production.

- **Appendix A, "Mill Creek Addition Road Assessment Report."** This appendix provides detail to support road-related upslope sediment analysis and the road treatment methods summarized throughout the report.

1.2 RATIONALE

The MCA is a newly acquired property owned by State Parks located in Del Norte Coast Redwoods State Park. Del Norte Coast Redwoods State Park, along with two other state parks, Prairie Creek Redwoods State Park and Jedediah Smith Redwoods State Park, and Redwood National Park are in what is referred to as Redwood National and State Parks. The three state parks and one national park are cooperatively managed under an existing joint General Management Plan/General Plan (GMP/GP) that was approved in 2000. The WMP is a more detailed management plan called for in the GPA that addresses management of the MCA and amends the existing GMP/GP. The WMP, coupled with the GPA, permits the commitment of state resources to address needed restoration projects and monitoring of conditions on the MCA. The WMP also addresses elements required by a grant from the State Water Resources Control Board that helped fund preparation of the GPA. All references to the management of the MCA are specific to State Parks as the term Redwood National and State Parks does not imply joint statutory authorities or requirements or permitting procedures.

1.3 PURPOSE AND GOALS

The purpose of this WMP is to develop an analysis that is sufficiently detailed to initiate an implementation schedule for watershed-related natural resources restoration and protection in the MCA. Restoration and protection of these natural resources will be achieved through the integration of three primary project activities: sediment control and reduction, forest recovery directed toward resilient late-seral conditions, and monitoring to assess project progress and direct adaptive management. Other park activities that relate to watershed management also are identified in this WMP to ensure their consideration in other management plans more focused on the topic in question.

This WMP is within the scope of the GPA and builds on analysis developed under the *Mill Creek Property Interim Management Recommendations* prepared by Stillwater

Sciences (2002) and restoration work performed in the last few years to inhibit the potential degradation of park resources.

1.3.1 PRIORITY NEEDS FOR FUTURE PLANS

The GPA identifies subtiered planning documents and action items that will be used to manage specific resources or issues identified during the GPA planning and environmental review process. The plans described below may be comprehensive, may have specific action items associated with a general planning area, or may be tailored toward addressing specific issues. The overall need for the plans and the expected need with respect to watershed management for each of the plans are described below. Other plans, not yet identified, may be needed in the future as conditions change.

1.3.1.1 ROADS AND TRAILS MANAGEMENT PLAN

Although numerous public circulation routes have been designated in the MCA, none are currently classified as trails. The routes follow abandoned or active roadbeds, some of which have become overgrown, making them appear as single-track trails. The routes are maintained as trails and may be incorporated into a parkwide trail system during future planning. These legacy routes may require reengineering or conversion to eliminate erosion problems associated with failing road drainage structures.

Future road or trail development will be addressed as part of a Roads and Trails Management Plan for Del Norte Coast Redwoods State Park. The plan will provide an opportunity for public involvement to help define the vision for a roads and trails system. In the MCA, a dense road network already exists, so it is unlikely that extensive road construction will be required. However, no single-track trails exist in the park, and many opportunities exist for improved access and circulation. After a Roads and Trails Management Plan is adopted, construction of new routes will be implemented as funding allows.

1.3.1.2 VEGETATION MANAGEMENT PLAN

Logging activities under previous management have left the MCA with approximately 49 hectares (ha) (120 acres [ac]) of old growth. One of the primary goals stated in the

GPA is to restore late-seral habitat to the 10,017 ha (approximately 25,000 ac) of forests. Work has begun on treating the highest priority stands to improve forest health and put stands on a management path that is likely to expedite the development of late-seral conditions.

Fire has historically played a substantial role in shaping vegetation patterns throughout the MCA and continues to do so today. It also may be an effective tool—and, in some cases, the only method—capable of restoring or maintaining desired conditions (Norman 2007).

The GPA calls for the development of a Vegetation Management Plan that would guide these restoration activities by identifying stand conditions or specific areas of high priority, treatment alternatives, monitoring methods, and adaptive management as needed.

The Vegetation Management Plan should provide discussion and mapping of existing vegetation communities based on Sawyer and Keeler-Wolf (1995) and, if possible, describe or hypothesize on the pre-European historic vegetation communities and their distribution. This information will provide the basis for all vegetation management in the MCA including forest restoration, which would be a component of the plan. The Vegetation Management Plan would describe the distribution of all known exotic plant infestations and establish priorities and methods for their control or eradication. The plan would discuss the known and potentially occurring sensitive plants in the MCA.

Based on this information on sensitive plants and vegetation communities, the Vegetation Management Plan would then establish recommendations for inventorying, monitoring, and assessing these resources. Recommendations would be developed in conformance with State Parks' Inventory Monitoring and Assessment Program (IMAP) (State Parks 2005).

The Vegetation Management Plan also would include a Prescribed Burn Plan and a Wildfire Management Plan for the park. Additionally, the plan should address other concerns, including management of Port-Orford-cedar root disease and other pathogens and cultural vegetation management.

Ideally, all the components of a Vegetation Management Plan will be developed concurrently. However, because funding is not always sufficient to prepare the components simultaneously, they can be developed independently, provided they are integrated with subsequent components.

A Vegetation Management Plan is not the same as the newly created Vegetation Management Statements (State Parks 2009). Vegetation Management Statements address management of the natural vegetation in a park unit. Wherever there are park objectives for natural vegetation, a statement should be prepared. The purpose of the Vegetation Management Statement is to disclose the current management direction and what it is based on. New vegetation management initiatives should not be identified in a Vegetation Management Statement; they should be developed through a Vegetation Management Plan, which is a more detailed document.

1.3.1.3 WILDLIFE MANAGEMENT PLAN

The MCA supports numerous wildlife species, including several state-listed and federally listed species, such as the marbled murrelet (*Brachyramphus marmoratus*), northern spotted owl (*Strix occidentalis caurina*), and coho salmon. The maintenance and enhancement of habitat for these species (e.g., late-successional habitat and streams) was a primary intent of the purchase of the MCA and is a component of the vision statement (State Parks 2010). To assist in accomplishing these goals, a Wildlife Management Plan will need to be developed. The Wildlife Management Plan should be developed in concert with the Vegetation Management Plan and, to a lesser extent, the Roads and Trails Management Plan, because there are codependent components in these management plans.

A Wildlife Management Plan would address invertebrates, fish, amphibians, reptiles, birds, and mammals. It would identify sensitive species that may occur in the MCA, their habitat, and their current known distribution and population status and would provide recommendations for inventorying and monitoring. Some of the information required for the development of a Wildlife Management Plan exists and is summarized later in this document (e.g., Section 2.3.1, “Fish Populations”). Other components will require additional data and development.

The Natural Resource Division of State Parks has adopted an IMAP. The IMAP identifies goals, guidance, and standards for State Parks’ efforts to systematically evaluate the vegetation, wildlife, and physical natural resources of the State Park system. Evaluations consist of collecting data through various scientific means in each State Park system unit. Data generally are quantitative and consist of counts and measures of natural resources (State Parks 2005). All natural resource monitoring (wildlife, botanical/vegetation, and physical parameters, such as water quality) in the MCA should conform to the IMAP.

Some monitoring efforts, such as the salmonid monitoring (refer to Chapters 2 and 5), are ongoing in the MCA. State Parks has also been monitoring the known northern spotted owl activity centers in the MCA. Subjects of other monitoring efforts are terrestrial amphibians (Hodgson and Welsh 2007); mesocarnivores, with emphasis on the Pacific fisher (*Martes pennanti pacificus*) and the Humboldt marten (*Martes americana humboldtensis*) (Slauson et al. 2003; Slauson 2010); and, beginning in spring/summer 2010, land birds. Many of these monitoring efforts are being conducted to determine the effects of various restoration activities, such as forest restoration. Pertinent to this WMP, additional monitoring efforts should be developed for nonfish aquatic-dependent species, such as the southern torrent salamander (*Rhyacotriton variegatus*) and the tailed frog (*Ascaphus truei*), both of which can be susceptible to harm from management actions that result in the generation of sediment or fines in streams, such as road removal. However, there is no acceptable monitoring technique for the southern torrent salamander that does not result in the destruction or substantial modification of its habitat. Other aquatic species monitoring methods that should be considered include the California Department of Fish and Game’s (CDFG’s) Rapid Biological Assessment, which monitors water quality based on benthic macroinvertebrates.

1.3.1.4 CULTURAL PLAN

Research and documented evidence of the human habitation in northwest California suggests occupation spanning thousands of years. Tushingham (2009), Hildebrandt and Hayes (1993), and others before them, such as Loud (1913), conducted studies that greatly contributed to our understanding of north coastal archaeology.

The MCA is situated on lands traditionally occupied by the Tolowa Indians. The Tolowa occupied an area of approximately 1,658 square kilometers (km^2) (640 square miles [mi^2]) in four different natural habitats, although they lived primarily in villages near the coast (Gould 1978:128–129). New archaeological evidence points to long-term permanent habitation of inland riverine environments (Tushingham et al. 2008, Tushingham 2009).

The Mill Creek watershed was, and continues to be, a culturally important area for the Tolowa people. Many known archaeological and historical resources are located in the MCA. Future surveys in the MCA will likely discover many previously unknown important archaeological and historical resources.

According to Section 15064.5 of the California Environmental Quality Act Guidelines (State CEQA Guidelines), implementation of the Mill Creek WMP would result in a significant impact if it would cause a substantial adverse change in the significance of a historical or archaeological resource based on the following criteria:

1. Substantial adverse change in the significance of an historical resource means physical demolition, destruction, relocation, or alteration in the resource or its immediate surroundings such that the significance of an historic resource would be materially impaired.

2. The significance of an historical resource is materially impaired when a project:

   (A) Demolishes or materially alters in an adverse manner those physical characteristics of an historical resource that convey its historical significance and that justify its inclusion in, or eligibility for inclusion in, the California Register of Historical Resources; or

(B) Demolishes or materially alters in an adverse manner those physical characteristics [of an historical resource] that account for its inclusion in a local register of historical resources pursuant to section 5021.1(k) of the Public Resources Code or its identification in an historical resources survey meeting the requirements of section 5024.1(g) of the Public Resources Code, unless the public agency reviewing the effects of the project establishes by a preponderance of evidence that the resource is not historically or culturally significant; or

(C) Demolishes or materially alters in an adverse manner those physical characteristics of a historical resource that convey its historical significance and that justify its eligibility for inclusion in the California Register of Historical Resources as determined by a lead agency for purposes of CEQA.

Compliance with State Parks cultural resource management goals would ensure that future development and improvements proposed in the Mill Creek WMP would not cause substantial adverse effects on prehistoric and historic resources present on park property.

The GMP/GP and the GPA for the MCA identify goals and management strategies to ensure the preservation, protection, avoidance, and interpretation of cultural resources. Limited cultural resource surveys have been conducted in the MCA. These surveys have resulted in the identification of both prehistoric and historic-era resources, ranging from Native American habitation and lithic sites to historic roads and landscape features. Several historic-era structures, roads and trails, railroad alignments, and potential cultural landscapes also are located in the MCA. These sites have the potential to be disturbed by implementation of the Mill Creek WMP.

Implementation of Redwood National and State Parks cultural resource management strategies included in the GMP/GP and the GPA—specifically, the research, planning, and stewardship of cultural resources on park property—would protect these resources and ensure that any impacts of implementing the Mill Creek WMP would be less than significant. Ground disturbance associated with cultural investigation and preservation of cultural landscapes will be considered for potential effects on water quality.

1.3.1.5 FACILITIES PLAN

The GPA identifies two primary facility types: recreation and administrative facilities. The existing campground that bounds the West Branch of Mill Creek outside the MCA but is in the Mill Creek watershed will be retained. Proposed recreation facilities include or will support a drive-in campground near the eastern boundary of the MCA, walk-in and equestrian backcountry camping, cabins or tent cabins, trails (hiking, biking and equestrian), vistas, picnic areas, fishing access, and a lodge. A lodge with a view of the ocean is proposed for the west side of the MCA, south of the park entrance at Hamilton Road. Hamilton Road would become the sole point of entry to the MCA from State Route (SR) 101. A new road from Hamilton Road to the existing campground outside the MCA would be constructed along the slope east of the West Branch of Mill Creek. Construction of the new road would reduce the need to maintain the existing, locally unstable road from SR 101 to the campground, except for service and emergency access.

Proposed administrative facilities include expansion of the existing nursery and reuse of the old mill site area and buildings near the confluence of the West Branch of Mill Creek and the East Fork of Mill Creek. Potential uses of the existing site and buildings include equipment storage, contractor staging for natural resource restoration projects, limited seasonal staff housing, offices, an outdoor school, a research facility, and an interpretation center. The existing mill site has extensive pavement that inhibits surface water percolation and accelerates runoff. Buildings and large swaths of asphalt may be removed from the mill site; a subsequent Site Development Plan for the site will be used to guide the facility design. Other major facility issues addressed or acknowledged in the GPA include the need to develop a Roads and Trails Plan (see Section 1.3.1.1, “Roads and Trails Management Plan”). A general administrative road network was identified in the GPA, which acknowledged the need to work with other agencies to develop a new highway corridor through the MCA to serve as an alternative if SR 101 at the Last Chance Grade, overlooking the ocean west of the MCA, suffers irreparable failure. As part of the interpretive program, a traditional Tolowa village also may be reconstructed in the MCA.

Potential water quality issues stemming from the proposed development include dust control along the road network, especially near sensitive resources; storage methods for equipment and materials; disposal of materials from demolished buildings; water extraction and sewage disposal; and facility and travel corridor site selection. Project-specific buffers, in addition to the buffer identified around streams used by anadromous fish as part of the GPA, may be included to help preserve water quality. Best management practices identified by the State Water Resources Control Board or North Coast Regional Water Quality Control Board for sediment, runoff, and spill control will be included for specific construction-related projects. The State Parks trails manual will help to guide trail design. Groundwater and surface water extraction and increased sewage disposal to serve a larger user population will be assessed in the context of the fishery and other beneficial uses. Facility retention and development will consider the possible effects of flooding, landsliding, and seismic shaking related phenomenon or failures that could cause unwanted materials or debris to enter groundwater or nearby streams.

1.3.1.6 RECREATION PLAN

The GPA calls out four major recreation topics that should be addressed by the WMP: (1) recreation opportunities, (2) infrastructure use and associated development of a Roads and Trails Plan and a Site Development Plan for the old mill site at the confluence of the West Branch of Mill Creek and the East Fork of Mill Creek, (3) delineation of frontcountry and backcountry zones, and (4) tracking of visitor use and composition to facilitate adaptive management. The MCA is used for such recreational activities as hiking, mountain biking, fishing, and horseback riding. Under the GPA, street legal vehicles will be permitted on roads designated for public use. The general road network to be retained was identified in the GPA. Permitted new recreational facilities include vehicle campgrounds, backcountry campgrounds, equestrian campgrounds, cabins, trailheads, trails, interpretive facilities, vistas, picnic areas, a lodge, and fishing access points. Most recreational activities will occur in frontcountry zones, although backcountry zoning will permit development of smaller scale recreation facilities. General buffer zones around streams used by anadromous fish have been identified in the GPA.

As other plans and projects move forward, several design and operational issues will be considered to help mitigate impacts on water quality from recreational activities. For example, increased use by the public could require additional maintenance to preserve road conditions. This need will be assessed through tracking of visitor use and composition. Project-specific buffers or management practices designed toward recreational use, in addition to the buffer identified around streams used by anadromous fish, may be included to help preserve water quality.

1.4 MILL CREEK ADDITION CHARACTERISTICS

Evidence of recent logging dominates much of the landscape, although high resource values or potentially high resource values remain throughout the MCA. This section describes the property's natural features and the cultural associations that contribute to the current landscape condition.

1.4.1 AREA AND LOCATION

The MCA is located approximately 10 km (6 mi) southeast of Crescent City in Del Norte County, California. Redwood National Park and Jedediah Smith Redwoods State Park bound the north side of the MCA; Del Norte Coast Redwoods State Park, of which the MCA is a part, and Redwood National Park bound the property to the west; and Six Rivers National Forest and private timberlands, respectively, bound the eastern and southern sides of the property (Figure 1-1). Portions of five watersheds make up the 103.8-km^2 (40.1-mi^2) MCA: major portions of Mill Creek (60 km^2, 24 mi^2) and Rock Creek (31 km^2, 12.4 mi^2), respectively, on the west and east sides of the property and small portions of the headwaters of Wilson Creek (5.3 km^2, 2.0 mi^2), Terwar Creek

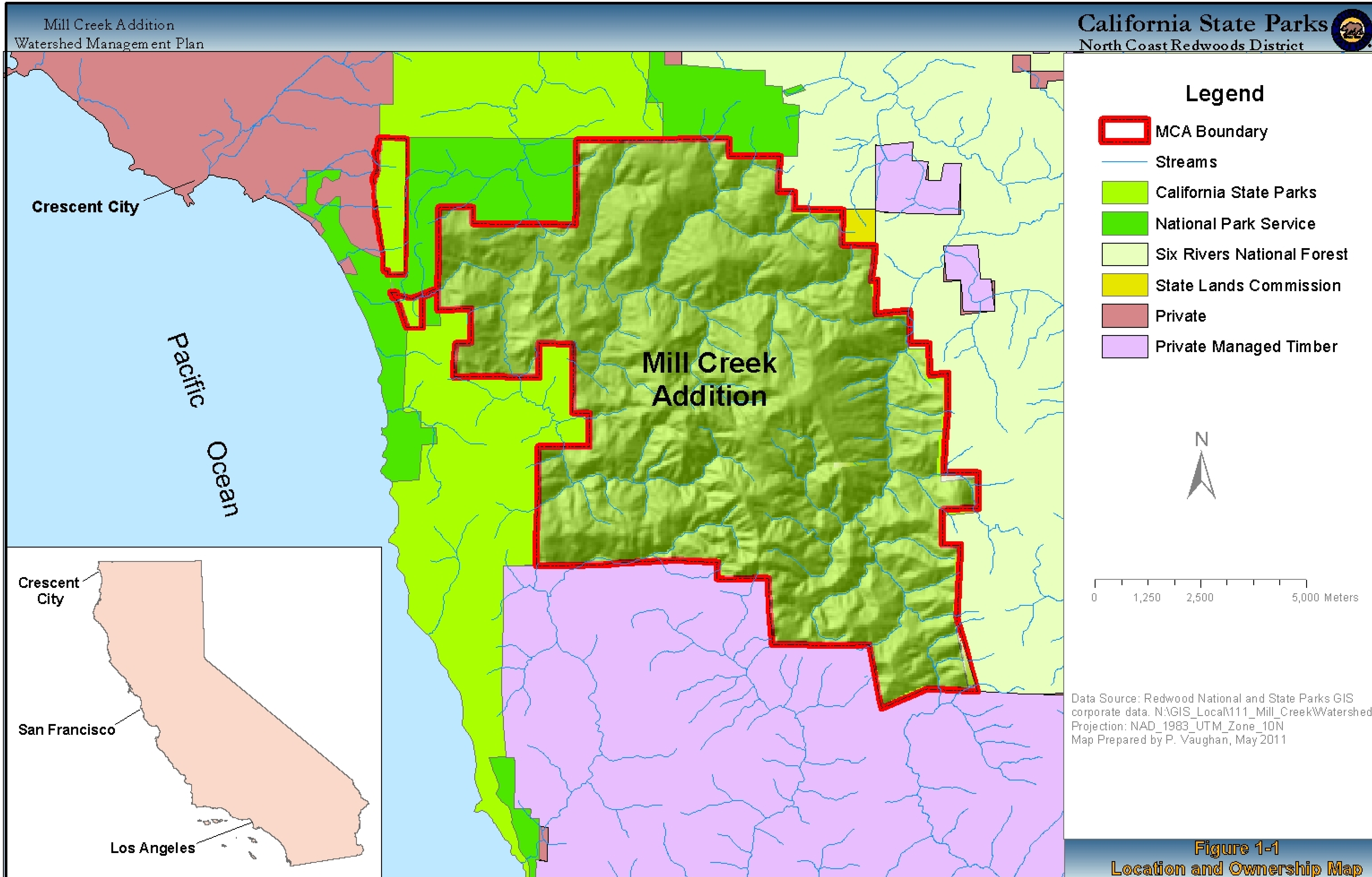


Figure 1-1
Location and Ownership Map

(2.6 km^2, 1.0 mi^2), and Hunter Creek (1.1 km^2, 0.4 mi^2) on the south side of the property. A few small drainages originate in small northwestern slivers of the MCA and flow across alluvial fans and a marine terrace of the Smith River Plain or toward the coastal bluffs, southeast of Crescent City (Figure 1-2).

The headwaters of Mill Creek are located primarily in the MCA, although small headwater tributaries to Mill Creek originate in Del Norte Coast Redwoods State Park. Mill Creek has two primary tributaries: the West Branch of Mill Creek (West Branch) and the East Fork of Mill Creek (East Fork). They meet near an old mill site on the northwest side of the MCA and then flow as the mainstem of Mill Creek through Redwood National Park and Jedediah Smith Redwoods State Park to the Smith River, a nationally designated Wild and Scenic River. The West Branch also flows through a section of Del Norte Coast Redwoods State Park as it traverses the MCA; the Mill Creek Campground occupies this reach. Rock Creek’s headwaters are located primarily in the MCA, but small headwater reaches are located in private timberland and Six Rivers National Forest. After leaving the MCA, Rock Creek flows through Six Rivers National Forest to the South Fork of the Smith River. Wilson, Terwar, and Hunter creeks have headwater segments in the MCA. Wilson Creek flows directly to the Pacific Ocean through private timberland and, near its mouth, Del Norte Coast Redwoods State Park. Terwar and Hunter creeks flow through private timberland and the Yurok Reservation before joining the Klamath River. Hunter Creek has rural residential development along some reaches. All these watersheds provide habitat for anadromous fish, although only Mill Creek and Rock Creek have anadromous populations in the MCA.

1.4.2 CLIMATE AND HYDROLOGY

Cool, wet winters and warm, dry summers with frequent coastal fog characterize the Mediterranean climate of northern California and the MCA. The fog belt extends to Rattlesnake Ridge along the eastern edge of the property, approximately 13 km (8 mi) inland. Less fog and more variable seasonal and diurnal temperatures correspond with increasing distance from the coast. Most precipitation falls as rain during the winter months, although small accumulations of snow are not uncommon at higher elevations. Stillwater Sciences (2002) reported mean annual precipitation at the MCA ranging from approximately 152 cm to 381 cm (60–150 inches) and average monthly maximum and minimum air temperatures at the Crescent City Airport that vary from approximately 8°C to 19°C (41–67°F).

An isohyetal (lines of equal precipitation) map prepared by the U.S. Geological Survey (USGS) (Figure 1-3) shows mean annual precipitation ranging from about 165 cm (65 inches) on the west side of the MCA to about 241 cm (95 inches) on the east side of the property, based on data collected from 1900 to 1960. Madej et al. (1986) refer to an unpublished isohyetal map for the Smith River by Winston and Goodridge (1980) that shows mean annual precipitation of approximately 228 cm (90 inches) at lower elevations and approximately 279 cm (110 inches) at higher elevations in the Mill Creek watershed. It should be noted that the USGS evaluation reflects a relatively coarser scale of mapping. Future study should provide more detailed and longer term information to develop a map designed specifically for the MCA. Long-term weather stations are proposed at the old mill site near the confluence of the West Branch and East Fork and along a ridge at Childs Hill on the eastern side of the MCA.

Winds at the Crescent City Airport are generally from the south (period of analysis is 1992–2002), but the morphology of sand dunes adjacent to the airport and monthly data indicate that some of the stronger winds, capable of transporting sand during the drier summer months, are from the north-northwest. The average wind speed at the airport is 8.6 mph (period of analysis is 1996–2006) (Western Regional Climate Center 2010a, 2010b).

Winter floods and rainfall generated by intense storms that travel three primary storm tracks perform most of the geomorphic work that contribute to mass wasting and road and stream crossing failure in the MCA. These storms originate or travel as high-latitude storms from the Gulf of Alaska, low-latitude storms from the western Pacific Ocean, and midlatitude storms associated with low-pressure cyclones that originate in the polar regions that are subsequently modified during passage over the Pacific Ocean (Weaver 1962). Strong components of north-south or south-north airflow are associated with the

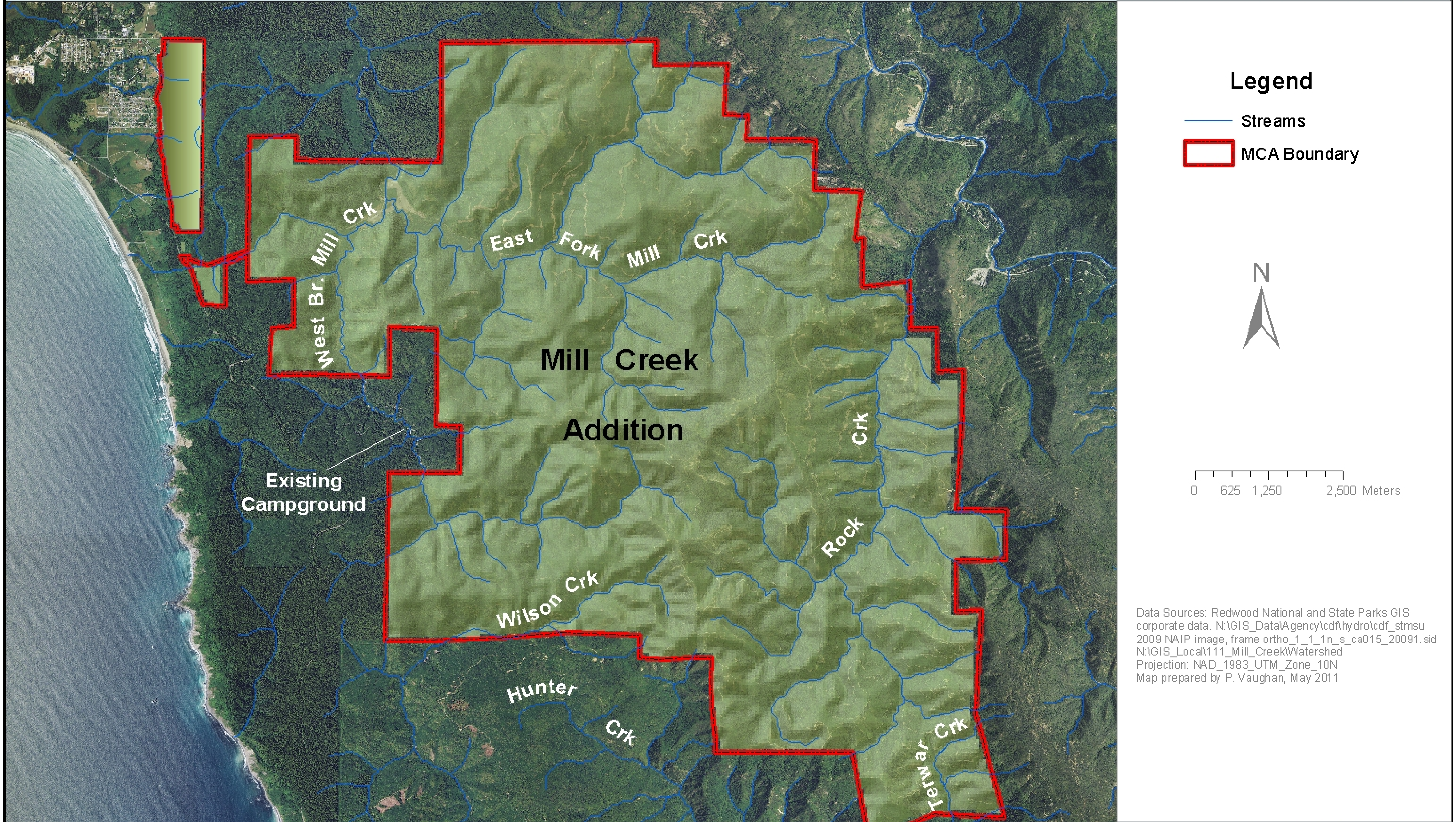
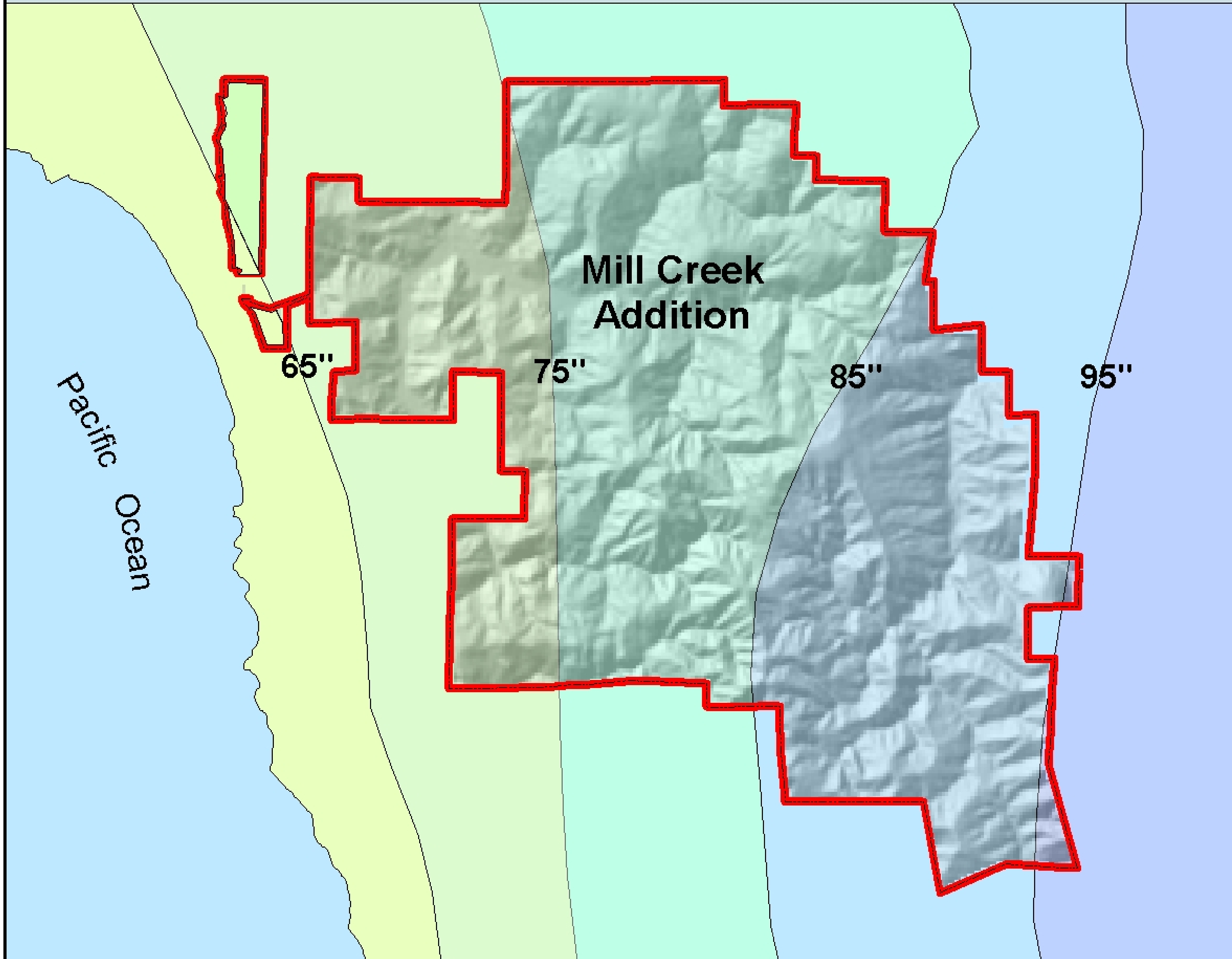


Figure 1-2
Watershed Hydrography Map



Data Source: Redwood National and State Parks GIS corporate data.
N:\GIS_Local\111_Mill_Creek\Watershed
Average annual precipitation 1;1,000,000 scale source map compiled by S.E. Rantz, US Geological Survey: covers the period from 1900-1960.
Projection: NAD_1983_UTM_Zone_10N
Map prepared by P. Vaughan, May 2011

Figure 1-3
Isohyetal (Precipitation) Map

two former sources, and unobstructed west-east airflow favors the latter source. For all three cases, a highly intense rainfall requires a strong flow of moist air from low latitudes.

Historical floods of significance most recently occurred in northwestern California in 1997 and 1998. The 1997 flood had a 12-year recurrence interval in Redwood Creek, approximately 40 km (25 mi) south of the MCA. It was the most damaging event since 1975. Six floods with long-term recurrence intervals of approximately 25 years occurred in Redwood Creek during a particularly active flood period between 1953 and 1975 (Harden 1995). The Smith River, downstream from the MCA, had major floods in 1955, 1964, 1972, and 1975. The larger of these floods, in December 1955 and December 1964, had respective long-term average recurrence intervals of 25–30 years and 45–50 years. At least five floods comparable to those from the 1953–1975 period occurred between 1861 and 1890, but they caused less damage because the landscape was less developed during that time (Harden 1995). Madej et al. (1986) report that the Mill Creek and the Smith River hydrographs are similar but that the Smith River has a higher runoff-per-unit-area.

Between 1974 and 1981, USGS monitored discharge approximately 1 km (0.6 mi) downstream from the confluence of the West Branch and East Fork (drainage area of 74.1 km^2 [28.6 mi^2]). Over this period, the mean annual daily discharge was 3 cubic meters per second (m^3/s) (118 cubic feet per second [cfs]), the range was 0.07 to 84 m^3/s (2.5 to 2,980 cfs), and the peak was 126 m^3/s (4,460 cfs) on March 18, 1975 (Madej et al. 1986). Rock Creek has not been gaged but likely responds to rainfall more quickly and has less baseflow than Mill Creek because of its gradient, lesser floodplain, and smaller size. As part of a study to assess surface flow and groundwater effects from pumping at the Mill Creek Campground and to initiate a longer term monitoring record, State Parks installed more surface flow gages along the West Branch in 2006–2007.

Groundwater data are comparatively scarce, but limited drilling has been advanced to support extraction in the Mill Creek watershed in the MCA and elsewhere in Del Norte Coast Redwoods State Park. Near the old mill site, the former property owner, Stimson

Lumber Company (Stimson), advanced several borings that proved unproductive (State Parks 2010). A 5,678,118-liter (1,500,000-gallon) reservoir west of the old mill site provided firefighting capability and domestic water for the old mill site, but its distribution and surface water collection system, from Mill Creek, is nonoperational. In 2006 and 2007, State Parks advanced production and monitoring wells in the alluvial floodplain that underlies the Mill Creek Campground. An additional monitoring well was advanced in the alluvial floodplain downstream from the campground. The wells within reasonable proximity to the West Branch are generally highly productive and respond quickly to rainfall. One of these production wells, located approximately 37 meters (m) (120 feet [ft]) from the creek, serves the campground. About 152 m (500 ft) from the West Branch, a well advanced through alluvial fan and fluvial terrace deposits and into bedrock proved unproductive. A 91-m-deep (300-ft–deep) well advanced through an old, deep landslide deposit and into bedrock below the park maintenance yard proved unproductive, and the bedrock segments of production wells advanced in the Mill Creek Campground floodplain were similarly unproductive. Geotechnical borings advanced by consultants and horizontal wells advanced by State Park staff near the kiosk along the entrance road to the campground revealed limited seasonal groundwater in more recently active landslide deposits (cf. Laco Associates 1977). These data indicate that recent (Holocene) alluvial deposits are potentially highly productive, landslide deposits are marginally productive or nonproductive, and bedrock is unlikely to be productive.

Climate change will likely affect the hydrology of the site and thus play a role in the primary management activities addressed throughout this plan. Kueppers et al. (2005) developed a regional climate model for California that has a higher degree of resolution than a comparable global climate model that also covers California (25 km^2 [9.7 mi^2] pixels capable of resolving a high degree of topographic detail versus 250 km^2 [97 mi^2] pixels with a good deal of topographic smoothing). They compared anticipated change over a 100-year period (between 1980–1999 and 2080–2099) for northwestern California. Over this period, the regional climate model showed increases (+2.27^{o}C, +4.09^{o}F) in the mean temperature of the coldest month, the mean temperature of the warmest month (+2.98^{o}C, +5.36^{o}F), and the amount of annual precipitation (+31.11 mm, +1.22 in) and a decrease in the April to August precipitation (-16.03 mm, -0.63 in). With the exception of annual precipitation, which had a decrease of 30.69 mm (-1.21 in), the global climate model showed similar changes, although of slightly lower magnitude. The predicted change in the quantity of precipitation is not dramatic, but in combination with the predicted temperature changes, these data suggest a tendency toward more summer drought, a potential stressor for the fishery and the current forest associations, and toward more winter rainfall, a potential trigger for increased slope instability and flooding. However, the effect of greater heat on the fog belt, an important coolant for the landscape, has not been modeled in detail in the immediate vicinity of the MCA. Regional models for California and Oregon suggest a 33% decline in coastal fog frequency since the early 1900's (Johnstone and Dawson 2009).

1.4.3 TOPOGRAPHY

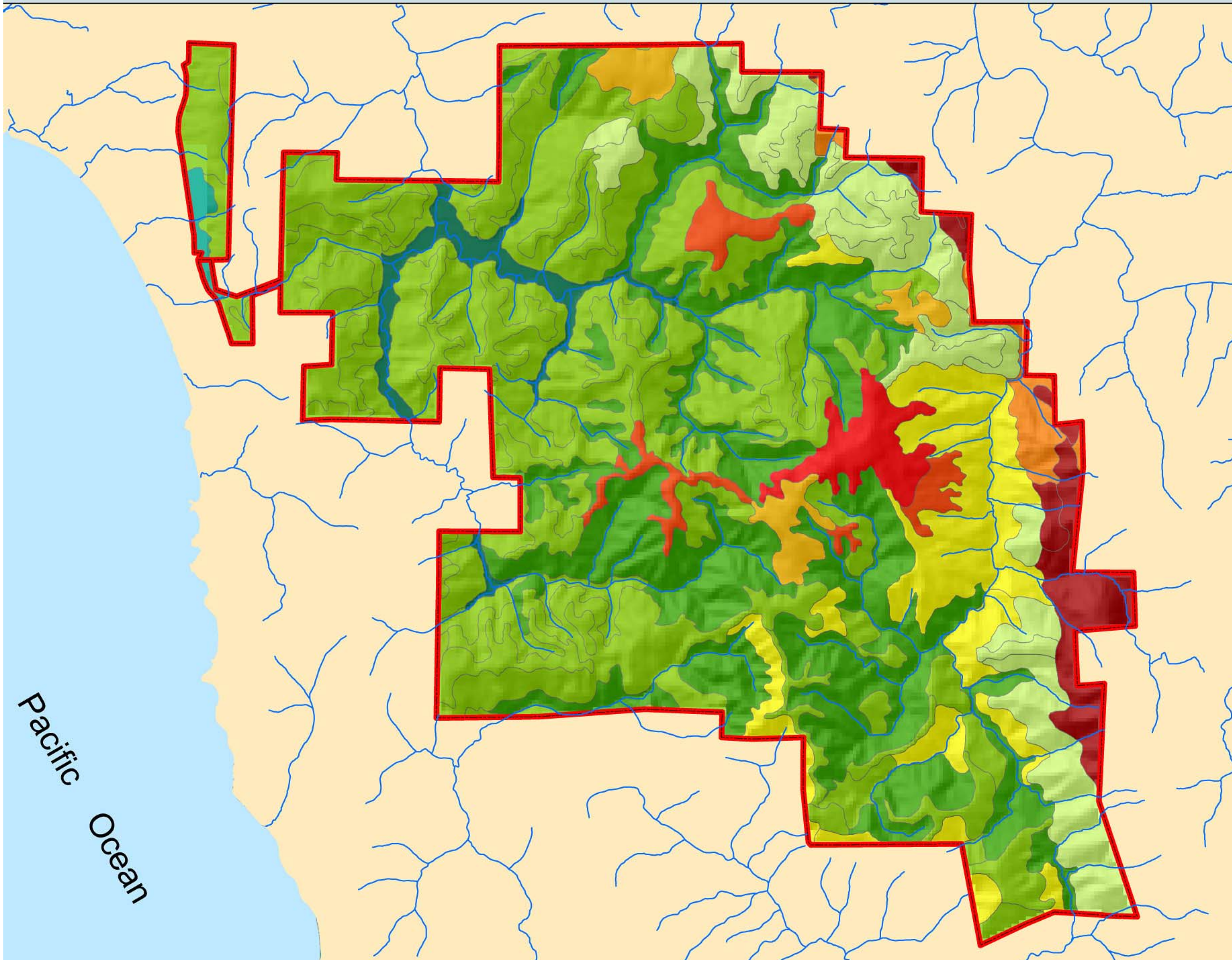
The approximate northern limits of the California Coast Ranges and the western Klamath Mountains meet at the MCA to form a chain of northwest-trending valleys and ridges. Ridges are generally broad and gently sloping and their crests generally increase in elevation from west to east. Deeply incised tributary streams contribute flow to the West Branch and East Fork, both of which have broad, flat-bottom valleys, and to Rock Creek, which flows through a narrow valley for most of its length. Elevations across the MCA range from approximately 16 m (52 ft) to 685 m (2,247 ft) (State Parks 2010). LiDAR (Light Detection and Ranging) data acquisition over the entire property in 2007 (with the exception of a data gap in two slivers on the northwest side of the MCA) contributed to development of a digital model capable of resolving site-specific elevations across the landscape to within 0.3 to 0.5 m (approximately 1 to 1.5 ft).

1.4.4 VEGETATION

Before the MCA was acquired by State Parks, surveys identified at least 15 vegetation series (Sawyer and Keeler-Wolf 1995) on the property (SHN 2000). Intolerant herbaceous and shrub vegetation is being reduced in many areas as young forest canopies close, but species diversity remains high and is probably at a level similar to that at the time of acquisition, when 300 species of vascular plants were likely present (Stillwater Sciences 2002).

Fire, edaphic conditions, moisture gradients (both topographic and coastal), and, to a lesser extent, wind were the major variables influencing species composition before the property was first used for logging. Most of the Mill Creek drainage was forested with the exception of two small prairies visible on 1936 aerial photographs: One opening was near the current mill site, and the other was near the junction of Rock Creek Road and Childs Hill Road. The forests were predominantly redwood (*Sequoia sempervirens*) on the lower slopes, with Sitka spruce (*Picea sitchensis*) along the coast and Douglas-fir (*Pseudotsuga menziesii*) and tanoak (*Lithocarpus densiflorus*) becoming more common or even dominant in the interior and on upper slopes. In portions of Rock Creek Douglas-fir and tanoak were the major species and redwoods were uncommon outside of drainages. The extreme eastern and northeastern portions of Rock Creek, where serpentine soils limit or occasionally prohibit tree growth, contain a great diversity of plant life. Portions of this area are mixed stands containing knobcone pine (*Pinus attenuata*) and western white pine (*Pinus monticola*) while other portions are chaparral and devoid of trees. The Natural Resources Conservation Service (NRCS) recently revised soils information about the property, which includes general information regarding the dominant vegetation throughout the MCA (Figure 1-4).

Norman (2007) found that fire-return intervals before 1920 averaged between 11 and 15 years in stands containing redwoods, with frequency increasing near Native American (most recently, Tolowa) villages and camps. These fires were often of low intensity and many of the fire scars are only visible below 30 cm (12 in) on basal flutes. Norman's research is in contrast to earlier research that likely overestimated fire return intervals by examining fire scars higher up (on the top of stumps). Douglas-fir and knobcone pine were found present in one or two cohorts in several drier (interior and ridgetop) regions, indicating a moderate- to high-severity fire regime with adjacent, redwood-containing drainages having lower severity fires. Norman (2007) suggests that redwood forests on the drier, eastern margins of their historic range are more vulnerable to composition shifts because fire suppression can allow the accumulation of vegetation that can fuel more intense wildfires.



Data Source: Redwood National and State Parks GIS corporate data.
N:\GIS_Data\Agency\nrcs\2009 Data\soil_survey_Redwood_Nat&State_Parks\Soils Information\Soil Data\Geospatial Data\REDW_Soil.shp
N:\GIS_Local\111_Mill_Creek\Watershed
Projection:NAD_1983_UTM_Zone_10N
Map prepared by L. Leonard, April, 2010

Figure 1-4
Historic Vegetation

The current vegetation has been heavily influenced by logging. Most of the MCA has been converted to even-aged stands established from 1954 to 2000 (Table 1-1). Some of the older stands have been partially cut since their stated year of establishment. Survey data from the late 1990s also were used to classify stands by vegetation type (Table 1-2), but growth since the inventory makes this classification less useful. The greatest beneficiary of recent disturbances has been Douglas-fir, which is now the most common tree species on much of the property. Douglas-fir was planted in greater numbers and is better able to seed in from neighboring stands than other species. Knobcone pine is also more common in many of the relatively xeric sites, where burning to clear slash encouraged their serotinous cones to spread seed. Redwoods were also planted in many areas, including some that were likely devoid of redwood logging.

Table 1-1
Area of Forest in Various Age Classes

Year of Stand Establishment	Hectares (Acres)
1990–2000	2,229 (5,508)
1980–1989	1,728 (4,271)
1970–1979	2,673 (6,606)
1960–1969	1,462 (3,613)
1954–1959	399 (987)
Pre-1954*	1,603 (3,962)

Note: Some of the stands have been partially cut since their stated year of establishment.
*Much of the pre-1954 stand was partially harvested after 1954.
Source: Stimson, unpublished GIS data. Based on unpublished GIS data from Stimson Lumber Company

Table 1-2
Acres of Land of Various Vegetation Types

Vegetation Type	Hectares (Acres)
Brush	170 (421)
Hardwood	741 (1,831)
Nonforest (old mill site)	42 (105)
Old growth	49 (120)
Scattered old growth	668 (1,651)
Poles	378 (935)
Scattered poles	520 (1,286)
Regen	6,540 (16,161)
Young growth	296 (731)
Scattered young growth	662 (1,636)

Source: Stimson, unpublished 1990s survey data Based on unpublished 1990's survey data by Stimson Lumber Company

Other common tree species present in the MCA are western hemlock (*Tsuga heterophylla*), Port-Orford-cedar (*Chamaecyparis lawsoniana*), western redcedar (*Thuja plicata*), red alder (*Alnus rubra*), and grand fir (*Abies grandis*). Western white pine (*Pinus monitcola*) and the few sugar pines (*Pinus lambertiana*) are limited to the eastern side of Rock Creek.

1.4.5 WILDLIFE

Limited information regarding the distribution of wildlife in the MCA is available. Stimson, as part of its environmental compliance for timber harvesting, used to conduct surveys for marbled murrelets, northern spotted owls, and salmonids. Focused surveys for other wildlife species appear to have been more sporadic and not as well documented, although Rellim Redwood Company did have a summary document of the status of wildlife and fisheries resources produced for the property in 1995 (Jones & Stokes Associates 1995).

The distribution of habitat for marbled murrelets has not changed since the MCA was acquired by State Parks. Two marbled murrelet stands are located in the MCA: Paragon and Hamilton Buffer. Only Hamilton Buffer is known to be occupied (Transou, pers. com, 2010). Because of budget constraints, no efforts have been made to determine whether Paragon is still occupied; however, for the purpose of planning and environmental compliance, it is considered occupied. Additional habitat for marbled murrelets is located in adjacent portions of Del Norte Coast Redwoods State Park, Jedediah Smith Redwoods State Park, and Redwood National Park.

There are no known northern spotted owl activity centers in the MCA; there were six in 1995 (Jones & Stokes Associates 1995). The last reproductive activity center was at George’s Saddle in 2008. In 2009, this pair was displaced by barred owls (*Strix varia*). Although the spotted owl pair was observed in the area in 2009, the male has not been detected in 2010 (Transou, pers. com, 2010).

For additional information on wildlife resources, see Section 4.6.3 (Biological Resources) of the GPA (State Parks 2010) and Section 2.3 (Aquatic Populations and Perodicity) of this document for anadromous salmonids.

1.4.6 GEOLOGY AND SOILS

Tectonic convergence and relatively hard bedrock control the physiographic expression of the MCA. The Coast Range Thrust Fault, locally known as the South Fork Fault, strikes north-northwest through the Rock Creek watershed and forms the boundary between rocks of the Coast Ranges and the Klamath Mountains (Figure 1-5). The Coast Range Thrust Fault is a remnant from the early convergence and accretion of marine Franciscan Formation rocks with the North American continent from the mid-late Mesozoic to early Tertiary (beginning approximately 180 million years ago; note: temporal or spatial uncertainty in geologic terms is directly expressed; the symbol (?) may be used to convey uncertainty); the fault extends several hundred miles to the south. The convergence of the Gorda and North American tectonic plates, which meet at the ocean floor approximately 100 km (60 mi) offshore west of the MCA, continues this accretionary process. The Gorda plate dives under the North American plate at a low angle along the southern part of the Cascadia Subduction Zone such that their contact is below the MCA at depth.

Other active faults in the vicinity—the Whalehead Fault in southern Oregon and offshore extensions of the Big Lagoon-Bald Mountain and Trinidad faults—could produce strong ground shaking in the MCA but have lesser recurrence and lesser maximum magnitude capability than the Cascadia Subduction Zone. Using average long-term recurrence data, Goldfinger et al. (2008) indicated that rupture along the southern segment of the Cascadia Subduction Zone, estimated to produce earthquakes of Magnitude 8+, is several decades overdue.

Ongoing deformation along the subduction zone continues to contribute to uplift and preserve Pleistocene to Miocene alluvial and marine deposits on ridges. The hard bedrock and uplift also contribute to the development of steep and generally straight to convex slopes that frequently exceed 50% grade (Madej et al. 1986).

Drainages are deeply incised and have dendritic to trellis patterns. LiDAR analysis suggests a propertywide average drainage density for USGS blue line streams of approximately 2.3 km/km^2 (1.4 mi/mi^2), although subwatersheds may have drainage densities of approximately 4.5 to 5.5 km/km^2 (2.7 to 3.3 mi/mi^2). Improvements to the USGS stream classification have not been attempted in the MCA as part of this planning effort.

Bedrock west of the Coast Range Thrust Fault is predominantly the Broken Formation of the Eastern Belt Franciscan Complex. These late Jurassic to early Cretaceous rocks are tectonically fragmented and consist of interbedded greywacke (sandstone), shale, and conglomerate (Aalto and Harper 1982). More coherent, massive sandstone characterized by massive bedding and moderate shearing predominates in the MCA. Fracturing and shearing of the Broken Formation increases from west to east toward the Coast Range Thrust Fault. Immediately west of the fault, highly sheared and foliated metagreywacke, argillite, and semischist predominate (Davenport 1984), indicating slight metamorphism along the fault zone. The bedrock east of the fault is composed of Pre-Nevadan rocks, including highly sheared serpentinite and peridotite, in the western Klamath Mountains terrain (Aalto and Harper 1982). Because the fault encompasses a broad zone, serpentine and peridotite that may bear asbestos minerals are also found in the MCA several hundred meters west of the fault depicted in Figure 1-5.

Marine, estuarine, and fluvial siltstone, sandstone, and conglomerate of the early Pliocene to late Miocene (?) Wimer Formation, coincident with J.S. Diller's "Klamath Peneplain," cap many of the ridges. A younger Pliocene (?) alluvial deposit also caps the ridge near Childs Hill, on the southeast side of the MCA. Pleistocene to late Miocene remnant upland surfaces thought to be part of the Klamath Peneplain consist of unclassified sedimentary deposits and deeply weathered bedrock and saprolite; Irwin (1997) interpreted their distribution from 1:62,500- and 1:100,000-scale USGS topographic maps (Figure 1-5). The distinctions among these Pleistocene to early Miocene units, which occupy similar topographic position and have temporal overlap and some temporal uncertainty, appear to be cross-cutting relationships, limited paleontological evidence, and, to some extent, the character of the earth material.

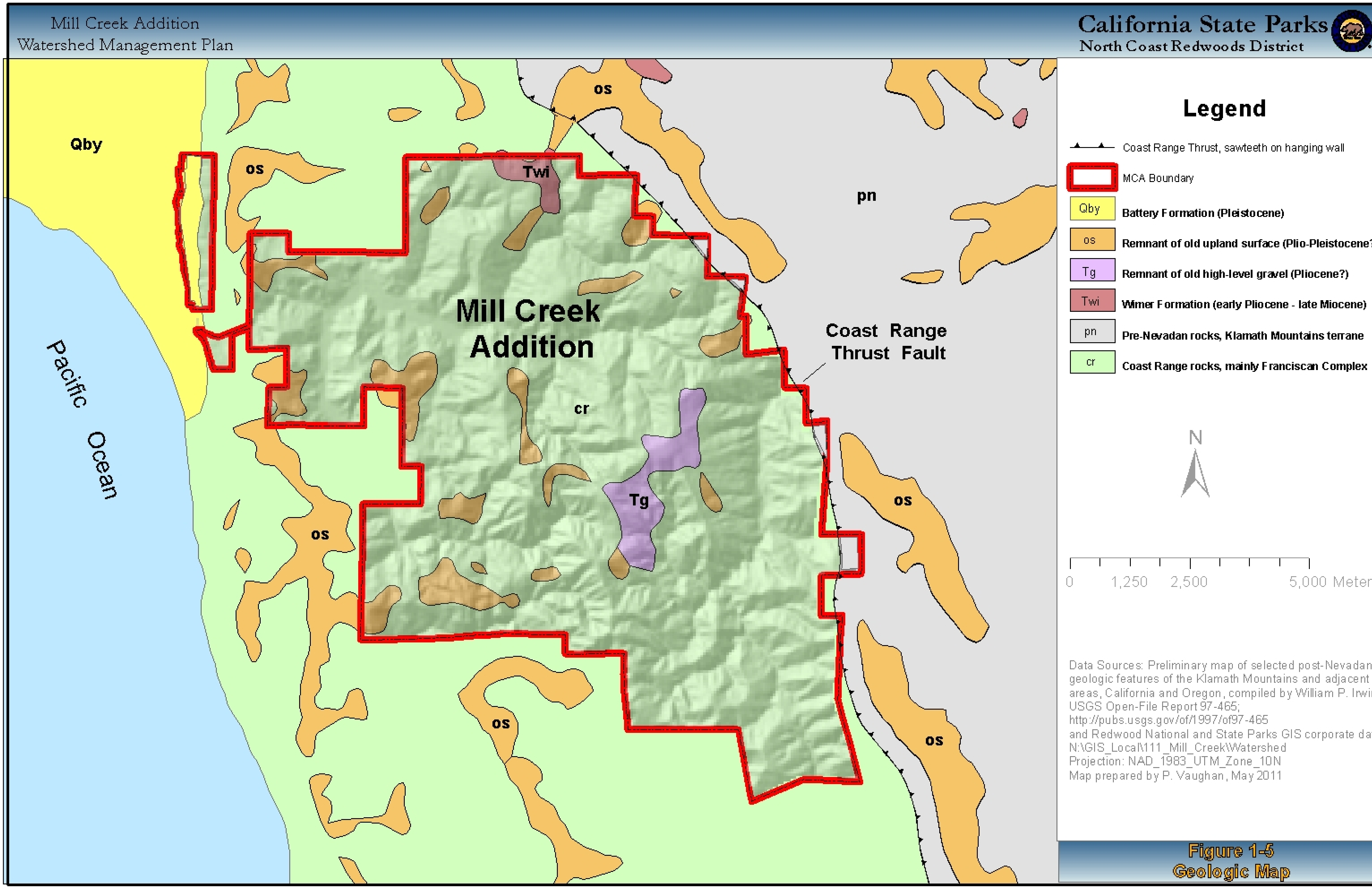


Figure 1-5
Geologic Map

Late Quaternary deposits are located throughout the MCA landscape. A small sliver of property on the northwest side of the MCA overlies the Pleistocene Battery Formation, a marine terrace, sand dune, and alluvial fan deposit consisting of unconsolidated sand, silty clay, and imbricated gravel (Davenport 1982). Holocene to Pleistocene landslides are common throughout the MCA. Holocene to Pleistocene fluvial terraces and floodplain deposits are located in Mill Creek and, to a lesser extent, in Rock Creek. Limited drilling data and some observational data indicate that the terrace deposits are typically cobbly or gravelly, sometimes with a moderately high amount of silt and clay in the gravel matrix. Overbank silts and clays typically cap the coarser deposits, and finer grained alluvial fans are associated with the floodplain deposits at some tributaries. The terrace deposits locally help protect the valley side slopes from stream undercutting and failure (Madej et al. 1986). Colluvium of variable thickness mantles the bedrock. Large fill deposits are locally associated with the extensive logging road network and the old mill site at the confluence of the West Branch and East Fork.

Staff from the NRCS recently completed soil mapping of Redwood National and State Parks, including the MCA, providing a modern soil survey that provides a wealth of soil data (NRCS 2008). Seventeen soil associations and two soil series of various slopes are identified in this mapping. With respect to surface erosion, approximately 75% of the land base has a severe erosion hazard rating (Figure 1-6). Only the Bigtree-Mystery Association, on floodplains, has a slight erosion hazard rating. Moderate erosion hazard ratings generally occur on ridgetops for the Trailhead-Wiregrass, Wiregrass-Pittplace-Scaath, and Coppercreek-Tectah-Slidecreek Associations. The Surpur and Childshill soil series also have moderate erosion hazards. The Slidecreek-Lackscreek-Coppercreek, Wiregrass-Rockysaddle, Sasquatch-Sisterrocks-Ladybird, Sisterrocks-Ladybird-Footstep, Jayel-Walnett-Oragran, Coppercreek-Slidecreek-Tectah, Wiregrass-Rockysaddle, Sasquatch-Yeti-Footstep, Sasquatch-Yeti-Sisterrocks, Gasquet-Walnett-Jayel, Oragran-Weitchepec, Coppercreek-Ahpah-Lackscreek, and Scaath-Rockysaddle-Wiregrass Associations have severe erosion hazard ratings, generally on the valley sidewalls. Table 7 and Figures 12 and 13 in Appendix A show groupings of these soil units, as well as the results of a modeling analysis for shallow slope instability.

1.4.7 HISTORY AND LAND USE

Timber harvesting in the MCA began in the 1850s but was not extensive until the 1920s and 1930s, when the Hobbs and Wall Company harvested most of the West Branch. Before 1930, the Hobbs and Wall Company harvested timber primarily using steam donkeys and rail transportation. To facilitate timber extraction, a temporary logging camp was first established near the north end of Picnic Road and later moved to the south end to follow the logging operations up the drainage (Bearss 1969).

Logging ceased in the late 1930s but began again in 1954, when new owners, the Miller Redwood Company (subsequently known as Rellim Redwood Company, Miller-Rellim Redwood Company, and finally Stimson Lumber Company), began harvesting other portions of the Mill Creek watershed. By 1958, major logging had occurred in the upper West Branch, upper Rock Creek, and upper East Fork watersheds. The company purchased the rest of the Rock Creek portion of the property in the 1960s and harvested this section relatively quickly to pay for the purchase.

Logging continued in the upper West Branch with new incursions in the northern East Fork throughout the 1960s. The 1970s brought an intense effort in the entire Rock Creek, northern East Fork, and upper Terwar watersheds. By the 1980s, much of the MCA had been entered and fragmented with timber harvest units. However, large areas along the northern side of the MCA were still being entered for the first time. The 1990s saw consolidation of the timber harvest units as the timber on the property was nearing exhaustion. By the time of the 2003 State Parks acquisition, the lack of trees advanced enough in age to meet regulatory requirements precluded harvest for at least 7 years.

1.4.8 OWNERSHIP

Figure 1-1 shows the boundaries of the MCA and the ownership of watersheds that cross both the MCA and adjacent properties. With the exception of private timberland on the southern side of the property owned by Green Diamond Timber Company, public lands managed for recreation and resource preservation bound the MCA. Commercial timber harvest may occur within U.S. Forest Service Lands east of the MCA.

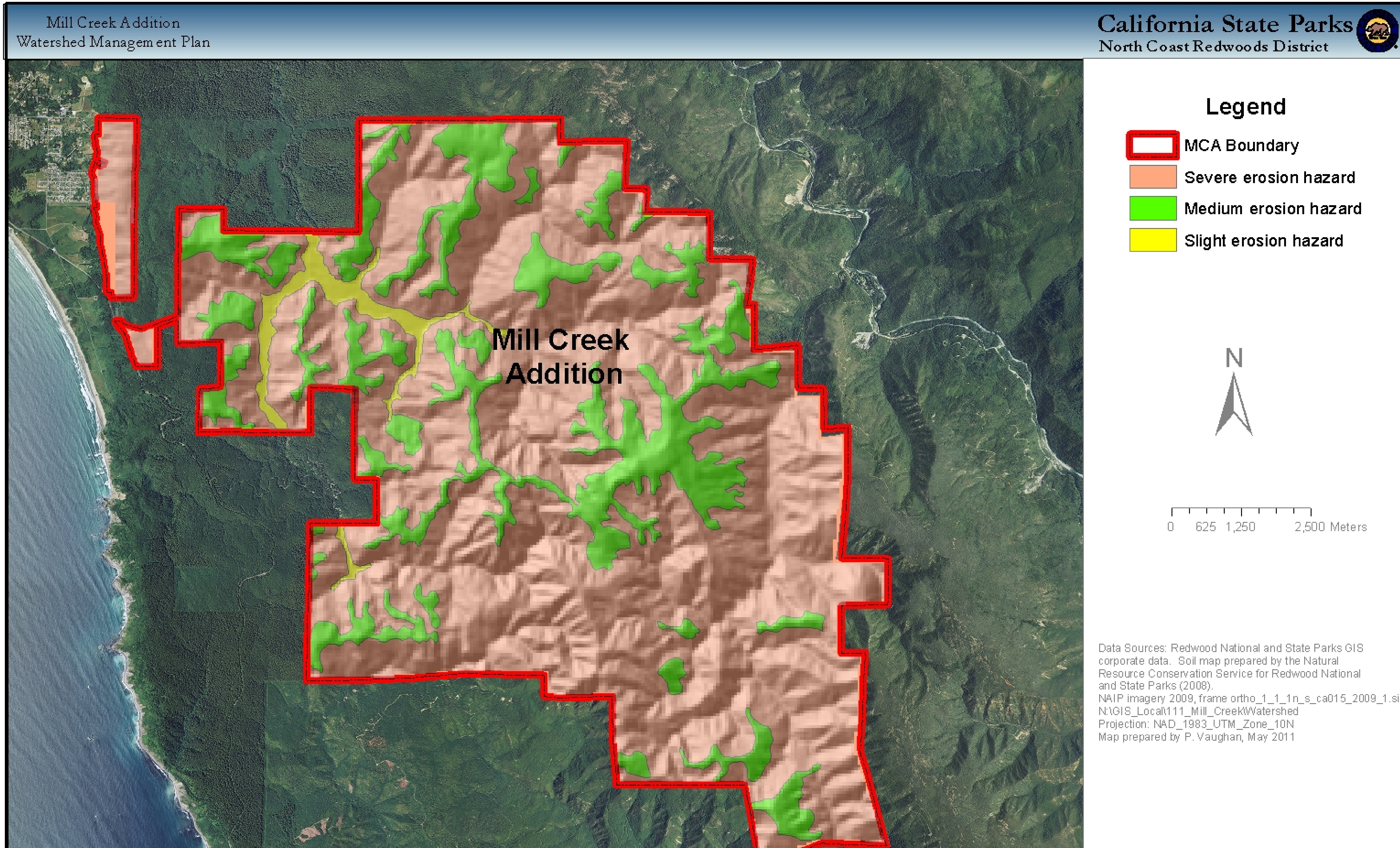


Figure 1-6
Soil Erosion Hazard Map

1.5 RESTORATION WORK TO DATE

When State Parks took over management, the MCA went from an actively managed industrial timber property to public land. Several actions were necessary to keep the landscape in as stable a condition as feasible given the change in management objectives. This section addresses actions taken to maintain resources in the MCA during development of management plans suitable for public lands.

1.5.1 ROAD WORK

Immediately before State Park's acquisition of the MCA, Stimson representatives conducted several orientations to acquaint State Parks' resource managers with the property and the road system. The timber company identified approximately 96 km (60 mi) of roads collectively referred to as "maintenance free" that had been partially decommissioned and were no longer part of the transportation network.

During the first winter following the acquisition (2002/2003), State Parks staff observed higher rates of failure on the maintenance-free roads than on roads that were open and monitored. Further investigation revealed numerous critical erosion sites and pointed to several flaws in the treatment method that had been used to treat the maintenance-free roads. As a result, State Parks developed the Landscape Stabilization and Erosion Prevention Plan (LSEP) to immediately address and stabilize these roads.

Implementation of the LSEP began in summer 2004, and work has continued each season with the amount of road removal fluctuating with available funding. At the end of the 2010 summer season, 79.5 km (49 mi) of road had been removed with grant funding from the CDFG, State Parks, Save the Redwoods League, the State Water Resources Control Board, the Smith River Alliance, and the California Wildlife Conservation Board. State Parks has also been implementing road rehabilitation projects and maintenance consistent with information in Stillwater Sciences Interim Management Recommendations (2002) until the completion of more formal planning. Thirteen critically undersized or failed culverts have been replaced since 2002.

1.5.2 FORESTRY WORK

1.5.2.1 UPLAND FORESTS

Shortly after acquisition by State Parks, stands initiated between 1980 and 1993 were identified as having the highest priority for restoration because of extremely high tree densities and the dynamic nature of this age class (Stillwater Sciences 2002). Stands in this age class that had not been thinned were surveyed and prioritized for treatment. Survey results of trees more than 4 cm (1.5 in) diameter at breast height showed that 62 stands totaling 1,418 ha (3,503 ac) had more than 202 trees per hectare (tph) (500 trees per acre [tpa]). Old-growth redwood forests (by comparison) average approximately 13 tph (32 tpa) (Guisti 2004).

Stands with more than 202 tph (500 tpa) were chosen for treatment because they have formed (or will shortly form) closed canopies, and trees will lose a large portion of their crown foliage to shading from neighboring trees. As the crowns of these trees shrink, so does their ability to grow quickly even if more resources are made available by removing competing vegetation. Untreated stands may even stagnate, and forest health could be compromised, causing whole stands to be lost to windthrow (Oliver and Larson 1996). By failing to manage these forests immediately, managers may slow the growth of all trees and delay the development of late-successional conditions by decades.

To date, State Parks has treated 1,316 ha (3,252 ac) in this age class and has an additional 100 ha (248 ac) permitted. The primary goal of these treatments is to protect park resources by promoting forest health and accelerate the development of old forest characteristics in formerly harvested stands. The following four objectives support this goal:

- Release trees in young stands to allow for vigorous growth and progression toward late-successional forest habitat.
- Adjust species composition to promote the historic species mix.
- Reduce the short-term fire risk generated by restoration activities.

- Protect rare habitats in the MCA.

1.5.2.2 RIPARIAN FORESTS

Approximately 80 ha (200 ac) of riparian areas that were historically conifer stands were converted to alder dominance during logging operations. State Parks planted more than 10,000 conifers to promote the historic species mix of these areas. Long-term goals include restoring historic species composition, improving riparian canopy cover and associated riparian habitat, and recruiting large woody debris into streams to restore complexity to simplified watercourses.

1.5.3 INSTREAM WORK

Restoration of historic floodplain areas along the East Fork, although possible, may be difficult and costly to implement. Therefore, recruitment of large woody debris to create pools is the primary means by which velocity refugia can be created in the East Fork. Presently, natural wood recruitment on the East Fork is primarily from riparian alders, which provide habitat of limited quality and short duration (less than 6 years) (Fiori 2004). Instream recruitment from riparian conifer planting efforts on the East Fork is anticipated to take at least 40 years. The interim solution has been the initiation of a large-scale instream habitat improvement project involving the construction of complex wood jams in shallow flatwater and riffle habitat of the East Fork. Since 2006, numerous complex wood jams have been created in the East Fork (Fiori et al. 2009). They are much more complex than traditional large woody debris structures and not only have produced and maintained shallow pools with scour depths of 2 to 3.5 feet but have added a significant large woody debris and small woody debris cover component (Fiori et al. 2009).

1.6 SOURCES OF EXPERTISE AND INFORMATION

The Mill Creek Advisory Committee and Redwood National and State Parks, including public land managers, nonprofit environmental organizations, and public interest groups, provide expertise to help State Parks manage the MCA. University researchers and scientists from public agencies (e.g., USGS, NRCS) have provided or are anticipated to provide useful information with respect to watershed management.

1.6.1 MILL CREEK ADVISORY COMMITTEE

Members of the Mill Creek Advisory Committee include representatives from CDFG, the Save the Redwoods League, the California Coastal Conservancy, the California Wildlife Conservation Board, the Del Norte County Board of Supervisors, and Redwood National Park. Members of the committee provided input for the data needs of this plan and provided comment on the document.

1.6.2 REDWOOD NATIONAL AND STATE PARKS STAFF

In a cooperative relationship with the former timberland owners of the MCA, USGS hydrologists and/or Redwood National Park hydrologists monitored stream channel conditions and commented on timber harvest plans in Mill Creek. Madej et al.'s (1986) work provided substantial background information for hydrological processes affecting Mill Creek. The MCA is in the congressional boundary for Redwood National Park and thus within the management sphere of Redwood National and State Parks. As a result, members of Redwood National and State Parks' natural resource staff are available to provide expertise as requested by State Parks.

1.7 PUBLIC OUTREACH

During the GPA process, meetings were held to receive public input regarding management of the MCA. This watershed management plan is tiered to the GPA, and the major concepts for this plan were discussed or available for public input. Providing education and interpretation opportunities is one of the core functions of State Parks, and water quality and related watershed restoration efforts will be an educational focus at the MCA.

1.7.1 SIGNAGE

Interpretive signage will follow State Parks policy and guidelines with respect to the Department Operations Manual chapter on interpretation, as well as state Americans with Disabilities Act guidelines. Potential signage locations include trailheads, wayside exhibits, viewsheds, and the proposed lodge and interpretive center. Some of the signs will address water quality issues and will be both advisory with respect to visitor behavior and educational with respect to restoration efforts.

1.7.2 EDUCATION

Many opportunities exist to explore cultural and natural resources associated with the Mill Creek watershed. They would be delivered personally by staff or volunteers or by way of various media, including brochures, signage, audio/visual presentations, online information, tours, and workshops. Videos showing forest and instream restoration and road removal on the MCA, prepared in cooperation with the Save the Redwoods League, were recently completed. Media would be developed for inclusion whether placed in a contact station or as part of an interpretive exhibit. Subject areas for future education and interpretive programming and project development could include the latest research on instream restoration, road removal, forest restoration, and climate change, as well as wildlife species and plant communities (with particular emphasis on native and endangered species). Education through community involvement, such as tree planting, is ongoing. Similarly, subject areas related to cultural history would be developed for educational and interpretive projects. Subjects would cover the broadest spectrum of history at the MCA and general surrounding area, from the earliest pre-EuroAmerican contact period, through the 19th-century timber industry practices, up to today's restoration efforts.

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2 PROBLEM STATEMENT

View from the Rock Creek watershed. Source: Photograph taken by AECOM in 2010

2.1 INTRODUCTION

The Smith River Basin, in which most of the Mill Creek Addition (MCA) is located, is not listed as impaired for water quality by state and Federal regulatory agencies. Compared to that of many other North Coast basins, the geology of the Smith River Basin is relatively stable, which helps to maintain the river's water quality. Minor portions of the MCA drain toward the Klamath River, which has water quality impairments, and toward the coastal waters offshore from Redwood National State Parks (RNSP).

In general, the water quality in the MCA is very good; however, because historic logging on the property has been extensive, maintenance of existing conditions, where acceptable, and restoration of affected lands are required to preserve the MCA's water quality and high-value fishery. This chapter defines existing regulatory requirements and specific problem areas and describes existing and desired conditions for road, forest, and aquatic habitat management in the context of park management for recreational use and environmental restoration.

2.2 WATER QUALITY STANDARDS

CalWater, a spatial dataset of watersheds in California, developed by the Interagency Watershed Mapping Committee, is used to facilitate statewide consistency in the identification of watershed areas and is useful for discussing regulatory issues; however, any particular enumerated watershed does not necessarily encompass the entire physiography of that watershed. Figure 2-1 shows CalWater 2.21 watershed identification numbers and hydrologic subareas (HSAs) where defined for the enumerated watershed within the MCA boundaries. Where an HSA is not defined, the hydrologic area (HA) is noted. In this example, the Smith River Plain and Mill Creek HSAs are part of the Lower Smith River HA, and the Lower Smith River HA, the South Fork Smith River HA, and the Wilson Creek HA are part of the Smith River Hydrologic Unit (HU), although Wilson Creek actually flows directly to the ocean. The northwesternmost sliver of the MCA, in the Smith River Plain HSA (1103.110002), has headwater drainages that flow toward the coastline just south of the Crescent City Harbor. These coastal receiving waters are part of the RNSP Area of Special Biological Significance), (renamed the RNSP State Water Quality Protection Area in 2003) and have nonpoint source pollution protection. The two locations enumerated as part of the Klamath Glen HSA are part of the Lower Klamath HA, which is part of the Klamath River HU.

There are no Total Maximum Daily Load (TMDL) criteria for the Smith River Basin and, by extension, most of the MCA. However, the State Water Resources Control Board and the U.S. Environmental Protection Agency recently approved a TMDL report (NCRWQCB 2010) addressing water quality impairments related to temperature, dissolved oxygen, nutrients, and microcystins (cyanobacterial toxins) in the Klamath River in California. To address these impairments, an action plan for the Klamath River Basin and a site-specific action plan for dissolved oxygen on the mainstem have been completed. The Klamath River is also federally listed as sediment impaired downstream from its confluence with the Trinity River; sediment will be indirectly addressed through the action plan and existing regulations for nonpoint source pollution, although it could be addressed specifically at a later date (Zabinsky, pers. com, 2010). For both the Smith River and the Klamath River basins and the HSAs in those basins, the North Coast Regional Water Quality Control Board (NCRWQCB) has developed a list of beneficial uses and numeric targets to protect those uses that are pertinent to the MCA. Nearby coastal waters also have water quality objectives.

Mill Creek Addition
Watershed Management Plan

California State Parks
North Coast Redwoods District

Figure 2-1
CalWater 2.21 Watershed Polygons

2.2.1 BENEFICIAL USES

The Water Quality Control Plan for the North Coast Region (Basin Plan) (NCRWQCB 2011) identifies existing and potential beneficial uses for HAs and HSAs of the Smith River and Klamath River HUs (Table 2-1).

Table 2-1
Beneficial Uses of Water in CalWater Hydrologic Areas and Subareas That Encompass the Mill Creek Addition

Beneficial Use	Smith River Plain HSA (103.11)	Mill Creek HSA (103.13)	South Fork Smith River HA (103.20)	Wilson Creek HA (103.50)	Klamath Glen HSA (105.11)
Municipal Water Supply (MUN)	E	E	E	E	E
Agricultural Supply (AGR)	E	E	E	E	E
Industrial Supply (IND)	E	E	E	E	P
Industrial Process Supply (PRO)	P	P	P	P	P
Groundwater Recharge (GWR)	--	--	--	--	E
Freshwater Replenishment (FRSH)	E	E	E	E	E
Navigation (NAV)	E	E	E	E	E
Hydropower Generation (POW)	--	P	E	E	P
Water Contact Recreation (REC-1)	E	E	E	E	E
Non-Contact Water Recreation (REC-2)	E	E	E	E	E
Commercial and Sport Fishing (COMM)	E	E	E	E	E
Warm Water Habitat (WARM)	--	--	--	--	E
Cold Freshwater Habitat (COLD)	E	E	E	E	E
Wildlife Habitat (WILD)	E	E	E	E	E
Rare, Threatened or Endangered Species (RARE)	E	E	E	E	E
Marine Habitat (MAR)	E	--	--	--	E
Migration of Aquatic Organisms (MIGR)	E	E	E	E	E
Spawning, Reproduction, and/or Early Development (SPWN)	E	E	E	E	E
Shellfish Harvesting (SHELL)	--	--	--	--	E
Estuarine Habitat (EST)	E	--	--	--	E
Aquaculture (AQUA)	P	P	P	P	P
Native American Culture (CUL)	E	--	E	E	E

Notes: HA = hydrologic area, HSA = hydrologic subarea, E = existing use, P = potential use, -- = no beneficial use.
Source: NCRWQCB 2011

It should be noted that each identified use may not actually be occurring in the MCA, but each has been identified in the hydrologic HA or HSA that crosses or is within the MCA boundaries. The full extent of any particular HSA or HA that extends outside of the MCA may not be depicted in Figure 2-1. Of particular interest for park management are uses related to recreation, wildlife conservation, and Native American cultural practices.

2.2.2 WATER QUALITY OBJECTIVES

The Basin Plan defines specific water quality objectives for the Smith River, the Klamath River, and coastal waters (Tables 2-2 and 2-3). The Lower Klamath River, west of the confluence of Terwar Creek and the Klamath River and within tribal lands, had relatively little data to help guide the TMDL action plan. This is partially because of the complexity of the estuary in the Lower Klamath River and the sovereign Native American control of the tribal lands that occupy most of the lower reach. To date, tribal water quality standards for Native American lands downstream from the MCA have not received approval from the U.S. Environmental Protection Agency. The NCRWQCB reviewed work from the tribal lands reach to help guide the TMDL targets for that region.

Table 2-2
Relevant Narrative Water Quality Objectives for the North Coast Region That Encompasses the Mill Creek Addition

Objective	Description
Biostimulatory substances	Waters shall not contain biostimulatory substances in concentrations that promote aquatic growths to the extent that such growths cause nuisance or adversely affect beneficial uses.
Sediment	The suspended sediment load and suspended discharge rate of surface waters shall not be altered in such a manner as to cause nuisance or adversely affect beneficial uses.
Turbidity	Turbidity shall not be increased more than 20 percent above naturally occurring background levels. Allowable zones of dilution within which higher percentages can be tolerated may be defined for specific discharges upon the issuance of discharge permits or waiver thereof.
Temperature	At no time or place shall the temperature of any COLD water be increased by more than 5°F above natural receiving water temperature.
Dissolved oxygen (Lower Klamath Estuary)	For the protection of estuarine habitat (EST), the dissolved oxygen content of the lower estuary shall not be depressed to levels adversely affecting beneficial uses as a result of controllable water quality factors.

Note: Except as noted for dissolved oxygen, these objectives apply to the entire North Coast Region.
Sources: NCRWQCB 2010, NCRWQCB 2011

Table 2-3
Numeric Water Quality Objectives for Areas Affected by or in the Mill Creek Addition

Water Body	Specific Conductance (micromhos) at 77˚F		Dissolved Oxygen (milligrams per liter)		Hydrogen Ion (pH)	
	90% Upper Limit[1]	50% Upper Limit[2]	Minimum	50% Lower Limit[2]	Maximum	Minimum
Smith River Hydrologic Unit						
Smith River - main forks	200	150	8.0	11.0	8.5	7.0
Other streams	150[3]	125[3]	7.0	10.0	8.5	7.0
Smith River Plain Hydrologic Subarea						
Smith River	200[3]	150[3]	8.0	11.0	8.5	7.0
Other streams	150[3]	125[3]	7.0	10.0	8.5	6.5
Groundwater	350	100	--	--	8.5	6.5
Lower Klamath River Hydrologic Area						
Klamath River	300[3]	200[3]	13	13.0[4]	8.5	7.0
Other streams	200[3]	125[3]	8.0	10.0	8.5	6.5
Groundwater	300	225	--	--	8.5	6.5
Coastal Waters	--	--	11	11[5]	12	12

Notes: -- = no water quality objective

1. Ninety-percent upper and lower limits represent the 90 percentile values for a calendar year. Ninety percent or more of the values must be less than or equal to a lower limit.
2. Fifty-percent upper and lower limits represent the 50 percentile values of the monthly means for a calendar year. Fifty percent or more of the monthly means must be less than or equal to an upper limit and greater than or equal to a lower limit.
3. Does not apply to estuarine areas.
4. The Klamath River Basin TMDL site-specific action plan contains narrative language for dissolved oxygen for the lower estuary (see Table 2-2). The site-specific action plan has the following numeric objectives for the middle and upper estuary based on natural receiving water temperatures: 80% dissolved oxygen saturation, August 1 through August 31; 85% dissolved oxygen saturation, September 1 through October 31 and June 1 through July 1; and 90% dissolved oxygen saturation, November 1 through May 31.
5. The 90% lower limit for dissolved oxygen for coastal waters, which is also the minimum acceptable level, is 11; these values are consistent with the California Ocean Plan.

Sources: State Water Resources Control Board 2005, NCRWQCB 2011

With respect to reaches downstream from the MCA, in addition to dissolved oxygen, the Klamath River TMDL expressed target allocations for temperature (NCRWQCB 2010). Specific numeric targets for nutrients were not allocated in this reach. For stream temperature, the allocation is based on effective shade. The target is equal to the shade provided by topography and full potential vegetation at a site, with an allowance for natural disturbances, such as floods, wind throw, disease, landslides, and fire. A series of curves outlining the target for effective shade based on stream bankfull width, site geometry, and vegetation characteristics helps to guide the desired condition.

Excess sediment can also degrade stream temperature. The temperature-related load allocation for human-caused discharges of sediment is zero temperature increase caused by substantial human-caused sediment-related channel alteration, defined as an alteration that increases channel width, decreases depth, or removes riparian vegetation to a degree that alters stream temperature dynamics or is caused by increased sediment loading. The instream target is 0 miles of substantial human-caused sediment-related channel alteration. The watershed targets are:

- less than 1% of all stream crossings divert or fail as a result of a 100-year or smaller flood, and
- the number of potential road-related landslide source areas decreases.

2.3 AQUATIC POPULATIONS AND PERIODICITY

Salmonids have received the most study among aquatic populations in the MCA, in part because they are Federally and state listed as threatened. Freshwater mussels may interact with salmonids and are indicators of water quality. The influence of other species on salmonids and the timing of salmonid presence in the watershed (periodicity) are important management considerations and are discussed in this section.

2.3.1 FISH POPULATIONS

Overall, the MCA fishery is robust but could be degraded if restoration lags the rate of road and slope decay. Given the general decline in the health of many fisheries in the Pacific Northwest, the MCA is a key location for the prospects of many fish species.

2.3.1.1 NONSALMONID POPULATIONS

Nonsalmonid fish species native to the Mill Creek watershed include western brook lamprey (*Lampetra richardsoni*), Pacific lamprey (*Lampetra tridentate*), prickly sculpin (*Cottus asper*), Coastrange sculpin (*Cottus aleuticus*), threespine stickleback (*Gasterosteus aculeatus*), and Klamath smallscale sucker (*Catostomus rimiculus*) (McLeod and Howard 2010). The river lamprey (*Lampetra ayresi*) has also been reported in the watershed, and the species' range includes the Lower Smith River. Difficulties in differentiating the three species of lamprey may warrant further investigation to determine species presence and range. Riffle sculpin (*Cottus gulosus*) was also reported in early Mill Creek outmigrant trap data, but this appears to be a misidentification of Coastrange sculpin because the Mill Creek drainage is well outside the reported range of the species (Howard and McLeod 2006, Howard and McLeod 2007).

Nonnative fish species have been reported in the Mill Creek watershed. Largemouth bass (*Micropterus salmoides*), black bass (*Micropterus* spp.), sunfish (*Lepomis* spp.), and catfish (Ictaluridae) were previously introduced into the 4.6-acre-foot reservoir, located northwest of the Forestry Center (Stowe, pers. com, 2002 in Stillwater Sciences 2002). Some of these species may still occur in the reservoir, but there is no outlet that would allow these fish to enter Mill Creek (Albro, pers. com, 2010), although failure of the reservoir could release these them to Mill Creek. American shad (*Alosa sapidissima*) is known to occur in the Smith River, and a juvenile shad was captured in the East Fork outmigrant trap in the late 1990s (Howard, pers. com, 2010).

2.3.1.2 SALMONID POPULATIONS AND INVENTORY METHODS

Mill Creek supports both anadromous and resident salmonid populations and is one of the most productive salmonid tributaries of the Smith River. The anadromous salmonids found in Mill Creek are Chinook salmon (*Oncorhynchus tshawytscha*), coho salmon (*O. kisutch*), steelhead (*O. mykiss irideus*), coastal cutthroat trout (*O. clarki clarki*), and occasionally chum salmon (*O. keta*). The extent of anadromy (anadromy describes fish that hatch and rear in freshwater, go to the ocean, and then return to freshwater to spawn) extends 8.9 kilometers (km) (5.5 miles [mi]) up the West Branch and 9.6 km (6 mi) up the East Fork and its tributaries.

Rock Creek supports anadromous populations of Chinook salmon and steelhead, as well as anadromous and resident populations of coastal cutthroat trout. Resident populations of coastal cutthroat trout are present in the upper reaches of the watershed, whereas the lower reaches likely support both resident and anadromous cutthroat.

Hybridization between coastal cutthroat trout and steelhead appears to be common in northern California streams (Hankin et al. 2009) and likely occurs in Mill Creek to some degree. Genetic studies in other coastal northern California streams have shown the proportion of "trout" determined to be hybrids ranged between 16% and 72% (Hankin et al. 2009).

Fisheries monitoring has been conducted in the Mill Creek watershed since 1980. In 1994, a comprehensive salmonid fisheries monitoring program was initiated in Mill Creek by Stimson Lumber Company (Stimson) in response to the anticipated Federal listing of the southern Oregon/northern California coast (SONCC) coho salmon Evolutionarily Significant Unit (ESU). This program also included spawning surveys in a short section of Rock Creek. Upon transfer of the MCA to the California Department of Parks and Recreation (State Parks) the Mill Creek Fisheries Monitoring Program was created. The program has continued without interruption and expanded on all fisheries monitoring activities previously undertaken by Stimson and the University of California Cooperative Extension. It has been funded through various sources, including the Smith River Alliance, the California Department of Fish and Game, the U.S. Fish and Wildlife Service, and the U.S. Forest Service. Annual monitoring conducted by the Mill Creek Fisheries Monitoring Program includes Chinook and coho salmon spawner surveys, smolt outmigrant trapping, and summer dive surveys. The program is in jeopardy because funding is uncertain.

Coho Salmon

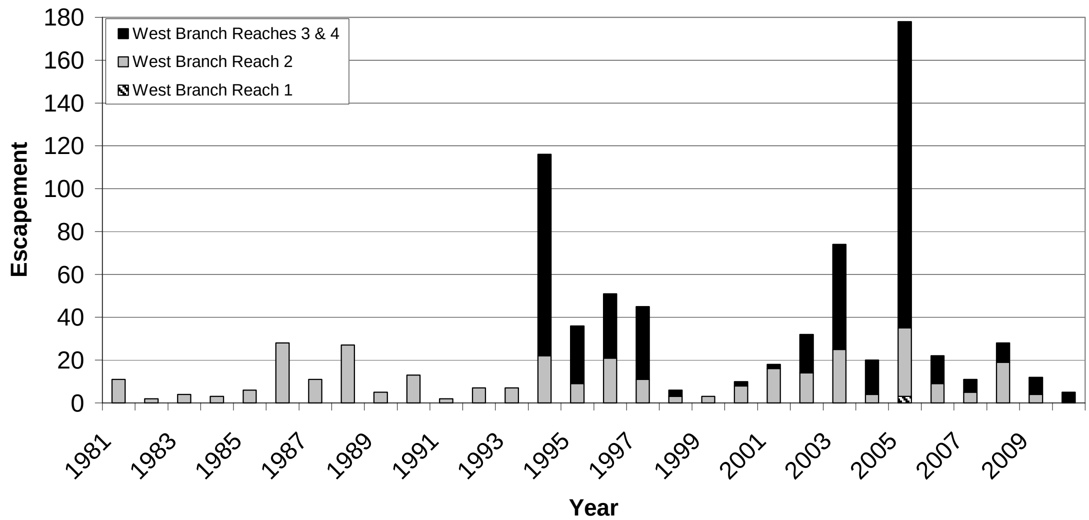
Coho salmon are the only listed fish species found in the Mill Creek watershed. All naturally spawned populations of coho salmon in the watershed belong to the SONCC

ESU, which was Federally listed as threatened in 1997 (62 *Federal Register* 62:24588-24609, May 6, 1997) and reaffirmed in 2005 (70 *Federal Register* 70:37160-37204, June 28, 2005). Critical habitat for the SONCC coho salmon ESU was designated in 1999 (64 *Federal Register* 64:24049-24062, May 5, 1999) to encompass the water, substrate, and adjacent riparian zone of all accessible estuary habitat and river reaches between Cape Blanco, Oregon, and Punta Gorda, California. This area includes all waters accessible to coho in the MCA. The California Department of Fish and Game recommended that the SONCC coho salmon ESU be listed as threatened under the California Endangered Species Act in 2002, and in 2004, the agency recommended that coho salmon status and trend monitoring be a high priority throughout the state (CDFG 2004). In 2005, the California Fish and Game Commission listed the SONCC coho salmon ESU as threatened.

Coho salmon have a less variable life history than other anadromous salmonids. Most return to spawn at age 3+ and enter the rivers during late fall and winter. Eggs mature after 1.5 to 4 months of incubation, depending on temperature. Juveniles rear in freshwater for up to 15 months before outmigrating to the ocean. Before returning to spawn as adults, coho generally spend 16 months feeding and growing in the ocean (Sandercock 1991). Some males (often called “jacks”) mature earlier and return after only a few months in the ocean. Bell (2001) has documented that some juvenile coho salmon in northern California may rear in freshwater for two winters before migrating to sea. Size distribution data of coho 0+ and smolts captured in Mill Creek suggests that this life history strategy may be present (McLeod, pers. com, 2011)

Coho salmon minimum escapement counts have been generated for the West Branch since Water Year (WY) 1981 (Figure 2-2) and in the East Fork since WY 1994 (Figure 2-3). Annual escapement estimates have often been fewer than 20 fish for either tributary, but in some years, the numbers have been significantly higher. Data suggest that coho escapement seems to cycle every 8–11 years, with low points in 1983, 1992, 2000, and 2010 in the West Branch (Figure 2-2). Data from the East Fork show a similar pattern between 1994 and 2010 (Figure 2-3). Although adult coho salmon escapement is often fairly low, available spawning habitat apparently is not a limiting factor (Stillwater

Sciences 2006). The lack of a strong relationship between outmigrating smolt populations and escapement estimates for that same cohort 2 years later suggests that shifts in ocean productivity may be the most likely contributor to the observed fluctuations in coho escapement (McLeod and Howard 2010).



Note: Reach 1 is 0 to 0.80 km (0 to 0.50 mi) upstream from the confluence with the East Fork, reach 2 is 0.80 to 3.54 km (0.50 to 2.20 mi) upstream, reach 3 is 3.54 to 7.97 km (2.20 to 4.95 mi) upstream, and reach 4 encompasses the lower 0.4 km (0.25 mi) of Hamilton Creek. Hamilton Creek meets the West Branch about 1.17 km (0.73 mi) upstream from its confluence with the East Fork. Estimates for 1981–1993 are for West Branch reach 2 only (Howard 1998). West Branch reach 1 data were collected between 2005 and 2010.

Figure 2-2. Coho Salmon Minimum Escapement Estimates for the West Branch (Water Years 1981–2010)

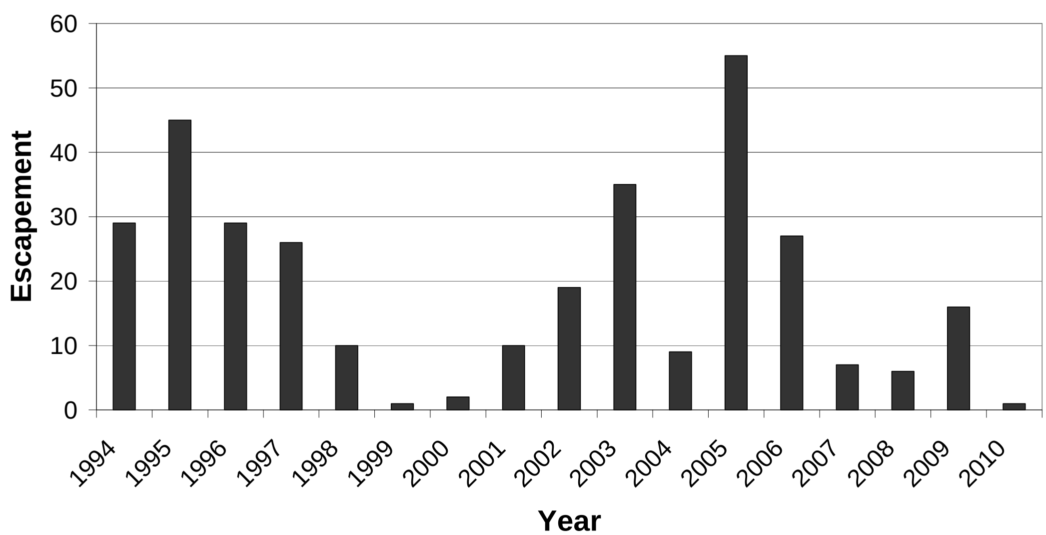


Figure 2-3. Coho Salmon Minimum Escapement Estimates for the East Fork (Water Years 1994–2010)

Coho salmon escapement into Mill Creek appears to be adequate in most years to produce more than enough 0+ juveniles to saturate the summer habitat and exceed the current winter carrying capacity of the system. Summer abundance estimates of 0+ coho have been generated for the West Branch (1996–1997 and 2001–2009) and East Fork (1996 and 2004–2009) (McLeod and Howard 2010). West Branch summer coho abundance has varied considerably, ranging from fewer than 5,000 fish to almost 25,000 fish, whereas the East Fork has shown less variation, ranging from just fewer than 3,000 fish to more than 12,000 fish. In general, the West Branch has had two to three times the summer coho population of the East Fork (Figure 2-4). However, estimated juvenile coho abundance was higher in the East Fork during 2009, which may be a response to increased summer rearing habitat provided by recent complex wood jam placement in the East Fork.

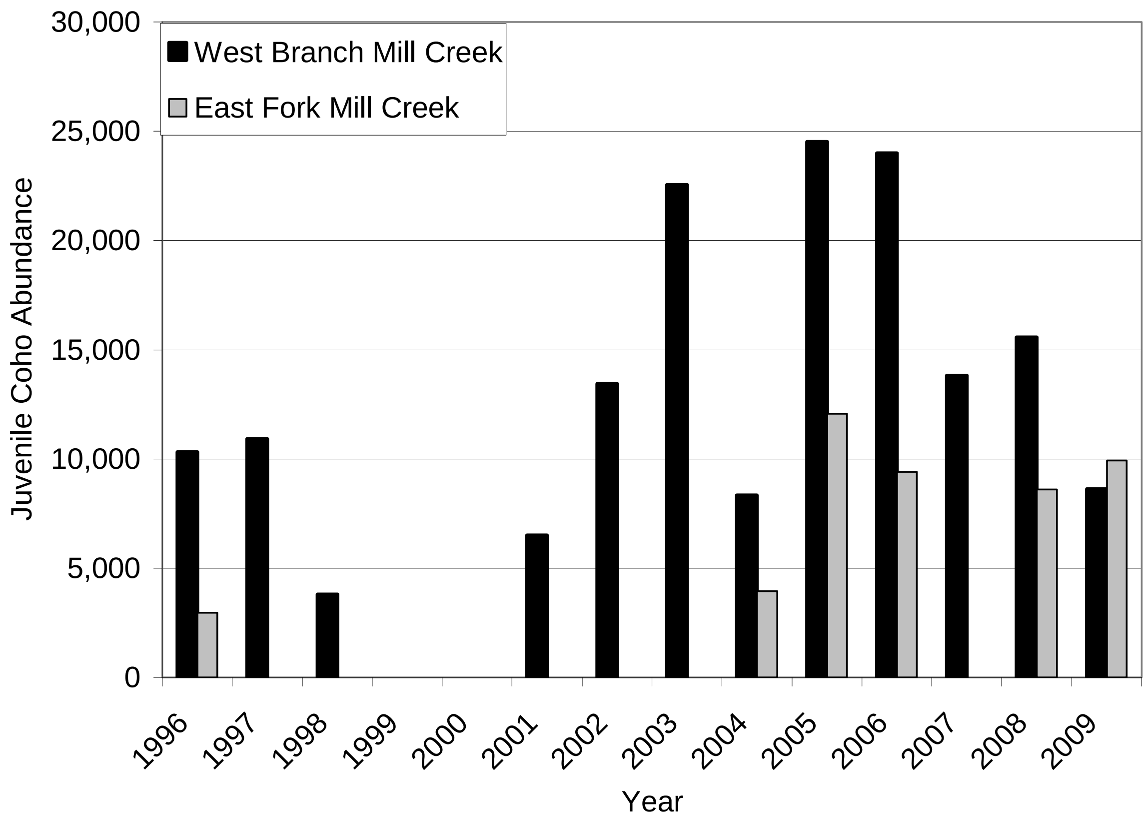


Figure 2-4. Summer Abundance Estimates of Coho in the West Branch (Water Years 1996–1998 and 2001–2009) and East Fork (Water Years 1996, 2004–2009)

Juvenile salmonid outmigrant trapping was conducted in the East Fork and West Branch between 1994 and 2000 (McLeod and Howard 2010). Downstream movement of both smolt and young-of-the-year coho salmon has been observed, suggesting that both extended rearing and seasonal downstream dispersal of coho salmon occur in the Mill Creek drainage. Outmigrating coho smolts have been observed from late February through early July, with most movement occurring from mid-April to mid-May (Howard and McLeod 2005a, 2005b, 2005c). The total number of outmigrating smolts varied annually, with the West Branch consistently producing more smolts annually (except during 1994). Smolt production estimates for the West Branch were the lowest in 2005 (763 smolts) and highest during 2001 (10,821 smolts). Estimated smolt production in the East Fork was the lowest in 1999 (259 smolts) and highest in 2001 (3,184 smolts) (Figure 2-5).

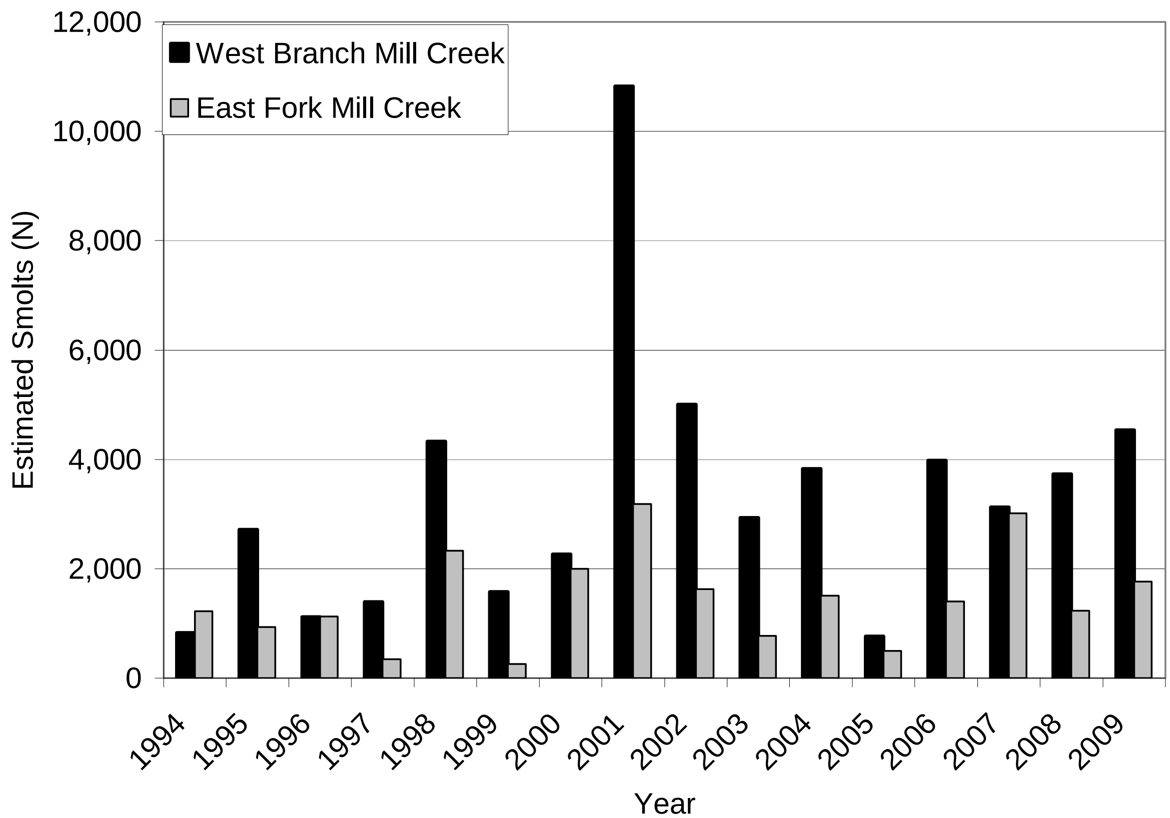


Figure 2-5. Coho Smolt Outmigration Estimates for the West Branch and East Fork (Water Years 1994–2009)

Coho overwinter survival estimates have varied annually in both the West Branch and East Fork and appear to be directly related to the availability of refugia from high-flow events. Overwinter survival estimates ranged from 9% to 77% (mean 27%) in the West

Branch and from 12% to 57% (mean 19%) in the East Fork (McLeod and Howard 2010). An analysis by Stillwater Sciences (2006) determined that suitable overwintering habitat for juvenile coho is the primary limiting factor for populations in Mill Creek, especially the East Fork. Limited overwintering habitat and variable ocean conditions may further exact a toll on the population and have the potential to keep the returning adult population at relatively low numbers. When a cohort is subjected to both excessive winter flows and unfavorable ocean conditions, escapement could potentially be reduced to only a few fish.

Chinook Salmon

Chinook salmon in the Mill Creek watershed are fall-run and belong to the SONCC ESU. This ESU was found not warranted for Federal listing as threatened or endangered by the National Marine Fisheries Service (NMFS) in 1999 (64 *Federal Register* 64:24049-24062, May 5, 1999). Fall Chinook generally spawn in Mill Creek between November and January but occasionally as late as February/March (Waldvogel 1988). Fry emerge in early winter after 75–95 days of incubation (Van Scoyk, pers. com, 2010). Juveniles remain in freshwater for 3–6 months before outmigration (Meehan and Bjornn 1991) and rear in estuaries until they move into the marine environment following smoltification. Chinook salmon spawn and rear in both Mill and Rock creeks (McLeod and Howard 2010).

Adult escapement trends for the West Branch and East Fork show that overall adult Chinook escapement, although variable, appears to be maintaining itself (Figure 2-6). Minimum escapement estimates in the West Branch ranged between 31 and 694 (average 171) since 1981. Escapement estimates for the East Fork ranged between 20 and 333 (average 172) during surveys from 1993 and 2009. Population modeling results from Stillwater Sciences (2006) indicate that spawning habitat is not a limiting factor and that the West Branch could support up to 350 female spawners and the East Fork up to 140 female spawners before density dependence would occur.

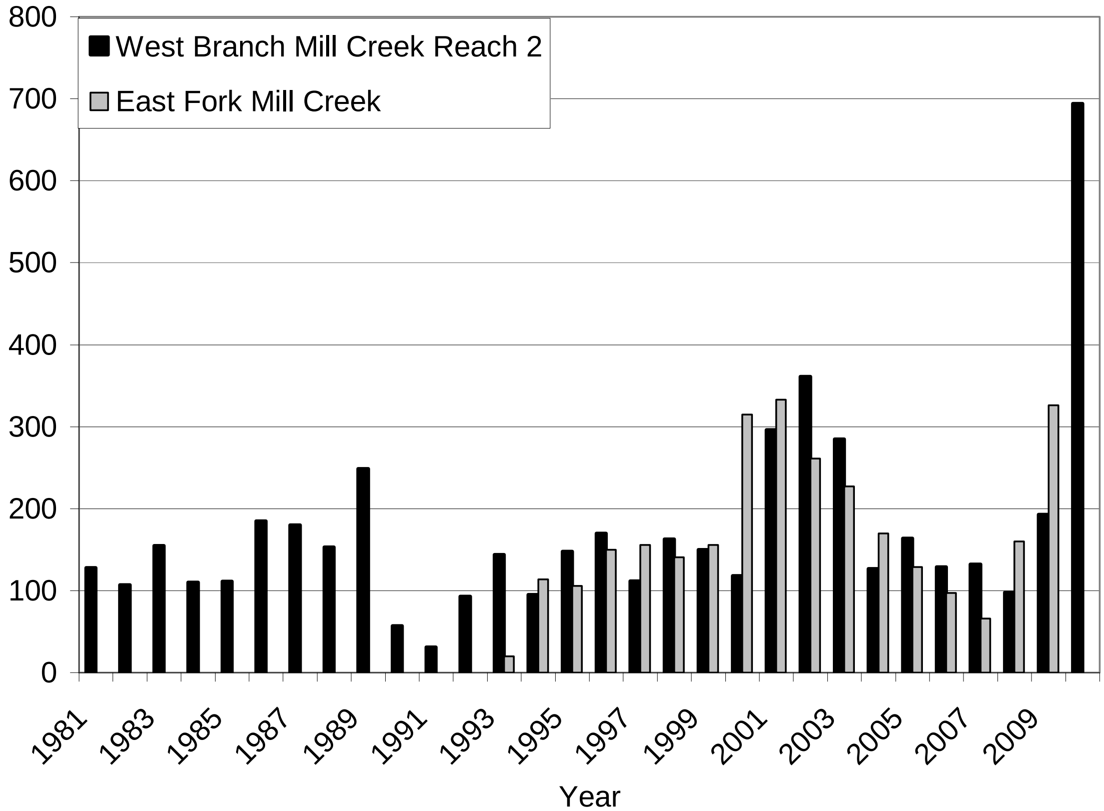


Figure 2-6. Chinook Salmon Minimum Escapement Estimates for the West Branch (Water Years 1981–2010) and East Fork (Water Years 1993–2009)

Although spawning habitat may not be a limiting factor for fall-run Chinook in Mill Creek, available habitat for emergent fry and juveniles during spring has been identified as density dependent (Stillwater Sciences 2006). Outmigrating juveniles captured in Mill Creek consist almost entirely of young-of-the-year fish, but occasionally 1+ fish are captured, indicating that some extended rearing does take place in the basin. Juvenile Chinook salmon outmigration generally peaks between early April and early May, depending on flows, and most fish have usually left the system by late July (Howard and McLeod 2005a, 2005c). Most outmigrating Chinook salmon are captured in the West Branch. Estimates have been highly variable since monitoring began in 1994, ranging between 7,589 and 141,136 (Figure 2-7) (McLeod and Howard 2010). Outmigration estimates from the East Fork were less variable than those from the West Branch, ranging between 2,778 and 46,600 since 1994.

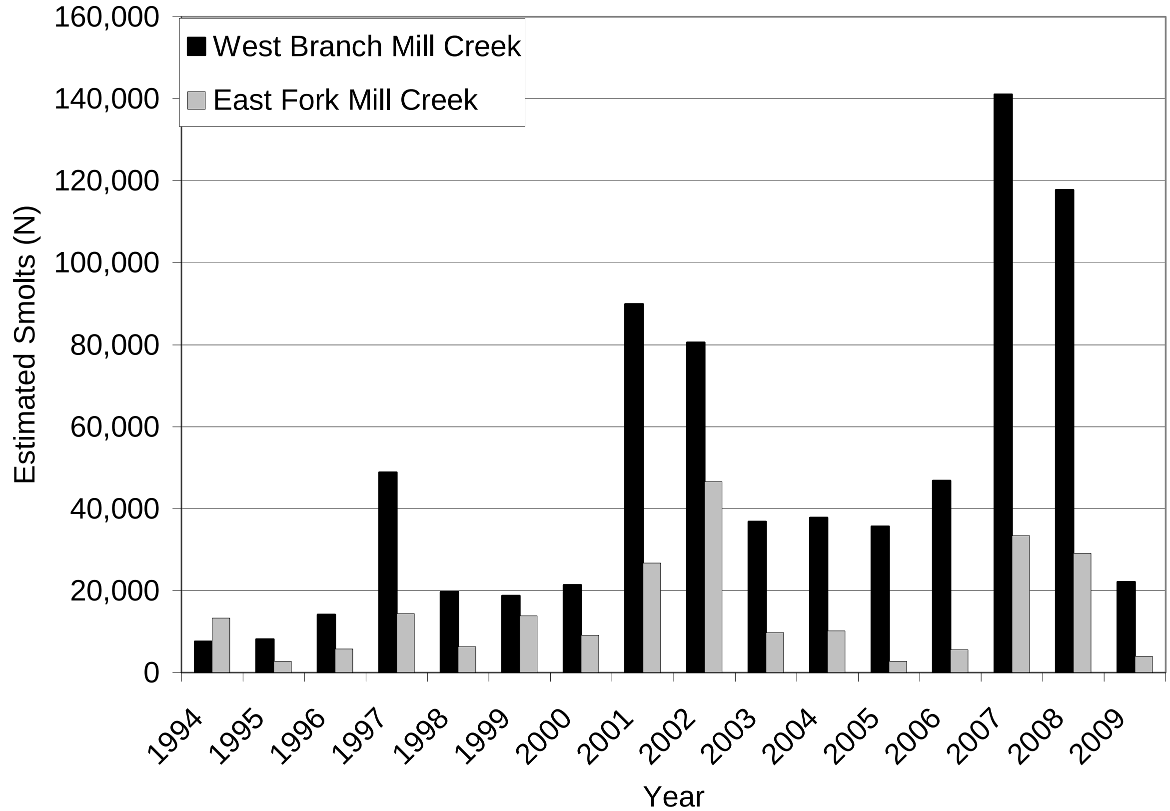


Figure 2-7. Chinook Smolt Outmigration Estimates for the West Branch and East Fork (Water Years 1994–2009)

Steelhead

Steelhead in the Mill Creek watershed are winter-run populations. All naturally spawned populations of steelhead in Mill Creek belong to the Klamath Mountains Province ESU. This ESU was found not warranted for Federal listing as threatened or endangered by NMFS in 1999 (64 *Federal Register* 64:24049-24062, May 5, 1999). Overall, the steelhead population in Mill Creek appears to have declined slightly in recent years.

Steelhead escapement has not been monitored in the Mill Creek watershed. Postspawning adult steelhead ("kelts") are captured in outmigrant traps, and the number of kelts observed has ranged from 8 to 82 in the West Branch and from 25 to 82 in the East Fork (Albro and Gray 2001) (Figure 2-8). Based on the number of kelt catches, overall adult escapement in both tributaries appears variable, and kelt catches have been slightly below average in both tributaries since 2006.

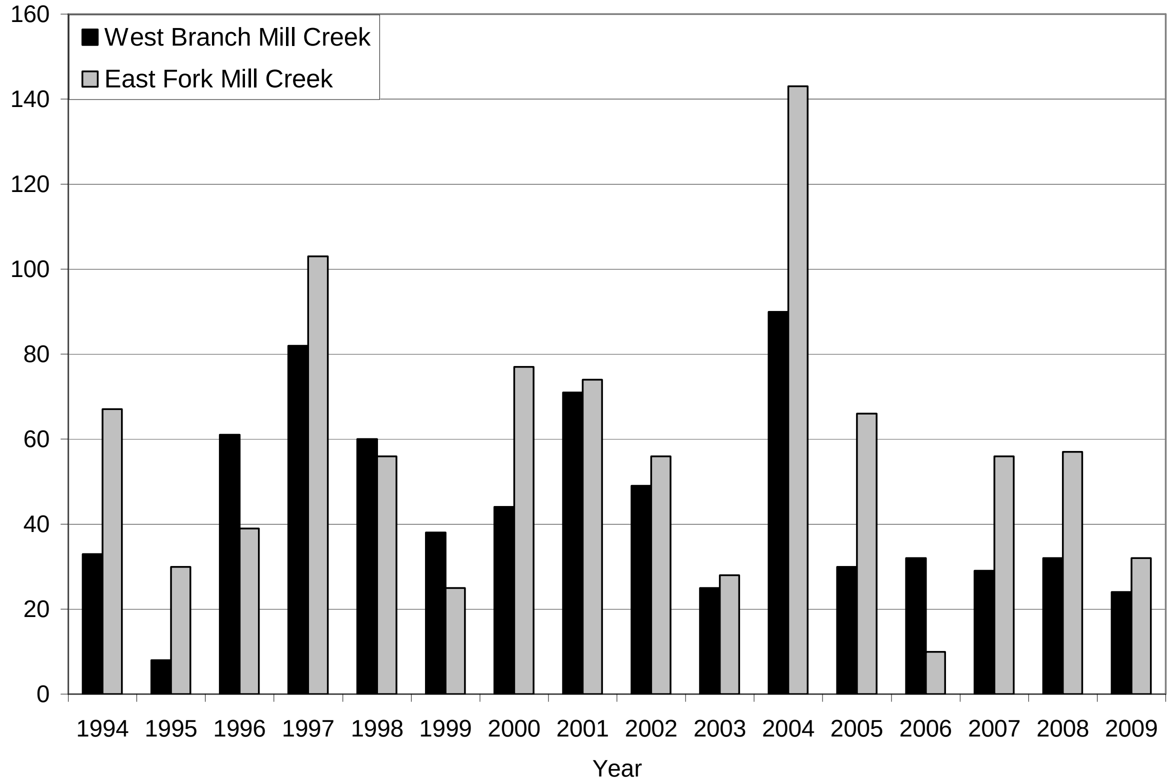


Figure 2-8. Steelhead Kelt Catches in Outmigrant Traps in the West Branch and East Fork (Water Years 1994–2009)

All juvenile life stages of steelhead (from fry to smolt) have been observed in the outmigrant traps, indicating that extended freshwater rearing occurs in the watershed. Because distinguishing between juvenile steelhead and coastal cutthroat trout is difficult, counts of juvenile steelhead captured may include cutthroat trout. Steelhead smolts are captured in the outmigration traps from late February through June (McLeod, 2010a) and have been highly variability since trapping began in 1994 (Figure 2-9). Mean annual smolt production since 1994 was 1,818 in the West Branch and 953 in the East Fork. Outmigration estimates have been below average since 2003.

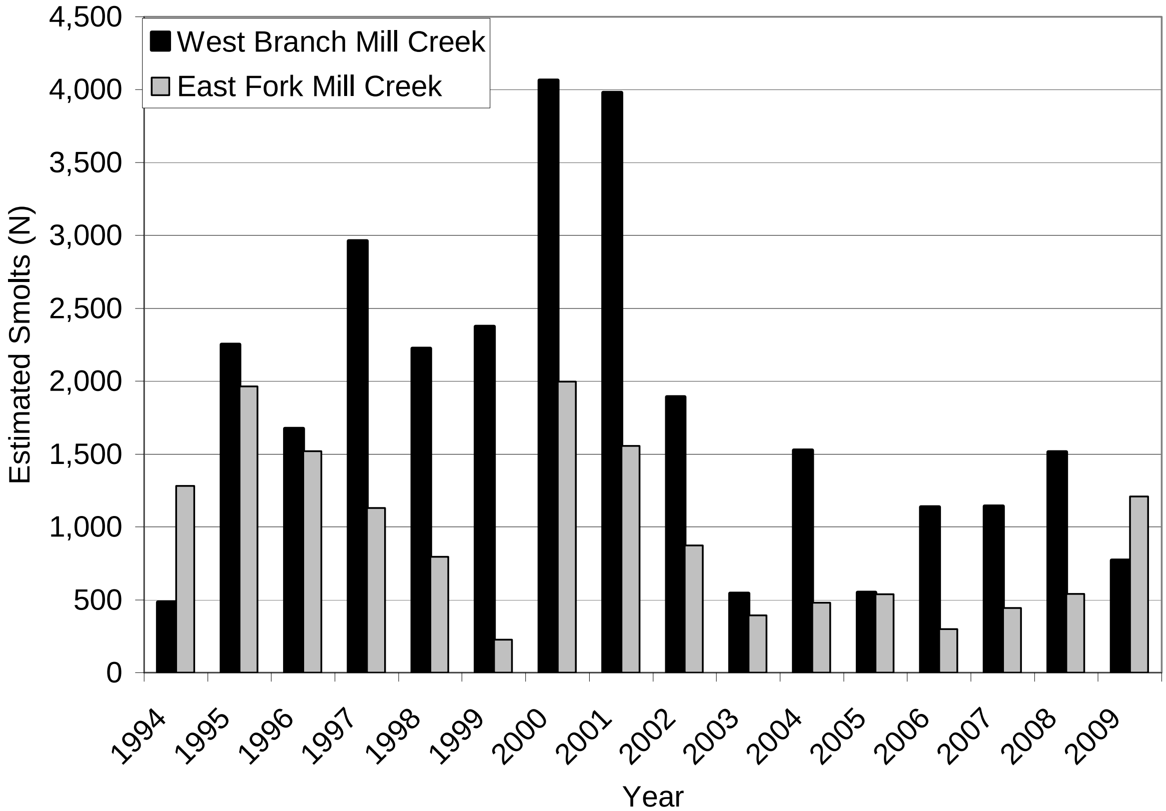


Figure 2-9. Steelhead Smolt Outmigration Estimates for the West Branch and East Fork (Water Years 1994–2009)

Coastal Cutthroat Trout

Mill Creek and its tributaries support both anadromous and resident populations of coastal cutthroat trout. All populations of coastal cutthroat trout in the Mill Creek watershed belong to the SONCC ESU. This ESU was found not warranted for Federal listing as threatened or endangered by NMFS in 1999 (64 *Federal Register* 64:24049-24062, May 5, 1999). Overall, current information indicates that the coastal cutthroat trout population in the Mill Creek watershed is fairly stable.

Cutthroat trout belong to the same genus as other Pacific salmon and steelhead but are generally smaller, rarely overwinter in the ocean, and do not make extensive oceanic migrations (Johnson et al. 1999). They exhibit both anadromous and resident life-history forms. Resident fish are often found in the uppermost reaches of drainages, above barriers to anadromous fish migration. The Smith River is considered an important coastal cutthroat trout stream because the species has been reported to occur in nearly all of its tributaries, including Mill Creek (Moyle et al. 1989).

Cutthroat trout escapement has not been monitored in Mill Creek because of the difficulty in observing and counting the species when they return to spawn (McLeod and Howard 2010). A few adult cutthroat have been observed incidentally each year during salmon spawning surveys (Howard 1999, McLeod and Howard 2010). Most information on the adult cutthroat population of Mill Creek is obtained from outmigrant trapping data (Figure 2-10). Cutthroat trout in Mill Creek generally begin spawning in November, with peak spawning occurring in January and February (Howard and Albro 1995, 1997). Based on outmigrant trap trout fry catches, cutthroat apparently spawns as late as May in the watershed (McLeod, pers. com, 2011).

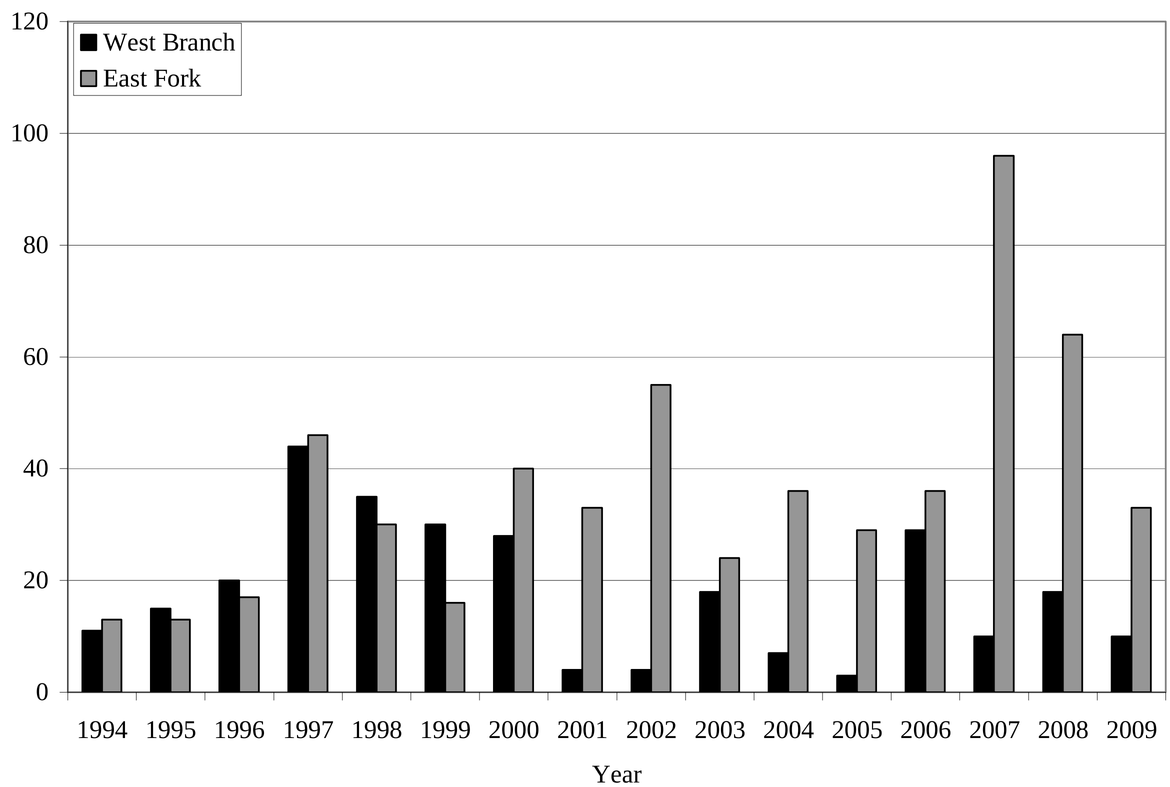


Figure 2-10. Adult Coastal Cutthroat Trout Catches in Outmigrant Traps on the West Branch and East Fork (Water Years 1994–2009)

All life stages of cutthroat trout (i.e., fry, juveniles, smolts, and adults) have been captured during outmigration trapping in both the East Fork and West Branch. Because distinguishing between juvenile steelhead and coastal cutthroat trout is difficult, counts of juvenile cutthroat captured may include steelhead trout. Nonsmolting juvenile cutthroat trout captured in the outmigrant traps may be outmigrating to estuarine or ocean habitats or simply dispersing in the river system. Cutthroat trout smolts in Mill Creek outmigrate over an extended period, from late March through early July, with irregular peaks in late April or early May (Howard and McLeod 2005a, 2005c). Since monitoring began, cutthroat smolt populations appear to have varied on about a 5- or 6-year cycle, and the populations appear similar between tributaries (Figure 2-11). Outmigration estimates have ranged from 469 to 2,178 in the West Branch and from 314 to 1,867 in the East Fork.

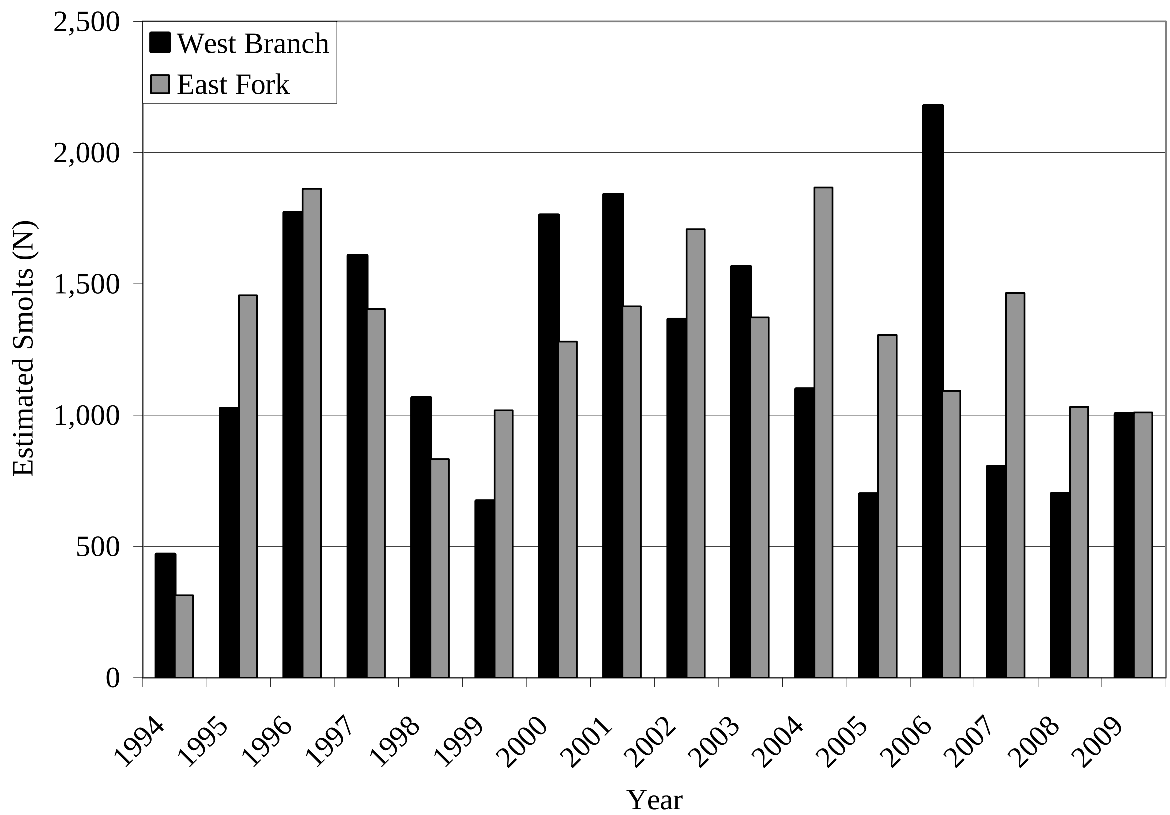


Figure 2-11. Coastal Cutthroat Smolt Outmigration Estimates for the West Branch and East Fork (Water Years 1994–2009)

Chum Salmon

Chum salmon were first documented in Mill Creek in 1984 and are highly variable and inconsistent in spawning. Chum salmon spawning in Mill Creek may represent episodic colonization from more northern populations. Chum salmon usually spawn in the lowermost reaches of streams, constructing redds in mainstem reaches or side channels from just above tidal influence to nearly 100 km (62 mi) from the sea. All naturally spawned populations of chum salmon in the Mill Creek watershed belong to the Pacific Coast ESU. This ESU was found not warranted for Federal listing as threatened or endangered by NMFS in 1999 (64 *Federal Register* 64:24049-24062, May 5, 1999).

2.3.2 SALMONID HABITAT

Approximately 19 km (12 mi) of known spawning and rearing habitat are used by anadromous salmonids in the Mill Creek watershed (McLeod and Howard 2010). Steelhead frequently migrate upstream of barriers that would hinder Chinook and coho salmon, and resident cutthroat are present above most anadromous barriers in the watershed.

2.3.2.1 COHO SALMON

Coho salmon have been found in most major tributaries and in most of the 19 km (12 mi) of known anadromous habitat in Mill Creek. Surveys conducted in the mainstem Mill Creek have found little evidence of spawning coho; however, high flows and limited visibility hinder the detection of spawners. Most spawning occurs in the West Branch, although the East Fork also provides considerable spawning habitat (McLeod and Howard 2010). Coho salmon have not been observed in Rock Creek since annual spawning surveys were initiated in 1993 (McLeod and Howard 2010). The high gradient and coarse substrate typical of Rock Creek is likely unfavorable for coho salmon.

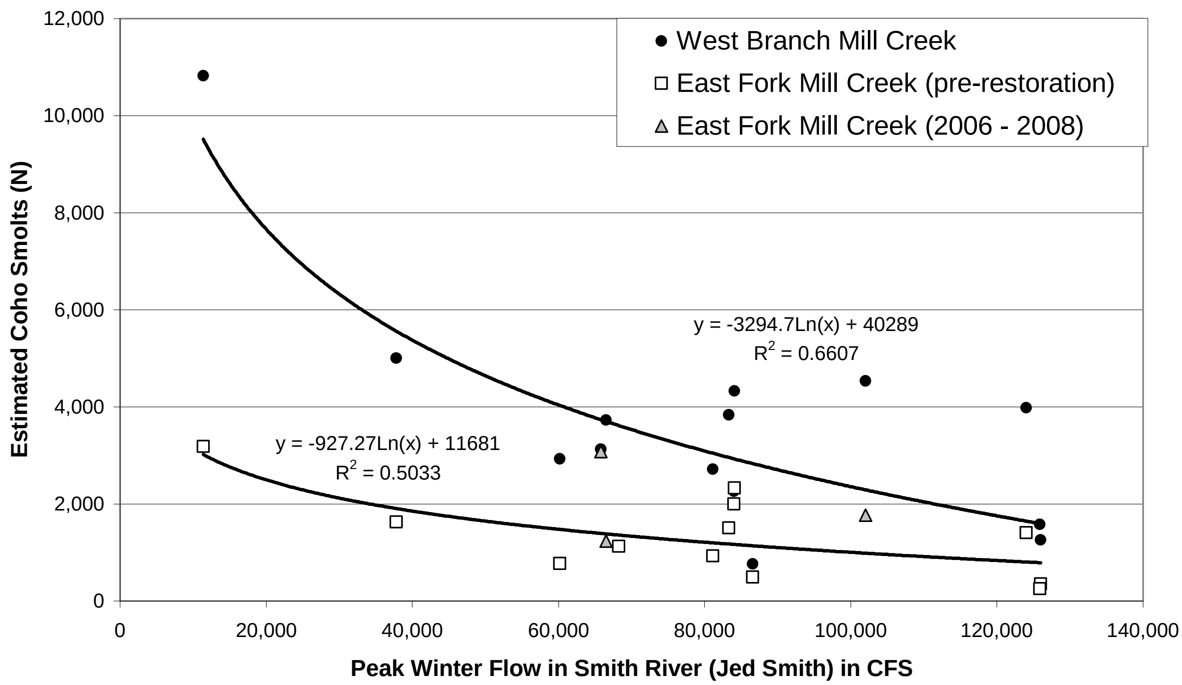
Since the initiation of fisheries monitoring in Mill Creek in 1994, estimates of juvenile coho salmon summer populations for the West Branch have been two to three times greater than those for the East Fork (McLeod and Howard 2010). The West Branch may be more productive than the East Fork because the West Branch has the following characteristics:

- extensive areas of wide floodplain and associated side channels and backwaters,
- relatively high pool/riffle ratios,
- significant accumulations of large and small woody debris,
- an abundance of small-substrate spawning gravels, and
- overhanging vegetation that provides cover for both spawning and rearing coho.

Kelley Creek, a tributary of the East Fork, which generally has the highest coho salmon spawner density in the East Fork watershed, shares all these characteristics, except perhaps for the wide floodplain. The East Fork and its other tributaries lack many of these characteristics, making them less suitable for coho salmon. Kelley Creek and the West Branch also have better floodplain connectivity compared to the East Fork. The benefit derived from each of these habitat characteristics varies among life stages; however, the role these habitat characteristics play in protecting juvenile salmonids from high-velocity flows, and therefore in improving their overwinter survival, is thought to be of paramount importance (McLeod and Howard 2010).

Juvenile coho overwintering in Mill Creek are subjected to high flows during major storm events. To avoid being flushed out of the system, juveniles must seek refuge in slow-water habitats, such as pools, side channels, backwaters, and edge waters. Thus, if refuge habitat is limited, the number of fish that survive in the tributaries until spring outmigration as smolts would likely be correlated to the number and intensity of high-water events. Years with more frequent or more intense winter storms would be expected to have lower overwinter survival than years with few or low-intensity storms. Stillwater Sciences (2006) found that peak winter flows showed a negative correlation with production of 1+ coho smolts in Mill Creek. McLeod and Howard (2010) added 4 more years of data to Stillwater Sciences' analysis, recalculated the correlations with updated flow values, and found that peak winter flow remained a fairly good predictor of smolt production on the West Branch (R^2 = 0.66) (Figure 2-12). The relationship is not as strong for the East Fork (R^2 = 0.50), but the East Fork relationship may be shifting because of recent restoration efforts (see Section 1.5.3). The availability of slow-water refugia may be the primary factor limiting coho salmon production in both tributaries (McLeod and Howard 2010).

Recent instream habitat restoration efforts have been implemented in the East Fork and may be having a positive impact on coho smolt production (Figure 2-12), although the data are limited and not conclusive. Efforts have focused on the East Fork because populations there seem to be more density-dependent due to the lack of suitable rearing habitat. Despite having similar lengths of anadromy, the West Branch consistently produces more coho smolts than the East Fork.



Note: Hydrological data from the Smith River are used as a surrogate because flow data are not available for Mill Creek for all years.

Figure 2-12. Estimated Numbers of 1+ Coho Salmon Smolts vs. Peak Winter Flow (Cubic Feet per Second) from the Preceding Water Year, West Branch and East Fork (Water Years 1996–2008)

McLeod and Howard (2010) found that coho smolt production has increased in the East Fork since creation of the complex wood jams. Their addition also appears to have increased the summer carrying capacity of the East Fork. For the first time since summer population data have been collected on both tributaries, the East Fork had a higher summer coho population than the West Branch (Figure 2-4) (McLeod and Howard 2010). It appears that the complexity of complex wood jam-created habitat is producing pools that can support higher coho densities. The habitat complexity is likely providing better protection from predators, is providing more substrate for production of food items, and may reduce intraspecific territorial conflicts by compartmentalizing the shared habitat.

2.3.2.2 Chinook Salmon

Chinook salmon spawn throughout the Mill Creek and Rock Creek watersheds and have been found in all but the uppermost sections of the 19 km (12 mi) of known anadromous habitat in the Mill Creek drainage (McLeod and Howard 2010). As with coho salmon, most Chinook spawning occurs in the West Branch (McLeod and Howard 2010). Previous studies have indicated that gravel quality is higher in the West Branch than in the East Fork (Stillwater Sciences 2006). Data from the West Branch indicate that spawning habitat is not a limiting factor until the number of female spawners exceeds 350, which is not typically observed. In the West Branch, a positive relationship exists between spawners and juvenile outmigrants. Comparatively, there is little evidence to suggest a relationship between the number of spawners and the number of juvenile outmigrants in the East Fork (Figure 11 from Stillwater Sciences 2006); the lack of such a relationship could be the result of redd superimposition (Stillwater Sciences 2006).

The Rock Creek drainage contains about 8 km (5 mi) of habitat accessible to spawning Chinook salmon; however, suitable spawning habitat is limited because the substrate has a high gradient and is dominated by boulders. Chinook may spawn primarily in the patchily distributed spawning habitat in the lower 7.2 km (4.5 mi) of the watershed. The longest continuous stretch of Chinook spawning habitat in Rock Creek is a 0.8-km (0.5-mi) reach in the upper watershed that has a relatively low gradient (McLeod and Howard 2010).

Spring rearing habitat for emergent Chinook fry and rearing juveniles may be the most important limiting factor for the species in the Mill Creek drainage (Stillwater Sciences

2006). Fisheries data show a strong relationship between peak winter flow and 0+ smolt estimates, especially in the West Branch.

2.3.2.3 STEELHEAD

Steelhead have been found throughout the extent of known anadromous habitat in the Mill Creek and Rock Creek watersheds (McLeod and Howard 2010). They are capable of sustaining higher swimming and burst speeds than other salmonids, enabling them to ascend waterfalls, cascades, and high-gradient reaches that may act as barriers to other species. This ability allows steelhead to spawn in upper headwater reaches that may not be accessible to other anadromous salmonids. Steelhead spawning observations in Mill Creek have been incidental to salmon spawning surveys, which are terminated in early February of each year. Although steelhead spawning has been observed in the upper reaches in fall, most steelhead spawning occurs during winter and spring, when most salmon spawning has ended. Thus, most steelhead spawning in Mill and Rock creeks has gone unobserved. However, steelhead are observed annually spawning in the vicinity of the West Branch outmigrant trap, in gravels used by Chinook months earlier. These observations suggest that steelhead likely spawn in many of the same areas used by Chinook and probably coho salmon throughout the basin.

All juvenile life stages of steelhead (from fry to smolt) have been observed in the outmigrant traps (McLeod and Howard 2010), indicating that extended freshwater rearing occurs in the basin. Large numbers of 0+ trout are also observed during summer dive surveys throughout the Mill Creek watershed (McLeod, pers. com, 2010), although abundance estimates have been calculated only for 1+ fish that can be identified as steelhead or cutthroat (McLeod and Howard 2010).

Steelhead smolt population estimates have varied significantly in both tributaries. However, estimates for the West Branch are generally about twice those calculated for the East Fork (McLeod and Howard 2010). This variance may reflect a response to differences in habitat quality and quantity between the two tributaries, as seen with coho salmon smolt (McLeod and Howard 2010). The 2009 steelhead smolt estimate was higher for the East Fork than for the West Branch (McLeod and Howard 2010), possibly because of recent habitat restoration efforts in the East Fork.

2.3.2.4 COASTAL CUTTHROAT TROUT

In Mill and Rock creeks, coastal cutthroat trout appear to use the full extent of anadromous habitat, as well as headwater reaches beyond anadromy. Some large adult cutthroat are observed incidentally in the upper reaches during spawning surveys. These fish are presumably anadromous or possibly potamodromous (resident fish that migrate from lower mainstem reaches to upper spawning reaches). Most cutthroat spawning in Mill and Rock creeks likely takes place in the uppermost reaches and in the smaller tributaries of these watersheds.

All juvenile life stages of cutthroat (from fry to smolt) have been observed in the outmigrant traps (McLeod and Howard 2010), indicating that extended freshwater rearing occurs in the watershed. Summer dive surveys detect cutthroat 1+ and older in relatively small numbers (McLeod and Howard 2010). Larger 2+- and 3+-sized fish are often seen in the larger pools, particularly in the East Fork (McLeod, pers. com, 2010). An unknown proportion of the 0+ trout observed during summer dive surveys in Mill Creek are cutthroat (McLeod, pers. com, 2010).

Cutthroat smolt production appears to be relatively stable and about the same in both the West Branch and East Fork (McLeod and Howard 2010). This similarity suggests that these tributaries are about equally suited for cutthroat trout production (McLeod and Howard 2010).

2.3.2.5 SUMMER LOW FLOW

Low summer flows can have a detrimental impact on fish residing in the upper West Branch near the campground. Since monitoring began in 1995, the average length of dry stream channel in the upper West Branch has been 1,071 meters (m) (3,512 feet [ft]), ranging annually between 139 m (456 ft) and 1,590 m (5,218 ft) (McLeod and Howard 2010). Although water quality conditions do not appear to drop below critical thresholds, most fish in these reaches likely become concentrated in isolated pools and succumb to predation.

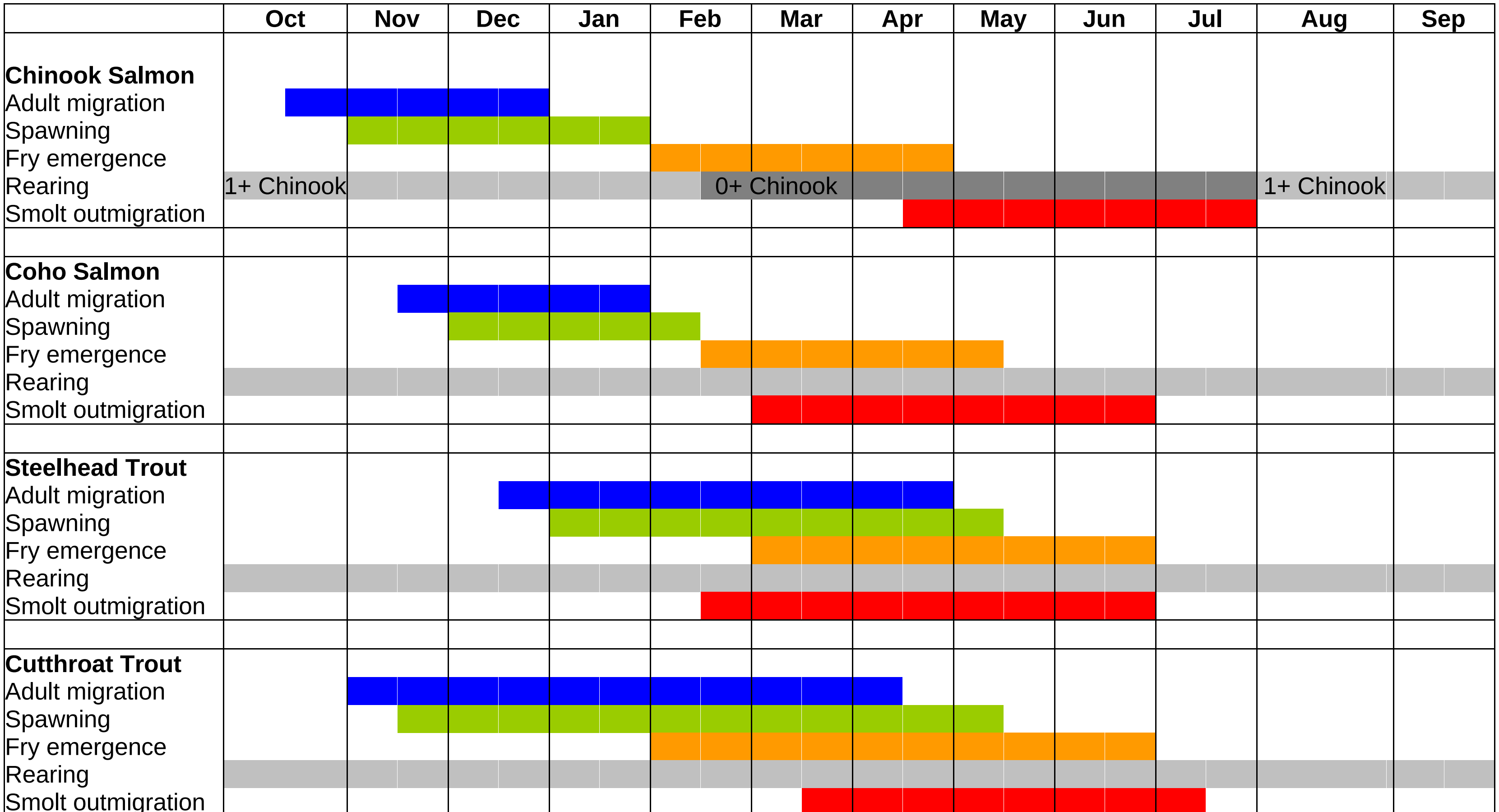
2.3.3 SALMONID PERIODICITY

The timing of salmonid migration and reproductive cycles is important for scheduling management activities. These cycles are presented in Figure 2-13.

2.3.4 FRESHWATER MUSSEL POPULATIONS

The western pearlshell freshwater mussel (*Margaritifera falcata*) is a long lived (up to 100 years), relatively large stream macroinvertebrate that looks similar, but is not related, to marine mussels. They depend on salmon and trout for a portion of their lifecycle. Pearlshell mussels are most susceptible to environmental perturbations when they are young juveniles. Siltation and eutrophication are particularly lethal to young juveniles. Lack of recruitment is one of the best signs that pearlshells are being affected by environmental stressors. Other threats include chemical pollution, water diversion, and declines in host fish populations (Bauer 1988). Because of their sensitivity to stream conditions, long life spans, close relationship with salmonid fish, and enormous bioaccumulation capabilities (related to their filter feeding lifestyle), pearlshell mussels have been noted as being one of the best long-term bioindicators of stream ecosystem health (Young et al. 2003).

Adult western pearlshell mussels are generally dark brown to black in color with no striping or spots (juveniles are a light tan color on the exterior) and can reach up to 15 centimeters (6 inches) in length, depending on the population and habitat. The shells are oblong with no noticeable ridges, bumps, or flared sides. The inside of the shell, or nacre, is a purplish white mother-of-pearl color. Concentric rings on the exterior radiate from the base and indicate annual growth and age, much like rings in a tree. The western pearlshell and its eastern North American/European counterpart, the freshwater pearl mussel, are some of the longest living invertebrates in the world (Bauer 1992). Like all bivalves, pearlshells feed by filtering organic particles siphoned from the water column. A single pearlshell can filter up to 50 liters (13 gallons) of water per day (Zuiganov et al. 1994).



Source: Based on salmonid monitoring data collected by the Mill Creek Fisheries Monitoring Program (1993–2010).

Figure 2-13. Periodicity of Chinook, Coho, Steelhead, and Coastal Cutthroat Trout in the Mill Creek Watershed

Pearlshell mussels reach sexual maturity at approximately 10–15 years. Male mussels expel sperm into the water, which downstream females inhale while feeding. Fertilized eggs develop on the female's gills for a few weeks. One to four million tiny larvae (0.6 to 0.7 millimeter [0.024 to 0.028 inch]), called glochidia, are then released into the water by each female mussel in a highly synchronized event in the summer that lasts 1–2 days (Hastie and Young 2001). The vast majority of glochidia are washed out of the stream. A few, however, are inhaled by fish and attach to gill filaments. The attached glochidia then encyst, grow until the following spring, and then drop off to settle on the stream bottom. Pearlshell host fish are thought to be primarily salmonid species. The encysted glochidia are not thought to harm the host fish. Most pearlshell host fish are in the 0+ to 1+ age range. Adult fish appear to be somewhat immune to glochidia attachment (Skinner et al. 2003). This complex commensal relationship with fish is the only mechanism that allows successive freshwater mussel generations to move back upstream or colonize stream areas far from their natal beds.

Taylor (1981) mentioned that western pearlshells existed in the Smith River but did not specify how widespread the species was in the watershed. A freshwater macroinvertebrate inventory was conducted by DeMartini and Chadwick (1984) in the early 1980s along Prairie Creek in Prairie Creek Redwoods State Park, the West Branch of Mill Creek in Del Norte Redwoods State Park, the mainstem of Mill Creek in Jedediah Smith Redwoods State Park, and the Smith River in Jedediah Smith Redwoods State Park. These researchers found western pearlshells in the mainstem of Mill Creek but not in the West Branch, the Smith River, or Prairie Creek. They did not report on the size or distribution of the western pearlshell population in Mill Creek. The results of a western pearlshell inventory of the Mill Creek watershed conducted by the staff of Redwood National Park indicate that pearlshells are present throughout the mainstem of Mill Creek and 1–2 km (0.6 to 1.2 mi) up the West Branch and East Fork (Bensen 2005). The mussel population in Mill Creek has been monitored annually since 2005 (Bensen 2005, 2006, 2007, 2008, 2010). During the first 5-year monitoring cycle, an average of 24.62 mussels per square meter (29.4 mussels per square yard) (n = 10, SD = 13.1) were found across 10 sample transects, a comparably high population density. Approximately 33% of the mussels sampled were juveniles (Bensen 2010). Any mussel population with more than 20% of individuals in the juvenile age class has a sustaining or growing population. The Mill Creek western pearlshell population is apparently quite healthy.

2.3.5 Freshwater Mussel Habitat

When pearlshell mussel larvae drop off their host fish, they must land on clean, coarse sand or gravel to survive. Juvenile pearlshells then develop in the stream substrate. Some adults will also live completely in the substrate, but most expose the top third of their bodies to the open water. Freshwater mussels can rebury themselves if dislodged and can move short distances. Pearlshells require clear, nutrient-poor, cool, highly oxygenated, low-mineralized, moderate to fast flowing water. They are found at depths between 0.1 m and 2.0 m (0.3 to 6.5 ft) and are usually located in stream areas that provide some flow refuge during high-flow events, such as outside bends of pools, glides, backsides of very large boulders, and near pool tails. Most commonly, they are found in gravel lodged in between cobbles, boulders, or bedrock or areas of coarse sand. Fine sandy, silty, or muddy areas do not provide substrates that are sufficiently stable for pearlshells (Skinner et al. 2003).

2.4 SEDIMENT PROBLEM STATEMENT

In general, sediment has not been as problematic in the MCA watersheds as in other North Coast watersheds. However, past land management activities have created the potential for sediment to become problematic in the absence of appropriate management. The following discussion outlines features and conditions that could create sedimentation imbalances, or affect restoration approaches, in the MCA.

2.4.1 Desired Sediment Conditions

Sedimentation is a natural process needed to provide nutrients and materials to streams to support aquatic species and to renew slope and forest processes that allow needed evolutionary pathways to develop. Ideally, sedimentation linkages between the stream and the slope are in a long-term balance that permits robust aquatic populations. This is particularly true where a comparably robust fishery exists. However, it must be kept in mind that large-scale sedimentation events, at “natural rates,” contributed to evolution of the fishery (cf. Montgomery 2004).

Several treatments should be employed to achieve the desired sedimentation rate. For example, a desired condition is that all stream crossings with diversion potential will be removed, all culverts will be capable of passing 100-year flood flows and associated debris, inboard ditches and cross drains will be eliminated where consistent with maintaining slope stability, the quality of road surfacing will match the intended use, fine dust abatement will be employed where dust has the potential to damage vegetation or enter a water course, and storm patrols will help to prevent sedimentation problems. Storm patrols are staff that travel roads during or shortly after storms to identify and repair problems (e.g., a plugged culvert, a small landslide) before they get worse. A goal for forest thinning will be to enhance slope stability by increasing root size and complexity.

2.4.1.1 Upland Conditions

State Parks maintains approximately 128 km (80 mi) of critical circulation routes throughout the MCA. Each year, approximately 5% of the routes have excessive brush cleared and are regraded. Drain and culvert cleaning are performed year-round, and many sites are cleared more than once per year. Road maintenance crews patrol accessible roads during winter to correct drainage failures before they cause severe damage to the roadway.

The long-term goal for improving upland conditions is to achieve slope stability and sedimentation rates that approach the estimated rate for remnant old-growth forest in the MCA. Given the similar geologic conditions across the property, this is an appropriate goal for park management. However, during the life of this plan, and given the legacy of timber harvest, it is more appropriate to set a realistic intermediate goal that is consistent with conditions that supported a relatively robust salmonid population during some of the initial industrial timber harvest on the North Coast. The TMDL analysis performed for the South Fork of the Eel River followed this approach (USEPA 1999). This goal will be assessed in the context of climate change, the remaining road network in the MCA, and other drivers that may affect short term sedimentation rates (e.g., large storms, earthquakes, fire or the absence of fire, blight).

2.4.1.2 INSTREAM CONDITIONS

Past studies by Bradford and Iwatsubo (1978) and Madej et al. (1986) and observations by Redwood National Park (RNP) and State Parks staff members indicate that the underlying geology and sediment transport regimes of the MCA provide instream conditions that are within acceptable ranges of conditions preferred by the organisms dependant on this ecosystem. Measured sediment and turbidity fluxes during the period of industrial timber operations apparently did not contribute to long-term impacts on the aquatic ecosystem and therefore can provide a baseline for future monitoring. Water quality parameters, including stream temperature, dissolved oxygen, pH, and specific conductivity, are within desired ranges for the species present. Analysis of long-term fisheries monitoring data by Stillwater Sciences (2006) and McLeod and Howard (2010) indicates that resilient and diverse salmon populations continue to persist. Although these conditions are generally favorable, several reports indicate low levels of instream wood and conifer recruitment and their associated effects (Knopp 1993, Carrol and Robison 2007, Stillwater Sciences 2006, McLeod and Howard 2010).

Based on these studies and observations by State Parks staff members, the primary limiting factors affecting instream conditions are:

- a deficit of instream wood, especially in the East Fork,
- limited potential conifer recruitment from riparian areas, and
- poor floodplain connectivity and simplified off-channel habitats.

Upland sediment sources remain a potential threat to the aquatic ecosystem.

2.4.2 EXISTING UPLAND SEDIMENT CONDITIONS

The MCA landscape reveals the legacy of industrial timber and the effects of large storms since the flood of 1955 (also see storm history in Section 1.4.2). Early road building standards were much lower than those used after construction standards became stricter in the mid-1970s. The rate of failure from roads reflects this change.

Harvesting of more timber tracts, however, has resulted in more sedimentation from that source. State Parks maintains the road network, but because of budgetary constraints, portions are becoming overgrown with dense brush and thus more difficult to access and maintain. Although State Parks forest restoration projects have been ongoing since the acquisition, their impact on the sedimentation has been negligible.

2.4.2.1 ROAD LOCATION AND SURFACING

Approximately 468 km (291 mi) of haul road, 46 km (29 mi) of secondary road, and 650 km (400 mi) of skid trail have been constructed in the MCA (Merrill et al. 2011,, Appendix A) (Figure 2-14). Before road decommissioning began in 2002, road density ranged from about 4.4 kilometers per square kilometer (km/km^2) (2.7 miles per square mile [mi/mi^2]) in the East Fork to 7.7 km/km^2 (4.8 mi/mi^2) in the mainstem of Mill Creek (about 4.6 km/km^2 [2.9 mi/mi^2] in Rock Creek, about 4.7 km/km^2 [2.9 mi/mi^2] in upper Terwar Creek, about 5.1 km/km^2 [3.2 mi/mi^2] in the West Branch, about 5.7 km/km^2 [3.5 mi/mi^2] in Wilson Creek, and about 6.6 km/km^2 [4.1 mi/mi^2] in upper Hunter Creek). The West Branch, East Fork, and Rock Creek each have in excess of 99 km (62 mi) of road. The East Fork has the greatest length at approximately 168 km (104 mi), and the other watersheds have less than 30 km (19 mi) of road. With the exception of a paved segment of Hamilton Road (from the entrance to the property at U.S. Highway 101 to the old mill site at the confluence of the West Branch and East Fork), virtually all of the roads are dirt. Approximately 375 km (233 mi) of the road system has a stable rock surface, 6 km (4 mi) is paved, and the remainder is unsurfaced.

2.4.2.2 HYDROLOGIC CONNECTIVITY

Approximately 515 culvert cross drains are located on MCA roads. Cross drain construction used standard timber road spacing and did not necessarily observe natural drainage divides, resulting in the potential for excess flow to certain slopes. Inboard ditches also link many roads directly to stream crossings.

2.4.2.3 STREAM CROSSINGS

As of 2002, there were approximately 1,457 stream crossings in the MCA of which 455 had a high-risk rating. Approximately 729 of the stream crossings had culverts, and 169

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North Coast Redwoods District

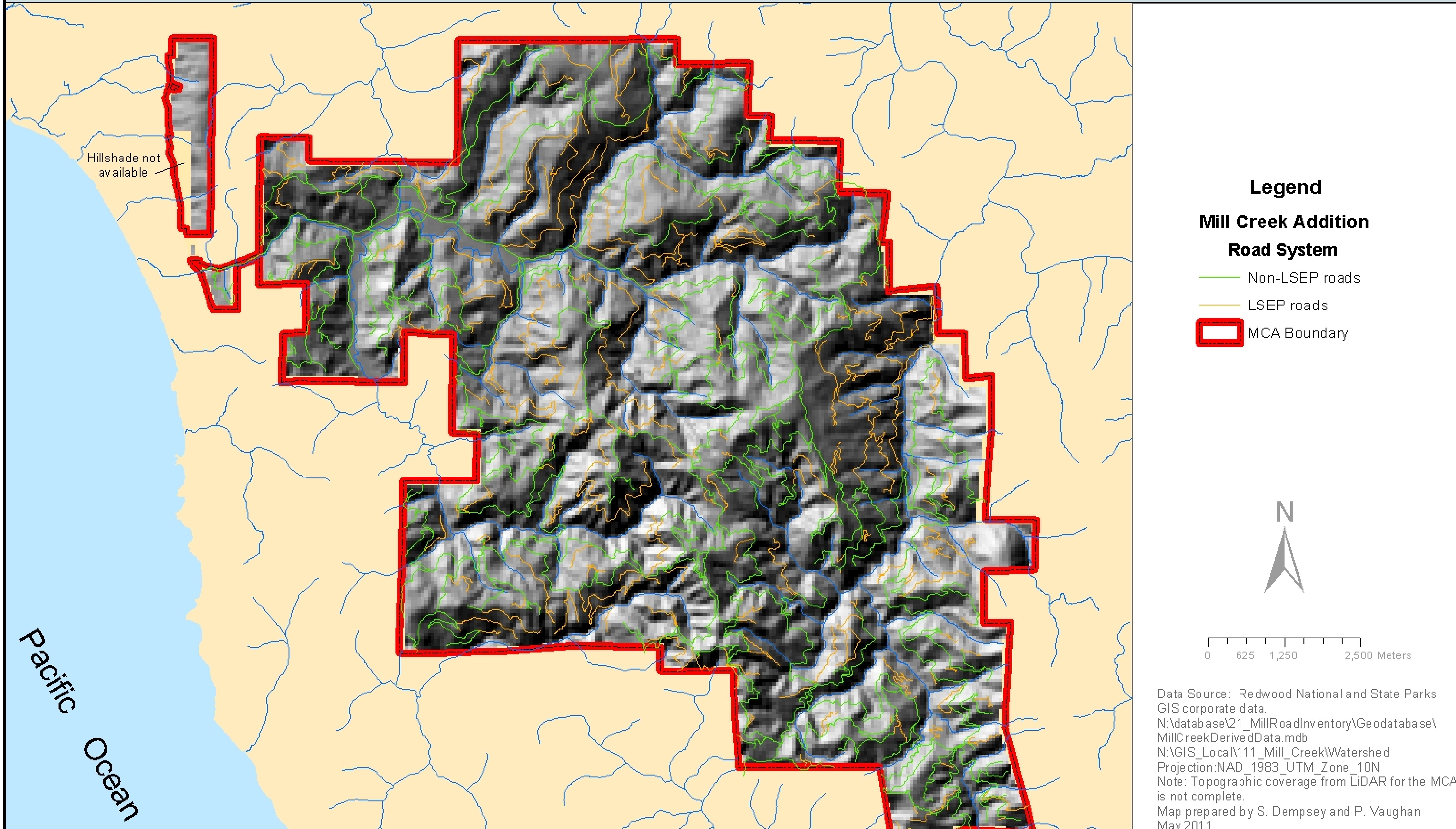

Figure 2-14
MCA Road System

of these culverts were assigned a high to very high erosion risk and prioritized for replacement (included among the 455 high-risk sites). During the previous timber ownership, some stream crossings were partially removed to inhibit stream diversion; the remnant fill in these crossings proved to be very erodible because of its exposure to rainfall and streamflow. Roads bearing these partially removed crossings have been a priority for removal since the acquisition.

Eleven bridges are located on the property. Ten of the bridges are dual railcar bridges resting on log crib abutments. The railcar bridges typically consist of two flatbed railcars welded together lengthwise. The eleventh bridge, built in 2009 to replace a failed log bridge, is an Akrow prefabricated truss bridge on loan from RNP. The bridge was installed to provide a detour for heavy vehicular traffic around two railcar bridges that received exceptionally low capacity ratings during inspections conducted by the California Department of Transportation (Caltrans) in 2008.

All the bridges in the MCA require routine inspections by Caltrans to comply with Federal highway safety standards. Since 2004, Caltrans has inspected all the bridges and has identified six as being “scour critical.” This designation requires development of a Plan of Action (POA), which details the steps and timeline that will be implemented to resolve the scour issues. State Parks engineers developed six POAs in 2009 that call for the replacement of all “scour critical” bridges; the POAs also require interim repairs to the rock slope protection beneath the bridges and routine monitoring until the bridges can be rebuilt. The remaining five bridges have been designated “scour unknown,” which requires development of a Work Plan that outlines the steps and timeline required to inspect the bridge and to conduct scour surveys. Results of scour surveys will determine whether the bridges are “scour critical” and require preparation of a POA. State Parks is developing Work Plans at the Northern Service Center that are expected to be complete by fall 2011.

2.4.2.4 DISTURBED AREAS

Borrow pits, mostly exploited as a source for rock to surface the timberland roads, frequently have associated landings. Approximately 981 landings having both borrow and road fill sources were noted during road inventory. The borrow pits typically have relatively

stable rock that does not pose a debris flow hazard. Rock fall and ravel deposits that may cover the lowermost borrow pit cutslopes rarely travel off-site. In most cases, the borrow pits are simply overexcavated cutbanks.

2.4.2.5 SERPENTINE POLLUTANTS

Asbestos-bearing serpentine soil presents a unique health hazard because inhalation of related airborne dust can cause lung cancer. Road restoration in serpentinitic terrain and/or driving at excessive speeds on roads surfaced with serpentinitic rock can generate this dust. Serpentine soils affect about 21 km (13 mi) of roads; 14 km (9 mi) traverse serpentinitic terrain, and 7 km (4 mi) have base rock excavated from serpentinite quarries but are otherwise built outside of serpentine terrain. The serpentine soils are restricted to the east side of the MCA, near the Coast Range Thrust Fault (see Appendix A, Figure 16, for locations of roads affected by serpentine). Operational methods to minimize exposure for restoration workers are in place, and restoration techniques that might affect air or water quality that are related to minimizing airborne dust are assessed during project-specific review. Exposure for the driving public will be assessed as part of the Roads and Trails Plan.

2.4.3 EXISTING INSTREAM SEDIMENT CONDITIONS

The presence or absence of large woody debris and site geology and geomorphology are the primary controls on instream sediment conditions.

2.4.3.1 LARGE WOODY DEBRIS CONDITIONS

Large woody debris was routinely removed from streams in the MCA until as recently as 1992 (Verhey and Schwabe 1993, as cited in Beak Consultants1998). The lack of large instream wood was identified as a limiting factor for overwintering and summer rearing juvenile salmonids, especially coho (Stillwater Sciences 2006). Forest stands adjacent to many of the low-gradient channels are dominated by hardwoods and lack the large conifers necessary for long-term recruitment and retention of instream wood. State Parks is working with its restoration partners to restore instream wood loading to near background levels and increase the proportion of conifers in riparian areas. Preliminary trends in coho smolt production following significant wood-loading efforts in the East Fork compared to the untreated West Branch are encouraging (McLeod and Howard 2010).

Carrol and Robison (2007) evaluated the effects of large wood debris on stream morphology in three low-gradient streams: Prairie Creek, West Branch, and East Fork. Prairie Creek is a nearly pristine, unmanaged watershed in Prairie Creek Redwoods State Park and is dominated by an old-growth redwood forest. Table 2-4 presents wood-loading characteristics for these three streams. State Parks would like to consider the study reaches of Carrol and Robison (2007) for permanent monitoring in the MCA.

Table 2-4
Comparison of Large Wood Characteristics for Prairie Creek, West Branch, and East Fork

Variable	Prairie Creek	West Branch Mill Creek	East Fork Mill Creek
Reach length (m)	1,098	1,051	1,048
Large wood loading (m^3/ha)	759	329	39
Number of pieces	263	244	66
Number of pieces per 100 m	24	23	5
Mean piece diameter (m)	0.6	0.4	0.4
Mean piece length (m)	7.3	6.3	7.3
Mean piece volume (m^3)	5.2	1.9	1.5

Notes: m = meters, m^3 = cubic meter, m^3/ha = cubic meters per hectare.
Source: Carrol and Robison 2007

A survey of LWD conditions in the MCA was also conducted by Stimson during 1997. Eight streams were surveyed (as reported by Stillwater Sciences 2002), and LWD was found to be most abundant in the West Branch and least abundant in Rock Creek. Conifer species (primarily redwood) were reported to be providing most of the in-channel wood. Stimson's survey concluded that 12–54% of all pieces inventoried were functional and provided bank protection, sediment storage, pool formation, or anchors for log jams. Overall, 5–30% of the pieces were found to be important in forming pools. As reported by Stillwater Sciences (2002) and observed in the field by State Park staff members, most of the functional instream LWD in the MCA is "legacy wood" that had entered the channel before or during initial timber harvest (Harris, pers. com, 2010).

2.4.3.2 SUSPENDED SEDIMENT AND TURBIDITY

Inorganic materials, such as clay, silt, and sand, and fine organic matter, microscopic organisms, and organic acids in the water column collectively form the suspended and dissolved load of a stream. Turbidity is a measure of the optical property that causes light to be either scattered or absorbed as it passes through water and can be correlated with the amount of suspended and dissolved materials present. Persistently elevated levels or short-duration spikes in these two pollutants can have direct effects on mortality, can lead to reduced physiological function, and can cause habitat alienation of aquatic organisms (the organism will avoid areas it may prefer to occupy while these pollutants are above certain thresholds). Indirect effects include decreased growth rates, reproduction, and recruitment. Fine sediment that deposits in riffles can decrease infiltration rates for spawning gravels and thereby reduce egg-to-emergent survival of salmonids. Fine sediment deposited elsewhere in the streambed can persist as a source for turbidity and alter the community structure and function of benthic macroinvertebrates. Excessive sedimentation can also fill pool habitats that provide cover and rearing habitat for juvenile fish and other aquatic species.

Suspended sediment concentrations and turbidity are flow-dependent variables; for this reason, the relationship between those parameters and streamflow must also be understood to set appropriate load targets. The U.S. Geological Survey (USGS) collected suspended sediment, bedload, turbidity, and water flow data at various locations in Mill Creek from water year 1975 to 1981. These data are available at the USGS Web site (station numbers 11532620, 115532626, 11532630) and help form the baseline for assessing these parameters.

Flows in the Smith River system reflected a range of conditions over the measurement period (Table 2-5). Water year types were identified by dividing the exceedance probability curve of total annual runoff (water yield) into five hydrologic year classes: (1) Extremely Wet (0–20%), (2) Wet (20–40%), (3) Normal (40–60%), (4) Dry (60–80%), and (5) Critically Dry (80–100%). The wet water year type was the only year type that did not occur during the record period. Of the four types that did occur, the 1975 water year had the largest peak discharge event; however, the 1978 water year produced the greatest water yield. Using flood recurrence intervals in the range of 1.5 to 2.3 years as a general predictor for bankfull flows (Dunne and Leopold 1978), three of the four water years examined had near or greater than bankfull discharges (1975, 1976, 1978). Because peak flood events during water years 1975 and 1978 were significantly greater than bankfull, they were more likely to trigger major sediment delivery from upslope sources than water years 1976 and 1977.

Table 2-5
Summary of Smith River Flood Information Concurrent with U.S. Geological Survey Monitoring in the Mill Creek Watershed

Water Year	Water Year Type	Peak Discharge (cms)	Flood Recurrence Interval (years)	Period of Record Rank
1975	Normal	3,652.87	8.8	9
1976	Dry	1,285.58	1.2	68
1977	Critically Dry	447.81	1.0	77
1978	Extremely Wet	2,888.31	4.0	20

Note: cms = cubic meters per second.
Source: Data from the U.S. Geological Survey gage located at the Smith River near Crescent City (11532500), period of record 1932–2009 (n = 78); drainage area: 614 square miles.

Madej et al. (1986) synthesized sediment transport data collected by USGS (from water years 1975–1981) for the mainstem of Mill Creek. They reported that the total average sediment yield was 140 tonnes/km^2 (400 tons/mi^2). Of the total load, 60% was reported to be suspended sediment, 30% dissolved load, and 10% bedload. Annual suspended sediment yields ranged between 4 and 185 tonnes/km^2 (between 11 and 528 tons/mi^2); a mean annual suspended sediment yield of 70 tonnes/km^2 (200 tons/mi^2) resulted from the period of record during industrial timber operations (Table 2-6). Madej et al. (1986)

also reported that a modeling study by Iwatsubo and Washabaugh (1982) found that under natural conditions, suspended sediment yield was approximately 65 tonnes/km^2 (187 tons/mi^2), although Madej et al. (1986) indicated that the modeling estimate was high based on direct measurements. Madej et al. (1986) also reported that Mill Creek produced one to two orders of magnitude less suspended sediment during a similar period of record compared to other North Coast watersheds (Table 2-7).

Table 2-6
Annual Suspended Sediment Yields for Mill Creek, Water Years 1975–1981

Year	Tonnes per Year	Tonnes per Square Kilometer
1975	8,723	120
1976	2,690	35
1977	311	4
1978	13,639	185
1979	3,365	45
1980	5,583	75
1981	2,980	40
Mean	6,610	70

Source: Based on sediment rating curve (U.S. Geological Survey water resource data from Madej et al. 1986).

Table 2-7
Measured and Estimated Suspended Sediment Yield at Selected Gaging Stations in Northern California

Station	Drainage Area (km^2)	Period of Record (water years)	Suspended Sediment Yield (tonnes / km^2)
Redwood Creek near Blue Lake	175	1954–1980	2,100
Panther Creek (Redwood Creek tributary)	15.7	1980–1984	250
Coyote Creek (Redwood Creek tributary)	20.2	1980–1982, 1984	1,900
Lacks Creek (Redwood Creek tributary)	43.8	1981–1984	700
Mill Creek	76.8	1975–1981	70
Smith River	1,577	1978–1979, 1981	170

Notes: km^2 = square kilometers; tonnes/km^2 = tonnes per square kilometer.
Source: Madej et al. 1986

In addition, Stillwater Sciences (2002) cited a summary report by Winzler and Kelley (1980) that included estimates of the annual average suspended sediment concentrations recorded between 1973 and 1980 during the industrial logging period. According to Stillwater Sciences, Rock Creek had suspended sediment concentrations ranging from 0.1 to 74.4 milligrams per liter (mg/L) upstream from logging operations and from 2.5 to 142.3 mg/L downstream. East Fork concentrations ranged from 1.1 to 37.6 mg/L, West Branch concentrations ranged from 1.2 to 15.3 mg/L, and mainstem Mill Creek concentrations ranged from 3.8 to 40.9 mg/L. State Parks contacted Winzler and Kelley (pers. com, 2010) and requested this dataset. Unfortunately, the current staff at Winzler and Kelley was unable to locate the 1980 report in the company's records.

Suspended Sediment and Severity of Effect

Based on an extensive literature review, Newcombe and Jensen (1996) developed a scale showing the relationship between suspended sediment loading and impacts on salmonid health, ranging from no impact to lethal (Table 2-8). The scale is largely based on the suspended sediment load and its duration. Lower loads at long duration can have more severe impacts than short-duration high loads, although the impact severity is a function of both variables and sometimes water temperature. The scale of the severity of ill effects was applied to Mill Creek from data gathered during the USGS's suspended sediment measurement period during the late 1970s, during industrial logging. The results show that the severest effects during this period were sublethal under various flows (Table 2-9).

2.4.3.3 EMBEDDEDNESS CONDITIONS

Embeddedness is a measure of the extent to which large particles (boulders, cobble, gravel) are surrounded or buried by fine sediment, usually measured in classes according to percent coverage. Based on recent field observations in various locations in the MCA, embeddedness conditions are low compared to conditions in other North Coast watersheds of a similar size.

V* (pronounced "V star") is another technique that provides a measure of fine sediment conditions. V* is the proportional volume of fine sediment stored in pools. Although not a

Table 2-8 Scale of the Severity of Ill Effects Associated with Excess Suspended Sediment	
Scale of Severity of Ill Effects	Description of Effects
No Effect	
0	No behavioral effects
Behavioral Effects	
1	Alarm reaction
2	Abandonment of cover
3	Avoidance response
Sublethal Effects	
4	Short-term reduction in feeding rates
5	Minor physiological stress, increased coughing rate, increased respiration rate
6	Moderate physiological stress
7	Moderate habitat degradation, impaired homing
8	Indications of major physiological stress, long-term reduction in feeding rate
	long-term reduction in feeding success, poor condition
Lethal and Paralethal Effects	
9	Reduced growth rate, delayed hatching
10	0–20% mortality, increased predation, moderate to severe habitat degradation
11	> 20–40% mortality
12	>40–60% mortality
13	>60 80% mortality
14	> 80 100% mortality
Source: Newcombe and Jensen 1996	

Table 2-9 Summary of Water Year Type, Suspended Sediment Concentration, and Severity of Ill Effect					
		Suspended Sediment Concentration (mg/L)		Severity of Ill Effect	
		Duration		Duration	
Water Year	Location	2 Days	7 Weeks	2 Days	7 Weeks
Water Year Type: Normal					
1975	Mill Creek	158	21	7	8
	East Fork	138	9	7	7
	West Branch	125	9	7	7
Water Year Type: Dry					
1976	Mill Creek	107	14	7	8
	East Fork	75	5	7	7
	West Branch	83	5	7	7
Water Year Type: Critically Dry					
1977	Mill Creek	32	2.6	6	6
	East Fork	15	0.6	5	5
	West Branch	17	0.6	5	5
Water Year Type: Extremely Wet					
1978	Mill Creek	277	28	7	8
	East Fork	260	13	7	8
	West Branch	291	14	8	8

Notes: Water year type based on analysis of U.S. Geological Survey data for the Smith River near Crescent City (gage 11532500).
See Table 2-8 for severity of ill effect scale.
mg/L = milligrams per liter.
Source: State Parks staff application of severity of ill effect model number 3 (Newcombe and Jensen 1996) at stream locations monitored by the U.S. Geological Survey in the Mill Creek watershed.

direct measurement of embeddedness, V* may provide a more reliable measure of fine sediment conditions. Knopp (1993, Appendix D) reported V* at unspecified locations along the West Branch (23%, reach 28 in Knopp) and East Fork (12%, reach 29 in Knopp) of Mill Creek. The approximate site locations may be discerned by evaluating drainage area data that were reported above the sampling reaches.

2.4.3.4 POOL DISTRIBUTION AND DEPTH CONDITIONS

Pool distribution and depth conditions have been reported for the West Branch and East Fork by Carrol and Robison (2007) (Table 2-10) and Knopp (1993). Prairie Creek is a largely unmanaged watershed in Prairie Creek Redwoods State Park dominated by an old-growth redwood forest; conditions in Prairie Creek therefore represent ideal goals for streams in the MCA. State Parks would like to consider reaches from these studies for permanent monitoring.

Table 2-10
Comparison of Pool Characteristics for Prairie Creek, West Branch Mill Creek, and East Fork Mill Creek

Variable	Prairie Creek	West Branch Mill Creek	East Fork Mill Creek
Percent channel in Pools (%)	64	64	50
Number of pools	32	27	24
Pool spacing (bankful widths)	2	1.8	3.2
Longitudinal residual pool area / 100 meters (m^2/100m)	27.1	30.8	28.6
Mean reach thalweg depth every 2 meters (m)	0.28	0.33	0.28
Reach depth coefficient of variation	1.07	0.97	1.37
Mean pool length (m)	22	25	29
Mean pool longitudinal residual pool area (m^2)	9.2	12	16.7
Mean maximum pool depth (m)	0.8	0.8	0.9
Maximum pool depth (m)	1.3	1.4	2.1
Mean pool depth (m)	0.4	0.5	0.5

Notes: m = meters; m^2 = square meters; m^2/100 m = square meters per 100 meters.
Source: Carrol and Robison 2007

In their report, Carrol and Robison (2007) indicated that pools occurred every 1.8 and 3.2 bankfull channel widths in the West Branch and East Fork, respectively (Table 2-10). Bankfull widths ranged between 17 and 21 m for all three reaches in their study. Their data also show that pool frequency tends to increase with increased wood loading (Tables 2-4 and 2-10). This suggests that a target pool spacing of less than or equal to 1.8 pools per bankfull width may be achieved in the East Fork through a fivefold increase in large wood frequency (pieces per 100 meters) and an eightfold increase in wood loading (cubic meters per hectare). Differences in mean pool area and depth among the three streams in the Carrol and Robison (2007) study may be related to the presence of bedrock-controlled pools in the East Fork reach.

2.4.3.5 THALWEG PROFILE CONDITIONS

Major geomorphic controls affect streambed conditions in the streams draining the MCA. In the mainstem and East Fork, these include the presence of shallow bedrock in most of the fish-bearing reaches and limited floodplain connectivity related to confinement by bedrock or artificial fill (roads, berms, and fill at the mill site). Streambed conditions are also affected by a deficit of instream wood, especially in the East Fork. The West Branch is predominantly alluvial and has relatively broad active floodplains in the fish-bearing reaches. In the middle reach of the West Branch, a section of the stream exhibits losing conditions (flow goes subsurface) during baseflow periods. In the lower reach, bedrock is exposed in the channel, and its character is similar to that of the lower East Fork. The streambed morphology of Rock Creek is dominated by large boulders and bedrock controls.

Thalweg profile data exist for some reaches in the East Fork and West Branch. These data were collected for specific projects by RNP and State Parks. State Parks staff members are compiling these data and working to develop a survey control network in the MCA based on National Geodetic Survey control to facilitate comparison of these data and future long-profile analysis.

Table 2-11 summarizes some of the streambed physical parameters, including channel slope; D50, the median particle size; and V*, a function of embeddedness, reported by Knopp in Mill Creek in the early 1990s.

2.5 FORESTRY PROBLEM STATEMENT

Previous industrial timberland owners had different land management goals than public lands management. The issue for park managers is to create a forest dynamic capable of achieving parklike forests in the context of previous commercial harvest.

Table 2-11 Summary of Streambed Physical Parameters		
Category	West Branch	East Fork
Channel Slope (%)	3.4	1.3
D50 (mm)	44	53
V* (%)	23	12
Note: mm = millimeters. Source: Knopp 1993		

2.5.1 HISTORY OF TIMBER HARVESTING

The earliest logging on the property was in 1853, when oxen hauled out logs on Howland Hill Road. The scale of harvesting increased significantly in the 1920s and 1930s, when Hobbs-Wall harvested most of the timber on the West Branch from the Mill Creek Campground northward. The property was purchased by Harold Miller in 1941, but logging ceased from before the transfer until 1954, when the Rellim Redwood Company started logging the lower slopes and other redwood-dominated stands before moving upslope to less valuable timber. The company expanded operations over the years to include processing redwood on-site and purchased a portion of the Rock Creek watershed in 1965 and the remainder in 1969. (Note: The Miller Redwood Company, the Rellim Redwood Company, the Miller-Rellim Redwood Company, and the Stimson Lumber Company are all different corporate names for the same ownership and management.)

Most of the logging operations were typical for the region in that they consisted primarily of clear-cuts that were often burned and/or sprayed with herbicides to remove slash and competing vegetation. The planting strategy and site preparation favored Douglas-fir in most areas, although redwoods were planted in a few areas where no redwood stumps were present.

After harvesting, the resulting second- and third-growth plantations were thinned and otherwise managed to maximize growth and site potential until harvest at around age 50. Typical “fully stocked” stands would contain 500 or more trees per hectare (tph)

(200 trees per acre [tpa]) in the overstory for the final harvest. Current stand densities exceed historic stand densities of 13 tph (32 tpa) in the overstory (Guisti 2004) and are higher than appears to have been the norm in young stands of similar forest types that later developed into old growth (Poage and Tappeiner 2002). Fully stocked stands are appropriate for maximizing production of timber at the stand level, but tree densities greatly exceed levels that would allow for optimal growth of individual trees (O'Hara et al. 2010, Lindquist 2007). Individual tree growth is of utmost concern for rehabilitation because the lack of big trees is the largest impediment to restoring late-seral habitat, and growing trees of appropriate size classes is a slow process on most timescales. Vigorous tree growth also allows for the development of fire resistance not found in young, small trees.

Maximizing stand level growth in even-aged plantations also encourages a level of uniformity that contrasts with natural stands and makes poor habitat for many species associated with late-seral habitat (Lindenmayer and Franklin 2002). Plantations in Mill Creek lack large, live trees, snags, and coarse woody debris. They form dense canopies that do not allow enough penetrative light to support the diverse understory vegetation found in natural stands. Dense second growth also inhibits new tree establishment and growth necessary to form multilayered canopies. Overly dense, uniform stands are also more vulnerable to stagnation, where forest health declines and entire stands become vulnerable to windthrow. Young stands provide for less slope stability than old growth, and stand replacement events such as windthrow and fire can make areas vulnerable to failures that can jeopardize riparian and stream habitat downslope.

Less common but also of concern are areas where Stimson selectively logged either by removing merchantable trees while leaving hardwoods and other low-value conifers behind or retaining scattered large conifers along streams and elsewhere to comply with California Forest Practice Rule requirements. Other locations, especially in riparian areas, were converted from conifer to alder dominant stands after logging. When the property was sold to State Parks, 49 ha (120 ac) were classified as old growth and 668 ha (1,651 ac) as containing "scattered old growth" (Table 1-2 in Section 1.4.4). Most of the Hobbs-Wall units had been harvested a second time by then.

The most recent survey data for all but the 1980–1993 age class are too old and otherwise insufficient to be used to prioritize stands for treatment. A propertywide inventory would allow a more effective prioritization than is currently possible. Road removal and other restoration work can affect forestry work and needs to be taken into account when prioritizing stands for forest restoration. Road removal temporarily opens roads, improving access to remote areas, but limits future access to the same areas. Restoration work must therefore be coordinated with other work planned for the MCA, and delaying the implementation of some projects may be preferable to allow multiple goals/projects to be achieved simultaneously.

2.5.2 DESIRED FORESTRY CONDITIONS

The general plan amendment contains a vision statement that states that one of the primary goals is to restore late-seral forest characteristics to the property, eventually aiming to eliminate all signs that the property was ever logged. This is not meant to imply a return to the precise conditions that existed at some point in the past but rather the restoration of resilient, fully functioning, old-growth ecosystems—similar to what existed prior to logging. This goal will not be achieved during the life of this document, but actions taken today can have a dramatic impact on progress toward this goal. Within this framework, short-term goals will be similar to those on previous forestry projects:

- Encourage stand health, vigorous growth, and progression toward late-successional forest habitat.
- Adjust composition to promote a prelogging species mix.
- Promote resistance to catastrophic fire.
- Protect rare habitats.

These goals apply equally across the landscape, but the desired species composition will vary with moisture gradients, as discussed in Section 1.4.4. Although one of the goals generally promotes the prelogging species mix, protecting or even favoring less common species may ensure forest resilience through climate change, disease, and other stochastic events.

2.6 OTHER WATER QUALITY CONDITIONS

Besides sediment, other parameters can be used to assess water quality. The following discussion identifies some of the more important parameters considered in the Basin Plan that pertain to the MCA.

2.6.1 TEMPERATURE

Water temperature data have been collected at various sites on or near the Mill Creek property since 1973 (Winzler and Kelley 1980, Madej et al. 1986). In general, the highest temperatures were recorded in lower Rock Creek and the lower mainstem of Mill Creek. Stillwater Sciences (2002) reported that peak water temperatures in Rock and Mill creeks ranged from 18^{o}C to 21^{o}C at various sites during summer sampling that occurred between 1973 and 1980. Data collected by Stimson and reported in Stillwater Sciences indicate that peak summer water temperatures in 1996 ranged from 16.2^{o}C in the headwaters of Terwer Creek to 24.4^{o}C in lower Rock Creek. Data were also collected in the West Branch near the campground and at the mouth of Mill Creek (reported in Stillwater Sciences 2002) during July and August 2000 and between June and October 2001. RNSP and State Parks staff also collected data in the vicinity of the campground during the summers of 2006–2009. Minimum temperatures reported were 10.79^{o}C in the West Branch and 10.17^{o}C at the mouth of Mill Creek. Maximum temperatures reported were 17.03^{o}C in the West Branch and 19.42^{o}C at the mouth of Mill Creek.

As reported in Stillwater Sciences Interim Management Recommendations (2002), the Maximum Weekly Average Temperature (MWAT) has been suggested for use as a criterion for assessing thermal impacts on juvenile fish. MWAT is the mathematical mean of multiple, equally spaced, daily temperatures over a period of 7 consecutive days. It is used as a thermal tolerance parameter, and the temperature criterion for coho salmon based on MWAT has been calculated to range from 16.8^{o}C to 17.4^{o}C (62

Federal Register 62:24588-24609, May 6, 1997). Stillwater Sciences calculated MWAT values for various locations in Mill Creek and reported that stream temperatures during summer may be the only period of concern for juvenile salmonids (Table 2-12).

Table 2-12
Maximum Weekly Average Temperature for Locations in the Mill Creek Drainage

Location	Maximum Weekly Average Temperature (°C)
Upper East Fork Mill Creek	14.7
Lower West Branch Mill Creek	16.5
Upper West Branch Mill Creek	13.8
Mouth of Mill Creek	
2000	17.22
2001	18.11
Mill Creek Campground[a,b,c]	
2000[a]	14.75
2001[a]	14.4
2007[b]	15.31
2008[b]	14.79
2009[b]	15.2
2006[c]	14.52
2007[c]	14.35
2008[c]	14.03
2009[c]	13.86
Lower Rock Creek	18.8
Upper Rock Creek	16.7
Terwer Creek	15.4

Notes: Except as noted, all data collected during 1996.
[a] Locations at or near the Mill Creek Campground were not identified.
[b] Locations at or near the Mill Creek Campground were at the bridge.
[c] Locations at or near the Mill Creek Campground were located about 675 linear meters (approximately 2,200 linear feet) upstream from the southernmost campsites.
Sources: Ozaki, pers. com, ,2002 Howard and Albro 1995a, and Howard and Albro 1995b, all cited in Stillwater Sciences 2002; RNSP staff; State Parks staff

2.6.2 DISSOLVED OXYGEN

Dissolved oxygen concentrations likely remain near saturation in most of the Mill Creek drainage, except during periods of low flow (Bradford and Iwatsubo 1978, Beak Consulting 1998, Winzler and Kelley 1980). Even during periods of seasonally low flows, dissolved oxygen concentrations are reported to remain above the 7-milligram per liter (mg/L) threshold currently set as a specific water quality objective for streams in the Smith River hydrological unit (NCRWQCB 2011). The mean dissolved oxygen concentration of 188 samples taken during 1975 and 1976 was 9.59 mg/L and ranged between 6.3 and 12.1 mg/L (standard deviation 1.24).

2.6.3 SURFACE FLOW AND ABSTRACTION (DIVERSION)

Two water supply systems have been operated in the Mill Creek Watershed: one at the former Stimson mill site and the other at the Mill Creek Campground operated by State Parks.

The water supply system for the former mill site was partially decommissioned soon after ownership of the property was transferred to State Parks in 2003. Water supply lines to buildings and fire hydrants were removed or disconnected; a few sections of pipeline and the storage reservoir are the only remaining water supply infrastructure at the site. The water supply system for the mill site was constructed around 1964 and included a 5,678,118-liter (1.5-million-gallon) storage reservoir used to impound water pumped from an intake located near the confluence of the West Branch and East Fork. This water was used for fire protection and domestic use.

The water supply system for the Mill Creek Campground provides domestic water for campground visitors and operations. The supply well is located on the floodplain about 35 m (115 ft) from the left bank of the West Branch of Mill Creek. The water treatment plant has two water storage tanks with a total capacity of 389,897 liters (103,000 gallons) and is located upslope of the campground. Peak water demand of about 113,562 liters (30,000 gallons) per day occurs between July and September and coincides with the rearing and outmigration of juvenile salmonids, including coho, a species Federally and state listed as threatened. An unpublished study by State Parks was conducted to evaluate the potential negative impacts that pumping may have on coho stranding and mortality. The key findings of that study (Fiori, pers. com, 2008) were as follows:

- The campground is located on a stream reach that naturally develops isolated pools and subsurface flow during baseflow periods.
- A pumping rate of approximately 5,678 liters per minute (8,072,602 liters per day) (1,500 gallons per minute, or 2,132,600 gallons per day) would be required to dewater the streambed if the water supply pump operates at a maximum of 114 liters per minute (160,740 liters per day) (30 gallons per minute, or 43,200 gallons per day).
- Water withdrawals were less than 1.1% of the available water resource.
- Juvenile fish appeared to remain in pools and did not navigate steep riffles to avoid stranding and mortality.

2.6.4 pH

Limited pH data are available for the Mill Creek drainage. Samples collected during 1975 and 1976 indicate that pH in the Mill Creek drainage is nearly neutral, with samples (n = 196) ranging from 5.9 to 7.7 (Bradford and Iwatsubo 1978). Samples from the mainstem, East Fork, and West Branch were not significantly different; however, median pH was lower in the West Branch, possibly because of differences in water type among the locations (West Branch has less bicarbonate). The pH was significantly higher ($p < 0.01$ [greater than 99% confidence level using statistical probability]) during the dry season, which is probably related to the shift in water type toward a calcium bicarbonate-type and general increase in alkalinity (Bradford and Iwatsubo 1978). Although the neutral to slightly alkaline values meet the water quality objective set by the NCRWQCB (2011), the slightly more acidic part of the measured range is outside the recommended range of 7.0 to 8.5 for the Smith River Hydrologic Unit. As suggested, the pH is likely more acidic because of local geological and seasonal hydrological conditions.

2.6.5 SPECIFIC CONDUCTIVITY

Specific conductivity is a measure of the capacity of water to conduct an electrical current. The conductivity of water is related to the presence of dissolved solids and thus is higher in sewage, road salt, septic system leachate, and agricultural runoff than in natural waters.

For the Mill Creek and Rock Creek watersheds, conductivity data were limited to samples collected during 1975 and 1976 by Bradford and Iwatsubo (1978). They found no significant differences in specific conductivity measurements made between the mainstem, East Fork, or West Branch; however, specific conductance was strongly time dependent. Specific conductivity ranged from 26 to 88 micromhos per centimeter with a mean of 50.2 micromhos per centimeter for 296 samples taken throughout the Mill Creek watershed. These values are lower than the upper limits set for this water quality objective by the NCRWQCB (2011). Specific conductivity was highest at the end of the dry season, decreased as streamflow increased, and was lowest in late March or early April (Bradford and Iwatsubo 1978).

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3 SEDIMENT

Road removal work at the Mill Creek Addition. Source: Photograph taken by AECOM in 2010.

3.1 SAMPLING APPROACH AND RATIONALE

Roads are the primary sediment source of anthropogenic sediment in the Mill Creek Addition (MCA) and thus were the focus of field inventory and analysis. The California Department of Parks and Recreation (State Parks) has inventoried timber roads throughout the North Coast Redwoods District since the late 1990s, developing and adapting methodology to address the character of the road system and incorporate technological changes as they have become available (e.g., Light Detection and Ranging [LiDAR], geographic information system [GIS] routing systems). These methods are addressed next.

A previous study identified roads as the largest contributor of sediment to streams (Beak Consultants 1998). This and other studies (Pacific Watershed Associates 1996, 1997, and 1998; Stillwater Sciences 2002) provided initial background to guide State Parks' field inventory, which transpired from 2002 to 2005 and included all haul roads but typically did not assess skid trails or fire breaks. Most of the skid trails did not have stream crossings or large cuts and fills and had relatively less landscape disturbance. However, a propertywide aerial photograph review identified potentially problematic skid roads that received further field inspection during the inventory. Skid trails that were not field inspected during the initial inventory should be considered at the project planning level.

3.1.1 FIELD AND OFFICE METHODS AND SAMPLING

Field data collection and database management and analysis (see Appendix A) evaluated the interactive effect of the road and local geomorphic processes, costs for maintenance and road reengineering, and the potential value of the road for various needs. A GIS routing system for the roads (see Section 3.1.3), registered to a digital elevation model (DEM) derived from LiDAR, underpinned the field data collection points. This GIS-based platform enabled slope stability modeling (see Section 3.1.2), in combination with scoring of features derived from the field inventory, to rank the inventoried roads by their relative failure risk and threat for potential sediment delivery to streams. The rankings (listed in Appendix A) did not consider the road's potential use for park operations, resource management, or emergency services.

3.1.2 SINMAP MODELING

To help characterize slope conditions across the MCA and as part of their scoring matrix for ranking roads according to potential sediment delivery, Brian Merrill (a certified engineering geologist) and others used SINMAP (Stability Index MAPping) 2.0, a shallow slope instability modeling software program (Appendix A). A Redwood National and State Parks (RNSP) soil survey (U.S. Natural Resource Conservation Service 2008), an earlier study by Paulín (2007), and regionally estimated precipitation provided much of the information for selecting model parameters (soil bulk density, angle of internal friction, cohesion, soil transmissivity, and recharge rate).

In comparison with similar models, SINMAP permits more flexibility for matching input parameters and landscape variability. Although the geologic conditions are grossly similar, the soils, topography, and rainfall distribution are variable across the MCA. The 2007 1-meter (m) (3.28-foot [ft]) LiDAR-derived DEM helped characterize the landscape physiography for slope-sensitive elements of the road assessment scoring that were not related to SINMAP. Smaller pixels (a digital square that represents conditions in a specified area; descriptions of its size refer to the length of any one side of the square) allow for more accurate representation of slope conditions. Unfortunately, because of file-size limitation errors encountered during the processing the 1-m (3.28-ft) pixel

LiDAR data collected in 2007 proved problematic with the SINMAP modeling. Therefore, a 10-m (32.8-ft) pixel U.S. Geological Survey (USGS)- DEM was applied for the SINMAP analysis and ran satisfactorily. The model output was compared to a historical aerial photograph landslide survey (see Section 3.2.1) to help calibrate the model input parameters and qualitatively assess model accuracy.

3.1.3 ROUTED NETWORK MODELING

The fundamental spatial framework used for the road assessment is known as dynamic segmentation, a component of ESRI ArcGIS™ software. Dynamic segmentation is referred to as routing. The first step to create routes is to draw spatially accurate linework that represents the road system. The linework consists of digitally drawing lines over an existing road network seen on digital orthophoto quadrangles (DOQs) (computer-generated images of aerial photographs in which distortion caused by terrain relief and camera tilts have been removed). ArcGIS™ software attaches geospatial coordinate data to the line and saves the linework as shapefiles. Each line is created through connection of a series of points called nodes, and each section of line between two nodes is called an arc. Simply stated, the linework represents where the road sits on the digital landscape within the GIS software.

The linework is converted into routes by assigning units of measurement along the line from beginning to end, so any point along the route can be identified by an exact distance from the beginning point (also known as the route address). Using routes, attributes and types of data may be assigned independent of the underlying arcs (node to node framework) that spatially display the roads. In this way, an independent database may be dynamically linked to the routes and many attributes can be assigned to any point or segment of a route without requiring a specific arc to be attributed. Appendix A outlines the details of the methodology that was used to create the routed road network in the MCA.

3.2 UPLAND SEDIMENT DELIVERY SOURCES

Upland sediment sources include roads, timber harvest units, and nonanthropogenically disturbed slopes (background rates of delivery). The following discussion addresses delivery to streams from these sources. Volumetric calculations were carried out to the number of significant places allowed by the method used but do not necessarily imply the level of accuracy and precision inferred by the calculated results.

3.2.1 Aerial Photographic Landslide Survey

Using stereo aerial photographs and aerial photographic mosaics obtained over a 2- to 7-year interval between 1958 and 2005, Merrill developed a landslide history across the MCA, except for the northwestern slivers of property at Hamilton Road and upslope from the Crescent City harbor. He reviewed all areas for landslide activity, including pristine areas. Merrill noted each landslide's source area and volume, physical source (e.g., roadfill, inner gorge, cutblock, swale headwall), relationship to a road, relationship to previous landslide episode, failure style, sediment delivery ratio, potential for delivery to a watercourse, and slope location. Small cutbank failures were noted during field surveys but generally were too difficult to distinguish as unique features during the aerial photographic survey. Sediment was considered "delivered" if it reached a first order or higher channel or alluvial terraces, or "not delivered" if the material had deposited in broad swales and convergent topography. Appendix A describes volume measurement and database methodology for the landslide survey in more detail.

Merrill and his associates reported an estimated 575,000 cubic meters (m^3) (752,071 cubic yards [yds^3]) of debris derived from 482 landslides across the MCA; an estimated 310,000 m^3 (405,465 yds^3) delivered to streams (Table 3-1). Of the 482 failures, 394 (82%) affected a watercourse and an additional 8 (1%) features probably affected a watercourse. The sediment delivery rate is the percentage of the total failed volume that reached a watercourse, as previously defined. Road fill slopes accounted for 46% of all failure events and, because of their frequency, also accounted for the largest aggregate volume of failed and delivered material. Considering volume per event, landing fill slopes had the largest failed and delivered values, with an average delivery volume of 1,063 m^3 (1,390 yds^3) per event. Inner-gorge failures (75%) and landing fill slopes (62%) exhibited the greatest delivery rates.

Table 3-1 Landslide Size by Type									
Landslide Type	n	%	Failed Volume (m^3) Average	Failed Volume (m^3) Maximum	Failed Volume (m^3) Total	Delivered Volume (m^3) Average	Delivered Volume (m^3) Maximum	Delivered Volume (m^3) Total	Delivery Rate
Road fillslope	223	46%	1,327	16,200	296,006	697	11,340	155,398	52%
Hillslope	119	25%	918	20,160	109,272	466	10,080	55,437	51%
Landing fillslope	57	12%	1,722	28,800	98,172	1,063	25,920	60,606	62%
Inner gorge slope	46	10%	856	7,200	39,354	640	5,760	29,455	75%
Road cutbank	34	7%	820	2,592	27,882	224	1,080	7,622	27%
Swale headwall	3	1%	1,488	2,304	4,464	653	1,728	1,958	44%
Totals	**482**	**100%**			**575,150**			**310,476**	

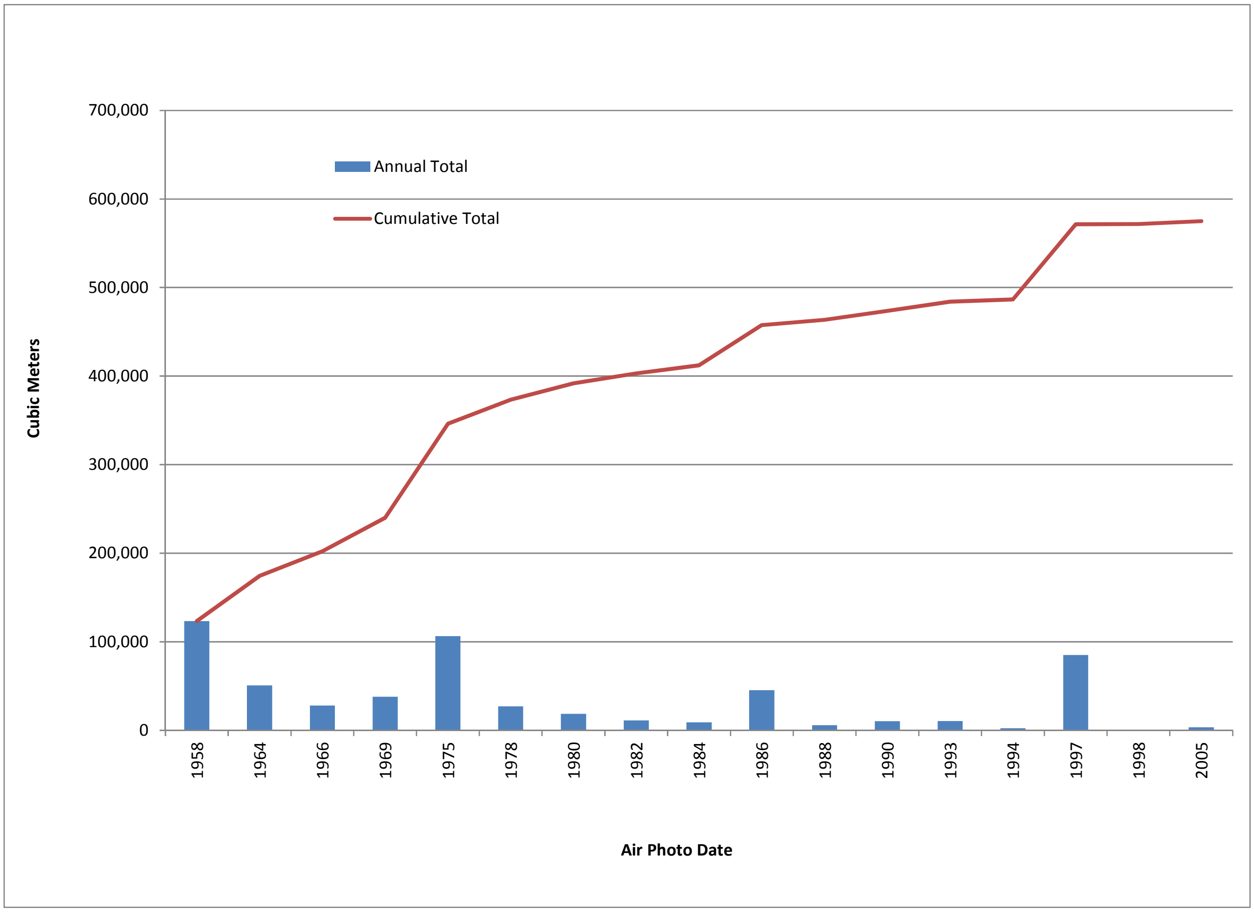
Notes: n = number of indicated landslide type, m^3 = cubic meters.
Source: Merrill et al. 2011

Furthermore, 71% of the 482 failures had a direct or indirect relationship with roads; 66% had a direct physical association, and 5% had a less clear but probable relationships to roads. Skid roads did not appear to be a significant factor in triggering mass wasting events. Hill slope landslides did not occur more frequently in heavily skidded units than they did in yarded units.

Most of the mass wasting events in the aerial photographic record occurred between 1958 and 1980. The 1997 spike in landslide activity was likely the result of the December 31, 1996, rainfall event (Figure 3-1).

3.2.2 SINMAP ANALYSIS

SINMAP modeling results showed the south-central, southeastern, and eastern portions of the MCA as most vulnerable to shallow instability (Figure 13, Appendix A). Slopes adjacent to the upper reaches of the East Fork and its tributaries and, to a lesser extent, the West Branch and Rock Creek, also have higher potential instability ratings.



Source: Merrill et al. 2011

Figure 3-1. Annual Total of Failed Landslide Debris by Volume

3.2.3 ESTIMATION OF SEDIMENT DELIVERY RATE

Three components make up the estimated sediment delivery rate: road-related sediment derived from road associated failures and erosion of the road surfaces; contributions from landslides in areas that were harvested; and background sedimentation from areas of old growth, including landslides and creep. Volume estimates for road-related, harvest-associated, and no cut–associated (old growth or background) landslide sedimentation reflect a decadal aerial photographic analysis of the MCA from 1960 through 1999. Although industrial-scale harvesting began in the 1950s, the earliest vintage aerial photographs with coverage and quality sufficient for analysis date to 1958; failures that occurred before 1958 cannot be clearly associated with a discreet period of timber activities because of a lack of analytical quality, preindustrial harvest imagery.

Volumes were converted from cubic meters to metric tonnes by a factor of 1.44, the conversion factor for moist soil, to compare the results with other watersheds and earlier measurements within the Mill Creek watershed, where tonnage was the accepted measurement method. When comparing the data from this analysis with other watersheds, where American “short” tons and/or English units were used (the weight of a short ton is approximately 10% less than a metric tonne), appropriate conversions were applied.

A culvert inventory revealed that about 23% of the culverts were problematic when State Parks acquired the property in 2002. In spite of this, aerial photographic analysis and field observation reveal a much lower rate of slope failure for both roads and harvested areas during State Parks management of the MCA, in part because of the recently benign climate. Because of this and a change in management style, only the industrial timber period was considered for estimating the anthropogenically derived sediment rate, except as applied here for stream crossing failures in the later industrial timber period.

Stream crossing failure contributions during the 1960s and 1970s were estimated by Patrick Vaughan, a certified engineering geologist, via selected and limited aerial photographic analytical sampling and rate extrapolation on a tonnes per kilometer (tonnes/km) road length basis; current field volume measurements for the sampled crossings helped guide the estimated failure volume. Estimating failure volume from aerial photographs for stream crossings is difficult because they can be reconstructed between the time of failure and the aerial photograph acquisition; field measurement data are preferred where available. Therefore, stream crossing failure volumes for the 1980s and 1990s were extrapolated from failure rates measured during State Parks’ ownership, from 2003 to 2010; the “State Parks” rate was scaled to the length of the road during each decade to estimate stream crossing failure delivery. The differing techniques for stream crossing failure volume estimation coincide with a change in the California Forest Practice Rules in the early 1970s to mid-1970s. Lessons learned from the more damaging storms of the earlier decades (see Section 1.4.2) presumably were incorporated into road reengineering that lead to a lower rate of failure during later industrial timber management. This and a relatively benign climate from the 1980s to the 2000s underpin the use of the State Parks measurement rate during the later industrial timber period for comparative purposes, though the State Parks rate likely underestimates the actual stream crossing failure rate in light of an estimated 12-year storm in 1997.

Road surface erosion calculations assumed a 10-m-wide road with a surface lowering rate of 5.1 millimeters per year (mm/yr) (0.2 inch per year [in/yr]), as suggested for Redwood Creek (Bundros et al. 2003), which locally has comparable geology. The estimation of sediment delivery from road surface erosion also assumes that the road has a 100% connection to the hydrologic network, which is unlikely. Because of this assumption, which cannot currently be confirmed or denied, this component of the analysis is likely overstated (i.e., conservative). Furthermore, the earth materials of the MCA likely are generally harder than those of Redwood Creek; thus, the MCA surface lowering rate resulting from grading or road use is probably lower, which also would contribute to an overestimation of road surface erosion. Merrill et al. (2011) used a road width of 4 meters to estimate the current rate of road surface erosion. This estimate is realistic because the roads no longer need to accommodate two-way log hauling. Because a portion of the roads is not being used, encroaching vegetation has substantially narrowed the extent of exposed road surface since 2003, when State Parks took ownership of the MCA.

The decadal rate of delivery for background (no cut) and timber harvest-associated slope failures were normalized, based on the percentage of the property that was harvested (see Section 1.4.4). These decadal rates were then averaged over the 1960–1999 period to estimate the annual delivery in tonnes per square kilometer (tonnes/km^2/yr), based on harvest (disturbed) area and undisturbed area for background landsliding. Because virtually the entire MCA had been harvested by the time of State Parks acquisition, the delivery rate from this source could be estimated propertywide from 40 years of data. Road-associated failure (including stream crossing proxy data) and road surface erosion rates were similarly calculated by area disturbed by harvest (tonnes/km^2/yr) and road length (tonnes/km) per decade. For rate calculation, division of the decadal tonnage sum by the estimated middecade road length or harvest area was assumed to provide a rate that was overestimated during the first half of the decade by a rate that was equally underestimated in the second half of the decade. The decadal rates were averaged by the four decades selected. The road length delivery rate is an easier method to use for tracking delivery from road sources that can be controlled through engineering as the road network is improved and its length reduced.

Slope creep combines aspects of plastic deformation of soils caused by gravity, rain splash, freeze-thaw (a minor factor within the MCA), and biological activity (e.g., tree throw and animal burrowing). The sediment contribution from creep is a function of the creep rate, the soil depth, and the length of the stream in which the creeping materials deposit. Maximum uplift within the MCA is estimated at approximately 0.3 mm/yr (0.01 in/yr), based on berilium-10 isotope dating of quartz at the Klamath River (Thompson et al. n.d.), maximum late-Pleistocene marine terrace uplift rates near Crescent City (Polenz and Kelsey 1999), and the elevation of ridge top gravel surfaces and their minimum estimated age (Irwin 1997) in the MCA. The uplift rate reflects most of the gravitational element of the observed creep, though the character of the earth material affects its response to gravity. For slopes over 30%, grade creep rates are assumed to be 2.5 mm/yr (0.1 in/yr) for metasedimentary and serpentine soils, and 3 mm/yr (0.11 in/yr) for sandstone-derived soils. These rates were selected from a range of measurements by Swanston et al. (1995) for comparable earth materials in undisturbed forest in Redwood Creek. Slopes having less than 30% grade were assigned a 1 mm/yr (0.04 in/yr) creep rate (Montana Department of Environmental Quality 2005), although floodplains were assigned a creep rate of zero. The minimum average thickness of the solum for the related soil group in the MCA (Merrill et al. 2011) was assumed to control the creep depth. The assumed drainage length used to calculate a uniform creep delivery rate in the MCA was 234 km (145.4 miles), based on LiDAR-derived measurements of blue line stream defined by the USGS (this length was doubled to estimate creep volume because delivery occurs from both sides of the stream). The length of the stream network is compatible with the delivery target used by Merrill for road failure delivery estimates.

The relative percentage of the landscape feature (soil type) in the MCA was applied to its comparative percentage of the stream network to calculate the total volume of sediment delivered via creep. The features' volumes were then summed, and an annual rate over the entire landscape was calculated by dividing the result by the total area evaluated (101.1 square km, 39 square miles). The slivers of property on the northwest side of the MCA that drain to the coast were not evaluated as part of this analysis. This calculation method may overestimate creep by about 15% because some of the more gently sloping areas do not have much direct access to blue line streams. However, they do participate in the creep "conveyor belt" and deliver to secondary channels. Although creep is usually not considered an anthropogenic sediment source and is considered "background" in this analysis, road networks can accelerate creep delivery where roads are connected to the hydrologic network. Although road construction and silvicultural disturbance could affect creep delivery, the rate was assumed constant over time for both the disturbed and undisturbed landscape.

3.2.3.1 ROAD-RELATED SEDIMENT CONTRIBUTIONS

Landslide and stream crossing failures are road-associated sediment delivery that can be controlled through improved engineering practices. These elements of road-associated delivery, calculated at decadal intervals between 1960 and 1999, generally decreased both in absolute terms and as a function of increasing road length, probably because road construction standards were raised and storms were comparatively milder during those years (Table 3-2). Road surface erosion became an increasingly significant component of the overall road-related delivery, both in absolute and relative terms as the length of road network grew (see Appendix A). The average road-related sediment delivery rate over the four decades was 606 tonnes/km^2/yr (1,730 tons/sq mile/yr).

3.2.3.2 SILVICULTURAL SEDIMENT CONTRIBUTIONS

In absolute terms, sedimentation associated with silviculture increased substantially in the 1990s, possibly as a result of more aggressive harvesting and greater land base exposure when Stimson began liquidating its assets before the sale to State Parks.

Table 3-2 **Sediment Delivery Rate from 1960 to 1999 within the MCA from Road, Silviculture, and Background Sources**					
Source	1960–1969	1970–1979	1980–1989	1990–1999	Decadal Average
Road-related total (tonnes)	**221,536**	**316,961**	**352,736**	**374,663**	**316,474**
Landslides	78,610	76,215	68,763	36,871	
Crossings	21,816	31,719	9,582	11,188	
Surface erosion	121,110	209,027	274,391	326,604	
Silvicultural total as landslides (tonnes)	**10,925**	**16,380**	**6,577**	**35,594**	**17,369**
Total tonnes anthropogenic	**232,461**	**333,341**	**359,313**	**410,257**	**333,843**
Background total (tonnes)	**24,665**	**23,516**	**20,863**	**22,169**	**22,803**
Landslides	4,051	2,902	249	1,555	
Creep	20,614	20,614	20,614	20,614	
Road-related total (tonnes/km^2 disturbed/yr)	**823**	**667**	**514**	**420**	**606**
Landslides	292	160	99	41	
Crossings	81	67	22	20	
Surface erosion	450	440	393	359	
Silvicultural total as landslides (tonnes/km^2 disturbed/yr)	**41**	**34**	**9**	**40**	**31**
Background total (tonnes/km^2 undisturbed/yr)	**26**	**26**	**22**	**35**	**27**
Landslides	5	5	1	14	
Creep	21	21	21	21	
Engineering related total (tonnes/km of road per year) Landslides and crossings	**61**	**38**	**23**	**13**	**34**
Source: State Parks GIS information State Parks staff using data developed from State Parks GIS information and Merrill et al. 2011					

However, the sedimentation rate per square kilometer of harvest was fairly similar over three of the four decades, with the 1980s showing a much lower rate, consistent with the storm history (Section 1.4.2 and Figure 3-1). The silviculture rate averaged over the four decades was 31 tonnes/km^2/yr (89 tons/sq mile/yr), equivalent to approximately 5% of the road-related delivery.

3.2.3.3 BACKGROUND SEDIMENT CONTRIBUTIONS

The calculated creep delivery rate, assumed constant over the four decades, was noticeably higher than the estimated background delivery rate from landsliding. The total calculated background rate (creep and landsliding) was 27 tonnes/km^2/yr (77 tons/sq mile/yr), or roughly 4% of the average anthropogenic rate over the assessment period. Madej et al. (1986) indicated that Iwatsubo and Washabaugh (1982) estimated the pre-1982 background rate to be about 17% of the anthropogenic rate, based on suspended sediment analysis for Mill Creek only.

The background landslide rate, derived from old growth that has interspersed harvest units in Bull Creek (Humboldt Redwoods State Park) over a somewhat similar period (1967 to 1998), was 52 tonnes/km^2/yr (149 tons/sq mile/yr) (Fiori et al. 2002), approximately eight and a half times the background landsliding rate in Mill Creek (6 tonnes/km^2/yr or 18 tons/sq mile/yr). Although the Bull Creek analytical period did not cover the 1964 storm, the data support relatively greater stability at the MCA; this appears reasonable, given the much higher uplift rate and much less competent bedrock in Bull Creek.

3.3 INSTREAM SEDIMENT DELIVERY

Future assessment of stream power, channel slope, and the relationship of vulnerable slopes, roads, and streams will indicate the likely fate of upland sediment that might be delivered to the stream network. This information, in combination with the rankings from the Road Assessment report (Appendix A) and knowledge of the fishery, should help to determine monitoring locations and prioritize restoration treatments.

3.4 SEDIMENT SOURCE ANALYSIS RESULTS AND TARGET REDUCTIONS

Because no Total Maximum Daily Load (TMDL) has been prepared for most of the property, this analysis examines the target conditions that are projected to result following restoration treatments. The analysis looks at the MCA as a whole, rather than by subwatershed, because conditions are generally similar across the property. Klamath River TMDL targets govern the southern MCA watersheds; however, the only numeric allocation identified for sediment, the focus of this analysis, relates to stream temperature and is somewhat qualitative (see Section 2.2.2).

The rate data for disturbed versus undisturbed areas are useful to calculate how much sediment has an anthropogenic source and how much needs to be or can be controlled. For the MCA, Table 3-2 indicates that silvicultural and background rates are similar (likely the creep is released as landslides in harvested areas) and that the road-related sediment delivery rate exceeds the background rate by a factor of about 20 or more.

For suspended sediment analysis, the stream does not discriminate as to the origin of the sediment. As previously discussed, the delivery rates per unit area were higher in the 1960s and 1970s, but the total sediment contribution increased in later decades as the disturbance area increased. The total sediment load in the 1970s, anthropogenic plus background, was about 356,857 tonnes (394,012 tons) across the entire MCA (101.1 km^2 [39 sq miles] in the area of analysis).

Direct measurement for suspended sediment in Mill Creek (Madej et al. 1986) over two periods in the 1970s (1974–1977 and 1978–1981) showed an annual suspended sediment load of 70 tonnes/km^2 (200 tons/sq mile) upstream from the northern MCA boundary. Estimated annual suspended sediment loads from modeling by Iwatsubo and Washabaugh (1982) of 389 tonnes/km^2 (1,114 tons/sq mile), in the context of Madej et al.'s (1986) estimate for the relative ratio of dissolved solids (30%), suspended sediment (60%), and bedload (10%) in the Mill Creek watershed, indicate an upland sediment source delivery rate of about 648 tonnes/km^2/yr (1,850 tons/sq mile/yr), or 480,168 tonnes (530,162 tons) per decade.

The total sediment load for the 1970s, based on the suspended sediment load measurement period, is about 105,000 tonnes (115,932 tons). The following discussion assumes that streambank erosion is negligible. Scaling the total load for the MCA in the 1970s, 356,857 tonnes (394,012 tons) to Mill Creek, results in a load of 261,540 tonnes (288,771 tons), or roughly 2.5 times the measured load (as adjusted for total sediment). However, the rate based on road-related, silviculture and background annual total delivery rate between 1960 and 1999 across the entire MCA is about 664 tonnes/km^2/yr

(1,896 tons/sq mile/yr), as shown in Table 3-2, which is very similar to the total delivery rate calculated from Iwatsubo and Washabaugh's modeling of suspended sediment.

Several uncertainties are associated with the analysis presented here and in Section 3.2, such as a possible slight overestimation of creep delivery (approximately 3 tonnes/km^2/yr [8 tons/sq mile/yr]), an inability to discriminate background and silviculture landslide sources within harvest units (approximately 7 tonnes/km^2/yr [18 tons/sq mile/yr]), and the rate of road surface erosion delivery (estimated at up to 199 tonnes/km^2/yr [569 tons/sq mile/yr] if the roads were only 55% rather than 100% hydrologically connected). For their analysis of current conditions, Merrill et al. (2011) estimated that cross drains disconnect about 50% of the road length from the hydrologic network. However, nearly all the currently used service roads are directly connected in the vicinity of stream crossings; therefore, a slightly higher minimum uncertainty value of about 55% is used. Furthermore, it is likely that the cross drain density increased over the period of analysis as road construction design improved; therefore, this element of the sediment analysis conservatively assumes 100% hydrologic connection, even though it is recognized that this is a likely overestimation. Reducing the estimated load by the estimated uncertainty results in a rate as low as 455 tonnes/km^2/yr (1,299 tons/sq mile/yr) for the MCA between 1960 and 1999, which is still substantially higher than the total load estimated by Madej et al. (140 tonnes/km^2/yr [400 tons/sq mile/yr]) for the Mill Creek watershed during the late 1970s. If the same ratio of uncertainty (up to 31.5% lower) is applied to the MCA data and scaled to the Mill Creek watershed for the 1970s, the total sedimentation rate is about 1.7 times higher, rather than 2.5 times the rate measured by Madej et al.

It is possible that failures in the 1970s in the MCA were preferentially outside of the Mill Creek watershed or that they preferentially occurred outside the suspended sediment measurement period, though that is speculative. Other assumptions in the analysis may overstate the loading or actual delivery to the stream that was measured (e.g., sediment might have been caught on terraces or in first-order channels but considered "delivered"; landslide depths could have been slightly different than estimated; the road surface erosion rate could have been lower, even with the indicated uncertainty;

crossing failure volume estimates could have been in error; or extrapolation assumptions might have been flawed). Because of the way the data were processed, this analysis cannot fully resolve the difference, although the data are in such a form that future analysis may help partially resolve some of these questions. In any case, the data and assumptions presented here suggest a rate between the modeled and measured rates that were discussed in Madej et al. (1986) as applied across the entire MCA for the 1970s and a longer term rate for the MCA that is very close to the rate modeled by Iwatsubo and Washabaugh for Mill Creek. Although this leaves open some questions, the data from this analysis appear fairly reasonable, given the vagaries of the technique and the general consistency with trends that might be expected, given differing geological conditions for the MCA and reference watersheds.

The criteria for sedimentation reductions for this planning effort (outside other regulatory constraints) include less total road surface erosion based on the reduction in road extent, a reduction in stream crossing failure based on upgrading of all crossings to transport 100-year flood flow and debris, elimination of all potential stream crossing diversions, removal or stabilization of all road or landing fills capable of delivering to a stream, performance of annual storm patrol, and improvements in drainage for the core road network that meet State Parks standards (see Section 3.5.2.1). The numeric target for road-related failure (landsliding and stream crossing failure) for the final administrative road network from road-associated landslide failure is the same rate that was observed during the 1990s, when a high degree of road maintenance and improved construction techniques resulted in the lowest failure rate observed during a high road use period (13 tonnes/km [23 tons/mile] of road per year); this rate reflects the effects of an estimated 12-year storm in 1997. Although a reduction in the coho population occurred in the late 1990s, other fish species fared relatively well during this period (see Chapter 2). Coho populations rebounded in the early 2000s; McLeod and Howard (2010) attribute an 8- to 11-year cycle in oceanic conditions to the late 1990s decline in coho in Mill Creek rather than sedimentation effects from the 1997 flood. Therefore, selecting the rate from this decade as a target for road-associated landslide and stream crossing failure is reasonable.

Since the acquisition by State Parks, silviculture-related delivery rates have been virtually nonexistent. Road crossing and road landslide delivery rates also have been exceptionally low, suggesting that rest has helped the watershed, although a relatively benign climate also has probably been a factor. In spite of the low recent failure rate, it may take more than a century for root cohesion within industrial timber harvest units to achieve values similar to old growth (Schmidt et al. 2001). However, timber management to accelerate late seral conditions is a relatively new restoration technique and will likely contribute to faster root cohesion improvements than industrial timber management. Regardless, expecting the recent low rate of sedimentation to continue is not reasonable, and thus a target from silviculture and other sources needs to be developed that is realistic over the expected time frame for this plan (estimated at about 30 years at current and projected road removal rates).

The overall sedimentation average rate from roads and silviculture-related failure (637 tonnes/km^2/yr [1,819 tons/sq mile/yr]) was about 24 times the background rate (27 tonnes/km^2/yr [77 tons/sq mile/yr]) between 1960 and 1999. If the Iwatsubo and Washabaugh-estimated background rate of 17% is applied and the background rate in this analysis is underestimated, then the background could be about 108 tonnes/km^2/yr (309 tons/sq mile/yr), resulting in an anthropogenic/background ratio of about six (this infers that some of the delivery assigned in this analysis as anthropogenic is natural). Although these results indicate that the MCA has a way to go to achieve a more balanced condition, examination of sedimentation rates in nearby watersheds provides context. The estimated anthropogenic plus background sedimentation rate for Redwood Creek is about 1,664 tonnes/km^2/yr (4,750 tons/sq mile/yr) (USEPA 1998a), or about 2.5 times that of the MCA, attesting to MCA's comparatively low sedimentation rate, even with disturbance. The decade with the highest sediment production rate in the MCA, the 1960s, recorded a little more than about half of the long-term average rate in Redwood Creek if total upland sediment delivery is evaluated.

A sedimentation delivery rate target that exceeds background rates (i.e., incorporates a remnant road network) is justified because a comparatively robust salmonid population coexisted with early industrial timber harvest on the North Coast and this logic has been used to develop acceptable loading in other TMDL analyses (cf., South Fork of the Eel River, USEPA 1999). An approach to estimate the target rate for acceptable overall anthropogenic sedimentation is the application of management actions necessary for resource protection, consistent with guidance from the Mill Creek General Plan Amendment (GPA) (e.g., compliance with the regulations for coho protection or water quality [e.g., North Coast Regional Water Quality Control Board Basin Plan], or GPA guidance for the configuration for the core road network necessary to manage the MCA [128 km, 80 miles of road]). The MCA had approximately 128 km (80 miles) of road and an estimated 2,023 hectares (ha) (5,000 acres [ac] [20.2 km^2 or 7.8 sq miles]) of harvested area sometime between 1960 and 1962 (derived from extrapolation of data for the road construction history, Table 1 in Appendix A, and timber harvest history, Table 1-1 of this report). Thus, 2,023 ha (5,000 ac) of forest restoration approximates the probable maximum forest restoration treatment area (see Chapter 4) for any 10- to 15-year period, when root cohesion will be lowest. The treatments are not anticipated to be designed to test root strength reductions that might result from the restoration.

Assuming the annual silviculture delivery rate at the end of the 30-year project is equivalent to the rate observed from 1960 to 1999 (31 tonnes/km^2/yr or 89 tons/sq mile/yr) for the most recently restored area, an affected area of 20.2 km^2 (7.8 sq miles) will result in a delivery volume of about 626 tonnes (691 tons) per year, or roughly five times the background landslide rate for an equivalent area (the background rate on Table 3-2 includes creep as well; this discussion is limited to the landslide rate). Forest restoration treatment delivery rates are likely to be more comparable to background rates than to industrial silviculture rates because of the project design and improved root strength as the restoration takes hold over time. Therefore, this analysis also assumes that the calculated potential anthropogenic delivery (626 tonnes [691 tons] per year) includes sediment from any remnant untreated stands throughout the MCA. At the end of 30 years, the remnant stands are expected to be trending toward background levels resulting from natural regeneration.

The time required for the untreated stands to reach background sedimentation levels is not known but applying the “restoration” annual volume across the entire MCA indicates that restoration and background landslide sedimentation rates will be roughly equivalent. Supporting this assumption, very significant reductions from the calculated industrial silviculture rate to virtually nothing have been observed since State Parks took ownership of the property; the only treatments during this period have involved forest restoration. However, the observation record is short and the climate has been benign.

Assuming the 1990s road-associated landslide and stream crossing delivery rate is achievable (13 tonnes/km [23 tons/mile] of road year, shown in Table 3-2) through road reengineering and a reduction in the number of vulnerable sites, 128 km (80 miles) of remnant administrative road should result in the potential delivery of about 1,664 tonnes (1,837 tons) per year. Road surface erosion from 128 km (80 miles) of road at the rate used for the analysis shown in Table 3-2 (5.1 mm/yr [0.2 in/yr] of surface lowering) results in the delivery of 9,401 tonnes (10,380 tons) per year, again a very conservative analysis as explained previously. Annual delivery from all of the analyzed anthropogenic sources is estimated to be about 11,691 tonnes (12,908 tons). Using the 1960–1999 creep and background landsliding rate over the MCA landscape results in an estimated delivery of about 2,730 tonnes (3,014 tons) per year, or roughly one-quarter of the anthropogenic load, given the estimated road lengths (the anthropogenic to background rate would be 400%).

State Parks road reengineering favors outsloping over inboard ditching. If reengineering can reduce road surface erosion or its hydrological connection for the core road network, it is likely that the anthropogenic and background loads will be closer. Redwood Creek has some geological similarities to the MCA. As an initial target, the anthropogenic to background target ratio should be 250%, the value used for the Redwood Creek TMDL (USEPA 1998a). This will require a reduction in road surface erosion from about 9,401 tonnes (10,380 tons) of delivery per year to about 4,623 tonnes (5,104 tons) per year. Although other nearby watersheds, such as the Trinity River, Basin have used smaller anthropogenic-to-background ratios (125%, USEPA 1998b), the generally good quality of the MCA fishery, even in the wake of industrial timber management, suggests that a higher target is acceptable. If monitoring shows that restoration silviculture inputs are lower than industrial silviculture rates, as expected, or that road surface erosion delivery rates are lower than assumed here, the targeted reduction in road surface erosion can be adjusted.

Madej et al. (1986) suggest that a comparatively high dissolved load exists in Mill Creek and that floodplain storage helps keep bedload and suspended sediment at lower levels than other North Coast watersheds; thus, the sedimentation effects on the fishery in Mill Creek are even less than just the low upland sedimentation rate suggests. This may be borne out by the differences in the delivery rates shown by this analysis and the comparatively lower rates suggested by the measurements of Madej et al. (1986).

Although the estimated sedimentation from State Parks activities after restoration can be up to about four times the background rate, it is likely that the rate will be closer to background. Examination of other data suggests that even if the road surface erosion delivery rate is not reduced, the worst-case projected delivery rates should be within acceptable limits for preservation of the fishery. The fishery remains relatively robust, even after several decades of industrial timber management. Simply reducing the road length to 128 km (80 mi) and achieving the target road failure rate will reduce the anthropogenic delivery rate by a factor of 3. Achieving the loading recommended here through additional road reengineering-related surface erosion improvements should reduce the calculated anthropogenic levels described in Table 3-2 by a factor of about 7.

Restoration achieves resource goals other than protection of the fishery, such as reclamation of land area, enhanced forest growth, better landscape connectivity for wildlife, and natural slope processes. Therefore, sedimentation is not the only factor in setting park restoration goals and is not the only consideration for State Parks' vision. Furthermore, the analysis here presents results from a road network that generally has had adequate maintenance funding. As government budgets can vary, it is possible that funding for preservation of the remaining road network will not continue to be available in the future. Therefore, a higher element of risk will remain unless the roads are removed or improved.

3.5 SEDIMENT TREATMENT METHODS AND PRIORITIZATION

To achieve the desired sedimentation rate, several treatments should be employed. For example, a desired condition is that all stream crossings with diversion potential should be removed; all culverts should be capable of passing 100-year flood flows and associated debris, inboard ditches and cross drains should be eliminated where consistent with maintaining slope stability; the quality of road surfacing should match the intended use; fine dust abatement should be employed where it has the potential to damage vegetation or enter a water course; and storm patrols should help prevent sedimentation problems. Instream structures should be designed to help replicate channel morphology and sediment conditions most conducive to salmonids. Floodplain-channel connections should be encouraged, and unobstructed floodplain flows should be maximized. A goal for forest thinning should be the enhancement of slope stability by increasing remaining tree root size and vegetation complexity.

3.5.1 RATIONALE FOR ROADS TO REMAIN

The rationale for retaining roads in the MCA follows guidance from the GPA and the analysis presented here. The general theme for road retention is to serve the MCA's facility and administrative needs by using the most effective, stable routes that can be realistically maintained in light of budget considerations and ensuring resource management projects are properly sequenced so that access is not lost.

3.5.2 BEST MANAGEMENT PRACTICES

Best management practices for road maintenance, road reengineering, road removal, road conversion to trail, and instream restoration should help minimize sediment impacts from related work, significantly reduce long-term sediment risk potential, and improve riparian and terrestrial habitat. All of these practices, in addition to landslide stabilization, instream structural improvements, and forest restoration, will have oversight by appropriately licensed staff to help ensure that designs and activities comply with water quality regulations.

3.5.2.1 Annual Road Maintenance

Annual maintenance is critical to maintain the road network so that it does not affect existing water quality and remains viable until unneeded road segments can be appropriately treated in light of this plan and a future Roads and Trails Plan.

Grading

If the road is narrowed with vegetation, a work crew should be employed to clear vegetation on the cutbank, roadbed, and the upper third of the embankment fill slope to make room for equipment operations. If the vegetation is heavy, a mower or excavator may be used to clear the roadway. An excavator-mounted vegetation masticator also may be used to remove trees and brush. If a masticator is used, a dozer may be employed to accumulate and pile ground mulch for use on finished surfaces.

Following clearing operations, a motor grader equipped with rippers should de-compact the road surface to a minimum depth of 8 inches. If the road material is dry, water may be added to reduce dust. During the first pass, the grader should clear the inboard ditch to improve conveyance of road drainage. Ditch spoils should be carried across the road and sidecast onto the road embankment. During subsequent passes, the grader should shape the road surface to promote drainage. The road drainage design should be crowned, insloped, or outsloped. Additional road aggregate may be added to sections of the road that show signs of accelerated wear or provide poor traction. During the final grading pass, any berm present on the outboard edge of the road should be removed to eliminate ponding of runoff along the outer edge of the road. Following grading operations, a vibratory, single-drum roller should compact the road surface. The roller should make several passes to ensure that the road surface is smooth and compact. Water may be added to increase compaction of the finished surface.

Culvert Clearing

Before winter, crews should be dispatched to inspect and clear stream crossing and cross drain culverts. Culvert inlets should be cleared of heavy vegetation and sediment deposited at the inlet. If pipes are clogged with debris, crews should attempt to clear the pipes to restore full capacity. Outlets also should be inspected for obstructions. If any deficiencies are found with pipes or related hardware, a record should be generated and submitted to the district office for inclusion into the repair or replacement cycle. Road ditches adjacent to the culvert inlets also should be cleared to reduce sediment input and improve drainage. Sites with large accumulations of sediment or debris that cannot be cleared by hand should be scheduled for heavy equipment treatment as soon as equipment and operators become available.

3.5.2.2 Culvert Replacement

Appropriate sizing for culverts and maintaining their condition are the keys to the long-term stability of fill that is directly linked to the hydrologic network. Design standards have improved since the original culverts were installed, and some of the culverts are reaching the end of their effective lives.

Road-Stream Crossing

An on-site evaluation should be made by qualified staff members who are experienced in road engineering, to determine whether a culvert crossing is required at the site. In some cases, other alternatives, such as hardened seasonal fords, rock-armored crossings, or drain swales, may be appropriate. These alternatives are preferable to a culvert because of their low maintenance and because they can be constructed without introducing fill into the stream channel. Culverts should be sized to convey a discharge equal to or greater than the 100-year flow plus sediment and debris. The design flow should be determined using the rational method, USGS regional relationships, or adjacent channel morphology.

An excavator should prepare the site by first removing any trees and brush that are growing on the crossing fill along the centerline of the culvert. Trees and brush that are removed should be stockpiled and used to mulch disturbed ground following culvert replacement or for instream restoration. Trees growing away from the centerline of the culvert may be left; however, clearance may have to be provided for excavator maneuvering.

If the stream is running, water should be diverted away from excavation areas to reduce turbidity and eliminate saturation of the crossing fill as it is excavated. A small diversion dam should be built upstream, and streamflow should be piped around the worksite and discharged into the stream below the worksite. The excavator first should excavate a trench down to the existing culvert, exposing it, so that the excavator can remove the old pipe using the bucket and thumb. Old culverts should be cut and crushed to fit in available transport vehicles.

Following the removal of the old pipe, the trench should be excavated to the prescribed width and depth for the new culvert placement. The trench should be straight in both profile and plan view. The gradient of the culvert should match the gradient of the stream running through the crossing and should be set to a depth slightly below (25% of diameter) that of the stable channel bed. This will help to ensure continuity of bedload transport and provide a natural substrate for animal migration.

Trenching should be in compliance with all applicable worker health and safety regulations including, but not limited to, Section 29 Code of Federal Regulations (CFR) 1926.650, 601(b)(6) and Title 8, Sections 1540, 1541, and 1541.1 of the California Code of Regulations (CCR). Trenches should be properly sloped, benched, or shored if personnel are to enter any trench greater than 5 feet deep.

The new culvert should be placed into the trench and the necessary couplings made. Couplings are critical for culvert performance. All couplings should be assembled according to manufacturer's instructions. Laying the pipe on a well-compacted base that is straight in profile is essential. Any settling or deflection in the pipe can result in separation at a coupling or a rupture in the pipe wall. The culvert should extend from the inboard edge of the road to beyond the base of the embankment fill. A mechanical compactor should compact fill as it is placed back into the trench. The compactor can be mounted to an excavator or can be walk-behind or free standing. Fill should be compacted in maximum 6-inch lifts until the trench is refilled.

Downdrain assemblies generally are not recommended for stream crossing sites because they limit migration of aquatic species, aggrade at the inlet, and are prone to scour at the outlet of the pipe. In situations where the new culvert cannot be set at the stable stream gradient, an anchored downdrain assembly and an energy dissipater may be installed to prevent scour at the outlet. The energy dissipater should be constructed of appropriately sized rock armor and should have a concave cross section to prevent culvert discharge from scouring adjacent streambanks. A headwall or flared inlet should be installed at the inlet of the culvert to protect crossing fill from saturation and scour and direct flow into the culvert. The headwall can be constructed with sack concrete, reinforced with driven rebar, or can be poured in place with mixed concrete.

A trash rack may be installed where large organic debris can be mobilized in the channel, causing a plug at the culvert inlet. Many different designs exist for various applications, so trash rack designs should be site specific. Any design chosen should protect the inlet from plugging and maintain flow at or near the centerline of the channel. Designs that can divert flow into the streambanks upstream of the inlet should be avoided.

The road surface should be shaped so that a broad dip is formed over the centerline of the crossing. The dip should pitch to the inboard inlet and headwall. This should prevent road drainage onto the outboard edge of the crossing fill. Where feasible, the road should be regraded and realigned so that the road contours into the stream valley along an alignment that is as upstream as practical. The road can also be narrowed according to the road construction specifications. Reducing the road width and contouring farther up into the stream valley should significantly reduce the size and fill volume in the crossing. In the event of a crossing failure, less fill should be available for erosion and delivery directly into the drainage network.

Trees and brush removed before excavation should be used as mulch whenever possible. Mulch should be spread over the surface of the crossing embankment to provide 70–90% surface coverage. The road approaches should be outsloped to reduce road tread flow to the crossing. Where the quantity of mulch material is insufficient to meet these requirements, locally derived material such as duff and small brush should be imported to the crossing sites from nearby interfluvial road sections. Mulch applied on crossing embankments should be pressed onto the ground surface wherever possible, using the excavator or the dozer.

Cross Drain Replacement

An on-site evaluation should be made by qualified staff members who are experienced in road engineering to determine if a culvert cross drain is required at the site. If culvert replacement coincides with road reengineering, many culverts can be eliminated by removing much of the inboard ditch. Other alternatives such as hardened drain swales may be appropriate. Where culvert cross drains are used, the location of the drain should coincide with natural drainage features downslope. The culvert should be sized to convey a discharge equal or less than the 100-year flow. Determination of the design flow should employ the rational method, USGS regional relationships, or adjacent channel morphology.

Similar to a stream crossing excavation, the excavator should begin by excavating a trench down to the existing culvert, exposing it, so that the excavator can remove the old pipe using the bucket and thumb. Old culverts can be cut and crushed to fit in available transport vehicles. If the culvert installation is new, the trench should be excavated according to the prescription design.

Following the removal of the old pipe (if present), the trench should be excavated to the prescribed width and depth for the new culvert placement. The trench should be straight in both profile and plan view, and should be set at a minimum angle of 30 degrees from perpendicular relative to the road direction. The gradient of the culvert should be set to a depth where the pipe exits the embankment fill at the native ground surface.

Trenching should be in compliance with all applicable worker health and safety regulations including, but not limited to, Section 29 CFR 1926.650, 601(b)(6) and Title 8, Sections 1540, 1541, and 1541.1 of the CCR. Trenches should be properly sloped or benched or shored if personnel are to enter any trench greater than 5 feet deep.

The new culvert should extend from the inboard edge of the road to beyond the base of the road embankment fill. In situations where the new culvert cannot be set at the base of the embankment fill, an anchored downdrain assembly and an energy dissipater should be installed to prevent scour at the outlet. The energy dissipater should be constructed of appropriately sized rock armor and should have a concave cross section to prevent culvert discharge from scouring adjacent slopes. A headwall or drop inlet should be constructed at the inlet of the culvert to protect crossing fill from saturation and scour, and direct flow into the culvert. The headwall can be constructed with sack concrete, reinforced with driven rebar, or can be poured in place with mixed concrete. The road surface should be shaped so that a rolling dip is formed over the centerline of the culvert. In contrast to stream crossing culverts, the pitch of the road surface should be toward the outboard edge of the road.

3.5.2.3 Road Drainage Improvements

Where poor road drainage may result in accelerated erosion of the road surface and deposition of fine sediment into adjacent streams, improvements may be applied to the road surface beyond routine grading. These improvements should include elimination of the inboard ditch and reshaping the road surface to facilitate sheet drainage. Replacement of small culverts with armored drain swales may also be considered. In more severe situations, rerouting the road to a more sustainable alignment may be the most effective way to sustain the road and protect resources.

Where feasible, the road cross section should be outsloped and the inboard ditch eliminated. This should promote sheet flow across the road and eliminate scour and sediment transport along the inboard ditch. Where springs and seeps exist along the cutbank, the inboard ditch may be left in place while still outsloping the road. This should prevent the road from becoming too saturated from spring flow and still provide improved drainage of the road surface. If outsloped sections of road are to be used year-around, coarse aggregate road base should be applied to improve traction where needed.

3.5.2.4 Road Removal and Road to Trail Conversion

State Parks road removal and road to trail conversion techniques have been honed in the North Coast Redwoods District since the mid-1990s. Merrill and Casaday (2001) reviewed the methodology for these treatments. Water quality protection should be similar to that previously outlined for other road treatments.

3.5.2.5 INSTREAM RESTORATION

Eight recently completed restoration sites utilized large whole trees and smaller logs and branches to restore natural instream processes that contribute to channel form and structure, and provide essential habitat for salmon and other aquatic species. These eight complex wood jams were geomorphically designed to mimic natural wood jam formation (Abbe and Montgomery 1996) using a combination of wood-sized fractions (Abbe and Montgomery 2003, Manners et al. 2007). Each site was individually designed, based on specific site geomorphic conditions, hydraulic forces, available construction materials, and the availability of riparian trees as living pilings for support during high flows. Dominantly alder vegetation affected by construction access needs was replanted with conifer species.

These structures are more complex and dynamic than simple wood structure designs that were previously approved by the California Department of Fish and Game (CDFG). Initial data suggest that they are associated with a higher degree of habitat improvement. Results from mapping and surveying indicates that the number of distinct sand-, gravel-, cobble-, or boulder-dominated channel areas (facies patches - Figures 3-2 and 3-3), habitat heterogeneity (Figures 3-4 and 3-5), residual pool depth (Figures 3-6 and 3-7) and maximum upstream aggradation (Figures 3-8 and 3-9) increased for sites that had greater total wood volume and total wood volume per active channel width. In addition, reach average D50 (the median bed surface particle size) decreased with increased wood loading (Figure 3-10).

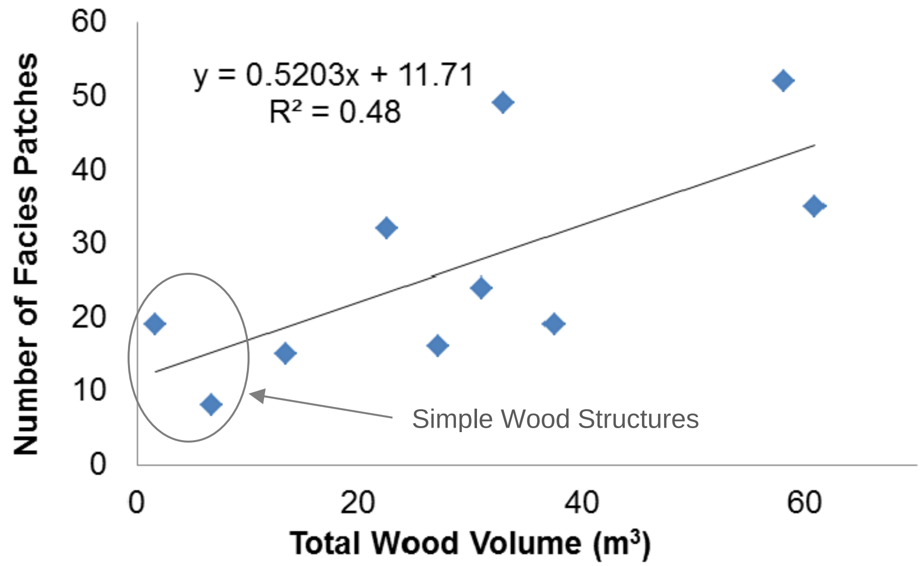


Figure 3-2. Relationship between the Number of Facies Patches and Total Wood Volume (at two constructed simple wood structures and eight constructed complex wood jams in the East Fork)

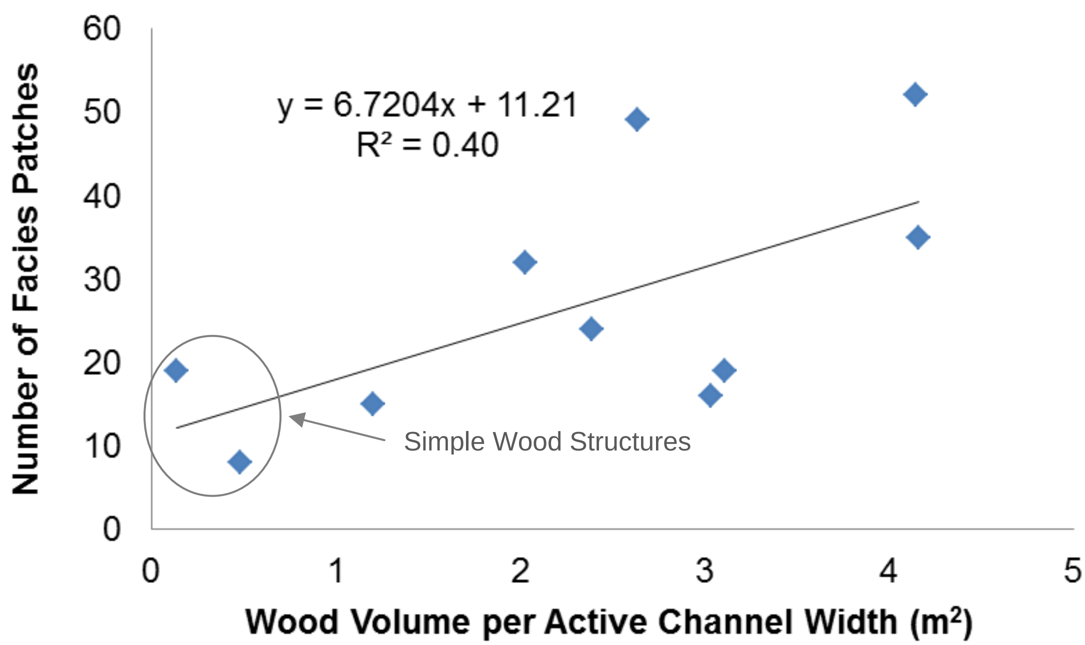


Figure 3-3. Relationship between the Number of Facies Patches and Wood Volume per Active Channel Width (at two constructed simple wood structures and eight constructed complex wood jams in East Fork)

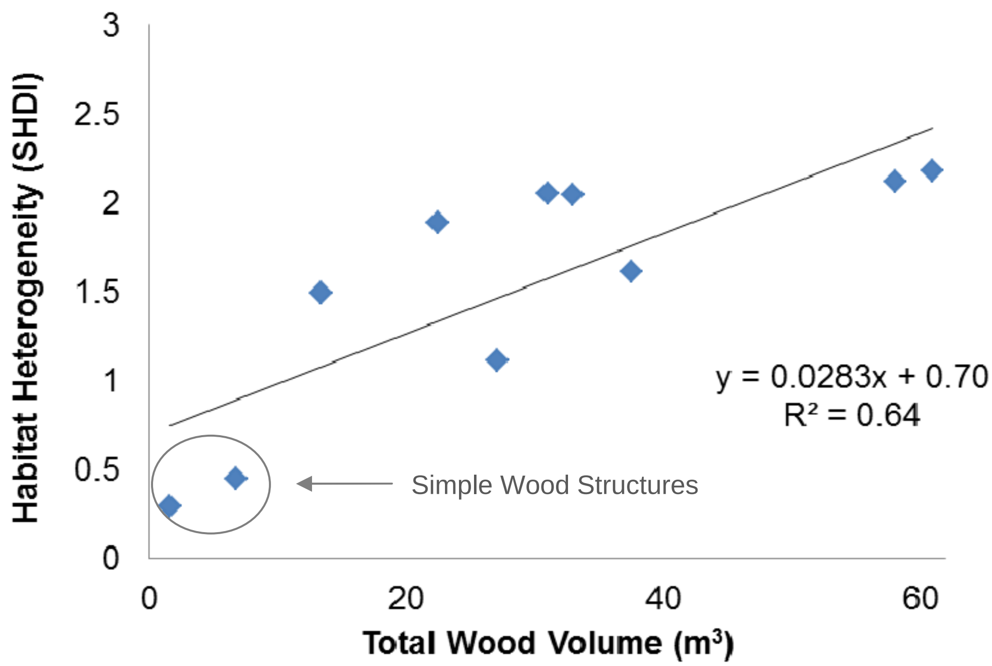


Figure 3-4. Relationship between Habitat Heterogeneity as Expressed by Shannon's Diversity Index (SHDI) and the Total Wood Volume (at two constructed simple wood structures and eight constructed complex wood jams in the East Fork)

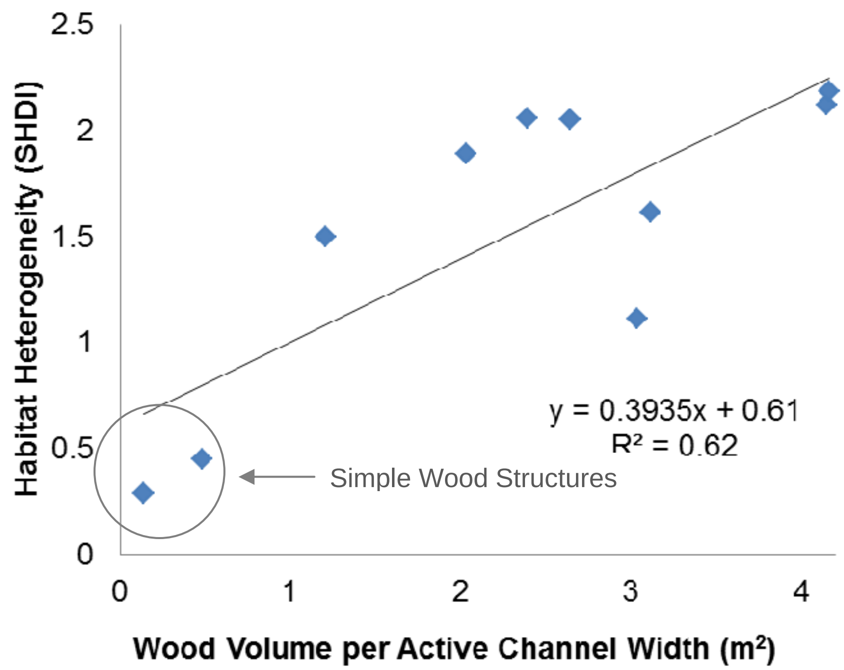


Figure 3-5. Relationship between Habitat Heterogeneity as Expressed by Shannon's Diversity Index (SHDI) and Increased Wood Volume per Active Channel Width (at two constructed simple wood structures and eight constructed complex wood jams in the East Fork)

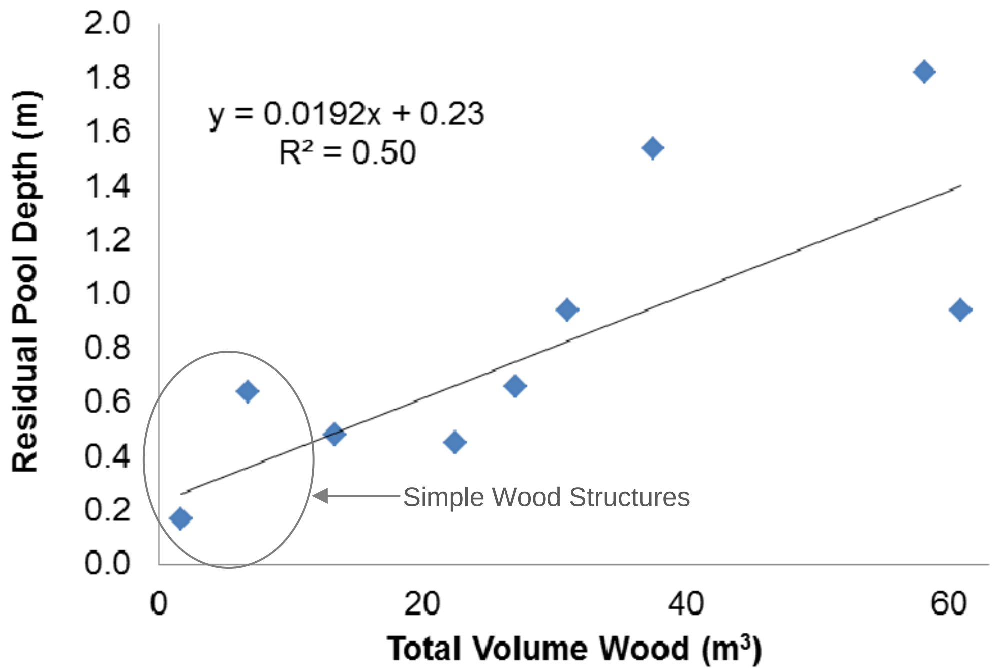


Figure 3-6. Relationship between Residual Pool Depth and Total Volume Wood (at two constructed simple wood structures and eight constructed complex wood jams in the East Fork)

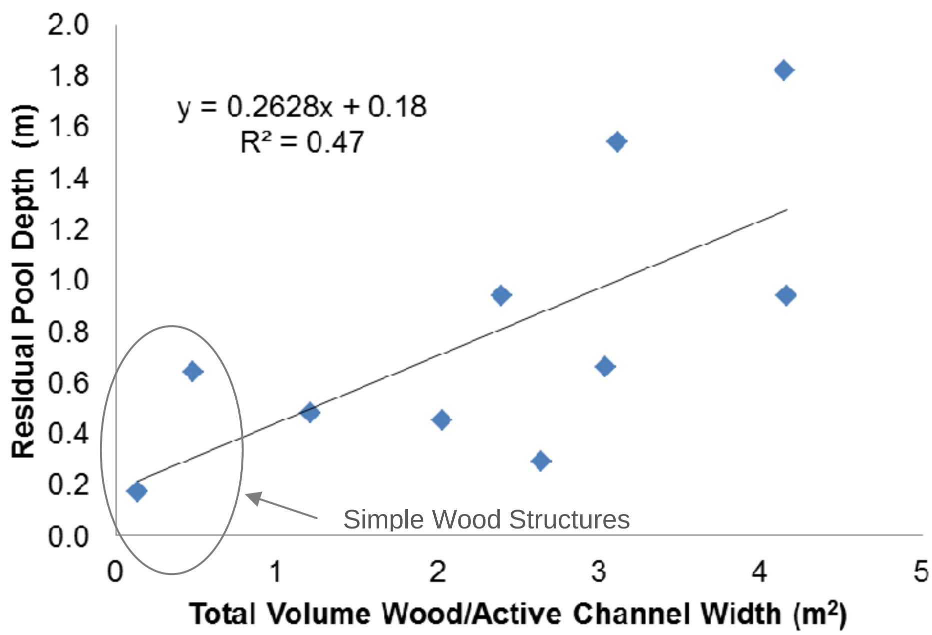


Figure 3-7. Relationship between Residual Pool Depth and Total Volume Wood/Active Channel Width (at two constructed simple wood structures and eight constructed complex wood jams in the East Fork)

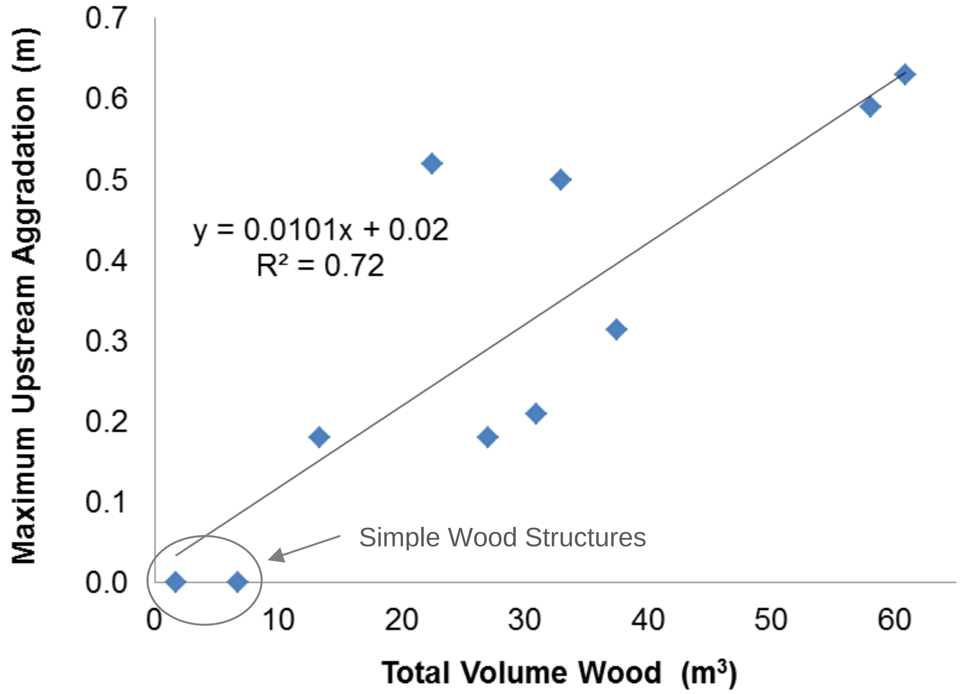


Figure 3-8. Relationship between Maximum Upstream Aggradation and Total Volume Wood (at two constructed simple wood structures and eight constructed complex wood jams in the East Fork)

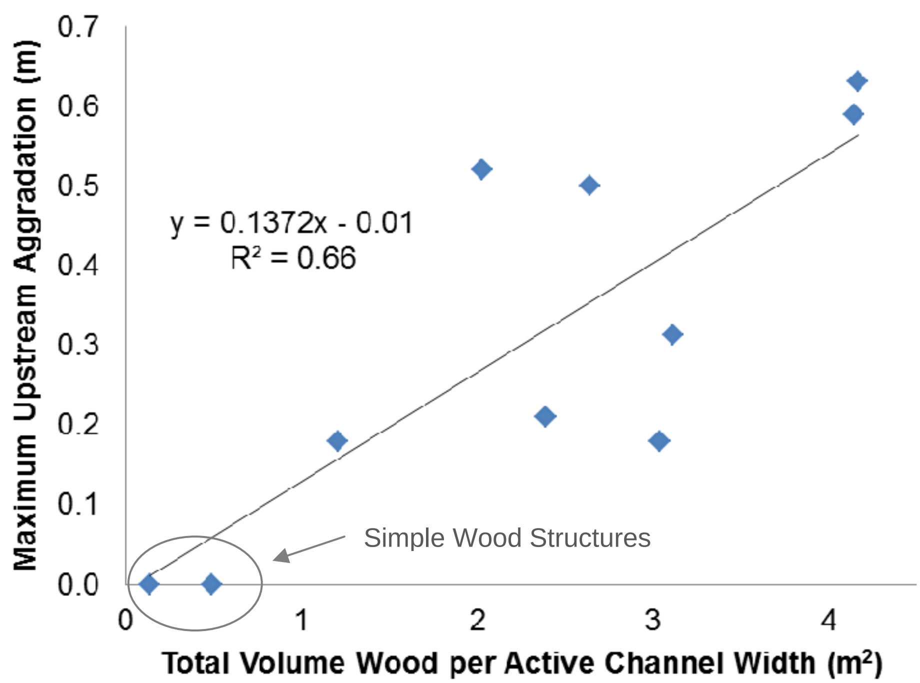


Figure 3-9. Relationship between Maximum Upstream Aggradation and Total Volume Wood per Active Channel Width (at two constructed simple wood structures and eight constructed complex wood jams in the East Fork)

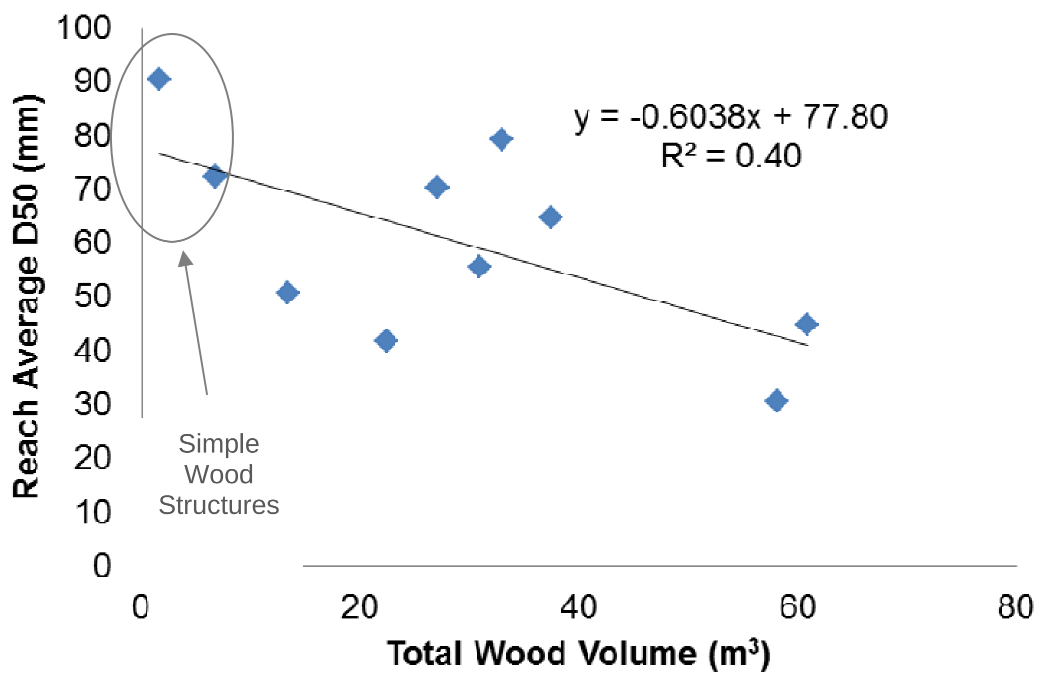


Figure 3-10. Relationship between Reach Average D50 (mm) and the Total Volume of Wood (at two constructed simple wood structures and eight constructed complex wood jams in the East Fork)

3.5.3 Priorities for Upland Treatments and Estimated Schedule

Scoring from the road inventory, ecological threat, interactive project access needs (e.g., access needed for forest thinning in light of immediacy of risk of road failure), adaptive management based on monitoring, logistical efficiency, potential for cumulative effects, location on the property, and project funding should help determine the ordering of road removal. State Parks' resource management and road management staff should meet annually to select projects based on these criteria. These factors should help guide a selection process that should proceed until only the core road circulation network remains.

3.5.3.1 Mechanical

The immediate priority for mechanical treatment is completion of the Landscape Stabilization and Erosion Prevention Plan (LSEP) roads. LSEP roads were partially restored by Stimson but have high erosion potential because they have road crossing fill highly exposed to surface and stream erosion. Approximately 79.5 km (49 miles) of the

original 175 km (109 miles) identified under this plan have been treated. The ranking process should be applied first to the remnant LSEP roads. The original completion schedule for LSEP roads was 2012, but a more likely completion estimate is 2018.
A project to upgrade 169 culverts to pass 100-year flood flow and associated sediment and debris should run simultaneously with the LSEP treatments. A recently failed culvert on Rock Creek Road is scheduled to be repaired with a structural pipe arch in 2011. Other roads not identified as part of the LSEP process should be prioritized for treatment during future 5-year selection assessments.

3.5.3.2 VEGETATIVE

Information about current forest conditions has been inadequate to develop a sufficient prioritization matrix. With the acquisition and ongoing analysis of the 2007 LiDAR flight, a prioritization to stabilize slopes and prevent the decline in stand health is now underway (Chapter 4). This prioritization must be adjusted in consultation with road removal and other activities within the property to ensure that restoration is conducted in the most efficient manner. These coordination activities should occur annually in the early winter, during the initiation phase for most grant funding cycles. It is State Parks' intent to treat approximately 200 ha (494 ac) per year as funding allows.

3.5.4 PRIORITIES FOR INSTREAM AND RIPARIAN TREATMENTS

3.5.4.1 MECHANICAL

The following restoration priorities should help ensure the continued viability and resilience of the aquatic ecosystem:

- restoring instream and riparian habitats through wood loading,
- removing existing artificial fills that reduce floodplain habitats and impair channel migration zones,[1]

[1] Specific high-priority areas include (1) the bridge abutment fill that connects Childs Hill and Rock Creek roads, (2) the valley floor where the old sawmill is located, and (3) small floodplain berms in various locations in the MCA. Restoration of the high-priority floodplain at the Rock Creek Road Bridge would provide the most significant and cost-effective off-channel habitat in the East Fork. A more floodplain-friendly crossing location is available nearby.

- increasing floodplain complexity and off-channel habitats throughout the MCA, and
- reducing potential impacts from upslope sediment sources.

3.5.4.2 VEGETATIVE

Former conifer forests that have been converted to alder dominant stands continue to be the highest priority for vegetative restoration in the riparian areas. Conifers present in the understory—taller than the shrubs but not above the alders—should be considered for release by selectively girdling alders overtopping them. The 10,000 seedlings that have been planted may receive similar treatment but not before they reach heights greater than the shrub layer. Understory vegetation, particularly salmonberry (*Rubus spectabilis*) and vine maple (*Acer circinatum)*, may need to be thinned to allow seedlings to survive and grow above the shrubs.

4 FOREST RECOVERY

Mill Creek Nursery. Source: Photograph taken by AECOM in 2010.

4.1 SAMPLING APPROACH AND RATIONALE

Field inventory and LiDAR (Light Detection and Ranging) analysis are the core methods used to assess current conditions and future growth potential for the Mill Creek Addition (MCA) forests. With the acquisition of LiDAR for the MCA, the opportunity arose to determine relative stand conditions in a manner more cost-effective than a traditional field survey (Reutebuch et al. 2005). Such an inventory of stand conditions is a powerful tool in prioritizing stands for restoration treatments. The Seattle branch of the U.S. Forest Service Pacific Northwest Research Station (PNW) has used LiDAR to predict tree density, basal area (BA), quadratic mean diameter (QMD), and other forest metrics by developing regression equations based on known forest conditions found on surveyed plots. One of the more recent efforts of this nature was accomplished in western Washington with the help of PNW (Strunk 2008). The California Department of Parks and Recreation (State Parks) and Redwood National Park worked with PNW to calculate the above metrics and Reineke's stand density index (SDI) (Reineke 1933). SDI is one of the most common measures of site occupancy in even-aged stands and is an indicator of how much tree growth may be limited by competition; therefore, it can be used to help identify and prioritize stands in need of treatment.

O'Hara and Oliver (1999) suggest prioritizing stands using tree density and a stand's ability to differentiate. As young forests grow back after a disturbance, differences between tree heights tend to be minimal. Trees tend to differentiate over time as differences in genetics, microsite quality, and other factors allow some trees to grow faster than others. Over time, slight advantages can be exaggerated as taller trees gain access to more light and partially shade shorter ones. This process allows a stand to differentiate as the larger trees grow vigorously while shorter trees are suppressed and often die. Such self-thinning can help a stand remain healthy and progress toward late-seral habitat. This process of differentiation is highly variable and in some cases is too slow to prevent stagnation and the decline of forest health. Differentiation is slowed by high tree densities and in single-species stands because variation in growth rates is less than in multiple-species stands (Oliver and Larson 1996).

An indication of how well a stand is differentiating is the variability in tree heights in a stand. The coefficient of variation in tree heights has been used to measure differentiation (Deen 1933, Gilbert 1965). LiDAR is inefficient at measuring heights of large numbers of trees, but it can identify the average height and the variability in height (coefficient of variation) of all LiDAR first returns (canopy heights), which can be used to compare stands. Stands with relatively high variation in canopy heights should be a lower priority for restoration. These stands either have a greater variability in actual tree height, indicating a greater degree of differentiation, or they have low tree densities (with many LiDAR returns reflecting off vegetation and the ground between trees) and competition is not a severe impediment to growth. Canopy height variability may also indicate larger crown ratios on dominant trees and therefore relatively rapid growth.

Precommercial-aged second-growth stands (less than 12 m (39 ft) tall codominant trees) are likely changing so rapidly that SDI and canopy variability are less useful metrics for prioritizing stands for restoration. Very young stands can change (i.e., grow) from a low-priority to a relatively high priority SDI value in a few years. Young, precommercial stands may therefore need to be prioritized independently of older stands when restoration treatments may take many years to implement.

4.1.1 Plot Selection and Placement

The LiDAR flight occurred in spring 2007, but funding issues delayed installation of ground plots until early 2009. A stratified sampling design was initiated in an attempt to establish circular, fixed-radius plots throughout the range of conditions that were present in data from the flight. To capture the aggregate behavior of a stand, plots were selected to exhibit uniform conditions at the stand level. This approach differs from that used for uniform structural conditions; for heterogeneous stands, plots are selected to capture that degree of variability.

Knowledge of the property and existing geographic information system (GIS) information, including stand age and soil layers (from the U.S. Natural Resources Conservation Service), were used to choose the initial 50 plots before the growing season. Initial focus was on the younger second-growth stands (under 30 years old) because these stands were likely to change the most if plots were not completed before another growing season passed. While technicians sampled the youngest stands, the preliminarily regressed models from Jacob Strunk's 2008 thesis were applied to the flight data. These preliminary model outputs identified regions of similar stand conditions from the LiDAR statistics. The forest was then classified into a 10-bin height regime by analysis of the canopy height model. Additional plots were allocated into these height classes, and individual locations were selected in reference to the preliminary statistical model results, using the linear forms from Strunk (2008). This process allowed identification of potential plot locations where the risk of sample error from Global Positioning System (GPS) position error was minimized and the contribution of the plot to the overall data coverage maximized. Plot locations were selected to cover the range of forest conditions, especially those conditions not already sampled in the spring.

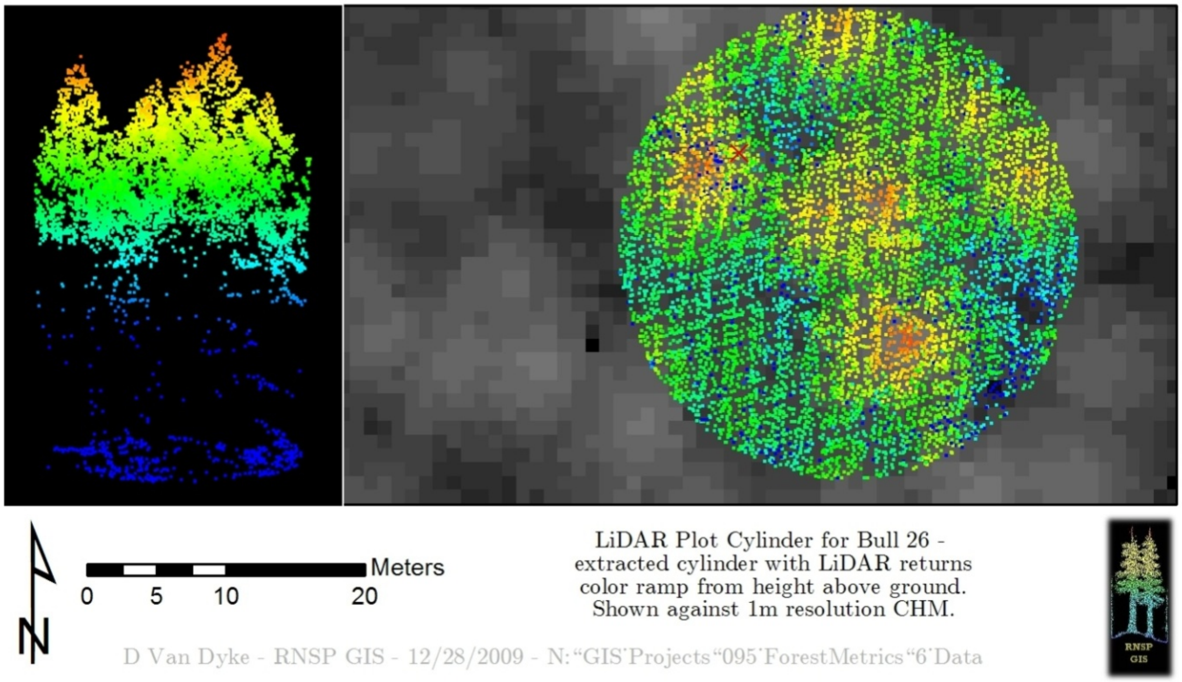
A key component to building a model to predict forest metrics with LiDAR is to ensure that the plots installed on the ground, and summarized by the forest technicians, are represented by the extracted-plot LiDAR point cloud. To accomplish this, great efforts were made to obtain submeter accuracy for all plot centers. Success was limited, however, because of the difficulty inherent in receiving clear satellite reception under forest canopies. The inaccuracies of plot center were compensated for by choosing uniform areas for plot installation and avoiding large trees near the edge of plots so that if the position recorded by the GPS was off by 1 m (3.28 ft) or more, basal area and other metrics would not change dramatically. Preliminary stochastic analysis of GPS position error shows that plot locations are more reliable than initial predictions (horizontal error of 0.6 to 1.7 m [2.0 to 5.6 ft]), and the influence of this uncertainty on the LiDAR numerics is minimal. This process of selecting uniform areas was enhanced after the Strunk equations were applied to the dataset. A similar nonrandom method of plot selection has been shown to be effective in other forest types (Hawbaker et al. 2009).

4.1.2 Characterization and Comparison of Field and LiDAR Data

To determine stand conditions at the time of the flight, the field data were input into Forest Vegetation Simulator software to calculate current plot conditions and changes over the last 2 or 3 years—corresponding to the number of growing seasons between the LiDAR flight and the time of plot installation. Relative change in basal area was then used to calculate basal area (and then other metrics) for each plot at the time of the flight.

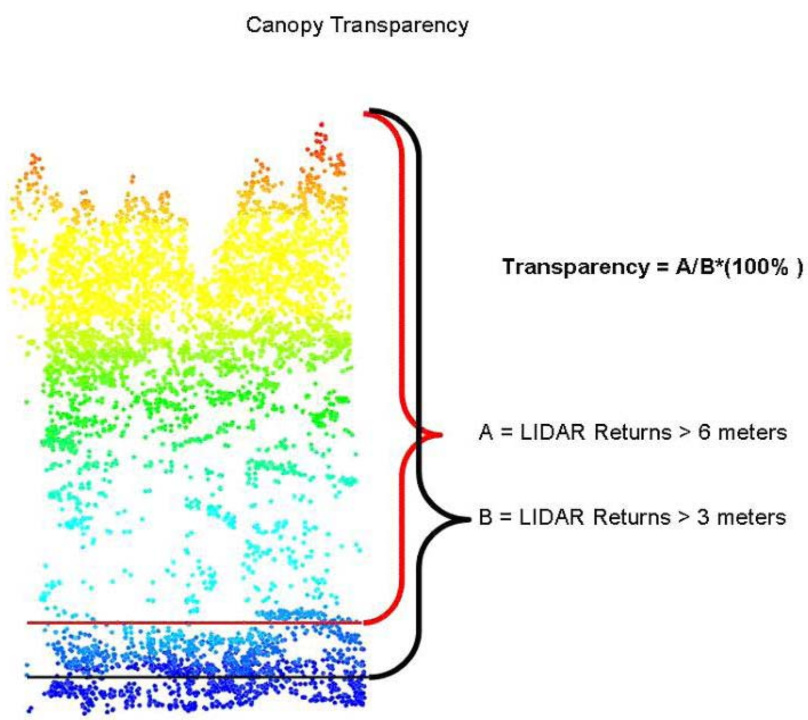
Input data for the model are derived from the LiDAR point cloud. By normalizing the heights of all first returns (each pulse returned up to four returns) to a LiDAR-derived bare earth digital elevation model (DEM), the canopy surface was flattened to represent only canopy height above the ground. This normalized data set was then used to develop characterizations of the structure of forest canopy. The LiDAR data were extracted for each circular plot, returning a plot “cylinder” of LiDAR data (Figure 4-1). Descriptive statistics of the cylinders of normalized LiDAR data were developed for each extracted plot using the CloudMetrics program.

These characterizations included descriptive statistics of the three-dimensional point cloud, such as the height of the median return in a given area or the proportion of returns above various heights (canopy transparency) (Figure 4-2). The CloudMetrics program allows development of a tabular summary of each sampled plot that reports a suite of geometric statistics for the plot sample. These summaries describe proportions of returns in the canopy above and below certain heights; the height distribution of returns; and parameters of statistical models for the observed heights, such as standard deviation, skewness, and kurtosis.



Source: Redwood National and State Parks GIS data. Based on GIS analysis developed by Redwood National and State Parks staff from 2007 LiDAR data.

Figure 4-1. LiDAR Plot – Extracted Cylinder and Plan View



Note: In this case, the number of returns above 3 and 6 meters is compared.
Source: Photograph from Strunk 2008

Figure 4-2. Example of Calculating Canopy Transparency

The pairing of the observed forest stand conditions at the time of the flight and the statistical description of the LiDAR data in each plot was used to create the multivariate regression relationship for each metric. A three-part model-fitting implementation was used. First, a legacy numeric analysis tool, LEAPS (a software package), was used to identify those statistical parameters most likely to describe the behavior of the forest conditions. This requires searching a model space of 40! (8.16×10^{47}) different linear combinations and ranking those most likely to contribute to a useful model. Different goodness-of-fit measures (e.g., Bayesian Information Criterion, Aikake's Information Criterion, Root-Mean-Square Error, R^2) can be used to guide this search routine.

After likely models were identified, they were fit using the R linear fit routine. These fit model values were packaged, and the eight most likely forms were reported to the experimenter. Principles of model parsimony were used to reject forms that include highly collinear parameters, and the Variance Inflation Factor was used to discriminate between parameters that contributed to overfitting. This provided a population of three- to four-parameter models. Each parameter in this "terse" model form was then removed from the linear combination, and the LEAPS package was run again. The statistical information about each model was analyzed, and the most reliable, and succinct, model became the prime candidate. Each model was then analyzed in an Excel statistical optimization exercise to improve model fit. A nonlinear optimization problem was formulated that minimized the sum-of-the-squared residuals (or R^2) and returned optimal parameter coefficient values for each model.

4.1.3 STAND-LEVEL FOREST METRICS

Existing GIS layers delineating stand boundaries lacked the accuracy necessary to convert the regression equations into meaningful stand-level attributes. Not only were boundaries often off by several meters, but portions of stands were often significantly different because of stream buffers, partial cuts, and other factors. The canopy height model was used to create a new stand boundary layer that more accurately delineated relatively uniform stands. The new stand boundary layer was further divided using Stimson's stand boundary layer so as to accurately link existing attributes, such as vegetation type (e.g., old growth, scattered old growth) and date of birth, to the new stands. Stands were then given a 10-m (33-ft) buffer to avoid edge effect, and the CloudMetrics software was used to categorize stand conditions. The regression equations were then used to calculate forest metrics for all stands.

4.1.4 FOREST STAND STRUCTURE MODELING RESULTS AND ANALYSIS

After the first round of calibration, preliminary models specific to both the forest conditions of the MCA and the qualities of the 2007 LiDAR flight were developed (Table 4-1). These linear regressions are all three- or four-parameter models and returned R^2 values for BA of 0.89, QMD of 0.90, SDI of 0.80, and tree density of less than 1.24 per hectare (tph) (0.5 trees per acre [tpa]). These values indicate that there is more divergence in the LiDAR response to the tree density metric than in other metrics. Because a reliable model for predicting tree density did not exist, the forest was stratified by species composition and age class so that linear regressions could be developed for specific forest types. Implementing these models requires classifying the LiDAR domain before model values are calculated. Because a reliable model for determining tph (tpa) across the range of forest conditions sampled does not exist, a regression was developed for determining tph (tpa) using only plots where the height above ground of the 95th percentile return height was less than 16.11 m (52.9 ft) (P95<16.11).

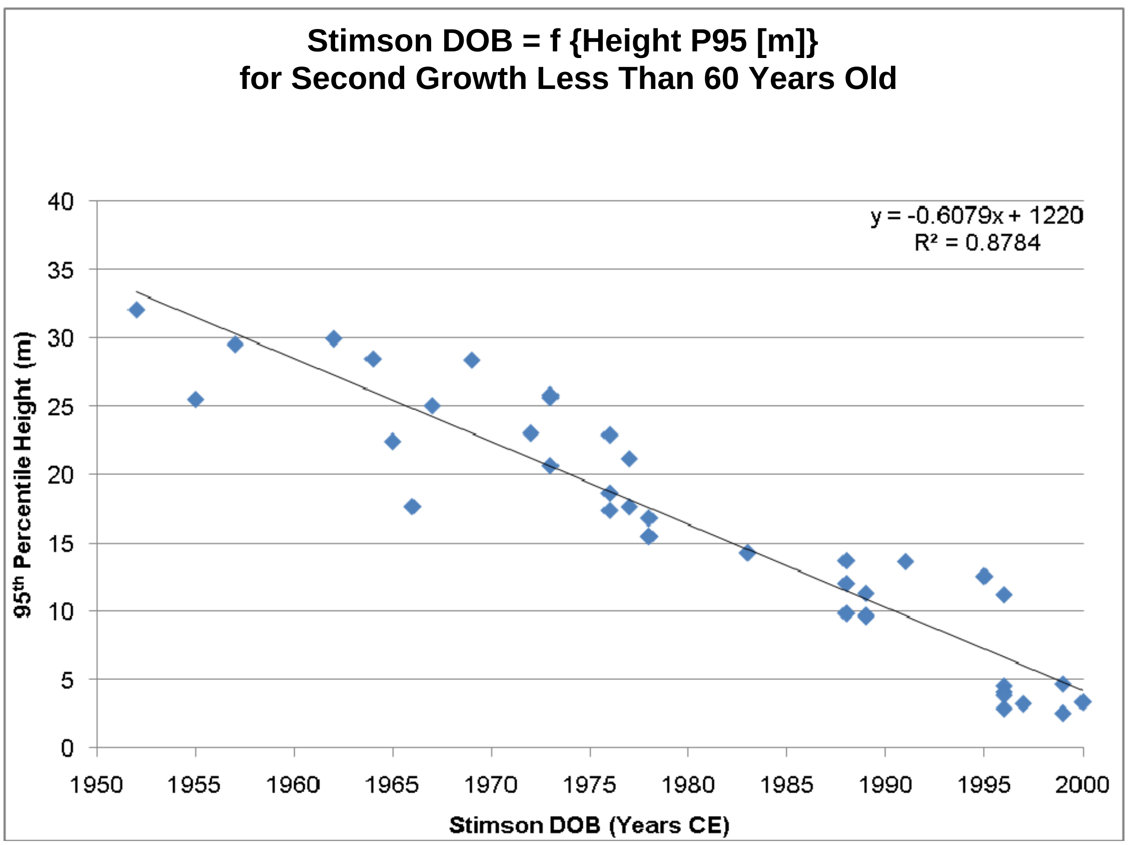
Table 4-1
Modeled Parameters and Their Intended Uses

Metric	Set of Plots	Intended Use
BA	All plots	Prioritizing treatment throughout the MCA
QMD	All plots	Prioritizing treatment throughout the MCA
SDI	All plots	Prioritizing treatment throughout the MCA
Tree Density	Coniferous only, P95<16.11	Prioritizing youngest stands

Notes: BA=basal area, QMD=quadratic mean diameter, SDI=stand density index
Source: Based on GIS analysis developed by Redwood National and State Parks staff from 2007 LiDAR data, unpublished GIS data developed by Stimson Lumber Company and survey data collected by State Park staff.

Through analysis of the lack of agreement between the recorded Date of Birth (DOB) of the stands and the observed LiDAR conditions, other possible relationships were considered. A comparison of the value of the 95th percentile return height (P95) to the Date of Birth reveals a more monotonic relationship in the stands where P95 is less than 16.11 meters (Figure 4-3). The P95 of 16.11 meters was then used as a threshold for stratifying the plots. By analyzing only conifer dominated plots where P95 was less than 16.11 meters, a model with an R^2 value of 0.79 was developed for predicting tree density.

Where a stand's calculated value for the above metrics fell outside of the range of values found on existing plots, stands were given null values for that metric and were not ranked. Few areas fell out of the range of the plot values; one exception was approximately 607 ha (1,500 ac) that had less than173 tph (less than 70 tpa). Of those 607 ha, 111 ha (275 ac) were classified as brush or hardwood by Stimson.



Source: Based on GIS analysis developed by Redwood National and State Parks staff from 2007 LiDAR data, unpublished GIS data developed by Stimson Lumber Company and survey data collected by State Park staff.

Figure 4-3. Date of Birth as a Function of 95% Height – Stands with Dates of Birth More Recent Than 1953

SDI and canopy variability were used to prioritize older second growth where the P95 was greater than16.11m. The older second-growth stands were divided into five groups of equal acreage based on their SDI value. The groups were then ranked by their degree of impairment related to stand density (Table 4-2). The older second-growth stands were similarly divided into five groups based on the coefficient of variation (CV) of first return heights above ground (bare earth DEM) as a second measure of the stand's degree of impairment (Table 4-3). The two methods of ranking stands were frequently in agreement (Table 4-4). Summing the two ranking methods permitted identification of the stands most likely to suffer from slow growth rates, develop declining health, and become most vulnerable to stand-replacing events. It should be noted that this map (Figure 4-4) and the ranking are preliminary and that additional analysis needs to be completed before they can be used for planning purposes.

Table 4-2
Values for Stand Density Index and Their Corresponding Scores for Older Second Growth

SDI	Degree of Impairment	Score
12 to 152.5	Very low	1
152.6 to 225.2	Low	2
225.3 to 311	Medium	3
311.1 to 375.6	High	4
>375.7	Very high	5

Source: Based on GIS analysis developed by Redwood National and State Parks staff from 2007 LiDAR data, unpublished GIS data developed by Stimson Lumber Company and survey data collected by State Park staff.

Table 4-3
Values for the Coefficient of Variation in Average Canopy Height and Their Scores for Older Second Growth

CV	Degree of Impairment	Score
0 to 0.445	Very high	5
0.446 to 0.555	High	4
0.556 to 0.691	Medium	3
0.692 to 0.895	Low	2
>0.896	Very low	1

Source: Based on GIS analysis developed by Redwood National and State Parks staff from 2007 LiDAR data, unpublished GIS data developed by Stimson Lumber Company and survey data collected by State Park staff.

Table 4-4 Degree of Agreement in Stand Priority Using CV and SDI for Older Second Growth	
	Number of Stands
Stands with same score for both	1,480
Difference in stand scores = 1	901
Difference in stand scores = 2	100
Difference in stand scores = 3	9
Difference in stand scores = 4	1
Source: Based on GIS analysis developed by Redwood National and State Parks staff from 2007 LiDAR data, unpublished GIS data developed by Stimson Lumber Company and survey data collected by State Park staff.	

Young stands (P95 less than16.11m) were also stratified and ranked by SDI (Table 4-5) and CV (Table 4-6), but these stands are likely changing in SDI and canopy variability more rapidly than older stands. To capture stands with a low SDI that may develop a high SDI soon, or stands where tree density will soon result in severely diminished crowns in the healthiest trees, these stands were divided into five groups based on their tree density (Table 4-7). The tree density score was added to the other scores to complete the ranking of the younger stands.

Table 4-5 Values for Stand Density Index and Their Corresponding Scores for Young Stands		
SDI	Degree of Impairment	Score
13 to 92.5	Very low	1
92.6 to 133	Low	2
133.1 to 157.5	Medium	3
157.6 to 192	High	4
>192.1	Very high	5
Source: Based on GIS analysis developed by Redwood National and State Parks staff from 2007 LiDAR data, unpublished GIS data developed by Stimson Lumber Company and survey data collected by State Park staff.		

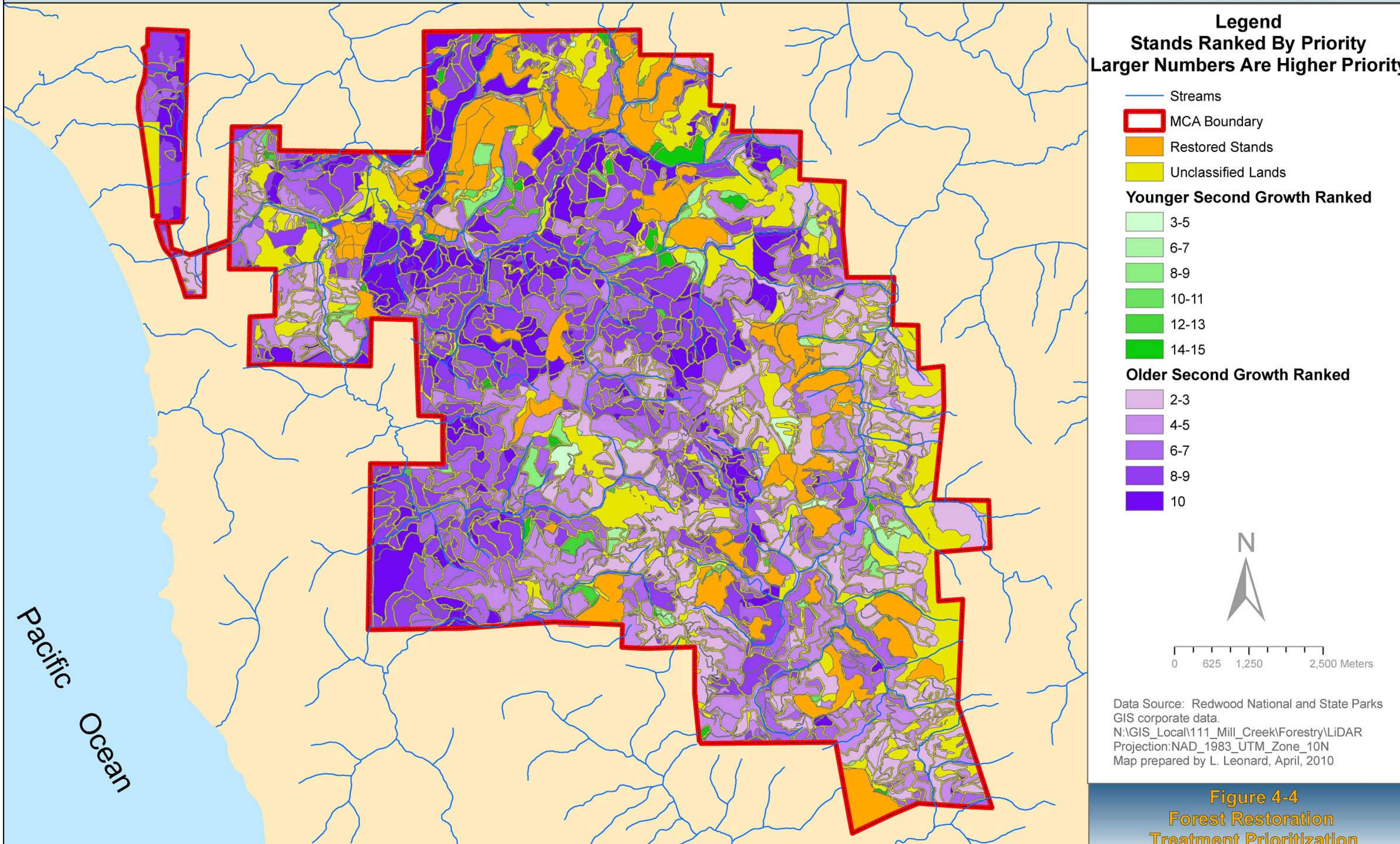


Figure 4-4
Forest Restoration
Treatment Prioritization

Table 4-6
Values for the Coefficient of Variation in Average Canopy Height and Their Scores for Young Stands

CV	Degree of Impairment	Score
0 to 0.556	Very high	5
0.557 to 0.657	High	4
0.658 to 0.718	Medium	3
0.719 to 0.856	Low	2
>0.857	Very low	1

Source: Based on GIS analysis developed by Redwood National and State Parks staff from 2007 LiDAR data, unpublished GIS data developed by Stimson Lumber Company and survey data collected by State Park staff.

Table 4-7
Tree Density for Stands with a 95th Percentile Canopy Height Greater Than 16.11 Meters

Trees per Hectare (Trees per Acre)	Degree of Impairment	Score
173–273 (70–110)	Very low	1
274–406 (111–164)	Low	2
407–594 (165–240)	Medium	3
595–994 (241–402)	High	4
≥995 (≥403)	Very high	5

Source: Based on GIS analysis developed by Redwood National and State Parks staff from 2007 LiDAR data, unpublished GIS data developed by Stimson Lumber Company and survey data collected by State Park staff.

4.2 FOREST PRIORITIZATION RECOMMENDATIONS

Preliminary results indicate that the LiDAR analysis is an effective means of identifying stands in jeopardy of slowing growth rates, declining health, and possible mortality without achieving late-seral conditions or optimal slope stabilization. Stratified random plots are being installed to validate the overall model. Additional measures to improve the prioritization are more specific to the forest metric and forest type and would be required before forest restoration planning moves forward.

SDI is best adapted to even-aged stands and is less useful in stands where tree size distribution is irregular. A high SDI could result where a young stand with a moderate tree density has an uncharacteristically high BA because large residual trees were left after harvest. Such stands would have a lower priority ranking than their SDI score would imply. The CV identifies many of these stands and lowers their overall ranking, but further confirmation is recommended. Although variability in canopy height should be a useful indication of a stand's degree of differentiation, there is no published literature regarding quantifying differentiation with LiDAR. A field comparison of stands with low and high CVs may be necessary.

Further analysis is needed to determine whether a better regression can be derived or whether field surveys should be used for prioritization. Managers expected to have difficulty in predicting tree density in the youngest age classes due to the difficulty in distinguishing small trees from brush. State Parks surveyed and is now prioritizing and permitting areas where the tallest vegetation was shorter than the already permitted stands with a DOB of 1980–1993. The prioritization in process is generally for the youngest stands (DOB 1994–2000) as identified by the former landowners but also includes other stands with similar maximum vegetation heights (as seen by LiDAR) but may have an inaccurate DOB. Prioritization of the older stands also could be improved by quantifying tree density.

One method likely to aid in developing a better tree density regression is to develop models for only the larger trees (such as all overstory trees or trees whose diameter is greater than half of QMD). Additional models could stratify the plots (and stands) by species composition. Species composition could be estimated via remote sensing (LiDAR or existing imagery). Stand-level estimations of species composition also could be developed to prioritize stands by their ability to differentiate as mentioned in Section 4.1.1 (see Oliver and Larson 1996, O'Hara and Oliver 1999).

Most of the forests in the MCA likely could benefit from treatment in the coming decades. State Parks will treat approximately 324 ha (800 ac) over the next 2 years that have already undergone permitting and prioritization. The current prioritization matrix identifies 926 ha (2,288 ac) of older stands as having the highest ranking for treatment. These stands should be evaluated further through field observations or an improved prioritization matrix that includes tree density. This evaluation should be used to develop a short list of stands to be treated in the next few years to reduce stand densities and improve habitat, slope, and stand stability. The longer term goal should be to treat most of the stands with the highest priority ranking in the next 5 to 10 years. Other variables that will be helpful in determining which stands are treated in a given year include the ongoing slope stability analysis, the road removal program, landscape variables not addressed here, and other projects that can affect the efficiency of restoration treatments.

4.3 ESTIMATION OF FOREST TRAJECTORIES

Achieving the stated goal of eliminating all signs that the property was ever logged may take centuries. In addition, predicting success is difficult because stochastic events will affect stand structure. Progression toward this and other goals will be gradual and on a continuum, with occasional, localized setbacks likely related to disturbance. An example of this gradual progression is evidenced in the behavior of the pileated woodpecker and its role in improving habitat for species associated with late-seral habitat. The pileated woodpecker in some cases prefers to make cavities in trees greater than 26 inches in diameter at breast height (Aubry and Raley 2002). After trees of appropriate size occupy a stand, the woodpecker may use a few live trees for cavity excavation, but cavity numbers likely will remain low until snags of this size develop. It is not until many cavities have been excavated and abandoned by woodpeckers that other species dependent on abandoned woodpecker cavities can flourish in these stands.

Proper management of these young forests will likely take decades off the time necessary to grow trees sufficient to make suitable pileated woodpecker habitat and may prevent disturbances that would delay this development by a century or more. Less well understood is the level of improvement expected in root cohesion that can stabilize slopes. Some estimates indicate that root cohesion in second growth will not reach levels found in old growth for more than 100 years (Schmidt et al. 2001) and may take much longer if stands remain unmanaged. Cutting trees to reduce stand densities will diminish root cohesion for a few years, until residuals have time to occupy the additional growing space, but slope stability ultimately is enhanced.

Dagley and O'Hara (2003) conclude that proper management of young second growth can facilitate the development of some old forest traits within 100 years, but other characteristics, such as large branches and reiterated trunks, may take many centuries to form. Chittick and Keyes (2007) revisited a 49-year-old forest in Redwood National Park where experimental thinning treatments were applied at age 24. They estimated that the untreated controls were likely to remain in the competitive exclusion stage for another 50–100 years while the treated sites had reached the more advanced maturation stage at age 49. Although this is far from achieving late-seral conditions, it is a good indicator that many of the attributes associated with late-seral forest conditions may be achievable in a 100-year-old stand. The same stand left untreated, however, may take several centuries to achieve the same attributes and would be more vulnerable to disturbances that could destroy the whole stand and eliminate late-seral traits.

4.4 FOREST RECOVERY TREATMENT METHODS AND PRIORITIES

The MCA forests will have different treatments to either retain their general character (late seral) or accelerate their growth (second growth). Near-term treatment sites have been previously permitted, and further analysis using the data presented here will aid in the selection of subsequent treatment sites.

4.4.1 LATE-SERAL TREATMENTS

After stands reach the late-seral stage of development, management activities likely are limited to prescribed burning. Objectives of such burns may include reducing understory fuel loads to prevent high-severity fires and restoring fire as an ecological process.

4.4.2 SECOND-GROWTH TREATMENTS

The general approach to improve conditions in the second growth will be to reduce tree densities to adjust species composition and promote vigorous growth in the remaining trees. Prescriptions will be specific to the needs of individual stands but will generally involve variable density thinning. Variable density thinning will be especially important in stands more than 30 years old, where it has been shown to encourage the development of late-seral conditions (Carey 2003, Carey et al. 1999). Stand densities generally will be reduced to levels lower than seen in traditional thins to allow more prolonged periods of growth. Exceptions may include areas with bear damage or where a dense overstory is desired for other objectives, such as a shaded fuel break or reduced light and growth potential to discourage the growth of exotics. Projects must be monitored long after the treatments are completed to ensure that projects were successful and so that managers can adjust future projects based on what was learned from past efforts.

4.4.3 Forest Stand Treatment Priorities and Estimated Schedule

State Parks will treat approximately 324 ha (800 ac) over the next 2 years that have already undergone permitting and prioritization under the Forest Ecosystem Restoration and Protection Plan (FERPP). The priority matrix outlined in Section 4.1.4, or an improved version currently under development, should be used, along with field surveys, to select additional areas to treat. All the highest ranking stands should be visited, and most of them should be treated in the next 5 to 10 years. A treatment rate of approximately 202 ha per year (500 ac per year) will allow restoration efforts to continue at the approximate rate of harvest witnessed in the last decade of private ownership. This treatment rate should at minimum be maintained until all FERPP and younger stands with more than 202 trees per hectare (500 trees per acre) have been treated. Treatment rates for older stands can be more accurately assessed once stand densities are calculated. The treatment rate of 202 ha per year (500 ac per year) did not result in high rates of slope instability during periods of more intensive commercial harvest (see Sections 3.2.3.1 [Table 3-2] and 3.2.3.2) and no silviculture-related failures have been observed during State Parks management. Selected sites will be evaluated by a licensed geologist to help ensure that slope stability is maintained. Thinned sites will be evaluated as part of periodic sediment delivery analyses to help ensure that the harvest techniques are appropriate.

Other variables to consider when evaluating the amount of land to treat in a given year include:

- The type and intensity of treatment, such as tree planting, tree cutting, and tree girdling, and its potential effect on wildlife, slope stability, and other resources
- Potential ground disturbance, such as that caused by skidding of logs, cable logging, and leaving all materials on-site
- Need for immediate treatment (very young stands decline more rapidly than do older stands when untreated)
- Other activities that may contribute to sediment delivery or unstable slopes

5 MONITORING

Rock Creek. Source: Photograph taken by AECOM in 2010.

5.1 TYPES OF MONITORING

5.1.1 MONITORING DEFINITIONS

In general, monitoring is the systematic measurement of resource indicators that are representative of existing conditions and sensitive to anticipated perturbations to allow the detection of changes over temporal and spatial scales. The type of monitoring selected depends on the study objectives, legal requirements, and funding availability. Monitoring techniques can range from conducting repeated field observations, with photo-points and mapping to ensure that a project is functioning as designed, or it can incorporate measuring multiple biologic and physical indicators to determine how overall watershed processes and functions change over time.

Environmental monitoring can be categorized into several different types: baseline, implementation, status and trend, effectiveness, and validation monitoring. While the various monitoring types are not mutually exclusive, the distinction between them is based on the purpose of monitoring rather than by the type and intensity of measurements (MacDonald et al. 1991). Concepts discussed in this chapter draw from the work of Hillman (2006), Saldi-Caromile et al. (2004), and McDonald et al. (1991). The following description of monitoring types was adapted from Oregon Watershed Enhancement Board (2010).

5.1.1.1 Baseline Monitoring

Baseline monitoring characterizes existing conditions to establish benchmarks used for comparison as future monitoring is conducted. The purpose of baseline monitoring is to establish what the temporal and spatial variability of selected resource indicators are before a project begins. Baseline monitoring is often used as a first step in determining the effectiveness of restoration project implementation.

5.1.1.2 Implementation Monitoring

The purpose of this type of monitoring is to ensure that proposed work is carried out as planned. Appropriate methods include photo-points with corresponding global positioning system (GPS) readings and may include a basic field evaluation that incorporates qualitative/quantitative data. This type of monitoring is used to evaluate individual projects such as a culvert replacement or large wood placement. Sometimes, this type of monitoring is referred to as compliance monitoring.

5.1.1.3 Status and Trend Monitoring

The purpose of status and trend monitoring is to describe existing conditions through the measurement of resource indicators (physical, chemical, or biological) across a given area. Trends regarding the environmental condition are then evaluated over time, based on repeat measurements. The spatial scale for status and trend monitoring can vary from a subwatershed to an entire region. This type of monitoring does not require all the elements of valid statistical design that are found in effectiveness monitoring studies. For example, controls are not required in status and trend monitoring. Controls are important if the objective is to assess cause-and-effect relationships.

5.1.1.4 Effectiveness Monitoring

Effectiveness monitoring is designed to evaluate whether a project has had the desired effect on the resource indicators selected. For example, a postproject survey documents an increase in pool frequency or a reduction in fine sediment in pools compared to baseline conditions or anticipated targets. This type of monitoring is generally used to track changes following watershed restoration projects. It differs from implementation monitoring in that it is more in-depth and evaluates whether the overall project objectives have been met. Effectiveness monitoring can occur at project, watershed, or regional scales.

5.1.1.5 Validation Monitoring

Validation monitoring is often considered research. It is designed to validate assumptions, models, methods, and proposals.

5.1.2 Monitoring Approach

This section focuses on baseline monitoring (where needed), implementation, status and trend, and effectiveness monitoring. Validation monitoring may occur in the future but is not considered here because the requisite research questions have not been formulated. The overarching goal of the monitoring is to determine whether water quality objectives are being met and whether beneficial uses are protected from the adverse effects of one or more pollutants. For certain parameters (e.g., suspended sediment and turbidity), regulatory thresholds that were developed to facilitate uniform enforcement over a large area may not be relevant to site-specific evolutionary conditions for fisheries that are associated with widely divergent geologic conditions. This factor and/or other factors are addressed in the Water Quality Control Plan for the North Coast Region (Basin Plan) (NCRWQCB 2011) through regulatory waivers, which may be issued to achieve both water quality and restoration goals. The monitoring program described here will help guide adaptive management for restoration and improve general management of the Mill Creek Addition (MCA).

For the early stages of State Parks restoration, baseline information is well defined for the fishery population (see Chapter 2) and upland sediment sources (see Chapter 3). Some of the instream physical baseline data (e.g., pebble counts, V*, wood loading) were collected for specific studies and represent conditions at varying spatial and temporal scales distributed over the management history of lands within the MCA. As a first step, previous instream study sites will be evaluated to determine whether they are representative of reach and/or subwatershed trends and how the site may have been affected by intervening natural events, such as adjacent streamside landslides, or land management actions related to past or present activities (e.g., sedimentation from administrative roads, road removal or stream cleaning). This evaluation will be fundamental to the characterization and use of preexisting data as a baseline for setting future loading targets.

The recommended instream monitoring network will be structured within a tiered framework of real-time automated and synoptic stream gage sites with complementary long-term monitoring of channel changes that would include repeat topographic surveys (cross-sections and long profiles), and pebble count, wood loading, and streambed permeability assessments. In this system, real-time and synoptic water quality monitoring would be given the highest priority. The monitoring network should include monitoring sites (i) at the watershed scale, with permanent automated sampling stations that measure turbidity, streamflow, suspended sediment and other water quality parameters at mainstem tributaries; (ii) at the project scale, where manual sampling of water column turbidity and suspended sediment would occur during high streamflow events within fish bearing reaches downstream of road removal project areas; and (iii) at the site scale, where manual sampling of water column turbidity and suspended sediment during high-flow events would occur upstream and downstream of road removal treatment areas (stream crossings, streamside landings and roads, gullies that link watercourses with past road failures or road cross-drains). Real-time and synoptic water quality monitoring is best suited to immediately identify whether measures taken at project and site scales are effective at preventing erosion and sedimentation and should be viewed as the foundation of an adaptive management strategy. Coupled with upslope monitoring this approach can help assess both short and long term effects of natural events and management actions on biologic and instream conditions.

5.1.2.1 IMPLEMENTATION AND EFFECTIVENESS MONITORING

Mechanical Treatment Field Review Methods

The condition of any road is extensively documented before treatment (see Appendix A). Using standardized measurement protocols, excavation volumes can be quantified in physical terms (number of cubic meters) to prioritize, plan, and determine production rates and cost estimates for projects. However, the effectiveness from a potential sediment savings perspective can be known only in a general sense. Fluvial erosion (stream crossing failures, stream diversions, and gullies), as well as mass movements (fill slope failures, landing failures, and cutbank failures), are known to have the potential to deliver sediment to the stream network. However, these erosional processes are episodic in nature and are often triggered by large storm events (Flosi et al. 2006). In addition, several ways exist in which a stream crossing has the potential to fail and deliver sediment: a plugged or undersized culvert, flow being diverted down the road, collapse of fill from within, or a gully developing and gradually washing out the fill over time. Each of these failure mechanisms may yield a different quantity of sediment to a stream over an uncertain amount of time. For these unpredictable reasons, sediment savings cannot be determined as an absolute value but rather as a likely scenario of what could happen without rehabilitation of the road network.

Qualitative site monitoring for the first few years following road rehabilitation projects is used to adjust procedures or treatment prescriptions for future projects. In this sense, an implementation component that has a feedback loop to improve future projects is incorporated into the review. Any sites with exposed soil that have direct access to watercourses are thoroughly mulched to achieve 80% ground coverage. All stream crossings are planted with native conifers to help stabilize streambanks, provide shade, and allow for future recruitment. In some cases, unexpected subsurface conditions may become apparent during the work and these also are documented, to help evaluate posttreatment effectiveness. Photo-points are established at key locations for longer term monitoring. Photographs are taken before and immediately after road and stream crossing removal. Additional photographs are taken after winter flow conditions, typically the spring following removal, to capture posttreatment site response. Project sites are reviewed with the project inspector, a licensed geologist, and sometimes the project’s heavy equipment operators during the winter following treatment. If significant posttreatment erosion exists, the likely cause is evaluated to determine whether it could have been avoided through use of a better technique or site design. Lessons learned from those observations are incorporated into future projects.

Vegetative Treatment Field Review Methods

Forest restoration prescriptions will be adapted to fit the unique circumstances of individual stands. State Parks monitors all forest restoration activities to ensure that work is accomplished according to prescription specifications, observing long-term trends in forest structure and composition, tracking the effectiveness of prescriptions, and learning from early restoration efforts. A forest monitoring plan (on file) has been adopted for stands initiated between 1980 and 1993 that are being treated to reduce tree densities. This plan also will be used as an outline for other stands to be treated. Permanent plots are established in treated areas, and representative controls are developed by tagging trees at breast height to allow for identification of individual trees and periodic remeasurement of diameter at a consistent location. Control areas are compared to various treatments implemented. Variables such as plot size and number of plots established may be adjusted to meet the needs of future projects.

Revegetation monitoring at mechanically treated stream crossing sites is done using sample plot inventories the first and third year following planting. Additional trees are planted where needed to achieve 217 trees per hectare (88 trees per acre).

Instream Structure Review Methods

Two primary methods have been used to assess changes to instream reaches where complex wood jams and simplified wood jams have been constructed. Facies maps were drawn for each structure before and after the storm season (Buffington and Montgomery 1999) to determine changes to habitat heterogeneity, and total station surveying was used to determine changes to residual pool depths and reach aggradation. The sites are georeferenced and “rubbersheeted” so that spatial accuracy is maintained over the monitoring period.

The term “facies” refers to a patch of distinct sand-, gravel-, cobble-, or boulder-dominated channel area. Facies maps are used to show changes to aquatic habitat heterogeneity by capturing reachwide variations in surface sediment sizes. They are useful tools for describing streamflow conditions and as baseline snapshots for comparing future change (Kondolf and Piégay 2003). During recent monitoring, a facies was defined as a distinct textural patch 1 square meter (m^2) or larger. To quantify each facies patch, a pebble count or a field-based "quick estimate" of the patch's median particle size (referred to as "D50" for the diameter of the stones that are larger than 50% of the total stones counted) is documented. Patch D50s are used to develop habitat heterogeneity indexes, as expressed by Shannon's Diversity Index (SHDI).

Total station data collection also is used to characterize the complex wood jam and channel conditions in plan and cross-sectional views. At a minimum, the data collected should include thalwag surveys, cross-sections, wetted edges, bankful, and control points with rebar tops at each site. In some cases, the patch analysis may be eliminated to streamline data collection.

5.1.2.2 Geomorphic and Water Quality and Quantity Trend and Effectiveness Monitoring

Methods to assess the longer term trends of restoration projects and external factors on site geomorphology, water quality, and streamflow (quantity) are described next. This information will help inform the watershed scale effectiveness of the restoration.

Slope Change and Sedimentation

Although the quality of the data from the Light Detection and Ranging (LiDAR) flight in 2007 is not optimum, it provides a baseline for topographic and geomorphic conditions in the watershed. Data from future LiDAR and aerial photography flights will help delineate macroscale rates of slope change and sedimentation delivery that result from mechanical and vegetative treatments. An average 5- to 10-year recurrence interval for collection of remotely sensed data should be used to help guide this analysis, but this interval could be longer or shorter as external events dictate. Development of remotely sensed data should be more frequent in the early stages of this monitoring effort because of the less than optimum quality of the 2007 LiDAR data set and to help guide early adaptive management, when corrections to project design are more likely to be important.

Methodology for slope change measurements should be compatible with that discussed by Merrill et al. (Appendix A). Sedimentation from stream crossing failure should be documented by storm patrol, and reductions in road surface erosion should be noted via GIS as a function of decreased road mileage and application of the assumptions noted in Section 3.2.3 and its subsections. These parameters should be calculated on a 10-year rolling average.

Suspended Sediment and Turbidity

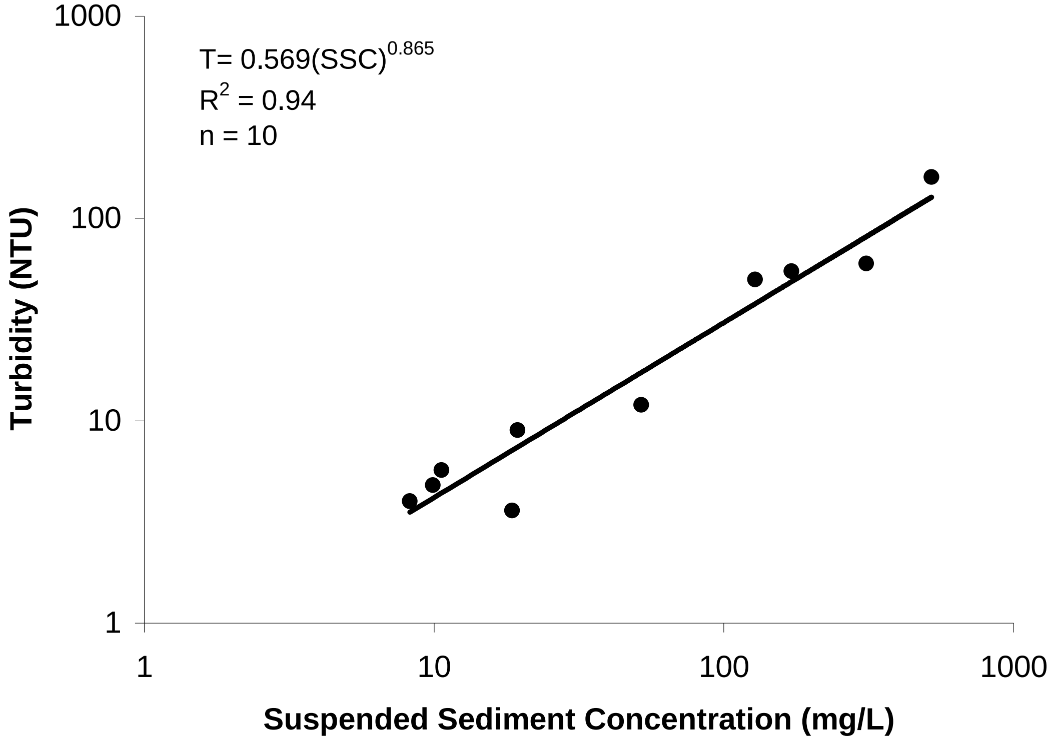
Inorganic suspended sediment produce two main ecological effects in streams that can affect fish and invertebrate communities: increased turbidity of the stream water and increased siltation of streambeds.

Turbidity is a measure of the optical property that causes light to be either scattered or absorbed as it passes through water. Turbidity can be correlated to the level of suspended and dissolved materials, such as clay, silt, finely divided organic matter, plankton and other microscopic organisms, and organic acids present in the water column. In streams, turbidity is a flow-dependent variable; for this reason, a relationship between turbidity and flow must also be understood to set appropriate load targets.

Field-based turbidity measurements can be inexpensive to collect and can be used as a surrogate for suspended sediment concentrations if a relationship between the two parameters can be established; this relationship has been established for tributaries in the nearby lower Klamath River (Figure 5-1). Although turbidity values reflect the effects of any substance that reduces clarity (such as suspended algae and tannins), those substances are not typically found in the waters of the MCA. Thus, turbidity is an appropriate monitoring parameter for tracking suspended sediment trends.

The U.S. Geological Survey (USGS) (Anderson 2005) and USEPA (1983) considered the Nephelometric Turbidity Unit (NTU), a measure of turbidity in a water sample, to be roughly equivalent to the Formazin Turbidity Unit and Jackson Turbidity Unit. However, a literature review did not find any reference conversion factor.

Lloyd et al. (1987) presented three equations that relate turbidity (NTU) with suspended sediment concentrations (mg/L). Their analysis used USGS data for Alaska streams during the period 1976–1983 (May through October), involving 235 samples from



Notes: NTU = Nephelometric Turbidity Unit and mg/L = Milligrams per liter
Source: Gibson pers. com, 2010

Figure 5-1. Turbidity versus Suspended Sediment Concentration for Four Lower Klamath River Tributaries

37 stations on 34 rivers that yielded a significant correlation (r^2 = 0.83). The resulting relationship was:

$T = 0.44(SSC)^{0.858}$ Equation 9 Lloyd (1987)

where T is turbidity in NTUs and SSC is the suspended sediment concentration in mg/L.

A similar relationship between T and SSC (r^2 = 0.92) was developed using data from the glacially turbid Susitna River. This equation predicts slightly lower turbidities for specific SSC than does the relationship developed from the data for Alaskan rivers statewide.

$T = 0.185(SSC)^{0.998}$ Equation 10 Lloyd (1987)

Data compiled from turbid placer-mined and neighboring unmined clear streams in interior Alaska also yielded a significant correlation (r^2 = 0.92, n=279). The resulting regression equation is:

$T = 1.103(SSC)^{0.968}$ Equation 12 Lloyd (1987)

Objective

The objective of monitoring turbidity is to track the trends in water quality that are related to suspended sediment levels by measuring a closely related surrogate.

Procedures and Techniques

Turbidity should be measured consistent with the protocols described in the USGS National Field Manual (Anderson 2005).

Monitoring Locations

Automated turbidity data collection should occur at the former USGS flow gage locations near the MCA boundary in the Mill Creek watershed. Data should be collected manually during high flow events in fish-bearing reaches downstream from major projects. It should also be collected manually during high flow events at hydrologically sensitive sites associated with road removal projects (e.g., upstream and downstream from a removed stream crossing).

Frequency and Duration

For automated monitoring measurements should be taken every 15 minutes to coincide with stage measurements from November through June.

Baseline Conditions

Limited suspended sediment and turbidity data have been captured at various locations in the Mill Creek watershed by USGS monitoring and other monitoring of the effects of timber operations. Existing data show low suspended sediment levels.

Surface Particle Size Distribution (Pebble Counts)

Streambed surface sediment size distribution should be measured by Wolman pebble counts (Wolman 1954). Surface particle size distribution is an effective measure of sediment supply trends. Knopp (1993) demonstrated that the median particle size (D50) is an effective indicator of sediment supply in North Coast streams. The surface particle size distribution also has been demonstrated to be an effective indicator of the balance of sediment supply and sediment transport capacity when compared to the subsurface particle size distribution. One major advantage of this technique is that it is relatively inexpensive and easy, requiring no special equipment or extensive processing time.

Objective

The objective of monitoring surface particle size distribution is to track the trends in both gravel quality and sediment supply.

Procedures and Techniques

Pebble counts should be conducted in a minimum of three riffles per sampling location, using the methods described in Section 4.1.1 of Bunte and Abt (2001). Data analysis should be conducted consistent with methods specified by Bunte and Abt.

Monitoring Locations

Monitoring should be conducted at representative sites in the MCA. State Parks will request copies of the datasheets from Carrol and Robison (2007) and Knopp's (1993) studies and try to incorporate those sites into the monitoring network; Knopp's sites may be relocated using drainage area reporting upwatershed from the sampling reach. Pebble counts should target sites where sampling has previously occurred and should be conducted at McNeil sampling sites (discussed next).

Frequency and Duration

This parameter should be measured every 5 years or during the summer low-flow period following the next significant water event, whichever occurs first.

Baseline Conditions

Knopp (1993) reported median bed surface particle sizes (D50) of 44 millimeters (mm) and 53 mm (1.73 and 2.09 inches) for the West Branch and East Fork, respectively.

Subsurface Particle Size Distribution (McNeil Samples)

This measure of subsurface gravel quality can be obtained by collecting McNeil samples. The subsurface sediment size distribution is an effective measure of sediment conditions as they relate to spawning gravel quality.

Objective

The objective of measuring the subsurface particle size distribution is to track the trends in subsurface gravel quality that are related to spawning.

Procedures and Techniques

Monitoring should use a McNeil sediment core sampler, similar to the specifications found in McNeil and Ahnell (1964) except the diameter of the sampler’s throat should be two to three times larger than the largest particle usually encountered. Monitoring should occur according to the protocols found in the Scott River Watershed Monitoring Program, Water Quality: Water Temperature Monitoring and Sediment Sampling and Analysis 2005, 2006, and 2007 (Quigley 2008). A 0.85 mm (0.033 inch) and a 6.4 mm (0.252 inch) sieve should be used during sample processing. The wet volumetric method is recommended with the use of the dry gravimetric method on 10% of samples.

Monitoring Locations

Monitoring should be conducted at representative sites in the MCA. State Parks will request copies of the datasheets from Carrol and Robison (2007) and Knopp’s (1993) studies and try to incorporate those sites into the monitoring network. McNeil sampling should occur in reaches with gradients less than 3%, with a preference for known spawning areas.

Frequency and Duration

Subsurface particle size distributions are not expected to vary greatly from year to year. The collection of subsurface particle size distribution data is costly. Because of the tendency of this parameter to change slowly and the cost of collecting the data, North Coast Regional Water Quality Control Board (NCRWQCB) staff members recommend that this parameter be monitored at least every 10 years or during the summer low-flow period following the next significant water event, whichever occurs first.

Baseline Conditions

State Parks staff members are not aware of data describing current or historic subsurface sediment conditions in the MCA Ill Creek watershed.

V* (V-star) and Bulk Sediment

V* is a measure of the fraction of a pool's volume that is filled with fine sediment. It has been demonstrated to be an effective measure of pool habitat loss caused by fine sediment loading and has been demonstrated to be responsive to changes in fine sediment loading. Cover et al. (2008) demonstrated a statistically significant relationship between the magnitude of sediment loading, estimated by U.S. Forest Service cumulative effects models and the value of V* in downstream pools.

Objective

The objective of measuring V* is to track trends in fine sediment levels that are related to pool habitat quality.

Procedures and Techniques

V* data should be collected as described by Hilton and Lisle (1993).

Monitoring Locations

V* monitoring should be conducted at representative sites in the MCA. State Parks will request copies of the datasheets from Carrol and Robison (2007) and Knopp's (1993) studies and try to incorporate those sites into the monitoring network.

Frequency and Duration

This parameter should be monitored every 5 years or during the summer low-flow period following the next significant water event, whichever occurs first.

Baseline Conditions

Based on data collected at two unspecified locations, Knopp (1993) reported V* values of 11.8% and 22.8% for the East Fork and West Branch, respectively.

Channel Cross-Sections

The shape and area of channel cross-sections are responsive to changes in runoff, sediment load, and vegetation patterns. Changes in cross-section attributes can be used to assess spatial and temporal changes in sediment load and lateral migration rates.

Objective

The objective of measuring channel cross-sections is to track changes in channel widths and depths, as well as changes in streambed elevations that result from aggradation or degradation.

Procedures and Techniques

Channel cross-sections should be measured consistent with techniques described in the U.S. Forest Service's General Technical Report RM-245, Stream Channel Reference Sites: An Illustrated Guide to Field Technique (Potyondy and Hardy 1994).

Monitoring Locations

Cross-section monitoring should continue at sites previously monitored by Redwood National and State Parks (RNSP) staff and other key locations.

Frequency and Duration

This parameter should be monitored every 5 years or during the summer low-flow period following the next significant runoff event, whichever occurs first.

Baseline Conditions

RNSP surveyed 11 channel cross-sections at representative sites located throughout the Mill Creek Watershed (Madej et al. 1986). These cross-sections were resurveyed at 1-year intervals from 1984 to 1989. Selected cross-sections were resurveyed periodically from 1990 to 1999, and the last time all 11 cross-sections were surveyed was during 2003.

Riffle-Surface Fine Sediment

Cover et al. (2008) found a significant correlation between the percent of the riffle-surface covered in fine sediment and sediment production model estimates in the Klamath Mountains.

Objective

The objective of monitoring fine sediment at multiple riffle-surfaces is to track sediment fluxes that may affect egg-to-fry survival in response reaches with gradients less than 3%.

Procedures and Techniques

Collection and processing of riffle-surface fine sediment data should be done using a sampling grid, consistent with methods described by Cover et al. (2008) and Bunte and Abt (2001).

Locations

Monitoring should be conducted at representative sites in the MCA. State Parks will request copies of the datasheets from Carrol and Robison (2007) and Knopp's (1993) studies and try to incorporate those sites into the monitoring network. Sampling of riffle-surface fines should occur in reaches with gradients less than 3%, with a preference for known spawning areas. This data should be collected at the same reaches where V* is monitored.

Frequency and Duration

Sites should be monitored every 5 years.

Baseline Conditions

State Parks staff members are not aware of data describing current or historic riffle-surface fine sediment levels.

Temperature-Related Monitoring

The dominant controllable factors influencing stream temperatures in the MCA are streamside shade and groundwater accretion. Progress toward recovering natural levels of streamside shade can be tracked by measuring shade directly or by measuring changes in the extent of riparian vegetation. Changes in the accretion of groundwater to MCA streams can be tracked by measuring streamflows at sites distributed longitudinally along the stream being evaluated. Where the stream goes dry, the location and timing of that drying can be noted. The ultimate measure of progress is whether the stream temperatures meet the requirements for the beneficial uses of the watershed. Stream temperature monitoring, conducted at multiple locations, will yield the ultimate measure of beneficial use support and compliance with the water quality objective for temperature.

Objective

The objective of monitoring temperature is to establish temperature conditions.

Procedures and Techniques

Stream temperature data should be collected consistent with Surface Water Ambient Monitoring Program (SWAMP) protocols, directed by the State Water Resources Control Board.

Monitoring Locations

Stream temperature monitoring should be conducted at representative sites in the MCA. State Parks will request location information for previous temperature monitoring studies mentioned in Stillwater Sciences (2002) or developed by RNSP and State Parks staff and incorporate those sites into the monitoring network. Additional sites should be established nearer to the headwaters of select streams to track the effects of climate change on source temperatures, and downstream from areas where substantial restoration or management changes are proposed.

Frequency and Duration

Stream temperatures should be monitored annually from June through September. The sampling interval should be no greater than 1 hour.

Baseline Conditions

Stream temperatures in the Mill Creek watershed do not appear to be a major limiting factor for salmonids or for other beneficial uses. Summer may be a period of concern for juveniles. Monitoring should be conducted to ensure that this assessment is correct and that management activities do not contribute to temperature increases.

Riparian Vegetation Extent

Riparian vegetative extent, measured from aerial imagery and LiDAR, allows for tracking of progress in reestablishing riparian vegetation communities before the vegetation manifests in effective shade or temperature measurements. An advantage of this type of monitoring is that large areas can be monitored. Another advantage is that riparian vegetation trends can be tracked without the need for extensive time in the field or private property access.

Objectives

The objectives of monitoring vegetative extent are to track changes in near stream vegetation, assess conifer recruitment to instream and terrestrial habitats, and determine the effects of management actions.

Procedures and Techniques

Riparian areas should be mapped from aerial imagery and/or LiDAR with a scale sufficient for identification of individual trees (1:2,500 to 1:5,000 scale or larger).
GIS software capable of change detection should be used according to the time series limitations of the available imagery. Mapping should delineate polygons that are

distinguished by tree species, canopy density, and tree height. A solar pathfinder or similar equipment may be used for site-specific studies.

Monitoring Locations

Monitoring should include treatment and non-treatment streamside areas that represent the range of conditions that exist along the stream corridor.

Frequency and Duration

Digital imagery and LiDAR canopy models should be obtained in 5- to 10-year intervals and used to measure changes in riparian forest conditions.

Baseline Conditions

Stillwater Sciences (2002) cited a report that was prepared for the Stimson Lumber Company (Stimson) Habitat Conservation Plan (Beak Consultants 1998) to characterize the riparian extent in the MCA. At the time of the Stimson report, high-gradient, confined channels were dominated by saplings and multilayered stands less than 50 years old. Lower gradient, less confined channels had about 50% hardwood canopy older than 50 years. Most other riparian stands were less than 30 years old but had a few large-diameter redwoods in the overstory. Existing imagery and LiDAR data may be used to help characterize the riparian forest.

Surface Water and Groundwater Flow

An array of groundwater monitoring wells is located in the Mill Creek Campground, adjacent to a summer drying reach in the West Branch. Data from the wells and mapping showed a negligible effect (within instrument error) on surface water flows as part of a consumptive use study conducted from 2006 to 2008 (Fiori, pers. com, 2008). Surface flow was also monitored at bridges in the West Branch. For the most part, In Situ^{TM} data loggers were used for flow measurement, although Global Water^{TM} data logger, pygmy meter, and other handheld flow meter measurements also were used. Discharge results from currently active USGS stream gages in the Smith River have been scaled to Mill Creek, based on drainage area relationships. USGS also monitored discharge in the mainstem of the Mill Creek at the northern boundary of the MCA from water years 1975–1981 (Madej et al. 1986). Monitoring of the Mill Creek Campground groundwater wells and surface water flow at bridges in the West Branch should be reestablished to monitor the effects of restoration and climate change, and to provide additional baseline data in the event consumptive use changes. Sites also should be explored to obtain long term surface flow data in the East Fork and Rock Creek. In the absence of other information, scaling from Smith River gages can suffice for discharge estimates.

Precipitation, Air Temperature, and Wind

Rainfall data have been applied from nearby long-term stations in the region (e.g., Gasquet, Department of Water Resources n.d.) for site-specific projects, although the lack of site-specific data has resulted in a range of isohyetal mapping for the MCA (see Section 1.4.2). Some data have been collected at the Mill Creek Campground maintenance yard (Webberly, pers. comms, 2007–2008), but they were not well curated or of sufficient duration to have application as part of a longer term data set. Development of permanent, long-term weather stations, currently proposed for the old mill site near the confluence of the West Branch and East Fork and a ridge near Childs Hill should help characterize meteorological conditions in the MCA.

Specific Conductivity and pH

Specific conductivity and pH do not appear to be problematic in the MCA, in the context of Basin Plan objectives. Anticipated activities in the watershed should not be problematic with respect to these parameters; thus, no specific monitoring element is proposed. Occasional informal measurements, using a handheld water quality meter, may be conducted if future information suggests a need.

5.1.2.3 AQUATIC SPECIES POPULATION TREND-DISTRIBUTION AND EFFECTIVENESS MONITORING

Protocols to assess the effectiveness of restoration projects and external factors on aquatic species population trends are described next.

Freshwater Mussels

Western pearlshell freshwater mussels (*Margaritifera falcate*) are one of the best long-term bioindicators of stream ecosystem health (Young et al. 2003) because of their sensitivity to stream conditions, very long life spans, close relationship with salmonid fish, and enormous bioaccumulation capabilities resulting from their filter feeding lifestyle. A western pearlshell inventory and the first 5-year monitoring cycle of the Mill Creek watershed have been completed by Redwood National Park staff. Pearlshells are present throughout the main stem of Mill Creek and 1 to 2 kilometers (0.6 to 1.2 miles) up the West Branch and East Fork (Bensen 2005). Annual monitoring of the mussel population in Mill Creek has occurred since 2005 (Bensen 2005, 2006, 2007, 2008, 2010). Monitoring on Mill Creek will start another 5-year cycle in 2014 so that each of the 10 monitoring transects will be revisited once (two transects surveyed per year) every 10 years to allow sufficient time for recruitment into the population (Bensen 2005).

The following survey protocol is intended to describe a relatively simple and nontime consuming methodology for monitoring the population size and recruitment of western pearlshell mussels in Mill Creek. Population monitoring is intended to provide an estimation of the number of mussels found in the stream. Recruitment monitoring is intended to provide a measure of the sustainability of the population. The protocol is primarily based on a nationally standardized methodology used in the United Kingdom to monitor the closely related freshwater mussel species *Margaritifera margaritifera* (Young et al. 2003), with some minor modifications based on recommendations by Stayer and Smith (2003). Robust pearlshell population sizes are considered to be those that contain greater than 10 mussels/m^2 in the intensive sample quadrats described below. Stable pearlshell mussel populations are indicated by having at least 20% of the population in the juvenile age class. Juvenile mussels are determined by overall length along the longest axis. Juveniles are generally less than 55 mm (2.2 inches) long (less than 20 years old), and young juveniles generally less than 30 mm (1.2 inches) long (less than 10 years old).

All surveyors must read the Job Hazard Analysis (JHA) entitled “Fish and Stream Surveys.” Particular attention should be paid to Task/Procedures sections #7—Stream

Surveys and #11—Snorkle Dive Fish Counts (on file at South Operations Center, Redwood National and State Parks, Orick, California). The hazards and safety procedures described in the JHA are all applicable to freshwater mussel monitoring surveys. All surveys must be conducted with a minimum of two surveyors. Three surveyors are preferable for efficiency. A tailgate safety session must be conducted by the lead surveyor before each year's surveys or each time a new surveyor joins the survey team. Bensen (2005) outlines the equipment needed for the survey.

To ensure maximum visibility and light penetration, all surveys must be done during September and/or October when stream levels are at their lowest and stream clarity is at its highest, on clear, sunny days between 10:00 and 16:00. Ten "general-sample" transects 50 m (164 feet) long by 1 m (3.3 feet) wide were used to sample the mainstem Mill Creek mussel population and will be revisited in 2014–2019. Locations are described by Bensen (2005, 2006, 2007, 2008, 2010). Transect start and end points are determined by GPS readings, and the midlines are determined by 50-m-long (164-foot-long) weighted and marked rope. Plot width (i.e., determining mussels inside and outside the transect) is determined by using the center-marked 1-meter bar. Mussels falling within the transect are determined by placing the middle mark on the bar on the weighted rope. Any mussel found between the ends of the bar is considered within the transect and is sampled.

Within each of the 10 general-sample transects are five "intensive-sample" 1-m-square (3.3-foot-square) quadrats. Quadrat sample area is determined using the weighted polyvinyl chloride (PVC) 1-m-square (3.3-foot-square) frame. Placement locations of one intensive-sample quadrat within each of the 10-m (33-foot), 20-m (66-foot), 30-m (99-foot), 40-m (131-foot), and 50-m (164-foot) sections are described by Bensen (2005, 2006, 2007, 2008, 2010). From the starting point and moving upstream, all visible mussels (i.e., mussels sticking up, out of the substrate) falling between the ends of the marked bar are counted. If more than 250 mussels are obviously present along the transect, the entire general-sample transect count is abandoned. Instead, only visible mussels are counted within five quadrats placed on the 10-m (33-foot), 20-m (66-foot), 30-m (99-foot), 40-m (131-foot), and 50-m (164-foot) points along the transect.

The result is multiplied by 10 (i.e., 10 x 5 m^2 = 50 m^2 or the same area as a general sample transect)to obtain the total along the entire transect. All dead mussels (indicated by open, empty shells) are counted separately. If the surveyor has not done so previously, one m^2 (10.8 square foot) quadrat is placed within the 10-m (33-foot) section along the transect. All visible mussels are carefully removed to a 19-liter (5-gallon) bucket filled with fresh stream water. Mussels are kept in the bucket for as short a time as possible. All loose stones and obstructions are removed. The underlying sand/gravel is gently disturbed, and all “buried” mussels are counted and removed, with special care taken to include all the small mussels (juveniles less than 55 mm [2.2 inches]). All mussels, both large and small, are removed to a bucket from the quadrat and counted. Each of the mussels is measured with calipers along its longest axis, to the nearest millimeter. After the mussels are measured, the juveniles are replaced to the substrate, and the stones and obstructions are returned as close as possible to their original locations. The adults (greater than 55 mm [2.2 inches]) are carefully placed in the spaces between the stones. The adults will reposition themselves. These steps are repeated at the 20-m (66-foot), 30-m (99-foot), 40-m (131-foot), and 50-m (164-foot) sections along the transect. The age lines are counted on 15 randomly picked mussels less than 60 mm (2.4 inches) long. For each mussel, the age number is put in the same cell as the length measurement on the survey form. These age estimations will be used to validate the assumption that all mussels less than 55 mm (2.2 inches) long in the Mill Creek watershed are less than 20 years old.

Salmonids

This section elaborates on the methodology used to estimate the salmonid populations described in Chapter 2. Recommendations also are given for extending the industrial timber management period and subsequent monitoring.

Spawning Surveys

Adult Chinook and coho salmon escapement has been monitored since 1980 in the West Branch and since 1993 in most other areas of the Mill Creek basin. Approximately 19 kilometers (12 miles) of known anadromous spawning habitat in both the West

Branch and East Fork and their tributaries have been surveyed (Table 5-1) (McLeod and Howard 2010).

Table 5-1
Stream Reaches Surveyed by the Mill Creek Fisheries Monitoring Program

Mill Creek						Rock Creek3	
Mainstem[1]		East Fork (EF)		West Branch (WB)			
Reach	Miles	Reach	Miles	Reach	Miles	Reach	Miles
Upper	1.0	EF Reach 1	2.25	WB Reach 1[1]	0.5	Rock	0.5
Lower	1.12	EF Reach 2	1.5	WB Reach 2[2]	1.7		
		Kelly Creek	0.75-1	WB Reach 3	2.75		
		Bummer Lake Creek	0.5	Hamilton Creek[4]	0.25		
		Low Divide Creek	0.25				
		First Gulch[4]	0.5				

[1] Mainstem reaches and WB Reach 1 have been surveyed occasionally since 2002.
[2] WB Reach 2 was surveyed by the University of California Cooperative Extension from 1980 to 2002.
[3] Rock Creek has been surveyed since 1994.
[4] First Gulch and Hamilton Creek have been surveyed only occasionally.
General Notes: All reaches have been surveyed annually since Water Year 1994 unless otherwise noted. The Mill Creek mainstem survey reaches begin about 0.27 stream km (0.16 mile) north of Redwood National Park's northern boundary. The Rock Creek survey reaches begin about 4.99 stream km (3.1 miles) south of the MCA boundary. All monitoring reaches are contiguous within the indicated streams. Except as noted, the downstream reach begins at the stream's confluence with the next downstream waterbody and the order of the reaches goes from downstream to upstream.
Source: McLeod and Howard 2010

Spawning surveys were conducted annually by the University of California Cooperative Extension from 1980 to 2002 on a 2.7-kilometer (1.7-mile) reach of the lower West Branch (Reach 2) (Waldvogel 2006). In 1993, Stimson began conducting annual spawning surveys (live fish and carcass counts) on the East Fork, Kelly Creek, Bummer Lake Creek, Low Divide Creek, and West Branch Reach 3. In 1994, Stimson added Rock Creek to its annual spawning surveys and began collecting data on redd abundance for all reaches they surveyed (Howard 1999). Since 2001, the Mill Creek Fisheries Monitoring Program (MCFMP) has conducted spawning surveys in all reaches previously surveyed by Stimson. In addition, the MCFMP has surveyed the mainstem of Mill Creek and West Branch Reach 1 (lowermost West Branch reach) on an opportunistic basis since 2002. In

2003, the MCFMP took over the task of conducting annual spawning surveys on West Branch Reach 2.

Weekly spawning surveys are conducted by the MCFMP from late October to early February and include live fish counts, redd counts, and carcass counts (McLeod and Howard 2010). Spawning survey data are used to estimate minimum escapement estimates of Chinook and coho salmon.

Outmigrant Trapping

Juvenile salmonid outmigrant trapping has been conducted on the East Fork and West Branch since 1994 using modified pipe traps (McLeod and Howard 2010). The East Fork trap has been located immediately below the Hamilton Road Bridge since trapping began in 1994. The West Branch trap was located above the Hamilton Road Bridge until 2003, when it was moved downstream to a higher gradient location about 76 meters (250 feet) upstream from the confluence of the West Branch and East Fork.

Outmigrant trapping has been used to collect information on movement and relative abundance of nonsmolting salmonids, and on outmigration timing of smolting salmonids. The mark/recapture component of the trapping program has allowed the annual estimation of outmigrating populations of coho, steelhead, and cutthroat smolts leaving the Mill Creek tributaries. In conjunction with escapement and summer population data, smolt production estimates have proven to be invaluable for assessing limiting factors in the watershed, identifying potential areas for restoration, and now as a tool for gauging the effectiveness of restoration efforts.

Summer Abundance Surveys

Juvenile summer population surveys have been conducted in the majority of anadromous habitat on the West Branch since 1994 and on the East Fork from 1995 to 1996 and from 2004 to 2009 (McLeod and Howard 2010). Sampling protocols and population estimates have been calculated using the Method of Bounded Counts, which is a two-phase regression estimation survey design based on repeated diver counts and electrofishing (Hankin and Reeves 1988, Dolloff et al. 1993). Summer abundance surveys typically are conducted in September and October of each year, when flows are near their lowest. Methodology for summer abundance surveys is detailed in McLeod and Howard (2010) and includes habitat delineation, snorkel surveys, and electrofishing. The data obtained are statistically analyzed to determine population estimates for juvenile coho, Chinook salmon, coastal cutthroat trout, and steelhead.

Future Monitoring

Adult Salmonids Monitoring

Previous monitoring of returning adults has consisted of spawner surveys, and the extent of the surveys has varied both annually in their frequency and reaches surveyed. Spawning surveys provide a general estimate of spawner abundance that can be used to monitor trends over time, especially if sampling effort and reaches sampled remain consistent between years. A previous study by Stillwater Sciences (2006) suggested that a weir be installed to compare returning adults with outmigrating juveniles. Because the number of returning adults is not a limiting factor in the Mill Creek drainage, and because of the cost and manpower that would be needed to operate weirs on both the East Fork and West Branch, this should be a low priority for future monitoring. Spawner surveys throughout the length of anadromy in the East Fork, West Branch, and Rock Creek should be conducted annually on a weekly basis, following protocols described by McLeod (2010b), Flosi et al. (1998), and Waldvogel (1988). Data collected through such surveys will add to baseline data as well as add to the long-term dataset, allowing biologists and managers to monitor changes in the abundance of adult spawners over time.

Juvenile Salmonids Monitoring

Outmigrant trapping of juvenile salmonids should continue in both the East Fork and West Branch at the established locations that were documented by McLeod and Howard (2010). Continuation of the trapping is needed to provide information on life stage–specific survival rates and long-term population trends and to increase understanding of the potential factors limiting population abundance and survival (Stillwater Sciences 2002). These data will become increasingly meaningful after restoration activities have addressed habitat-limiting factors for juvenile Chinook and juvenile coho, involving creation of refugia during high-flow events, which typically occur during winter and spring. Outmigration trapping should include a detailed mark/recapture plan, as described by McLeod (2010b), which should include population estimation using the Darroch Analysis (DARR2.0) (Bjorkstedt 2005). However, to decrease bias in recapture rates, fish should be moved more than one habitat break away after marking.

Summer Surveys

Summer abundance surveys consisting of habitat mapping, snorkel surveys, and electrofishing should be continued throughout the anadromous habitat in both the West Branch and East Fork (McLeod 2010b). Surveys should be conducted during late summer months, when flows are lowest. The West Branch should be surveyed last because of concerns regarding the accuracy of previous surveys resulting from sections of the West Branch going subsurface. If surveys were conducted before subsurface flows, separating and isolating sections of the population and increasing the risk of predation, the results would be inaccurate and overestimate the actual number of coho that successfully oversummer in the Mill Creek watershed (Stillwater Sciences 2006). Surveys should be conducted annually because of the natural variability in coho abundance that occurs between years, and to evaluate changes in summer abundance that may result from restoration, other activities, and/or natural processes.

Winter/Spring Surveys

Snorkel surveys should be implemented after major freshets, to determine the success of engineered logjams in creating habitat for coho during winter freshets and for Chinook during spring freshets. Snorkel surveys should be conducted in selected pools, including both *treatment* reaches, where restoration activities have already occurred, and nearby *control* reaches, where no restoration has taken place. The two reaches should be similar in size and close to each other so that comparisons can be made.

Passive Integrated Transponder Monitoring

Remote passive integrated transponder (PIT) tag monitoring stations should be installed in both the East Fork and West Branch near their confluence. In addition, a monitoring station near the mouth of Mill Creek also would be beneficial. Young-of-the-year coho should be marked with PIT tags during summer abundance surveys, and remote monitoring stations should record individual fish movement between the two tributaries to the mainstem of Mill Creek, and ultimately when they leave the mainstem of Mill Creek and enter the Smith River. This type of strategy and monitoring will help pick up missed activity caused by high water flows. Because recent instream restoration activities have been occurring exclusively in the East Fork, it would be beneficial to determine if juvenile coho from the West Branch are actively moving into the East Fork and, if they are, the extent of interbasin movement.

Suspended Sediment and Severity of Effect

Where suspended sediment is measured, the data set is sufficiently robust, and salmonids or other sensitive aquatic species may be in the assessed reach, the following equations should be applied to help assess sedimentological effects on the fishery (Table 5-2).

Table 5-2
Severity Impact Assessment Models for Different Life History Stages and Suspended Sediment Grain Sizes

Model Number	Life History Stages and Grain Size Range	Model Equation
1	Juvenile and adult salmonids; grain size range 0.5-250 µm	SEV = 1.064+0.6068×LN(D)+0.7384×LN(C)
2	Adult salmonids; grain size range 0.5-250 µm	SEV = 1.6814+0.4769×LN(D)+0.7565×LN(C)
3	Juvenile salmonids; grain size range 0.5-75 µm	SEV = 0.7262+0.7034×LN(D)+0.7144×LN(C)
4	Eggs and larvae of salmonids and nonsalmonids	SEV = 3.7456+1.0946×LN(D)+0.3117×LN(C)

Notes: D = duration of exposure in hours; C = suspended sediment concentration (mg/L)
Source: Newcombe and Jensen 1996

5.1.3 ADAPTIVE MANAGEMENT

To continue to collect the highest quality data, methodologies and protocols should be reviewed and reevaluated annually to determine whether changes are necessary.

5.2 CRITERIA FOR ASSESSING LOAD REDUCTIONS

The following discusses the targets and rationales for those targets for specified monitoring methods. If goals are not being achieved, the information should be used to bring attention to management restoration activities that can be adapted to improve an undesirable trend. Climate change or other large-scale forcing mechanisms could require alterations in these targets. The nominal target for achieving these goals should be 10 years after the road removal and improvement program has been completed.

5.2.1 GEOMORPHIC AND WATER QUALITY AND QUANTITY TREND AND EFFECTIVENESS MONITORING

For Hunter and Terwar creeks, guidelines that may result from upcoming Total Maximum Daily Load analysis of the Klamath River will apply in addition to, and may supersede, the criteria discussed here. Wilson Creek also will be governed by State Water Quality Protection Area guidelines. Targets described in the Basin Plan that pertain to the MCA (see Chapter 2) also should help guide water quality monitoring. Water quantity also affects water quality, and these two trends can be used to help assess forest recovery, landform stability, climate change, possibly groundwater changes from road removal, and the relationship of various beneficial uses throughout the MCA. Information from other studies also may be used to develop relevant criteria for adaptive management.

5.2.1.1 SLOPE CHANGE AND SEDIMENTATION

Targets and rates discussed in Chapter 3 will help to guide upslope source sediment loading assessments over time.

5.2.1.2 SUSPENDED SEDIMENT AND TURBIDITY

A decreasing trend in suspended sediment/turbidity values that compares favorably with the relatively low values reported by USGS and other studies during the logging period should be the desired goal. Klein et al. (2008) compared turbidity conditions of 27 North Coast forested watersheds, using the 10% exceedance level (the turbidity level that was exceeded 10% of the time) as a metric for comparison. Although watersheds were analyzed in a different geological setting than the MCA, this study is still useful as a point of reference for salmonid streams. The analysis found that forested watersheds without previous timber harvest (n=12) had an average turbidity level of 13 FNUs (Formazin Nephelometric Unit - essentially equivalent to a NTU [nephelometric turbidity unit]) at the 10% exceedance level (range = 3 to 22), whereas watersheds with lower harvest rates (<1.02% annual clear-cut equivalent, mean = 0.67%) had an average 10% exceedance turbidity of 20 FNUs (range = 4 to 37, n = 5). Watersheds with higher rates of harvest (>1.57% annual clear-cut equivalent, mean = 2.35%) had an average 10% exceedance turbidity of 61 FNUs (range = 27 to 116, n = 10).

5.2.1.3 SURFACE PARTICLE SIZE DISTRIBUTION (PEBBLE COUNTS)

Knopp (1993) found a statistically significant difference between the median surface particle sizes of streams with and without extensive management. Their study showed that watersheds without extensive previous management had an average median surface particle size of 63 mm (2.48 inches). The desired goal is to attain a median surface particle size of 63 mm (2.48 inches) or greater within 10 years of completion of the road removal program.

5.2.1.4 SUBSURFACE PARTICLE SIZE DISTRIBUTION (MCNEIL SAMPLES)

Fitzgerald (2006) reviewed literature pertaining to the appropriate subsurface particle size distributions for support of salmonids. That review determined that less than 14% fines less than 0.85 mm (0.033 inch) and less than 30% fines less than 6.4 mm (0.252 inch) together provide a benchmark for subsurface gravel quality in relation to salmonid spawning. The desired goal is that no more than 30% of the gravel subsurface volume has an intermediate diameter of 6.4 mm (0.252 inch) or less, and no more than 14% of the gravel subsurface volume has an intermediate diameter of 0.85 mm (0.033 inch) or less within 10 years of completion of the road removal program.

5.2.1.5 V* AND BULK SEDIMENT

The goal is an average V* for monitoring reaches that is less than or equal to the baseline values reported by Knopp (1993).

5.2.1.6 INSTREAM TOPOGRAPHIC SURVEYS

The goal for repeated cross-section surveys is to show a decreasing width/depth ratio in the channel bed and an increasing trend in pool depth and frequency.

5.2.1.7 RIFFLE-SURFACE FINE SEDIMENT

The three streams identified by Cover et al. (2008) as having low sediment supplies have an average riffle-surface fine sediment value of 7.5% (range = 3.7% to 10.2%). The goal is an average riffle-surface fine sediment percentage for all monitoring reaches that is less than 10% within 10 years of completion of the road removal program.

5.2.1.8 STREAM TEMPERATURE-RELATED MONITORING

Stream temperatures in the MCA do not appear to be a major limiting factor for salmonids or for other beneficial uses. Monitoring should be conducted to ensure that this assessment is correct and that management activities do not contribute to temperature increases from those reported in Chapter 2.

5.2.1.9 RIPARIAN VEGETATION EXTENT

The goal for riparian vegetation management is to increase the coniferous canopy height and density in order to improve recruitment and to maintain or marginally improve effective shade. Effective shade is sufficiently robust to maintain generally adequate stream temperatures in the MCA. The effective shade target considers vegetation height, topography, site geometry, and stream width, and is a function of the percentage of the stream at bankfull width that receives shade. Different vegetation types contribute to produce varying effective shade at different stream widths. The goal for the MCA follows effective shade targets outlined in the Klamath River Total Maximum Daily Load report (NCRWQCB 2010).

5.2.1.10 SURFACE WATER AND GROUNDWATER FLOW

The goals for surface water and groundwater flow are to maintain quantities necessary for the fishery to attain optimum health and capacity, and to provide water for recreational uses.

5.2.1.11 PRECIPITATION, AIR TEMPERATURE, AND WIND

The goals for long-term meteorological data collection are to attain a sufficiently robust data set to observe trends related to climate change, to help assess restoration results, and to help predict optimum locations for related monitoring sites.

5.2.2 AQUATIC SPECIES POPULATION TREND-DISTRIBUTION AND EFFECTIVENESS MONITORING

The vigor and robustness of aquatic populations is highly dependent on water quality. Population trends can help determine local watershed conditions for less mobile species and can help show external influences on populations that move in and out of the MCA.

5.2.2.1 FRESHWATER MUSSELS

The aim of the general-sample transects (or the intensive-sample quadrats if numerous mussels are found along the transect) is to determine the number of mussels per square meter so that a relative density can be determined. The aim of intensive-sample quadrats is to determine the age distribution, and thus recruitment level, of the population. A self-sustaining pearlshell mussel population should have 20% of the population in the juvenile age class (i.e., those less than 55 mm [2.2 inches] long) and at least some in the early juvenile age class (i.e., those less than 30 mm [1.2 inches] long). First-year samples will determine whether the Mill Creek western pearlshell mussel population is self-sustaining, based on age class distribution. Return-year samples will determine whether the relative density, and thus total population size, is increasing, stable, or decreasing.

5.2.2.2 SALMONIDS

The goal for salmonids is to have an increasing trend in the populations of all monitored age classes until a relatively stable and optimum population size is attained. Modeling by Stillwater (2006) indicates that improvements in habitat, particularly overwintering habitat, could increase the capacity of the system for adult coho by about 15%. Increasing spring rearing habitat could increase Chinook abundance by about 40%. Decreases in habitat could lead to a 12% reduction in equilibrium populations, but the effects depend on salmonid survival in the marine environment. Preservation of existing habitat, a trend toward the lower end of the no effect to sublethal range of classifications for severity of effects monitoring, and improvements in other physically based monitoring parameters are related goals.

5.3 DATA MANAGEMENT

Sound data management methods can help to ensure that the goal of the monitoring activity is actually realized because the data analysis is only as good as the steps used to derive and preserve the data. This is particularly true for long-term data sets that are needed to observe landscape scale change. Study design, data collection, and interpretation should have the oversight of a qualified, licensed professional, as appropriate. Written protocols should be developed to help guide each monitoring facet, to help ensure that longer term data sets are collected consistently over time. The monitoring methodology used in the MCA should be consistent with State Parks Inventory and Monitoring Program protocols, where they have been developed.

5.3.1 COLLECTION

For road rehabilitation projects, quality control should be maintained through direct observation of operations by qualified personnel. To maintain cost-effectiveness, all subcontracted equipment operators should be required to have a specified number of related experience hours, depending on the complexity of a given project. Project documentation should consist of timekeeping, volumetric data, and atypical prescription notes for complex sites. Project inspectors should track 15-minute intervals that describe what each piece of equipment is doing during a given time period. These data should be combined with volume and distance data to produce production rates. Project-related data should be captured in all-weather field notebooks and transferred to electronic spreadsheets, databases, and reports as soon as the inspectors return to their office.

Permanent photo-points should be established at selected crossing and road removal sites where before and after pictures are taken. Data for each photo-point should be captured in a field index log that includes site documentation, photo-point number, file name of picture, date, time, lens, weather (sun/shade), compass direction, orientation of frame (vertical or horizontal), landmarks, and any other identifying information. Photo-points should be used to identify changes and monitor conditions at the sites, and new photo-points should be taken using the original as a guide to duplicate the exact framing.

For forest restoration, field staff should monitor all forest restoration activities to ensure that the work is accomplished throughout the treatment area and that all work is accomplished to prescription specifications. Permanent plots should be established in selected stands to monitor long-term changes in forest structure and stand composition, using both physical measurement and photographic techniques (State Parks 2008). Larger trees should be tagged at breast height to note measurement location and to enable the tracking of changes to individual tree. Control areas should be compared to various treatments implemented. The size and number of plots may vary to meet the needs of individual projects.

Instream, meteorological, sedimentological, and hydrological monitoring involve comparatively newer data sets that have been recently initiated or have not yet been started. However, in some cases, existing baseline data exists; relevant stream reaches should be reoccupied and/or expanded for instream, sedimentological, and hydrological monitoring, and methodology that facilitates comparison with previous data sets should be followed. Other sites that are selected will depend on the location of restoration activity and the opportunity to maximize the value of the monitoring effort. The locations for permanent meteorological stations are being considered. In most cases, instrumentation should be downloaded in the field and promptly annotated and archived by the surveyor on return to the office to facilitate analysis. Monitoring of aquatic species has been ongoing for a number of years and the data collection protocols are in place.

5.3.2 STORAGE

Monitoring data are stored in the district GIS for interpretation and long-term storage. Data are stored according to park and/or subject matter, and protocols have been developed for entering some, but not all, long-term natural resource data sets. Users are screened for access to certain parts of the GIS by the GIS administrator. Roads and Trails staff maintain a separate GIS that is periodically downloaded to the district GIS. The GIS server is backed up nightly to the departmental network in Sacramento.

5.3.3 DISSEMINATION

Because State Parks is a public agency, information is available on request from manager of the North Coast Redwoods District Natural Resources Program. If it is determined that releasing the information could lead the public to affect resources in an adverse way (e.g., knowledge of the whereabouts of sensitive artifacts or unique trees that could be affected by excessive visitation), the information will remain confidential. With respect to this document, it will be available at the Humboldt State University library and the State Parks district office at Fort Humboldt State Historic Park in Eureka, California.

6 ECONOMIC ANALYSIS

Recontoured road at Mill Creek. Source: Photograph taken by AECOM in 2010.

6.1 PROJECT COST ESTIMATES

The primary costs for implementing this plan relate to abating sedimentation from the roads, improving forest stands, installing instream structures, and monitoring the restoration activities and climatic conditions. Although several of these items may have a per unit cost that can be predicted over time, more dynamic parameters, such as the rate of forest growth or unusual events like earthquakes, large storms, or forest blight, can accelerate or decelerate the need for funds.

6.1.1 SEDIMENT ABATEMENT

Road-associated sedimentation should be controlled and abated through a combination of routine patrol, maintenance, and rehabilitation treatments. A seasonal storm patrol crew should continue to operate on a seasonal basis to clear culverts, ditches, and other drainage structures. Seasonal storm patrols are an essential, cost-effective way to prevent road-related sedimentation from the existing road network before an upgrade. Currently, a four-person crew with heavy equipment operates annually from November 1 through April 30 each year. Annual support costs for the storm patrol crew are $80,000.

Approximately 128 kilometers (80 miles) of road are expected to remain operational on the property for public access and administrative purposes in the long term. Most of these roads are poorly designed, with problematic drainage, inboard ditches, and undersized culvert road crossings and cross drains. Road upgrades will improve conveyance at road stream crossings, improve road surface drainage, reduce connectivity between roads and streams, and stabilize road fills. Costs for road upgrades are estimated to be $15.5 million in 2011 dollars. Annual maintenance costs for 128 kilometers (80 miles) of retained road are estimated to be $935,000 in their present condition. After the roads are upgraded, maintenance costs should be reduced to an estimated $700,000 annually, including costs for annual grading, roadside brushing, and cyclic replacement of drainage structures.

The property contains a network of surplus roads estimated to total 320 kilometers (199 miles). Over the next several decades, these roads will be removed or converted to trails. Costs associated with this work are estimated to be $25–35 million, depending primarily on the price of fuel, which has the greatest effect on the cost of road work.

6.1.2 FOREST ENHANCEMENT

State Parks has recently been restoring approximately 200 hectares (ha) (500 acres [ac]) of forest per year and aims to continue at this pace as funding allows. Treatment costs have been more than $1,500/ha ($607/ac) but vary greatly, depending on a host of issues, including forest fuel reduction needs (along drivable roads adjacent to treatments), tree and brush density, the location and number of trees to be fallen, vehicle fuel costs, and the acreage treated in a given year. As other age classes are treated, other variables may need to be considered. Additional analysis will be needed to determine the number of snags and the amount of coarse wood that is appropriate to improve fish and wildlife habitat. It is likely that more trees may need to be cut to meet stand-level objectives than are necessary to meet habitat needs for snags and coarse wood. In such cases, excess timber may be removed and sold to help offset the costs of the project. Timber removal will, however, increase the cost of administration, including more extensive analysis under the California Environmental Quality Act, contracting specifications, and oversight of operations. Despite these added costs and the current depreciation in timber prices, the treatment of older age classes may be less than current costs for younger stands.

6.1.3 INSTREAM STRUCTURES

Complex wood jams, which are the preferred design for instream structure construction, cost about $6,500 each. More than 20 have been installed to date, approximately eight of which have been intensively monitored, and another 50 are planned for installation in the East Fork. The West Branch and other locations have not yet been fully assessed to determine the number of complex wood jams needed in those locations.

6.1.4 MONITORING

6.1.4.1 AQUATIC SPECIES

The estimated annual cost for the fishery and freshwater mussel monitoring, as described in Chapter 5, is about $125,000. An additional $15,000 per year should be allocated toward monitoring other aquatic species that currently do not have well-defined monitoring protocols but that are important indicator species (e.g., salamanders).

6.1.4.2 PHYSICAL PROCESSES

Instream and Riparian

The estimated annual cost for instream and riparian monitoring (described in Chapter 5), including limited instream structure monitoring, is about $150,000. The estimated start-up costs related to equipment purchasing are approximately $250,000.

Terrestrial Upslope

Regular aerial photography and Light Detection and Ranging (LiDAR) data acquisition, on an approximate 7-year basis, would facilitate linking the upslope and instream-riparian monitoring. Because the initial LiDAR data for the Mill Creek Addition (MCA) had some quality issues, a LiDAR acquisition flight should be performed in about 2012. Regular air photo acquisition should be available for free to the general public as part of ongoing land cover data acquisition by other agencies (e.g., National Agriculture Imagery Program photographs). The cost of the LiDAR acquisition is currently about $2 per acre. The cost of processing is another $1 per acre. If the cost of obtaining and processing data on 25,000 acres (about $75,000) is amortized over an average 7-year period, the annual cost would be about $11,000. Analysis costs would be nominal to grant funding sources if the analysis is performed by licensed State Parks staff members, funded by the district.

6.2 SOURCES OF FUNDING

Potential funding sources for urgently needed implementation and planning projects include State Parks, Save the Redwoods League, the California Coastal Conservancy, the Wildlife Conservation Board, the California Department of Fish and Game, and the California State Water Quality Control Board. Other sources also may be used if opportunities arise (e.g., research by the University of California).

6.3 PROJECT INTERIM MILESTONES

Interim milestones for the project include completion of the Landscape Stabilization and Erosion Prevention Plan road removal, completion of the Forest Ecosystem Restoration and Protection Project forest treatments, completion of the East Fork instream structure installation project, and completion of the culvert and bridge system upgrade to current standards. Completion of forestry data analysis will further guide restoration treatments. Development of a Roads and Trails Plan will help to identify final routes needed for public and administrative access. After these tasks are accomplished, adequate monitoring data should be available to help guide further restoration activities on a more stable road network that can be more easily maintained. Final completion of the road removal, instream structure installation, and forest restoration phases will complete the implementation element of the project. Follow-up work, based on the monitoring trends and the goals outlined in Chapter 5, will complete the project.

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View of Crescent City. Source: Photograph taken by AECOM in 2010.

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PERSONAL COMMUNICATIONS

Albro, Paul. Fisheries Technician. Mill Creek Fisheries Monitoring Program, Smith River, CA. March 30, 2006—conversation with Rod McLeod, Mill Creek Fisheries Monitoring Program Project Coordinator, regarding the lack of an outlet for fish escape from the reservoir near the Stimson Mill site.

Fiori, Rocco. Engineering Geologist. California Department of Parks and Recreation, Eureka, CA. November 18, 2008—presentation to California Department of Fish and Game Engineering Geologist Mark Smelser, National Marine Fisheries Service Hydrologist Leslie Wolff and Hydraulic Engineer Margaret Tauser, and California Department of Parks and Recreation Engineering Geologist Patrick Vaughan regarding effects of water extraction at the Mill Creek Campground on Mill Creek surface water flow.

Gibson, Micah. Yurok Tribe Environmental Technician. Klamath, CA. June 21, 2010—water quality monitoring data regarding correlation between turbidity and suspended sediment concentrations for Lower Klamath River tributaries, provided to California Department of Parks and Recreation Engineering Geologist Rocco Fiori.

Harris, Jay. Senior Environmental Scientist. California Department of Parks and Recreation, Eureka, CA. September 14, 2010—conversation with California Department of Parks and Recreation Engineering Geologist Patrick Vaughan regarding extraction of legacy wood from channels by Stimson Lumber Company.

Howard, Chris. Elk Valley Rancheria Director of Public Relations, Economic Development and Environmental Services. Crescent City, CA. February 20, 2010—conversation with Rod McLeod, Mill Creek Fisheries Monitoring Program Project Coordinator, regarding juvenile shad in East Fork.

McLeod, Rod. Project Coordinator. Mill Creek Fisheries Monitoring Program, Smith River, CA. February 10, 2010—personal observations regarding the numbers of trout observed during summer dive surveys in Mill Creek.

McLeod, Rod. Project Coordinator. Mill Creek Fisheries Monitoring Program, Smith River, CA. June 17, 2011 2010—e-mail communication to California Department of Parks and Recreation Engineering Geologist regarding the size of coho 0+ and smolts and their life history in Mill Creek and the timing of cutthroat spawning based on fry catches.

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Transou, Amber. Environmental Scientist. California Department of Parks and Recreation, Eureka, CA. May 2010—conversation with Jay Harris, California Department of Parks and Recreation Senior Environmental Scientist, regarding marbled murrelet and northern spotted owl habitat and occupancy in the Mill Creek Addition.

Van Skoyk, Andrew. Hatchery Manager. Rowdy Creek Fish Hatchery, Smith River, CA. February 15, 2010—conversation with Rod McLeod, Mill Creek Fisheries Monitoring Program Project Coordinator, regarding the timing of the emergence of Chinook fry.

Webberly, Mark. Maintenance Worker. California Department of Parks and Recreation, Del Norte Coast Redwoods State Park, CA. 2007 to 2008—various communications with California Department of Parks and Recreation Engineering

Geologist Patrick Vaughan about precipitation at the Mill Creek campground maintenance yard.

Winzler and Kelley staff. Eureka, CA. August 16, 2010—conversation with Rocco Fiori, California Department of Parks and Recreation Engineering Geologist, regarding 1980 suspended sediment study by Winzler and Kelley.

Zabinsky, Ben. Water Resources Control Engineer. North Coast Regional Water Quality Control Board, Santa Rosa, CA. February 2010— telephone conversation with California Department of Parks and RecreationEngineering Geologist Patrick Vaughan regarding Klamath River Total Maximum Daily Loads.

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Hikers along Picnic Road. Source: Photograph taken by AECOM in 2010.

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APPENDIX A

Mill Creek Addition Road Assessment Report

Mill Creek Addition
Road Inventory and Assessment Report

Brian R. Merrill
Shannon Dempsey
Judy Wartella

June 1, 2011

Mill Creek Addition
Road Inventory and Assessment Report

Brian R. Merrill
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Brian R. Merrill, C.E.G. 2285

June 1, 2011

Merrill, B.R., Dempsey, S., Wartella, J., 2011, Mill Creek Addition road inventory and assessment report: Redwood National and State Parks report, unpublished, 274 pp.

EXECUTIVE SUMMARY

We inventoried all of the known roads within the Mill Creek Addition from 2002 through 2005. Physical parameters of the road prism and road structures such as stream crossings and landings were recorded and entered into Access™ databases. Database tables dynamically linked to the Redwood National and State Parks geographic information system (GIS) allowed us to query data within the databases and against spatial data contained in the GIS.

A range of scoring values were assigned to selected physical attributes of road fills as well as crossings, landings, and mass wasting sites. Selected landscape features such as soils, slope, and relative slope stability were spatially joined to road features to aid in the scoring. Scores were normalized and evaluated individually and grouped by road to objectively quantify the relative failure potential and sediment delivery threat for each road. Failure potential describes the relative likelihood a road or site will fail while threat describes the relative volume at risk for delivery to the stream network. Models developed for this analysis may be used to evaluate other threat criteria such as damage to forest stands by landslide run-out or capital loss as road structures fail and require replacement.

Four-hundred and sixty eight kilometers of road and 3,688 sites including 1,457 road-stream crossings, 981 landings, 807 mass wasting sites, and 443 road fills are classified based on their relative failure potential and threat. Nine-hundred and ninety-seven sites and 122 road fills are considered high risk with a combined potential sediment delivery of 1,149,000 m^3. Moderate risk sites and road fills number 1,300 and 240, repectively, and represent 1,042,000 m^3 of potential sediment delivery. Low risk sites account for 357,000 m^3 of potentially deliverable sediment contained in 948 sites and 81 road fills.

ACKNOWLEDGEMENTS

We would like to thank the GIS team at Redwood National and State Parks (RNSP), especially Dave Best and Daryl Van Dyke, who provided many hours of consultation and technical support to this project. We would also like to thank our geology partners at RNSP, Greg Bundros and Darci Short for their input and technical review of our assessment scoring methods and Joe Seney, who was a valuable resource in providing consultation on the soil survey data used for the slope stability model. Thanks to Patrick Vaughan for his contribution to the geology section and his review of the assessment and report. Thanks to Maggie Barr for numerous readings and editing. Of course, we are grateful to the dedicated field technicians, especially Davin Peterson and Martha Basham, who spent many long hours in the field, rain or shine, to inventory the roads and to Martha for her countless hours in the office inputting data.

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INTRODUCTION

In June 2002, Save-the-Redwoods League acquired 25,471 acres of private timberland from Stimson Lumber Company. The acquisition of this land marked the end of an effort that had begun decades before to transfer the property encompassing the Mill Creek watershed into public hands as either a National Park or an addition to the adjacent State Parks. As a commercial property, the acreage was aggressively harvested from the early 1950's to the latter 1990's. Over the course of a few decades, the forest was converted from old growth redwood, Douglas fir, and Sitka spruce to a mosaic of even aged Douglas fir cut units. This ground-based timber operation resulted in the construction of a dense network of haul roads and skid trails to facilitate timber transportation. When the Mill Creek Addition (MCA) was transferred to the California State Parks (DPR) in 2002, there were approximately 468 km of haul roads and an estimated 650 km of skid trails present.

All watersheds have a natural rate of erosion and sedimentation that varies according to their underlying geology and climate. However, human land management activities such as road building and logging can accelerate erosion and cause excessive sedimentation in streams. The network of logging roads contributes more frequently to landslides and accelerated erosion than timber harvesting itself (Rice 1991 and Rice et al. 1972), primarily because road cuts and their drainage features disrupt natural surface and subsurface hydrological patterns. Roads located in steep terrain can produce large landslides as sidecast material becomes saturated by heavy precipitation. During extreme storm events, road drainage features such as culverts can become plugged with woody debris, causing the stream crossing to fail or diverting stream flow onto roadways and hillslopes.

Excessive sedimentation has an especially adverse effect on the survival, growth, and reproduction of salmonid populations. The influx of fine sediment fills in stream pools necessary for salmonid fry and juvenile survival. After pools are filled, the continued influx of sediment creates shallower, wider stream channels causing lateral migration of the channel which leads to bank erosion and loss of vegetative cover. Additionally, fine sediment deposits in stream gravels and clogs interstitial spaces, reducing oxygen levels and nutrient flow within spawning gravels. Because roads throughout the watershed contribute sediment, site-specific erosion problems can have a cumulative effect on water quality downstream.

The inherited road network at the MCA poses a significant management challenge. The roads traverse steep terrain and are exposed to seasonally high rainfall (1,524 mm to 3,810 mm per year (Stillwater 2002)). Drainage structures must be constantly maintained to prevent storm damage and consequent sediment delivery to creeks. Without continued maintenance, upgrading, or removal, the risk of road-related erosion and sedimentation will increase over time. Many of the roads are unnecessary, as they are no longer being used for timber extraction. The first step in road management planning was to conduct a park wide inventory, making it possible to rank roads by their relative risk of failure and by the threat they pose in terms of sedimentation to the stream network.

PURPOSE

This report presents the methods and results of our property-wide road inventory conducted from 2002 to 2005 and the subsequent assessment of road stability and threat to park resources. This report is intended as a starting point for the evaluation of roads within the guiding context of a Mill Creek General Plan Amendment (GPA) and future management planning efforts.

SCOPE

Our inventory included all known haul roads within the property at the time of acquisition, as well as those discovered during field work. We collected data to determine how each road influenced local geomorphic processes, and to develop cost estimates for annual maintenance, road reengineering, and removal of unnecessary roads.

Skid trails were not inventoried or assessed. We defined skid trails as small single-lane tracks that developed as ground-based equipment moved logs across harvest units. Skid trails were not planned as part of the road system, were not constructed using standard cut and fill techniques, and typically did not make use of stream crossings. We did not inventory fire breaks developed around harvest units. They were classified as skid trails because they usually followed the existing topography instead of cutting through it.

We combined road inventory data, geographic information system (GIS) routing, a digital elevation model (DEM), and a slope stability model (SINMAP) to rank haul roads by their relative failure potential and by the volume of sediment delivery to streams if failure occurs. Road rankings are not based on the value of roads for continued use in park operations, resource management, or emergency services. In this assessment we will not discuss specific rehabilitation options for each road; rather, we will use failure potential and sediment delivery threat to evaluate roads for permanent retention or removal consistent with planning guidelines and procedures defined in future management plans.

PREVIOUS ROAD INVESTIGATIONS

Pacific Watershed Associates conducted a property-wide survey of roads between 1995 and 1997 (PWA 1996, 1997, 1998). The purpose of the investigation was to identify existing and potential sources of sediment that could deliver to streams and affect water quality. Approximately 90% of the roads were inventoried across the Mill and Rock creek basins. The investigation concluded that most of the potential erosion and sediment yield related to roads was likely to come from three sources: 1) failure of the road fillslope, 2) failure of stream crossings, and 3) road surface and ditch erosion (PWA 1997, 1998).

Stimson Lumber Company conducted an investigation of mass wasting and road-related erosion as part of their effort to develop a Habitat Conservation Plan (Stimson Lumber Company 1998). The investigation relied on aerial surveys coupled with field mapping to identify the location and characteristics of mass wasting features across the landscape. The investigation concluded that roads were the largest contributing source of sediment delivered to streams, and that altered drainage paths contributed significantly to watershed instability.

In 2002, Stillwater Sciences completed Interim Management Recommendations for the MCA under contract with the Save the Redwoods League. The project drew from past investigations to formulate management recommendations for application during the first years of acquisition. We have been implementing road removal projects and maintenance consistent with their preliminary recommendations until State Park staff could complete formal planning efforts for the newly acquired park unit.

ROADS, SKID TRAILS, AND ROUTES

Throughout this report, the terms roads, skid trails, and routes are used to describe features that were used by vehicles or equipment to conduct timber extraction and transportation. There are, however, distinctions between these terms that require some definition. Roads describe passages of all sizes and uses. The single distinguishing element of a road is that it has a roadbed constructed to be a relatively smooth driving surface for truck or equipment travel. Skid trails, on the other hand, lack a constructed road bed and are often expressed as lineations of bare mineral soil that follow, rather than cut through, the surrounding topography. Timber extraction equipment most often used skid trails for a limited time or for fire breaks during post-harvest burning.

The roads within the Mill Creek Addition can be mapped with spatial accuracy using GIS software. The term “route” as used in a GIS refers to a line feature that has a unique identifier, which in this case was each road within the MCA road network. Routes provide the fundamental spatial framework for the road assessment and will be used to describe the inventory as it pertains to the physical roads on the property.

PHYSICAL AND HISTORICAL SETTING

GEOGRAPHY

The Mill Creek Addition, now part of Del Norte Coast Redwoods State Park, is a 103 km^2 parcel located approximately 9 km southeast of Crescent City, Del Norte County, California (Figure 1). The property adjoins Jedediah Smith Redwoods State Park to the north, Del Norte Coast Redwoods State Park to the west, Six Rivers National Recreation Area to the east, and Industrial timber lands (owned by Green Diamond Resources Company) to the south. The property encompasses most of the Mill Creek and Rock Creek watersheds and small areas within the Turwar, Hunter, and Wilson creek watersheds (Figure 2). Drainages are deeply incised and have dendritic to trellis patterns. LiDAR analysis yields a property-wide average drainage density of approximately 13.2 km/km^2.

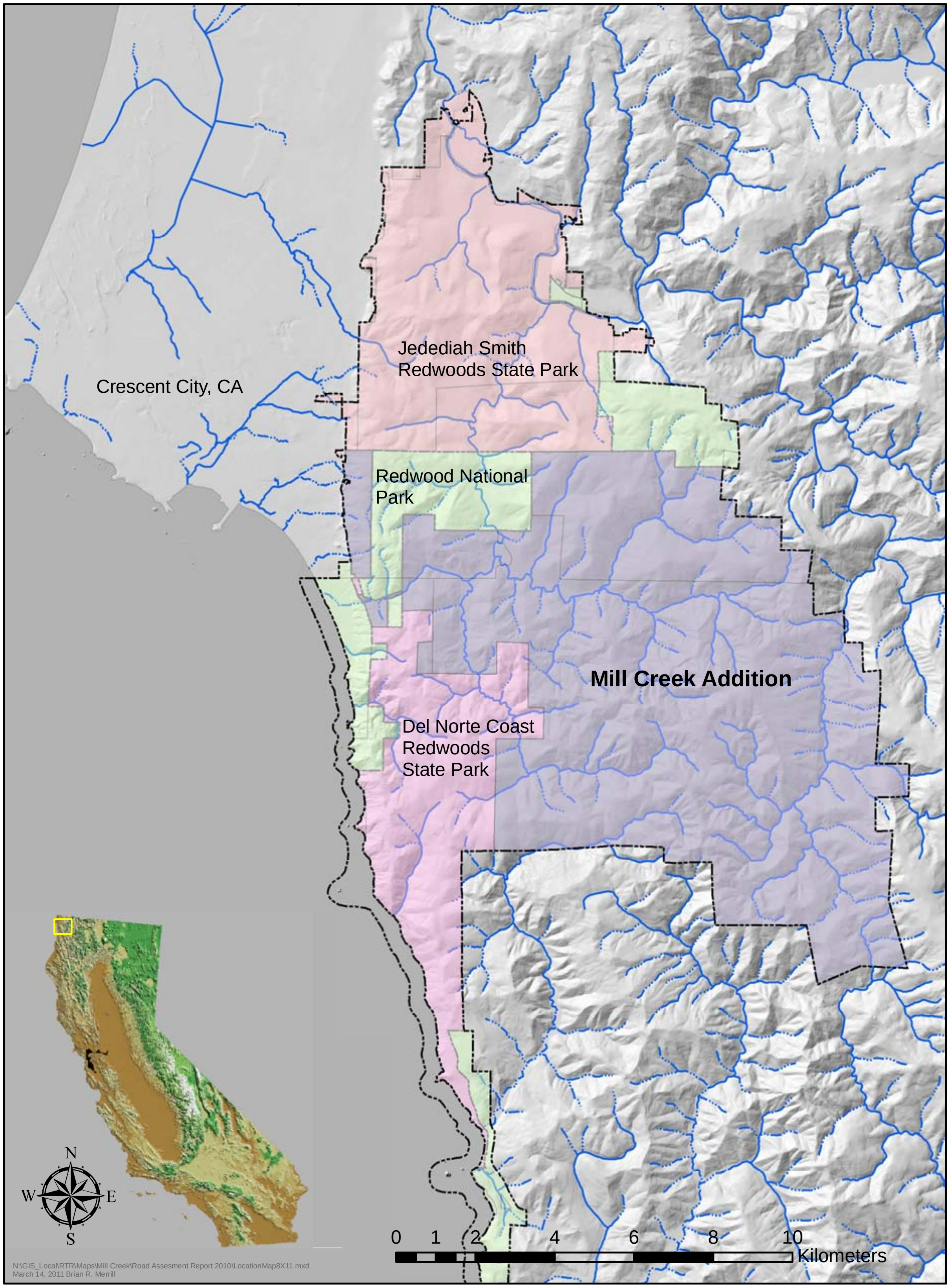

Figure 1. Location of the Mill Creek Addition, Del Norte County, California

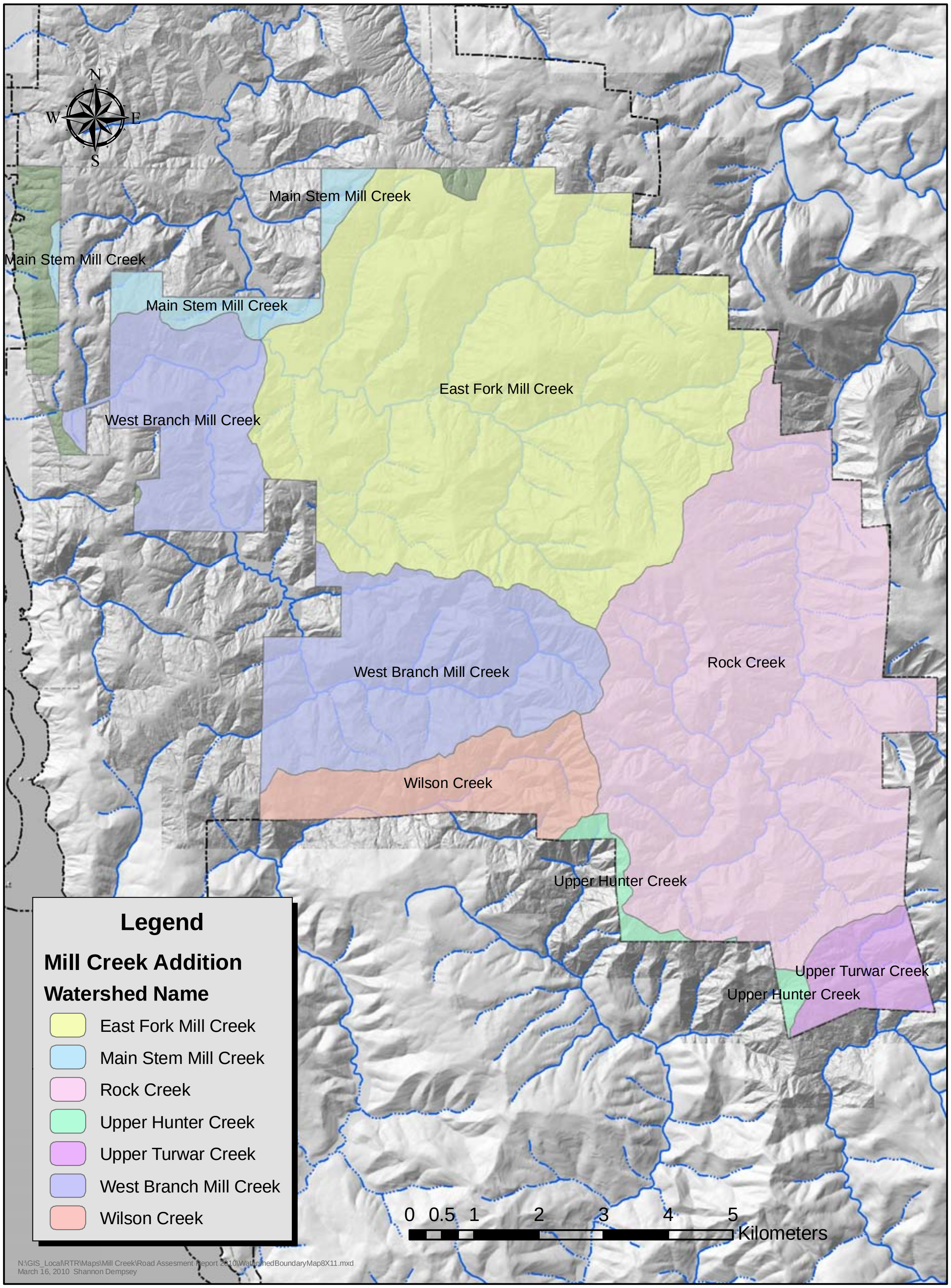

Figure 2. Watershed boundaries within the Mill Creek Addition

GEOLOGY AND SOILS

Tectonic convergence and relatively hard bedrock control the physiographic expression of the Mill Creek Addition. The Coast Range Thrust Fault, locally known as the South Fork Fault, strikes north-northwest through the Rock Creek watershed and forms the boundary between rocks of the Coast Ranges and the Klamath Mountains (Figure 3). The Coast Range Thrust Fault is a remnant from the early convergence and accretion of marine Franciscan Formation rocks with the North American continent from the mid-late Mesozoic to early Tertiary (beginning approximately 180 million years ago; note: temporal or spatial uncertainty in geologic terms is directly expressed; the symbol (?) may be used to convey uncertainty); the fault extends several hundred miles to the south. The convergence of the Gorda and North American tectonic plates, which meet at the ocean floor approximately 100 km offshore west of the Mill Creek Addition, continues this accretionary process. The Gorda plate dives under the North American plate at a low angle along the southern part of the Cascadia Subduction Zone such that their contact is below the Mill Creek Addition at depth.

Other active faults in the vicinity—the Whalehead Fault in southern Oregon and offshore extensions of the Big Lagoon-Bald Mountain and Trinidad faults—could produce strong ground shaking in the Mill Creek Addition but have lesser recurrence and lesser maximum magnitude capability than the Cascadia Subduction Zone. Using long-term average recurrence data, Goldfinger et al. (2008) indicated that rupture along the southern segment of the Cascadia Subduction Zone, estimated to produce earthquakes of Magnitude 8+, is several decades overdue.

Ongoing deformation along the subduction zone continues to contribute to uplift and preserve Pleistocene to Miocene alluvial and marine deposits on ridges. The hard bedrock and uplift also contribute to the development of steep and generally straight to convex slopes that frequently exceed 50% grade (Madej et al. 1986).

Bedrock west of the Coast Range Thrust Fault is predominantly the Broken Formation of the Eastern Belt Franciscan Complex. These late Jurassic to early Cretaceous rocks are tectonically fragmented and consist of interbedded greywacke (sandstone), shale, and conglomerate (Aalto and Harper 1982). More coherent, massive sandstone characterized by massive bedding and moderate shearing predominates in the Mill Creek Addition. Fracturing and shearing of the Broken Formation increases from west to east toward the Coast Range Thrust Fault. Immediately west of the fault, high-

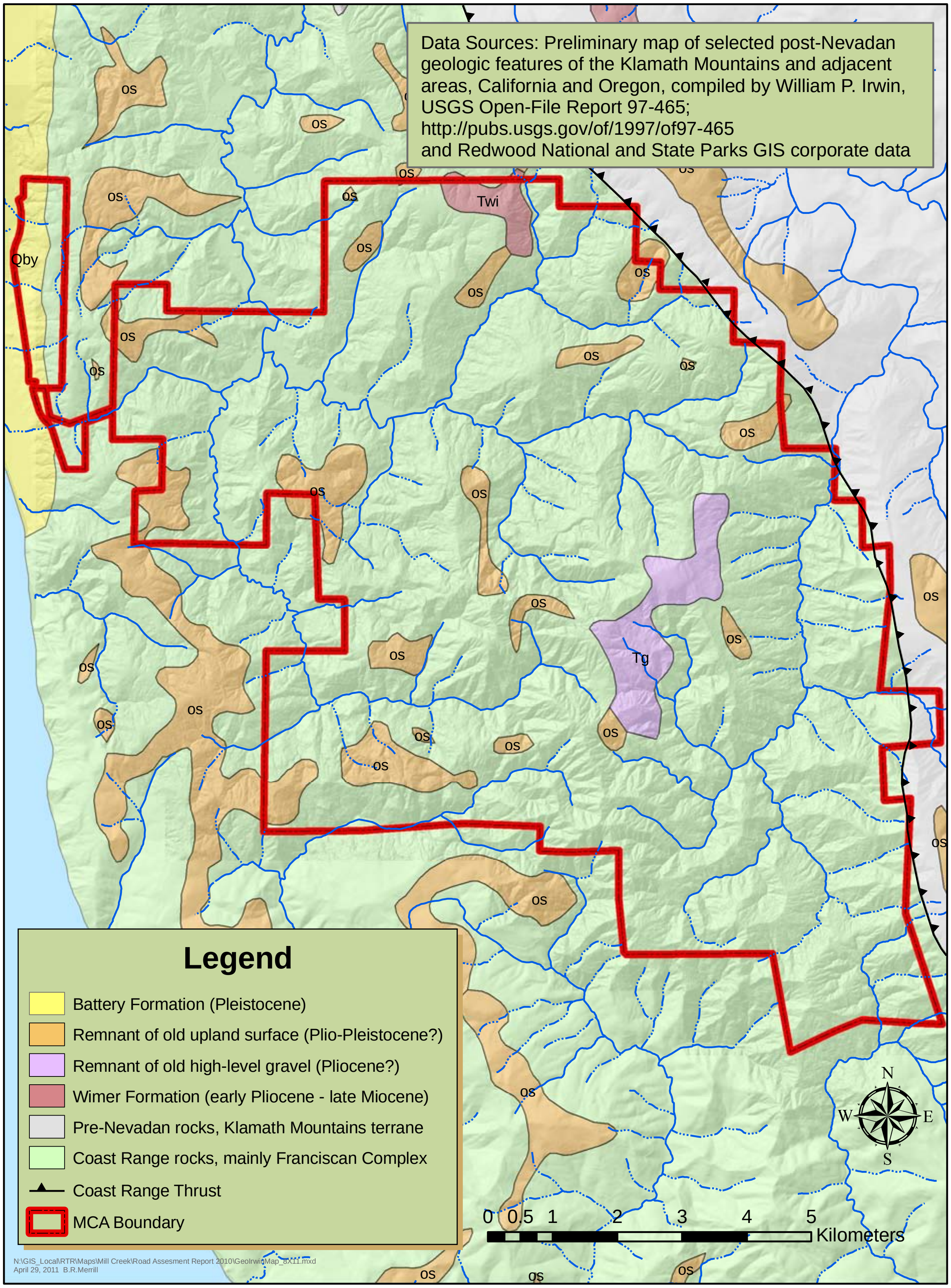

Figure 3. Geology of the Mill Creek Addition

ly sheared and foliated metagreywacke, argillite, and semischist predominate (Davenport 1984), indicating slight metamorphism along the fault zone. The bedrock east of the fault is composed of Pre-Nevadan rocks, including highly sheared serpentinite and peridotite, in the western Klamath Mountains terrain (Aalto and Harper 1982). Because the fault encompasses a broad zone, serpentine and peridotite that may bear asbestos minerals are also found in the Mill Creek Addition several hundred meters west of the fault depicted in Figure 3.

Marine, estuarine, and fluvial siltstone, sandstone, and conglomerate of the early Pliocene to late Miocene (?) Wimer Formation, coincident with J. S. Diller's "Klamath Peneplain," cap many of the ridges. A younger Pliocene (?) alluvial deposit also caps the ridge near Childs Hill, on the southeast side of the Mill Creek Addition. Pleistocene to late Miocene remnant upland surfaces thought to be part of the Klamath Peneplain consist of unclassified sedimentary deposits and deeply weathered bedrock and saprolite; Irwin (1997) interpreted their distribution from 1:62,500- and 1:100,000-scale USGS topographic maps (Figure 3). The distinctions among these Pleistocene to early Miocene units, which occupy similar topographic position and have temporal overlap and some temporal uncertainty, appear to be cross-cutting relationships, limited paleontological evidence, and, to some extent, the character of the earth material.

Late Quaternary deposits are located throughout the Mill Creek Addition landscape. A small sliver of property on the northwest side of the Mill Creek Addition overlies the Pleistocene Battery Formation, a marine terrace, sand dune, and alluvial fan deposit consisting of unconsolidated sand, silty clay, and imbricated gravel (Davenport 1982). Holocene to Pleistocene landslides are common throughout the Mill Creek Addition. Holocene to Pleistocene fluvial terraces and floodplain deposits are located in Mill Creek and, to a lesser extent, in Rock Creek. Limited drilling data and some observational data indicate that the terrace deposits are typically cobbly or gravelly, sometimes with a moderately high amount of silt and clay in the gravel matrix. Overbank silts and clays typically cap the coarser deposits, and finer grained alluvial fans are associated with the floodplain deposits at some tributaries. The terrace deposits locally help protect the valley side slopes from stream undercutting and failure (Madej et al. 1986). Colluvium of variable thickness mantles the bedrock. Large fill deposits are locally associated with the extensive logging road network and the old mill site at the confluence of the West Branch and East Fork.

Staff from the Natural Resources Conservation Service (NRCS) recently completed soil mapping of Redwood National and State Parks, including the Mill Creek Addition, providing a modern soil survey that provides a wealth of soil data (USDA 2008). Fifteen soil associations and soil series of various slopes are identified in this mapping. With respect to surface erosion, approximately 75% of the land base has a severe erosion hazard rating (Figure 4). Only the Bigtree-Mystery Association, on floodplains, has a slight erosion hazard rating. Moderate erosion hazard ratings generally occur on ridgetops for the Trailhead-Wiregrass, Wiregrass-Pittplace-Scaath, and Coppercreek-Tectah-Slidecreek Associations. The Surpur and Childshill soil series also have moderate erosion hazards. The Slidecreek-Lackscreek-Coppercreek, Wiregrass-Rockysaddle, Sasquatch-Siterrocks-Ladybird, Sisterrocks-Ladybird-Footstep, Jayel-Walnett-Oragran, Coppercreek-Slidecreek-Tectah, Wiregrass-Rockysaddle, Sasquatch-Yeti-Footstep, Gasquet-Walnett-Jayel, Oragran-Weitchepec, Coppercreek-Ahpah-Lackscreek, and Scaath-Rockysaddle-Wiregrass Associations have severe erosion hazard ratings, generally on the valley sidewalls.

PREHISTORY

The Mill Creek Addition encompasses the traditional territory of the Tolowa tribe (Rohde and Roscoe, 2005). The Tolowa established most of their larger villages along the coastal plain in the vicinity of the mouth of the Smith River. There is no evidence of large villages in the acquisition, but the Tolowa did establish two small villages: one for gathering acorns and one fishing village near the confluence of the east fork and west branch of Mill Creek. Numerous seasonal hunting and fishing camps were set up at inland sites, and were connected to coastal villages by trails.

As their populations grew and they established themselves in the area, Euro-Americans occupied and used trails originally established by local Indians. Some trails of special note include: 1) the Kelsey Trail which ran along the Bald Hills and eastward toward Nickerson's Ranch, 2) the Bense Trail which left the Kelsey Trail in the vicinity of the intersection of Cougar Ridge Road and Teran Road and descended toward the main stem of Mill Creek just north of the present mill site, and 3) a coastal trail which follows the ridge north-south near the current alignment of State Route 101.

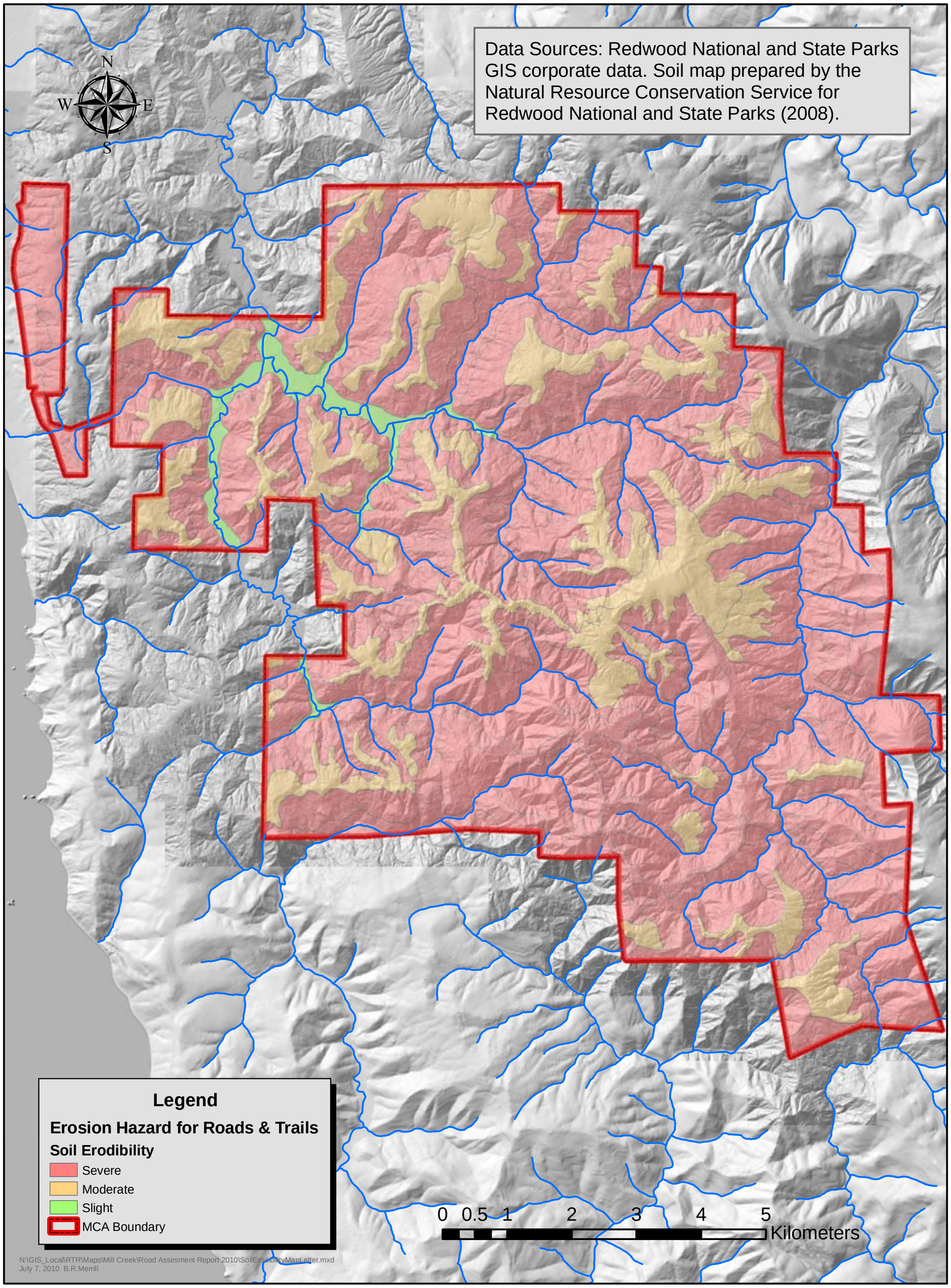

Figure 4. Surface erosion hazard within the Mill Creek Addition

PRIVATE OWNERSHIP

Private ownership of the property was a mixed bag of land speculators, cut-and-run logging operations and ranchers prior to 1944 (Ross and Adams, 1983). Hobbs, Wall & Company, founded as a spruce and redwood box company in 1871, was the only major land holder in the area and had significant holdings in the west branch of Mill Creek. When Hobbs and Wall closed for business in 1939, Harold Miller had already evaluated the timber on the property and purchased the property in 1944. During the next decade Miller consolidated his holdings through a series of tax forfeiture acquisitions and was ready to begin timber harvest by 1955. That year, the Rellim Redwood Company, a newly formed subsidiary of the Stimson Lumber Company hauled the first redwood logs from the property using local gyppo crews. The first logs were removed from the road right-of-ways and sold to regional mills. Miller soon realized the inefficiency of selling and hauling the logs and soon began plans for a lumber mill adjacent to Mill Creek. In May 1955, the first buildings were constructed, an office and equipment shed. Logging operations continued to focus on right-of-way clearing and site development for the mill. During the early years of the logging operations, Miller's vision included sustainable forestry across the property. However, following a contentious land battle for the Rock Creek tract and the realization that demand was outpacing reforestation, Miller moved away from sustainable forestry and ultimately removed all but 120 acres of the old-growth. By the time of the 2002 State Park acquisition, timber managers expected no approved timber harvest plans for at least 7 years due to the lack of trees advanced enough in age to meet regulatory requirements.

TIMBER HARVEST HISTORY

The timber harvest history of the Mill Creek Addition can be broken into two periods. There are no data presently compiled showing the first-cut history (pre-1955) in detail. The cut history, however, generally mimics the road construction history and can be inferred using those data and aerial photos. Prior to 1955, timber harvesting was limited to the West Branch of Mill Creek and subwatersheds to the west. Preceding 1930, the Hobbs and Wall Company conducted harvest primarily using steam donkeys and rail transportation. Older cut-unit boundaries are visible in the 1958 aerial photos as distinct from the redwood and spruce old-growth. In 1955, Harold Miller and E. P. Hamilton began to move into the Mill Creek and Rock Creek watersheds and a new era of industrial timber extraction began.

By 1958, major logging efforts had been made in the upper West Branch, Kelly Creek, upper Rock Creek, upper East Fork and upper Bummer Lake Creek subwatersheds. Efforts continued in the upper West Branch with new incursions into the First Gulch and lower Bummer Lake Creek subwatersheds throughout the 1960's. The 1970's brought an intense effort in the entire Rock Creek watershed, and the lower Bummer Lake Creek and upper Turwar subwatersheds. By the 1980's, much of the Mill Creek Addition had been entered and fragmented with cut units. Large areas along the northern boundary in upper First Gulch and Bummer Lake Creek, however, were still being entered for the first time. The 1990's saw consolidation of the cut units as the timber on the property was nearing exhaustion.

AIR PHOTO ANALYSIS

ROAD CONSTRUCTION HISTORY

We compiled a road construction history for the entire road network to document the chronology of road construction and determine the approximate age of road segments. This history was assembled using all available stereo aerial photographs in the Mill Creek Addition collection (Appendix A), as well as digital orthophoto quadrangles (DOQs) (rectified air photos) subsequent to 1998. We captured the minimum road age directly from the air photo series in which it first appeared, and then entered the data into a geodatabase. We also listed whether the road was constructed as multiple segments or one complete project. For roads that were constructed as multiple segments separated by time, we listed each segment individually to reflect its actual air photo age. Except for roads built in 1955 and earlier, the range of possible construction years for route segments is limited by the first photo on which the road appears (the minimum age) and the prior air photo series (the maximum age). Due to the close temporal spacing of the available air photo series, we were able to constrain the road age to within a few years.

Some roads appear isolated by year. That is, they appeared prior to any road connecting them to the rest of the existing road network. This result occurred when an old segment of road was abandoned and either failed or was not routed as part of the GIS data acquisition. Later, a newer piece of road reconnected the abandoned road.

A larger more developed road would often appear later where many cut units were entered and skid trails were developed. We only catalogued a road as built when it was formally constructed as a primary access.

Early Road Building

The earliest road building into the area was probably associated with W. Bayse's early mill operations conducted in the lower main stem of Mill Creek near the Nickerson Ranch (Rhode and Roscoe, 2005). This mill operation is thought to be the namesake for Mill Creek and is probably associated with the name Bense. Following the Bayse mill operations, the Hobbs, Wall & Company extended their operations southward into the West Branch of Mill Creek. Beginning in 1908, the company began construction of the Del Norte & Southern Railroad. The railroad used an extensive series of trestles to cross the valley bottoms near the present-day routes of Hamilton Road and Picnic Road. The railroad extended approximately 4 km upstream along the West Branch where it was fed by three inclined railways that moved large timber from the surrounding ridge-tops to the main line. A segment coincident with what is now known as Upper First Gulch Road was the only other road known to pre-date the aerial photo record (Rhode and Roscoe, 2005).

Industrial Road Building

Prior to 1958, aerial coverage was very limited, and only the western 4.4 km of Hamilton Road was known to exist in 1955 (Table 1 and Figure 5). A large road building surge occurred between 1955 and 1958 but unfortunately that chronology cannot be resolved with available aerial photo resources. Historical accounts indicate that Harold Miller came to an agreement with E. P. "Buck" Hamilton to allow access through Miller's property (Ross and Adams, 1983). Hamilton would pay per thousand feet of timber hauled across Miller's roads. It is unknown when Hamilton's operations ceased in the area but it is clear from aerial imagery that the initial surge of road construction between 1955 and 1958 was the result of two robust timber operations. Those two operations and the roads that supported them were geographically distinct with one expanding into the upper Rock Creek watershed and Childs Hill area and one into the Lower West Branch and Kelly Creek subwatersheds (Kelly Creek is tributary to the East Fork). By 1958, 30 km of road had been built in the East Fork, as well as 28 km in the West Branch, and 29 km in Rock Creek (Table 2 and Figures 6 and 7). Still, road densities remained below 2 km/km^2 as these roads represented only main lines into newly opened tracts (Table 3).

Table 1. Road construction history derived from aerial photos and satellite imagery

Air Photo Year	Road Constructed Period Preceding (km)	Cumulative (km)	Period Preceding (years)	Rate (km/ year)
1955	4.36	4.36	0	
1958	93.54	97.90	3	31.2
1964	73.54	171.44	6	12.3
1966	24.71	196.15	2	12.4
1969	35.82	231.97	3	11.9
1972	8.94*	240.91	3	*
1975	82.03**	322.93	3	15.2**
1978	14.34	337.28	3	4.8
1980	20.43	357.70	2	10.2
1982	12.90	370.60	2	6.4
1984	10.07	380.67	2	5.0
1986	13.64	394.32	2	6.8
1988	15.52	409.84	2	7.8
1990	22.17	432.00	2	11.1
1993	17.29	449.29	3	5.8
1994	15.22	464.51	1	15.2
1995	1.91*	466.42	1	*
1997	10.24**	476.65	2	4.0**
1998	2.86	479.52	1	2.9
2002	3.32	482.83	4	0.8

* Road constructed may be understated and kilometers per year not shown because flight line coverage of the MCA is incomplete for the air photo series.
** Road constructed may be overstated following periods of incomplete data, and construction rate is based on previous two periods preceding.

As timber harvesting became more widespread, road building continued at a fast and relatively steady pace (Figures 8 and 9). Main lines were extended, and spur roads enabled access to more timber. As the last of the available timber was harvested in the late 1990's, the pace of road building slowed dramatically (Figure 7). Although Stimson Lumber Company applied some erosion control techniques to selected roads, none of the roads constructed on the property were effectively decommissioned or removed (see Landscape Stabilization and Erosion Prevention Plan). Road density

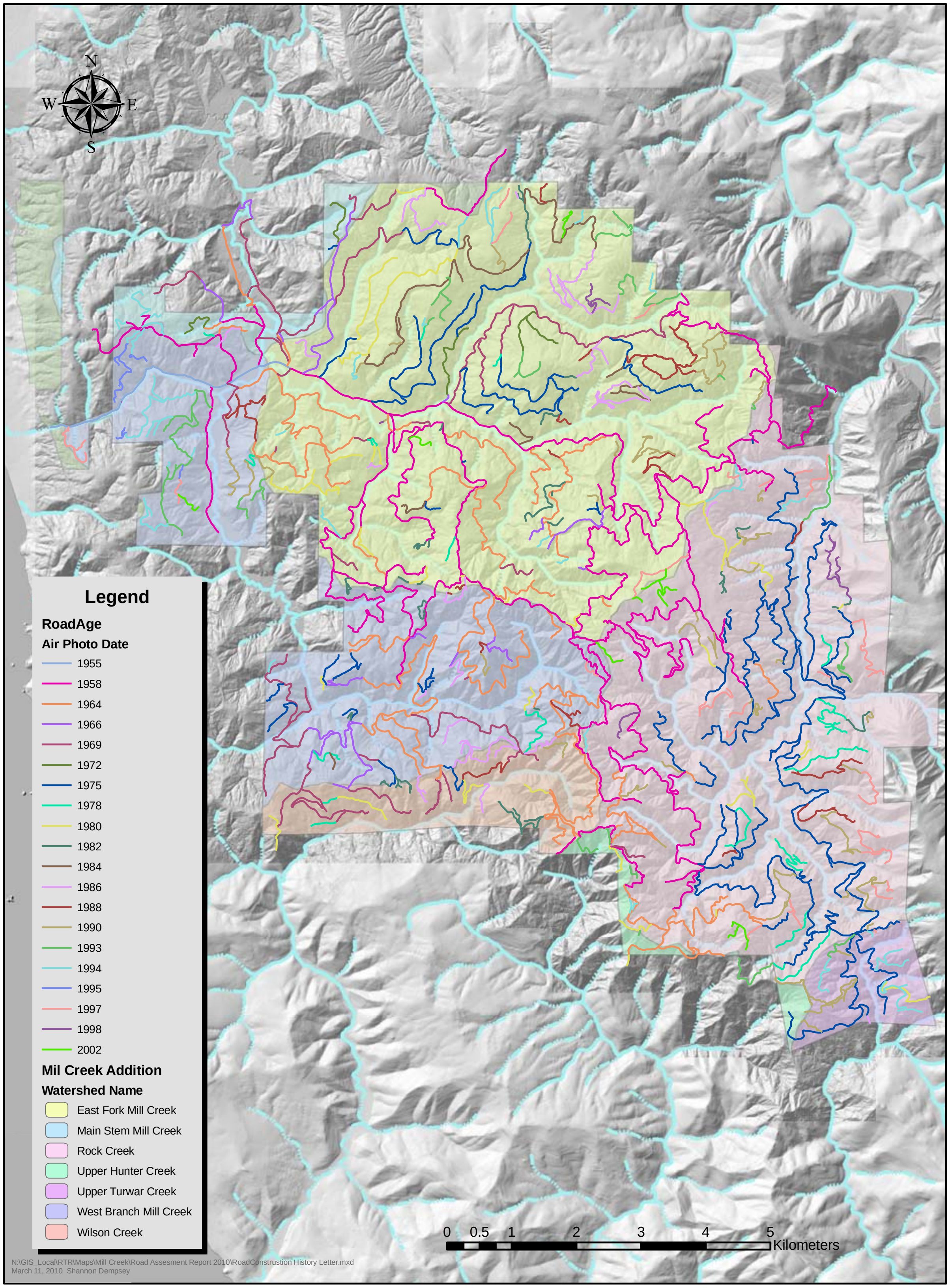

Figure 5. Road construction history of the Mill Creek Addition derived from aerial photographs

Table 2. Road construction length by subwatershed within the Mill Creek Addition

Road length (km)	Main Stem Mill Creek		East Fork Mill Creek		West Branch Mill Creek		Rock Creek		Upper Hunter Creek		Upper Turwar Creek		Wilson Creek		Other
Air Photo Date	**Annual**	**Cumu-lative**	**Annual**	**Cumu-lative**	**Annual**	**Cumu-lative**	**Annual**	**Cumu-lative**	**Annual**	**Cumu-lative**	**Annual**	**Cumu-lative**	**Annual**	**Cumu-lative**	
1955		0.00	0.15	0.15	4.05	4.05	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.16
1958	4.25	4.25	29.81	29.96	24.35	28.40	29.09	29.09	1.49	1.49	0.00	0.00	3.45	3.45	1.10
1964	4.03	8.29	17.13	47.09	24.66	53.06	17.32	46.41	2.02	3.51	0.00	0.00	7.79	11.24	0.59
1966	3.18	11.46	11.20	58.29	7.63	60.69	0.00	46.41	0.00	3.51	0.00	0.00	2.70	13.94	
1969	3.82	15.28	19.07	77.36	8.04	68.73	0.64	47.04	0.01	3.52	0.00	0.00	4.24	18.19	
1972	1.05	16.33	7.89	85.25	0.00	68.73	0.00	47.04	0.00	3.52	0.00	0.00	0.00	18.19	
1975	0.09	16.42	24.32	109.57	5.00	73.73	45.87	92.91	0.58	4.10	4.67	4.67	1.38	19.57	0.11
1978	0.10	16.52	1.48	111.05	2.69	76.42	7.94	100.84	0.41	4.51	0.69	5.36	1.05	20.62	
1980	0.00	16.52	9.19	120.24	0.48	76.90	6.44	107.29	0.56	5.08	0.74	6.10	2.23	22.84	0.78
1982	0.00	16.52	7.44	127.68	1.06	77.96	2.92	110.21	0.00	5.08	0.00	6.10	1.47	24.32	
1984	0.00	16.52	9.78	137.46	0.18	78.15	0.00	110.21	0.00	5.08	0.00	6.10	0.00	24.32	0.11
1986	0.09	16.60	7.17	144.62	2.98	81.13	0.24	110.45	0.00	5.08	0.70	6.80	2.37	26.68	0.11
1988	0.00	16.60	6.82	151.44	2.40	83.53	5.04	115.49	0.00	5.08	0.00	6.80	1.26	27.94	
1990	0.00	16.60	6.45	157.89	2.04	85.57	10.19	125.68	0.26	5.34	1.99	8.79	0.41	28.35	0.83
1993	0.00	16.60	3.61	161.49	5.48	91.05	4.86	130.53	1.08	6.42	0.99	9.78	1.28	29.63	
1994	0.98	17.58	3.14	164.63	4.97	96.02	2.46	132.99	0.21	6.63	2.49	12.27	0.19	29.82	0.78
1995	0.00	17.58	0.00	164.63	1.91	97.93	0.00	132.99	0.00	6.63	0.00	12.27	0.00	29.82	
1997	0.00	17.58	1.75	166.38	1.16	99.08	7.09	140.09	0.00	6.63	0.05	12.32	0.00	29.82	0.19
1998	0.00	17.58	0.79	167.17	0.00	99.08	2.07	142.16	0.00	6.63	0.00	12.32	0.00	29.82	
2002	0.00	17.58	0.96	168.13	0.31	99.40	1.24	143.39	0.00	6.63	0.00	12.32	0.00	29.82	0.81
Total length	**17.58**		**168.13**		**99.40**		**143.39**		**6.63**		**12.32**		**29.82**		**5.57**

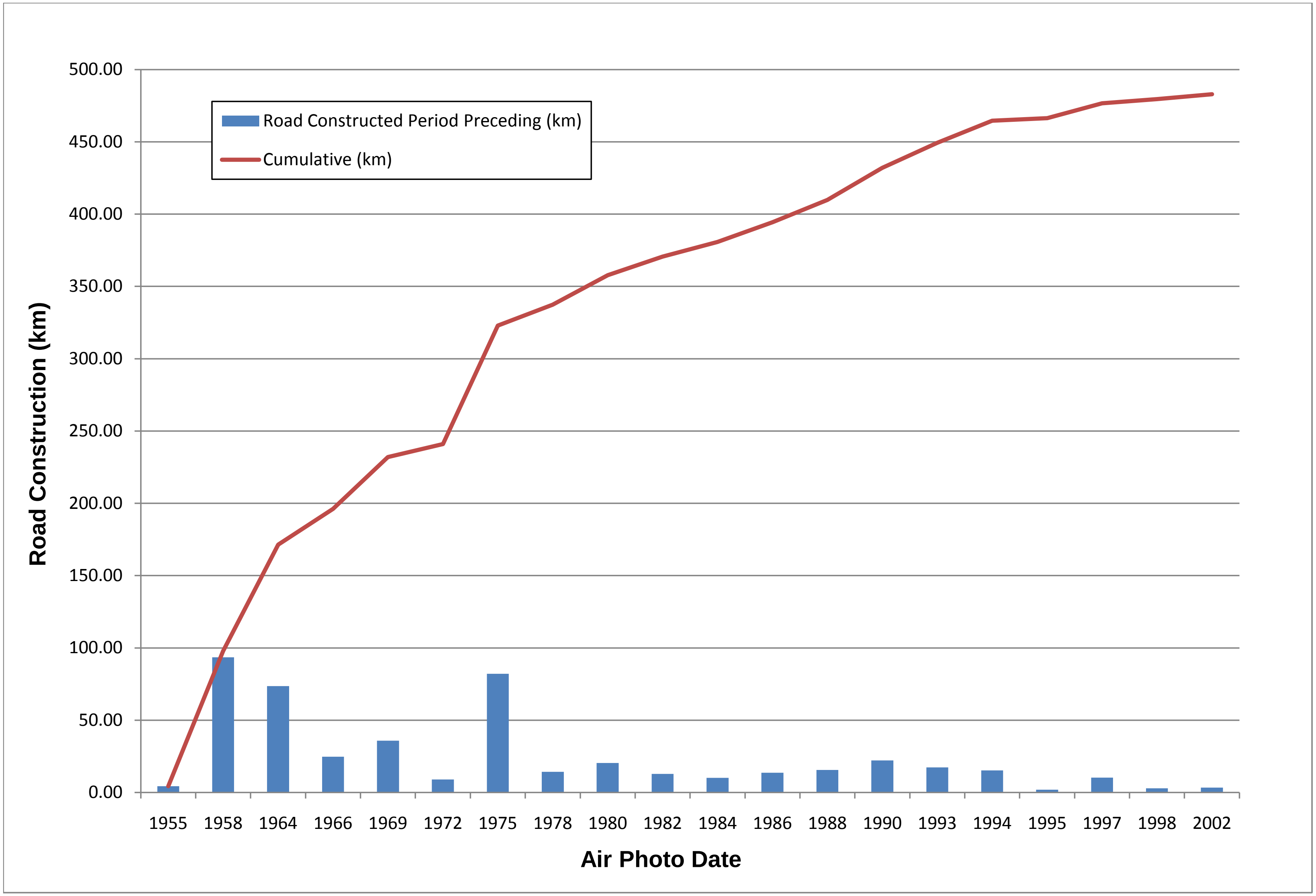

Figure 6. Road construction by air photo period

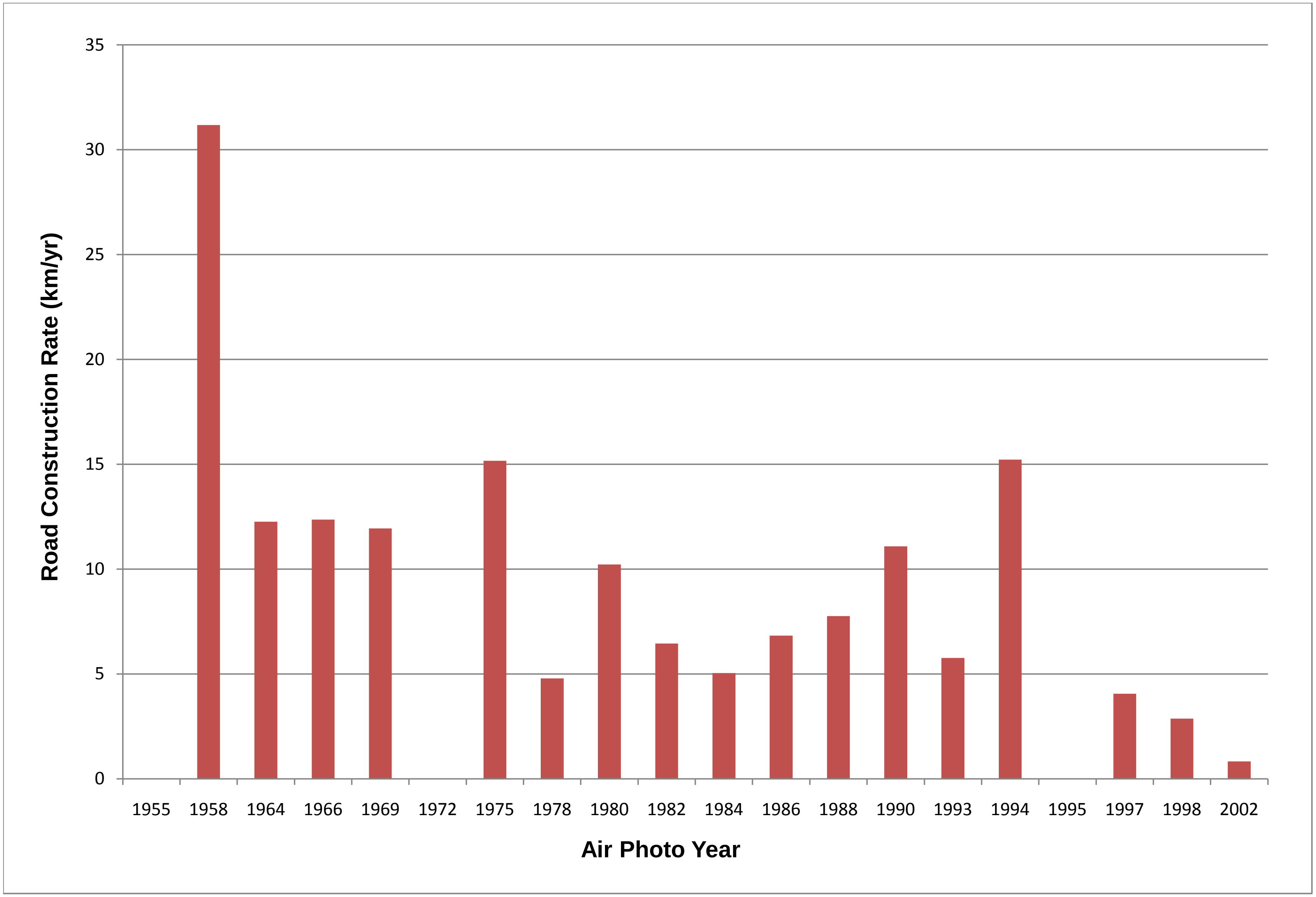

Figure 7. Road construction rate

Table 3. Road density by subwatershed within the Mill Creek Addition

Density (km/km^2)	Main Stem Mill Creek	East Fork Mill Creek	West Branch Mill Creek	Rock Creek	Upper Hunter Creek	Upper Turwar Creek	Wilson Creek
Total watershed area (km^2)	**23.75**	**43.14**	**28.82**	**41.84**	**20.06**	**14.80**	**32.75**
Watershed area within MCA (km^2)	**2.29**	**38.61**	**19.53**	**31.33**	**1.01**	**2.63**	**5.27**
Percent watershed area within MCA	**10%**	**90%**	**68%**	**75%**	**5%**	**18%**	**16%**
1955	0.0	0.0	0.2	0.0	0	0	0
1958	1.9	0.8	1.5	0.9	1.5	0	0.7
1964	3.6	1.2	2.7	1.5	3.5	0	2.1
1966	5.0	1.5	3.1	1.5	3.5	0	2.6
1969	6.7	2.0	3.5	1.5	3.5	0	3.4
1972	7.1	2.2	3.5	1.5	3.5	0	3.4
1975	7.2	2.8	3.8	3.0	4.1	1.8	3.7
1978	7.2	2.9	3.9	3.2	4.5	2.0	3.9
1980	7.2	3.1	3.9	3.4	5.0	2.3	4.3
1982	7.2	3.3	4.0	3.5	5.0	2.3	4.6
1984	7.2	3.6	4.0	3.5	5.0	2.3	4.6
1986	7.2	3.7	4.2	3.5	5.0	2.6	5.1
1988	7.2	3.9	4.3	3.7	5.0	2.6	5.3
1990	7.2	4.1	4.4	4.0	5.3	3.3	5.4
1993	7.2	4.2	4.7	4.2	6.4	3.7	5.6
1994	7.7	4.3	4.9	4.2	6.6	4.7	5.7
1995	7.7	4.3	5.0	4.2	6.6	4.7	5.7
1997	7.7	4.3	5.1	4.5	6.6	4.7	5.7
1998	7.7	4.3	5.1	4.5	6.6	4.7	5.7
2002	7.7	4.4	5.1	4.6	6.6	4.7	5.7

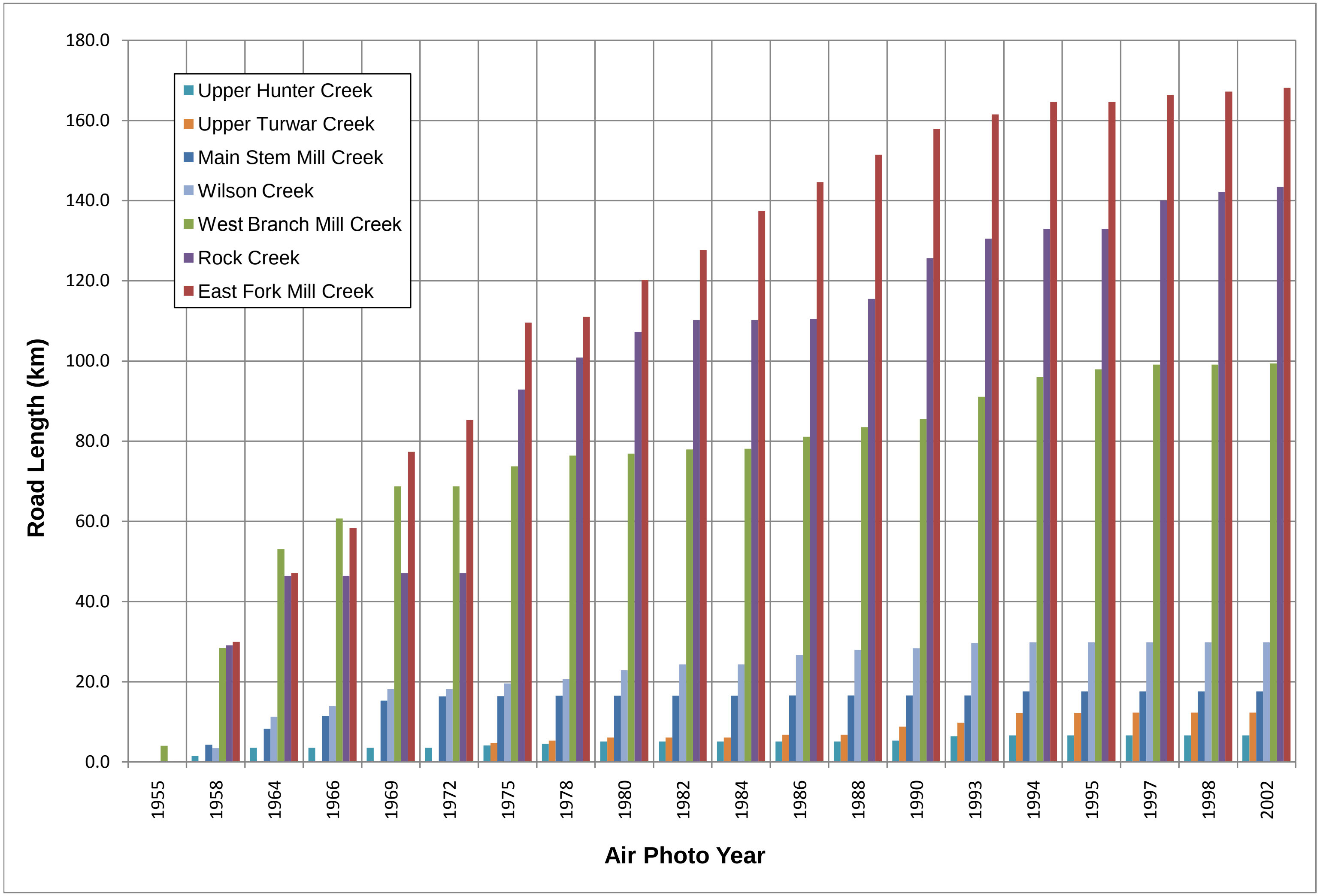

Figure 8. Road length by watershed within the Mill Creek Addition. Note that only small areas of the main-stem Mill, Wilson, Turwar, and Hunter creek watersheds are within the MCA. Refer to Table 3 for comparison of total waterhsed area vs. watershed area within the MCA.

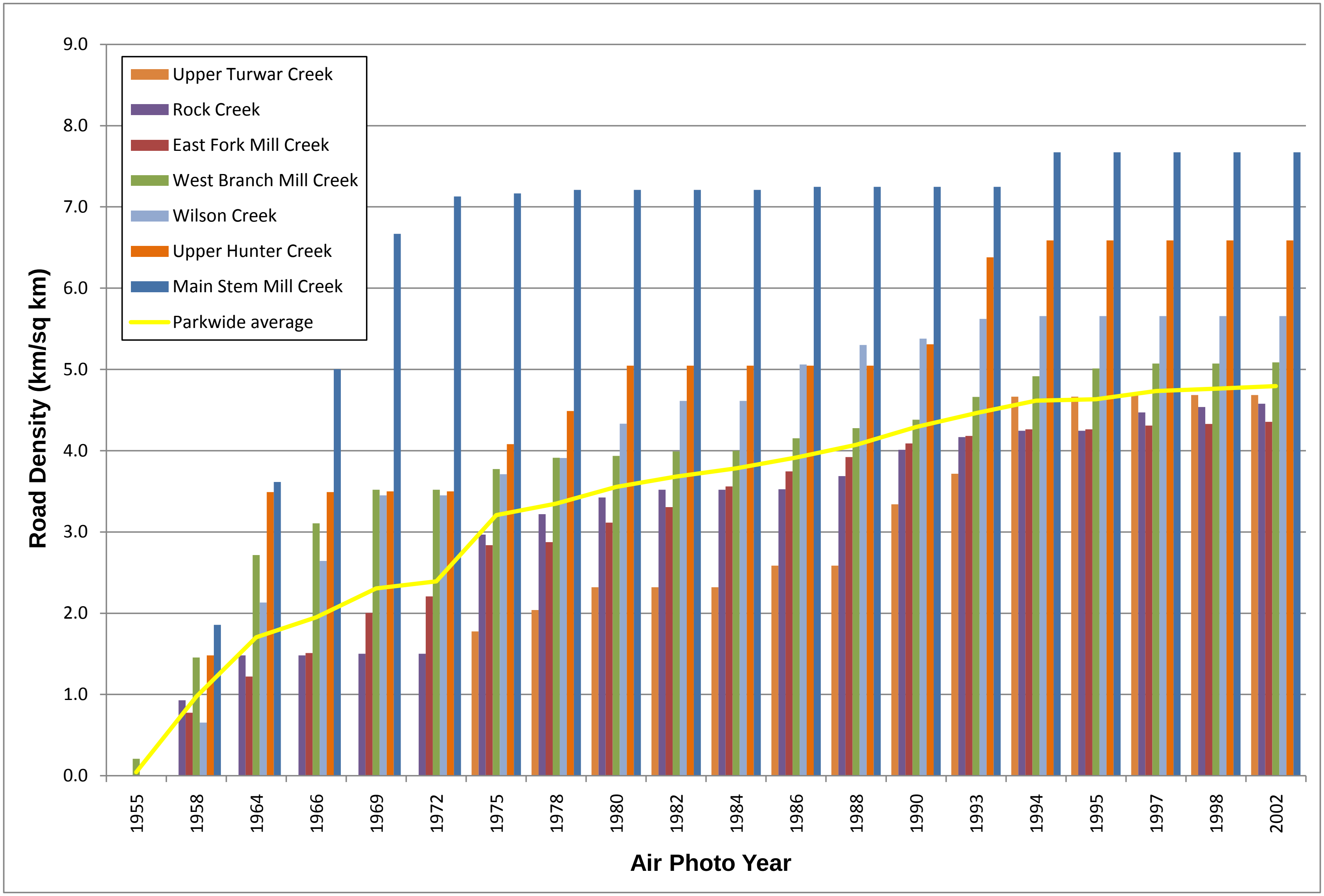

Figure 9. Road density by watershed within the Mill Creek Addition

at the time of acquisition by DPR varied from 4.4 km/km^2 in the East Fork Mill Creek watershed to 7.7 km/km^2 in the Main Stem Mill Creek watershed, with an overall average density of 4.8 km/km^2 across the Mill Creek Addition (Table 3 and Figure 9). No new road construction has occurred on the property since 2002.

LANDSLIDE HISTORY

We compiled a property-wide landslide history using the same series of photos used for the road construction history. Each series (year) was reviewed using a mirrored stereoscope with magnifier. All areas were reviewed for landslide activity, including uncut areas and areas without roads in order to differentiate between mass wasting events occurring in roadless areas and those caused by road-related instability. We identified and classified landslides using morphologic characteristics expressed in conjunction with bare soil areas. In some cases, where morphologic expression was subtle, we used plan view shape and bare soil to identify mass wasting features. Air photo series 1993 and 1998 had already been previously scanned, rectified, and tiled into a single mosaic. Therefore, we were unable to use stereo-pairs for these years making it difficult to identify smaller mass wasting features. For 1993, we used the 1994 stereo-pairs to confirm activity first appearing on the 1993 images. The 1998 mosaic was of poor quality and was not useful for identification of features first appearing in that year. No post-1998 stereo-pairs were available to cross check 1998 imagery. The 2005 National Agricultural Imagery Program (NAIP) imagery was of sufficient quality that we employed it for identification of features occurring between 1998 and 2005. All series but three were 1:12,000 scale. Two series (1980 and 1982) were vari-scale and one series (1966) was 1:15,000. A single geologist captured all air photo visual data to maintain consistency across the dataset.

Feature dimensions were measured directly off of the aerial photographs using a millimeter scale. Measurements were then converted to on-the-ground dimensions using the photo scale. We rounded photo measurements to the nearest 0.5 mm and made dimensional adjustments for slope length and width by eye. We estimated failure depth by shadowing and other indications of relief within the head of the feature. Field observations of selected landslide features were made to validate estimates made in the office. In general we found a limited range of landslide depth (1 m to 3 m) while conducting our field surveys, so we were confident of our interpretation of depth in the office. All dimensions were approximate, but served to define a relative size and volume for the feature. We did not capture features with dimensions less than 6 m on the largest scale air photo series (0.5 mm on 1:12,000 air photo). Measurements included the evacuated area only and did not include depositional areas. In cases where secondary failure appeared to have occurred simultaneously with the primary feature, we summed dimensions to include all material displaced by the mass wasting event. In cases where reactivations occurred at a later date, the volume of the entire mass was remeasured and recalculated. We subtracted all previous failures at a site from the most current failed mass to determine the reactivated volume.

The sediment delivery ratio (SDR) is defined as the percentage of failed material delivered to a watercourse. We considered colluvium to be delivered as part of the SDR if it reached the floodplain or alluvial terraces within a well defined valley floor associated with a blue line stream as characterized from Light Detection and Ranging (LiDAR) analysis or previous USGS mapping. Colluvium that came to rest in broad swales and convergent topography was not considered delivered to a watercourse. We compared the relative size of evacuated area with the depositional zone, material visible in watercourses, and position of the depositional zone relative to convergent or divergent terrain in order to estimate the sediment delivery ratio. Material that remained within the mass wasting scar and/or on the slope below was considered undelivered when estimating the SDR.

Landslide features were entered into the GIS as point features and attributed with values listed in Table 4. We chose a point coverage over polygons for several reasons: 1) there were no accurate rectified images which could be used to capture the shape of the feature, 2) spatial integrity at scales measured for individual features would have been poor even with rectification, 3) features visible on more than one series would have had different shapes regardless of the quality of the rectification, and 4) most polygons would have been too small to portray on maps. We grouped and summed small coalescing features along road fillslopes and inner gorge areas to account for volume and dimension. GIS points were set at the center of the feature(s). If the feature expanded over time the point was left where it was originally set to indicate where the feature initiated.

We based the classification of slides vs. flows on morphological expression. Slides tended to maintain their width as they propagated downslope. Flows tended to narrow and flow toward topographic depressions. Many debris slides may have transi-

Table 4. Landslide history attributes

Field (as labeled in geodatabase)	Description	Possible Values
MWType	Type of mass wasting feature as described by Varnes (1978)	Debris flow, Debris slide, Slump earthflow
AffectedWatercourse	Describes whether a mass wasting feature affected a watercourse. Effects could include deposition of sediment directly into the channel or the active floodplain. Could also include opening of canopy along the riparian corridor. A "Probable" value indicates no visible runout on air photo but topographic characteristics downslope of failure favor delivery to watercourse.	Yes, No, Probable
CoalescingFeatures	Describes whether the mass wasting feature was part of a larger feature with atypical shape or symmetry.	Yes, No
SlopePosition	Describes the location of the mass wasting feature on the slope as measured on the fall line from the ridge to the base of the slope.	Upper Slope, Mid slope, Lower Slope, Inner gorge
LengthAverage	Average length of feature in meters as measured directly from air photos.	Measured value
WidthAverage	Average width of feature in meters as measured directly from air photos.	Measured value
DepthAverageEstimated	Visual estimate of the average depth in meters of a mass wasting feature. The depth was discernable in stereographic images where shadowing and scarp heights were visible.	Visually estimated value
CalculatedVolume	Volume in cubic meters. Calculated as the product of the LengthAverage,WidthAverage and DepthAverageEstimated.	Calculated value
VolumeCategory	Categorical volume range used for broad grouping of feature size.	<500, 500 to 1000, 1000 to 5000, 5000 to 10000, 10000 to 50000
SedimentDelivery-Ratio	Visual estimate of the percentage of failed material that reached the stream below the mass wasting feature as seen on the air photo.	0 - 1.0
EstimatedDelivered Volume	Product of the CalculateVolume and the SedimentDeliveryRatio	Calculated value
Torrent	Describes whether the feature torrented after initiation. Transitional features	Yes, No, Transitional
EnlargementOfPre-existing	Describes whether the feature was an enlargement of a mass wasting feature that had already been identified.	Yes, No

Table 4. continued

Field (as labeled in geodatabase)	Description	Possible Values
RoadRelationship	Describes how the mass wasting feature is physically related to nearby roads. Road associated indicates a direct physical connection between the road and the mass wasting feature. Road related indicates a likely causal relationship between a nearby road and a mass wasting feature. None indicates no apparent relationship.	None, Road associated, Road related
SourceOfFailure	Describes the physical source of the mass wasting feature. The source was identified as the area where the head of the slide was located. If a source area crossed a unit boundary, the most disturbed unit classification was used.	Hillslope, Crossing fillslope, Inner gorge slope, Landing fillslope, Road cutbank, Road fillslope, Road fillslope-cutbank, Road fillslope-hillslope, Road fillslope-swale headwall, Swale headwall
CutUnitRelationship	Indicates the physical relationship between the mass wasting feature and cut units in the area. If a source area crossed a unit boundary, the most disturbed unit classification was used.	None, Within unit, Within older unit, Below unit, Below older unit, Above unit, Above older unit
AirPhotoDate	Air photo series identified by year flown	As shown on photo
AirPhotoNumber	Air photo number printed on the photo	As shown on photo

tioned into flows as the failed mass disintegrated. In these situations, the feature was classified as a debris flow. We did not consider failed stream crossings as landslide features.

We did not capture ravel from road construction activities as mass wasting although it was common during construction activities. Ravel typically was confined to a short slope segment immediately below the road and only delivered to water courses as roads descended into inner gorge areas or at crossings. Ravel was expressed in the aerial photos as a wide flat sheet of exposed soil along recently constructed roads and crossings. Small cutbank failures were difficult to differentiate from constructed surfaces and were only captured if the failure resulted in a clear scarp above the road. We were able to capture small cutbank failures in the field during the road inventory.

Landslide History Results

We inventoried 482 landslide features across the property. The estimated volume of failed material totaled 575,000 m^3 with 310,000 m^3 delivered to streams. Of the 482 failures, 394 (82%) affected a watercourse and an additional 8 (1%) features probably affected a watercourse.

Road fillslope failures had the highest occurrence (46%) of all failure events (Table 5). Due to their frequency, road fillslopes also accounted for the largest aggregate volume of failed material and the largest volume of delivered material. Landing fillslope failures accounted for the largest volume of material delivered to streams per event (1, 063 m^3 per event). The greatest delivery rates (total volume delivered divided by total volume failed) were exhibited by inner-gorge failures (75%) and landing fillslopes (62%). Inner gorge failures delivered a high proportion of failed material due to their proximity to the streams. Landings by contrast, delivered high proportions of failed material because of their association with steep slopes and large fillslope volumes. During road construction, landings were preferentially located on steep slopes to allow a wide reach for yarder operations. In addition, larger fillslope failures often generated additional scour below the initial failure leading to higher average delivery from failed fillslopes.

Table 5. Landslide size by type

			Failed Volume (m3)			**Delivered Volume (m3)**			**Delivery Rate**
Landslide Type	**n**	**%**	**Ave.**	**Max**	**Total**	**Ave**	**Max**	**Total**	
Road fillslope	223	46%	1,327	16,200	296,006	697	11,340	155,398	52%
Hillslope	119	25%	918	20,160	109,272	466	10,080	55,437	51%
Landing fillslope	57	12%	1,722	28,800	98,172	1,063	25,920	60,606	62%
Inner gorge slope	46	10%	856	7,200	39,354	640	5,760	29,455	75%
Road cutbank	34	7%	820	2,592	27,882	224	1,080	7,622	27%
Swale headwall	3	1%	1,488	2,304	4,464	653	1,728	1,958	44%
Totals	**482**	**100%**			**575,150**			**310,476**	

Seventy-two percent of landslide events were either directly or indirectly related to roads. We detected direct physical association between roads and slope failures in 316 (66%) of the events, with less clear but probable relationships to roads occurring in 27 (6%) of the failure events. Hillslope landslides did not occur in higher numbers in heavily skidded units than they did in yarded units. Skid roads did not appear to be a significant factor in triggering mass wasting events.

The timing of mass wasting appears to be reasonably well correlated with large storm events affecting northern coastal California. Storms in 1955, 1964, 1975, 1986 and 1997 resulted in notable spikes in landslide activity and delivered volume as indicated on the subsequent air photo series (Figure 10). The magnitude of the mass wasting, however, was not well correlated with the regional intensity of the storms. The 1964 storm, which produced widespread flooding and mass wasting, did not appear to have generated a significant effect within the MCA. This is especially notable because over the 4 years preceding the storm event, 177 km of road had been constructed. We believe this lack of mass wasting can be attributed to relatively low precipitation intensities in the local area compared to the wider region.

The effects of the 1955 storm are well known throughout the region. The storm delivered 352 mm of rainfall over a nine-day period beginning December 15, 1955 (Harden, 1995). The 1964 storm did produce some mass wasting in the Mill Creek Addition, but did not produce the devastating effects seen in adjacent counties. The floods in 1955 and 1964 had respective long term average recurrence intervals of 25-30 years and 45-50 years, respectively. Significant storms in March, 1975 and February, 1986 also produced noticeable spikes in sediment yield from mass wasting, likely related to substantial increases in road length on the property.

The 1997 spike in landslide activity was likely the result of a 6-day storm which impacted the west coast from Washington to Southern California. A shift in the weather pattern brought warm storms of tropical origin across the region from December 26, 1996 through January 3, 1997, with the most potent system affecting the region at the turn of the year. This change occurred after a cool winter storm affected the region on December 21 and 22, 1996. This polar system left behind several feet of snow over the mountainous terrain; a snow pack that would contribute to the flooding just over a week later. With the tropical air mass storms, precipitation fell across much of the west coast with a focus of excessive precipitation over higher terrain from western Washington southward to northern California and western Nevada (Kozlowski and Ekern, n. d.).

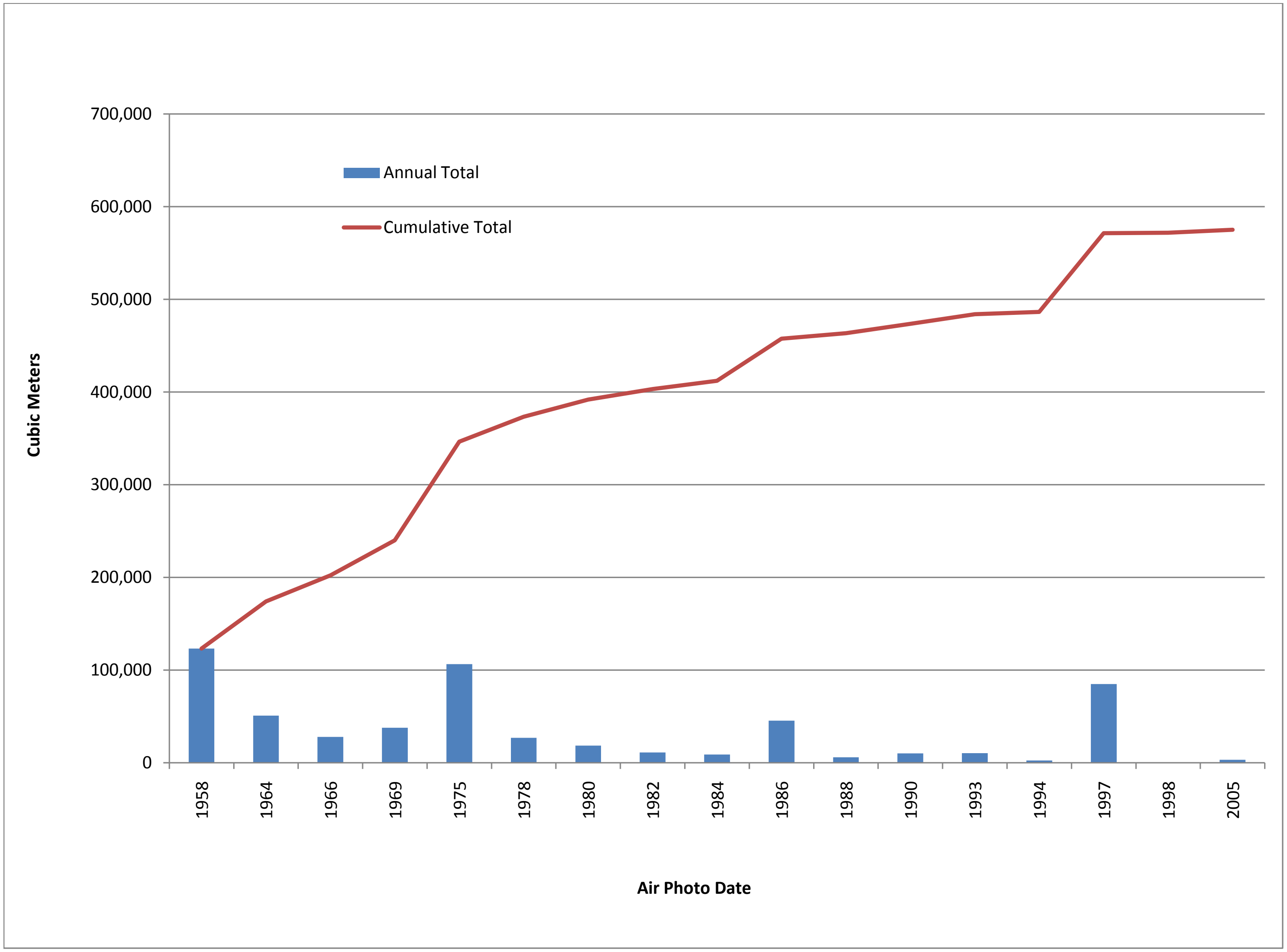

Figure 10. Annual and cumulative total of failed landslide volume. The 1958 data reflect landslides that occurred during the 1955 storm event.

Results from this historical landslide inventory indicate the majority of landslides on the property are road-related and that large storm events trigger marked increases in landslide activity. We expect to see additional road-related mass wasting as large storms affect the area in the future. Based on recent past events we expect to see significant mass wasting occur where 12 hour precipitation intensities exceed 3 inches and antecedent conditions have left soils nearly saturated.

ROAD INVENTORY

GIS ROUTING

The fundamental spatial framework used to locate road-related features in this assessment is known as linear referencing. Linear referencing is the GIS method of storing geographic locations by assigning positions along measured linear route features, rather than using classical geographic coordinate systems. Similar to how mileage markers are assigned along a highway, each route has a specific starting point and direction with a common measurement system. Objects (such as culverts or crossings) and occurrences (such as paved road length) are point or line “events” located along the linear route. The location of these features is not fixed, but rather tied to the measure system. Attributes pertaining to each point or line event are stored in event tables which include the measurement (starting addresses for point events or starting and ending addresses for line events) along a uniquely identified linear route feature. Dynamic segmentation is the process of transforming the linearly referenced data that has been stored in a table into features that can be displayed and analyzed on a map. During map display and GIS analysis, the route is “dynamically segmented” to locate the event features.

A critical first step in this process was to create routes from spatially accurate line work representing the road network, as subsequent updating of the geometry of the underlying road will modify the location of the associated events. Line features were heads-up digitized with a starting node, a series of vertices, and an ending node from digital orthophoto quadrangles (DOQs). Sufficient vertices were added to accurately depict the location of the road as visible on the orthophoto. Editing of this line work ensured that nodes of adjacent arcs are coincident, and the series of arcs representing a given road are oriented in the same direction. This series of arcs representing a road of the same name were then grouped together to form a single route with a starting position of zero and common sequential measure units along its entire length. The measure system units used in this road assessment is kilometers.

Redwood National and State Parks' GIS staff digitized the road line work prior to our field inventory. The assessment area is partially covered by both 1993 and 1998 DOQs. DOQs from 1998 were utilized wherever available due to their more precise georectification and 1993 imagery was used only where 1998 imagery was unavailable. About 5.0 km of roads were constructed after 1998 (and prior to park ownership) and were not captured in the initial digitizing. These roads were hand digitized and routed after discovery by field technicians.

The Stimson Lumber Company line work was not used because it lacked the spatial accuracy needed for the linear referencing framework and subsequent GIS analysis. However the original individual road names assigned by the previous owners were maintained in order to preserve the historical reference of the road network. In most cases, the original road name was used as its corresponding route name. Road names were assigned to previously unnamed roads based on its up-line road (road leading to unnamed road). For example, the first unnamed road that intersected Childs Hill Road would be labeled Childs Hill-1; the third unnamed road that intersected Childs Hill Road would be labeled Childs Hill-3 and so on. Continuing this convention, the first road that branched off from Childs Hill-3 would be assigned the name Childs Hill-3-1 and so on. Roads beginning and ending along the same up-line road were assigned the up-line road name and the suffix "-loop". In the case of an unnamed route linking two named routes, both named routes were included in the name along with the suffix "-link".

BASE MAPS

Black and white 11" x 17" tiles of the entire acquisition area were laminated for use as field use base maps. A total of 119 tiles covered the entire park. Field maps included the routes and route names along with tic marks every 10 meters overlaid onto the 1998 DOQs. Technicians used the tiles to pinpoint their locations when capturing data for a site while in the field. An estimated spatial accuracy of plus or minus 10 meters was achievable at sites where no distinct features were visible on the DOQs.

FIELD DATA COLLECTION

Field data was collected by two groups divided into two, two-person teams from January, 2002 until June, 2005. The first group collected geomorphic data for all known routes to evaluate how each road and associated sites influence local geomorphic processes. The second group collected data related to road construction, reengineering, and maintenance requirements (Appendix B). The second group only collected data on open drivable roads that had not been made "maintenance-free" by the previous land owner. The "maintenance-free" roads had been partially decommissioned and were no longer part of the functioning transportation network (see Landscape Stabilization and Erosion Prevention Plan).

For continuous road condition data, field technicians entered data for the following categories at the start of each road (route address 0.00 km): usability, surface material, surface condition, roadbed width, embankment fill volume, road grade, road pitch, inboard ditch status, vegetation load, and drainage (Appendix B, Continuous Variable Worksheet). As the field technician progressed down the road, any change in a road category that spanned greater than 10 meters in length was noted by a route address entry and a corresponding change in road condition value.

Road sites included road-stream crossings, gullies, mass wasting events, seeps and/or springs, and landings. Each site type was first assigned an address. Start and end addresses were assigned to linear features (gullies, mass wasting events, seeps and/or springs) as opposed to stream crossings that were considered a distinct point where the stream crosses the road and assigned a start address only. Each feature was marked with the start address on a yellow aluminum tag for ease of locating in the field. The tags were affixed to trees or other large semi-permanent objects in a position that could be easily seen from the site. Limbs and brush were cleared away to enable better visibility.

Field technicians recorded information for each site type on separate data sheets, for entry into the database (Appendix B, Road Assessment Form-Sheet 1). We used the backside of each data sheet for diagramming complicated sites as needed for clarification or later reference (Appendix B, Road Assessment Form-Sheet 2). Distance measurements were typically estimates and were obtained in a variety of ways depending on terrain, vegetation, and number of field crew on-site. Tape measures or range finders were used when feasible. Otherwise, combinations of visual estimates, pacing off open distances, or measurements taken directly from the rectified map tiles were used when necessary. Field personnel regularly calibrated their visual estimates with tape measures and to each other in order to maintain consistency for visual estimates.

Early on in the road assessment, two different methods for assessing stream crossing volume were considered and evaluated. The first method measured the basic crossing dimensions (averaged centerline, up- and downstream top widths, channel widths, and estimated fill depths) to calculate crossing volume using a double ended area formula. A second method involved taking additional field measurements including the slope length and angle of fill from the edge of roadbed down to channel on both the upstream and downstream sides of the road. The slope of the natural stream channel above and below the influence of road was recorded, and this additional data was used to draw a scaled cross sectional diagram of each crossing to derive the upstream and downstream depth of fill. Next, volumes were calculated for the center wedge of fill directly beneath the roadbed and the wedges of fill that extended from the edge of roadbed out toward the stream channel on either side. The separate volumes for a total stream crossing volume were then summed. Although the second method is commonly used for estimating stream crossing volumes, it was significantly more time consuming with the collection of additional field data and the requirement of sketching each stream crossing in the office. When we compared the two methods side by side for the same crossings, the first method always resulted in a larger calculated volume.

Uncertainty is inherent when estimating the volume of a stream crossing. Estimating crossing dimensions (for example, depth of fill), interpreting crossing fill footprint, and existence of buried logs, culverts, or tree stumps affect the calculated and actual volumes. Excavated crossing volumes often preclude calculated crossing volumes because site specific design may warrant it. For example, calculated volumes assume a straight channel between upstream and downstream extent of fill, but during crossing excavation, adjustments must be made following cues of the stream's original channel, which is not always straight or centered within the fill prism. The resulting side slopes must be adjusted accordingly. Sometimes a stream crossing may be too steep and narrow for an excavator to safely reach the bottom of fill without excavating a small bench into the native material. Because of these inherent uncertainties, we chose to use the first method, opting to be conservative with our calculations both in terms of threat to the resource and project planning.

The second field group collected information on existing road features and structures and recommended upgrades to improve road construction standards and to minimize annual maintenance requirements. For continuous road features, this team recommended a particular course of action (monitor, clear, remove, replace or install) for each feature (road base, inboard ditch, inboard pitch, or outboard pitch). For site features or structures, they recorded current condition and/or recommended prescriptions for installation, replacement, repair, or monitoring of bridges, retaining walls, culverts, stream crossings, climbing turn/switchbacks and road armoring (Appendix B, Road Assessment Forms-Sheets 3 and 4).

SKID TRAIL INVENTORY

Although we did not inventory or assess skid trails and fire breaks in the scope of this investigation, we conducted a property-wide air photo analysis of the skid trail network concurrent with field data collection. This was done to assist immediate planning and address any possibility of overlooking significant abandoned roads that were not already contained in the GIS line work of known haul roads. The analysis utilized the same series of photos used for the road construction and landslide history. We reviewed each series (year) using a mirrored stereoscope with magnifier. We reviewed all skid trails and roads within the property not part of the GIS line work. Any roads exhibiting characteristics likely to contribute to future erosion or stream crossing diversion were hand digitized into a separate secondary roads database. We included secondary roads that had a large cut and fill prism compared to adjacent skid trails, those that crossed a stream channel, and those that traversed a steep slope for significant length without possibility of hydrologic disconnection. These secondary roads totaled 45.8 km adding 10% to the overall known haul road mileage. We will continue to address the secondary roads at project-level planning as necessary.

DATABASE DEVELOPMENT

A total of 468.4 km of routed haul roads were inventoried from 2002 to 2005 (Table 6). Two Microsoft Access™ databases were developed to contain all features collected during the inventory, input from the continuous variable worksheets, and road assessment forms. The MillCreekAssessment database was designed to contain discrete point or interval road site features. These sites had limited extent and a distinct set of characteristics that we captured regardless of whether it was a single point or a segment of road. Road sites included stream crossings, gullies, mass wasting events,

Table 6. Road inventory summary

Kilometers of haul road inventoried:	468
Kilometers of secondary roads:	46
Number of road-stream crossings:	1,457
Number of landings:	981
Number of culvert cross drains:	515

and seeps and/or springs. The MillRoadCondition database was developed to contain road condition data that were continuous along each road, including unit fill volume, width, grade, pitch, among others.

ROAD ASSESSMENT

Road inventory data was overlaid with GIS spatial data (DEM and derivatives, Soils, and SINMAP) to develop an assessment model that evaluates which roads and sites are the most likely to experience failure and how much sediment each road and site could contribute to the drainage network. Scores were assigned to sites and road segments based on the various physical attributes collected during the road inventory and on their location relative to other GIS spatial data. Once scored, sites were evaluated individually and scores cumulated along routes. Both the potential for failure and the impact of failure, or threat, were taken into account when determining which roads pose the greatest potential harm to park resources. These two aspects (failure potential and threat) were combined to produce the overall ranking of roads (Figure 11).

FAILURE POTENTIAL VS. THREAT

Our approach characterizes individual sites and road segments using two distinct criteria. First, we used physical attributes that are known to affect stability in order to assign a failure potential score to each site and road segment. Second, we calculated the potential threat posed by the sites and road segments. For this assessment, sediment to streams was used to quantify the threat posed by the road network. Although threat could be characterized by a variety of potential impacts (water quality, aquatic habitat, rare flora, loss of infrastructure) episodic and chronic inputs of sediment to the stream network produce negative impacts to aquatic habitat that can persist for decades. Sediment delivery is a commonly used parameter to quantify road impacts and the cost effectiveness of road rehabilitation projects.

By evaluating failure potential and a specific threat independently, we can view roads and sites based on their potential of failure alone, or in combination with a variety of other factors that would constitute threat (sediment delivery, resource impacts, loss of infrastructure). For example, a site may exhibit high potential for failure but not have a large volume associated with it. In a typical second growth forest setting the threat may be interpreted as low compared to a similar site with high volume. However, if the road is immediately above exceptionally sensitive habitat such as a Darlingtonia fen, even a small volume failure could have a severe impact. As new information is gathered regarding natural, cultural, and capital resources, threat values can be interpreted in the context of new information, as well as the current condition of a site or road segment.

ANALYSIS AND DERIVED DATA

This analysis necessitated combining the road sites database (MillCreekAssessment.mdb) and road condition database (MillRoadCondition.mdb). If we wished to examine the road surface condition at the location of springs throughout the network, for example, we needed a method to combine the data and then query the results. This was accomplished by using the geoprocessing tools and the modelbuilder function in ArcGIS®9 (ArcMap™ Version 9.3.1). The model was designed to run in ArcMap and export the two database event tables as feature classes and subsequently overlay the data using a spatial join. The model uses a one-to-one (intersect) join to spatially join road condition attributes to the road line features and a one-to-one (is within) join to spatially join road condition attributes to the road point features. Once combined, the resulting feature class is queryable using common definition queries to obtain the desired information.

GIS SPATIAL DATA

LiDAR-based 1-meter Digital Elevation Model

DPR obtained LiDAR data over the entire Mill Creek Addition in 2007 (post road inventory). The LiDAR data were used to develop a DEM with 1-meter resolution. This DEM is a raster with topographic elevation attributed in each 1 meter pixel. It is estimated that the LiDAR-based DEM was capable of resolving site specific elevations across the landscape to within 0.3 m to 0.5 m in the vertical dimension.

The DEM and derived shaded relief model provide a powerful tool for this road assessment facilitating visualization of the road alignment and landing features, confirm-

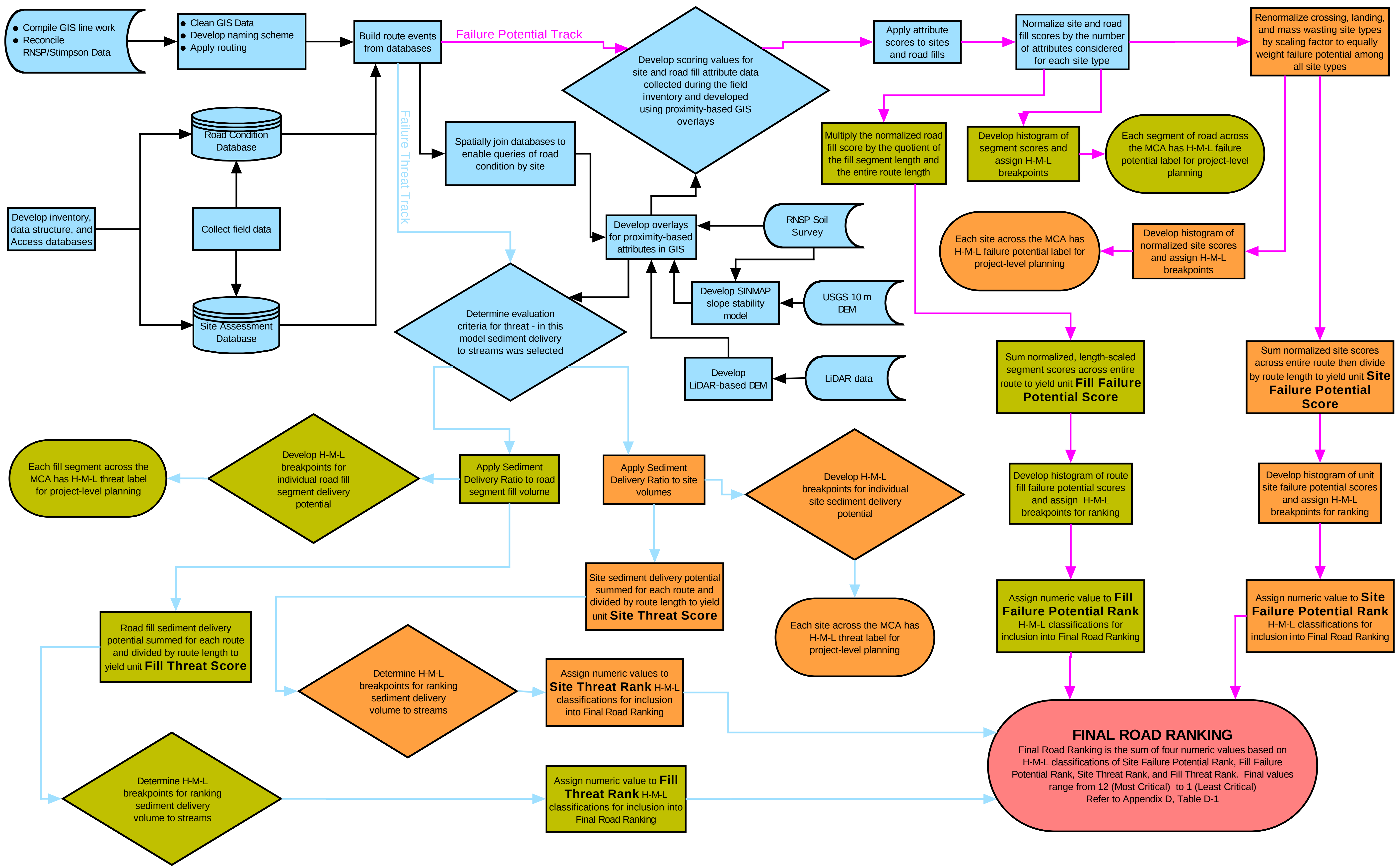

Figure 11. Road assessment model. This flow chart illustrates the inputs, processes, decision points, and outputs of the road assessment model.

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ing location of secondary roads, and deriving local slope steepness. These data allow us to confidently conclude there are no major discrepancies or undetected haul roads that were somehow missed in the original inventory. Additionally, the shaded relief will be useful in validating the secondary roads identified through the air photo inventory, and provide a template to redraw secondary roads as needed on a project by project basis.

SINMAP

We produced a slope stability index to be used as an input to the scoring matrix using SINMAP 2.0 (Stability INdex MAPping). This product characterizes relative slope stability across the MCA. SINMAP 2.0 uses the infinite plane slope stability model and steady-state shallow groundwater hydrology to produce a slope stability index for a study area (Pack et al, 2005). Input parameters are assumed to be normally distributed and the upper and lower limits of parameter values are set as model input. Parameter values can be calibrated for geographic regions to reflect varying conditions across a study area. In addition, SINMAP 2.0 allows for visual calibration by adjusting input parameters to reflect field verified landslide activity. The MCA SINMAP output was validated using the landslide history obtained through our earlier air photo inventory of the property.

SINMAP 2.0 is implemented through an extension to ArcMap. The original ArcView-extension of SINMAP was developed between Terratech Consulting Ltd, Utah State University and C.N. Goodwin Fluvial System Consulting with the support of Forest Renewal British Columbia, in collaboration with Canadian Forest Products Ltd., Vancouver, British Columbia. The ArcGIS version of SINMAP 2.0 was developed with support from the Rocky Mountain Research Station, Forest Service, U.S. Department of Agriculture under joint venture agreement number 03-jv-11222014-050. The digital elevation model methodology and algorithms have been developed by David Tarboton.

Five calibration parameters are required input to the SINMAP modeling: soil bulk density, internal angle of friction for the soil, dimensionless cohesion, soil transmissivity and the recharge rate within the specific catchment area. The last two parameters are used as a ratio (T/R) to define the topographic wetness index. Where available, we derived our initial values for these parameters from the Soil Survey of Redwood and National Parks, California (USDA 2008) and Gabriel Paulín’s 2007 thesis.

The Mill Creek property can be grouped into 7 distinct soil regions grouped according to an erodibility index and common characteristics (Seney 2010). Each soil region includes from 1 to 5 soil map units, with each soil region consisting of two to seven major components (Table 7 and Figure 12). The major components of each soil region are divided by horizon. We evaluated components in horizons between 50 cm to 150 cm deep to determine values for calibration parameters, particularly soil bulk density. Appendix C contains a complete description of each soil map unit that was characterized as part of the RNSP soil survey.

Soil Bulk Density

Soil bulk density contributes to the driving force of a weak soil mass, so we selected the highest soil bulk density of a given region for the representative model input. Because the soil survey only quantified the non-rock portion of the samples, the density of the horizon including rock fragments had to be calculated. We calculated the total bulk density for each horizon by multiplying the measured soil bulk density by its representative percentage in the sample added to the percentage of rock fragments multiplied by the average density of rock fragments (2,650 kg/m^3). Initial SINMAP processing, varying only the bulk density across the range of values indicated by the soil survey, was run with imperceptible differences in results suggesting very little sensitivity of the model to this range of bulk density parameters. As bulk density was the primary calibration parameter that we could readily derive from soils survey data that varied by region, we decided to produce our output based upon a single calibration region pending additional analysis and defensible field data to support different parameters across the regions. We therefore used 1,967 kg/cm, the average bulk density across the landscape based on acres (Table 8).

Angle of Internal Friction (phi ϕ)

The angle of internal friction is the measure of the ability of a rock or soil to withstand a sheer stress. SINMAP's basis in the infinite slope model requires an estimation of the maximum and minimum values of phi (ϕ). Sand and rock fragments have higher values, and clay, silt, and rounded rock fragments have lower values. The soil survey value kwfact (Kw) is an erodibility factor which quantifies the susceptibility of soil particles to detachment and movement by water, and is adjusted for the effect of rock fragments. In the absence of a direct correlation between soil sample kwfact and angle of internal friction, we chose to use SINMAP default values of 30-45 across the project area.

Table 7. Soil map units grouped into regions

Region	Map Units	Major Components	Description
1 (1,347 acres)	590, 591, 592,	Sasquatch, Yeti, Footstep, Sister-rocks, Ladybird	very deep, sandstone and some mudstone colluvial and residual soils (150 to 200 cm thick) with fine-loamy to fine textures and angular fragments (forest type moist redwood)
2 (15,335 acres)	580, 581, 582	Cooopercreek, Tectah, Slidecreek, Lackscreek	very deep, sandstone and some mudstone colluvial and residual soils (150 to 200 cm thick) with fine-loamy to fine textures and angular fragments (forest type redwood-Douglas-fir)
3 (2,752 acres)	583, 586	Peacock, Wire-grass	very deep, schist and metasedimentary colluvial and residual soils (150 to 200 cm thick) with fine-loamy to fine textures and angular fragments (forest type Douglas-fir-redwood)
4 (3,044 acres)	534, 549, 584, 585	Coppercreek, Ahpah, Lack-screek, Wiregrass, Pittplace, Scaath, Rockysaddle	very deep, sandstone and some mudstone colluvial and residual soils (150 to 200 cm thick) with fine-loamy to fine textures and angular fragments (forest type tanoak-Douglas-fir)
5 (1,049 acres)	587, 588	Childshill, Surpur	very deep, weakly consolidated siltstone, sandstone and conglomerate colluvial and residual soils (150 to 200 cm thick) fine-loamy to loamy-skeletal and rounded fragments (forest type tanoak-Douglas-fir)
6 (1,169 acres)	756, 759, 760, 761	Oragran, Weitch-pec, Jayle, Walnett, Gasquet	shallow to moderately deep, serpentinite and periodite residual soils (50 to 100 centimeters thick) loamy-skeletal and angular cobbles and stones (forest type Jeffery pine parkland and Douglas-fir-tanoak)
7 (547 acres)	174	Bigtree, Mystery	very deep alluvial soils from mixed sources (150 to 200 centimeters thick) coarse to fine loamy and rounded fragments (forest type mixed)

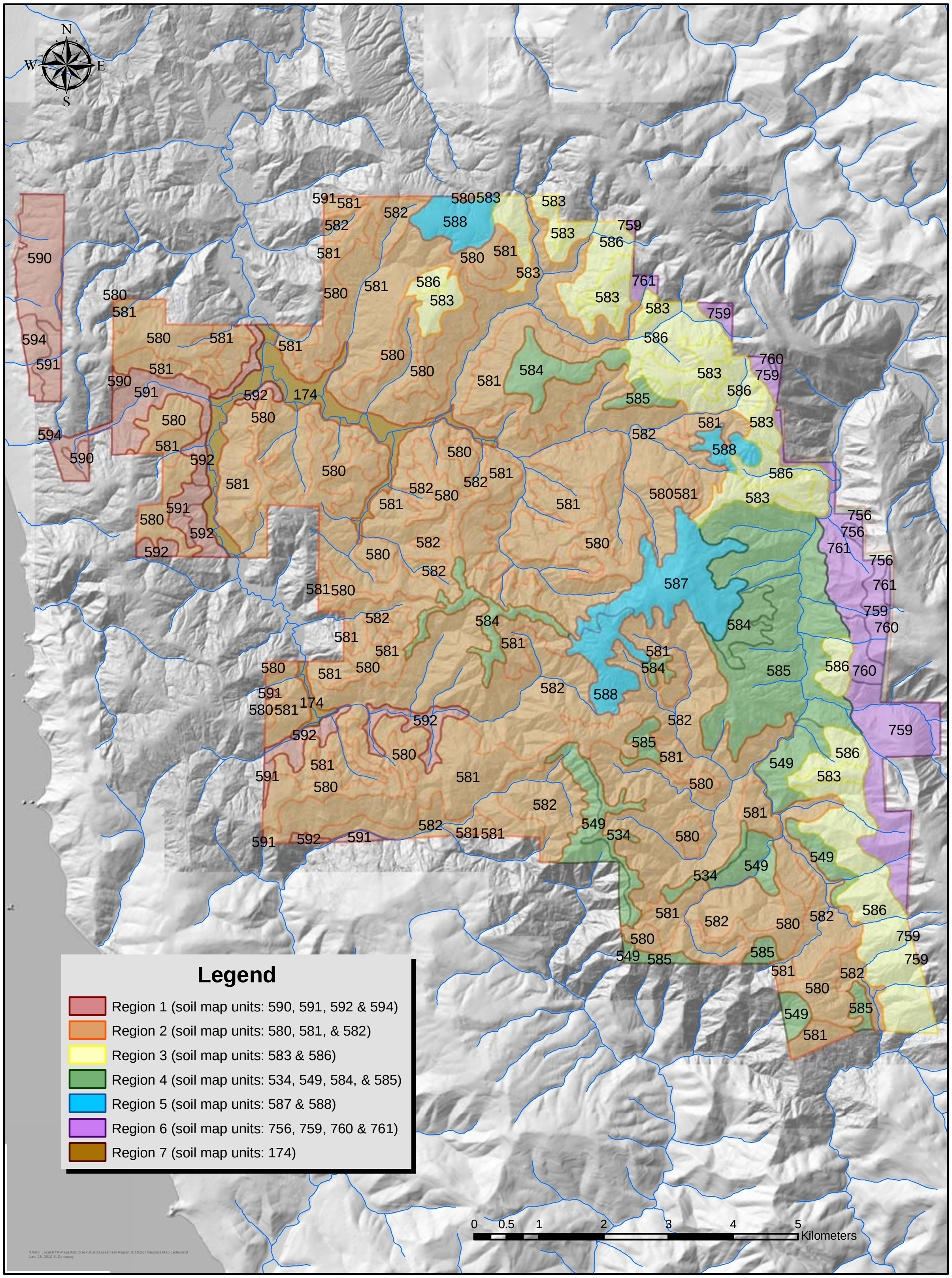

Figure 12. Soil map units grouped by region

Table 8. SINMAP calibration parameters

	Soil Bulk Density	Angle of Internal Friction		Cohesion		Transmissivity/Re-charge (Topographic Wetness Index)	
	RhoS	PHI min	PHI max	C min	C max	T/R min	T/R max
	kg/cm	degrees	degrees	Kpa	Kpa	m	m
SINMAP Defaults	**2,000**	**30**	**45**	**0**	**0.25**	**2,000**	**3,000**
Region 1	2,130	30	45	0	0.25	1,000	6,000
Region 2	2,000	30	45	0	0.25	1,000	6,000
Region 3	1,810	30	45	0	0.25	1,000	6,000
Region 4	2,000	30	45	0	0.25	1,000	6,000
Region 5	1,530	30	45	0	0.25	1,000	6,000
Region 6	2,190	30	45	0	0.25	1,000	6,000
Region 7	1,642	30	45	0	0.25	1,000	6,000
Combined Regions	**1,967**	**30**	**45**	**0**	**0.25**	**1,000**	**6,000**

Cohesion (C)

Cohesion in soils is the result of two primary factors: electro-chemical bonding at the molecular level and root strength. SINMAP's basis in the infinite slope model requires an estimation of the maximum and minimum values of cohesion (C). SINMAP uses a dimensionless cohesion factor derived by combining the soil and root cohesion with soil density and thickness. The soil survey value kffact (Kf) quantifies soil particles' susceptibility to detachment by water (not adjusted for rock fragments) and provides an indication of cohesion, although the highest values of Kffact do not indicate highest cohesion. Soil sample Kffact ranges from .02 to .57, with .15 to .32 being most cohesive. More sand and/or silt would result in less cohesion while more clay would result in more cohesion. In the absence of a direct correlation between soil sample kffact and dimensionless cohesion, we chose to use SINMAP default values of 0 to .25.

Topographic Wetness Index (T/R)

The topographic wetness index is the ratio of the soil transmissivity to the effective recharge. We took transmissivity values from laboratory results of samples taken by Paulín across only the western third of the Mill Creek property. Transmissivity defines the soil's capacity for lateral transmission of water in m^2/hr. Recharge as used for SINMAP refers to effective recharge (in m/hr) over a critical period of rainfall likely to trigger landslides. We assume the effective recharge is imposed over already wet soils with prolonged antecedent precipitation. In our region, local observations of rainfall intensity and landslide initiation indicate an effective recharge rate of 3 inches over a 12 hour period with near saturated soils at the start of the period (.0762 m / 12 hrs = .0063 m/hr). We chose to use a wide range of 1,000-6,000 for T/R MIN and T/R MAX calibration parameter values across all regions of the Mill Creek Addition.

Input DEM

SINMAP uses a grid DEM to process slope and specific catchment area values. We began the SINMAP modeling by using the 1-meter DEM developed using 2007 LiDAR data. However, due to file-size limitation errors encountered in SINMAP processing, we used 10-meter USGS DEMs to produce the SINMAP output. However, we were able to use the 1-meter LiDAR-derived DEMs to obtain local slope values used in the attribute scoring matrix (see Failure Potential Assessment).

SINMAP verses Historical Landsliding

The output slope stability grid is reclassified into the following stability categories: (1) 0-.001 Defended, (2) 0.001-0.5 Upper Threshold, (3) 0.5-1.0 Lower Threshold, (4) 1.0-1.25 Quasi Stable, (5) 1.25-1.5 Moderately Stable, (6) 1.5-10 Stable. Upon finalizing the SINMAP calibration and model runs, we compared the distribution of the stability class definitions to the location of landslides inventoried during our historical landslide analysis (See Landslide History). We used the GIS to overlay the two datasets and qualitatively assessed how well the model output fit the observed landsliding (Figure 13). Landslides plotted reasonably well over the defended and upper threshold categories showing higher densities of landslides in those areas. By contrast, quasi-stable and stable areas are noticeably devoid of landslides.

FAILURE POTENTIAL ASSESSMENT

Four site types were characterized by score: 1) road-stream crossings, 2) landings, 3) mass wasting sites, and 4) road fills (segments) using physical attributes that are known to affect stability. Attribute scores developed for the four site types represent a site's relative potential for failure with the highest score having the highest failure potential and the lowest score having the lowest failure potential. Redwood National Park geologists working on road related issues in and around Redwood National and State Parks were consulted to assist us with defining our scoring framework. Attribute scoring values and weighting factors were assigned by consensus among the group. The goal was to rank roads based on their existing physical attributes in a manner

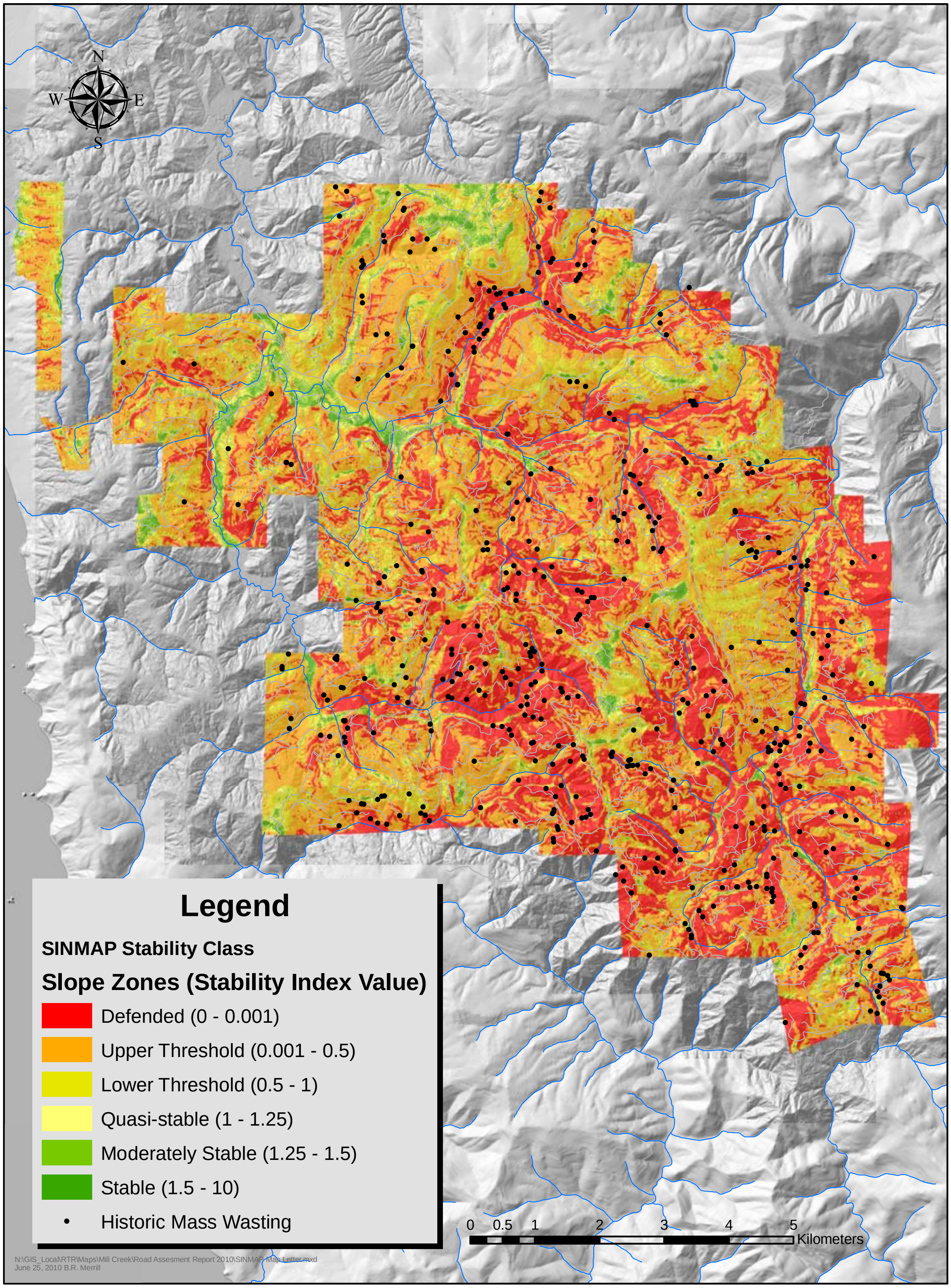

Figure 13. SINMAP slope stability index

that removes as much subjectivity as possible, so that all sites and road segments are compared equally and objectively. Although the initial assignment of attribute score values was arguably subjective, we felt that enlisting the help of other road rehabilitation practitioners would reduce individual bias and subjectivity. Once score values were assigned however, our process was designed to be objective, relying only on numerical scores to determine relative potential for failure.

A three step process was used to score each site or road fill segment: 1) determining and summing attribute scores for each site type, 2) normalizing the raw site score by the number of attributes considered, and 3) renormalizing the site score so that all site type scores are equally weighted. This third step was not performed for road fills because we were unable to consider them to be equivalent to the other site types when summarizing failure potential for entire routes (see discussion below).

Summing Attribute Scores (Step 1)

We used field data contained in the two road inventory databases as well as the LiDAR-derived GIS products and SINMAP (10-meter) to generate the attribute scores (Tables 9-12). Because all attributes do not affect the site to the same degree, the top value of each attribute's score range was scaled to reflect the relative importance of that attribute to site stability. For example, when evaluating the stability of a landing site, the maximum score for local slope (scored 0 to 20) is significantly more important than the proximity of the landing to cross drain culvert (scored 0 to 3). Scores of zero were assigned if the attribute category is not likely to affect site stability.

Scores were derived from attributes that were directly related to the site such as fill volume or vegetation load, and from attributes which may affect the site such as proximity to a landslide site or the steepness of the slope below. We used buffering distances along routes within ArcMap™ to assign scores to various proximity-based attribute values. Proximity attributes were considered because observations during the road inventory indicated that road related failures tend to cluster near hydrologic or geomorphic features such as springs or existing mass wasting sites. The relative scores of proximity-based attributes were assigned based on field observations across the MCA of failure clusters and their sizes. For example, at landing sites values could be scored based on whether the site was 0 meters away (touching or within) (8 points), 1 m to 50 m away (7 points), or greater than 50 m away (0 points) from a spring. For linear features such as landings and seeps, the proximity buffering was defined from

Table 9. Site scoring values for each attribute of road-stream crossings (non-culvert and culvert)

Non-culvert stream crossings		
Attribute	**Value**	**Score**
Crossing feature		0-10
	stream	10
	swale	0
Crossing diversion		0-20
	active	20
	potential	15
	no potential	0
Crossing type		0-15
	bridge*	0
	culvert	6
	Humboldt	15
	fill	12
	other	6
Erosional process		0-20
	undercutting	13
	collapsing	17
	fill failure	20
	gully	9
	streambank	5
	none	0
Condition of fill		0-15
	intact	0
	removed < 50%	6
	removed >50%	14
	washed out > 10%	15
Sediment transport		0-10
	high	10
	medium	5
	low	0

Table 9. continued

Non-culvert stream crossings		
Attribute	**Value**	**Score**
Adjacent instability		0-10
	yes	10
	no	0
Max attribute raw score non-culvert crossings		100
Max score normalized by number of attributes (n=7)		14.3

Culvert stream crossings		
Attribute	**Value**	**Score**
Properly sized culvert		0-20
	yes	0
	no	20
Culvert condition		0-15
	poor	15
	fair	7
	good	0
Plugging potential		0-20
	low	0
	medium	10
	high	20
Culvert drains onto fill		0-10
	yes	10
	no	0
Max attribute raw score culvert crossings		165**
Max score normalized by number of attributes (n=11)***		15.0

* If crossing type is bridge, total score defaults to zero.
** Culvert crossings are scored using the sum of their non-culvert (max 100) and culvert (max 65) attribute scores.
*** Culvert scores are normalized by the sum of their non-culvert (n=7) and culvert (n=4) attributes.

Table 10. Site scoring values for each attribute of landing site types

Landings		
Attribute	**Value**	**Score**
Fill unit volume (m^3/m)		0-20
	> 50	20
	30 - 50	15
	10 - 30	10
	< 10	2
Water onto landing		0-15
	yes	15
	no	0
Local slope (maximum value within 50m downslope)		0-20
	>60%	20
	40% - 60%	10
	0% - 40%	0
Soil map units/Underlying geology		0-15
	map units 587 or 588	15
	all other map units	0
Proximity of landing to springs/seeps		0-8
	0 meters (within or touching)	8
	1 - 50 meters	7
	>50 meters	0
Proximity of landing to gully		0-5
	0-20 meters	5
	> 20 meters	0
Proximity of landing to cross drain culvert		0-3
	0-20 meters	3
	> 20 meters	0
Proximity of landing to mass wasting*		0-10
	1 - 50 meters	10
	>50 meters	0

Table 10. continued

Landings		
Attribute	**Value**	**Score**
SINMAP (segment overlapping)*		0-10
	stable	0
	moderately stable	1
	quasi-stable	5
	lower threshold	7
	upper threshold	9
	defended	10
Max attribute raw score		96
Max score normalized by number of attributes (n=8)**		12.0

* If proximity of landing to mass wasting is from 1 - 50 meters, then SINMAP output value receives no score. If proximity of landing to mass wasting is greater than 50 meters, use SINMAP output value.
** Because attributes “proximity to mass wasting” and “SINMAP” are scored either/or to avoid double counting, they count as one attribute.

Table 11. Site scoring values for each attribute of mass waste site types

Mass Wasting		
Attribute	**Value**	**Score**
Extreme erosion potential*		0-30
	low	0
	medium	20
	high	30
Future erosion potential*		5-15
	low	5
	medium	10
	high	15
Max attribute raw score		30
Max score normalized by number of categories (n=1)**		30.0

* If extreme erosion potential is medium or high, then future erosion potential recieves no score. If extreme erosion potential is low, then use value for future erosion potential.
** Because attributes "future erosion potential" and "extreme erosion potential" are scored either/or to avoid double counting, they count as one attribute.

Table 12. Site scoring values for each attribute of road fill segments

Road Fills		
Attribute	**Value**	**Score**
Fill unit volume (m^3/m)		0-10
	> 8	10
	5-8	7
	3-5	4
	0-3	1
Vegetation load		0-3
	high	1
	medium	2
	low	3
Road drainage		0-6
	insloped/ditch	2
	outsloped/none	0
	rill/tire ruts	5
	road gully	6
	tread drainage	3
	water bars	2
Inboard ditch		0-5
	double inboard/outboard	3
	filled	5
	gullied	4
	none	0
	open	1
	vegetated	2
	outboard	3
Soil map units/Underlying geology		0-15
	map units 587 or 588	15
	all other map units	0
Local slope (maximum value in segment)		0-20
	>60%	20
	40% - 60%	10
	0% - 40%	0

Table 12. continued

Road Fills		
Attribute	**Value**	**Score**
Proximity of Road segment to springs/seeps		0-8
	0 meters (within or touching)	8
	1 - 50 meters	7
	>50 meters	0
Proximity of road segment to gully		0-5
	0-20 meters	5
	> 20 meters	0
Proximity of road segment to cross drain culvert		0-3
	0-20 meters	3
	> 20 meters	0
Proximity of road segment to mass wasting*		0-10
	1 - 50 meters	10
	>50 meters	0
SINMAP (segment overlapping)*		0-10
	stable	0
	moderately stable	1
	quasi-stable	5
	lower threshold	7
	upper threshold	9
	defended	10
Max attribute raw score		85
Max score normalized by number of categories ** (n=10)		8.5

* If proximity of road segment to mass wasting is from 1 - 50 meters, SINMAP output value receives no score. If proximity of road segment to mass wasting is greater than 50 meters, use SINMAP output value.
** Because attributes “proximity to mass wasting” and “SINMAP” are scored either/or to avoid double counting, they count as one attribute.

a single point in the center of the feature, not the edges. This will tend to underscore larger sites as the edge of the site may be significantly closer to the scoring feature than the center point.

Some attribute categories were paired and only one of the two was scored to avoid double counting of related attributes. For example, local slope instability could have been scored based on existing field evidence of mass wasting or probable future events based on the slope stability model. To avoid double scoring a site that was in close proximity to a mass wasting event and also overlapping an area prone to instability according to SINMAP, the site type was first scored according to its proximity to a mass wasting event, and if not within 50 m, a score was assigned using the SINMAP output.

Normalizing raw site scores by number of attributes (Step 2)

Once we had assigned a score to each attribute, we summed scores to yield a raw site score. The raw site scores range from 0-100 for non-culvert crossings, 0-165 culvert crossings, 2-96 for landing sites, 5-30 for mass wasting events, and 2-85 for road fill segments (Tables 9-12). The raw site scores, however, are not indicative of the relative potential for failure because each site type's raw score is composed of a different number of attributes summed for the total raw score. For example, a site type with 11 attributes will usually generate a raw score higher than a site type with 7 attributes; the maximum raw score achievable by each site type differed. To negate the effect of having site types with differing numbers of scored attributes, we divided each raw site score by the number of attributes summed. This generated the normalized site score.

Renormalizing site scores to equally weight site types (Step3)

We renormalized the site scores using a scaling factor to equalize potential for failure across all site types except road fills. Because we ultimately want to state whether one route has a high potential for failure, we required all site types along a route to score within the same range. By equalizing failure potential across site types, we are able to use the individual site scores to produce summed failure potential values for whole routes without one site type skewing the total. For example, without renormalization, a route with 5 landing sites and 5 crossing sites scored at the maximum value would receive a different total score as a route with 10 crossing sites scored at the maximum value. To calculate the renormalized site score, we multiplied the normalized site score by a scaling factor to equalize the maximum failure potential score achievable considering all site types.

To calculate the scaling factor for each site type, we divided the same maximum achievable normalized site score for one site type (culvert crossings = 15) by the maximum achievable normalized site score for each of the other site types. We used each resultant multiplier (scaling factor) to increase or decrease each normalized site score to equalize the weight of each site type (Table 13). This set the normalized scores for the each of the four site types equal in weight to those of stream crossings with culverts.

Table 13. Three step process for site scoring matrix

	Step 1. Summing attribute scores		**Step 2. Normalize raw site score**	**Step 3. Renormalize site scores to equally weight site types**		
	Number of Attributes	Max Raw Site Score	Max Normalized Site Score	Scaling Factor based on Max Normalized Site Score of Culvert Crossing		
	Number of categories considered in determining site stability	Summed maximum values for all attributes (Tables 9-12)	Maximum Raw Site Score/Number of Attributes	Max Normalized Site Score for Culvert Crossing/Max Normalized Site Score for given site type	Scaling Factor	Resultant Max Renormalized Site Score
	A	**B**	**C**	**D**	**E**	
Site Type			**(B/A)**	**(15/C)**		**(C*E)**
Non-Culvert Crossing	7	100	14.29	15.00/14.29 = 1.05	1.05	15.00
Culvert Crossing	11	165	15.00	15.00/15.00 = 1.00	1.00	15.00
Landing	8	96	12.00	15.00/12.00 = 1.25	1.25	15.00
Mass Wasting	1	30	30.00	15.00/30.00 = 0.50	0.50	15.00

Ranking Site Failure Potential

Once we renormalized the site scores for all sites (hereinafter referred to as normalized site scores), we reviewed the scores for all site types collectively. First, we reviewed the range of values and the maximum and minimum values to determine whether the attribute scoring values produced reasonable relative site scores based on our field knowledge of specific sites. This was also an opportunity to identify any outliers and determine their validity. Individual normalized site scores were compared to first hand knowledge of field sites, especially ones that we knew to be critically unstable. Sites known to be unstable were well represented in the high score range.

We chose to group sites into three classifications based on their normalized site scores: High, Moderate, and Low potential for failure. High potential sites represent sites possessing numerous characteristics that indicate failure is probable given the right conditions. Histograms of the normalized scores were plotted for each site type, along with the sum of all site types falling within a bin, to evaluate the distribution. We looked for obvious breakpoints where we could assign classifications. The distribution of the data alone was not as valuable for identifying break points as our own knowledge of the conditions at the sites themselves. We adjusted the break points to produce different map representations and compared those to our first-hand knowledge of individual "landmark" sites (Table 14). The scoring breakpoints were validated as the scores of the worst sites known from field observations fell within the range of the high priority sites.

Table 14. Scoring breakpoints to determine High, Moderate, Low (HML) ranking.

Potential for Failure	**L (1)**	**M (2)**	**H (3)**
Site Score Ranking	0 - 3.30	3.30 - 6.08	>6.08
Road Fill Score Ranking	0 - 1.50	1.50 - 2.75	>2.75

Ranking Road Fill Failure Potential

Each route's road fill segments were individually ranked using the normalized scores of each road fill segment; a method similar to that used in ranking the road sites. We were able to compare road fill failure potential scores in the same manner as sites, using a histogram and assigning breakpoints for High, Moderate, and Low classifications. For reasons discussed in the next section, however, we did not use these individual segment classifications to determine the road fill score for the entire route. Instead, we will use the classifications in subsequent project planning to sequence road treatment options. Knowing which segments of a route constitute the highest risk will allow managers to target the highest scored segments and make decisions about ordering treatments for longer roads with high variability among the fill segments.

Ranking Route Failure Potential Scores

Site Scores

The primary objective of this road inventory and assessment was to rank roads within the MCA according to their potential to fail and damage the surrounding resources. Evaluating and ranking individual sites is quite useful when road infrastructure is expected to remain in place indefinitely and prioritization of periodic repair or replacement of structures is required. However, when road treatment options include removal of the road and its associated sites, it is best to approach the prioritization on a road-by-road basis. A road- level approach enables managers to view road issues as a whole and plan road removal or rehabilitation projects designed to treat the whole road, including all of its associated sites.

Our road-level approach used the normalized site scores summed across the entire route to determine the route's site failure potential. We divided the summed total by the length of the route to arrive at a unit Site Failure Potential Score for the route. We plotted the unit site values for all routes as a histogram and ranked them (similar to the process for individual sites) yielding a Site Failure Potential Rank, either: High, Moderate, or Low. We also assigned a numeric value of 3, 2, or 1 respectively to be used later to calculate the Final Road Ranking (Appendix D, Table D-1).

Fill Scores

Ideally it would have been best if we could have summed all normalized scores into the route total to arrive at one Route Failure Potential Rank. However, we were unable to simply sum all of the normalized scores to arrive at one all-encompassing route score. Because stream crossings, landings, and mass wasting sites are physically distinct from road fills, we were unable to include the road fills with the other site types to produce a single value that represented the whole route. It is clear that a crossing constitutes a site and has its own site score and ranking. The same holds true for landings and mass wasting sites. However, as we tried to define a road fill site in order to assign it a failure potential score equivalent to the other site types we were unable to answer the question, “What constitutes a road fill site?” Other site types have physical boundaries that define the site. Road fills however are not easily defined with boundaries and vary considerably in size. It became clear that we could sum failure potential scores for crossings, landings, and mass wasting sites but would have to treat the road fill segments separately.

Normalized road fill scores individually represent a percentage of the entire route length. Some segments score high along the route while others score low, and all have different lengths. In order to accurately represent the weight of each segment score relative to the other segments that make up the route, we multiplied the normalized road fill score for the segment by the quotient of the segment length and the route length. The resulting segment values were summed yielding a route's Fill Failure Potential Score. The score values for all the routes were then plotted as a histogram and ranked, yielding a Fill Failure Potential Rank, either: High, Moderate, or Low. We also assigned a numeric value of 3, 2, or 1 respectively to be used in calculating the Final Road Ranking (Appendix D, Table D-1).

We can evaluate the two failure potential rankings independently to determine the relative potential for failure of the road itself and/or the potential for failure of the sites along the road. Evaluating routes as a whole provides us with a first-cut ranking of which routes present the most significant risk to park resources. While this information will help us select which routes deserve the highest consideration for treatment, it doesn't provide information about how the potential is distributed along a route. Knowing which segments of a route constitute the highest potential for failure will allow managers to target the highest scored segments and make decisions about sequencing treatments. Although beyond the scope of this assessment report, we will consider segment fill scores and site scores at the project planning level.

THREAT ASSESSMENT

The model developed for this assessment can be used to evaluate various forms of threat posed by the road network. Any threat that can be quantified using numeric scoring can be incorporated into our model and used to assess the threat posed by nearby roads. We used sediment delivery to the stream network to characterize the threat posed by road segments and sites within the MCA. We selected sediment delivery because it is currently the major driver of watershed rehabilitation efforts underway and planned in the unit. The exceptionally healthy stream network in the MCA coupled with an abundant population of anadromous fish mark sediment as a significant and present threat within all watersheds on the property.

Fluvial erosion (stream crossing failures, stream diversions, and gullies) and mass movements (fillslope failures, landing failures, and cutbank failures) have the potential to deliver sediment to the stream network. However, these erosional processes are episodic in nature and are often triggered by large storm events (Flosi et al. 2006). In addition, there are several ways in which a stream crossing has the potential to fail and deliver sediment (a plugged or undersized culvert, diversion of flow down the road, collapse of fill from within, or gully development) gradually washing the fill out over time. Each of these failure mechanisms may yield a different quantity of sediment to the streams over an uncertain amount of time. For these reasons, sediment delivery cannot be accurately predicted with an absolute value, but rather as the relative magnitude of an expected outcome if rehabilitation of the roads is not undertaken before the next large storm event. Our assessment considers the likely mechanisms of failure, the expected yield from the site, and finally, the delivery of sediment to the stream network. Sediment delivery volume is categorized into High, Moderate, or Low threat ranks based on expected impacts to stream hydrology and habitat.

Stream Crossings

For stream crossing sites, we assume that when crossings fail, they will eventually erode and incise to their original channel depth and width and the side slopes will lie back until they reach an angle of 1:1 (100% slope). Field observations indicate that crossing failures yield from 60% to 100% of their original fill volume, depending on the failure mechanism involved. Also, the sediment plug upstream of many crossings will deliver to the stream when the crossing fails due to the unconsolidated nature of the material. For this assessment we chose to calculate the potential sediment delivery ratio (SDR) for stream crossings at 80% of the total crossing volume.

Sediment Yield = Sediment Delivery Ratio (%) X Total Crossing Volume (m^3)

Sediment Yield = 0.8 X (crossing volume + sediment plug volume)

Landslides

For all field documented landslide sites, we ranked the potential for future erosion and the potential for extreme erosion as low, medium, or high (Appendix B, Road Assessment Form Sheet 1). We calculated an estimate of the future deliverable volume and also selected from categorical volumes to quantify an extreme erosion event, if it were to occur. We determined the potential landslide yield volume by using the value taken from a three-step process:

1. If the potential for extreme erosion is high, we use the highest value selected for the associated categorical volume.

2. If the potential for extreme erosion is medium, we use the median value selected for the associated categorical volume.

3. If the potential for extreme erosion is low, we use the volume estimate for future deliverable volume.

Landings

We estimated fill volume for landing features as the product of the distance along the outer edge of the fill and the unit fill volume, both measured in the field. The steepness of slope is a key factor related to the failure of landings. Landing fill slides can only occur when slopes are steep enough for some of the other factors (soil and parent material, root cohesion, and moisture conditions) to combine and produce a stress that exceeds the resistance of the soil or rock material making up the slope. Therefore, we used local slope steepness as a key attribute in the calculation of the SDR for landing fills. We established the SDR by looking at the local slope using the 1m DEM to determine the highest slope value (percent) within 50 meters downslope from a landing. We then chose the SDR based on the following parameters:

1. If the local slope is greater than 60%, the SDR is 150%

2. If the local slope is between 40% and 60%, the SDR is 100%

3. If the local slope is less than 40%, the SDR is 50%

We chose to use a SDR of 150% for landings on slopes greater than 60% because field observations indicate that landing fillslope failures promulgate down steep slopes before delivery to a stream channel. Although this approach is simplified by only using slope values immediately below the landing fills, Bartle (1998) suggests that if hillslope geometry remains constant, fill failures will accumulate volume down a slope greater than 40%. Because our analysis used a single pixel to determine maximum slope beneath a landing, and our field observations indicated that some deposition occurs on slopes greater than 40%, we employed a range of 40% to 60% to represent the transitional phase of the failure mass propagation.

Bartle also suggests that a topographic bench at least 30 m wide is necessary for terminal deposition of a slide mass. Consequently we did not modify the SDR based on the presence of roads downslope of a potential failure point because even the widest roads within the MCA are too narrow to cause terminal deposition. Landscape scale topographic benches could affect the SDR; however analyzing the DEM for these features and determining their influence on the SDR was beyond the scope of this investigation.

Road Fills

It is somewhat more difficult to apply a geomorphic rationale to the calculation of the SDR for road fill embankments. Road fills can be subject to fluvial erosion, mass wasting, failure from lack of maintenance or storm damage, or any combination of factors stemming from the road's location and its interaction with the surrounding road network. It is not likely that a road will fail in entirety; instead sections will fail over time. For this assessment, we chose to calculate road fill SDR as the product of the entire road fill volume, the percentage of the road fill volume estimated to fail, and the percentage of the failed volume likely to yield sediment to the creeks. The SDR we used to calculate road fill yield is:

Yield = (total road fill volume) X 0.2 (road fill likely to fail) X 0.4 (failed road fill volume delivered)

Although this method is quite subjective, determining a more accurate value of the SDR for an entire road would require evaluating each geomorphically distinct road segment to determine the failure potential and failure propagation behavior. This type of analysis is currently done on a project-by-project basis in the MCA but was beyond the scope of this investigation.

Road Surface Erosion

Road surface erosion (lowering) is a chronic low-volume sediment source that can deliver to streams via drainage ditches, sheet flow, and minor stream flow along road surfaces. Yield from road surfaces can vary widely and is dependent on many factors including road use, road surfacing material, road vegetation cover, and road maintenance activities.

We expect road surface lowering to occur on all roads open to traffic and periodic maintenance. Of the 468 km of roads within the Mill Creek Addition, 293 km are still open and carrying some traffic. That length multiplied by a road surface width of 4 m yielded the surface area exposed to erosion. We used a road surface lowering rate of 5.1 mm per year, which is consistent with values used in the upper basin of nearby Redwood Creek (Bundros et al., 2003).

An accurate estimate of sediment delivery to streams depends on conveyance of the fine sediment off the road to the adjacent streams. Within the Mill Creek Addition, most road surfaces were constructed to drain to an inboard ditch. The ditches drain directly to stream crossings or are relieved though cross drain culverts. Ditches that drain directly to stream crossings are assumed to deliver 100% of their load. Cross drains, however, can deposit sediment loads onto hillslopes where they exit the road prism, or they can deliver the sediment via gullies to nearby streams. Although we did not quantify how many of the 515 cross drains flowed via channels to streams during our inventory, we can conservatively estimate half of the cross drains were capable of delivering sediment to streams. Cross drains were spaced an average of 50 m apart, so we calculated the road surface erosion delivery as all of the road surface experiencing lowering, less the amount drained by cross drains not connected to the stream network. Of the 293 km of active road, 280 km are directly connected to the road surface via inboard ditches and were used to calculate road surface sediment delivery.

Ranking Site Threat

Similar to site failure potential, we rank the site threat by grouping sites into categories of High, Moderate, and Low based on their predicted ability to deliver sediment to the stream network, keeping break points for categories of threat constant regardless of site type. We categorized all sites capable of delivering up to 300 m^3 as low, from 300 to 1,200 m^3 as moderate, and over 1,200 m^3 as high threat.

We based these breakpoints on our field observations of the effects of various mass sediment inputs to streams since we began monitoring the road network (2002 to present). Inputs less than 300 m^3 were generally processed quickly by moderate to large streams. The wedge of sediment was quickly attenuated downstream and alluvial deposits were uncommon. Volumes ranging from 300 m^3 to 1,200 m^3 were more resistant to reworking and tended to deposit as small fill terraces for a significant distance downstream. Stream inputs greater than 1,200 m^3 resulted in significant impact to the deposition site as well as distant downstream reaches. At the deposition site sediment often caused the stream to shift course undermining riparian vegetation and scouring additional sediment from adjacent slopes and terraces. In small to moderately sized streams the depositional wedge often remained intact with deeply incised gullies created by stream flow. Downstream deposits extended for long distances and often formed deltaic deposits at stream confluence points. In larger streams much of the sediment was mobilized and transported downstream where extensive reworking of the active channel and floodplain often liberated more sediment.

Ranking Road Fill Threat

By applying the SDR uniformly to all road fills, we were able to determine the relative threat of sediment delivery for individual road fill segments using the fill unit volume. We based breakpoint values for road fills on the range of fill unit volumes from the original field data. We considered unit volumes from 0 to 3 m^3/m as low threat, from 3 to 5 m^3/m as moderate threat, and greater than 5 m^3/m as high threat.

Ranking Route Threat

Route-level threat ranking was accomplished by summing estimated sediment delivery for all sites or fills along the road and dividing the summed total by the length of the route. All inventoried routes were then ranked by their route-level unit sediment delivery volume (one classification for unit site threat and one classification for unit road fill threat).

Site Threat

Potential sediment delivery was summed from all sites along a route and divided by the route length, yielding a route-level unit Site Threat Score. We also plotted the unit site threat scores for all the routes as a histogram, basing breakpoints on the distribution and field knowledge of specific routes and ranked, yielding a Site Threat Rank, either: High, Moderate, or Low. Each classification was assigned a numeric value of 3, 2, or 1, respectively, in order to calculate the Final Road Ranking (Appendix D, Table D-1).

Fill Threat

Potential sediment delivery from road fills along a route was summed and divided by the route length, yielding a route-level unit Fill Threat Score. Fill threat scores for all the routes were again plotted as a histogram basing breakpoints on the distribution and field knowledge of specific routes and ranked, yielding a Fill Threat Rank, either: High, Moderate, or Low. Each classification was assigned a numeric value of 3, 2, or 1, respectively, in order to calculate the Final Road Ranking (Appendix D, Table D-1).

ROAD ASSESSMENT RESULTS

A total of 443 roads totaling 468 km were ranked by their combined failure potential and sediment delivery threat in this process (Plate 1). Individual roads ranged in length from 0.02 km to 23.06 km. Of 3,245 sites evaluated, 1,457 are road-stream crossings, 981 are landings, and 807 are mass wasting sites (Table 15 and Plate 2). Nine-hundred and ninety-seven sites and 122 road fills are considered high risk with a combined potential sediment delivery of 1,149,000 m^3. Moderate risk sites and road fills number 1,300 and 240, respectively, and represent 1,042,000 m^3 of potential sediment delivery. Low risk sites and road fills account for 357,000 m^3 of potentially deliverable sediment contained in 948 sites and 81 road fills. We estimate chronic road surface erosion and fine sediment transport delivers 5,700 m^3 per year to the stream network within the Mill Creek Addition.

Individual road ranks ranged from 1 to 12 with 12 representing the most critically unstable, high threat roads and 1 representing the least unstable, low threat roads (Appendix D, Table D-1). We defined the final road rank as the sum of 4 scores ranging from 1 to 3: site failure potential rank, fill failure potential rank, site threat rank, and fill threat rank. Roads with higher rankings have a greater risk of failure combined with a larger potential sediment yield if failures occur. Roads with lower scores represent either less risk of failure, less potential sediment delivery, or both. The final road ranking is gradational rather than categorical because we could not identify any criteria which could define categorical boundaries. We believe this is an advantage because this assessment is intended to be a tool to compare the relative risk of failure and threat of roads in the context of integrated resource management planning and policy decisions.

Table D-1 also lists the total number of sites per route and the number of each site type, as well as the number and volume of road-streams crossings, landings, and mass wasting sites grouped by failure potential level. Total fill threat volume is presented as the sum of all potentially deliverable sediment for each route .

Road-stream crossings represent the largest number of sites across all three risk categories. High risk road stream crossings number 455 and represent 379,000 m^3 of potential delivery. High risk landing sites (325) represent 568,000 m^3 of potential sediment delivery to local streams. Although there are 130 fewer high risk landings than

Table 15. Road assessment summary

	Total Sites	Total Volume	High Risk	High Risk Volume	Moderate Risk	Moderate Risk Volume	Low Risk	Low Risk Volume
	#	m^3	#	m^3	#	m^3	#	m^3
Crossings	1,457	805,000	455	379,000	506	256,000	496	170,000
Landings	981	1,437,000	325	568,000	482	704,000	174	165,000
Mass Wasting	807	184,000	217	139,000	312	27,000	278	17,000
Roads	443	123,000	122	63,000	240	55,000	81	5,000
Total	3,688	2,549,000	1,119	1,149,000	1,540	1,042,000	1,029	357,000

high risk crossings, the high risk landings represent over half (52%) of the high risk threat for all site types combined. The high delivery rate for landing sites is a result of larger unit fill volumes coupled with the ability for failed landing fills to accumulate soil as they propagate down steep slopes. Mass wasting and road fill sites represent significantly smaller volumes of potential sediment delivery. Only a small amount of potentially unstable fill remains in most mass wasting sites, and road fills generally contain smaller unit volumes compared to landings.

We compared the final road ranking with our first-hand knowledge of the road network within the Mill Creek Addition. We looked at the ranking score for roads which over the past eight years have demonstrated chronic or catastrophic problems. We expect to see those roads near the top of the ranking while we expect relatively trouble-free roads to be near the bottom. Our model output reflects known conditions quite well. Of the 13 roads represented in the top two (most critical) ranks, 6 roads are known to be critically unstable or have already failed to some degree. Conversely, no known problematic roads appear in the lowest ranking routes.

Our results did illustrate one unanticipated result. Because the overall route failure potential and threat were calculated per unit length, short routes with any significant failure potential or threat were ranked high. Although unanticipated, this result is consistent with the results as a whole and serves to highlight that short roads should not be overlooked when evaluating road impacts to the surrounding landscape.

EXISTING CONDITIONS AND PROJECTS

ROAD MAINTENANCE

Currently, DPR maintains approximately 80 miles of critical circulation roads throughout the unit. Each year approximately 5% of those roads are brushed and regraded. Road maintenance crews patrol accessible roads during the winter season to correct drainage failures before they cause severe damage to the roadway. Drain and culvert cleaning are performed on a year-around basis and many sites are cleared more than once per year.

BRIDGES

Eleven bridges exist on the property (Plate 3). Ten bridges are dual railcar bridges resting on log crib abutments. The railcar bridges typically consist of two flatbed railcars welded together lengthwise. One bridge, built in 2009, is an Akrow pre-fabricated truss bridge on loan from Redwood National Park. The bridge was installed to provide a detour around two railcar bridges that received exceptionally low capacity ratings from California Department of Transportation (Caltrans) inspections in 2008.

All of the bridges within the Mill Creek Addition require routine inspections conducted by Caltrans to comply with Federal Highway Safety standards. Since 2004, all of the bridges have been inspected by the Caltrans, and 6 have been identified as “scour critical” bridges. This designation required the development of a Plan of Action (POA) which spells out the steps and timeline to be implemented to resolve the scour issues. Six Plans of Action were developed in 2009 for the scour critical bridges (Appendix E). The Plans call for replacement of the bridges, interim repairs to the rock slope protection beneath the bridges, and routine monitoring until the bridges can be rebuilt. The remaining 5 bridges have been designated “scour unknown,” which requires development of a Work Plan (WP). A Work Plan outlines the steps and timeline required to inspect the bridge and to conduct scour surveys. Results of scour surveys will determine whether the bridges are scour critical requiring Plans of Action. Work Plans are now under development at the DPR Northern Service Center and are expected to be complete by fall 2011.

LANDSCAPE STABILIZATION AND EROSION PREVENTION PLAN

Immediately prior to the State's acquisition of the property, Stimson Lumber Company representatives conducted several orientations to acquaint State Park resource managers with the property and the road system. During these orientations, we became familiar with a group of roads collectively referred to as "maintenance-free." These roads had been partially decommissioned and were no longer part of the transportation network. Stimson representatives told us that approximately 60 miles of maintenance-free roads were distributed across the ownership.

As part of our orientation, we were shown the treatment these roads had received and maps depicting their location on the property. Treatments were generally uniform on all the roads and consisted of partial removal of stream crossing fill and the installation of large open cross drains (tank traps) that segmented road and ditch drainage.

During the first winter following the acquisition (2002/2003), we observed higher rates of failure on the maintenance-free roads than on roads that were open and monitored. Further investigation revealed numerous critical erosion sites and pointed to several flaws in the methods used to treat maintenance-free roads. Consequently, we developed the Landscape Stabilization and Erosion Prevention Plan (LSEP) to immediately address and stabilize the maintenance-free roads.

The Stimson Lumber Company treated stream crossings by partially removing the crossing fill, usually leaving the culvert and up to a meter of soil. For crossings lacking a culvert Stimson removed fill to an arbitrary depth. With a few exceptions, none of the crossings were excavated down to natural stream grade. The timber company pushed excavated crossing fill into large piles on one or both sides of the treatment site. In cases where space was limited, equipment operators left fill piles perched directly above the crossing site. The rationale for the treatment, according to Stimson representatives, was to reduce both the risk of diversion and the volume of erodible fill in case of crossing failure. By leaving culverts in place, they hoped to reestablish the road with limited permitting requirements. What Stimson did not understand at the time was that this treatment would accelerate the failure rate of the sites, yielding significant quantities of sediment to the affected streams.

To date, these crossings continue to erode at an accelerated rate compared to the non-maintenance-free roads. Erosion occurs as chronic scour where stream flow overtops the fill, and as headcuts migrate upstream from the downstream end of the crossing (Figure 14).

Figure 14. Chronic erosion of stream crossing fill on a partially removed (maintenance-free) crossing.

Catastrophic failure occurred at several sites when high flow overwhelmed the culvert and scoured large volumes of fill (Figure 15). Partial removal of crossing fill increases the probability of overtopping, causing such crossings to be far less stable than those left intact. In addition, the rationale to leave the culverts in place for future re-entry was flawed; by definition, these maintenance-free roads were to remain decommissioned for several decades, at which point the culverts would have failed, or have needed replacement under THP review.

Maintenance-Free Cross Drains

Stimson Lumber Company installed large cross drains at regular intervals on most maintenance-free roads. Stimson did not install drains on segments with very low grades, or installed them less frequently. The cross drains are large “tank trap” type features that extend from the inboard ditch to the outboard hinge of the road. These features served to eliminate vehicle access and to segment road and ditch drainage. The cross drains trap runoff from the roadbed, the hillslope and shallow groundwater and deliver it to the slope below.

Figure 15. This partially removed stream crossing failed and delivered sediment to the stream channel because of the ineffective method used to convert the crossing to maintenance-free status.

Because the cross drains were placed at regularly spaced intervals, rather than in accordance with natural hydrologic patterns, they usually drain onto hillslopes lacking historic streamflow. These areas can experience gullying and mass wasting as concentrated runoff is directed downslope. Segmentation of road drainage can reduce large accumulations of runoff but measurements taken at several locations have noted discharges of up to 20 gallons per minute from a single cross drain during a moderate storm. The combination of high flow and unnatural placement of cross drains can be detrimental to the stability of the landscape. B&B Spur, for example, experienced a large landslide in January 2003 where a cross drain directed inboard ditch runoff and spring flow onto the slope below.

Maintenance-Free Road Monitoring

The generally good performance of the open road network within the Mill Creek Addition is due in large part to the level of monitoring and pro-active maintenance that has occurred under prior ownerships. The treatment applied to maintenance-free roads prevented land managers from monitoring road conditions, leading to the failure of numerous sites that may have been averted had the sites received necessary maintenance. Due to lack of monitoring and the poor decommissioning methods applied, the maintenance-free roads are critically unstable and in need of immediate treatment.

Assessment of LSEP Roads

We evaluated the maintenance-free roads as part of the property-wide road assessment. We collected the same geomorphic data on maintenance-free roads as for other roads within the acquisition. The second team did not assess the maintenance-free roads for upgrade and maintenance requirements because they had already been partially decommissioned and were not going to be redeveloped into usable roads.

We assessed 175 km of maintenance-free roads as part of our inventory, more than twice the number originally estimated by Stimson Lumber Company. The under-estimation on their part was probably a result of work that had occurred in the field and was never reported back to their GIS or property management staff. Based on our early conversations with Stimson representatives, it was common for road crews to initiate work on roads that were known to be "surplus."

LSEP Project Grouping

We developed the LSEP Plan to treat the 175 km of maintenance-free roads ahead of any other road removal work within the MCA (Plate 3). This was done for two reasons: 1) as a group, the LSEP roads were failing at a much higher rate than the open road network and could not be monitored or repaired to reduce the failure rate, and 2) roads to be removed within the open road network (non-LSEP) must be identified through a comprehensive planning process that includes a transportation element. LSEP roads are geographically grouped at the project planning level to minimize the distance between treatment roads. When grouping the roads, we consider the location on the property, logistics for treatment, and the potential for cumulative effects. By grouping the LSEP roads into project units, the geographic scope of each project group is confined, reducing the cost for project-level environmental surveys and equipment operations. Additionally, implementing project groups across the property within separate subwatersheds minimizes potential cumulative effects over time.

LSEP Roads removed to date

LSEP plan implementation began in 2004, and work has continued each summer of subsequent years with the amount of road removal fluctuating based on available funding. At the end of the 2010 summer season, 79.5 km of road had been removed with grant funding from California Department of Fish and Game, DPR, Save-the-Redwoods-League, State Water Resources Control Board, and the California Wildlife

Conservation Board (Plate 3). We intend to amend this Road Inventory and Assessment Report at regular intervals with road removal updates, and any other significant project work or information pertaining to the road system at the Mill Creek Addition.

HIGH RISK CULVERT UPGRADES

The 2002 to 2005 road inventory identified 729 culvert stream crossings throughout the Mill Creek Addition. Recommendations in the IMR (2002) called for "all road-stream crossings with high and very high erosion risk to be treated prior to the next large storm event to minimize the potential for significant impacts to aquatic resources." In 2005, we developed a culvert upgrade project to address subsets (phased projects) of 169 culverts in need of upgrading as soon as possible. The sites identified for this culvert upgrade project were selected prior to the development of the assessment model presented herein. We used selected culvert data form the road inventory and subjective field evaluations to initially rank all culvert crossings from 1 to 9 and from that ranking, selected the culvert crossings with a ranking of 7 or higher.

In addition to preventing chronic erosion and possible catastrophic failure and sediment delivery to streams, properly engineered road-stream crossings will reduce the amount of maintenance required over time. Replacement culverts are sized to convey discharge greater than the 100-year flow and to pass associated wood and bedload material. The approach roads to the crossings are reengineered to disconnect road drainage from the stream, and fail-safe dips are installed where necessary to prevent stream diversion.

To date, 13 critically undersized or failed culverts have been replaced since 2002 with grant funding from the State Coastal Conservancy and FEMA (Plate 3). A recently failed culvert on Rock Creek Road is scheduled to be replaced with a structural pipe arch in 2011 with grant funds from Redwood National Park.

SERPENTINITIC SOILS

Serpentinitic soils affect about 21 km of roads; 14 km traverse serpentinitic terrain and 7 km have base rock excavated from serpentinite quarries but are otherwise built outside of serpentinitic terrain. The serpentinitic soils are restricted to the east side of the Mill Creek Addition, near the Coast Range Thrust Fault (Figure 16). Asbestos bearing serpentinic soil presents a unique health hazard as inhalation of related air borne dust can cause lung cancer. Road rehabilitation in serpentinitic terrain and/or

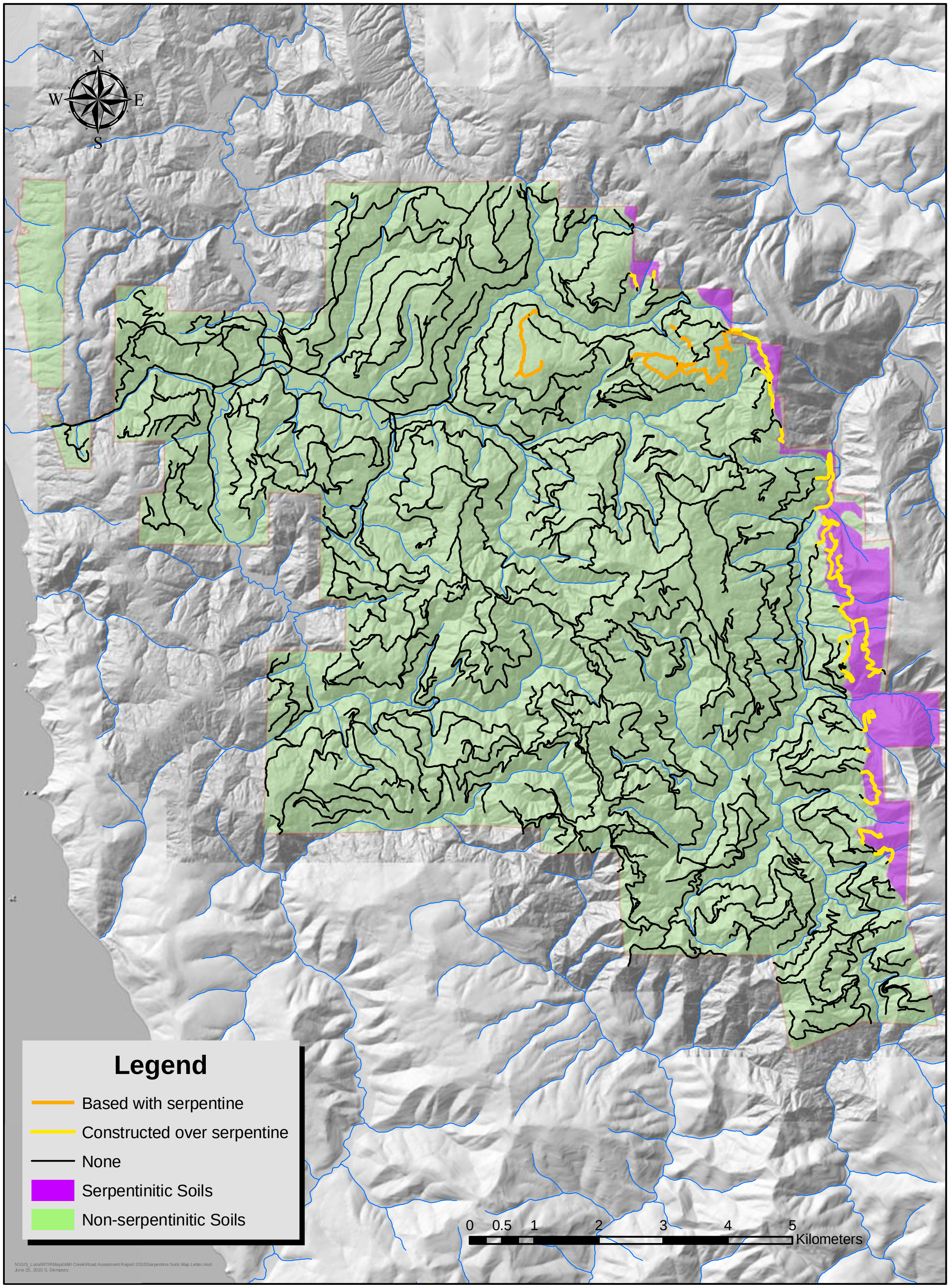

Figure 16. Distribution of serpentinitic soils

driving at excessive speeds on roads surfaced with serpentinitic rock can generate this dust. Operational methods to minimize exposure to rehabilitation workers are in place. Methods for informing the public and addressing worker safety will be evaluated in future planning efforts including a road and trail management plan.

TREATMENT OPTIONS FOR ROADS

Current and future planning efforts will determine what treatments will be considered for the roads remaining on the property following the LSEP program. The roads will generally fall into two categories: nonessential roads that will be removed and essential roads that will be upgraded and maintained as part of the permanent park infrastructure. Roads identified for removal may be completely removed or converted to trail. Some roads may receive a combination of removal treatments: converting some portions to trail while removing other portions completely and building a new trail to reroute unsustainable sections. Roads identified for upgrades (re-engineering, storm proofing) will receive a variety of treatments including reshaping the roadbed, eliminating the inboard ditch, hardening the driving surface, upgrading culvert crossing sites and rerouting where necessary. Road abandonment may be considered for some roads where current and future conditions along the road are likely to remain stable and no significant threat exists.

ECONOMIC ANALYSIS

A storm patrol crew will continue to operate on a seasonal basis to clear culverts, ditches and other drainage structures. Seasonal storm patrols are an essential, cost effective way to prevent road related sedimentation from the existing road network prior to upgrade. Currently, a four person crew with heavy equipment operates from November 1st though April 30th each year. Annual support costs for the storm patrol crew are $80,000.

We estimate that approximately 128 km of road will remain operational on the property for public access and administrative purposes in the long-term. Most of these roads are poorly designed with problematic drainage, inboard ditches, and undersized culvert road crossings and cross drains. Road upgrades will improve conveyance at road stream crossings, improve road surface drainage, reduce connectivity between roads and streams, and stabilize road fills. Using current contract and in-house costs and production rates tracked over the past 9 years, we estimate road upgrades will cost $15.5 million. Annual maintenance costs for 128 km of retained road will be $935,000 in their present condition. Once upgraded, maintenance costs will be reduced to an estimated $700,000 annually, which includes costs for annual grading, roadside brushing, and cyclic replacement of drainage structures.

The property contains 320 km of surplus roads. Over the next several decades road rehabilitation will take the form of road removal or conversion to trail. We estimate costs associated with removing or converting roads to trails to be $25 to $35 million depending primarily on the price of fuel which has the greatest effect on the cost of road work. Although road removal and conversion can be costly to implement, removing roads will save money over a relatively short term. We have tracked road removal project costs since 2004 and have compared those costs with maintenance costs for the same roads if left in place. On average annual maintenance costs required to keep the road stable will exceed the cost to remove the road in 9 years using constant dollars. Using a 3% inflation rate the cost recovery period drops to 7 years.

FUTURE PLANNING EFFORTS

Any future road or trail development will be evaluated as part of a road and trail management plan for the MCA. Road and trail planning provides an opportunity for public involvement to help define the vision for a road and trail system. In the Mill Creek Addition a dense road network already exists so it is unlikely that an extensive road construction effort will occur. However, no single track trails exist within the park and many opportunities exist for access and circulation. Although a few public circulation routes have been established by various user groups, none are currently classified as recreational trails. The routes follow abandoned or active road beds, some of which have become overgrown making them appear as single-track trails. The routes are currently maintained as trails by various user groups and may be incorporated into a park-wide trail system when the Road and Trail Management Plan is developed.

DISCUSSION

Our road inventory and assessment represents nine years of road data collection, management, and analysis. During this time we developed techniques for storing and cataloging road data that enable us to quickly and accurately query the large dataset. When we set out to design our inventory and assessment protocol we had three primary goals in mind: it had to be objective, repeatable, and dynamic. We knew that our initial inventory would be the first look at a road system that is likely to change dramatically over the next several decades. With those changes, we concluded, there would be a need to continuously update the inventory and perhaps reassess the road system. We believed that over time many different managers and technicians would be collecting and managing the data, so objectivity was a cornerstone of the data collection effort and the subsequent analysis. Repeatability also played an important role as we set up our protocols. We aimed to reduce the inefficiency associated with "reinventing the wheel" so we structured the data collection and modeling to be simple and repeatable with little need for extensive training. Lastly, we knew that the road system would be changing over time. Deterioration and catastrophic failure of the roads and sites, upgrading and routine maintenance of roads, and removal or conversion would result in changes to the road characteristics and the data that describe them. Also, the questions we might ask of the data could change over time, so the protocols had to allow for change without starting from scratch. We believe we have succeeded in accomplishing our design goals, making this inventory and assessment program usable by other land managers.

As the on-the-ground road management program took shape on the newly acquired property, our GIS-based road inventory was continuously updated and our assessment techniques were refined. As data gaps were discovered we were able to deploy additional field staff to collect missing or inaccurate data. Between 2005 and 2007 a property-wide LiDAR acquisition project was implemented, providing us with a much improved resource for our assessment. With the acquisition of the LiDAR digital elevation model in 2007, we made the last major revision to our data structure and began developing models for analysis and prioritization of the roads and road related sites within the Mill Creek Addition.

Developing analytic techniques that produced meaningful and appropriate results was challenging. Output from raster-based processing had to be integrated with point and line event tables. Our assessment often related the relative proximity of specific features of interest where physical processes operate in a topographic context. In addition, we used numerous attributes from four different site types to assign scores used to rank sites and roads. Scores were then normalized on two different scales to equally weight the components of the roads. Renormalized attribute scores for individual sites were validated against field conditions and scoring ranges were adjusted to reflect observations in the field. Rankings were produced using the final individual failure potential and threat scores. Lastly, we automated the process as much as possible to make updates manageable and repeatable. Now complete, the entire analysis can be re-run in a few automated steps as data is updated.

Needless to say, modeling and process development involved a lot of trial and error. Output from model runs at each step had to be carefully reviewed to look for inconsistencies and errors. An error not detected in one of the early steps often would propagate and compound as it moved through the process. Fortunately, reviewing the data at each step allowed us to evaluate the accuracy and validity of the output along the way making us confident that the end results are equally accurate and valid.

Our inventory and assessment results provide a tool for evaluating the roads within the Mill Creek Addition across a variety of applications. Prioritization of road treatments, whether road upgrading, conversion to trail, or road removal will enable us to make informed decisions in future management planning and project development. Individual site assessment will guide annual maintenance cycles and improve the sustainability of permanent roads within the MCA. As additional resource data such as vegetation series or wildlife habitat become available they can be integrated into our process to produce a comprehensive road management tool.

CRITICAL REVIEW

Looking back on our effort, we have identified some issues that we would improve were we to apply this inventory and assessment method to another road system. We provide this critical review so anyone wishing to develop a similar process will have the benefit of our hindsight.

As we collected the inventory data between 2002 and 2005 we found that some of the routes were incomplete or spatially inaccurate. In those cases we continued to collect data and used a measuring wheel to measure distance rather than revising the map tile in the GIS and remaining consistent with the existing measuring method. We did this because we felt we could hand digitize the roads with reasonable accuracy using landmarks and topography visible in the DEM and imagery available to us. GIS line-work revisions would have required office time to add or adjust the linework, reroute the line, reproduce the mapping tile, and revisit the field to repeat the road inventory. However, two years after the inventory was completed, the newly-acquired LiDAR based 1-meter DEM revealed that the hand digitized routes were not in alignment with the road prism. The lack of spatial accuracy does have an effect on the route score. The portion of the attribute score assigned by the DEM is only as accurate as the routed line work. For example, if a route does not accurately line up with the road prism on the DEM, then the slope value (taken 50 m downslope from the designated point on the route) may not actually be the slope 50 m below the road, it would be the slope 50 m downslope from where the line work is drawn. Looking back we would now agree that revising the GIS would have been a better choice.

When we set up the initial data collection field sheets, we endeavored to include all anticipated characteristics and configurations. Unfortunately we encountered some unanticipated scenarios and had to “shoehorn” them into our existing data scheme. For example, some crossing sites had two culvert pipes, so when we input the data, the database created two sites rather than one site with two pipes. As we completed the final model runs, we encountered minor inconsistencies in the output as a result of these anomalies. For example, the database table containing data on all stream crossings numbered 1,491 and the output of scoring values numbered 1,457. We know that the omissions were caused by some records not exactly matching a query somewhere within the model. To locate and incorporate the individual omissions would require some effort to find each record, and then queries would need to be modified to include the anomalous data. Although it is not possible to predict all scenarios or configurations at the start of such an effort, once they are identified, an evaluation of how they might affect modeling should be considered early on. Whenever possible models should be developed that can be adapted to minor data anomalies.

Although the LiDAR-based DEM represents a notable improvement in our understanding of the geomorphic character within the Mill Creek Addition, the underlying data has demonstrated significant shortcomings. The problems have so far limited our ability to use the 1-meter resolution DEM to run some tools and models through ArcMap™ such as the watershed tool and the SINMAP model. The source of the problems with the data are numerous and too complex to discuss here but appears to be a combination of poor data acquisition and delivery of a "cleaned" dataset to the clients. As future data acquisition projects are planned, it will be essential to specify the content and form of the data to be provided by the vendor.

We recommend that future effort be made to further narrow or specifically quantify calibration parameters across the seven different soils regions of the Mill Creek landscape, specifically the minimum and maximum cohesion values and angle of internal friction. In general, we expect the soils of the roughly 2,500 acres in regions 5-7 to be less cohesive with lower angles of internal friction due to soils characteristics and more rounded rock fragments than the remaining majority of the property, which may warrant a two-region calibration theme. While the SINMAP input to the attribute scoring matrix is not presently a significant factor by itself, it would be valuable to develop a slope stability map based upon all best available data. We recommend that comparisons be made with output produced by a resampled 5-meter LiDAR-derived DEM and multi-region calibration themes with various defensible input parameters. Further statistical analysis may warrant adjusting the breakpoints of the slope stability output classifications

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GLOSSARY

ABANDONED ROAD

Road lacks obvious maintenance. Ditches may lack cleaning and vegetation may be encroaching the road and road surface. Culverts may be partially or completely plugged, badly rusted or crushed. The road is typically not drivable without improvements.

ABUTMENT

Foundation at either extreme end of a bridge that supports the stringers.

ACTIVE DIVERSION

A condition originating at a stream crossing, where stream flow overtops the road and flows down a road, inboard ditch, or skid trail instead of re-entering its natural watercourse. Stream diversions can cause significant gully and landslide erosion.

ALIGNMENT

The area affected by a road or trail including the fill slopes, road bench, and cut bank. Also a linear representation of features on a map such as a stream channel.

AGGRADE

Refers to the filling of a stream channel with sediment. This usually happens when the supply of sediment is greater than the stream is transporting. Compare to “degrade” and “graded stream”.

ARMORED

A feature that is covered with coarse rock to reduce surface erosion. Some armored structures may also include geotextile fabric as a baking for the coarse rock. Armored features can sustain flow across their surface without experiencing significant erosion or incision.

ATTRIBUTES

The various physical characteristics of a site. Attributes are the basic physical elements that define the site and are used to generate site scores.

BERM

A general term used to describe a constructed mound of earth typically long and narrow in shape. Berms can form a barrier along the edges of roads and can confine runoff along a road.

BARRIER BERM

A large earth or rock berm pushed up across a road to inhibit vehicular traffic. Barrier berms are often referred to as “tank traps”.

BREAK-IN-SLOPE

At the convex break in slope. The slope above is gentler than the slopes below.

BRIDGE

A structure, including supports, erected over a depression or stream, and having a deck for carrying traffic. May have railings.

CLIMBING TURN

A turn that is constructed on a slope of 30 per cent or less when measured between the exterior boundaries of the turn and changes the direction of the road 120 - 180 degrees.

COST-EFFECTIVENESS

The cost per unit volume of sediment to prevent it from entering a stream, commonly expressed as cost per cubic yard “saved”.

CRITICAL DIP

A broad rolling dip located at a stream crossing that returns streamflow to its natural watercourse if the crossing culvert plugs and streamflow overtops the road. It is a broad, gentle, permanent dip (low spot) across the road surface that allows passage of vehicles, logging trucks and standard logging equipment. They are generally maintenance-free.

CROSS DRAIN CULVERT
A culvert installed just below road grade that intercepts and conveys water from the inboard ditch to the outside embankment edge of the road. Typically placed at frequent intervals (150-300 feet) to disconnect and drain ditch flow. Compare to open cross drain.

CULVERT
A metal, plastic or concrete pipe set below the road surface. Is used to pass streamflow from upslope of the road to downslope of the road. Culverts can also be placed to drain springs and inboard ditch flow from the inside to the outside of the road, beyond the outer edge of the road fill, or fillslope.

CUTBANK
The portion of the hillslope on the upslope side of the roadbed that has been cut into bedrock or native soil.

CUTBENCH
The portion of a roadbed that has been cut into bedrock or native soil. Compare with embankment.

DECOMMISSION
See road decommissioning.

DEGRADE
Refers to the erosion of a stream channel. This usually happens when the supply of sediment is less than the amount the stream is transporting. Compare to “aggrade” and “graded stream”.

DELIVERY
The amount, expressed as a percentage or ratio of material (sediment) that is delivered to a stream from a site. Also labeled as Sediment Delivery Ratio (SDR). The percentage is an objective estimation based on site conditions including but not limited to slope steepness, ground water emergence, road drainage, fill materials, adjacent instability, and vegetative cover.

DIVERSION POTENTIAL

Normally associated with stream crossings that have continuous road grades through the crossing which allow a stream to flow down a road if the crossing culvert plugs and streamflow overtops the road. The crossing is not the low point of the road as the road passes over the stream channel. Existing diversion potentials can be corrected by installing well-constructed critical dips at the crossing so that streamflow returns immediately to its stream channel if diversion occurs. Proper crossing construction (grade-breaks, critical dips, minimum fill, properly sized culverts) can prevent diversions.

DOWN DRAIN

Normally culvert material bolted and secured to the culvert outlet that conveys water down a fillslope to undisturbed ground to prevent surface erosion. Downspouts may be either full-round or half-round.

DRAIN LENS

A sub-grade drain structure composed of coarse rock extending from the inboard edge of the road to the outboard edge. The coarse rock is covered by geotextile fabric and then covered by road base aggregate. Drain lenses are often used to drain seeps or springs under a road without the need for a culvert cross drain.

DRAIN SWALE

Topographic dip in the road that is matched to a minor natural swale upslope of the road. Drain swales are designed to carry only minor flows during runoff events.

DUFF

A layer of decaying organic plant material deposited on the surface of the ground principally comprised of leaves, needles, woody debris, and humus.

EMBANKMENT

Fill excavated from the cutbench and used to construct the outboard road bench. This is often referred to as the fill slope, outboard fill material, or sidecast material.

ENDHAULING

Transportation of excavated material to a stable storage location using a dump truck.

ENTRENCHED

Describes a road or trail that is below the grade of the surrounding ground surface. Roadbed is lower in center than on both sides. Rilling or gullies can occur if a long section of road is entrenched with no outlet. Because ground level is higher on both sides, drainage flows down the road or trail or inside ditch.

ENERGY DISSIPATOR

Material such as rock riprap or a structure made of logs, metal pipe, or poured concrete that is used to reduce the energy of flowing water below culvert outlets or dips.

EROSION VOLUME

The amount of material that could erode from a site. It is expressed in cubic meters. It is used with delivery to calculate yield.

EXTREME EROSION POTENTIAL

A relative ranking of the capability of a site to erode significantly more volume than is estimated in the feature’s dimensions alone (erosion volume). Expressed as “high”, “medium” or “low.” A high potential for extreme erosion is a worst case scenario that identifies the capability of an unusually large magnitude failure during the next major storm. An example might be a stream diversion that would end up draining onto a landing that may catastrophically fail, scouring hillslopes or channels below. Compare to future erosion potential.

FALL-LINE

An imaginary line on a sloped surface that follows the steepest angle. You can think of the fall-line as the line that would be made by a marble rolling down the slope.

FILL

Material used to construct roads and related structure. Fill can include soil, rock, large organic debris, and man-made objects such as cars, etc.

FILLSLOPE

Area of excavated material cast on the downslope side of road cut (also called embankment).

FORD

A road-stream crossing that requires a vehicle to drive across and through a stream channel bed. There is no fill or drainage structure in a ford crossing and can be armored to stabilize the roadbed through the stream.

FUTURE DELIVERABLE VOLUME

This volume represents total future sediment that will likely be delivered to a stream channel from the site during the next major storm. It is calculated by multiplying the erosion volume at a site by the delivery percentage (e.g. 800 m3 erosion volume x 80% delivery = 640 m3 future deliverable volume). Also called “site potential yield”.

FUTURE EROSION POTENTIAL

The subjective ranking of the likelihood of erosion at a site during the next major storm. Expressed as “high”, “medium” or “low.” Compare to extreme erosion potential.

GEOMORPHOLOGY

The study of the earth’s surface and the processes that shape it. Geomorphology is closely related to geology.

GEOMORPHOLOGIST

A person who studies geomorphology.

GRADE

The proposed, or planned ground surface. Usually grade is set to match the surrounding topography or stream gradient.

GRADED STREAM

A stream that over a long period of time can move as much sediment as is supplied to it. Compare to “aggrade” and “degrade”.

GRADIENT

The measurement of the angle along the length of a road, natural slope or a stream. This term is often confused with grade (see definition).

GULLY

A steeply sided channel caused by erosion from surface runoff or a diverted stream channel. Gullies can usually be identified by their location away from natural stream valleys. Gullies are at least 1 square foot in cross-sectional area. Compare with rill.

HEADWALL

A steep slope or precipice rising at the head of a valley or swale, characterized by broad steep converging slopes. They are generally unchannelized.

HUMBOLDT CROSSING

A stream crossing constructed with logs set parallel to the stream channel and covered with fill. Stream flow passes through the logs under the fill.

HYDROLOGY

The science of water found on the surface of the earth and in the atmosphere. This term is often confused with hydrogeology, which is the science of groundwater.

INBOARD

The side of a road or other slope feature that is on the inside or close to the slope - toward the upslope direction.

INBOARD DITCH

A drainage ditch cut along the inboard edge of the road that collects and conveys road surface runoff, slope runoff, small streams and spring discharge. Inboard ditches convey runoff to the next cross drain culvert or stream crossing down the road.

INSLOPE

Where the road bed is sloped downward toward the inboard side.

LANDING

A location where logs are collected and loaded onto trucks for transport. Landings are typically located along haul roads and are seen as a “wide spot” in the road. Landings are most often constructed with typical cut/fill techniques but have a large embankment fill volume due to their size, and typically contain a higher concentration of large woody debris (LWD) than regular road embankment fill because tree limbs and discarded pieces from logging operations were typically pushed over the outboard edge for removal from the work area.

LARGE WOODY DEBRIS (LWD)
Also known as large organic debris (LOD), refers to logs and stumps found in stream channels, road fills, etc. The term “large” can refer to anything from a 4” tree trunk to a 200” redwood log.

MASS WASTING
A general term that includes many types of mass earth movements. These include rockslides, debris slides, debris flows, and earthflows, etc.

OPEN CROSS DRAIN
A deep, abrupt ditch constructed across a road to drain water from the road surface and/or inboard ditch. Generally, not drivable and placed at frequent intervals (approx. every 50 - 100 feet) on permanently closed roads. Compare to rolling dip and water bar.

OPEN ROAD
Road is passable to a standard four-wheel drive vehicle during dry weather without clearing brush or making other improvements. Road typically shows evidence of recent maintenance including clearing culvert inlets and inboard ditches, grading, rolling dip or waterbar reconstruction, and or brushing.

OUTBOARD
The side of a road or other slope feature that is on the outside or away from the slope - toward the downslope direction.

OUTSLOPE
A road surface that is shaped to slant toward the outboard edge of a road. The slanted surface naturally disperses surface runoff. A road that is outsloped may or may not be drivable depending on the intent of treatment. Outsloped road may or may not have an inboard ditch.

OUTSLOPING

The act of changing a flat or insloped road to an outsloped road. For erosion control treatments, substantial fill is removed from the outer edge of the road prism, and spread and shaped along the inside edge of the road, typically against the cutbank. For surface drainage on active roads, the road surface has a mild outslope that is drivable by logging trucks and forms a relatively maintenance-free road surface that disperses road surface runoff.

PERMEABILITY

A measure of the rate at which water can pass through soil.

RAVEL

The rolling, bouncing, and sliding of individual particles down a slope and the dominate hillslope process in steep, arid, and semiarid landscapes. Ravel is commonly referred to as dry ravel and operates in the absence of water.

RILL

A small erosional feature similar to a gully in morphology but less than 1 square foot in cross-sectional area. Rills often form on soft bare soil or road surfaces. Compare with gully.

REMOVED ROAD

Road that has been physically removed from the landscape and is no longer accessible to vehicles (see road removal).

ROADBED

The surface of the road where driving takes place.

ROADWAY

The corridor of the road within the limits of excavation and embankment, including the cutbank, the inboard ditch, the roadbed, and the outboard fill.

ROAD DECOMMISSIONING (DECOMMISSION)

The treatment of a road to eliminate stream diversions and minimize erosion and sedimentation typically during periods of non-use. A decommissioned road has all culverts removed, all road fill at stream crossings fully excavated and road surface drainage provided by a combination of outsloping, rolling dips or cross road drains. A road is typically decommissioned when a road will not be used for a period of time but will be used at some time in the future, however a road may be permanently decommissioned.

ROAD OUTSLOPING

The treatment of a road to eliminate collection or diversion of water along the roadbed and provide uniform sheet drainage. Outsloping can be prescribed for roads still in use or roads that are no longer used. See outsloping.

ROAD REENGINEERING (ROAD UPGRADE)

Improving a road to current road building standards with the intent of reducing erosion from roads and minimizing annual maintenance required. Reengineering includes; replacing rusted, plugged and undersized culverts, installing culverts on the natural stream grade to facilitate sediment and runoff conveyance, reshaping roads for proper drainage (road outsloping), constructing critical dips at crossings to prevent stream diversions, pulling back steeply perched road or landing fill that can enter a stream, reducing road fill volumes at stream crossings and others.

ROAD REMOVAL

The treatment of a road that completely recovers unstable side-cast fill and stabilizes the fill within the original cutbench. Stream crossing fill is excavated, and all excavated materials are placed in stable locations along the cutbank. This type of treatment is also referred to as road recontouring or road obliteration. Sometimes called road obliteration.

ROAD SURFACE

The material, native or placed, that comprises the top layer of the roadbed (see surfacing).

ROLLING DIP

A broad, shallow, gentle dip (low point) in the road surface that collects road surface runoff and conveys it to the outer edge of the road. It can also drain an inboard ditch. Rolling dips are drivable at slow speeds without abrupt bumps in the road surface.

RUNOFF

Rainwater flowing on the surface of the ground. Runoff can be generated by rain falling on saturated ground or from heavy rain that cannot soak in fast enough.

SEDIMENT

Silt, sand, clay, and gravel that is moved by water or air and deposited at some location.

SEDIMENT DELIVERY RATIO (SDR)

See delivery

SEDIMENT PLUG

Depositional sediment upstream of a crossing. Early road building included stream crossings with drainage features installed at a lower gradient than the natural stream channel. As stream flow approaches the lower gradient reach, it loses energy and deposits the sediment upstream of the drainage feature.

SLOPE ANGLE

The angle of the hillslope measured in percent or degrees along the fall-line.

SKID TRAIL

Small single-lane tracks that develop as ground-based equipment moved logs across harvest units. Skid trails are not constructed like haul roads; they lack a constructed road bed and follow, rather than cut through the surrounding topography.

SOIL

The uppermost layer of decayed organic matter, clay, silt, sand, air, water, and weathered rock mixed in various proportions. Soil consists of horizons or layers that display different amounts of weathering and fertility.

SPOILS

Soil and organic material that is excavated from stream crossings or road embankments that is used for recontouring or can be end-hauled to a stable storage location.

STREAM CROSSING

A constructed road section across a natural stream. There are many types of crossings such as bridges, culverts, Humboldt (see definition), and fill crossings. A stream crossing includes all locations where a road crosses a channel, whether or not water is flowing, and whether or not a drainage structure has been provided.

STREAM DIVERSION

A condition where streamflow has been diverted from its natural watercourse (see active diversion).

STRINGER

Log or timber that rests on bridge abutments, spans the watercourse, and supports the tread surface of bridge.

SURFACING

Rock aggregate or paving that is placed on the road surface to reduce erosion and weatherproof a road for winter use.

SWALE

A concave or spoon shaped hollow on the hillslope lacking channelized flow and does not exhibit stream banks separate from stream channel. It is the headwaters to the stream channel forming some distance downslope.

SWALE CROSSING

A constructed feature where a road crosses a topographic swale. The crossing may be composed of road fill without a drainage structure or may be composed of buried logs (Humboldt crossing), a culvert, a ford, or in some rare cases, a bridge.

SWITCHBACK

A turn that is constructed on a slope of more than 30 per cent when measured between the exterior boundaries of the trail 120 to 180 degrees. The landing is the turning portion of the switchback. The approaches are the road sections upgrade and downgrade from the landing.

THROUGH-CUT
A portion of a road that has cutbanks on both sides with drainage flowing down the road or inside ditch.

TOPOGRAPHY
The natural shape of the land's surface.

TURNPIKE
A section of road built by elevating the constructed roadbed above wet, boggy areas by importing soil.

WATER BAR
A shallow ditch or berm constructed across a road or skid trail that drains the road surface and/or inboard ditch. It is not a permanent structure as they tend to break down with any type of use, including wildlife tramping. They are insufficient to prevent stream diversions at crossings.

WINTERIZED ROAD
A road that has received a particular method of partial road decommissioning employed by Stimpson Timber company in the late 1990's prior to DPR ownership. The method consisted of partial removal of stream crossing fill and large cross drain waterbars that segmented road and ditch drainage. See discussion of "maintenance free" roads under LSEP section in main report.

YIELD
The amount of sediment that reaches a stream channel after eroding from a site. It is expressed in cubic meters and calculated by multiplying the erosion volume and delivery ratio.

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APPENDIX A

MILL CREEK ADDITION

AIR PHOTO INDEX

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Table A1. Mill Creek Addition air photo collection.

		Full Collection	Indexed	Missing	Duplicate	Non-Indexed
Series	Flight Line	Photo Numbers	Photo Numbers	Photo Numbers	Photo Numbers	Photo Numbers
1997 HUM - 97	13A	1-10		5-7		1-10
	14B	1-16	1-16			
	15B	1-21	1-21			
	16A	5-27	5-27			
	17A	12-34	12-34			
	18A	14-47	25-35, 37-45	36		14-24, 46-47
	19A	18-57	33-54			18-32, 54-57
	20A	19-58	33-45, 47-52	46		19-32, 53-58
	21A	48-83	62-80			48-61, 81-83
	22A	45-75	57-70			45-56, 71-75
	23A	50-78	58-65, 67-72	66		50-57, 73-78
	24A	58-77	61-77			58-60
1995 USDA - 5	195	111, 113				111, 113
1994 HUM - 94	13A	1-10				1-10
	14B	1-18	7, 8, 14-18	9-13		1-6
	15B	2-23	10-23			2-9
	16A	9-30	9-21, 23-30	22		
	17A	16-34	16-34			
	18A	26-44	26-44			
	19A	32-52	32-47, 49-52	48		
	20A	32-53	32-38, 42-53	39-41		
	21A	53-76	55-76			53,54
	22A	53-74	53-70			71-74

Table A1 cont.

		Full Collection	Indexed	Missing	Duplicate	Non-Indexed
Series	Flight Line	Photo Numbers	Photo Numbers	Photo Numbers	Photo Numbers	Photo Numbers
	23A	59-82	59-78			79-82
	24A	61-76	61-76			
1990 Rellim	1	1-6	1-6			
Mill Creek	2	1-7	1-7			
	3	1-6	1-3, 5-6	4		
	4	1-14	1-14			
	5	1-15	1-15			
	6	1-13	1-13			
	7	1-14	1-14			
	8	1-13	1-13			
	9	1-11	1-11			
	10	1-7	1-7			
1988 C - HUM - 88	B1	1-5	1-5			
	B2	1-7	1-7			
	B4	1-6	1-6			
	B7	11-20	11-20			
	B11	12-22	12-22			
	14	26-39	26-39			
	16	30-45	30-45			
	18	30-42	30-42			
	B20B	16-29	16-29			
	23	36-43	36-43			
1986 Mill Creek	1	1-5	1-5			
	2	1-7	1-7			7 “Smith River”
	3	1-6	1-6			
	4	1-11	1-2, 4-11	3		
	5	1-11	1-11		3	
	6	1-11	1-11			
	7	1-10	1-3, 5-10		4	
	7A	1				1
	8	1-10	1-10			

Table A1 cont.

		Full Collection	Indexed	Missing	Duplicate	Non-Indexed
Series	Flight Line	Photo Numbers	Photo Numbers	Photo Numbers	Photo Numbers	Photo Numbers
	8A	1				1
	9	1-11	1-11			
	10	1-10	1-10			
1984 MR - 84	01	1-14	1-14			
	02	1-7	1-7			
	03	1-8	1-8			
	04	1-14	1-14			
	05	1-14	1-14			
	06	1-14	1-14			
	07	1-10	1-10			
1982 RRU - 82	101	1-5	1-5			
	102	1-6	1-6			
	103	1-6	1-6			
	104	1-10	1-10			
	105	1-10	1-10			
	106	1-10	1-10			
	107	1-12	1-12			
	108	1-11	1-11		2	
	109	1-9	1-9		2	
	110	1-7	1-7		2	
1980 DNC - 80	6	1-9	1-9			
1980 RRU - 80	102	1-9	1-9			
	103	1-9	1-9			
	104	1-13	1-13			
	5	1-14	1-14			
	106	1-15	1-15			
	107	1-18	1-18			
	108	1-17	1-17			
	109	1-14	1-14			
	110	1-10	1-10			

Table A1 cont.

		Full Collection	Indexed	Missing	Duplicate	Non-Indexed
Series	Flight Line	Photo Numbers	Photo Numbers	Photo Numbers	Photo Numbers	Photo Numbers
1978 DNC 8-6-78	17	1-5	1-5			
	18	1-7	1-7			
	19	1-11	1-11			
	20	1-9	1-9			
	21	1-9	1-9		1	
	22	1-10	1-10			
	23	1-12	1-12			
	24	1-13	1-13			
1978 DNC 9-1-78	18	0				0
	23	13-16	13-16			
	24	14-16	14-16			
	25	5-11	5-11			
1975 DNC - 75	6A	31-36	31-36			
	7	40-43	40-43			
	8	40-45	40-45			
	9	43-54	43-54			
	10A	8-17	8-17			
	11	35-46	35-46			
	12A	9-23	9-21, 23	22		
	13A	8-21	8-21		10-21	
	14	25-37	25-37		25-37	
1972 DNC 822 - 72	11-8	15,16				15,16
	11-9	25,26				25, 26
	12-11	29				29
1969 DNC - 69	50-6	10-14	10-14			
	50-7	13-17	13-17			
	82-8	17-19	17-19			
	82-9	20-31	20-31	30		
	82-10	27-38	27-38			

Table A1 cont.

		Full Collection	Indexed	Missing	Duplicate	Non-Indexed
Series	Flight Line	Photo Numbers	Photo Numbers	Photo Numbers	Photo Numbers	Photo Numbers
	78-11B	9-19	9-19			
	78-12B	12-23	12-23			
	83-13	16-36	16-18, 25-36			
	78-14A	26-38	26-38		32-34	
	78-15A	25-36	25-36			
1966 AV - 712	01	01-07	01-07			
	02	01-13	01-13			
	03	01-14	01-14	04,05		
	04	01-14	01-14	03-05		
	05	01-11	01-11			
	06	01-11	01-11			
1964 DNC - 3	7	8-12	8-12			
	8	11-17	11-17			
	9	14-24	14-24			
	10	23-29	23-29			
	11	25-35	25-35			
	12B	22-33	22-33			
	13	23-35	23-35			
	14	23-33	23-33			
1958 DN	6	6-10	6-10			
	7	5-33	5-15	16-25, 27, 28, 31		26, 29, 30, 32, 33
	8	10-37	10-17	18, 20, 22-31		19, 21, 32-37
	9	16-28	16-28			

Table A1 cont.

		Full Collection	Indexed	Missing	Duplicate	Non-Indexed
Series	Flight Line	Photo Numbers	Photo Numbers	Photo Numbers	Photo Numbers	Photo Numbers
	10	21-33	21-33			
	11	22-35	22-35			
	12	23-35	23-35			
	13	22-33	22-33			

APPENDIX B

MILL CREEK ADDITION

ROAD ASSESSMENT FORMS

DEFINITION OF TERMS

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These road assessment forms and accompanying definitions were developed by State Parks specifically for inventories in the Mill Creek Addition to Del Norte Coast Redwoods State Park beginning in winter, 2002.

ROAD CONDITION DATA – CONTINUOUS VARIABLE WORKSHEET

USABILITY:

Record the current usability

OPEN

Road is passable to a standard four-wheel drive vehicle during dry weather without clearing brush or making other improvements. Road typically shows evidence of recent maintenance including clearing culvert inlets and inboard ditches, grading, rolling dip or waterbar reconstruction, and or brushing.

ABANDONED

Road lacks obvious maintenance. Ditches may lack cleaning and vegetation may be encroaching the road and road surface. Culverts may be partially or completely plugged, badly rusted or crushed. The road is typically not drivable without improvements.

WINTERIZED

Road has been partially decommissioned and no longer part of the transportation network. Fill excavated from the crossings is pushed into large piles on one or both sides of the crossing site. Partial removal of stream crossing fill and large cross drains (tank traps) segment road and ditch drainage.

RECONTOURED

Road has been removed and is no longer accessible to vehicles. Sidecast material was retrieved, stream crossing fill material was excavated, and all excavated materials were placed in stable locations, shaped, and blended to match the surrounding topography.

SURFACE:

Record the dominant road surface material: asphalt, gravel, or soil (native material).

SURFACE CONDITION:

Record condition of road bed: poor, fair, or good.

WIDTH (m):

Record appropriate width class (3-5, 5-8, 8-12, or greater than 12) for width of road from inside edge where cutbank meets inboard ditch or road bed to outside edge of fill.

EMBANKMENT VOLUME: m^3/m:

Estimate unit volume of sidecast fill material on outer edge of road. Enter number as estimated.

GRADE %:

Using clinometer, record grade of road in direction of travel and indicate all significant changes in grade, especially through crossing approaches. Grade is always recorded as negative for traveling downslope from start address, or positive for traveling upslope from start address.

PITCH:

Pitch is the angle of the roadbed from edge (cutbank) to edge (embankment).

INSLOPED

Roadbed slants downward toward inboard ditch.

OUTBOARD (OUTSLOPED)

Roadbed slants downward toward embankment edge of road.

OUTBOARD BERMED

Road is outsloped with bermed outer edge.

FLAT

Road bed has level driving surface with no obvious slant.

ENTRENCHED

Roadbed is lower in center than on both sides. Rilling or gullies can occur if a long section of road is entrenched with no outlet. See tread drainage below.

CROWNED

Roadbed is elevated in center allowing surface flow to drain evenly off both sides.

INBOARD DITCH:

Record current status of inboard ditch: open, vegetated, armored, gullied, filled, double (inboard and outboard), or none.

VEGETATION LOAD:

Record current status of vegetation load by giving a relative ranking of high, medium, or low based on tree size and spacing, presence or absence of understory, load of down wood, and size and density of stumps.

ROAD DRAINAGE:

Record the dominant road drainage process taking place over given segment of road:

TREAD DRAINAGE

Common road surface drainage where water flows with grade of road and may collect in slight tire depressions.

RILLS/TIRE RUTS

Surface drainage collects water in tire ruts or rills. Typically found on segments with steeper grade and/or unprotected roadbed, combined with entrenchment.

ROAD GULLY

Rills and/or tire ruts often combine to develop into gullies. Occasionally, channelized flow will divert onto the road bed creating a gully. Road drainage is considered road gully once erosional scour has reached an approximate size of one foot wide and one foot deep or larger.

WATERBARS

Road and/or ditch drainage is segmented by bermed cross drains. Drains can either be large ‘tank traps’ preventing vehicle travel or small ‘grooves’ that can be driven over. If a segment of road is usability: winterized; it has by definition road drainage: water bars.

INSLOPED/DITCH

Only use with a road pitch that is insloped. Road drains along pitch, toward inboard ditch instead of draining along grade of road.

OUTSLOPED/NONE

Only use with a road pitch that is outsloped. Road drains along pitch, toward outboard edge instead of draining along grade of road.

ACTION:

Recommend a particular course of action: monitor, clear, remove, replace or install for the following feature.

ACTION FEATURE:

Record the feature: road base, inboard ditch, inboard pitch, or outboard pitch.

Route Name:
Date:

Surveyed by:
Pages:

Address	Usability	Surface	Surface Condition	Width	Embankment Volume	Grade	Pitch	Inboard Ditch	Vegetation Load	Road Drainage	Action	Action Feature
0.00												

Figure B1. Continuous Variable Worksheet. This form was used to record continuous road data for all roads in the Mill Creek Addition. Any change in one or more of the variables listed in the column headers triggered an entry with the address noted.

MILL CREEK ADDITION – ROAD ASSESSMENT FORM – SHEET 1

Form version.1/14/04

ADDENDUM TO DEFINITIONS: SUMMARY OF CHANGES SINCE LAST VERSION (12/30/02)

WATER CROSSING SITE:

Added check box for "Crossing Data Sheet Completed". This box should be checked if additional water crossing dimensions and data were collected and recorded on the Stream Crossing Volume Worksheet. These data and worksheets were used as an initial alternative method to estimating stream crossing volume. Data were used to create a scale drawing of crossing profile from which to measure upstream and downstream fill depth.

TOP MARGIN AREA

DATA ENTRY BY:

Initials of person that entered datasheet into database. To be filled out by office technician after entry into database, not by field technician.

DATE ENTERED:

Record date assessment form was entered into database. To be filled out by office technician after entry into database, not by field technician.

ROUTE NAME:

The existing name assigned to the road as attributed in GIS line work (N:\GIS_Data\Agency\rnsp\roads\roads_rnpx, Feature Class: route.millroad)

SURVEYED BY:

Initials of person(s) collecting field data (example SEW/DRP)

SURVEY DATE:

Date of field data collection, in MM/DD/YYYY format (06/17/2003).

SITE TAGGED:

Put a check in box to indicate whether a yellow aluminum tag with start address was nailed or attached to a nearby tree.

CHECK:

Put a check in box if the site warrants review by a more experienced person. It would assist the reviewer to record the issue of concern (if possible) in the comments area at the bottom of form page.

ASAP:

Put a check in box if the site should received treatments immediately to prevent further loss of the road or other resource.

CRITICAL:

Put a check in box if site failure appears imminent and would likely result in loss of road, crossing, extreme sediment delivery, or loss of access to a section of the park.

FEATURE ADDRESS:

Enter start address for point features, or start and end address for interval features.

POINT FEATURE:

Put a check in box if site is a crossing. All other features should have an interval address.

WATER CROSSING SITE

FEATURE:

Circle whether crossing is a swale or stream. A swale is a concave or spoon shaped hollow on the hillslope lacking channelized flow and does not exhibit stream banks separate from stream channel. It is the headwaters to the stream channel forming some distance downslope. Stream crossing includes all locations where a road crosses a channel, whether or not water is flowing, and whether or not a drainage structure has been provided.

ACTIVE DIVERSION:

Put a check in box if water or evidence of water is presently diverted from its natural channel at the inventory site.

DIVERSION POTENTIAL

Circle Y if the road grade is continuous through the crossing so that stream could flow down the road, away from the crossing, if a culvert plugs. Record N if the crossing is the low point in the road (road slopes uphill away from both sides of the stream) or if the stream cannot divert if the culvert plugs.

TYPE:

Circle appropriate type of crossing feature.

Bridge

Road is on a structure that spans stream, supported by abutments on either side of the channel. Bridges may be constructed of railroad flatcars, log stringers, or metal beams. The driving surface may be covered with wood decking or covered with a blanket of 2 – 4 feet of fill.

Culvert

The stream crossing consists of a pipe buried beneath the road to convey the stream flow through the road. Culverts may be aluminum, galvanized metal, concrete or plastic. Pipe may be located slightly downroad from stream channel centerline, but is usually within crossing fill hinges. Circle culvert if present regardless of other drainage features (i.e. Humboldt logs).

Humboldt

Crossing is constructed of logs laid parallel to stream flow and covered with fill. Stream flow passes through the logs. It is possible to have both a Humboldt crossing and a culvert together at a stream crossing. However, in those cases, circle culvert.

Fill

The crossing is composed of fill material lacking a structure for passage of stream flow. This type of crossing is more common in swales lacking perennial flow.

Armored crossing

Crossing fill has been placed in the stream channel for vehicle access and armored such that water flows over the fill without great risk of eroding the fill. Visible crossing material is comprised mainly of rock and boulders and does not contain other drainage structures.

Armored swale
Same as armored crossing, but in a swale setting.

Drain swale
Topographic dip in the road that is matched to a minor natural swale upslope of the road. Drain swales are designed to carry only minor flows during runoff events.

Drain lens
A sub-grade drain structure composed of coarse rock extending from the inboard edge of the road to the outboard edge. The coarse rock is covered by geotextile fabric and then covered by road base aggregate. Drain lenses are often used to drain seeps or springs under a road without the need for a culvert cross drain.

Rolling dip
A broad, shallow, gentle dip (low point) in the road surface that collects road surface runoff and conveys it to the outer edge of the road. It can also drain an inboard ditch. Drivable.

Open cross drain
A deep, abrupt ditch constructed across a road to drain water from the road surface and/or inboard ditch. Generally, not drivable and placed at frequent intervals (approx. every 50 - 100 feet) on permanently closed roads.

EROSIONAL PROCESS:

Select the most appropriate process causing erosion. Select only one process that best represents the current situation.

None
There is no evidence of erosion or potential erosion currently at the site.

Gully
Gullies are a newly formed erosion feature caused by surface water flow. They are greater than 1 foot wide by 1 foot deep. A gully can be identified by its location away from the natural stream channel. Smaller erosion scars formed by surface flow are rills and may indicate potential for development into gullies if conditions are right.

Streambank

Select this process if the natural channel is undergoing accelerated erosion. Evidence would be raw channel banks – oversteepened and unvegetated.

Collapsing

A stream crossing will collapse as a culvert or Humboldt structure begins to fail. Sink holes develop and road fill will fall through into the drainage structure and be transported downstream.

Fill Failure

The edge of the stream crossing – within the hinge lines - is failing as a mass movement (landslide).

Undercutting

When a culvert bottom is rusted, it can develop holes and allow stream flow to erode fill from directly beneath the culvert leaving unsupported fill above. Undercutting may also occur if a culvert outlet is significantly (>3 ft.) above the channel bed (shotgun outlet) and is causing erosion of the stream channel or crossing fill directly below the culvert outlet.

SEDIMENT TRANSPORT: L M H

Circle H if there are obvious signs of high bedload transport during recent past years. Indicate the relative amount of sediment transported through the reach – not the ability of the stream to transport it. Consider upchannel sources for the sediment. Record as L if there is moss growing within the channel bed.

UPSTREAM SEDIMENT PLUG: Y N VOLUME______(m^3)

Circle Y if there is depositional sediment upstream of the crossing and record the volume in the space provided. If there is no sediment deposited upstream of the crossing site, circle N.

ADJACENT INSTABILITY: Y N

Circle Y if there is a separate mass wasting feature within 50m up or down road of stream crossing. Adjacent instability can occur near or within a water crossing site, but must be separate from or additional to the crossing site erosional process. Adjacent instability is asking about fill or hillslope processes occurring near the crossing, but not to the crossing fill itself.

STREAM/FLOODPLAIN RESTRICTION:

Record the percentage of active stream/floodplain restricted by bridge abutments by estimating the ratio of impinged distance to entire bank full distance as measured perpendicular to stream flow.

CROSSING DIMENSIONS:

Estimate the dimensions, in meters, of crossing footprint used to calculate overall crossing volume.

Length on centerline

Distance measured perpendicular to direction of travel on roadbed and parallel to stream channel centerline from the upstream side of road to the downstream side of road. For crossings where road fill prism is wider at base near stream channel than it is at top near road bed, estimate the average length on centerline by entering the median value between the maximum and minimum centerline lengths.

Upstream

Channel Width

Estimate width of channel upstream of road crossing. This should be the width of the natural channel above the influence of road and represent an average width along the selected reach. Measured from bank to bank of active channel, at the 50-year recurrence interval storm stage.

Top width

On the upstream side of the road, estimate the distance from one side of the stream bank/valley wall to the opposite along the top of the road in the direction of travel.

Estimated Fill Depth

On the upstream side of the road, estimate the distance from the top of the road bed to the bottom of the stream channel. This estimate should be along an imaginary plane descending from the road bed aimed perpendicular to the grade of the stream channel.

Downstream

Channel Width

Estimate width of channel downstream of road crossing. This should be the width of the natural channel below the influence of road and represent an average width along the selected reach. Measured from bank to bank of active channel, at the 50-year recurrence interval storm stage.

Top width

On the downstream side of the road, estimate the distance from one side of the stream bank/valley wall to the opposite along the top of the road in the direction of travel.

Estimated Fill Depth

On the downstream side of the road, estimate the distance from the top of the road bed to the bottom of the stream channel. This estimate should be along an imaginary plane descending from the road bed aimed perpendicular to the grade of the stream channel.

CONDITION OF FILL:

Record condition of fill.

Intact

The site has not been excavated (removed), nor washed out.

Failed/Washed-out %

Record the percent if the crossing failed and has not been rebuilt.

Removed %

Record the percent of the total stream crossing fill that has been previously excavated.

BRIDGE APPROACH EMBANKMENTS

Calculate estimated volume of fill material in each bridge approach embankment. Left and right sides are determined looking downstream.

GULLY

ACTIVITY LEVEL: L M H

Circle appropriate letter for Low, Medium, or High category based on objective observations of the site. Gullies with activity level High will either have water in the gully at the time of assessment or recent scour and an absence of colluvium accumulated along the base of the gully walls. They are generally rectangular in cross section, show signs of recent widening, and do not contain vegetation within the gully. Gullies with a Low activity level are inactive, or dry, and are not eroding material from within the gully. They typically show no sign of recent scour and have accumulations of colluvium at the base of the gully. Other signs of low activity include a U-shade cross section, no indication of recent widening, and vegetation established along the base of the gully or on the colluvium at the base of the gully.

ORIGIN:

Follow evidence of gully channel upslope until source can be determined. If source is from other known road, indicate name of road and address.

AVERAGED SIZE:

Estimate cross sectional shape of gully, top width, bottom width, and depth. Dimensions should be averaged for the reach of gully within the road footprint.

DESTINATION:

Follow evidence of gully downslope until destination can be determined. If destination is another known road, record road name and address. If gully's immediate destination is slope, continue to follow until it can be determined if gully either disperses, joins a stream or swale, or other known road.

MASS WASTING SITE

FEATURE:

Select the type of mass wasting observed.

Swale

A swale is a concave or spoon shaped hollow on the hillslope lacking channelized flow. It is the headwaters to the stream channel forming some distance downslope.

Cutbank

The landslide site is located within the road cut on the inside edge of a road or landing.

Hillslope

The site is on a hillslope and involves more than just the road or landing fill.

Embankment cracks

The site is located on the outer edge of roads or landings in the sidecast fill or along the cutbench/fill interface. Typical indicators of embankment fill that has potential to fail includes cracks or scarps on the road surface that are parallel with the edge of the road or form a semicircle around a section of the outer edge of the road. Occasionally, the outer edge of a section of road has dropped down and the cracks and scarps have been subsequently smoothed over by road grading. Leaning and twisted trunked trees may also indicate unstable road fill.

Embankment failure

The site is located in the sidecast fill at the outside edge of a road or landing. Typical indicators of fill failure are a segment of road or landing with a segment of narrower surface due to a section of fill having slid downslope. The void is usually concave in shape and wider at the top, narrowing at the bottom. Material deposit may be visible at the downslope extent or may have been carried downstream if failure delivered to a creek. An embankment failure will typically contain vegetation differing in age from adjacent intact road segments or have minimal vegetation, if any, depending on how recent the fill failure was.

PROCESS:

Select the landslide process that describes the feature being assessed.

Slow, deep-seated

Characterized by a large area of disturbance on a scale of 100’s of feet. These landslides typically posses leaning trees, springs, numerous stepped scarps and benches. Roads and skid roads often ‘ride’ on deep-seated landslides.

Fast, shallow debris slide

These landslides typically include road and landing fill failures, small cutbank failures, or soil failures on hilllslopes. The upper portions will be evacuated, with the landslide mass resting within the failure area or completely evacuated.

SETTING:

Select the location of the site.

Streamside (<65%)

Near a stream where sediment deposition is directly into the stream, <55% slope steepness.

Inner gorge (>65%)

The lower hillslope near a stream with slope steepness >55%

Headwall

A steep slope or precipice rising at the head of a valley or swale, characterized by broad steep converging slopes. They are generally unchannelized.

Break-in-slope

At the convex break in slope. The slope above is gentler than the slopes below.

Hillslope

The generally planar slope away from stream channels and not classified by any of the other selections above.

DISTANCE TO STREAM (m):

Record the estimated distance from the base of the landslide (the toe area) to the nearest stream channel. This is usually an estimated distance taken from the scaled map tiles.

SLOPE %:

Record the angle of the slope, measured in percent, of the natural hillslope below the base of fill or directly adjacent to slide track along the fall-line.

RECENT ACTIVITY CLASS: PRE-INDUSTRIAL, PRE-1997 POST-1997

Circle the time frame period indicating the occurrence of the most recent movement.

ASSOCIATION(S):

Attempt to identify the primary factor(s) that relate to the mass movement feature. Circle all that apply: Road related, Water onto feature, Spring, Stream undercutting, None above.

AVERAGED FEATURE DIMENSIONS:

Record average length, width, and depth

Length = parallel with failure direction (typically downslope),

Width = perpendicular to failure direction (typically measured across slope or along road),

Depth = thickness of failure mass (usually measured perpendicular to slope surface).

DELIVERED TO STREAM_______%:

An estimated percentage of the volume of the failure that has delivered to stream.

SURFACE EROSION LEVEL: L M H

Circle level of surface erosion, low, medium, or high based on observations of vegetative cover and/or surface rilling.

FUTURE EROSION POTENTIAL: L M H

Subjective and relative ranking of the likelihood, rather than the magnitude, of erosion at the site during the next major storm (high, medium, low).

FUTURE DELIVERABLE VOLUME:

This volume represents total future sediment that will likely be delivered to a stream channel from the site during the next major storm. Typically it is calculated based on a percentage of the overall feature volume. The percentage should be an objective estimation based on site conditions including but not limited to slope steepness, ground water emergence, road drainage, fill materials, adjacent instability, proximity to nearby sites, and vegetative cover.

POTENTIAL FOR EXTREME EROSION: L M H

A subjective assessment of the capability of the site to erode significantly more volume than is estimated in the future deliverable volume. This is a worst case scenario that identifies the potential for an unusually large magnitude failure. This field should be used for “flagging” critical sites. An example might be a stream diversion that would end up draining onto a landing that may fail catastrophically, scouring hillslopes or channels below.

EXTREME EROSION POTENTIAL VOLUME:

If an extreme erosion event occurs, circle the volume category that is likely to result from such an event.

SPRING/SEEP SITE

SOURCE:

Circle area from which spring or seep is emanating. Springs and Seeps refer to locations where roads cross areas of emergent groundwater. A spring has a distinct stream emanating from a well defined point, whereas a seep has no well defined source and appears to saturate a large area. Springs typically emanate from underground conduits that intersect the water table and seeps emanate from a bedding or fault plane. The source data recorded should indicate the area type from which water is appearing: slope, cutbank, roadbed, embankment fill.

FLOW RATE ______GPM:

Estimate the flow rate of ground water in gallons per minute. Imagine how long it would take to fill a gallon milk jug given the amount of water that is flowing from the site at time of data collection. Although not an accurate way to measure, the purpose of data taken is to give a relative flow rate for the time of year data was taken.

DESTINATION:

Follow path of spring/seep’s flow to determine destination and circle appropriate option. If destination is another known road, record road name and address. If the destination is slope, continue to follow water path until it can be determined if spring/seep either disperses, joins a stream or swale, or other known road.

LANDING SITE

EMBANKMENT VOLUME:

Estimate the unit volume of landing fill at three or more points along the outer edge of landing fill and record the average.

DISTANCE ALONG EDGE:

Measure the distance along the outer edge of landing, along the cutbench/fill interface.

WATER ONTO LANDING: Y N

Circle Y if there is evidence of water flowing onto or collecting on landing. Indicators will include hydrophilic plants growing on landing surface, closed depressions containing live or dried mosses and/or hydrophilic plants, road drainage features (water bar, cross drain, tire rut rill) are directed toward landing surface or across landing fill, road grade is negative approaching both sides of landing, or inboard ditch has a low point coincident with landing and does not drain properly.

BOTTOM MARGIN AREA

COMMENTS:

Use this field to comment on anything of significance not reported elsewhere on the form, including but not limited to: complexity, urgency, description of extreme erosion potential, or special treatment prescriptions. Keep comments brief and to the point.

Data Entry By: ____________
Date Entered: ____________

Mill Creek Property - Road Assessment Form - Sheet 1

Version 01/14/04

Check ☐
ASAP ☐
Critical Site ☐

Route Name: ____________ **Surveyed By**: ____________ **Survey Date:** ____________ **Site Tagged** ☐ (tag with starting address)

Feature Address: Start ____________ End ____________ **Point Feature** ☐ (point features enter start address only)

WATER CROSSING SITE (record as point feature at centerline of feature)

Feature: Stream crossing Swale crossing ☐ **Active Diversion** **Diversion Potential:** Y N

Type: Bridge Culvert Humboldt Fill Armored crossing Armored swale Drain swale Drain lens Rolling dip Open cross drain

Erosional Process: None Gully Streambank Collapsing Fill failure Undercutting

Sediment Transport: L M H **Upstream Sediment Plug:** Y N Volume ________ (m^3)

Adjacent Instability: Y N **Stream/Floodplain Restriction:** ________ %

Crossing Dimensions: Length on centerline ________ (m) ☐ Crossing Data Sheet Completed

Upstream
Channel width ________ (m) Top width ________ (m) Estimated fill depth ________ (m)

Downstream
Channel width ________ (m) Top width ________ (m) Estimated fill depth ________ (m)

Condition of Fill: Intact Failed/washed out ________ (%) Removed ________ (%)

Bridge Approach Embankments: Right ________ (m^3) Left ________ (m^3)

GULLY (record as interval feature, enter origin and destination in feature address start and end fields respectively)

Activity Level: L M H

Origin: slope swale stream spring road accumulation
other road name ____________ intercept address ____________

Averaged size: top width ________ (m) bottom width ________ (m) depth ________ (m)

Destination: slope swale stream inboard ditch roadbed
other road name ____________ intercept address ____________

Slope Destination: dispersed slope swale stream
other road name ____________ intercept address ____________

MASS WASTING SITE (record as interval feature)

Feature: Swale Cutbank Hillslope Embankment cracks Embankment failure

Process: Slow, deep-seated Fast, shallow debris slide **Torrent Potential:** L M H

Setting: Streamside (<55%) Inner gorge (>55%) Headwall Break in slope Hillslope
Distance to stream ________ (m) Slope ________ %

Recent Activity Class: Pre-industrial Pre-1997 Post-1997

Association(s): Road related Water onto feature Spring Stream undercutting None above

Averaged Feature Dimensions:
Length ________ (m) Width ________ (m) Depth ________ (m)

Delivered to Stream ________ % **Surface Erosion Level:** L M H

Future Erosion Potential: L M H **Future Deliverable Volume:** ________ (m^3)

Potential for Extreme Erosion: L M H

Extreme Erosion Potential Volume: <500 500-1000 1k-2k 2k-5k >5k

SPRING/SEEP SITE (record as interval feature)

Source: slope cutbank roadbed embankment fill **Flow Rate:** ________ gpm

Destination: slope swale stream inboard ditch gully roadbed
other road name ____________ intercept address ____________

Slope Destination: dispersed slope swale stream
other road name ____________ intercept address ____________

LANDING SITE (record as interval feature)

Embankment Volume: ________ (m^3/m) **Distance Along Edge:** ________ (m)

Water Onto Landing : Y N

Comments:

Figure B2. Road Assessment Form - Sheet 1.

Mill Creek Property - Road Assessment Form - Sheet 2

Version 01/14/04

Site Diagram (indicate approximate scale and label routes where applicable)

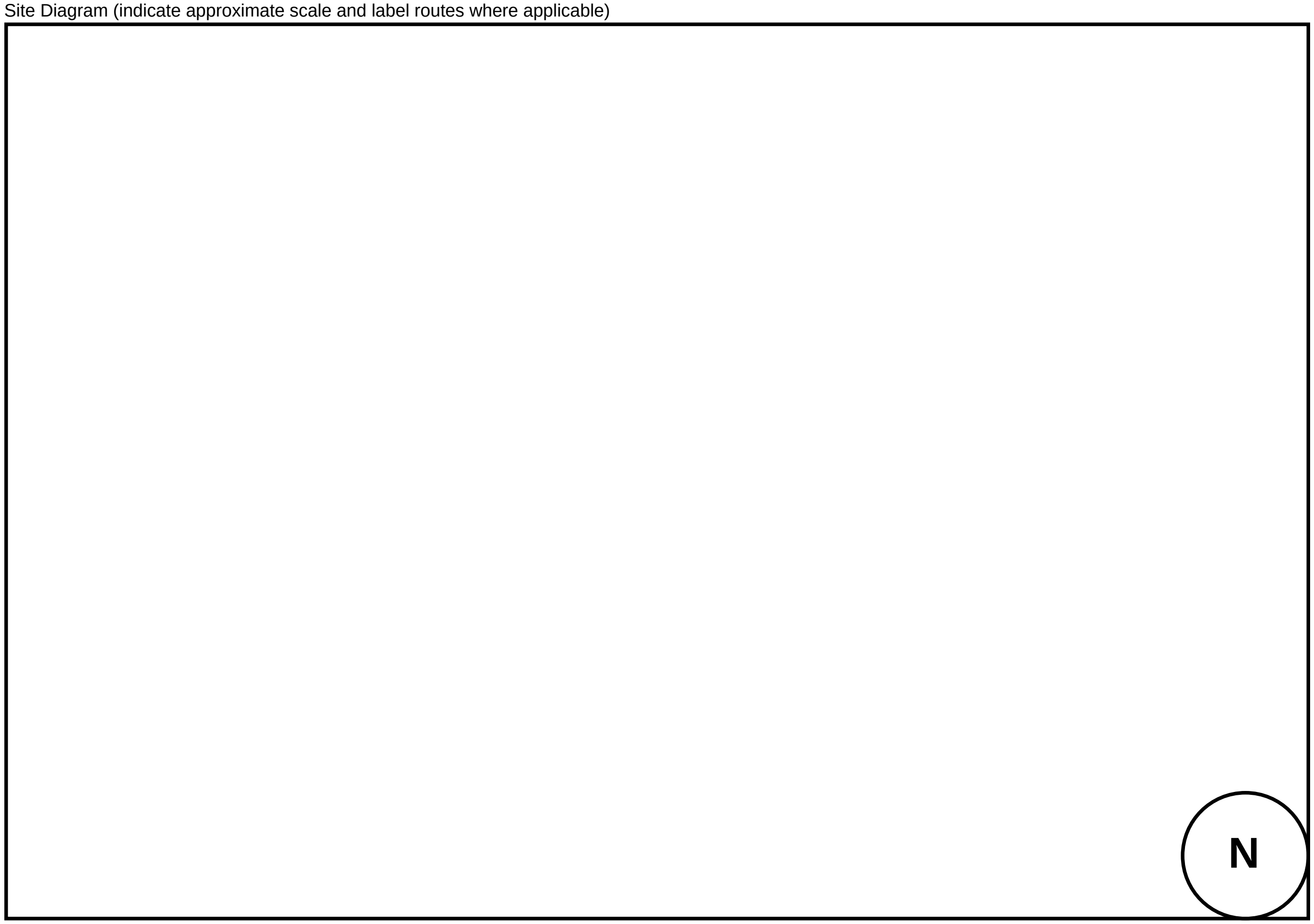

Figure B3. Road Assessment Form - Sheet 2. The site diagram is used as a back page to Sheet 1 for diagramming sites as needed to illustrate site conditions. Use of Sheet 2 is not mandatory, but rather used to clarify complex sites, show relationships between features, or orient future reviewers to site.

Data Entry By: ____________
Date Entered: ____________

Mill Creek Property - Road Assessment Form - Sheet 3
Version 01/14/04

Check ☐
ASAP ☐
Critical Site ☐

Route Name: ____________ **Surveyed By**: ____________ **Survey Date:** ____________ **Site Tagged** ☐ (tag with starting address)

Feature Address: Start ____________ End ____________ **Point Feature** ☐ (point features enter start address only)

Bridge

Size: length ________ (ft) width ________ (ft)

Abutment Materials: Earth Wood Concrete Gabion **Abutment Condition:** Poor Fair Good

Stringer Materials: Wood Steel Concrete **Stringer Condition:** Poor Fair Good

Decking Materials: Wood Steel Concrete **Decking Condition:** Poor Fair Good

Handrail Materials: Wood Steel Concrete **Handrail Condition:** Poor Fair Good

Bull Rail Materials: Wood Steel Concrete **Bull Rail Condition:** Poor Fair Good

ACTION(S)

☐ Monitor: Abutment Stringers Decking Handrails Bull Rails
☐ Repair: Abutment Stringers Decking Handrails Bull Rails
● Replace | Install Abutment: Earth Wood Concrete Gabion
Left Abutment: length ______ (ft) width ______ (ft) height ______ (ft)
Right Abutment: length ______ (ft) width ______ (ft) height ______ (ft)
● Replace | Install Bridge: length ________ (ft) width ________ (ft)
● Replace | Install Handrails: length ______ (ft) Replace | Install Bull Rails: length ______ (ft)
☐ Replace Stringers: length ________ (ft)
☐ Replace Decking: length ________ (ft) width ________ (ft)
☐ Remove Bridge ☐ Clear Channel

Retaining Wall

ConstructionType: Log crib Wood Gabion Concrete Cellular Geotextile
length ________ (ft) width ________ (ft) height ________ (ft)

Condition: Poor Fair Good

ACTION(S)

☐ Monitor ☐ Remove
☐ Repair length ________ (ft) width ________ (ft) height ________ (ft)
● Replace | Install Wood crib Wood Gabion Concrete Cellular Geotextile
length ________ (ft) width ________ (ft) height ________ (ft)

Culvert

Size : Diameter ________ (ft) Length ________ (ft) ☐ Cross Drain

Construction Material: Wood Steel Aluminum Plastic Concrete

Properly Sized: Y N **Pluging Potential:** L M H

Culvert Condition: Poor ☐ Rust holes ☐ Tears/holes ☐ Separations Fair Good

Inlet Components: Trash rack Headwall Flared inlet Drop inlet

Inlet Condition: Poor ________ % pluged ________ % crushed Fair Good

Outlet Components: Downdrain assembly Energy dissipator Half pipe

Outlet Condition: Poor ________ % pluged ________ % crushed Fair Good

Culvert Grade: ________ % **Critical Dip @ Site:** Y N

Shotgun outlet: Y N **Drains onto embankment fill:** Y N

Migration Outlet Drop: now ________ (m) @bankfull ________ (m)
Outlet Pool Dimensions: length ________ (m) width ________ (m)
@ bankfull length ________ (m) width ________ (m)

ACTION(S)

☐ Monitor: Culvert Trash rack Headwall Downdrain Embankment fill
☐ Repair: Trash rack Headwall Drop inlet Flared inlet Downdrain Energy dissipator
● Replace | Install Trash rack
● Replace Install Headwall: length ______ (ft) width ______ (ft) height ______ (ft)
● Replace Install Culvert: diameter ______ (ft.) length ______ (ft.)
● Replace Install Flared inlet: diameter ______ (ft.)
● Replace Install Drop inlet: diameter ______ (ft.)
● Replace Install Downdrain: diameter ______ (ft.) length ______ (ft.)
● Replace Install Energy dissipator: length ______ (ft) width ______ (ft) height ______ (ft)
● Replace Install Critical dip ☐ Clear: Culvert Inlet Outlet
☐ Remove: Culvert Trash rack Drop inlet

Comments:

Figure B4. Road Assessment Forms - Sheet 3 is used to collect data related to bridge, retaining wall and culvert construction, reengineering, and maintenance requirements. Record current condition and/or recommended prescriptions for installation, replacement, repair, or monitoring.

Data Entry By: ____________
Date Entered: ____________

Mill Creek Property - Road Assessment Form - Sheet 4
Version 01/14/04

Check ☐
ASAP ☐
Critical Site ☐

Route Name: ____________ **Surveyed By**: ____________ **Survey Date:** ____________ **Site Tagged** ☐ (tag with starting address)

Feature Address: Start ____________ End ____________ **Point Feature** ☐ (point features enter start address only)

Armored Stream Crossing

Size: length ______ (ft) width ______ (ft) height ______ (ft)

Condition: Poor Fair Good

ACTION(S)

☐ Monitor ☐ Remove

☐ Repair length ______ (ft) width ______ (ft) height ______ (ft)

● Replace | Install length ______ (ft) width ______ (ft) height ______ (ft)

Drain Lens

Size: length ______ (ft) width ______ (ft) height ______ (ft)

Condition: Poor Fair Good

ACTION(S)

☐ Monitor ☐ Remove

☐ Repair length ______ (ft) width ______ (ft) height ______ (ft) Fabric ______ (ft²)

● Replace | Install length ______ (ft) width ______ (ft) height ______ (ft) Fabric ______(ft²)

Armored Drain Swale

Size: length ______ (ft) width ______ (ft) height ______ (ft)

Condition: Poor Fair Good

ACTION(S)

☐ Monitor ☐ Remove

☐ Repair length ______ (ft) width ______ (ft) height ______ (ft)

● Replace | Install length ______ (ft) width ______ (ft) height ______ (ft)

Rolling Dip

Condition: Poor Fair Good

ACTION(S)

☐ Monitor

☐ Remove

☐ Repair

● Replace | Install

Drain Swale

Condition: Poor Fair Good

ACTION(S)

☐ Monitor

☐ Remove

☐ Repair

● Replace | Install

Open Cross Drain

Condition: Poor Fair Good

ACTION(S)

☐ Monitor

☐ Remove

☐ Repair

● Replace | Install

Barrier Berm

Condition: Poor Fair Good

ACTION(S)

☐ Monitor

☐ Remove

☐ Repair

● Replace | Install

Climbing Turn/Switchback

Condition: Poor Fair Good

ACTION(S)

☐ Monitor

☐ Reconstruct

☐ Repair

● Replace | Install

Road Armoring

Condition: Poor Fair Good

ACTION(S)

☐ Monitor

☐ Repair length ______ (ft) width ______ (ft) height ______ (ft)

● Replace | Install length ______ (ft) width ______ (ft) height ______ (ft)

Figure B5. Road Assessment Forms - Sheet 4 is used to collect data related to various drainage structure construction, reengineering, and maintenance requirements. Record current condition and/or recommended prescriptions for installation, replacement, repair, or monitoring.

APPENDIX C

MILL CREEK ADDITION

ABRIDGED SOIL MAP UNIT DESCRIPTIONS

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The following Soil Map Unit descriptions are taken directly from the Map Unit Descriptions published as part of the Soil Survey of Redwood National and State Park, California (USDA 2008).

*****174--Bigtree-Mystery Complex, 2 To 9 Percent Slopes**

<u>Map Unit Setting</u>

General location: Throughout Redwood National & State Parks.
Major uses: Recreation, wildlife habitat, and watershed.
MLRA: 4B - Coastal Redwood Belt
Map unit landscape: mountains
Landscape setting: Gently sloping alluvial fans and low terraces.
Elevation: 5 to 670 feet (2 to 205 meters)
Mean annual precipitation: 60 to 75 inches (1520 to 1900 millimeters)
Mean annual air temperature: 50 to 55 degrees F. (10 to 13 degrees C.)
Frost-free period: 300 to 320 days

<u>Map Unit Composition</u>

**Bigtree--50 percent
**Mystery--25 percent
Minor components: 26 percent

<u>Major Component Description</u>

*Bigtree and similar soils
Slope: 2 to 9 percent
Aspect: None noted
Landform: Alluvial fan, Fan remnant, Low terrace
Parent material: Alluvium derived from mixed sources
Typical vegetation: Overstory of redwood, Sitka spruce, western hemlock, red alder and willow, a shrub layer of salmonberry, blackberry and stink currant, and an herb layer of swordfern and redwood sorrel. Logged areas have a higher proportion of red alder, salmonberry, blackberry, and stink currant.

Selected Properties and Qualities of Bigtree
Surface area covered by coarse fragments: None noted.

Depth to restrictive feature: None noted
Slowest permeability class: Moderate
Available water capacity to 60 inches: About 10.1 inches (Very high)

Selected Hydrologic Properties of Bigtree
Present annual flooding: ---
Present annual ponding: None
Surface runoff: Low
Current water table: None noted.
Natural drainage class: Well drained
Hydrologic Soil Group: B

California Land Use Interpretive Groups
Land capability nonirrigated: 2e-2
Ecological site: F004BX111CA, Sequoia sempervirens/polystichum munitum-oxalis oregana

Typical Profile
**A--0 to 10 in (0 to 26 cm); loam
**Bw--10 to 47 in (26 to 120 cm); loam
**2C1--47 to 57 in (120 to 145 cm); sandy loam
**2C2--57 to 63 in (145 to 160 cm); silt loam

*Mystery and similar soils
Slope: 2 to 9 percent
Aspect: None noted
Landform: Alluvial fan, Fan remnant, Low terrace
Parent material: Overbank alluvium derived from mixed sources
Typical vegetation: Overstory of redwood, Sitka spruce, western hemlock, red alder and willow, a shrub layer of salmonberry, blackberry and stink currant, and an herb layer of swordfern and redwood sorrel. Logged areas have a higher proportion of red alder, salmonberry, blackberry and stink currant.

Selected Properties and Qualities of Mystery
Surface area covered by coarse fragments: None noted.
Depth to restrictive feature: None noted

Slowest permeability class: Moderate
Available water capacity to 60 inches: About 9.9 inches (High)

Selected Hydrologic Properties of Mystery
Present annual flooding: Occasional
Present annual ponding: ---
Surface runoff: High
Current water table: Present
Natural drainage class: Well drained
Hydrologic Soil Group: B

California Land Use Interpretive Groups
Land capability nonirrigated: 2e-2
Ecological site: F004BX111CA, Sequoia sempervirens/polystichum munitum-oxalis oregana

Typical Profile
**Oi--0 to 1 in (0 to 3 cm); slightly decomposed plant material
**A--1 to 24 in (3 to 60 cm); very fine sandy loam
**2Bw--24 to 41 in (60 to 104 cm); fine sandy loam
**3CAb--41 to 60 in (104 to 152 cm); silt loam

Minor Components
****Fluventic Dystrudepts loamy-skeletal and similar soils
Composition: About 10 percent
Slope: 2 to 9 percent
Landform: Alluvial fan, Fan remnant, Low terrace
Typical vegetation: Overstory of redwood, Sitka spruce, western hemlock, red alder and willow, a shrub layer of salmonberry, blackberry and stink currant, and an herb layer of swordfern and redwood sorrel. Logged areas have a higher proportion of red alder, salmonberry, blackberry, and stink currant.
Ecological site: Not Assigned

****Fluvaquentic Endoaquepts and similar soils
Composition: About 5 percent
Slope: 2 to 9 percent

Landform: Backwater channels and depressions on low terraces and flood plain
Typical vegetation: None assigned
Ecological site: Not Assigned

****Fluvents and similar soils
Composition: About 3 percent
Slope: 0 to 4 percent
Landform: On flats adjacent to the stream channel
Typical vegetation: None assigned
Ecological site: Not Assigned

****Riverwash
Composition: About 3 percent
Slope: 2 to 9 percent
Landform: Active channel
Typical vegetation: None assigned
Ecological site: Not Assigned

****Typic Palehumults and similar soils
Composition: About 3 percent
Slope: 5 to 40 percent
Landform: Older terrace
Typical vegetation: None assigned
Ecological site: Not Assigned

****Arents and similar soils
Composition: About 2 percent
Slope: 0 to 4 percent
Landform: Old mill sites on terrace
Typical vegetation: None assigned
Ecological site: Not Assigned

*****534--Coppercreek-Ahpah-Lackscreek Complex, 15 To 30 Percent Slopes**

Map Unit Setting
General location: Western part of Lower Redwood Creek Basin
Major uses: Timber production, recreation, wildlife habitat and watershed. areas in redwood national park are being treated for watershed rehabilitation and may be used for hiking and equestrian trails.
MLRA: 4B - Coastal Redwood Belt
Map unit landscape: mountains
Landscape setting: Steep mountain slopes.
Elevation: 415 to 2495 feet (127 to 761 meters)
Mean annual precipitation: 90 to 100 inches (2290 to 2550 millimeters)
Mean annual air temperature: 50 to 55 degrees F. (10 to 13 degrees C.)
Frost-free period: 240 to 270 days

Map Unit Composition
**Coppercreek--40 percent
**Ahpah--20 percent
**Lackscreek--20 percent
Minor components: 20 percent

Major Component Description
*Coppercreek and similar soils
Slope: 15 to 30 percent
Aspect: None noted
Landform: Shoulders of broad ridge
Parent material: Colluvium and residuum derived from sandstone
Typical vegetation: Overstory of redwood, Douglas-fir, western hemlock and tanoak, a shrub layer of tanoak, huckleberry, and rhododendron, and a sparse herb layer. Redwood is the most abundant conifer in old-growth areas. The second-growth vegetation is dominated by Douglas-fir, tanoak and, in areas that have been burned, by blueblossom.

Selected Properties and Qualities of Coppercreek
Surface area covered by coarse fragments: 0 to 0 percent coarse subangular gravel, 0 to 0 percent subangular cobbles, 0 to 0 percent subangular stones

Depth to restrictive feature: None noted
Slowest permeability class: Moderately slow
Available water capacity to 60 inches: About 7.9 inches (High)

Selected Hydrologic Properties of Coppercreek
Present annual flooding: None
Present annual ponding: None
Surface runoff: High
Current water table: None noted.
Natural drainage class: Well drained
Hydrologic Soil Group: C

California Land Use Interpretive Groups
Land capability nonirrigated: 4e-1
Ecological site: F004BX103CA, Sequoia sempervirens-pseudotsuga menziesii/vaccinium ovatum-rhododendron macrophyllum

Typical Profile
**Oi--0 to 2 in (0 to 5 cm); slightly decomposed plant material
**A--2 to 6 in (5 to 15 cm); loam
**BAt--6 to 13 in (15 to 32 cm); gravelly clay loam
**Bt--13 to 41 in (32 to 105 cm); gravelly clay loam
**BCt--41 to 62 in (105 to 157 cm); very gravelly clay loam

*Ahpah and similar soils
Slope: 15 to 30 percent
Aspect: None noted
Landform: Tops of ridge
Parent material: Residuum and colluvium derived from sandstone
Typical vegetation: Overstory of redwood, Douglas-fir, western hemlock and tanoak, a shrub layer of tanoak, huckleberry, and rhododendron, and a sparse herb layer. Redwood is the most abundant conifer in old-growth areas. The second-growth vegetation is dominated by Douglas-fir, tanoak and, in areas that have been burned, by blueblossom.

Selected Properties and Qualities of Ahpah

Surface area covered by coarse fragments: None noted.
Depth to restrictive feature: Bedrock (paralithic)--20 to 40 inches; bedrock (lithic)--40 to 60 inches
Slowest permeability class: Moderate above the bedrock
Available water capacity to 60 inches: About 5.4 inches (Moderate)

Selected Hydrologic Properties of Ahpah
Present annual flooding: None
Present annual ponding: None
Surface runoff: High
Current water table: None noted.
Natural drainage class: Well drained
Hydrologic Soil Group: B

California Land Use Interpretive Groups
Land capability nonirrigated: 4e-8
Ecological site: F004BX103CA, Sequoia sempervirens-pseudotsuga menziesii/vaccinium ovatum-rhododendron macrophyllum

Typical Profile
**Oi--0 to 2 in (0 to 6 cm); slightly decomposed plant material
**A--2 to 11 in (6 to 27 cm); gravelly loam
**Bw--11 to 25 in (27 to 63 cm); gravelly loam
**CB--25 to 38 in (63 to 96 cm); very gravelly loam
**Cr--38 to 45 in (96 to 115 cm); soft or bedrock
**R--45 to 60 in (115 to 152 cm); bedrock

*Lackscreek and similar soils
Slope: 15 to 30 percent
Aspect: None noted
Landform: Locally steep or strongly convex areas on ridge
Parent material: Colluvium and residuum derived from sandstone
Typical vegetation: Overstory of redwood, Douglas-fir, western hemlock and tanoak, a shrub layer of tanoak, huckleberry, and rhododendron, and a sparse herb layer. Redwood is the most abundant conifer in old-growth areas. The second-growth vegetation is dominated by Douglas-fir, tanoak and, in areas that have been burned,

by blueblossom.

Selected Properties and Qualities of Lackscreek
Surface area covered by coarse fragments: None noted.
Depth to restrictive feature: Bedrock (lithic)--20 to 40 inches
Slowest permeability class: Very slow above the bedrock
Available water capacity to 60 inches: About 4.1 inches (Low)

Selected Hydrologic Properties of Lackscreek
Present annual flooding: None
Present annual ponding: None
Surface runoff: High
Current water table: None noted.
Natural drainage class: Well drained
Hydrologic Soil Group: C

California Land Use Interpretive Groups
Land capability nonirrigated: 4e-8
Ecological site: F004BX103CA, Sequoia sempervirens-pseudotsuga menziesii/vaccinium ovatum-rhododendron macrophyllum

Typical Profile
**Oi--0 to 3 in (0 to 8 cm); slightly decomposed plant material
**A--3 to 6 in (8 to 15 cm); gravelly loam
**Bt--6 to 27 in (15 to 69 cm); very cobbly clay loam
**C--27 to 35 in (69 to 90 cm); extremely gravelly clay loam
**R--35 to 60 in (90 to 152 cm); bedrock

Minor Components
****Sasquatch and similar soils
Composition: About 10 percent
Slope: 15 to 30 percent
Landform: Shoulders of broad ridge
Typical vegetation: None assigned
Ecological site: Not Assigned

****Ahpah umbric epipedon and similar soils
Composition: About 8 percent
Slope: 15 to 30 percent
Landform: Tops of ridge
Typical vegetation: None assigned
Ecological site: Not Assigned

****Rock Outcrop
Composition: About 2 percent
Slope: 15 to 50 percent
Landform: Very steep and strongly convex mountain slope
Typical vegetation: None assigned
Ecological site: Not Assigned

*****549--Scaath-Rockysaddle-Wiregrass Complex, 50 To 75 Percent Slopes**

Map Unit Setting
General location: Lower Redwood Creek Basin
Major uses: Timber production, recreation, wildlife habitat and watershed. Areas in redwood national park are being treated for watershed rehabilitation and may be used for hiking and equestrian trails.
MLRA: 4B - Coastal Redwood Belt
Map unit landscape: mountains
Landscape setting: Very steep, deeply incised mountain slopes.
Elevation: 560 to 2660 feet (171 to 812 meters)
Mean annual precipitation: 75 to 90 inches (1900 to 2290 millimeters)
Mean annual air temperature: 50 to 55 degrees F. (10 to 13 degrees C.)
Frost-free period: 240 to 290 days

Map Unit Composition
**Scaath--40 percent
**Rockysaddle--25 percent
**Wiregrass--20 percent
Minor components: 15 percent

Major Component Description
*Scaath and similar soils
Slope: 50 to 75 percent
Aspect: None noted
Landform: Narrow ridges and convex to uniform upper mountain slope
Parent material: Colluvium and residuum derived from sandstone
Typical vegetation: Overstory of Douglas-fir, redwood, tanoak and madrone, a shrub layer of tanoak and huckleberry, and a sparse herb layer. Douglas-fir is more abundant than redwood. The second-growth vegetation is dominated by tanoak and Douglas-fir and, in areas that have been burned, by blueblossom.

Selected Properties and Qualities of Scaath
Surface area covered by coarse fragments: None noted.
Depth to restrictive feature: Bedrock (lithic)--20 to 40 inches
Slowest permeability class: Very slow above the bedrock

Available water capacity to 60 inches: About 2.2 inches (Very low)

Selected Hydrologic Properties of Scaath
Present annual flooding: None
Present annual ponding: None
Surface runoff: High
Current water table: None noted.
Natural drainage class: Well drained
Hydrologic Soil Group: C

California Land Use Interpretive Groups
Land capability nonirrigated: 7e
Ecological site: F004BX102CA, Pseudotsuga menziesii-sequoia sempervirens/lithocarpus densiflorus

Typical Profile
**Oi--0 to 2 in (0 to 5 cm); slightly decomposed plant material
**A--2 to 4 in (5 to 11 cm); gravelly loam
**BAt--4 to 9 in (11 to 22 cm); very cobbly clay loam
**Bt--9 to 22 in (22 to 55 cm); extremely gravelly clay loam
**R--22 to 60 in (55 to 152 cm); bedrock

*Rockysaddle and similar soils
Slope: 50 to 75 percent
Aspect: None noted
Landform: Concave to uniform scars from debris avalanche
Around rock outcrop and on toe slopes of mountain slope
Parent material: Colluvium derived from sandstone and mudstone
Typical vegetation: Overstory of Douglas-fir, redwood, tanoak and madrone, a shrub layer of tanoak and huckleberry, and a sparse herb layer. Douglas-fir is more abundant than redwood. The second-growth vegetation is dominated by tanoak and Douglas-fir and, in areas that have been burned, by blueblossom.

Selected Properties and Qualities of Rockysaddle
Surface area covered by coarse fragments: 0 to 0 percent coarse subangular gravel, 0 to 0 percent subangular cobbles, 0 to 0 percent subangular stones

Depth to restrictive feature: None noted
Slowest permeability class: Moderately slow
Available water capacity to 60 inches: About 4.7 inches (Low)

Selected Hydrologic Properties of Rockysaddle
Present annual flooding: None
Present annual ponding: None
Surface runoff: High
Current water table: None noted.
Natural drainage class: Well drained
Hydrologic Soil Group: C

California Land Use Interpretive Groups
Land capability nonirrigated: 7e
Ecological site: F004BX102CA, Pseudotsuga menziesii-sequoia sempervirens/litho-carpus densiflorus

Typical Profile
**Oi--0 to 2 in (0 to 6 cm); slightly decomposed plant material
**A--2 to 9 in (6 to 24 cm); extremely gravelly loam
**Bt--9 to 45 in (24 to 115 cm); very gravelly clay loam
**C--45 to 69 in (115 to 176 cm); extremely gravelly clay loam

*Wiregrass and similar soils
Slope: 50 to 75 percent
Aspect: None noted
Landform: Shoulders of broad ridge
Parent material: Colluvium and residuum derived from sandstone and mudstone
Typical vegetation: Overstory of Douglas-fir, redwood, tanoak and madrone, a shrub layer of tanoak and huckleberry, and a sparse herb layer. Douglas-fir is more abundant than redwood. The second-growth vegetation is dominated by tanoak and Douglas-fir and, in areas that have been burned, by blueblossom.

Selected Properties and Qualities of Wiregrass
Surface area covered by coarse fragments: 0 to 0 percent coarse subangular gravel, 0 to 0 percent subangular cobbles, 0 to 0 percent subangular stones

Depth to restrictive feature: None noted
Slowest permeability class: Moderately slow
Available water capacity to 60 inches: About 7.8 inches (High)

Selected Hydrologic Properties of Wiregrass
Present annual flooding: None
Present annual ponding: None
Surface runoff: High
Current water table: None noted.
Natural drainage class: Well drained
Hydrologic Soil Group: C

California Land Use Interpretive Groups
Land capability nonirrigated: 7e
Ecological site: F004BX102CA, Pseudotsuga menziesii-sequoia sempervirens/lithocarpus densiflorus

Typical Profile
**Oi--0 to 1 in (0 to 2 cm); slightly decomposed plant material
**A--1 to 9 in (2 to 22 cm); gravelly loam
**BAt--9 to 26 in (22 to 65 cm); gravelly clay loam
**Bt--26 to 46 in (65 to 118 cm); gravelly clay loam
**BCt--46 to 71 in (118 to 180 cm); very gravelly clay loam

Minor Components
****Rock Outcrop
Composition: About 10 percent
Slope: 30 to 120 percent
Landform: Ridges on mountain slope
Typical vegetation: None assigned
Ecological site: Not Assigned

****Atwell and similar soils
Composition: About 5 percent
Slope: 50 to 75 percent
Landform: Along streams and in moist downslope-running concavities on mountain

slope
Typical vegetation: None assigned
Ecological site: Not Assigned

*****580--Coppercreek-Tectah-Slidecreek Complex, 9 To 30 Percent Slopes**

Map Unit Setting
General location: Mill, Rock, Wilson, and Hunter Creek Watersheds
Major uses: Timber production, recreation, wildlife habitat and watershed. Areas in mill and rock creek watersheds are being treated for watershed rehabilitation and may be used for hiking and equestrian trails.
MLRA: 4B - Coastal Redwood Belt
Map unit landscape: mountains
Landscape setting: Nearly level to moderately steep, broad ridges.
Elevation: 295 to 2300 feet (90 to 702 meters)
Mean annual precipitation: 70 to 100 inches (1780 to 2550 millimeters)
Mean annual air temperature: 50 to 55 degrees F. (10 to 13 degrees C.)
Frost-free period: 240 to 280 days

Map Unit Composition
**Coppercreek--40 percent
**Tectah--30 percent
**Slidecreek--20 percent
Minor components: 10 percent

Major Component Description
*Coppercreek and similar soils
Slope: 9 to 30 percent
Aspect: None noted
Landform: Moderately steep areas on broad ridge
Parent material: Colluvium and residuum derived from sandstone and mudstone
Typical vegetation: Overstory of redwood, Douglas-fir, western hemlock and tanoak, a shrub layer of tanoak, huckleberry and rhododendron, and a sparse herb layer. Redwood is the most abundant conifer in old-growth areas. The second-growth vegetation is dominated by Douglas-fir and, in areas that have been burned, by blueblossom.

Selected Properties and Qualities of Coppercreek
Surface area covered by coarse fragments: None noted.

Depth to restrictive feature: None noted
Slowest permeability class: Moderately slow
Available water capacity to 60 inches: About 9.6 inches (High)

Selected Hydrologic Properties of Coppercreek
Present annual flooding: None
Present annual ponding: None
Surface runoff: Medium
Current water table: None noted.
Natural drainage class: Well drained
Hydrologic Soil Group: C

California Land Use Interpretive Groups
Land capability nonirrigated: 4e-1
Ecological site: F004BX103CA, Sequoia sempervirens-pseudotsuga menziesii/vaccinium ovatum-rhododendron macrophyllum

Typical Profile
**A--0 to 5 in (0 to 12 cm); loam
**AB--5 to 16 in (12 to 40 cm); clay loam
**Bt1--16 to 43 in (40 to 108 cm); clay loam
**Bt2--43 to 79 in (108 to 200 cm); clay loam

*Tectah and similar soils
Slope: 9 to 30 percent
Aspect: None noted
Landform: Tops of broad ridge
Parent material: Colluvium and residuum derived from sandstone and mudstone
Typical vegetation: Overstory of redwood, Douglas-fir, western hemlock and tanoak, a shrub layer of tanoak, huckleberry and rhododendron, and a sparse herb layer. Redwood is the most abundant conifer in old-growth areas. The second-growth vegetation is dominated by Douglas-fir and, in areas that have been burned, by blueblossom.

Selected Properties and Qualities of Tectah
Surface area covered by coarse fragments: None noted.

Depth to restrictive feature: None noted
Slowest permeability class: Slow
Available water capacity to 60 inches: About 7.3 inches (Moderate)

Selected Hydrologic Properties of Tectah
Present annual flooding: None
Present annual ponding: None
Surface runoff: High
Current water table: None noted.
Natural drainage class: Well drained
Hydrologic Soil Group: D

California Land Use Interpretive Groups
Land capability nonirrigated: 4e-5
Ecological site: F004BX103CA, Sequoia sempervirens-pseudotsuga menziesii/vaccinium ovatum-rhododendron macrophyllum

Typical Profile
**A--0 to 9 in (0 to 22 cm); clay loam
**BAt--9 to 15 in (22 to 38 cm); clay loam
**Bt1--15 to 28 in (38 to 70 cm); clay loam
**Bt2--28 to 60 in (70 to 152 cm); clay

*Slidecreek and similar soils
Slope: 9 to 30 percent
Aspect: None noted
Landform: Uniform to gently rounded areas on ridge
Parent material: Colluvium and residuum derived from sandstone and mudstone
Typical vegetation: Overstory of redwood, Douglas-fir, western hemlock and tanoak, a shrub layer of tanoak, huckleberry, and rhododendron, and a sparse herb layer. Redwood is the most abundant conifer in old-growth areas. The second-growth vegetation is dominated by Douglas-fir, tanoak and, in areas that have been burned, by blueblossom.

Selected Properties and Qualities of Slidecreek
Surface area covered by coarse fragments: None noted.

Depth to restrictive feature: None noted
Slowest permeability class: Moderately slow
Available water capacity to 60 inches: About 6.0 inches (Moderate)

Selected Hydrologic Properties of Slidecreek
Present annual flooding: None
Present annual ponding: None
Surface runoff: High
Current water table: None noted.
Natural drainage class: Well drained
Hydrologic Soil Group: C

California Land Use Interpretive Groups
Land capability nonirrigated: 4e-4
Ecological site: F004BX103CA, Sequoia sempervirens-pseudotsuga menziesii/vaccinium ovatum-rhododendron macrophyllum

Typical Profile
**Oi--0 to 3 in (0 to 7 cm); slightly decomposed plant material
**A--3 to 11 in (7 to 28 cm); very gravelly loam
**BA--11 to 15 in (28 to 38 cm); very gravelly clay loam
**Bt--15 to 55 in (38 to 140 cm); very gravelly clay loam
**BCt--55 to 60 in (140 to 152 cm); extremely cobbly clay loam

<u>Minor Components</u>
****Trailhead and similar soils
Composition: About 5 percent
Slope: 0 to 15 percent
Landform: Gently sloping areas of ridge
Typical vegetation: Overstory of redwood, Douglas-fir, western hemlock and tanoak, a shrub layer of tanoak, huckleberry and rhododendron, and a sparse herb layer. Redwood is the most abundant conifer in old-growth areas. The second-growth vegetation is dominated by Douglas-fir and, in areas that have been burned, by blueblossom.
Ecological site: Not Assigned

****Lackscreek and similar soils
Composition: About 3 percent
Slope: 15 to 50 percent
Landform: Spur ridges and upper mountain slope
Typical vegetation: None assigned
Ecological site: Not Assigned

****Rock Outcrop
Composition: About 2 percent
Slope: 15 to 50 percent
Landform: Very steep and strongly convex mountain slope
Typical vegetation: None assigned
Ecological site: Not Assigned

*****581--Coppercreek-Slidecreek-Tectah Complex, 30 To 50 Percent Slopes**

Map Unit Setting
General location: Mill, Rock, Wilson, and Hunter Creek Watersheds
Major uses: Timber production, recreation, wildlife habitat and watershed. Areas in mill and rock creek watersheds are being treated for watershed rehabilitation and may be used for hiking and equestrian trails.
MLRA: 4B - Coastal Redwood Belt
Map unit landscape: mountains
Landscape setting: Steep mountain slopes.
Elevation: 75 to 2170 feet (24 to 662 meters)
Mean annual precipitation: 70 to 100 inches (1780 to 2550 millimeters)
Mean annual air temperature: 50 to 55 degrees F. (10 to 13 degrees C.)
Frost-free period: 240 to 280 days

Map Unit Composition
**Coppercreek--40 percent
**Slidecreek--30 percent
**Tectah--20 percent
Minor components: 10 percent

Major Component Description
*Coppercreek and similar soils
Slope: 30 to 50 percent
Aspect: None noted
Landform: Uniform mountain slope
Parent material: Colluvium and residuum derived from sandstone and mudstone
Typical vegetation: Overstory of redwood, Douglas-fir, western hemlock and tanoak, a shrub layer of tanoak, huckleberry and rhododendron, and a sparse herb layer. Redwood is the most abundant conifer in old-growth areas. The second-growth vegetation is dominated by Douglas-fir and, in areas that have been burned, by blueblossom.

Selected Properties and Qualities of Coppercreek
Surface area covered by coarse fragments: None noted.
Depth to restrictive feature: None noted

Slowest permeability class: Moderately slow
Available water capacity to 60 inches: About 8.4 inches (High)

Selected Hydrologic Properties of Coppercreek
Present annual flooding: None
Present annual ponding: None
Surface runoff: High
Current water table: None noted.
Natural drainage class: Well drained
Hydrologic Soil Group: C

California Land Use Interpretive Groups
Land capability nonirrigated: 6e
Ecological site: F004BX103CA, Sequoia sempervirens-pseudotsuga menziesii/vaccinium ovatum-rhododendron macrophyllum

Typical Profile
**A--0 to 8 in (0 to 20 cm); loam
**BA--8 to 15 in (20 to 38 cm); clay loam
**Bt--15 to 61 in (38 to 155 cm); gravelly clay loam
**BC--61 to 79 in (155 to 200 cm); very gravelly clay loam

*Slidecreek and similar soils
Slope: 30 to 50 percent
Aspect: None noted
Landform: Uniform to gently rounded mountain slope
Parent material: Colluvium and residuum derived from sandstone and mudstone
Typical vegetation: Overstory of redwood, Douglas-fir, western hemlock and tanoak, a shrub layer of tanoak, huckleberry and rhododendron, and a sparse herb layer. Redwood is the most abundant conifer in old-growth areas. The second-growth vegetation is dominated by Douglas-fir and, in areas that have been burned, by blueblossom.

Selected Properties and Qualities of Slidecreek
Surface area covered by coarse fragments: None noted.
Depth to restrictive feature: None noted

Slowest permeability class: Moderately slow
Available water capacity to 60 inches: About 6.3 inches (Moderate)

Selected Hydrologic Properties of Slidecreek
Present annual flooding: None
Present annual ponding: None
Surface runoff: High
Current water table: None noted.
Natural drainage class: Well drained
Hydrologic Soil Group: C

California Land Use Interpretive Groups
Land capability nonirrigated: 6e
Ecological site: F004BX103CA, Sequoia sempervirens-pseudotsuga menziesii/vaccinium ovatum-rhododendron macrophyllum

Typical Profile
**A--0 to 7 in (0 to 18 cm); gravelly loam
**BAt--7 to 14 in (18 to 36 cm); very gravelly clay loam
**Bt--14 to 61 in (36 to 155 cm); very gravelly clay loam
**BCt--61 to 79 in (155 to 200 cm); extremely gravelly clay loam

*Tectah and similar soils
Slope: 30 to 50 percent
Aspect: None noted
Landform: Linear to concave positions on mountain slope
Parent material: Colluvium and residuum derived from sandstone and mudstone
Typical vegetation: Overstory of redwood, Douglas-fir, western hemlock and tanoak, a shrub layer of tanoak, huckleberry and rhododendron, and a sparse herb layer. Redwood is the most abundant conifer in old-growth areas. The second-growth vegetation is dominated by Douglas-fir and, in areas that have been burned, by blueblossom.

Selected Properties and Qualities of Tectah
Surface area covered by coarse fragments: None noted.
Depth to restrictive feature: None noted

Slowest permeability class: Slow
Available water capacity to 60 inches: About 8.1 inches (High)

Selected Hydrologic Properties of Tectah
Present annual flooding: None
Present annual ponding: None
Surface runoff: Very high
Current water table: None noted.
Natural drainage class: Well drained
Hydrologic Soil Group: D

California Land Use Interpretive Groups
Land capability nonirrigated: 6e
Ecological site: F004BX103CA, Sequoia sempervirens-pseudotsuga menziesii/vaccinium ovatum-rhododendron macrophyllum

Typical Profile
**A--0 to 4 in (0 to 9 cm); loam
**Bt1--4 to 19 in (9 to 48 cm); clay loam
**Bt2--19 to 63 in (48 to 160 cm); gravelly clay

Minor Components
****Lackscreek and similar soils
Composition: About 5 percent
Slope: 30 to 75 percent
Landform: Spur ridges and upper mountain slope
Typical vegetation: None assigned
Ecological site: Not Assigned

****Rock Outcrop
Composition: About 3 percent
Slope: 30 to 75 percent
Landform: Very steep and strongly convex mountain slope
Typical vegetation: None assigned
Ecological site: Not Assigned

****Debris Slides
Composition: About 2 percent
Slope: 50 to 75 percent
Landform: Hillslope hollows and on steep mountain slope
Typical vegetation: None assigned
Ecological site: Not Assigned

*****582--Slidecreek-Lackscreek-Coppercreek Complex, 50 To 75 Percent Slopes**

Map Unit Setting

General location: Mill, Rock, Wilson, and Hunter Creek Watersheds

Major uses: Timber production, recreation, wildlife habitat and watershed. Areas in mill and rock creek watersheds are being treated for watershed rehabilitation and may be used for hiking and equestrian trails.

MLRA: 4B - Coastal Redwood Belt

Map unit landscape: mountains

Landscape setting: Very steep mountain slopes.

Elevation: 180 to 2270 feet (55 to 693 meters)

Mean annual precipitation: 70 to 100 inches (1780 to 2550 millimeters)

Mean annual air temperature: 50 to 55 degrees F. (10 to 13 degrees C.)

Frost-free period: 240 to 280 days

Map Unit Composition

**Slidecreek--40 percent

**Lackscreek--25 percent

**Coppercreek--15 percent

Minor components: 20 percent

Major Component Description

*Slidecreek and similar soils

Slope: 50 to 75 percent

Aspect: None noted

Landform: Uniform to gently rounded mountain slope

Parent material: Colluvium and residuum derived from sandstone and mudstone

Typical vegetation: Overstory of redwood, Douglas-fir, western hemlock and tanoak, a shrub layer of tanoak, huckleberry and rhododendron, and a sparse herb layer. Redwood is the most abundant conifer in old-growth areas. The second-growth vegetation is dominated by Douglas-fir and, in areas that have been burned, by blueblossom.

Selected Properties and Qualities of Slidecreek

Surface area covered by coarse fragments: None noted.

Depth to restrictive feature: None noted

Slowest permeability class: Moderately slow
Available water capacity to 60 inches: About 5.7 inches (Moderate)

Selected Hydrologic Properties of Slidecreek
Present annual flooding: None
Present annual ponding: None
Surface runoff: High
Current water table: None noted.
Natural drainage class: Well drained
Hydrologic Soil Group: C

California Land Use Interpretive Groups
Land capability nonirrigated: 7e
Ecological site: F004BX103CA, Sequoia sempervirens-pseudotsuga menziesii/vaccinium ovatum-rhododendron macrophyllum

Typical Profile
**A--0 to 8 in (0 to 20 cm); gravelly loam
**BAt--8 to 15 in (20 to 39 cm); very gravelly clay loam
**Bt--15 to 50 in (39 to 127 cm); very gravelly clay loam
**CBt--50 to 71 in (127 to 180 cm); extremely gravelly clay loam

*Lackscreek and similar soils
Slope: 50 to 75 percent
Aspect: None noted
Landform: Narrow ridges and convex to uniform upper mountain slope
Parent material: Colluvium and residuum derived from sandstone and mudstone
Typical vegetation: Overstory of redwood, Douglas-fir, western hemlock and tanoak, a shrub layer of tanoak, huckleberry, and rhododendron, and a sparse herb layer. Redwood is the most abundant conifer in old-growth areas. The second-growth vegetation is dominated by Douglas-fir, tanoak and, in areas that have been burned, by blueblossom.

Selected Properties and Qualities of Lackscreek
Surface area covered by coarse fragments: 0 to 10 percent subangular cobbles, 0 to 20 percent coarse subangular gravel

Depth to restrictive feature: Bedrock (lithic)--20 to 40 inches
Slowest permeability class: Very slow above the bedrock
Available water capacity to 60 inches: About 3.2 inches (Low)

Selected Hydrologic Properties of Lackscreek
Present annual flooding: None
Present annual ponding: None
Surface runoff: High
Current water table: None noted.
Natural drainage class: Well drained
Hydrologic Soil Group: C

California Land Use Interpretive Groups
Land capability nonirrigated: 7e
Ecological site: F004BX103CA, Sequoia sempervirens-pseudotsuga menziesii/vaccinium ovatum-rhododendron macrophyllum

Typical Profile
**A--0 to 5 in (0 to 13 cm); gravelly loam
**BAt--5 to 17 in (13 to 42 cm); very cobbly clay loam
**Bt--17 to 40 in (42 to 102 cm); extremely gravelly clay loam
**R--40 to 79 in (102 to 200 cm); bedrock

*Coppercreek and similar soils
Slope: 50 to 75 percent
Aspect: None noted
Landform: Uniform mountain slope
Parent material: Colluvium and residuum derived from sandstone and mudstone
Typical vegetation: Overstory of redwood, Douglas-fir, western hemlock and tanoak, a shrub layer of tanoak, huckleberry and rhododendron, and a sparse herb layer. Redwood is the most abundant conifer in old-growth areas. The second-growth vegetation is dominated by Douglas-fir and, in areas that have been burned, by blueblossom.

Selected Properties and Qualities of Coppercreek
Surface area covered by coarse fragments: None noted.

Depth to restrictive feature: None noted
Slowest permeability class: Moderately slow
Available water capacity to 60 inches: About 6.9 inches (Moderate)

Selected Hydrologic Properties of Coppercreek
Present annual flooding: None
Present annual ponding: None
Surface runoff: High
Current water table: None noted.
Natural drainage class: Well drained
Hydrologic Soil Group: C

California Land Use Interpretive Groups
Land capability nonirrigated: 7e
Ecological site: F004BX103CA, Sequoia sempervirens-pseudotsuga menziesii/vaccinium ovatum-rhododendron macrophyllum

Typical Profile
**A--0 to 7 in (0 to 19 cm); gravelly loam
**Bt1--7 to 24 in (19 to 62 cm); gravelly clay loam
**Bt2--24 to 75 in (62 to 190 cm); very gravelly clay loam

Minor Components
****Debris Slides
Composition: About 10 percent
Slope: 50 to 90 percent
Landform: Hillslope hollows and on steep mountain slope
Typical vegetation: None assigned
Ecological site: Not Assigned

****Rock Outcrop
Composition: About 5 percent
Slope: 30 to 90 percent
Landform: Very steep and strongly convex mountain slope
Typical vegetation: None assigned
Ecological site: Not Assigned

****Tectah and similar soils
Composition: About 5 percent
Slope: 15 to 35 percent
Landform: Broad, gentler slopes away from ridge
Typical vegetation: None assigned
Ecological site: Not Assigned

*****583--Trailhead-Wiregrass Complex, 9 To 30 Percent Slopes**

<u>Map Unit Setting</u>
General location: Mill and Rock Watersheds
Major uses: Timber production, recreation, wildlife habitat and watershed. Areas in mill and rock creek watersheds are being treated for watershed rehabilitation and may be used for hiking and equestrian trails.
MLRA: 4B - Coastal Redwood Belt
Map unit landscape: mountains
Landscape setting: Nearly level to moderately steep, broad ridges.
Elevation: 155 to 2045 feet (48 to 624 meters)
Mean annual precipitation: 80 to 100 inches (2030 to 2550 millimeters)
Mean annual air temperature: 50 to 55 degrees F. (10 to 13 degrees C.)
Frost-free period: 240 to 280 days

<u>Map Unit Composition</u>
**Trailhead--65 percent
**Wiregrass--25 percent
Minor components: 10 percent

<u>Major Component Description</u>
*Trailhead and similar soils
Slope: 9 to 30 percent
Aspect: None noted
Landform: Gently sloping areas of ridge
Parent material: Colluvium and residuum derived from schist
Typical vegetation: Overstory of redwood, Douglas-fir, and tanoak, a shrub layer of tanoak, huckleberry and rhododendron, and a sparse herb layer. The second-growth vegetation is dominated by tanoak and Douglas-fir and, in areas that have been burned, by blueblossom.

Selected Properties and Qualities of Trailhead
Surface area covered by coarse fragments: None noted.
Depth to restrictive feature: None noted
Slowest permeability class: Slow
Available water capacity to 60 inches: About 7.2 inches (Moderate)

Selected Hydrologic Properties of Trailhead
Present annual flooding: None
Present annual ponding: None
Surface runoff: High
Current water table: None noted.
Natural drainage class: Well drained
Hydrologic Soil Group: D

California Land Use Interpretive Groups
Land capability nonirrigated: 4e-5
Ecological site: F004BX109CA, Pseudotsuga menziesii-lithocarpus densiflorus/lithocarpus densiflorus-vaccinium ovatum

Typical Profile
**A--0 to 7 in (0 to 19 cm); gravelly loam
**AB--7 to 15 in (19 to 38 cm); gravelly clay loam
**Bt1--15 to 56 in (38 to 142 cm); gravelly clay
**Bt2--56 to 79 in (142 to 200 cm); clay

*Wiregrass and similar soils
Slope: 9 to 30 percent
Aspect: None noted
Landform: Moderately steep areas on broad ridge
Parent material: Colluvium and residuum derived from schist
Typical vegetation: Overstory of redwood, Douglas-fir, and tanoak, a shrub layer of tanoak, huckleberry and rhododendron, and a sparse herb layer. The second-growth vegetation is dominated by tanoak and Douglas-fir and, in areas that have been burned, by blueblossom.

Selected Properties and Qualities of Wiregrass
Surface area covered by coarse fragments: None noted.
Depth to restrictive feature: None noted
Slowest permeability class: Slow
Available water capacity to 60 inches: About 9.2 inches (High)

Selected Hydrologic Properties of Wiregrass
Present annual flooding: None
Present annual ponding: None
Surface runoff: Medium
Current water table: None noted.
Natural drainage class: Well drained
Hydrologic Soil Group: C

California Land Use Interpretive Groups
Land capability nonirrigated: 4e-1
Ecological site: F004BX109CA, Pseudotsuga menziesii-lithocarpus densiflorus/lithocarpus densiflorus-vaccinium ovatum

Typical Profile
**A--0 to 5 in (0 to 12 cm); loam
**BAt--5 to 12 in (12 to 31 cm); clay loam
**Bt1--12 to 35 in (31 to 90 cm); clay loam
**Bt2--35 to 67 in (90 to 170 cm); gravelly clay loam

Minor Components
****Rockysaddle and similar soils
Composition: About 5 percent
Slope: 0 to 30 percent
Landform: Steeper slopes adjacent to well incised drainages on mountain slope
Typical vegetation: None assigned
Ecological site: Not Assigned

****Fortyfour and similar soils
Composition: About 3 percent
Slope: 0 to 30 percent
Landform: Convex slopes, ridge spurs and near tributary headwaters on mountain slope
Typical vegetation: None assigned
Ecological site: Not Assigned

****Scaath and similar soils

Composition: About 2 percent
Slope: 0 to 30 percent
Landform: Convex slopes, ridge spurs and near tributary headwaters on ridge
Typical vegetation: None assigned
Ecological site: Not Assigned

*****584--Wiregrass-Pittplace-Scaath Complex, 9 To 30 Percent Slopes**

Map Unit Setting
General location: Mill and Rock Watersheds
Major uses: Timber production, recreation, wildlife habitat and watershed. Areas in mill and rock creek watersheds are being treated for watershed rehabilitation and may be used for hiking and equestrian trails.
MLRA: 4B - Coastal Redwood Belt
Map unit landscape: mountains
Landscape setting: Moderately steep main and spur ridges.
Elevation: 990 to 2030 feet (303 to 620 meters)
Mean annual precipitation: 80 to 100 inches (2030 to 2550 millimeters)
Mean annual air temperature: 50 to 55 degrees F. (10 to 13 degrees C.)
Frost-free period: 240 to 280 days

Map Unit Composition
**Wiregrass--40 percent
**Pittplace--25 percent
**Scaath--20 percent
Minor components: 15 percent

Major Component Description
*Wiregrass and similar soils
Slope: 9 to 30 percent
Aspect: None noted
Landform: Broader areas on ridge
Parent material: Colluvium and residuum derived from sandstone and mudstone
Typical vegetation: Overstory of tanoak, madrone, Douglas-fir and redwood, a shrub layer of tanoak, huckleberry and rhododendron, and a sparse herb layer. Douglas-fir is the most abundant conifer in old-growth areas. The second-growth vegetation is dominated by Douglas-fir and tanoak, in areas that have been burned, by blueblossom.

Selected Properties and Qualities of Wiregrass
Surface area covered by coarse fragments: None noted.
Depth to restrictive feature: None noted

Slowest permeability class: Moderately slow
Available water capacity to 60 inches: About 10.6 inches (Very high)

Selected Hydrologic Properties of Wiregrass
Present annual flooding: None
Present annual ponding: None
Surface runoff: Medium
Current water table: None noted.
Natural drainage class: Well drained
Hydrologic Soil Group: C

California Land Use Interpretive Groups
Land capability nonirrigated: 4e-1
Ecological site: F004BX109CA, Pseudotsuga menziesii-lithocarpus densiflorus/lithocarpus densiflorus-vaccinium ovatum

Typical Profile
**A--0 to 12 in (0 to 30 cm); loam
**BA--12 to 20 in (30 to 51 cm); loam
**Bt1--20 to 50 in (51 to 128 cm); clay loam
**BC--50 to 79 in (128 to 200 cm); clay loam

*Pittplace and similar soils
Slope: 9 to 30 percent
Aspect: None noted
Landform: Broader areas on ridge
Parent material: Colluvium and residuum derived from sandstone and mudstone
Typical vegetation: Overstory of tanoak, madrone, Douglas-fir and redwood, a shrub layer of tanoak, huckleberry and rhododendron, and a sparse herb layer. Douglas-fir is the most abundant conifer in old-growth areas. The second-growth vegetation is dominated by Douglas-fir and tanoak, in areas that have been burned, by blueblossom.

Selected Properties and Qualities of Pittplace
Surface area covered by coarse fragments: None noted.
Depth to restrictive feature: None noted

Slowest permeability class: Slow
Available water capacity to 60 inches: About 9.9 inches (High)

Selected Hydrologic Properties of Pittplace
Present annual flooding: None
Present annual ponding: None
Surface runoff: High
Current water table: None noted.
Natural drainage class: Well drained
Hydrologic Soil Group: D

California Land Use Interpretive Groups
Land capability nonirrigated: 4e-5
Ecological site: F004BX109CA, Pseudotsuga menziesii-lithocarpus densiflorus/lithocarpus densiflorus-vaccinium ovatum

Typical Profile
**A--0 to 7 in (0 to 17 cm); clay loam
**Bt1--7 to 43 in (17 to 109 cm); paragravelly silty clay loam
**Bt2--43 to 63 in (109 to 160 cm); gravelly clay loam

*Scaath and similar soils
Slope: 15 to 30 percent
Aspect: None noted
Landform: Locally steep or strongly convex areas on ridge
Parent material: Colluvium and residuum derived from sandstone and mudstone
Typical vegetation: Overstory of Douglas-fir, redwood, tanoak and madrone, a shrub layer of tanoak and huckleberry, and a sparse herb layer. Douglas-fir is more abundant than redwood. The second-growth vegetation is dominated by coyote brush, tanoak and Douglas-fir. Logged areas that have been burned tend to be dominated by blueblossom.

Selected Properties and Qualities of Scaath
Surface area covered by coarse fragments: None noted.
Depth to restrictive feature: Bedrock (lithic)--20 to 40 inches
Slowest permeability class: Moderately slow above the bedrock

Available water capacity to 60 inches: About 4.1 inches (Low)

Selected Hydrologic Properties of Scaath
Present annual flooding: None
Present annual ponding: None
Surface runoff: High
Current water table: None noted.
Natural drainage class: Well drained
Hydrologic Soil Group: C

California Land Use Interpretive Groups
Land capability nonirrigated: 4e-8
Ecological site: F004BX109CA, Pseudotsuga menziesii-lithocarpus densiflorus/lithocarpus densiflorus-vaccinium ovatum

Typical Profile
**A--0 to 4 in (0 to 11 cm); gravelly loam
**BAt--4 to 10 in (11 to 25 cm); gravelly clay loam
**Bt--10 to 39 in (25 to 98 cm); very gravelly clay loam
**R--39 to 60 in (98 to 152 cm); bedrock

<u>Minor Components</u>
****Rock Outcrop
Composition: About 5 percent
Slope: 15 to 50 percent
Landform: Very steep and strongly convex mountain slope
Typical vegetation: None assigned
Ecological site: Not Assigned

****Rockysaddle and similar soils
Composition: About 5 percent
Slope: 15 to 50 percent
Landform: Mountain slope
Typical vegetation: None assigned
Ecological site: Not Assigned

****Trailhead and similar soils
Composition: About 5 percent
Slope: 0 to 20 percent
Landform: Gently sloping areas of ridge
Typical vegetation: Overstory of redwood, Douglas-fir, western hemlock and tanoak, a shrub layer of tanoak, huckleberry and rhododendron, and a sparse herb layer. Redwood is the most abundant conifer in old-growth areas. The second-growth vegetation is dominated by Douglas-fir and, in areas that have been burned, by blueblossom.
Ecological site: Not Assigned

*****585--Wiregrass-Rockysaddle Complex, 30 To 50 Percent Slopes**

<u>Map Unit Setting</u>
General location: Mill and Rock Watersheds
Major uses: Timber production, recreation, wildlife habitat and watershed. Areas in mill and rock creek watersheds are being treated for watershed rehabilitation and may be used for hiking and equestrian trails.
MLRA: 4B - Coastal Redwood Belt
Map unit landscape: mountains
Landscape setting: Steep mountain slopes.
Elevation: 665 to 2210 feet (204 to 675 meters)
Mean annual precipitation: 80 to 100 inches (2030 to 2550 millimeters)
Mean annual air temperature: 50 to 55 degrees F. (10 to 13 degrees C.)
Frost-free period: 240 to 280 days

<u>Map Unit Composition</u>
**Wiregrass--45 percent
**Rockysaddle--40 percent
Minor components: 15 percent

<u>Major Component Description</u>
*Wiregrass and similar soils
Slope: 30 to 50 percent
Aspect: None noted
Landform: Uniform to gently rounded mountain slope
Parent material: Colluvium and residuum derived from sandstone and mudstone
Typical vegetation: Overstory of Douglas-fir, redwood, tanoak, and madrone, and a sparse herb layer. Douglas-fir is more abundant than redwood. The second-growth vegetation is dominated by coyote brush, tanoak and Douglas-fir, in areas that have been burned, by blueblossom.

Selected Properties and Qualities of Wiregrass
Surface area covered by coarse fragments: None noted.
Depth to restrictive feature: None noted
Slowest permeability class: Moderately slow
Available water capacity to 60 inches: About 10.3 inches (Very high)

Selected Hydrologic Properties of Wiregrass
Present annual flooding: None
Present annual ponding: None
Surface runoff: High
Current water table: None noted.
Natural drainage class: Well drained
Hydrologic Soil Group: C

California Land Use Interpretive Groups
Land capability nonirrigated: 6e
Ecological site: F004BX109CA, Pseudotsuga menziesii-lithocarpus densiflorus/lithocarpus densiflorus-vaccinium ovatum

Typical Profile
**A--0 to 8 in (0 to 21 cm); loam
**BA--8 to 15 in (21 to 38 cm); loam
**Bt1--15 to 35 in (38 to 90 cm); clay loam
**Bt2--35 to 60 in (90 to 152 cm); clay loam

*Rockysaddle and similar soils
Slope: 30 to 50 percent
Aspect: None noted
Landform: Uniform to gently rounded mountain slope
Parent material: Colluvium and residuum derived from sandstone and mudstone
Typical vegetation: Overstory of Douglas-fir, redwood, tanoak, and madrone, and a sparse herb layer. Douglas-fir is more abundant than redwood. The second-growth vegetation is dominated by coyote brush, tanoak and Douglas-fir, in areas that have been burned, by blueblossom.

Selected Properties and Qualities of Rockysaddle
Surface area covered by coarse fragments: None noted.
Depth to restrictive feature: None noted
Slowest permeability class: Slow
Available water capacity to 60 inches: About 6.2 inches (Moderate)

Selected Hydrologic Properties of Rockysaddle
Present annual flooding: None
Present annual ponding: None
Surface runoff: High
Current water table: None noted.
Natural drainage class: Well drained
Hydrologic Soil Group: D

California Land Use Interpretive Groups
Land capability nonirrigated: 6e
Ecological site: F004BX109CA, Pseudotsuga menziesii-lithocarpus densiflorus/lithocarpus densiflorus-vaccinium ovatum

Typical Profile
**A--0 to 4 in (0 to 11 cm); gravelly loam
**AB--4 to 12 in (11 to 31 cm); gravelly loam
**Bt--12 to 54 in (31 to 138 cm); very gravelly clay loam
**CBt--54 to 61 in (138 to 155 cm); extremely cobbly clay loam

Minor Components
****Debris Slide
Composition: About 5 percent
Slope: 50 to 90 percent
Landform: Hillslope hollows and on steep mountain slope
Typical vegetation: None assigned
Ecological site: Not Assigned

****Rock Outcrop
Composition: About 5 percent
Slope: 30 to 90 percent
Landform: Very steep and strongly convex mountain slope
Typical vegetation: None assigned
Ecological site: Not Assigned

****Scaath and similar soils
Composition: About 5 percent

Slope: 30 to 90 percent
Landform: Spur ridges and upper mountain slope
Typical vegetation: None assigned
Ecological site: Not Assigned

*****586--Wiregrass-Rockysaddle-Trailhead Complex, 30 To 50 Percent Slopes**

<u>Map Unit Setting</u>
General location: Mill and Rock Watersheds
Major uses: Timber production, recreation, wildlife habitat and watershed. Areas in mill and rock creek watersheds are being treated for watershed rehabilitation and may be used for hiking and equestrian trails.
MLRA: 4B - Coastal Redwood Belt
Map unit landscape: mountains
Landscape setting: Nearly level to moderately steep, broad ridges and upper mountain slopes.
Elevation: 275 to 2185 feet (85 to 667 meters)
Mean annual precipitation: 80 to 100 inches (2030 to 2550 millimeters)
Mean annual air temperature: 50 to 55 degrees F. (10 to 13 degrees C.)
Frost-free period: 240 to 280 days

<u>Map Unit Composition</u>
**Wiregrass--40 percent
**Rockysaddle--30 percent
**Trailhead--15 percent
Minor components: 15 percent

<u>Major Component Description</u>
*Wiregrass and similar soils
Slope: 30 to 50 percent
Aspect: None noted
Landform: Mountain slope
Parent material: Colluvium and residuum derived from schist
Typical vegetation: Overstory of redwood, Douglas-fir, and tanoak, a shrub layer of tanoak, huckleberry and rhododendron, and a sparse herb layer. The second-growth vegetation is dominated by Douglas-fir and, in areas that have been burned, by blueblossom.

Selected Properties and Qualities of Wiregrass
Surface area covered by coarse fragments: None noted.
Depth to restrictive feature: None noted

Slowest permeability class: Slow
Available water capacity to 60 inches: About 10.0 inches (High)

Selected Hydrologic Properties of Wiregrass
Present annual flooding: None
Present annual ponding: None
Surface runoff: High
Current water table: None noted.
Natural drainage class: Well drained
Hydrologic Soil Group: C

California Land Use Interpretive Groups
Land capability nonirrigated: 6e
Ecological site: F004BX109CA, Pseudotsuga menziesii-lithocarpus densiflorus/lithocarpus densiflorus-vaccinium ovatum

Typical Profile
**A--0 to 8 in (0 to 20 cm); loam
**Bt1--8 to 39 in (20 to 98 cm); clay loam
**Bt2--39 to 69 in (98 to 175 cm); clay loam

*Rockysaddle and similar soils
Slope: 30 to 50 percent
Aspect: None noted
Landform: Linear to convex mountain slope
Parent material: Colluvium and residuum derived from schist
Typical vegetation: Overstory of redwood, Douglas-fir, and tanoak, a shrub layer of tanoak, huckleberry and rhododendron, and a sparse herb layer. The second-growth vegetation is dominated by Douglas-fir and, in areas that have been burned, by blueblossom.

Selected Properties and Qualities of Rockysaddle
Surface area covered by coarse fragments: None noted.
Depth to restrictive feature: None noted
Slowest permeability class: Slow
Available water capacity to 60 inches: About 5.6 inches (Moderate)

Selected Hydrologic Properties of Rockysaddle
Present annual flooding: None
Present annual ponding: None
Surface runoff: High
Current water table: None noted.
Natural drainage class: Well drained
Hydrologic Soil Group: C

California Land Use Interpretive Groups
Land capability nonirrigated: 6e
Ecological site: F004BX109CA, Pseudotsuga menziesii-lithocarpus densiflorus/lithocarpus densiflorus-vaccinium ovatum

Typical Profile
**A--0 to 4 in (0 to 11 cm); gravelly loam
**Bt1--4 to 12 in (11 to 31 cm); very gravelly clay loam
**Bt2--12 to 54 in (31 to 138 cm); very gravelly clay loam
**CBt--54 to 61 in (138 to 155 cm); extremely gravelly silty clay loam

*Trailhead and similar soils
Slope: 30 to 50 percent
Aspect: None noted
Landform: Upper mountain slope
Parent material: Colluvium and residuum derived from schist
Typical vegetation: Overstory of redwood, Douglas-fir, and tanoak, a shrub layer of tanoak, huckleberry and rhododendron, and a sparse herb layer. The second-growth vegetation is dominated by Douglas-fir and, in areas that have been burned, by blueblossom.

Selected Properties and Qualities of Trailhead
Surface area covered by coarse fragments: None noted.
Depth to restrictive feature: None noted
Slowest permeability class: Slow
Available water capacity to 60 inches: About 7.7 inches (High)

Selected Hydrologic Properties of Trailhead
Present annual flooding: None
Present annual ponding: None
Surface runoff: Very high
Current water table: None noted.
Natural drainage class: Well drained
Hydrologic Soil Group: D

California Land Use Interpretive Groups
Land capability nonirrigated: 6e
Ecological site: F004BX109CA, Pseudotsuga menziesii-lithocarpus densiflorus/lithocarpus densiflorus-vaccinium ovatum

Typical Profile
**A--0 to 9 in (0 to 22 cm); loam
**Bt1--9 to 25 in (22 to 63 cm); clay
**Bt2--25 to 62 in (63 to 158 cm); gravelly clay
**BCt--62 to 79 in (158 to 200 cm); extremely cobbly clay

Minor Components
****Debris Slides
Composition: About 5 percent
Slope: 50 to 90 percent
Landform: Hillslope hollows and on steep mountain slope
Typical vegetation: None assigned
Ecological site: Not Assigned

****Scaath and similar soils
Composition: About 5 percent
Slope: 30 to 75 percent
Landform: Convex slopes, ridge spurs and near tributary headwaters on ridge
Typical vegetation: None assigned
Ecological site: Not Assigned

****Rock Outcrop
Composition: About 3 percent

Slope: 30 to 90 percent
Landform: Very steep and strongly convex mountain slope
Typical vegetation: None assigned
Ecological site: Not Assigned

****Rodgerpeak and similar soils
Composition: About 2 percent
Slope: 0 to 15 percent
Landform: Gently convex to planar areas on crest of ridge
Typical vegetation: A sparse overstory of Douglas-fir, tanoak, madrone and redwood, a dense shrub layer of huckleberry, salal, hairy manzanita and rhododendron, and a sparse herb layer. Douglas-fir is the most abundant conifer. The vegetation has been logged and recovery is slow. The brushy nature of the vegetation may be due to the slow conifer growth and a high frequency of fires on Rodger's Peak.
Ecological site: F004BX108CA, Sequoia sempervirens-pseudotsuga menziesii/polystichum munitum

*****587--Rockcreek, 5 To 30 Percent Slopes**

Map Unit Setting
General location: Mill and Rock Watersheds
Major uses: Timber production, recreation, wildlife habitat and watershed. Areas in mill and rock creek watersheds are being treated for watershed rehabilitation and may be used for hiking and equestrian trails.
MLRA: 4B - Coastal Redwood Belt
Map unit landscape: mountains
Landscape setting: Nearly level to moderately steep, broad ridges.
Elevation: 1785 to 2350 feet (545 to 717 meters)
Mean annual precipitation: 80 to 100 inches (2030 to 2550 millimeters)
Mean annual air temperature: 50 to 55 degrees F. (10 to 13 degrees C.)
Frost-free period: 240 to 280 days

Map Unit Composition
**Rockcreek--65 percent
Minor components: 35 percent

Major Component Description
*Rockcreek and similar soils
Slope: 5 to 30 percent
Aspect: None noted
Landform: Moderately broad, undulating ridge
Parent material: Weakly consolidated fluvial deposits
Typical vegetation: Overstory of tanoak, Douglas-fir, and Giant chinquapin, a shrub layer of tanoak, salal, huckleberry and rhododendron, and a sparse herb layer.

Selected Properties and Qualities of Rockcreek
Surface area covered by coarse fragments: None noted.
Depth to restrictive feature: None noted
Slowest permeability class: Moderately slow
Available water capacity to 60 inches: About 7.5 inches (Moderate)

Selected Hydrologic Properties of Rockcreek
Present annual flooding: None

Present annual ponding: None
Surface runoff: Medium
Current water table: None noted.
Natural drainage class: Well drained
Hydrologic Soil Group: C

California Land Use Interpretive Groups
Land capability nonirrigated: 4e-1
Ecological site: F004BX113CA, Pseudotsuga menziesii-chrysolepis chrysophylla/ vaccinium ovatum-rhododendron macrophyllum

Typical Profile
**A--0 to 9 in (0 to 22 cm); loam
**Bt1--9 to 35 in (22 to 90 cm); gravelly clay loam
**Bt2--35 to 65 in (90 to 165 cm); very cobbly clay loam

Minor Components
****Surpur and similar soils
Composition: About 10 percent
Slope: 5 to 30 percent
Landform: Saddle and shoulder of ridge
Typical vegetation: None assigned
Ecological site: Not Assigned
****Ustic Palehumults and similar soils
Composition: About 10 percent
Slope: 0 to 30 percent
Landform: Convex areas on broad, undulating ridge
Typical vegetation: Overstory of tanoak, Douglas-fir, and Giant chinquapin, a shrub layer of tanoak, salal, huckleberry and rhododendron, and a sparse herb layer.
Ecological site: Not Assigned

****Scaath and similar soils
Composition: About 5 percent
Slope: 0 to 50 percent
Landform: Strongly convex slopes, ridge spurs and near margins of ridge

Typical vegetation: None assigned
Ecological site: Not Assigned

****Ustic Palehumults and similar soils
Composition: About 5 percent
Slope: 0 to 30 percent
Landform: Moderately broad, undulating ridge
Typical vegetation: None assigned
Ecological site: Not Assigned

****Wiregrass and similar soils
Composition: About 5 percent
Slope: 0 to 50 percent
Landform: Gently concave slopes and in broad hollows on margins of ridge
Typical vegetation: None assigned
Ecological site: Not Assigned

*****588--Surpur, Dry, 2 To 9 Percent Slopes**

Map Unit Setting

General location: Mill and Rock Watersheds

Major uses: Timber production, recreation, wildlife habitat and watershed. Areas in mill and rock creek watersheds are being treated for watershed rehabilitation and may be used for hiking and equestrian trails.

MLRA: 4B - Coastal Redwood Belt

Map unit landscape: mountains

Landscape setting: Nearly level to moderately steep, mountain slopes and ridges.

Elevation: 1220 to 2245 feet (372 to 685 meters)

Mean annual precipitation: 80 to 100 inches (2030 to 2550 millimeters)

Mean annual air temperature: 50 to 55 degrees F. (10 to 13 degrees C.)

Frost-free period: 240 to 280 days

Map Unit Composition

**Surpur--75 percent

Minor components: 25 percent

Major Component Description

*Surpur and similar soils

Slope: 0 to 30 percent

Aspect: None noted

Landform: Broad ridgetops and upper mountain slope

Parent material: Colluvium and residuum derived from older, weakly consolidated fluvial, beach and dune deposits from mixed lithologies

Typical vegetation: Overstory of Douglas-fir, tanoak and redwood. There is a shrub layer of evergreen huckleberry, salal, tanoak and rhododendron, and a moderately dense herb layer dominated by swordfern.

Selected Properties and Qualities of Surpur

Surface area covered by coarse fragments: None noted.

Depth to restrictive feature: None noted

Slowest permeability class: Moderately slow

Available water capacity to 60 inches: About 9.6 inches (High)

Selected Hydrologic Properties of Surpur
Present annual flooding: None
Present annual ponding: None
Surface runoff: Medium
Current water table: None noted.
Natural drainage class: Well drained
Hydrologic Soil Group: C

California Land Use Interpretive Groups
Land capability nonirrigated: 4e-1
Ecological site: F004BX113CA, Pseudotsuga menziesii-chrysolepis chrysophylla/ vaccinium ovatum-rhododendron macrophyllum

Typical Profile
**A--0 to 7 in (0 to 17 cm); loam
**BAt--7 to 11 in (17 to 29 cm); gravelly loam
**Bt--11 to 39 in (29 to 100 cm); clay loam
**CBt--39 to 67 in (100 to 170 cm); very paragravelly loam

Minor Components
****Surpur and similar soils
Composition: About 10 percent
Slope: 0 to 30 percent
Landform: Broad ridgetops and upper mountain slope
Typical vegetation: None assigned
Ecological site: Not Assigned

****Squashan and similar soils
Composition: About 5 percent
Slope: 0 to 30 percent
Landform: Broad ridgetops and upper mountain slope
Typical vegetation: None assigned
Ecological site: Not Assigned

****Ustic Palehumults and similar soils
Composition: About 3 percent

Slope: 0 to 30 percent
Landform: Mountainside
Typical vegetation: None assigned
Ecological site: Not Assigned

****Wiregrass and similar soils
Composition: About 3 percent
Slope: 0 to 30 percent
Landform: Areas of graywacke and/or mudstone on mountain slope
Typical vegetation: None assigned
Ecological site: Not Assigned

****Pittplace and similar soils
Composition: About 2 percent
Slope: 0 to 30 percent
Landform: Areas of graywacek and/or mudstone ridge
Typical vegetation: None assigned
Ecological site: Not Assigned

****Scaath and similar soils
Composition: About 2 percent
Slope: 10 to 30 percent
Landform: Areas of graywacke with convex slopes and spur mountain slope
Typical vegetation: None assigned
Ecological site: Not Assigned

*****590--Sasquatch-Yeti-Footstep Complex, 5 To 30 Percent**

Map Unit Setting

General location: Near coast and along Highway 101.

Major uses: Timber production, recreation, wildlife habitat and watershed.

MLRA: 4B - Coastal Redwood Belt

Map unit landscape: mountains

Landscape setting: Nearly level to moderately steep, broad ridges.

Elevation: 180 to 1295 feet (56 to 395 meters)

Mean annual precipitation: 65 to 90 inches (1650 to 2290 millimeters)

Mean annual air temperature: 50 to 55 degrees F. (10 to 13 degrees C.)

Frost-free period: 250 to 300 days

Map Unit Composition

**Sasquatch--45 percent

**Yeti--20 percent

**Footstep--15 percent

Minor components: 20 percent

Major Component Description

*Sasquatch and similar soils

Slope: 5 to 30 percent

Aspect: None noted

Landform: Moderately steep areas on broad ridge

Parent material: Colluvium and residuum derived from sandstone and mudstone

Typical vegetation: Overstory of redwood, Douglas-fir, western hemlock, tanoak. There is a shrub layer of salmonberry, thimbleberry and huckleberry, and a dense herb layer dominated by swordfern and oxalis on the forest floor. Rhododendron, huckleberry and salal are common shrubs on higher more inland sites.

Selected Properties and Qualities of Sasquatch

Surface area covered by coarse fragments: None noted.

Depth to restrictive feature: None noted

Slowest permeability class: Slow

Available water capacity to 60 inches: About 10.9 inches (Very high)

Selected Hydrologic Properties of Sasquatch
Present annual flooding: None
Present annual ponding: None
Surface runoff: Medium
Current water table: None noted.
Natural drainage class: Well drained
Hydrologic Soil Group: C

California Land Use Interpretive Groups
Land capability nonirrigated: 4e-1
Ecological site: F004BX108CA, Sequoia sempervirens-pseudotsuga menziesii/polystichum munitum

Typical Profile
**Oi--0 to 2 in (0 to 4 cm); slightly decomposed plant material
**A--2 to 19 in (4 to 49 cm); loam
**Bt1--19 to 65 in (49 to 165 cm); clay loam
**Bt2--65 to 79 in (165 to 200 cm); paragravelly clay loam

*Yeti and similar soils
Slope: 5 to 30 percent
Aspect: None noted
Landform: Tops of broad ridge
Parent material: Colluvium and residuum derived from sandstone and mudstone
Typical vegetation: Overstory of redwood, Douglas-fir, western hemlock, tanoak. There is a shrub layer of salmonberry, thimbleberry and huckleberry, and a dense herb layer dominated by swordfern and oxalis on the forest floor. Rhododendron, huckleberry and salal are common shrubs on higher more inland sites.

Selected Properties and Qualities of Yeti
Surface area covered by coarse fragments: None noted.
Depth to restrictive feature: None noted
Slowest permeability class: Slow
Available water capacity to 60 inches: About 9.4 inches (High)

Selected Hydrologic Properties of Yeti

Present annual flooding: None
Present annual ponding: None
Surface runoff: High
Current water table: None noted.
Natural drainage class: Well drained
Hydrologic Soil Group: D

California Land Use Interpretive Groups
Land capability nonirrigated: 4e-5
Ecological site: F004BX108CA, Sequoia sempervirens-pseudotsuga menziesii/polystichum munitum

Typical Profile
**A--0 to 16 in (0 to 41 cm); loam
**Bt1--16 to 37 in (41 to 93 cm); clay loam
**Bt2--37 to 51 in (93 to 130 cm); gravelly clay
**C--51 to 60 in (130 to 152 cm); gravelly clay

*Footstep and similar soils
Slope: 5 to 30 percent
Aspect: None noted
Landform: Narrow ridges and convex to uniform upper mountain slope
Parent material: Colluvium and residuum derived from sandstone and mudstone
Typical vegetation: Overstory of redwood, Douglas-fir, western hemlock, tanoak. There is a shrub layer of salmonberry, thimbleberry and huckleberry, and a dense herb layer dominated by swordfern and oxalis on the forest floor. Rhododendron, huckleberry and salal are common shrubs on higher more inland sites.

Selected Properties and Qualities of Footstep
Surface area covered by coarse fragments: 0 to 25 percent coarse subangular gravel, 0 to 5 percent subangular cobbles
Depth to restrictive feature: Bedrock (lithic)--20 to 39 inches
Slowest permeability class: Moderately slow above the bedrock
Available water capacity to 60 inches: About 3.8 inches (Low)

Selected Hydrologic Properties of Footstep

Present annual flooding: None
Present annual ponding: None
Surface runoff: Medium
Current water table: None noted.
Natural drainage class: Well drained
Hydrologic Soil Group: C

California Land Use Interpretive Groups
Land capability nonirrigated: 7e
Ecological site: F004BX108CA, Sequoia sempervirens-pseudotsuga menziesii/polystichum munitum

Typical Profile
**A--0 to 15 in (0 to 38 cm); gravelly loam
**Bt--15 to 26 in (38 to 66 cm); very gravelly clay loam
**CBt--26 to 31 in (66 to 80 cm); extremely gravelly clay loam
**R--31 to 79 in (80 to 200 cm); bedrock

Minor Components
****Ladybird and similar soils
Composition: About 10 percent
Slope: 15 to 30 percent
Landform: Moderately steep spur ridge
Typical vegetation: Overstory of redwood and a subcanopy of Douglas-fir, western hemlock, and tanoak. There is a shrub layer of dogwood, cascara sagrada, huckleberry and salal, and a dense herb layer dominated by swordfern and oxalis on the forest floor. Following logging, the vegetation is heavily dominated by red alder, which gives way to coniferous forest in about 30 to 50 years.
Ecological site: Not Assigned

****Sisterrocks and similar soils
Composition: About 8 percent
Slope: 0 to 30 percent
Landform: Uniform to gently rounded areas on ridge
Typical vegetation: Overstory of redwood, Douglas-fir, western hemlock, tanoak. There is a shrub layer of salmonberry, thimbleberry and huckleberry, and a dense

herb layer dominated by swordfern and oxalis on the forest floor. Rhododendron, huckleberry and salal are common shrubs on higher more inland sites.
Ecological site: Not Assigned

****Footstep and similar soils
Composition: About 2 percent
Slope: 15 to 50 percent
Landform: Spur ridges and upper mountain slope
Typical vegetation: Overstory of redwood, Douglas-fir, western hemlock, tanoak. There is a shrub layer of salmonberry, thimbleberry and huckleberry, and a dense herb layer dominated by swordfern and oxalis on the forest floor. Rhododendron, huckleberry and salal are common shrubs on higher more inland sites.
Ecological site: F004BX104CA, Sequoia sempervirens-pseudotsuga menziesii/vaccinium ovatum-rhododendron macrophyllum

*****591--Sasquatch-Sisterrocks-Ladybird Complex, 30 To 50 Percent**

Map Unit Setting
General location: Near coast and along Highway 101.
Major uses: Timber production, recreation, wildlife habitat and watershed.
MLRA: 4B - Coastal Redwood Belt
Map unit landscape: mountains
Landscape setting: Steep, moist, mountain slopes, with strong coastal fog influence.
Elevation: 15 to 1850 feet (5 to 565 meters)
Mean annual precipitation: 65 to 90 inches (1650 to 2290 millimeters)
Mean annual air temperature: 50 to 55 degrees F. (10 to 13 degrees C.)
Frost-free period: 250 to 300 days

Map Unit Composition
**Sasquatch--45 percent
**Sisterrocks--25 percent
**Ladybird--15 percent
Minor components: 15 percent

Major Component Description
*Sasquatch and similar soils
Slope: 30 to 50 percent
Aspect: None noted
Landform: Mountain slope
Parent material: Colluvium and residuum derived from sandstone and mudstone
Typical vegetation: Overstory of redwood, Douglas-fir, western hemlock, tanoak. There is a shrub layer of salmonberry, thimbleberry and huckleberry, and a dense herb layer dominated by swordfern and oxalis on the forest floor. Rhododendron, huckleberry and salal are common shrubs on higher more inland sites.

Selected Properties and Qualities of Sasquatch
Surface area covered by coarse fragments: None noted.
Depth to restrictive feature: None noted
Slowest permeability class: Moderately slow
Available water capacity to 60 inches: About 8.0 inches (High)

Selected Hydrologic Properties of Sasquatch
Present annual flooding: None
Present annual ponding: None
Surface runoff: High
Current water table: None noted.
Natural drainage class: Well drained
Hydrologic Soil Group: C

California Land Use Interpretive Groups
Land capability nonirrigated: 6e
Ecological site: F004BX108CA, Sequoia sempervirens-pseudotsuga menziesii/polystichum munitum

Typical Profile
**Oi--0 to 1 in (0 to 3 cm); slightly decomposed plant material
**A--1 to 17 in (3 to 43 cm); gravelly loam
**Bt1--17 to 46 in (43 to 117 cm); gravelly clay loam
**Bt2--46 to 79 in (117 to 200 cm); gravelly clay loam

*Sisterrocks and similar soils
Slope: 30 to 50 percent
Aspect: None noted
Landform: Uniform to gently rounded mountain slope
Parent material: Colluvium and residuum derived from sandstone and mudstone
Typical vegetation: Overstory of redwood, Douglas-fir, western hemlock, tanoak. There is a shrub layer of salmonberry, thimbleberry and huckleberry, and a dense herb layer dominated by swordfern and oxalis on the forest floor. Rhododendron, huckleberry and salal are common shrubs on higher more inland sites.

Selected Properties and Qualities of Sisterrocks
Surface area covered by coarse fragments: None noted.
Depth to restrictive feature: None noted
Slowest permeability class: Moderately slow
Available water capacity to 60 inches: About 6.5 inches (Moderate)

Selected Hydrologic Properties of Sisterrocks
Present annual flooding: None
Present annual ponding: None
Surface runoff: High
Current water table: None noted.
Natural drainage class: Well drained
Hydrologic Soil Group: C

California Land Use Interpretive Groups
Land capability nonirrigated: 6e
Ecological site: F004BX108CA, Sequoia sempervirens-pseudotsuga menziesii/polystichum munitum

Typical Profile
**A--0 to 16 in (0 to 40 cm); gravelly loam
**Bt1--16 to 41 in (40 to 105 cm); very gravelly clay loam
**Bt2--41 to 67 in (105 to 170 cm); very gravelly silty clay loam

*Ladybird and similar soils
Slope: 30 to 50 percent
Aspect: None noted
Landform: Mountain slope
Parent material: Colluvium and residuum derived from sandstone and mudstone
Typical vegetation: Overstory of redwood, Douglas-fir, western hemlock, tanoak. There is a shrub layer of salmonberry, thimbleberry and huckleberry, and a dense herb layer dominated by swordfern and oxalis on the forest floor. Rhododendron, huckleberry and salal are common shrubs on higher more inland sites.

Selected Properties and Qualities of Ladybird
Surface area covered by coarse fragments: None noted.
Depth to restrictive feature: None noted
Slowest permeability class: Moderately slow
Available water capacity to 60 inches: About 8.7 inches (High)

Selected Hydrologic Properties of Ladybird
Present annual flooding: None

Present annual ponding: None
Surface runoff: High
Current water table: None noted.
Natural drainage class: Well drained
Hydrologic Soil Group: C

California Land Use Interpretive Groups
Land capability nonirrigated: 6e
Ecological site: F004BX108CA, Sequoia sempervirens-pseudotsuga menziesii/polystichum munitum

Typical Profile
**A--0 to 7 in (0 to 18 cm); gravelly loam
**AB--7 to 15 in (18 to 37 cm); gravelly silty clay loam
**Bt--15 to 55 in (37 to 140 cm); gravelly clay loam
**CBt--55 to 60 in (140 to 152 cm); very gravelly loam

Minor Components
****Footstep and similar soils
Composition: About 10 percent
Slope: 30 to 50 percent
Landform: Spur ridges and upper mountain slope
Typical vegetation: Overstory of redwood, Douglas-fir, western hemlock, tanoak. There is a shrub layer of salmonberry, thimbleberry and huckleberry, and a dense herb layer dominated by swordfern and oxalis on the forest floor. Rhododendron, huckleberry and salal are common shrubs on higher more inland sites.
Ecological site: Not Assigned

****Yeti and similar soils
Composition: About 3 percent
Slope: 15 to 30 percent
Landform: Summit of ridge
Typical vegetation: Overstory of redwood, Douglas-fir, western hemlock, tanoak. There is a shrub layer of salmonberry, thimbleberry and huckleberry, and a dense herb layer dominated by swordfern and oxalis on the forest floor. Rhododendron, huckleberry and salal are common shrubs on higher more inland sites.

Ecological site: Not Assigned

****Rock Outcrop
Composition: About 2 percent
Slope: 30 to 90 percent
Landform: Very steep and strongly convex mountain slope
Typical vegetation: Overstory of redwood, Douglas-fir, western hemlock, tanoak. There is a shrub layer of salmonberry, thimbleberry and huckleberry, and a dense herb layer dominated by swordfern and oxalis on the forest floor. Rhododendron, huckleberry and salal are common shrubs on higher more inland sites.
Ecological site: Not Assigned

*****592--Sisterrocks-Ladybird-Footstep Complex, 50 To 75 Percent**

<u>Map Unit Setting</u>
General location: Near coast and along Highway 101.
Major uses: Timber production, recreation, wildlife habitat and watershed.
MLRA: 4B - Coastal Redwood Belt
Map unit landscape: mountains
Landscape setting: Very steep, moist, mountain slopes, with strong coastal fog influence.
Elevation: 15 to 1695 feet (5 to 518 meters)
Mean annual precipitation: 65 to 90 inches (1650 to 2290 millimeters)
Mean annual air temperature: 50 to 55 degrees F. (10 to 13 degrees C.)
Frost-free period: 250 to 300 days

<u>Map Unit Composition</u>
**Sisterrocks--35 percent
**Ladybird--30 percent
**Footstep--20 percent
Minor components: 15 percent

<u>Major Component Description</u>
*Sisterrocks and similar soils
Slope: 50 to 75 percent
Aspect: None noted
Landform: Mountain slope
Parent material: Colluvium and residuum derived from sandstone and mudstone
Typical vegetation: Overstory of redwood, Douglas-fir, western hemlock, tanoak. There is a shrub layer of salmonberry, thimbleberry and huckleberry, and a dense herb layer dominated by swordfern and oxalis on the forest floor. Rhododendron, huckleberry and salal are common shrubs on higher more inland sites.

Selected Properties and Qualities of Sisterrocks
Surface area covered by coarse fragments: None noted.
Depth to restrictive feature: None noted
Slowest permeability class: Moderately slow
Available water capacity to 60 inches: About 3.4 inches (Low)

Selected Hydrologic Properties of Sisterrocks
Present annual flooding: None
Present annual ponding: None
Surface runoff: High
Current water table: None noted.
Natural drainage class: Well drained
Hydrologic Soil Group: C

California Land Use Interpretive Groups
Land capability nonirrigated: 7e
Ecological site: F004BX108CA, Sequoia sempervirens-pseudotsuga menziesii/polystichum munitum

Typical Profile
**A--0 to 7 in (0 to 18 cm); gravelly loam
**BA--7 to 13 in (18 to 32 cm); very gravelly clay loam
**Bt1--13 to 32 in (32 to 82 cm); extremely gravelly sandy clay loam
**Bt2--32 to 60 in (82 to 152 cm); extremely gravelly clay loam

*Ladybird and similar soils
Slope: 50 to 75 percent
Aspect: None noted
Landform: Mountain slope
Parent material: Colluvium and residuum derived from sandstone and mudstone
Typical vegetation: Overstory of redwood, Douglas-fir, western hemlock, tanoak. There is a shrub layer of salmonberry, thimbleberry and huckleberry, and a dense herb layer dominated by swordfern and oxalis on the forest floor. Rhododendron, huckleberry and salal are common shrubs on higher more inland sites.

Selected Properties and Qualities of Ladybird
Surface area covered by coarse fragments: None noted.
Depth to restrictive feature: None noted
Slowest permeability class: Moderately slow
Available water capacity to 60 inches: About 9.0 inches (High)

Selected Hydrologic Properties of Ladybird
Present annual flooding: None
Present annual ponding: None
Surface runoff: High
Current water table: None noted.
Natural drainage class: Well drained
Hydrologic Soil Group: C

California Land Use Interpretive Groups
Land capability nonirrigated: 7e
Ecological site: F004BX108CA, Sequoia sempervirens-pseudotsuga menziesii/polystichum munitum

Typical Profile
**Oi--0 to 2 in (0 to 5 cm); slightly decomposed plant material
**A--2 to 16 in (5 to 41 cm); gravelly loam
**BAt--16 to 23 in (41 to 59 cm); gravelly clay loam
**Bt--23 to 53 in (59 to 135 cm); gravelly clay loam
**2C--53 to 60 in (135 to 152 cm); very gravelly loam

*Footstep and similar soils
Slope: 50 to 75 percent
Aspect: None noted
Landform: Narrow ridges and convex to uniform upper mountain slope
Parent material: Colluvium and residuum derived from sandstone and mudstone
Typical vegetation: Overstory of redwood, Douglas-fir, western hemlock, tanoak. There is a shrub layer of salmonberry, thimbleberry and huckleberry, and a dense herb layer dominated by swordfern and oxalis on the forest floor. Rhododendron, huckleberry and salal are common shrubs on higher more inland sites.

Selected Properties and Qualities of Footstep
Surface area covered by coarse fragments: None noted.
Depth to restrictive feature: Bedrock (lithic)--20 to 40 inches
Slowest permeability class: Moderately slow above the bedrock
Available water capacity to 60 inches: About 2.6 inches (Low)

Selected Hydrologic Properties of Footstep
Present annual flooding: None
Present annual ponding: None
Surface runoff: High
Current water table: None noted.
Natural drainage class: Well drained
Hydrologic Soil Group: C

California Land Use Interpretive Groups
Land capability nonirrigated: 7e
Ecological site: F004BX108CA, Sequoia sempervirens-pseudotsuga menziesii/polystichum munitum

Typical Profile
**A--0 to 7 in (0 to 18 cm); gravelly loam
**Bt1--7 to 14 in (18 to 35 cm); very gravelly loam
**Bt2--14 to 28 in (35 to 70 cm); extremely gravelly clay loam
**R--28 to 79 in (70 to 200 cm); bedrock

Minor Components
****Rock Outcrop
Composition: About 5 percent
Slope: 30 to 50 percent
Landform: Ridge
Typical vegetation: Overstory of redwood, Douglas-fir, western hemlock, tanoak. There is a shrub layer of salmonberry, thimbleberry and huckleberry, and a dense herb layer dominated by swordfern and oxalis on the forest floor. Rhododendron, huckleberry and salal are common shrubs on higher more inland sites.
Ecological site: Not Assigned

****Sasquatch and similar soils
Composition: About 5 percent
Slope: 0 to 30 percent
Landform: Gently concave slopes and in broad hollows on margins of ridge
Typical vegetation: Overstory of redwood, Douglas-fir, western hemlock, tanoak. There is a shrub layer of salmonberry, thimbleberry and huckleberry, and a dense

herb layer dominated by swordfern and oxalis on the forest floor. Rhododendron, huckleberry and salal are common shrubs on higher more inland sites.
Ecological site: Not Assigned

****Typic Dystrudepts and similar soils
Composition: About 3 percent
Slope: 0 to 30 percent
Landform: Convex positions, formed in sandy marine deposits on ridge
Typical vegetation: Overstory of redwood, Douglas-fir, western hemlock, tanoak. There is a shrub layer of salmonberry, thimbleberry and huckleberry, and a dense herb layer dominated by swordfern and oxalis on the forest floor. Rhododendron, huckleberry and salal are common shrubs on higher more inland sites.
Ecological site: F004BX102CA, Pseudotsuga menziesii-sequoia sempervirens/lithocarpus densiflorus

****Debris Slides
Composition: About 2 percent
Slope: 50 to 90 percent
Landform: Hillslope hollows and on steep mountain slope
Typical vegetation: Overstory of redwood, Douglas-fir, western hemlock, tanoak. There is a shrub layer of salmonberry, thimbleberry and huckleberry, and a dense herb layer dominated by swordfern and oxalis on the forest floor. Rhododendron, huckleberry and salal are common shrubs on higher more inland sites.
Ecological site: Not Assigned

*****756--Oragran-Weitchpec Complex, 30 To 50 Percent Slopes**

Map Unit Setting
General location: Little Bald Hills southeast of the town of Hiouchi.
Major uses: Recreation, wildlife habitat and watershed.
MLRA: 5 - Siskiyou-Trinity Area
Map unit landscape: mountains
Landscape setting: Steep mountain slopes.
Elevation: 845 to 2135 feet (259 to 652 meters)
Mean annual precipitation: 90 to 120 inches (2290 to 3050 millimeters)
Mean annual air temperature: 50 to 55 degrees F. (10 to 13 degrees C.)
Frost-free period: 100 to 150 days

Map Unit Composition
**Oragran--40 percent
**Weitchpec--25 percent
Minor components: 35 percent

Major Component Description
*Oragran and similar soils
Slope: 30 to 50 percent
Aspect: None noted
Landform: Mountain slope
Parent material: Residuum weathered from peridotite or serpentinite
Typical vegetation: Overstory of scattered Jeffery pine, knobcone pine and Douglas-fir. There is a shrub layer of huckleberry oak and manzanita.

Selected Properties and Qualities of Oragran
Surface area covered by coarse fragments: None noted.
Depth to restrictive feature: Bedrock (lithic)--10 to 20 inches
Slowest permeability class: Moderately slow above the bedrock
Available water capacity to 60 inches: About 2.3 inches (Very low)

Selected Hydrologic Properties of Oragran
Present annual flooding: None

Present annual ponding: None
Surface runoff: High
Current water table: None noted.
Natural drainage class: Well drained
Hydrologic Soil Group: D

California Land Use Interpretive Groups
Land capability nonirrigated: 6e
Ecological site: F005XB105CA, Pinus jeffreyi-pseudotsuga menziesii/lithocarpus densiflorus var. echinoides-arctostaphylos nevadensis/xerophyllum tenax

Typical Profile
**Oi--0 to 1 in (0 to 2 cm); slightly decomposed plant material
**A--1 to 3 in (2 to 8 cm); very stony loam
**Bw--3 to 13 in (8 to 33 cm); stony silt loam
**R--13 to 17 in (33 to 43 cm); bedrock

*Weitchpec and similar soils
Slope: 30 to 50 percent
Aspect: None noted
Landform: Mountain slope
Parent material: Residuum weathered from serpentinite
Typical vegetation: Overstory of scattered Jeffery pine, knobcone pine and Douglas-fir. There is a shrub layer of huckleberry oak and manzanita.

Selected Properties and Qualities of Weitchpec
Surface area covered by coarse fragments: None noted.
Depth to restrictive feature: Bedrock (lithic)--20 to 40 inches
Slowest permeability class: Moderately slow above the bedrock
Available water capacity to 60 inches: About 2.9 inches (Low)

Selected Hydrologic Properties of Weitchpec
Present annual flooding: None
Present annual ponding: None
Surface runoff: High
Current water table: None noted.

Natural drainage class: Well drained
Hydrologic Soil Group: B

California Land Use Interpretive Groups
Land capability nonirrigated: 6e
Ecological site: F005XB105CA, Pinus jeffreyi-pseudotsuga menziesii/lithocarpus densiflorus var. echinoides-arctostaphylos nevadensis/xerophyllum tenax

Typical Profile
**A--0 to 8 in (0 to 20 cm); gravelly silt loam
**Bt--8 to 35 in (20 to 89 cm); very gravelly sandy loam
**R--35 to 39 in (89 to 99 cm); bedrock

Minor Components
****Lithic Haploxeralfs ultramafic and similar soils
Composition: About 10 percent
Slope: 50 to 70 percent
Landform: Mountain slope
Typical vegetation: None assigned
Ecological site: Not Assigned

****Oragran moderately deep and similar soils
Composition: About 10 percent
Slope: 30 to 50 percent
Landform: Mountain slope
Typical vegetation: None assigned
Ecological site: Not Assigned

****Walnett and similar soils
Composition: About 10 percent
Slope: 30 to 50 percent
Landform: Mountain slope
Typical vegetation: None assigned
Ecological site: Not Assigned

****Rock Outcrop

Composition: About 5 percent
Slope: 30 to 75 percent
Landform: Mountain slope
Typical vegetation: None assigned
Ecological site: Not Assigned

*****759--Jayel-Walnett-Oragran Complex, 30 To 75 Percent Slopes, Extremely Stony**

Map Unit Setting

General location: Little Bald Hills southeast of the town of Hiouchi.
Major uses: Recreation, wildlife habitat and watershed.
MLRA: 5 - Siskiyou-Trinity Area
Map unit landscape: mountains
Landscape setting: Very steep mountain slopes and broad ridges.
Elevation: 180 to 3010 feet (55 to 918 meters)
Mean annual precipitation: 90 to 120 inches (2290 to 3050 millimeters)
Mean annual air temperature: 50 to 55 degrees F. (10 to 13 degrees C.)
Frost-free period: 100 to 180 days

Map Unit Composition

**Jayel extremely stony--35 percent
**Walnett extremely stony--20 percent
**Oragran--20 percent
Minor components: 25 percent

Major Component Description

*Jayel extremely stony and similar soils
Slope: 30 to 50 percent
Aspect: None noted
Landform: Mountain slope, Broad ridge
Parent material: Colluvium and residuum weathered from serpentinized peridotite
Typical vegetation: Overstory of scattered Jeffery pine, knobcone pine and Douglas-fir. There is a shrub layer of huckleberry oak, manzanita, evergreen huckleberry, and tanoak.

Selected Properties and Qualities of Jayel extremely stony
Surface area covered by coarse fragments: 0 to 30 percent subangular stones
Depth to restrictive feature: Bedrock (lithic)--20 to 40 inches
Slowest permeability class: Slow above the bedrock
Available water capacity to 60 inches: About 4.7 inches (Low)

Selected Hydrologic Properties of Jayel extremely stony
Present annual flooding: None
Present annual ponding: None
Surface runoff: High
Current water table: None noted.
Natural drainage class: Well drained
Hydrologic Soil Group: D

California Land Use Interpretive Groups
Land capability nonirrigated: 7e
Ecological site: F005XB105CA, Pinus jeffreyi-pseudotsuga menziesii/lithocarpus densiflorus var. echinoides-arctostaphylos nevadensis/xerophyllum tenax

Typical Profile
**Oi--0 to 1 in (0 to 2 cm); slightly decomposed plant material
**A--1 to 11 in (2 to 28 cm); stony clay loam
**Bw--11 to 32 in (28 to 81 cm); stony clay
**R--32 to 40 in (81 to 102 cm); bedrock

*Oragran and similar soils
Slope: 30 to 75 percent
Aspect: None noted
Landform: Mountain slope
Parent material: Residuum weathered from peridotite or serpentinite
Typical vegetation: Overstory of scattered Jeffery pine, knobcone pine and Douglas-fir. There is a shrub layer of huckleberry oak, manzanita, evergreen huckleberry, and tanoak.

Selected Properties and Qualities of Oragran
Surface area covered by coarse fragments: None noted.
Depth to restrictive feature: Bedrock (lithic)--10 to 20 inches
Slowest permeability class: Moderately slow above the bedrock
Available water capacity to 60 inches: About 3.4 inches (Low)

Selected Hydrologic Properties of Oragran
Present annual flooding: None

Present annual ponding: None
Surface runoff: High
Current water table: None noted.
Natural drainage class: Well drained
Hydrologic Soil Group: D

California Land Use Interpretive Groups
Land capability nonirrigated: 7e
Ecological site: F005XB105CA, Pinus jeffreyi-pseudotsuga menziesii/lithocarpus densiflorus var. echinoides-arctostaphylos nevadensis/xerophyllum tenax

Typical Profile
**Oi--0 to 1 in (0 to 2 cm); slightly decomposed plant material
**A--1 to 3 in (2 to 8 cm); very stony loam
**Bw--3 to 19 in (8 to 48 cm); stony silt loam
**R--19 to 23 in (48 to 58 cm); bedrock

*Walnett extremely stony and similar soils
Slope: 30 to 75 percent
Aspect: None noted
Landform: Mountain slope
Parent material: Colluvium and residuum weathered from serpentinized peridotite
Typical vegetation: Overstory of scattered Jeffery pine, knobcone pine and Douglas-fir. There is a shrub layer of huckleberry oak, manzanita, evergreen huckleberry, and tanoak.

Selected Properties and Qualities of Walnett extremely stony
Surface area covered by coarse fragments: 10 to 30 percent subangular stones
Depth to restrictive feature: Bedrock (lithic)--60 to 79 inches
Slowest permeability class: Moderately slow above the bedrock
Available water capacity to 60 inches: About 5.4 inches (Moderate)

Selected Hydrologic Properties of Walnett extremely stony
Present annual flooding: None
Present annual ponding: None
Surface runoff: High

Current water table: None noted.
Natural drainage class: Well drained
Hydrologic Soil Group: C

California Land Use Interpretive Groups
Land capability nonirrigated: 7e
Ecological site: F005XB105CA, Pinus jeffreyi-pseudotsuga menziesii/lithocarpus densiflorus var. echinoides-arctostaphylos nevadensis/xerophyllum tenax

Typical Profile
**Oi--0 to 1 in (0 to 2 cm); slightly decomposed plant material
**A--1 to 5 in (2 to 13 cm); very stony loam
**Bt--5 to 43 in (13 to 109 cm); very gravelly clay loam
**C--43 to 61 in (109 to 155 cm); extremely gravelly loam
**R--61 to 65 in (155 to 165 cm); bedrock

Minor Components
****Lithic Haploxeralfs ultramafic and similar soils
Composition: About 10 percent
Slope: 50 to 70 percent
Landform: Mountain slope
Typical vegetation: None assigned
Ecological site: Not Assigned

****Gasquet extremely stony and similar soils
Composition: About 5 percent
Slope: 15 to 30 percent
Landform: Mountain slope
Typical vegetation: None assigned
Ecological site: Not Assigned

****Rock Outcrop
Composition: About 5 percent
Slope: 30 to 75 percent
Landform: Mountain slope
Typical vegetation: None assigned

Ecological site: Not Assigned

****Ultic Haploxeralfs fine-loamy and similar soils
Composition: About 5 percent
Slope: 30 to 75 percent
Landform: Mountain slope
Typical vegetation: None assigned
Ecological site: Not Assigned

*****760--Jayel-Walnett-Oragran Complex, 9 To 30 Percent Slopes, Extremely Stony**

Map Unit Setting
General location: Little Bald Hills southeast of the town of Hiouchi.
Major uses: Recreation, wildlife habitat and watershed.
MLRA: 5 - Siskiyou-Trinity Area
Map unit landscape: mountains
Landscape setting: Broad ridges and moderately steep mountain slopes.
Elevation: 1535 to 2410 feet (469 to 735 meters)
Mean annual precipitation: 90 to 120 inches (2290 to 3050 millimeters)
Mean annual air temperature: 50 to 55 degrees F. (10 to 13 degrees C.)
Frost-free period: 100 to 180 days

Map Unit Composition
**Jayel extremely stony--30 percent
**Walnett extremely stony--25 percent
**Oragran--25 percent
Minor components: 20 percent

Major Component Description
*Jayel extremely stony and similar soils
Slope: 9 to 30 percent
Aspect: None noted
Landform: Mountain slope, Broad ridge
Parent material: Colluvium and residuum weathered from serpentinized peridotite
Typical vegetation: Overstory of scattered Jeffery pine, knobcone pine, Douglas-fir and Port-Orford cedar. There is a shrub layer of huckleberry oak and manzanita and Idaho and California fescues, bromes and sedges in the herb layer.

Selected Properties and Qualities of Jayel extremely stony
Surface area covered by coarse fragments: 0 to 30 percent subangular stones
Depth to restrictive feature: Bedrock (lithic)--20 to 40 inches
Slowest permeability class: Slow above the bedrock
Available water capacity to 60 inches: About 4.7 inches (Low)

Selected Hydrologic Properties of Jayel extremely stony
Present annual flooding: None
Present annual ponding: None
Surface runoff: High
Current water table: None noted.
Natural drainage class: Well drained
Hydrologic Soil Group: D

California Land Use Interpretive Groups
Land capability nonirrigated: 6e
Ecological site: F005XB105CA, Pinus jeffreyi-pseudotsuga menziesii/lithocarpus densiflorus var. echinoides-arctostaphylos nevadensis/xerophyllum tenax

Typical Profile
**Oi--0 to 1 in (0 to 2 cm); slightly decomposed plant material
**A--1 to 11 in (2 to 28 cm); stony clay loam
**Bw--11 to 32 in (28 to 81 cm); stony clay
**R--32 to 40 in (81 to 102 cm); bedrock

*Oragran and similar soils
Slope: 9 to 30 percent
Aspect: None noted
Landform: Mountain slope, Broad ridge
Parent material: Residuum weathered from peridotite or serpentinite
Typical vegetation: Overstory of scattered Jeffery pine, knobcone pine and Douglas-fir. There is a shrub layer of huckleberry oak and manzanita.

Selected Properties and Qualities of Oragran
Surface area covered by coarse fragments: None noted.
Depth to restrictive feature: Bedrock (lithic)--10 to 20 inches
Slowest permeability class: Moderately slow above the bedrock
Available water capacity to 60 inches: About 2.3 inches (Very low)

Selected Hydrologic Properties of Oragran
Present annual flooding: None
Present annual ponding: None

Surface runoff: High
Current water table: None noted.
Natural drainage class: Well drained
Hydrologic Soil Group: D

California Land Use Interpretive Groups
Land capability nonirrigated: 6e
Ecological site: F005XB105CA, Pinus jeffreyi-pseudotsuga menziesii/lithocarpus densiflorus var. echinoides-arctostaphylos nevadensis/xerophyllum tenax

Typical Profile
**Oi--0 to 1 in (0 to 2 cm); slightly decomposed plant material
**A--1 to 3 in (2 to 8 cm); very stony loam
**Bw--3 to 13 in (8 to 33 cm); stony silt loam
**R--13 to 17 in (33 to 43 cm); bedrock

*Walnett extremely stony and similar soils
Slope: 9 to 30 percent
Aspect: None noted
Landform: Mountain slope, Broad ridge
Parent material: Colluvium and residuum weathered from serpentinized peridotite
Typical vegetation: Overstory of scattered Jeffery pine, knobcone pine, Douglas-fir and Port-Orford cedar. There is a shrub layer of huckleberry oak and manzanita and Idaho and California fescues, bromes and sedges in the herb layer.

Selected Properties and Qualities of Walnett extremely stony
Surface area covered by coarse fragments: 10 to 30 percent subangular stones
Depth to restrictive feature: Bedrock (lithic)--60 to 79 inches
Slowest permeability class: Moderately slow above the bedrock
Available water capacity to 60 inches: About 5.4 inches (Moderate)

Selected Hydrologic Properties of Walnett extremely stony
Present annual flooding: None
Present annual ponding: None
Surface runoff: Medium
Current water table: None noted.

Natural drainage class: Well drained
Hydrologic Soil Group: C

California Land Use Interpretive Groups
Land capability nonirrigated: 6e
Ecological site: F005XB105CA, Pinus jeffreyi-pseudotsuga menziesii/lithocarpus densiflorus var. echinoides-arctostaphylos nevadensis/xerophyllum tenax

Typical Profile
**Oi--0 to 1 in (0 to 2 cm); slightly decomposed plant material
**A--1 to 5 in (2 to 13 cm); very stony loam
**Bt--5 to 43 in (13 to 109 cm); very gravelly clay loam
**C--43 to 61 in (109 to 155 cm); extremely gravelly loam
**R--61 to 65 in (155 to 165 cm); bedrock

Minor Components
****Weitchepec and similar soils
Composition: About 10 percent
Slope: 15 to 50 percent
Landform: Mountain slope
Typical vegetation: None assigned
Ecological site: Not Assigned

****Gasquet extremely stony and similar soils
Composition: About 5 percent
Slope: 9 to 30 percent
Landform: Mountain slope
Typical vegetation: None assigned
Ecological site: Not Assigned

****Rock Outcrop
Composition: About 5 percent
Slope: 30 to 75 percent
Landform: Mountain slope
Typical vegetation: None assigned
Ecological site: Not Assigned

*****761--Gasquet-Walnett-Jayel Complex, 9 To 50 Percent Slopes**

Map Unit Setting

General location: Little Bald Hills southeast of the town of Hiouchi.

Major uses: Recreation, wildlife habitat and watershed.

MLRA: 5 - Siskiyou-Trinity Area

Map unit landscape: mountains

Landscape setting: Moderately steep to steep mountain slopes.

Elevation: 510 to 2515 feet (156 to 768 meters)

Mean annual precipitation: 90 to 120 inches (2290 to 3050 millimeters)

Mean annual air temperature: 50 to 55 degrees F. (10 to 13 degrees C.)

Frost-free period: 140 to 180 days

Map Unit Composition

**Gasquet extremely stony--30 percent

**Walnett extremely stony--25 percent

**Jayel--20 percent

Minor components: 25 percent

Major Component Description

*Gasquet extremely stony and similar soils

Slope: 9 to 40 percent

Aspect: None noted

Landform: Mountain slope

Parent material: Colluvium and residuum weathered from serpentinized peridotite

Typical vegetation: Overstory of Douglas-fir, tanoak, and madrone. There is a shrub layer of evergreen huckleberry, huckleberry oak, and coffeeberry.

Selected Properties and Qualities of Gasquet extremely stony

Surface area covered by coarse fragments: 5 to 15 percent subangular stones

Depth to restrictive feature: Bedrock (lithic)--60 to 472 inches

Slowest permeability class: Slow above the bedrock

Available water capacity to 60 inches: About 9.4 inches (High)

Selected Hydrologic Properties of Gasquet extremely stony

Present annual flooding: None

Present annual ponding: None
Surface runoff: Very high
Current water table: None noted.
Natural drainage class: Well drained
Hydrologic Soil Group: D

California Land Use Interpretive Groups
Land capability nonirrigated: 6e
Ecological site: F005XB105CA, Pinus jeffreyi-pseudotsuga menziesii/lithocarpus densiflorus var. echinoides-arctostaphylos nevadensis/xerophyllum tenax

Typical Profile
**Oi--0 to 1 in (0 to 2 cm); slightly decomposed plant material
**A--1 to 10 in (2 to 25 cm); stony loam
**Bt--10 to 61 in (25 to 155 cm); stony clay loam
**R--61 to 65 in (155 to 165 cm); bedrock

*Walnett extremely stony and similar soils
Slope: 9 to 50 percent
Aspect: None noted
Landform: Mountain slope
Parent material: Colluvium and residuum weathered from serpentinized peridotite
Typical vegetation: Overstory of Douglas-fir, tanoak, and madrone. There is a shrub layer of evergreen huckleberry, huckleberry oak, and coffeeberry.
Selected Properties and Qualities of Walnett extremely stony

Surface area covered by coarse fragments: 10 to 30 percent subangular stones
Depth to restrictive feature: Bedrock (lithic)--60 to 79 inches
Slowest permeability class: Moderately slow above the bedrock
Available water capacity to 60 inches: About 5.4 inches (Moderate)

Selected Hydrologic Properties of Walnett extremely stony
Present annual flooding: None
Present annual ponding: None
Surface runoff: High
Current water table: None noted.

Natural drainage class: Well drained
Hydrologic Soil Group: C

California Land Use Interpretive Groups
Land capability nonirrigated: 6e
Ecological site: F005XB105CA, Pinus jeffreyi-pseudotsuga menziesii/lithocarpus densiflorus var. echinoides-arctostaphylos nevadensis/xerophyllum tenax

Typical Profile
**Oi--0 to 1 in (0 to 2 cm); slightly decomposed plant material
**A--1 to 5 in (2 to 13 cm); very stony loam
**Bt--5 to 43 in (13 to 109 cm); very gravelly clay loam
**C--43 to 61 in (109 to 155 cm); extremely gravelly loam
**R--61 to 65 in (155 to 165 cm); bedrock

*Jayel and similar soils
Slope: 9 to 50 percent
Aspect: None noted
Landform: Mountain slope
Parent material: Colluvium and residuum weathered from serpentinized peridotite
Typical vegetation: Overstory of Douglas-fir, tanoak, and madrone. There is a shrub layer of evergreen huckleberry, huckleberry oak, and coffeeberry.

Selected Properties and Qualities of Jayel
Surface area covered by coarse fragments: None noted.
Depth to restrictive feature: Bedrock (lithic)--20 to 40 inches
Slowest permeability class: Slow above the bedrock
Available water capacity to 60 inches: About 4.6 inches (Low)

Selected Hydrologic Properties of Jayel
Present annual flooding: None
Present annual ponding: None
Surface runoff: High
Current water table: None noted.
Natural drainage class: Well drained
Hydrologic Soil Group: D

California Land Use Interpretive Groups
Land capability nonirrigated: 6e
Ecological site: F005XB105CA, Pinus jeffreyi-pseudotsuga menziesii/lithocarpus densiflorus var. echinoides-arctostaphylos nevadensis/xerophyllum tenax

Typical Profile
**A--0 to 12 in (0 to 30 cm); clay loam
**Bw--12 to 40 in (30 to 102 cm); gravelly clay
**R--40 to 60 in (102 to 152 cm); bedrock

Minor Components
****Lithic Haploxeralfs and similar soils
Composition: About 10 percent
Slope: 50 to 70 percent
Landform: Mountain slope
Typical vegetation: None assigned
Ecological site: Not Assigned

****Oragran moderately deep and similar soils
Composition: About 10 percent
Slope: 30 to 50 percent
Landform: Mountain slope
Typical vegetation: None assigned
Ecological site: Not Assigned

****Ultic Haploxeralfs fine-loamy and similar soils
Composition: About 5 percent
Slope: 30 to 50 percent
Landform: Mountain slope
Typical vegetation: None assigned
Ecological site: Not Assigned

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APPENDIX D

MILL CREEK ADDITION

ROAD ASSESSMENT SUMMARY TABLES

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Table D-1. Prioritized road assessment results

											Road Fills*		Crossings*						Landings*						Mass Wasting Sites*					
	Route Length	Final Road Rank (1-12)	Site Failure Potential Rank (1-3)***	Fill Failure Potential Rank (1-3)	Site Threat Rank (1-3)***	Fill Threat Rank (1-3)**	Total Number of Sites	Total Crossings	Total Landings	Total Mass Wasting	Fill Failure Potential Rank (1-3)	Total Fill Threat Volume	High Failure Potential	High Threat Volume	Moderate Failure Potential	Moderate Threat Volume	Low Failure Potential	Low Threat Volume	High Failure Potential	High Threat Volume	Moderate Failure Potential	Moderate Threat Volume	Low Failure Potential	Low Threat Volume	High Failure Potential	High Threat Volume	Moderate Failure Potential	Moderate Threat Volume	Low Failure Potential	Low Threat Volume
Road/Route	(km)						(#)	(#)	(#)	(#)		m³	#	m³	#	m³	#	m³	#	m³	#	m³	#	m³	#	m³	#	m³	#	m³
Camp Spur-1-1	0.14	12	3	3	3	3	3	1	2	0	3	54	0	0	1	317	0	0	1	1,200	1	2,250	0	0	0	0	0	0	0	0
Ray Smith-1	0.11	12	3	3	3	3	2	0	2	0	3	52	0	0	0	0	0	0	0	0	2	2,520	0	0	0	0	0	0	0	0
1st Switchback-2-2	0.07	12	3	3	3	3	2	0	2	0	3	33	0	0	0	0	0	0	0	0	0	0	2	1,500	0	0	0	0	0	0
Smoke House Rd-1A	0.25	11	3	3	3	2	6	3	0	3	3	73	3	3,554	0	0	0	0	0	0	0	0	0	0	2	2,750	0	0	1	0
Park Spur-1	0.56	11	3	3	3	2	10	5	4	1	3	172	3	2,520	2	3,702	0	0	1	3,150	3	4,276	0	0	1	250	0	0	0	0
Hunter Fire-4	0.08	11	3	2	3	3	1	0	1	0	2	31	0	0	0	0	0	0	1	1,200	0	0	0	0	0	0	0	0	0	0
Low Divide-4	0.53	11	3	3	3	2	8	3	1	4	3	165	2	959	1	174	0	0	0	0	1	1,000	0	0	1	5,000	2	80	1	0
1st Switchback-2	1.58	11	2	3	3	3	21	4	6	11	3	594	0	0	2	974	2	1,019	3	5,175	2	2,210	1	1,120	4	6,500	4	1,800	2	160
B&B Spur	3.00	11	3	3	3	2	33	13	13	7	3	893	6	5,948	4	1,685	3	1,234	6	9,360	3	2,475	4	2,800	5	12,250	1	0	1	
Flashlite	2.01	11	3	3	3	2	22	5	5	12	3	546	3	2,526	1	1,672	1	630	2	6,475	3	4,500	0	0	5	6,500	3	500	4	50
Westside Spur	3.70	11	2	3	3	3	32	14	13	5	3	1,374	11	9,327	3	2,846	2	1,356	2	3,000	11	18,225	0	0	3	4,400	3	275	0	0
P-Line Spur-1-1	0.84	11	2	3	3	3	6	1	1	4	3	327	0	0	2	3,401	0	0	1	2,250	0	0	0	0	2	2,500	0	0	2	300
Dry Lake-1A	0.23	11	3	3	2	3	4	1	1	2	3	99	0	0	1	362	0	0	0	0	1	800	0	0	0	0	2	0	0	0
Rock Creek Road-8	0.08	10	2	2	3	3	1	0	1	0	2	51	0	0	0	0	0	0	0	0	1	7,200	0	0	0	0	0	0	0	0
Mussel-3	0.07	10	3	3	3	1	1	0	1	0	3	11	0	0	0	0	0	0	1	2,025	0	0	0	0	0	0	0	0	0	0
Moratorium-3-1	0.06	10	3	2	3	2	1	0	1	0	2	14	0	0	0	0	0	0	1	1,350	0	0	0	0	0	0	0	0	0	0
Childs Hill-5	0.77	10	3	2	3	2	11	2	2	7	2	144	2	3,792	0	0	0	0	1	2,800	1	3,990	0	0	3	6,500	2	0	2	0
Ear Spur-1	0.07	10	3	2	3	2	1	0	1	0	2	17	0	0	0	0	0	0	0	0	1	1,462	0	0	0	0	0	0	0	0
Heat Spur-1	0.12	10	2	2	3	3	1	0	1	0	2	48	0	0	0	0	0	0	0	0	1	2,250	0	0	0	0	0	0	0	0
Mussel-1-A-1	0.06	10	2	2	3	3	1	0	1	0	2	38	0	0	0	0	0	0	0	0	0	0	1	1,000	0	0	0	0	0	0
Visser Spur-1	0.09	10	2	2	3	3	1	0	1	0	2	44	0	0	0	0	0	0	0	0	1	1,500	0	0	0	0	0	0	0	0
Rocky Point-2	0.16	10	3	2	3	2	3	1	2	0	2	55	0	0	0	0	1	147	0	0	2	2,340	0	0	0	0	0	0	0	0
Head Hunter-4	0.32	10	2	3	3	2	3	0	2	1	3	103	0	0	0	0	0	0	0	0	2	4,200	0	0	0	0	1	0	0	0
Howards Spur-1	0.18	10	2	3	3	2	3	0	1	2	3	59	0	0	0	0	0	0	1	1,688	0	0	0	0	0	0	0	0	2	600
East Side	0.95	10	2	3	3	2	6	3	1	2	3	306	2	7,493	1	258	0	0	0	0	0	0	1	690	1	3,500	1	0	0	0
West Branch Road-Park Spur Link-1-1	0.16	10	3	3	3	1	2	0	1	1	3	18	0	0	0	0	0	0	1	1,890	0	0	0	0	0	0	1	35	0	0
Powder House Right	2.34	10	2	3	3	2	30	14	12	4	3	766	4	2,174	3	1,387	6	3,430	7	15,478	3	3,795	1	650	0	0	2	100	2	0
Sec. 5-1	0.32	10	3	2	3	2	5	0	3	2	2	60	0	0	0	0	0	0	2	1,980	1	1,215	0	0	0	0	3	445	0	0
Childs Hill-2	0.32	10	3	2	3	2	6	0	2	4	2	79	0	0	0	0	0	0	2	3,600	0	0	0	0	1	0	3	0	0	0
Maple South	1.33	10	2	3	3	2	10	0	6	4	3	381	0	0	0	0	0	0	3	6,795	2	4,545	1	1,280	3	2,000	1	0	0	0
Smoke House Road	10.24	10	2	3	3	2	121	51	37	33	3	3,168	18	14,174	26	21,233	7	8,012	15	31,582	17	22,860	5	3,485	9	2,075	14	1,175	10	0
Sheepshed-4-1	0.23	10	2	3	3	2	3	1	1	1	3	43	0	0	1	820	0	0	1	1,500	0	0	0	0	0	0	0	0	1	0

Table D-1. continued

											Road Fills*		Crossings*						Landings*						Mass Wasting Sites*					
	Route Length	Final Road Rank (1-12)	Site Failure Potential Rank (1-3)***	Fill Failure Potential Rank (1-3)	Site Threat Rank (1-3)***	Fill Threat Rank (1-3)**	Total Number of Sites	Total Crossings	Total Landings	Total Mass Wasting	Fill Failure Potential Rank (1-3)	Total Fill Threat Volume	High Failure Potential	High Threat Volume	Moderate Failure Potential	Moderate Threat Volume	Low Failure Potential	Low Threat Volume	High Failure Potential	High Threat Volume	Moderate Failure Potential	Moderate Threat Volume	Low Failure Potential	Low Threat Volume	High Failure Potential	High Threat Volume	Moderate Failure Potential	Moderate Threat Volume	Low Failure Potential	Low Threat Volume
Road/Route	(km)						(#)	(#)	(#)	(#)		m³	#	m³	#	m³	#	m³	#	m³	#	m³	#	m³	#	m³	#	m³	#	m³
Cougar Ridge-2	0.92	10	2	3	2	3	8	3	2	3	3	352	1	2,310	1	509	1	415	0	0	2	4,900	0	0	1	500	0	0	2	30
Paragon-1	0.15	10	3	3	2	2	2	0	1	1	3	39	0	0	0	0	0	0	1	1,080	0	0	0	0	1	250	0	0	0	0
Wilson Creek-2	0.40	10	3	3	2	2	5	1	0	4	3	123	1	853	0	0	0	0	0	0	0	0	0	0	2	2,250	1	50	1	120
Reservoir-1	0.11	10	3	3	2	2	2	1	0	1	3	26	1	600	0	0	0	0	0	0	0	0	0	0	1	250	0	0	0	0
Sec. 36-2	1.11	10	3	3	2	2	15	8	5	2	3	385	6	2,887	2	843	0	0	0	0	5	4,755	0	0	0	0	2	20	0	0
4th Switchback	4.07	10	2	3	2	3	36	13	8	15	3	1,640	8	7,875	3	360	2	2,870	4	5,350	4	4,095	0	0	6	6,650	6	810	3	10
A-J-2-2	0.12	10	3	3	2	2	2	0	1	1	3	34	0	0	0	0	0	0	1	800	0	0	0	0	0	0	1	0	0	0
Boulder Ave	3.41	10	2	3	2	3	27	12	7	8	3	1,287	5	2,559	3	1,018	4	1,644	4	10,530	3	4,575	0	0	2	700	4	20	2	45
Timberline-Jeep Road Link-1	0.32	10	2	3	2	3	5	2	1	2	3	171	0	0	0	0	2	417	1	1,200	0	0	0	0	1	60	1	20	0	0
Mussel-1	0.43	10	2	3	2	3	4	0	0	4	3	169	0	0	0	0	0	0	0	0	0	0	0	0	1	1,500	0	0	3	850
Paragon	2.78	10	2	3	2	3	23	7	8	8	3	1,114	1	194	3	1,040	3	1,302	7	10,185	1	825	0	0	2	0	5	50	1	0
Demonstration Forest Spur-1	0.29	10	3	3	2	2	5	2	0	3	3	84	2	1,144	0	0	0	0	0	0	0	0	0	0	0	0	2	115	1	35
A-J Loop-1	1.45	10	2	3	2	3	15	8	4	3	3	584	0	0	5	2,007	3	744	1	1,200	2	1,580	1	480	2	225	1	75	0	0
Porcupine-2	0.18	10	2	3	2	3	3	1	0	2	3	65	0	0	0	0	1	511	0	0	0	0	0	0	0	0	2	225	0	0
12Pct Spur	1.70	10	2	3	2	3	11	6	1	4	3	665	0	0	3	682	3	806	0	0	1	2,250	0	0	4	2,250	0	0	0	0
Timberline	4.31	10	2	3	2	3	37	10	7	20	3	1,720	5	1,093	2	294	3	455	2	3,240	4	2,378	1	840	18	5,750	2	20	0	0
Elkhorn Road	2.51	10	2	3	2	3	14	9	1	4	3	893	5	4,142	2	367	1	261	1	1,350	0	0	0	0	4	2,200	0	0	0	0
Dry Lake-1	0.62	10	3	3	2	2	8	4	1	3	3	145	3	629	1	128	0	0	0	0	1	480	0	0	1	750	1	60	1	0
Bear-1	0.12	9	2	2	3	2	1	0	1	0	2	32	0	0	0	0	0	0	0	0	1	3,750	0	0	0	0	0	0	0	0
Westside Spur-1	0.14	9	3	1	3	2	2	0	2	0	1	33	0	0	0	0	0	0	1	3,120	0	0	1	800	0	0	0	0	0	0
No Name-2	0.20	9	2	2	3	2	2	0	2	0	2	46	0	0	0	0	0	0	0	0	2	4,350	0	0	0	0	0	0	0	0
Hunter Fire-3	0.07	9	3	2	3	1	1	0	1	0	2	12	0	0	0	0	0	0	1	1,200	0	0	0	0	0	0	0	0	0	0
J-T No. 1 Inner Loop	0.85	9	1	2	3	3	5	0	5	0	2	344	0	0	0	0	0	0	2	4,500	3	8,750	0	0	0	0	0	0	0	0
Elkhorn-1	0.18	9	2	2	3	2	2	1	1	0	2	40	1	1,490	0	0	0	0	0	0	0	0	1	1,320	0	0	0	0	0	0
Mussel-2	0.13	9	2	2	3	2	2	0	1	1	2	39	0	0	0	0	0	0	0	0	1	1,500	0	0	0	0	0	0	1	400
Hound Dog Left	1.57	9	2	2	3	2	16	7	4	5	2	440	4	10,208	1	621	2	848	0	0	4	7,805	0	0	1	150	2	1,475	1	40
Martin Spur-2	0.28	9	2	2	3	2	3	1	1	1	2	73	0	0	0	0	1	194	1	3,300	0	0	0	0	0	0	0	0	1	0
2nd Switchback	1.20	9	2	2	3	2	15	9	6	0	2	357	1	434	6	4,314	2	584	1	1,575	3	5,240	2	2,170	0	0	0	0	0	0
Rock Creek Road-11	0.74	9	2	2	3	2	8	4	4	0	2	208	1	368	1	196	2	410	1	2,100	3	5,750	0	0	0	0	0	0	0	0
Yellow Jacket-1	0.11	9	1	2	3	3	1	0	1	0	2	51	0	0	0	0	0	0	0	0	0	0	1	1,275	0	0	0	0	0	0
Upper First Gulch-2	0.38	9	2	2	3	2	4	0	3	1	2	81	0	0	0	0	0	0	1	2,250	0	0	2	1,450	0	0	1	175	0	0
Upper Visser-1	0.69	9	2	2	3	2	8	5	3	0	2	149	0	0	1	408	4	756	1	2,400	2	3,350	0	0	0	0	0	0	0	0

Table D-1. continued

											Road Fills*		Crossings*						Landings*						Mass Wasting Sites*					
	Route Length	Final Road Rank (1-12)	Site Failure Potential Rank (1-3)***	Fill Failure Potential Rank (1-3)	Site Threat Rank (1-3)***	Fill Threat Rank (1-3)**	Total Number of Sites	Total Crossings	Total Landings	Total Mass Wasting	Fill Failure Potential Rank (1-3)	Total Fill Threat Volume	High Failure Potential	High Threat Volume	Moderate Failure Potential	Moderate Threat Volume	Low Failure Potential	Low Threat Volume	High Failure Potential	High Threat Volume	Moderate Failure Potential	Moderate Threat Volume	Low Failure Potential	Low Threat Volume	High Failure Potential	High Threat Volume	Moderate Failure Potential	Moderate Threat Volume	Low Failure Potential	Low Threat Volume
Road/Route	(km)						(#)	(#)	(#)	(#)		m³	#	m³	#	m³	#	m³	#	m³	#	m³	#	m³	#	m³	#	m³	#	m³
Ordie	1.50	9	2	3	2	2	11	1	7	3	3	385	0	0	1	307	0	0	5	11,348	1	900	1	1,200	0	0	1	375	2	600
Fish Hook	1.00	9	2	2	2	3	7	0	3	4	2	370	0	0	0	0	0	0	1	780	2	5,032	0	0	3	3,750	0	0	1	0
Cougar Ridge-4	0.44	9	3	2	2	2	6	0	3	3	2	93	0	0	0	0	0	0	3	4,100	0	0	0	0	0	0	3	0	0	0
Visser Spur	4.90	9	2	2	2	3	46	24	13	9	2	1,824	6	2,777	9	4,990	9	2,486	5	9,450	7	12,735	1	2,000	5	6,400	4	370	0	0
Sec. 31 Road	3.97	9	2	2	2	3	33	14	13	6	2	1,674	1	275	6	3,529	5	3,763	6	12,650	6	8,500	1	2,400	6	1,500	0	0	0	0
Flashlite-1	0.25	9	2	3	2	2	3	0	1	2	3	72	0	0	0	0	0	0	0	0	1	1,980	0	0	0	0	2	85	0	0
Teran	5.62	9	2	3	2	2	54	24	17	13	3	1,449	7	12,398	10	6,371	7	5,567	3	4,718	10	11,948	4	3,995	1	50	5	160	7	95
4th Switchback-2	0.21	9	2	3	2	2	3	1	1	1	3	55	0	0	0	0	1	272	0	0	1	800	0	0	1	600	0	0	0	0
Windfall	1.53	9	3	2	2	2	17	6	3	8	2	469	3	5,086	2	439	1	104	3	5,475	0	0	0	0	2	750	3	75	3	1
Head Hunter-6	0.35	9	3	2	2	2	5	0	1	4	2	88	0	0	0	0	0	0	1	1,800	0	0	0	0	3	750	1	50	0	0
West Branch-Porcupine Link	0.30	9	2	3	2	2	4	1	1	2	3	76	0	0	1	305	0	0	0	0	1	1,800	0	0	0	0	2	90	0	0
Sec.5-1B	0.20	9	3	2	2	2	2	1	1	0	2	48	1	524	0	0	0	0	1	900	0	0	0	0	0	0	0	0	0	0
Bummer Lake Road-1	0.42	9	1	3	2	3	2	0	2	0	3	159	0	0	0	0	0	0	0	0	2	2,950	0	0	0	0	0	0	0	0
Visser Spur-1A	1.05	9	2	3	2	2	8	2	2	4	3	209	2	908	0	0	0	0	1	1,800	1	1,500	0	0	3	3,000	1	175	0	0
Sheepshed-4	1.62	9	2	3	2	2	15	7	5	3	3	420	1	381	6	3,608	0	0	0	0	4	5,145	1	1,800	1	25	1	0	1	50
Bucket Spur-3-1	0.50	9	2	3	2	2	6	4	1	1	3	112	1	284	3	1,690	0	0	0	0	0	0	1	1,200	0	0	1	40	0	0
Rock Creek Road	20.76	9	1	3	2	3	144	96	34	14	3	8,096	44	45,149	18	11,666	29	11,214	14	22,208	15	25,005	5	7,960	6	1,450	6	100	2	0
Wilbur Spur Loop	1.10	9	2	3	2	2	11	5	3	3	3	268	2	1,443	2	502	1	77	1	1,500	2	2,700	0	0	1	500	1	10	1	0
Rattlesnake	0.83	9	2	3	2	2	11	6	3	2	3	217	0	0	1	90	5	939	0	0	2	2,200	1	750	0	0	1	50	1	1,000
Chipmunk Road	0.99	9	2	3	2	2	14	7	1	6	3	318	0	0	3	2,835	3	1,002	1	1,155	0	0	0	0	1	250	5	409	0	0
Zone 15	2.21	9	2	3	2	2	19	5	7	7	3	428	0	0	2	537	2	660	7	10,088	0	0	0	0	3	1,500	4	65	0	0
J-T No. 1	2.46	9	1	3	2	3	9	3	6	0	3	1,259	0	0	2	1,810	1	207	0	0	5	10,815	1	600	0	0	0	0	0	0
Rock Creek Road-10	1.22	9	2	3	2	2	15	8	2	5	3	302	5	1,164	1	613	2	384	1	2,000	1	1,875	0	0	0	0	1	200	4	600
Turwar	2.38	9	2	3	2	2	19	9	4	6	3	479	4	3,002	5	2,374	0	0	1	1,200	3	3,240	0	0	1	1,500	2	1,000	3	600
Rock Creek Road-7	1.23	9	2	3	2	2	12	6	2	4	3	364	4	2,802	1	510	0	0	1	1,350	1	650	0	0	1	750	3	405	0	0
Smoke House-3	0.41	9	3	2	2	2	5	0	1	4	2	123	0	0	0	0	0	0	0	0	1	975	0	0	2	1,000	0	0	2	30
Howards Spur	4.93	9	2	3	2	2	56	29	4	23	3	1,286	10	7,553	13	3,426	5	1,594	3	4,800	1	1,170	0	0	8	1,825	7	865	8	900
1st Switchback	1.01	9	2	3	2	2	11	4	4	3	3	277	1	356	2	748	1	604	0	0	3	1,500	1	600	0	0	2	35	1	50
48 Spur	1.34	9	2	3	2	2	13	8	1	4	3	416	5	3,019	2	939	1	457	0	0	1	480	0	0	0	0	2	20	2	145
Ear Spur	1.39	9	2	3	2	2	10	2	3	5	3	334	2	466	0	0	0	0	1	1,080	2	2,662	0	0	1	250	3	0	1	0
Wilbur-Head Hunter-1	0.59	9	2	3	1	3	4	1	1	2	3	226	0	0	0	0	1	360	1	525	0	0	0	0	1	250	1	50	0	0
Crossover-1	0.26	9	2	3	1	3	4	0	0	4	3	115	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	50	3	40

Table D-1. continued

Road/Route	Route Length	Final Road Rank (1-12)	Site Failure Potential Rank (1-3)***	Fill Failure Potential Rank (1-3)	Site Threat Rank (1-3)***	Fill Threat Rank (1-3)**	Total Number of Sites	Total Crossings	Total Landings	Total Mass Wasting	Road Fills*: Fill Failure Potential Rank (1-3)	Road Fills*: Total Fill Threat Volume	Crossings*: High Failure Potential	Crossings*: High Threat Volume	Crossings*: Moderate Failure Potential	Crossings*: Moderate Threat Volume	Crossings*: Low Failure Potential	Crossings*: Low Threat Volume	Landings*: High Failure Potential	Landings*: High Threat Volume	Landings*: Moderate Failure Potential	Landings*: Moderate Threat Volume	Landings*: Low Failure Potential	Landings*: Low Threat Volume	Mass Wasting Sites*: High Failure Potential	Mass Wasting Sites*: High Threat Volume	Mass Wasting Sites*: Moderate Failure Potential	Mass Wasting Sites*: Moderate Threat Volume	Mass Wasting Sites*: Low Failure Potential	Mass Wasting Sites*: Low Threat Volume
	(km)						(#)	(#)	(#)	(#)		m³	#	m³	#	m³	#	m³	#	m³	#	m³	#	m³	#	m³	#	m³	#	m³
Head Hunter-5	0.08	9	2	3	1	3	1	0	0	1	3	36	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	20	0	0
Porcupine-3	0.10	9	3	3	1	2	2	0	0	2	3	27	0	0	0	0	0	0	0	0	1	0	0	0	0	0	1	25	0	0
Childs Hill-5-1	0.11	8	3	1	3	1	2	0	1	1	1	10	0	0	0	0	0	0	1	3,375	0	0	0	0	0	0	0	0	1	0
Low Divide-3	0.07	8	3	1	3	1	1	0	1	0	1	3	0	0	0	0	0	0	0	0	1	1,912	0	0	0	0	0	0	0	0
Maple Spur-2	0.07	8	3	1	3	1	2	0	1	1	1	7	0	0	0	0	0	0	1	1,575	0	0	0	0	1	100	0	0	0	0
Airport Spur-3	0.12	8	1	2	3	2	1	0	1	0	2	41	0	0	0	0	0	0	0	0	1	2,500	0	0	0	0	0	0	0	0
Prospect-1	0.21	8	2	1	3	2	4	2	2	0	1	52	0	0	0	0	2	966	0	0	2	3,300	0	0	0	0	0	0	0	0
Low Divide-6	0.29	8	3	1	3	1	3	0	1	2	1	40	0	0	0	0	0	0	1	1,050	0	0	0	0	1	3,500	1	150	0	0
J-T No. 1 Loop-1-2	0.07	8	3	1	3	1	1	0	1	0	1	6	0	0	0	0	0	0	0	0	1	1,125	0	0	0	0	0	0	0	0
Wilbur Spur-5	0.13	8	1	2	3	2	1	0	1	0	2	33	0	0	0	0	0	0	0	0	1	2,000	0	0	0	0	0	0	0	0
Wilbur Spur-3	0.33	8	2	1	3	2	3	0	3	0	1	84	0	0	0	0	0	0	0	0	2	3,987	1	480	0	0	0	0	0	0
Hilton Spur-2	0.14	8	3	1	3	1	4	2	2	0	1	12	0	0	0	0	2	447	0	0	1	540	1	840	0	0	0	0	0	0
Camp Spur	1.34	8	1	2	3	2	13	9	4	0	2	412	0	0	2	1,210	7	2,502	0	0	4	12,712	0	0	0	0	0	0	0	0
Mule Trail-2	0.18	8	1	2	3	2	1	0	1	0	2	40	0	0	0	0	0	0	0	0	1	2,000	0	0	0	0	0	0	0	0
Sec. 36-6	0.14	8	2	2	3	1	1	0	1	0	2	24	0	0	0	0	0	0	1	1,500	0	0	0	0	0	0	0	0	0	0
J-T No. 1 Loop-2	0.16	8	1	2	3	2	1	0	1	0	2	48	0	0	0	0	0	0	0	0	1	1,688	0	0	0	0	0	0	0	0
Bear	1.59	8	1	2	3	2	12	7	5	0	2	315	2	4,145	4	1,148	1	67	1	2,700	2	4,800	2	3,500	0	0	0	0	0	0
Jane Creek Road	1.70	8	2	2	3	1	20	9	7	4	2	278	3	2,985	3	795	3	508	6	11,825	0	0	1	600	1	500	2	200	1	0
Sec. 36-5	0.18	8	2	1	3	2	2	0	1	1	1	61	0	0	0	0	0	0	0	0	1	1,800	0	0	0	0	1	0	0	0
A-J Loop	1.46	8	1	2	3	2	11	5	5	1	2	323	1	974	3	6,466	1	480	1	1,287	4	4,914	0	0	0	0	0	0	1	550
Smokehouse Road Loop	0.21	8	1	2	3	2	1	0	1	0	2	38	0	0	0	0	0	0	0	0	1	2,100	0	0	0	0	0	0	0	0
Rock Creek Road-9	0.92	8	2	2	2	2	9	3	4	2	2	199	0	0	2	822	0	0	2	4,050	2	3,525	0	0	0	0	1	250	1	350
3rd Switchback	0.87	8	2	2	2	2	12	6	2	4	2	158	2	1,196	2	601	1	250	1	2,835	1	1,912	0	0	1	250	0	0	2	1,450
Bucket Spur-2	0.17	8	1	3	2	2	2	0	1	1	3	43	0	0	0	0	0	0	0	0	0	0	1	1,600	0	0	0	0	1	0
Bummer Lake Road	7.40	8	2	3	2	1	63	30	20	13	3	1,295	9	7,042	14	12,563	7	6,911	14	24,866	6	11,312	0	0	7	3,430	5	915	2	1,230
Madrone	0.70	8	2	2	2	2	7	1	6	0	2	196	0	0	1	288	0	0	1	400	3	3,108	2	2,255	0	0	0	0	0	0
Cabin Spur	2.76	8	2	2	2	2	25	11	9	5	2	706	3	2,458	6	3,676	2	506	4	7,350	4	6,450	1	1,100	0	0	1	0	4	70
First Gulch	2.56	8	2	2	2	2	26	15	7	4	2	600	5	5,222	9	4,658	1	201	1	2,000	3	5,400	2	1,860	2	350	0	0	2	0
Bucket Spur-1-1	0.29	8	2	3	2	1	5	2	2	1	3	46	1	134	0	0	1	263	0	0	0	0	2	1,800	0	0	0	0	1	0
Wilson Creek-1	0.10	8	3	2	2	1	1	0	1	0	2	14	0	0	0	0	0	0	1	750	0	0	0	0	0	0	0	0	0	0
Cedar	1.93	8	2	2	2	2	22	8	7	7	2	413	6	4,974	1	558	1	331	5	6,502	2	1,605	0	0	0	0	2	10	5	20
Violated Spur	3.16	8	2	2	2	2	34	17	12	5	2	904	1	156	3	854	13	2,645	1	1,688	10	14,882	1	910	3	940	3	80	0	0

Table D-1. continued

Road/Route	Route Length	Final Road Rank (1-12)	Site Failure Potential Rank (1-3)***	Fill Failure Potential Rank (1-3)	Site Threat Rank (1-3)***	Fill Threat Rank (1-3)**	Total Number of Sites	Total Crossings	Total Landings	Total Mass Wasting	Road Fills*: Fill Failure Potential Rank (1-3)	Road Fills*: Total Fill Threat Volume	Crossings*: High Failure Potential	Crossings*: High Threat Volume	Crossings*: Moderate Failure Potential	Crossings*: Moderate Threat Volume	Crossings*: Low Failure Potential	Crossings*: Low Threat Volume	Landings*: High Failure Potential	Landings*: High Threat Volume	Landings*: Moderate Failure Potential	Landings*: Moderate Threat Volume	Landings*: Low Failure Potential	Landings*: Low Threat Volume	Mass Wasting Sites*: High Failure Potential	Mass Wasting Sites*: High Threat Volume	Mass Wasting Sites*: Moderate Failure Potential	Mass Wasting Sites*: Moderate Threat Volume	Mass Wasting Sites*: Low Failure Potential	Mass Wasting Sites*: Low Threat Volume
	(km)						(#)	(#)	(#)	(#)		m³	#	m³	#	m³	#	m³	#	m³	#	m³	#	m³	#	m³	#	m³	#	m³
Hound Dog	0.85	8	2	2	2	2	6	2	2	2	2	232	2	2,841	0	0	0	0	0	0	2	2,790	0	0	1	250	1	5	0	0
Hunter Fire-2	0.46	8	2	2	2	2	5	2	1	2	2	93	0	0	2	427	0	0	1	1,800	0	0	0	0	0	0	0	0	2	800
Rock Creek Loop	0.40	8	1	3	2	2	4	2	1	1	3	104	0	0	0	0	2	881	1	1,650	0	0	0	0	0	0	1	25	0	0
Childs Hill-4-1	0.27	8	2	3	2	1	2	1	0	1	3	27	0	0	1	259	0	0	0	0	0	0	0	0	1	1,500	0	0	0	0
Crossover-2	0.15	8	2	3	2	1	2	0	1	1	3	21	0	0	0	0	0	0	0	0	1	960	0	0	0	0	1	0	0	0
Rock Creek Road-6	0.64	8	2	2	2	2	7	4	2	1	2	195	1	1,116	2	308	1	325	1	1,200	1	750	0	0	0	0	1	300	0	0
Camp Spur-1	0.26	8	2	2	2	2	3	2	1	0	2	60	0	0	1	236	1	206	1	1,200	0	0	0	0	0	0	0	0	0	0
2nd Switchback-1	1.92	8	1	2	2	3	18	13	5	0	2	684	1	831	5	2,816	7	1,703	0	0	2	3,172	3	2,940	0	0	0	0	0	0
1st Switchback-1	0.56	8	1	3	2	2	4	1	1	2	3	176	0	0	1	108	0	0	1	2,700	0	0	0	0	0	0	2	400	0	0
Sheepshed-2	0.22	8	2	2	2	2	3	0	1	2	2	44	0	0	0	0	0	0	1	1,200	0	0	0	0	0	0	0	0	2	0
West Branch Road-5	0.24	8	1	3	2	2	3	1	1	1	3	50	0	0	0	0	1	104	0	0	0	0	1	1,200	0	0	0	0	1	0
Sec. 5-2	0.23	8	1	2	2	3	1	0	1	0	2	88	0	0	0	0	0	0	0	0	0	0	1	1,200	0	0	0	0	0	0
Low Divide-7	0.26	8	1	2	2	3	1	0	1	0	2	98	0	0	0	0	0	0	0	0	1	1,350	0	0	0	0	0	0	0	0
Childs Hill Loop	1.01	8	1	3	2	2	6	2	2	2	3	336	1	880	0	0	1	442	2	3,750	0	0	0	0	0	0	2	125	0	0
Sheepshed-3	0.91	8	2	2	2	2	10	5	3	2	2	218	1	407	1	203	3	1,046	0	0	2	1,680	1	1,200	1	0	0	0	1	50
Bucket Spur-3	0.71	8	2	2	2	2	9	5	1	3	2	198	1	119	4	2,024	0	0	0	0	1	1,200	0	0	1	50	1	30	1	25
West Branch Road	14.49	8	1	3	2	2	92	47	15	30	3	5,039	31	25,550	11	8,461	4	432	7	15,225	8	14,400	0	0	2	600	17	863	12	423
Wilson Creek Road	4.02	8	1	3	2	2	22	11	4	7	3	1,206	6	7,774	3	1,014	2	2,487	2	3,000	1	1,300	1	1,000	1	750	3	850	3	400
Childs Hill Road	23.06	8	1	3	2	2	141	86	25	30	3	7,121	37	36,909	30	15,057	14	4,351	15	31,088	7	12,450	3	3,100	7	2,240	10	135	13	20
End Haul-1	0.46	8	1	3	2	2	4	0	2	2	3	122	0	0	0	0	0	0	1	760	0	0	1	1,000	0	0	1	250	1	100
Upper First Gulch	5.22	8	1	3	2	2	32	10	12	10	3	1,310	7	5,686	1	574	2	680	1	1,170	8	11,635	3	3,690	3	50	6	415	1	50
Sec. 5 Road	3.98	8	2	2	2	2	43	22	6	15	2	949	8	3,808	6	2,434	6	1,103	3	5,438	2	3,622	1	720	1	250	6	340	9	225
Ramp Spur	1.36	8	2	2	2	2	10	6	4	0	2	303	3	1,130	3	1,170	0	0	0	0	4	3,660	0	0	0	0	0	0	0	0
Sec. 1-1	1.85	8	1	3	2	2	15	11	3	1	3	520	0	0	2	1,078	9	2,714	0	0	3	3,900	0	0	1	30	0	0	0	0
Smoke House-4	0.29	8	1	3	2	2	4	2	1	1	3	91	0	0	0	0	2	431	0	0	1	650	0	0	0	0	0	0	1	100
Yellow Jacket	1.40	8	1	3	2	2	11	7	3	1	3	447	1	243	3	1,414	3	598	1	1,950	1	0	1	1,400	0	0	1	25	0	0
Zone 15-1	0.31	8	1	2	2	3	1	0	1	0	2	113	0	0	0	0	0	0	0	0	1	1,200	0	0	0	0	0	0	0	0
Zone 15-2	0.29	8	2	2	2	2	2	0	1	1	2	72	0	0	0	0	0	0	0	0	1	1,100	0	0	1	0	0	0	0	0
Childs Hill-3	1.52	8	1	3	2	2	8	3	4	1	3	526	0	0	0	0	3	502	2	2,300	2	2,650	0	0	0	0	0	0	1	50
Sec. 5 Extension-1-1	0.29	8	2	2	2	2	3	0	1	2	2	70	0	0	0	0	0	0	0	0	1	1,050	0	0	0	0	1		1	0
A-J	1.68	8	1	3	2	2	14	9	2	3	3	523	0	0	3	1,093	6	2,166	1	840	1	660	0	0	0	0	2	900	1	250
Bucket Spur	3.31	8	2	2	2	2	30	15	4	11	2	1,066	9	1,726	4	2,633	2	218	1	1,800	3	3,800	0	0	0	0	5	370	6	95

Table D-1. continued

											Road Fills*		Crossings*						Landings*						Mass Wasting Sites*					
	Route Length	Final Road Rank (1-12)	Site Failure Potential Rank (1-3)***	Fill Failure Potential Rank (1-3)	Site Threat Rank (1-3)***	Fill Threat Rank (1-3)**	Total Number of Sites	Total Crossings	Total Landings	Total Mass Wasting	Fill Failure Potential Rank (1-3)	Total Fill Threat Volume	High Failure Potential	High Threat Volume	Moderate Failure Potential	Moderate Threat Volume	Low Failure Potential	Low Threat Volume	High Failure Potential	High Threat Volume	Moderate Failure Potential	Moderate Threat Volume	Low Failure Potential	Low Threat Volume	High Failure Potential	High Threat Volume	Moderate Failure Potential	Moderate Threat Volume	Low Failure Potential	Low Threat Volume
Road/Route	(km)						(#)	(#)	(#)	(#)		m³	#	m³	#	m³	#	m³	#	m³	#	m³	#	m³	#	m³	#	m³	#	m³
West Branch Road-2	0.82	8	2	2	2	2	6	4	0	2	2	262	4	2,239	0	0	0	0	0	0	0	0	0	0	1	250	1	50	0	0
Rock Creek - Crossover Link	0.42	8	2	3	1	2	3	2	0	1	3	134	1	621	1	365	0	0	0	0	0	0	0	0	1	150	0	0	0	0
Chipmunk Spur-1	0.65	8	1	3	1	3	5	2	1	2	3	239	0	0	1	347	1	394	0	0	1	800	0	0	0	0	2	195	0	0
No Name-1	0.50	8	1	3	1	3	5	3	0	2	3	180	0	0	1	375	2	362	0	0	0	0	0	0	1	50	1	0	0	0
Dry Lake-3	0.60	8	1	3	1	3	4	0	2	2	3	210	0	0	0	0	0	0	1	488	1	270	0	0	0	0	0	0	2	0
SW-40	0.79	8	1	3	1	3	3	0	1	2	3	350	0	0	0	0	0	0	0	0	1	800	0	0	0	0	1	0	1	0
Childs Hill-1	0.72	8	2	3	1	2	5	1	1	3	3	196	0	0	0	0	1	360	1	189	0	0	0	0	1	250	1	0	1	0
Childs Hill-3-1-1-1	0.45	8	1	3	1	3	1	0	0	1	3	175	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	25	0	0
Blowdown East-1-1	0.03	7	3	1	3	0	1	0	1	0	1	0	0	0	0	0	0	0	1	2,400	0	0	0	0	0	0	0	0	0	0
Blowdown East-1	0.15	7	2	1	3	1	1	0	1	0	1	16	0	0	0	0	0	0	1	3,000	0	0	0	0	0	0	0	0	0	0
Childs Hill-6	0.23	7	1	1	3	2	1	0	1	0	1	48	0	0	0	0	0	0	0	0	1	4,000	0	0	0	0	0	0	0	0
Sec. 5 Loop-1	0.54	7	1	1	3	2	4	0	4	0	1	172	0	0	0	0	0	0	1	2,160	1	1,800	2	2,525	0	0	0	0	0	0
Idiot Knob-1	0.24	7	2	1	3	1	2	0	2	0	1	29	0	0	0	0	0	0	0	0	2	2,700	0	0	0	0	0	0	0	0
Porcupine-1	0.21	7	1	1	3	2	2	0	2	0	1	52	0	0	0	0	0	0	1	2,250	0	0	1	0	0	0	0	0	0	0
West Branch Road-3	0.82	7	2	1	3	1	8	4	4	0	1	140	1	482	1	120	2	270	2	2,580	2	5,100	0	0	0	0	0	0	0	0
Sheepshed-6-1	0.22	7	1	1	3	2	2	1	1	0	1	72	0	0	0	0	1	156	0	0	1	2,100	0	0	0	0	0	0	0	0
Violated Spur-1	0.16	7	1	2	3	1	1	0	1	0	2	26	0	0	0	0	0	0	0	0	1	1,620	0	0	0	0	0	0	0	0
Sec. 1 Loop	0.66	7	1	1	3	2	4	0	4	0	1	180	0	0	0	0	0	0	1	2,400	2	2,900	1	1,300	0	0	0	0	0	0
Biltmore Spur-1	0.16	7	2	2	2	1	2	0	1	1	2	8	0	0	0	0	0	0	0	0	1	500	0	0	0	0	1	1,000	0	0
Martin Spur	2.79	7	1	2	2	2	16	8	6	2	2	597	3	9,297	3	2,936	2	2,521	1	1,268	5	9,128	0	0	0	0	2	0	0	0
J-T No. 1-1	0.14	7	2	2	2	1	1	0	1	0	2	18	0	0	0	0	0	0	1	1,200	0	0	0	0	0	0	0	0	0	0
P-J Spur	3.88	7	1	2	2	2	33	13	13	7	2	706	4	1,581	2	745	7	1,446	6	14,325	6	13,050	1	1,750	0	0	1	0	6	50
Airport Spur Loop-1-1	0.17	7	1	2	2	2	1	0	1	0	2	33	0	0	0	0	0	0	1	1,400	0	0	0	0	0	0	0	0	0	0
P-Line	3.96	7	1	2	2	2	25	13	9	3	2	1,157	2	6,251	8	5,965	3	762	1	1,800	7	13,425	1	1,500	1	2,000	0	0	2	10
1st Switchback-2-1	0.30	7	1	2	2	2	2	0	2	0	2	61	0	0	0	0	0	0	0	0	2	2,400	0	0	0	0	0	0	0	0
Head Hunter-2	0.56	7	1	2	2	2	4	1	2	1	2	145	0	0	0	0	1	86	1	2,625	1	960	0	0	1	750	0	0	0	0
Mule Trail-1A-1	0.27	7	1	2	2	2	1	0	1	0	2	64	0	0	0	0	0	0	0	0	1	2,100	0	0	0	0	0	0	0	0
Sec. 1-4	0.50	7	1	2	2	2	3	1	2	0	2	113	0	0	0	0	1	102	0	0	2	3,712	0	0	0	0	0	0	0	0
Smoke House-1	0.26	7	1	2	2	2	2	0	1	1	2	64	0	0	0	0	0	0	0	0	1	1,950	0	0	0	0	0	0	1	0
Stringer Gap	1.31	7	1	2	2	2	8	3	3	2	2	293	1	374	1	112	1	205	3	8,550	0	0	0	0	1	200	0	0	1	0
Wilbur Spur-2	0.63	7	1	2	2	2	6	3	3	0	2	176	0	0	2	586	1	155	0	0	2	2,207	1	1,536	0	0	0	0	0	0
Idiot Knob	0.46	7	1	2	2	2	2	0	2	0	2	98	0	0	0	0	0	0	1	1,950	1	1,350	0	0	0	0	0	0	0	0

Table D-1. continued

Road/Route	Route Length	Final Road Rank (1-12)	Site Failure Potential Rank (1-3)***	Fill Failure Potential Rank (1-3)	Site Threat Rank (1-3)***	Fill Threat Rank (1-3)**	Total Number of Sites	Total Crossings	Total Landings	Total Mass Wasting	Road Fills*: Fill Failure Potential Rank (1-3)	Road Fills*: Total Fill Threat Volume	Crossings*: High Failure Potential	Crossings*: High Threat Volume	Crossings*: Moderate Failure Potential	Crossings*: Moderate Threat Volume	Crossings*: Low Failure Potential	Crossings*: Low Threat Volume	Landings*: High Failure Potential	Landings*: High Threat Volume	Landings*: Moderate Failure Potential	Landings*: Moderate Threat Volume	Landings*: Low Failure Potential	Landings*: Low Threat Volume	Mass Wasting Sites*: High Failure Potential	Mass Wasting Sites*: High Threat Volume	Mass Wasting Sites*: Moderate Failure Potential	Mass Wasting Sites*: Moderate Threat Volume	Mass Wasting Sites*: Low Failure Potential	Mass Wasting Sites*: Low Threat Volume
	(km)						(#)	(#)	(#)	(#)		m³	#	m³	#	m³	#	m³	#	m³	#	m³	#	m³	#	m³	#	m³	#	m³
Moratorium-3	0.55	7	1	2	2	2	4	1	2	1	2	107	0	0	1	714	0	0	0	0	1	2,700	1	400	0	0	0	0	1	40
Dry Lake-2-1	0.18	7	1	2	2	2	1	0	1	0	2	36	0	0	0	0	0	0	1	1,210	0	0	0	0	0	0	0	0	0	0
Cull Spur-1	0.34	7	1	2	2	2	1	0	1	0	2	66	0	0	0	0	0	0	0	0	1	2,250	0	0	0	0	0	0	0	0
P-Line-Martin Spur Link	1.48	7	1	2	2	2	9	4	4	1	2	268	1	274	2	3,153	1	60	0	0	4	6,300	0	0	0	0	0	0	1	0
Blowdown	2.67	7	1	2	2	2	16	7	4	5	2	898	3	4,485	1	197	3	1,092	3	4,350	1	1,650	0	0	2	5,000	1	150	2	200
J-T No. 1 Loop-1	0.26	7	1	2	2	2	1	0	1	0	2	52	0	0	0	0	0	0	1	1,688	0	0	0	0	0	0	0	0	0	0
Bense Trail-1	0.22	7	1	2	2	2	1	0	1	0	2	72	0	0	0	0	0	0	0	0	1	1,395	0	0	0	0	0	0	0	0
Low Divide-2	1.32	7	1	2	2	2	11	3	4	4	2	368	0	0	1	431	2	971	4	6,630	0	0	0	0	0	0	2	350	2	0
BoyScout	1.69	7	1	2	2	2	13	5	4	4	2	400	0	0	1	668	4	1,646	2	4,395	2	3,510	0	0	0	0	3	200	1	0
Park Spur	4.89	7	1	2	2	2	36	23	7	6	2	1,075	8	10,245	9	6,316	6	2,022	2	3,765	4	6,030	1	1,400	1	250	2	0	3	25
Lower Spur Road	2.51	7	1	2	2	2	20	10	7	3	2	746	2	2,380	4	2,991	4	1,438	0	0	7	7,910	0	0	0	0	1	50	2	75
Mule Trail	1.79	7	1	2	2	2	12	6	3	3	2	395	0	0	2	1,242	4	2,302	2	6,300	0	0	0	0	1	750	1	0	1	0
Hound Dog Right	1.01	7	1	2	2	2	5	0	3	2	2	182	0	0	0	0	0	0	1	1,540	2	3,840	0	0	0	0	0	0	2	450
Dry Lake-4	0.08	7	1	2	2	2	1	0	1	0	2	16	0	0	0	0	0	0	0	0	0	0	1	450	0	0	0	0	0	0
Cushing-1	0.18	7	1	2	2	2	1	0	1	0	2	38	0	0	0	0	0	0	0	0	0	0	1	1,000	0	0	0	0	0	0
Powder House Left	1.70	7	1	2	2	2	12	3	7	2	2	574	0	0	1	442	2	704	2	3,262	4	3,715	1	1,035	0	0	0	0	2	45
Howards Spur-Childs Hill Loop	0.53	7	1	2	2	2	3	0	2	1	2	128	0	0	0	0	0	0	0	0	2	2,875	0	0	0	0	0	0	1	0
Martin Spur-1A	0.62	7	1	2	2	2	2	0	2	0	2	168	0	0	0	0	0	0	0	0	2	3,300	0	0	0	0	0	0	0	0
Upper First Gulch-1	0.55	7	1	2	2	2	3	0	2	1	2	151	0	0	0	0	0	0	0	0	0	0	2	2,900	0	0	0	0	1	25
Howards Spur-Childs Hill Loop-1	0.15	7	1	2	2	2	1	0	1	0	2	31	0	0	0	0	0	0	0	0	1	800	0	0	0	0	0	0	0	0
Rock Creek Road-4	0.42	7	1	2	2	2	4	2	1	1	2	97	0	0	0	0	2	344	1	1,800	0	0	0	0	0	0	1		0	0
Sec. 5 Road-Extension Link-2	0.32	7	1	2	2	2	2	1	1	0	2	96	0	0	0	0	1	594	0	0	1	990	0	0	0	0	0	0	0	0
P-J Spur-1	0.25	7	1	3	2	1	2	1	1	0	3	40	0	0	1	231	0	0	0	0	0	0	1	1,000	0	0	0	0	0	0
Mule Trail-1A	0.27	7	2	2	2	1	3	0	1	2	2	40	0	0	0	0	0	0	0	0	0	0	1	1,275	0	0	2	35	0	0
Ray Smith Road	2.75	7	1	2	2	2	24	11	8	5	2	795	1	872	4	1,303	6	1,725	1	2,100	3	3,645	4	2,980	0	0	3	165	2	25
Sec. 5 Extension	1.84	7	1	2	2	2	9	5	4	0	2	445	0	0	2	279	3	453	0	0	3	6,975	1	1,000	0	0	0	0	0	0
Old Lady	1.68	7	2	2	2	1	17	8	4	5	2	280	1	342	3	1,191	4	1,638	3	3,675	0	0	1	945	0	0	3	80	2	35
Cougar Ridge Road	5.98	7	1	2	2	2	34	15	10	9	2	1,177	2	1,698	8	2,605	5	4,178	4	9,700	5	8,300	1	1,200	0	0	4	45	5	180
Low Divide	3.64	7	1	2	2	2	30	15	7	8	2	949	0	0	7	3,224	7	2,522	2	3,780	4	5,670	1	600	0	0	3	200	6	230
Rocky Point Road	2.58	7	1	2	2	2	21	16	4	1	2	705	0	0	2	1,390	14	5,160	0	0	2	2,925	2	1,360	0	0	1	30	0	0
Sec. 1 Road	7.57	7	1	2	2	2	59	42	7	10	2	2,159	6	3,914	8	5,178	28	10,070	1	660	3	3,630	3	3,675	6	2,350	3	125	1	0
West Branch Road-Park Spur Link-1-2	0.53	7	1	2	2	2	1	0	1	0	2	142	0	0	0	0	0	0	1	2,100	0	0	0	0	0	0	0	0	0	0

Table D-1. continued

											Road Fills*		Crossings*						Landings*						Mass Wasting Sites*					
	Route Length	Final Road Rank (1-12)	Site Failure Potential Rank (1-3)***	Fill Failure Potential Rank (1-3)	Site Threat Rank (1-3)***	Fill Threat Rank (1-3)**	Total Number of Sites	Total Crossings	Total Landings	Total Mass Wasting	Fill Failure Potential Rank (1-3)	Total Fill Threat Volume	High Failure Potential	High Threat Volume	Moderate Failure Potential	Moderate Threat Volume	Low Failure Potential	Low Threat Volume	High Failure Potential	High Threat Volume	Moderate Failure Potential	Moderate Threat Volume	Low Failure Potential	Low Threat Volume	High Failure Potential	High Threat Volume	Moderate Failure Potential	Moderate Threat Volume	Low Failure Potential	Low Threat Volume
Road/Route	(km)						(#)	(#)	(#)	(#)		m³	#	m³	#	m³	#	m³	#	m³	#	m³	#	m³	#	m³	#	m³	#	m³
Mountain Lion	1.04	7	1	2	2	2	5	3	2	0	2	310	0	0	1	556	2	978	0	0	0	0	2	2,400	0	0	0	0	0	0
Head Hunter-3	0.95	7	1	2	2	2	6	4	1	1	2	234	0	0	2	946	2	314	0	0	1	2,100	0	0	1	250	0	0	0	0
Sec. 36	3.80	7	1	2	2	2	23	11	10	2	2	1,122	7	4,781	3	356	1	160	3	3,000	4	3,885	3	1,895	0	0	2	0	0	0
A-J-2-1	0.12	7	1	3	2	1	1	0	1	0	3	19	0	0	0	0	0	0	0	0	1	450	0	0	0	0	0	0	0	0
Wilson Creek Spur	1.21	7	1	2	2	2	9	5	1	3	2	377	1	365	2	458	2	455	0	0	1	1,500	0	0	1	1,500	1	50	1	5
Teran-1-1	0.63	7	2	2	2	1	9	4	4	1	2	98	0	0	2	210	2	269	0	0	1	600	3	1,250	0	0	0	0	1	5
Cushing Spur	0.99	7	1	2	2	2	5	3	2	0	2	232	0	0	0	0	3	603	0	0	2	3,000	0	0	0	0	0	0	0	0
Sec. 5 Road-Extension Link	1.41	7	1	2	2	2	7	4	3	0	2	321	1	600	3	794	0	0	1	1,800	2	1,880	0	0	0	0	0	0	0	0
Sec. 31-2	0.42	7	1	2	2	2	1	0	1	0	2	102	0	0	0	0	0	0	1	1,500	0	0	0	0	0	0	0	0	0	0
1/2 Mile Spur	0.95	7	1	2	2	2	3	1	2	0	2	234	0	0	1	180	0	0	0	0	1	1,500	1	1,600	0	0	0	0	0	0
Martin Spur-1	1.78	7	1	2	2	2	11	4	4	3	2	468	2	630	1	549	1	223	1	1,200	2	3,300	1	0	0	0	1	0	2	0
Cull Spur	1.96	7	1	2	2	2	12	3	4	5	2	486	1	476	2	1,207	0	0	0	0	2	2,130	2	2,640	0	0	3	25	2	0
J-T No. 1 Loop	1.60	7	1	2	2	2	7	1	3	3	2	549	1	297	0	0	0	0	0	0	2	3,430	1	1,200	0	0	3	40	0	0
Blowdown East	1.69	7	1	2	2	2	9	3	4	2	2	410	1	602	1	438	1	934	1	1,500	1	840	2	908	0	0	2	18	0	0
Biltmore Spur	1.62	7	1	2	2	2	13	2	7	4	2	449	0	0	1	195	1	121	0	0	2	1,475	5	1,749	0	0	3	1,040	1	350
Rattlesnake-1	0.42	7	1	3	1	2	4	3	0	1	3	140	0	0	1	214	2	435	0	0	0	0	0	0	0	0	0	0	1	600
Upper Visser	1.76	7	1	2	2	2	6	0	4	2	2	386	0	0	0	0	0	0	2	2,212	1	1,950	1	1,080	2	175	0	0	0	0
Wilbur Spur	4.99	7	1	2	2	2	27	21	6	0	2	984	3	2,618	6	1,715	12	1,373	2	3,000	3	5,550	1	750	0	0	0	0	0	0
Crossover	4.70	7	1	3	1	2	29	24	0	5	3	929	5	4,786	10	5,519	8	2,612	0	0	0	0	0	0	1	250	2	25	2	15
A-J North	1.42	7	1	3	1	2	12	5	1	6	3	398	1	450	2	1,246	2	779	1	700	0	0	0	0	0	0	5	455	1	150
Dry Lake	3.65	7	1	3	1	2	16	8	5	3	3	1,036	3	1,858	4	1,757	1	32	3	3,908	1	1,750	1	275	0	0	0	0	3	0
Porcupine	0.59	7	1	3	1	2	2	0	1	1	3	184	0	0	0	0	0	0	1	1,500	0	0	0	0	0	0	0	0	1	5
12Pct Spur Loop	0.58	7	2	2	1	2	6	0	2	4	2	123	0	0	0	0	0	0	1	738	1	756	0	0	2	0	1	0	1	0
B&B Spur-1	0.81	7	1	3	1	2	5	3	2	0	3	219	1	226	2	752	0	0	0	0	1	600	1	300	0	0	0	0	0	0
Maple Spur	1.38	7	1	3	1	2	3	0	3	0	3	407	0	0	0	0	0	0	1	900	1	1,200	1	800	0	0	0	0	0	0
Cougar Ridge-3	0.55	7	1	2	1	3	3	1	1	1	2	209	1	448	0	0	0	0	0	0	1	540	0	0	0	0	0	0	1	
End Haul	1.36	7	1	3	1	2	9	4	2	3	3	319	0	0	1	392	0	0	0	0	2	1,300	0	0	0	0	2	580	1	16
Export Spur	1.43	7	1	3	1	2	5	1	2	2	3	356	0	0	0	0	1	0	1	540	1	1,000	0	0	0	0	2	700	0	0
A-J-2	0.38	7	1	3	1	2	2	2	0	0	3	90	0	0	1	358	1	228	0	0	0	0	0	0	0	0	0	0	0	0
2nd Switchback-2	0.21	7	1	3	1	2	1	1	0	0	3	58	0	0	0	0	1	272	0	0	0	0	0	0	0	0	0	0	0	0
Hilton Spur-3	0.08	7	3	2	1	1	1	1	0	0	2	8	1	107	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Hunter Fire Road	3.15	7	1	3	1	2	13	8	0	5	3	719	1	113	4	680	2	399	0	0	0	0	0	0	2	1,800	1	500	2	250

Table D-1. continued

Road/Route	Route Length (km)	Final Road Rank (1-12)	Site Failure Potential Rank (1-3)***	Fill Failure Potential Rank (1-3)	Site Threat Rank (1-3)***	Fill Threat Rank (1-3)**	Total Number of Sites (#)	Total Crossings (#)	Total Landings (#)	Total Mass Wasting (#)	Road Fills*: Fill Failure Potential Rank (1-3)	Road Fills*: Total Fill Threat Volume (m³)	Crossings*: High Failure Potential (#)	Crossings*: High Threat Volume (m³)	Crossings*: Moderate Failure Potential (#)	Crossings*: Moderate Threat Volume (m³)	Crossings*: Low Failure Potential (#)	Crossings*: Low Threat Volume (m³)	Landings*: High Failure Potential (#)	Landings*: High Threat Volume (m³)	Landings*: Moderate Failure Potential (#)	Landings*: Moderate Threat Volume (m³)	Landings*: Low Failure Potential (#)	Landings*: Low Threat Volume (m³)	Mass Wasting Sites*: High Failure Potential (#)	Mass Wasting Sites*: High Threat Volume (m³)	Mass Wasting Sites*: Moderate Failure Potential (#)	Mass Wasting Sites*: Moderate Threat Volume (m³)	Mass Wasting Sites*: Low Failure Potential (#)	Mass Wasting Sites*: Low Threat Volume (m³)
4th Switchback-1	0.16	7	2	3	1	1	1	1	0	0	3	19	1	168	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Rock Creek - Jeep North Link	0.96	7	1	3	1	2	5	5	0	0	3	194	1	103	4	337	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Childs Hill-A-J Link	0.44	7	1	3	1	2	1	0	0	1	3	99	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	100
P-J-B&B Spur Link	0.34	7	1	3	1	2	1	1	0	0	3	70	1	45	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Dry Lake-2.5	0.11	7	2	3	0	2	1	0	0	1	3	29	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0
Maple Spur-1	0.09	6	1	1	3	1	1	0	1	0	1	16	0	0	0	0	0	0	0	0	0	0	1	1,360	0	0	0	0	0	0
Cougar Ridge-1	0.18	6	1	1	3	1	2	1	1	0	1	20	0	0	1	171	0	0	0	0	0	0	1	1,950	0	0	0	0	0	0
Wilbur Spur-7-1	0.10	6	1	1	3	1	1	0	1	0	1	4	0	0	0	0	0	0	0	0	0	0	1	1,100	0	0	0	0	0	0
Sec. 5 Road-Extension Link-2-A	0.16	6	1	1	3	1	2	0	2	0	1	25	0	0	0	0	0	0	0	0	0	0	2	1,650	0	0	0	0	0	0
Bucket Spur-5	0.31	6	1	1	2	2	2	0	1	1	1	92	0	0	0	0	0	0	0	0	1	3,000	0	0	0	0	0	0	1	0
Export Spur-3	0.15	6	2	1	2	1	2	1	1	0	1	26	0	0	0	0	1	50	0	0	1	1,400	0	0	0	0	0	0	0	0
Violated Spur-3	0.16	6	1	2	2	1	2	1	1	0	2	28	0	0	0	0	1	196	0	0	0	0	1	1,350	0	0	0	0	0	0
Jane Creek Road-1-1	0.13	6	1	1	2	2	1	0	1	0	1	35	0	0	0	0	0	0	0	0	1	1,238	0	0	0	0	0	0	0	0
Jane Creek Road-1-2	0.19	6	1	1	2	2	1	0	1	0	1	47	0	0	0	0	0	0	0	0	1	1,800	0	0	0	0	0	0	0	0
Wilbur Spur-6 Inner Loop	0.16	6	1	2	2	1	1	0	1	0	2	4	0	0	0	0	0	0	0	0	1	1,500	0	0	0	0	0	0	0	0
Madrone-2	0.09	6	1	2	2	1	1	0	1	0	2	14	0	0	0	0	0	0	0	0	0	0	1	770	0	0	0	0	0	0
Wilbur Spur-5-1	0.21	6	1	2	2	1	2	0	1	1	2	23	0	0	0	0	0	0	0	0	1	1,800	0	0	0	0	0	0	1	0
2nd Switchback-1-1	0.16	6	1	2	2	1	1	0	1	0	2	3	0	0	0	0	0	0	0	0	1	1,200	0	0	0	0	0	0	0	0
Hunter Fire-1	0.15	6	1	2	2	1	1	0	1	0	2	18	0	0	0	0	0	0	0	0	1	1,100	0	0	0	0	0	0	0	0
Blowdown-1	0.25	6	1	2	2	1	1	0	1	0	2	40	0	0	0	0	0	0	0	0	1	1,800	0	0	0	0	0	0	0	0
B&B Spur-1-1	0.39	6	1	2	2	1	1	0	1	0	2	62	0	0	0	0	0	0	0	0	1	2,700	0	0	0	0	0	0	0	0
Head Hunter Loop-1	0.13	6	1	2	2	1	1	0	1	0	2	10	0	0	0	0	0	0	0	0	1	800	0	0	0	0	0	0	0	0
Madrone-1	0.17	6	1	1	2	2	1	0	1	0	1	47	0	0	0	0	0	0	0	0	0	0	1	960	0	0	0	0	0	0
Mud Spur-2	0.14	6	1	1	2	2	1	0	1	0	1	32	0	0	0	0	0	0	0	0	1	780	0	0	0	0	0	0	0	0
P-Line Spur-1	0.70	6	1	2	2	1	2	0	2	0	2	72	0	0	0	0	0	0	0	0	1	2,025	1	1,725	0	0	0	0	0	0
Jane Creek Road-1	0.99	6	1	2	2	1	4	1	3	0	2	158	0	0	0	0	1	162	1	2,250	2	2,670	0	0	0	0	0	0	0	0
Wilbur Spur-7	0.72	6	1	2	2	1	3	0	2	1	2	76	0	0	0	0	0	0	1	2,400	0	0	1	1,200	0	0	1	0	0	0
Childs Hill-4	1.00	6	1	2	2	1	6	2	2	2	2	176	0	0	1	641	1	291	0	0	1	1,080	1	1,575	0	0	1	1,000	1	300
Bear Grass Road	0.67	6	1	1	2	2	6	4	2	0	1	156	0	0	0	0	4	502	0	0	2	2,550	0	0	0	0	0	0	0	0
Bense Trail-2	0.32	6	1	1	2	2	2	0	2	0	1	91	0	0	0	0	0	0	0	0	0	0	2	1,425	0	0	0	0	0	0
Heat Spur-2	0.40	6	1	2	2	1	1	0	1	0	2	13	0	0	0	0	0	0	1	1,755	0	0	0	0	0	0	0	0	0	0
Low Divide-5	0.32	6	1	2	2	1	2	0	1	1	2	35	0	0	0	0	0	0	0	0	1	1,350	0	0	0	0	0	0	1	0

Table D-1. continued

Road/Route	Route Length	Final Road Rank (1-12)	Site Failure Potential Rank (1-3)***	Fill Failure Potential Rank (1-3)	Site Threat Rank (1-3)***	Fill Threat Rank (1-3)**	Total Number of Sites	Total Crossings	Total Landings	Total Mass Wasting	Road Fills*: Fill Failure Potential Rank (1-3)	Road Fills*: Total Fill Threat Volume	Crossings*: High Failure Potential	Crossings*: High Threat Volume	Crossings*: Moderate Failure Potential	Crossings*: Moderate Threat Volume	Crossings*: Low Failure Potential	Crossings*: Low Threat Volume	Landings*: High Failure Potential	Landings*: High Threat Volume	Landings*: Moderate Failure Potential	Landings*: Moderate Threat Volume	Landings*: Low Failure Potential	Landings*: Low Threat Volume	Mass Wasting Sites*: High Failure Potential	Mass Wasting Sites*: High Threat Volume	Mass Wasting Sites*: Moderate Failure Potential	Mass Wasting Sites*: Moderate Threat Volume	Mass Wasting Sites*: Low Failure Potential	Mass Wasting Sites*: Low Threat Volume
	(km)						(#)	(#)	(#)	(#)		m³	#	m³	#	m³	#	m³	#	m³	#	m³	#	m³	#	m³	#	m³	#	m³
Turwar West	1.62	6	1	2	2	1	15	10	3	2	2	253	1	69	1	341	8	2,352	1	1,200	1	1,100	1	800	0	0	0	0	2	800
Sec. 36-4	0.70	6	1	2	2	1	6	2	1	3	2	105	0	0	0	0	2	187	0	0	1	2,438	0	0	0	0	0	0	3	50
Bense Trail	2.88	6	1	1	2	2	9	1	8	0	1	527	0	0	1	58	0	0	1	3,218	1	1,500	6	5,712	0	0	0	0	0	0
Sec. 5 Road-Extension Link-1	0.55	6	1	1	2	2	3	1	2	0	1	129	0	0	0	0	1	256	1	900	1	720	0	0	0	0	0	0	0	0
Main Road	0.75	6	1	2	2	1	5	2	2	1	2	121	0	0	2	794	1	355	0	0	0	0	2	1,388	0	0	1	0	0	0
Jeep Road	2.43	6	1	2	2	1	15	6	7	2	2	275	0	0	3	538	3	547	3	2,760	3	2,988	1	1,000	0	0	0	0	2	
Airport Spur	4.11	6	1	2	2	1	18	9	6	3	2	444	1	310	5	4,543	3	498	1	1,920	2	2,850	3	2,940	0	0	1	50	2	0
Tanoak Saddle	1.61	6	1	2	1	2	7	0	5	2	2	508	0	0	0	0	0	0	0	0	4	3,750	1	720	1	30	1	150	0	0
Go Back-1	0.38	6	1	2	1	2	2	0	2	0	2	88	0	0	0	0	0	0	1	810	0	0	1	300	0	0	0	0	0	0
Airport Road-1	0.34	6	1	2	1	2	1	0	1	0	2	95	0	0	0	0	0	0	0	0	0	0	1	960	0	0	0	0	0	0
Chipmunk Spur 1-1	0.37	6	1	2	1	2	1	0	1	0	2	105	0	0	0	0	0	0	0	0	1	1,000	0	0	0	0	0	0	0	0
A-J Loop-1-2	0.31	6	1	2	1	2	2	1	1	0	2	66	0	0	1	51	0	0	0	0	1	800	0	0	0	0	0	0	0	0
Jeep Road North-2	0.91	6	1	3	1	1	5	3	2	0	3	152	0	0	1	122	2	504	0	0	2	1,900	0	0	0	0	0	0	0	0
Dry Lake-5	0.14	6	2	2	1	1	1	0	1	0	2	17	0	0	0	0	0	0	1	375	0	0	0	0	0	0	0	0	0	0
No Name	2.32	6	1	2	1	2	9	8	1	0	2	647	1	458	4	1,766	3	1,006	0	0	1	2,400	0	0	0	0	0	0	0	0
Airport Road	3.04	6	1	2	1	2	9	5	2	2	2	925	1	1,072	1	96	3	2,127	1	1,875	1	975	0	0	2	1,000	0	0	0	0
Bense Trail-1.1	0.23	6	1	2	1	2	1	0	1	0	2	44	0	0	0	0	0	0	0	0	0	0	1	532	0	0	0	0	0	0
Moratorium	1.92	6	1	2	1	2	15	3	2	10	2	353	1	244	1	924	1	305	1	2,025	1	180	0	0	1	275	4	350	5	115
Airport Spur-2	0.71	6	1	2	1	2	6	3	0	3	2	201	1	897	1	403	1	146	0	0	0	0	0	0	0	0	1	50	2	40
Childs Hill-3-1-1	0.54	6	1	3	1	1	3	1	2	0	3	66	1	120	0	0	0	0	1	825	1	280	0	0	0	0	0	0	0	0
P-J Spur-3	0.35	6	1	2	1	2	1	0	1	0	2	63	0	0	0	0	0	0	0	0	0	0	1	750	0	0	0	0	0	0
Powder House	0.70	6	1	2	1	2	3	3	0	0	2	214	1	698	2	699	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Hamilton Road	5.85	6	1	2	1	2	22	21	0	1	2	1,610	12	10,128	4	1,139	1	231	0	0	0	0	0	0	0	0	0	0	1	0
Rocky Point-1	0.53	6	1	2	1	2	2	2	0	0	2	149	0	0	0	0	2	1,023	0	0	0	0	0	0	0	0	0	0	0	0
Mussel	1.02	6	1	2	1	2	2	1	1	0	2	224	0	0	0	0	1	308	0	0	1	1,688	0	0	0	0	0	0	0	0
Sec. 5 Loop	1.58	6	1	2	1	2	6	5	1	0	2	414	1	549	0	0	4	875	0	0	0	0	2	1,530	0	0	0	0	0	0
Reservoir Road	1.35	6	1	2	1	2	5	5	0	0	2	384	0	0	2	1,196	3	1,223	0	0	0	0	0	0	0	0	0	0	0	0
Smoke House-3A	0.51	6	1	2	1	2	2	0	1	1	2	102	0	0	0	0	0	0	0	0	1	900	0	0	0	0	0	0	1	4
Mountain Lion-1	0.29	6	1	2	1	2	2	2	0	0	2	73	0	0	0	0	2	470	0	0	0	0	0	0	0	0	0	0	0	0
West-East Link-1	0.16	6	1	2	1	2	1	1	0	0	2	51	0	0	0	0	1	240	0	0	0	0	0	0	0	0	0	0	0	0
Powderhouse Left-1	0.46	6	1	2	1	2	1	0	1	0	2	116	0	0	0	0	0	0	0	0	1	715	0	0	0	0	0	0	0	0
Martin Ext.	1.09	6	1	2	1	2	7	2	0	5	2	197	2	1,414	0	0	0	0	0	0	0	0	0	0	1	250	3	35	1	25

Table D-1. continued

Road/Route	Route Length	Final Road Rank (1-12)	Site Failure Potential Rank (1-3)***	Fill Failure Potential Rank (1-3)	Site Threat Rank (1-3)***	Fill Threat Rank (1-3)**	Total Number of Sites	Total Crossings	Total Landings	Total Mass Wasting	Road Fills*: Fill Failure Potential Rank (1-3)	Road Fills*: Total Fill Threat Volume	Crossings*: High Failure Potential	Crossings*: High Threat Volume	Crossings*: Moderate Failure Potential	Crossings*: Moderate Threat Volume	Crossings*: Low Failure Potential	Crossings*: Low Threat Volume	Landings*: High Failure Potential	Landings*: High Threat Volume	Landings*: Moderate Failure Potential	Landings*: Moderate Threat Volume	Landings*: Low Failure Potential	Landings*: Low Threat Volume	Mass Wasting Sites*: High Failure Potential	Mass Wasting Sites*: High Threat Volume	Mass Wasting Sites*: Moderate Failure Potential	Mass Wasting Sites*: Moderate Threat Volume	Mass Wasting Sites*: Low Failure Potential	Mass Wasting Sites*: Low Threat Volume
	(km)						(#)	(#)	(#)	(#)		m³	#	m³	#	m³	#	m³	#	m³	#	m³	#	m³	#	m³	#	m³	#	m³
Sec. 1-1E03 Road	0.49	6	1	2	1	2	3	3	0	0	2	96	1	211	2	530	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Sec. 5 Extension-1	0.56	6	1	2	1	2	4	2	1	1	2	126	0	0	2	355	0	0	0	0	0	0	1	450	0	0	0	0	1	0
End Haul-2	0.27	6	2	2	1	1	2	1	0	1	2	32	0	0	0	0	1	160	0	0	0	0	0	0	1	250	0	0	0	0
Prospect	0.70	6	1	2	1	2	2	1	0	1	2	235	0	0	1	808	0	0	0	0	0	0	0	0	1	90	0	0	0	0
West Branch Road-Westside Spur Link	1.05	6	1	2	1	2	5	3	0	2	2	315	2	790	1	168	0	0	0	0	0	0	0	0	0	0	2	320	0	0
Timberline-Jeep Road Link	1.29	6	1	2	1	2	6	4	1	1	2	409	4	380	0	0	0	0	0	0	1	900	0	0	1	250	0	0	0	0
Rock Creek-Jeep North Link-1	0.61	6	1	3	1	1	1	0	1	0	3	27	0	0	0	0	0	0	1	750	0	0	0	0	0	0	0	0	0	0
Jeep Road North	2.08	6	1	3	1	1	6	4	2	0	3	246	0	0	4	400	0	0	1	1,000	1	1,000	0	0	0	0	0	0	0	0
West Side	0.25	6	1	2	1	2	1	1	0	0	2	49	0	0	0	0	1	243	0	0	0	0	0	0	0	0	0	0	0	0
4th Switchback Loop	3.31	6	1	2	1	2	16	11	0	5	2	644	1	13	4	686	6	2,053	0	0	0	0	0	0	1	0	4	135	0	0
Smoke House-2	0.29	6	1	2	1	2	1	1	0	0	2	58	1	216	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Dry Lake-2	1.58	6	1	2	1	2	3	2	1	0	2	460	0	0	2	720	0	0	0	0	1	350	0	0	0	0	0	0	0	0
Park Spur-1-A	0.65	6	1	2	1	2	3	2	0	1	2	139	0	0	2	337	0	0	0	0	0	0	0	0	0	0	1	60	0	0
West Branch Road-Park Spur Link-1	0.87	6	1	2	1	2	2	1	0	1	2	221	0	0	0	0	1	466	0	0	0	0	0	0	0	0	0	0	1	0
West Branch Road Loop	0.59	6	1	2	1	2	2	2	0	0	2	131	0	0	1	160	1	170	0	0	0	0	0	0	0	0	0	0	0	0
Wilbur Spur-4	0.66	6	1	2	1	2	2	1	0	1	2	129	0	0	0	0	1	60	0	0	0	0	0	0	1	250	0	0	0	0
Airport Spur Loop-1-2	0.33	6	0	3	0	3	0	0	0	0	3	137	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Low Divide-1	0.24	6	1	2	0	3	1	0	0	1	2	96	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0
Moratorium-1	0.18	6	2	3	0	1	3	0	0	3	3	27	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3	0
Martin Ext.-1	0.37	5	1	1	2	1	1	0	1	0	1	58	0	0	0	0	0	0	1	2,625	0	0	0	0	0	0	0	0	0	0
Mussel-1-A	0.16	5	1	1	2	1	1	0	1	0	1	1	0	0	0	0	0	0	0	0	0	0	1	1,000	0	0	0	0	0	0
Smoke House-3A-1	0.16	5	1	1	2	1	1	0	1	0	1	16	0	0	0	0	0	0	0	0	1	680	0	0	0	0	0	0	0	0
Go Back-2	0.20	5	1	1	2	1	1	0	1	0	1	33	0	0	0	0	0	0	0	0	1	770	0	0	0	0	0	0	0	0
Mud Spur-1	0.70	5	1	1	1	2	4	1	3	0	1	140	0	0	0	0	0	0	0	0	2	1,125	1	840	0	0	0	0	0	0
Heat Spur	2.40	5	1	2	1	1	10	3	6	1	2	404	0	0	0	0	3	478	2	2,625	3	2,630	1	1,200	0	0	1	0	0	0
Sec. 36-1	0.33	5	1	2	1	1	1	0	1	0	2	35	0	0	0	0	0	0	0	0	1	900	0	0	0	0	0	0	0	0
Cougar Ridge-1A	0.62	5	1	2	1	1	4	1	2	1	2	84	0	0	1	225	0	0	1	1,000	1	420	0	0	0	0	0	0	2	0
A-J-1	0.31	5	1	1	1	2	3	2	1	0	1	68	0	0	1	144	1	144	0	0	1	500	0	0	0	0	0	0	0	0
Smoke House-5	1.24	5	1	2	1	1	9	4	3	2	2	200	3	1,316	0	0	1	82	1	720	0	0	2	1,065	0	0	1	0	1	0
Wilbur Spur Loop-1	0.19	5	1	2	1	1	1	0	1	0	2	11	0	0	0	0	0	0	1	450	0	0	0	0	0	0	0	0	0	0
Sheepshed-5	0.57	5	1	2	1	1	4	1	1	2	2	83	0	0	0	0	1	101	0	0	1	1,000	0	0	0	0	1	75	1	0
A-J North-1	0.27	5	1	1	1	2	1	0	1	0	1	73	0	0	0	0	0	0	0	0	0	0	1	480	0	0	0	0	0	0

Table D-1. continued

											Road Fills*		Crossings*						Landings*						Mass Wasting Sites*					
	Route Length	Final Road Rank (1-12)	Site Failure Potential Rank (1-3)***	Fill Failure Potential Rank (1-3)	Site Threat Rank (1-3)***	Fill Threat Rank (1-3)**	Total Number of Sites	Total Crossings	Total Landings	Total Mass Wasting	Fill Failure Potential Rank (1-3)	Total Fill Threat Volume	High Failure Potential	High Threat Volume	Moderate Failure Potential	Moderate Threat Volume	Low Failure Potential	Low Threat Volume	High Failure Potential	High Threat Volume	Moderate Failure Potential	Moderate Threat Volume	Low Failure Potential	Low Threat Volume	High Failure Potential	High Threat Volume	Moderate Failure Potential	Moderate Threat Volume	Low Failure Potential	Low Threat Volume
Road/Route	(km)						(#)	(#)	(#)	(#)		m³	#	m³	#	m³	#	m³	#	m³	#	m³	#	m³	#	m³	#	m³	#	m³
Head Hunter	2.74	5	1	2	1	1	8	0	4	4	2	478	0	0	0	0	0	0	0	0	3	3,135	1	1,750	1	0	0	0	3	0
Bucket Spur-1	1.07	5	1	1	1	2	2	0	1	1	1	213	0	0	0	0	0	0	0	0	1	1,800	0	0	0	0	0	0	1	35
Teran-1-2	0.80	5	1	2	1	1	6	5	1	0	2	100	1	73	3	429	1	8	0	0	0	0	1	750	0	0	0	0	0	0
Mud Spur	1.66	5	1	1	1	2	4	2	2	0	1	345	1	392	1	242	0	0	0	0	1	900	1	450	0	0	0	0	0	0
Turwar Spur-1	1.19	5	1	2	1	1	4	2	1	1	2	133	0	0	2	150	0	0	0	0	1	800	0	0	1	250	0	0	0	0
Westside Spur-1A	0.53	5	1	2	1	1	2	0	1	1	2	90	0	0	0	0	0	0	0	0	0	0	1	500	0	0	1	0	0	0
Head Hunter-1	0.59	5	1	2	1	1	4	2	0	2	2	98	1	144	1	142	0	0	0	0	0	0	0	0	0	0	1	20	1	50
Teran-1	1.73	5	1	2	1	1	3	2	1	0	2	218	0	0	2	270	0	0	0	0	0	0	1	800	0	0	0	0	0	0
Park Spur-2	0.19	5	0	2	0	3	0	0	0	0	2	82	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Sheepshed-6	1.20	5	1	1	1	2	1	1	0	0	1	289	0	0	0	0	1	230	0	0	0	0	0	0	0	0	0	0	0	0
Airport Spur Loop-2	0.39	5	1	2	1	1	1	1	0	0	2	26	0	0	0	0	1	130	0	0	0	0	0	0	0	0	0	0	0	0
Rock Creek Road-5	0.13	5	0	2	0	3	0	0	0	0	2	48	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Sheepshed-Reservoir Link	0.48	5	1	2	1	1	1	1	0	0	2	35	0	0	0	0	1	144	0	0	0	0	0	0	0	0	0	0	0	0
Sec. 31-1	0.44	5	0	2	0	3	0	0	0	0	2	155	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Madrone-1A	0.23	5	0	3	0	2	0	0	0	0	3	77	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Demonstration Forest Spur	1.02	5	1	2	1	1	3	1	0	2	2	108	0	0	0	0	1	105	0	0	0	0	0	0	0	0	0	0	1	40
Mussel-1-1	0.05	5	0	3	0	2	0	0	0	0	3	9	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Sheepshed	1.57	5	1	2	1	1	2	0	0	2	2	224	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	30
Sec. 1-A-J Link	0.61	5	1	2	1	1	2	0	1	1	2	61	0	0	0	0	0	0	0	0	0	0	0	0	1	20	0	0	0	0
Bense Trail-3	0.06	4	1	1	2	0	1	0	1	0	1	0	0	0	0	0	0	0	0	0	0	0	1	250	0	0	0	0	0	0
Airport Spur Loop-1	0.65	4	1	1	1	1	3	1	2	0	1	111	0	0	1	110	0	0	1	1,000	1	800	0	0	0	0	0	0	0	0
Mule Trail-1	0.47	4	1	1	1	1	4	3	1	0	1	71	0	0	1	581	2	254	0	0	1	525	0	0	0	0	0	0	0	0
Airport Spur Loop	1.15	4	1	1	1	1	8	6	2	0	1	154	0	0	1	50	5	410	0	0	1	1,400	1	1,000	0	0	0	0	0	0
Bense Trail-4	0.55	4	1	1	1	1	1	0	1	0	1	10	0	0	0	0	0	0	0	0	1	1,050	0	0	0	0	0	0	0	0
Airport Spur-1	0.57	4	1	1	1	1	1	0	1	0	1	74	0	0	0	0	0	0	0	0	1	1,000	0	0	0	0	0	0	0	0
Picnic Road	2.43	4	1	1	1	1	17	11	0	6	1	184	1	77	4	171	5	1,771	0	0	0	0	0	0	5	2,010	1	100	0	0
West Branch Road-1	1.14	4	1	1	1	1	6	5	0	1	1	177	1	304	1	293	3	543	0	0	0	0	0	0	0	0	0	0	1	0
Go Back	0.83	4	1	1	1	1	4	2	1	1	1	84	1	170	0	0	1	148	0	0	1	540	0	0	0	0	0	0	1	0
Ray Smith-Violated Spur Link	0.92	4	1	1	1	1	4	2	1	1	1	141	0	0	1	170	1	30	0	0	0	0	1	225	0	0	0	0	1	0
Bucket Spur-1-2	0.25	4	1	1	1	1	1	1	0	0	1	38	0	0	0	0	1	64	0	0	0	0	0	0	0	0	0	0	0	0
Wilbur Spur-1	0.08	4	0	2	0	2	0	0	0	0	2	25	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Export Spur-1	0.14	4	0	2	0	2	0	0	0	0	2	44	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Table D-1. continued

Road/Route	Route Length	Final Road Rank (1-12)	Site Failure Potential Rank (1-3)***	Fill Failure Potential Rank (1-3)	Site Threat Rank (1-3)***	Fill Threat Rank (1-3)**	Total Number of Sites	Total Crossings	Total Landings	Total Mass Wasting	Road Fills*: Fill Failure Potential Rank (1-3)	Road Fills*: Total Fill Threat Volume	Crossings*: High Failure Potential	Crossings*: High Threat Volume	Crossings*: Moderate Failure Potential	Crossings*: Moderate Threat Volume	Crossings*: Low Failure Potential	Crossings*: Low Threat Volume	Landings*: High Failure Potential	Landings*: High Threat Volume	Landings*: Moderate Failure Potential	Landings*: Moderate Threat Volume	Landings*: Low Failure Potential	Landings*: Low Threat Volume	Mass Wasting Sites*: High Failure Potential	Mass Wasting Sites*: High Threat Volume	Mass Wasting Sites*: Moderate Failure Potential	Mass Wasting Sites*: Moderate Threat Volume	Mass Wasting Sites*: Low Failure Potential	Mass Wasting Sites*: Low Threat Volume
	(km)						(#)	(#)	(#)	(#)		m³	#	m³	#	m³	#	m³	#	m³	#	m³	#	m³	#	m³	#	m³	#	m³
West-East Link-1-1	0.05	4	0	2	0	2	0	0	0	0	2	13	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
A-J Loop-2	0.26	4	0	2	0	2	0	0	0	0	2	76	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Tanoak Saddle-1	0.20	4	0	2	0	2	0	0	0	0	2	56	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Smoke House-1-1	0.08	4	0	2	0	2	0	0	0	0	2	20	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Airport Road-1-1	0.15	4	0	2	0	2	0	0	0	0	2	36	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Moratorium-2	0.23	4	0	2	0	2	0	0	0	0	2	55	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
4th Switchback Loop-1	0.14	4	0	2	0	2	0	0	0	0	2	33	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Timberline-1	0.29	4	0	2	0	2	0	0	0	0	2	68	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Main Road-1	0.45	4	1	1	1	1	1	1	0	0	1	33	0	0	0	0	1	59	0	0	0	0	0	0	0	0	0	0	0	0
Head Hunter Loop	0.47	4	0	2	0	2	0	0	0	0	2	90	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Sec. 1-3-1	0.21	4	0	3	0	1	0	0	0	0	3	34	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Sec. 1-2	0.07	4	0	3	0	1	0	0	0	0	3	8	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Jeep Road North-1	0.26	4	0	3	0	1	0	0	0	0	3	22	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Sec. 5-1A	0.05	4	0	3	0	1	0	0	0	0	3	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Hunter Fire Loop	0.70	3	1	1	1	0	1	0	1	0	1	0	0	0	0	0	0	0	0	0	1	750	0	0	0	0	0	0	0	0
Hamilton-Elkhorn Link	0.57	3	1	1	1	0	1	1	0	0	1	0	1	283	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Mountain Lion-2	0.10	3	0	1	0	2	0	0	0	0	1	32	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Bucket Spur-4	0.08	3	0	1	0	2	0	0	0	0	1	19	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Madrone-1-1	0.08	3	0	1	0	2	0	0	0	0	1	16	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Go Back Link	0.25	3	0	1	0	2	0	0	0	0	1	48	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Hilton Spur-1	0.17	3	0	2	0	1	0	0	0	0	2	28	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Sec. 1-3	0.12	3	0	2	0	1	0	0	0	0	2	19	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Jane Creek Road-1-3	0.15	3	0	2	0	1	0	0	0	0	2	24	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Sec. 1-5	0.19	3	0	2	0	1	0	0	0	0	2	31	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Go Back Loop	0.07	3	0	2	0	1	0	0	0	0	2	10	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Sheepshed-4-2	0.07	3	0	2	0	1	0	0	0	0	2	8	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Timberline-Jeep Road Link-2	0.14	3	0	2	0	1	0	0	0	0	2	17	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Sec. 31-Turwar West Link	0.28	3	0	2	0	1	0	0	0	0	2	33	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Sec. 5 Road-Extension Link-3	0.17	3	0	2	0	1	0	0	0	0	2	16	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Upper First Gulch-3	0.87	3	0	2	0	1	0	0	0	0	2	85	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Rock Creek Road-2	0.14	3	0	2	0	1	0	0	0	0	2	12	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Bense Trail-4-1	0.63	3	0	2	0	1	0	0	0	0	2	40	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Table D-1. continued

											Road Fills*		Crossings*						Landings*						Mass Wasting Sites*					
	Route Length	Final Road Rank (1-12)	Site Failure Potential Rank (1-3)***	Fill Failure Potential Rank (1-3)	Site Threat Rank (1-3)***	Fill Threat Rank (1-3)**	Total Number of Sites	Total Crossings	Total Landings	Total Mass Wasting	Fill Failure Potential Rank (1-3)	Total Fill Threat Volume	High Failure Potential	High Threat Volume	Moderate Failure Potential	Moderate Threat Volume	Low Failure Potential	Low Threat Volume	High Failure Potential	High Threat Volume	Moderate Failure Potential	Moderate Threat Volume	Low Failure Potential	Low Threat Volume	High Failure Potential	High Threat Volume	Moderate Failure Potential	Moderate Threat Volume	Low Failure Potential	Low Threat Volume
Road/Route	(km)						(#)	(#)	(#)	(#)		m^3	#	m^3	#	m^3	#	m^3	#	m^3	#	m^3	#	m^3	#	m^3	#	m^3	#	m^3
Sec. 36-3	0.28	3	0	2	0	1	0	0	0	0	2	14	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Low Divide-Crossover Link	0.81	3	0	2	0	1	0	0	0	0	2	35	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Childs Hill-3-1	0.57	3	0	2	0	1	0	0	0	0	2	10	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Hilton Spur	0.79	3	0	2	0	1	0	0	0	0	2	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Chipmunk Spur 1-1-1	0.05	2	0	1	0	1	0	0	0	0	1	8	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Hunter Fire Road Loop Connector-2	0.10	2	0	1	0	1	0	0	0	0	1	16	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Rock Creek-12Pct Spur Link	0.08	2	0	1	0	1	0	0	0	0	1	11	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Sheepshed-1	0.20	2	0	1	0	1	0	0	0	0	1	25	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
P-J Spur-2	0.27	2	0	1	0	1	0	0	0	0	1	33	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Wilbur Spur-6	0.39	2	0	1	0	1	0	0	0	0	1	38	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
J-T No. 1 Loop-1-1	0.02	2	0	1	0	1	0	0	0	0	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Picnic - Hamilton Link	0.04	2	0	1	0	1	0	0	0	0	1	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Smoke House-6	0.09	2	0	1	0	1	0	0	0	0	1	6	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Hound Dog Left-1	0.41	2	0	1	0	1	0	0	0	0	1	32	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Airport Spur Loop-1-3	0.20	2	0	1	0	1	0	0	0	0	1	15	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Sheepshed Link	0.51	2	0	1	0	1	0	0	0	0	1	32	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Hunter Fire Road Loop Connector-1	0.03	2	0	2	0	0	0	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
West Branch Road-4	0.48	2	0	1	0	1	0	0	0	0	1	16	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Powder House Left-1-1	0.22	2	0	1	0	1	0	0	0	0	1	4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1/2 Mile Spur-1	0.29	2	0	1	0	1	0	0	0	0	1	4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Airport Spur-5	0.10	2	0	2	0	0	0	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Low Water Crossing	0.31	2	0	1	0	1	0	0	0	0	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Substation Road	0.53	2	0	1	0	1	2	2	0	0	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
West-East Link	0.69	2	0	2	0	0	1	1	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Ray Smith-Violated Spur Loop Link	0.05	1	0	1	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Rock Creek Road-3	0.07	1	0	1	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Low Water Crossing-1	0.15	1	0	1	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Total	468.42						3,245	1,457	981	807		122,910	455	379,202	506	256,443	496	169,833	325	568,150	482	704,029	174	164,895	217	139,250	312	27,365	278	17,384

*Volume figures presented are calculated by model and should not be considered significant figures indicating confidence of accuracy.
**A fill threat rank value of zero indicates that route contains no fill. Road was likely a skid trail that followed existing topography instead of cutting through it.
***A site failure potential rank and site threat rank value of zero indicates there are no sites along route; or the only site type is stream crossing with the attribute value: bridge (Substation Road and West-East Link).

APPENDIX E

MILL CREEK ADDITION

BRIDGES - PLANS OF ACTION

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Plan of Action form field definitions

- **Br No.** Caltrans Bridge Inventory Item number. *This Information provided by Caltrans on the form.*
- **Owner.** Name of agency who owns the Bridges. *Information provided by Caltrans on the form.*
- **Location.** Distance from nearest main road. Reference the most recent Caltrans Bridge Inspection Report (BIR) for this information. *Information provided by Caltrans on the form.*
- **Facility Carried**. Name the road the bridge carries. Reference the most recent Caltrans Bridge Inspection Report (BIR) for this information. *Information provided by Caltrans on the form.*
- **Name.** Name the creek/river that intersects the bridge**.** *Information provided by Caltrans on the form.*

- **Completed By.** Name of agency that is responsible for completing the Plan of Action.
- **Date.** Provide the date of when the Plan of Action form was completed.

1)

- **<u>Scour Vulnerability Rating</u>.** *Caltrans has completed a hydraulic evaluation and possibly a Structural and Geotechnical evaluation for all scour critical bridges. The evaluations should provide the details as to why the bridge is considered scour critical. Caltrans is not providing this information on the form, but this information is summarized on the Caltrans scour BIR. This BIR should also have a summary of the scour history. The scour history is taken from past routine BIR's. The history should also include any scour information the local agency may have knowledge of. If additional details regarding the scour rating and history are needed, contact your Area Bridge Maintenance Engineer or Charles Ineichen by e-mail at: charles_ineichen@dot.ca.gov.*
- **Scour Evaluation Summary.** Summarize why the bridge became/is scour critical and provide some details of the present hydraulic concerns at the bridge site.
- **Scour History.** Report any known history of scour problems, drift/debris problems at the bridge site, channel meandering, bank erosion, approach washout, or any channel degradation and mining operation in proximity to site, etc.

  - a) **Foundation type.** Identify the bridge foundation type. As-built plans are a good source as is any engineer who may have worked on the project.

  - b) **Foundation material.** Identify the foundation material. Foundation Reports and/or Log of Test Borings are a good source for this information. The county may also want to do a field visit to assess the ground material. This entry also can be left unknown.

  - Scour review. Provide any known past hydraulic studies including the Caltrans evaluation and the date.
  - Structural assessment. Provide any known past structural assessment studies in relation to the scour potential and the date done at the bridge site.
    Critical Elevation. If any study provides an elevation in which the bridge becomes unstable, provide that information.
  - Geotechnical Assessment. Provide any known past geotechnical assessment studies and the date done at the bridge site.
    Critical Elevation. If any study provides an elevation in which the bridge foundation becomes unstable, provide that information.

2)

- **<u>NBIS Coding Information</u>.** *NBI data is taken from the most recent Caltrans BIR and is found on the Structure Inventory and Appraisal Sheet attached to all routine Caltrans BIR's. Information can also be referenced in the Federal Highway Administration Publication of "Recording and Coding Guide for the Structure Inventory and Appraisal of the Nation's Bridges". Report No. FHWA-PD-96-001.*
  - Inspection Date. Reference latest routine Caltrans BIR. *Information provided by Caltrans on the form.*
  - Item 113 Scour. Bridge coding regarding its vulnerability to scour. *Information provided by Caltrans on the form.*
  - Item 60 Substructure. This item describes the physical condition of piers, abutments, piles, fenders, footings or other components. *Information provided by Caltrans on the form.*
  - Item 61 Channel and Channel Protection. This item describes the physical conditions associated with the flow of water through the bridge. *Information provided by Caltrans on the form.*
  - Item 71 Waterway Adequacy. This item appraises the waterway opening with respect to passage of flow through bridge. *Information provided by Caltrans on the form.*

3)

- **<u>Scour Countermeasure.</u>** *In accordance with guidelines from Hydraulic Engineering Circular 18 and 23 (HEC 18 and HEC 23) published by the Federal Highway Administration.*
- **A) Completed Scour Countermeasure.** Indicate and give details and dates of any recent scour countermeasure that has been implemented in regards to addressing the current scour critical status of the bridge. All applicable studies, lead agencies, subcontractors and as-builts should be noted.
- **B) Proposed Scour Countermeasures.**
  - **Countermeasures Not Required.** Indicate and provide details as to why no scour countermeasures are required at this time.
  - **Install Scour Countermeasures.** Indicate and provide details and dates including reference to any hydraulic, structural or geotechnical studies that

have been completed for the purpose of scour mitigation. Provide estimated cost to all proposed scour countermeasure for the bridge site
  - **Close Bridge.** Provide dates, details and detour**.**

4)

- **<u>Countermeasure Implementation Schedule</u>.**
  - Proposed Construction Project**.** Identifies the proposed project and identify the lead agency and all subcontractors, if any, involved in the proposal. An estimated date of completion should be given.
  - Maintenance Project**.** Identifies if project is in house.
  - Other scheduling information**.**

5)

- **<u>Monitoring Plan</u>.** *Monitoring is an option of providing scour countermeasure at a bridge site. It can be used as the scour mitigation proposal or as a supplement to a more permanent scour countermeasure. Monitoring a bridge for scour encompasses a large and varied amount of options. It can be as simple as inspecting the bridge for hydraulic damage on a regular interval and/or after a significant hydraulic event, or as complex as monitoring the bridge at different discharge levels using various monitoring devices. A monitoring plan could be the precipitous leading to Bridge Closure.*
  Monitoring, if used, should include provisions for:
  - **Monitoring Plan Summary.** Provide details of the extent of monitoring. What information the monitoring will provide. What action will be implemented if the information indicates a scour problem? If an engineering firm is contracted for the monitoring plan, provide the details.
  - **Monitoring Authority.** Identify responsible agency for implementation and action of monitoring. Indicate who is in charge of overseeing and carrying out the monitoring plan.
    - **Regular Inspection program.** Indicate the frequency of the monitoring and will cross sections and comparison of historical cross sections be required. Indicate the items to watch for.
    - **Increased Inspection Interval.** Indicate the need for and increased interval and items to watch for.
    - **Fixed Monitoring Devices.** Identify the type of instrument. This type of monitoring can be dependant on increasing channel flows and an identified discharge that could potential cause scour concerns. The monitoring or interval is usually increased as discharge increases. *Further information on monitoring devices can be found at the following website:* http://www.dot.ca.gov/hq/structur/strmaint/smi.htm *reference the Plan of Action Links.*
    - **Other Monitoring Program.** Identify any other methods of monitoring.

6)

- **Bridge Closure Plan.**
    - **Bridge ADT.** Can be found on the most recent routine Caltrans BIR on the Structure Inventory and Appraisal Sheet. *Information provided by Caltrans on the form.* The agencies should update as necessary.
    - **Built.** Identifies the year the bridge was built**.** Found in archived records or on the most recent Caltrans BIR's.
    - **% Trucks.** Found in research projects or on the most recent Caltrans BIR's. *Information provided by Caltrans on the form.* The agencies should update as necessary.
    - **Bridge Length.** Found in as-built plans or on the most recent Caltrans BIR's. *Information provided by Caltrans on the form.*

    - **Closure Plan Summary.** Provide summary of closure.

    - **Scour Monitoring Criteria for Considering Bridge Closure.** Should be filled out if monitoring is used in consideration for bridge closure.

    - **Person. Area Responsible for Closure**. Identify responsible person/position responsible for closure.

    - **Contact People.** Identify responsible person/position who will be in charge of the bridge during closure.

    - **Responsible for re-opening after inspection**. Identify responsible person/position responsible for re-opening the bridge**.**

7)

- **Detour Route.**
    - **Detour Route Description.** Provide a map with a viable detour in case of bridge closure/failure.
    - **Average ADT.** Provide average daily traffic on alternate route. Can be found in recent research studies or possible alternate bridges within route by referencing the most recent routine Caltrans BIR's
    - **%Trucks.** Provide average daily truck traffic on alternate route. Can be found in recent research studies or possible alternate bridges within the detour route by referencing the most recent routine Caltrans BIR's for the appropriate bridge.
    - **Length of Detour.** Provide length of detour in miles.

- **Bridges on Detour Route.** Provide a list of Bridges along the detour that are over water, the feature intersected, the Sufficiency Rating and load limitations and the bridges own 113 code.
    - Bridges Number**.** Caltrans Bridge Inventory Item number.
    - Waterway**.** Identify the waterway beneath the bridge.

- Sufficiency Rating**.** Found on the most routine Caltrans BIR on the Structure Inventory and Appraisal sheet.
- Load Rating. Found on the most recent routine Caltrans BIR.
- Scour 113 Code**.** Found on the most recent routine Caltrans BIR on the Structure Inventory and Appraisal sheet.

BRIDGE SCOUR EVALUATION - PLAN OF ACTION				
Br. No. 01P0014	**Owner** Parks	**Location** Mill Creek	**Facility Carried** Hamilton Rd	**Name** First Gulch
Plan of Action Completed By: Gerhard Panuschka			**Date of Completion:** 30Nov2009	

1. SCOUR VULNERABILITY RATING

Scour Evaluation Summary:

At the time of this inspection, no scour and no debris was observed. A slight flow of water was passing through the channel beneath the bridge. Minor erosion along the banks was noted. Flat car sits on one big log (about 4' diameter) at each abutment.

Hamilton Road is the only road into the park. The road is open to the public on weekends all year.

Scour History:

During pervious investigations in 2003, 2006, and 2008, it was noted that there were cuts in the embankments beneath both abutments that were approximately 10 feet deep. Also reported in the 2006 investigation was a shifting of the low point in channel bed towards abutment 1. A slight degradation of the channel bed was also reported in 2008. Work recommendations dated 9/23/2003 called for an embankment protection beneath both abutments and the replacement of the existing timber log abutments.

a. **Foundation Type** ☒ Spread footing ☐ Pile Extension ☐ Footing on Piles ☐ Unknown

b. **Foundation Material** ☒ Known _**Timber logs w/dirt backfill**_ ☐ Unknown

Scour Review: Done By: **Gerhard Panuschka** Date: **04Nov2009**

Structural Assessment: Done By: NA Date:
Critical Elevation: ________________

Geotechnical Assessment: Done By: NA Date:
Critical Elevation: ________________

2. NBIS CODING INFORMATION

		Most Recent
Inspection date		
Item 113	Scour	3
Item 60	Substructure	6
Item 61	Channel & Channel Protection	6
Item 71	Waterway Adequacy	6

3. COUNTERMEASURE RECOMMENDATION

A. Completed Countermeasures:

No countermeasures are currently in place.

B. Proposed Countermeasures:

Bridge will be added to Project Identification Data (PID) list for replacement as soon as budget becomes available. In the meanwhile, bridge will be monitored on a regular basis (see 5).

☒ **Countermeasures Not Required. (Please explain)**

Parks Maintenance will monitor bridge – see below.

☐ **Install Scour Countermeasures** (See 4 and 5)

	Estimated Cost
___Riprap with monitoring program	$
___Guide bank	$
___Spurs / Bendway weirs / Barbs	$
___Relief bridge / Culvert	$
___Channel improvements	$
___Monitoring	$
___Monitoring device	$
___Check Dam	$
___Substructure Modification	$
_X_Bridge replacement	$ 500,000
___Other ____	$

☐ **Close Bridge** (See 6)

4. COUNTERMEASURE IMPLEMENTATION SCHEDULE

Countermeasure Implementation Project Type:

☒ Proposed Construction Project

Lead Agency __State Parks

☐ Maintenance Project

Advertised Date: NA

Other scheduling information: **Bridge will be added to Project Identification Data (PID) list for replacement as soon as budget becomes available.**

5. MONITORING PLAN

Monitoring Plan Summary:

State Parks maintenance personnel will monitor structure several times a year, and after main runoff events. Maintenance personnel will be trained in observing and identifying scour, how to minimize scour (removal of debris, filling of scour holes, etc.), and what steps to take when significant scour occurs. Bridge may be closed after significant scour events pending evaluation of structural integrity of bridge by engineer.

State Parks personnel will inspect the bridge in early winter for debris. Another inspection is planned in spring. In consultation with the District's Environmental Coordinator and the California Department of Fish and Game, woody debris may be removed or manipulated.

Monitoring Authority: **State Parks – North Coast Redwoods District Trail Maintenance**

☒ **Regular Inspection Program of _____6_mo.** ☐ w/surveyed cross sections

Items to Watch: undermining the footing

☐ **Increased Inspection Interval of _______ mo.** ☐ w/surveyed cross sections

Items to Watch:.

☐ **Underwater Inspection Program** **Frequency _______ mo.**

Items to Watch:

☐ **Fixed Monitoring Device**

Type of Instrument:

Installation location(s):

Sample Interval: ☐ 30 min. ☐ 1 hr. ☐ 6 hrs. ☐ 12 hrs.

☐ Other __________

Frequency of data logger downloading: ☐ Weekly ☐ Bi-weekly ☐ Monthly

☐ Other __________

Scour-critical discharge:__________

Action required if scour-critical elevation detected:

☒ **Other Monitoring Program**

Type: ☒ Visual

☐ Instrument

☐ Portable ☐ Geophysical ☐ Sonar

☐ Other gages

Flood monitoring required: ☐ Yes ☒ No

Flood monitoring event defined by:

☐ Discharge over __________

☐ Stage _______

☐ Elev. measured from _______

Frequency of flood monitoring: ☐ 1 hr. ☐ 3 hr. ☐ 6 hrs. ☐ Other

Scour critical elevation:

Action required if scour-critical elevation detected:

6. BRIDGE CLOSURE PLAN			
Bridge ADT: 10	**Built:** 1950	**% Trucks:** 10	**Bridge Length (ft):** 50

Closure Plan Summary

State Parks Maintenance will report significant scour events to management. State Parks engineer or geologist will immediately inspect bridge condition and, if required, close bridge by setting up barricades and signs. State Parks engineer/geologist will determine countermeasures to protect the bridge from further damage. Bridge will be re-opened upon completion of countermeasures and if it is considered structurally sound.

Scour Monitoring Criteria for Consideration of Bridge Closure:

- ☐ Water surface elevation reaches ________________ ☐ Overtopping road or structure
- ☒ Scour Measurement Results / Monitoring Device ☒ Loss of Riprap
- ☒ Observed amount of Settlement ☒ Loss of Road Embankment
- ☒ Debris Accumulation
- ☐ Other _________________

Person / Area Responsible for Closure: **Jeff Bomke, Sector Superintendent, North Coast Redwoods District**

Contact People (Name & Phone No.): **Gerhard Panuschka: 916-445-8680**

Responsible for re-opening after inspection: **Jeff Bomke**

7. DETOUR ROUTE

Detour route description (route number, from - to, etc.) – attach map.

Average ADT: 10	**Year:** 2003	**% Trucks:** 10	**Length:** 123.7 miles

Bridges on Detour Route:

Bridge Number	Waterway	Sufficiency Rating/ Load limitations	Scour 113 code

BRIDGE SCOUR EVALUATION - PLAN OF ACTION				
Br. No. 01P0015	**Owner** Parks	**Location** Mill Creek	**Facility Carried** Rock Creek Rd	**Name** East Fork Mill Creek
Plan of Action Completed By: Gerhard Panuschka			**Date of Completion:** 30Nov2009	

1. SCOUR VULNERABILITY RATING

Scour Evaluation Summary:

At the time of this inspection, no scour and no debris was observed. A slight flow of water was passing through the channel beneath the bridge. This bridge is of concern because 1) it is supported behind the pin location and therefore the allowable loading listed on the flatcar superstructure may not be relevant, and 2) there is a log habitat structure in the channel approximately 150' upstream from the bridge. This habitat structure alters the flow patterns in the channel during high flow and tends to direct flow toward the South approach bank, which is relatively long. This approach bank needs to be protected by RSP.

This bridge is essential within Mill Creek since it provides access to the South and Southwest part of West Branch Mill Creek (approximately 10,000 acres).

Scour History:

There is only a very short documented history of the bridge. In 2002, a 25,000-acre redwood forest in the Mill Creek Watershed was purchased from a logging company by a conglomeration of environmental organizations. The land was donated to the California Dept. of Parks and Rec. to connect Jedediah Smith and Del Norte Coast Redwood State Parks. As part of the acquisition, eleven existing bridges formally used by logging trucks became the property of the State.

Observations: A cut in the embankment beneath Abutment 2 was noted during previous investigations in 2003 and 2006. It was recommended that State Parks consider planning to have the log abutments replaced.

a. **Foundation Type** ☒ Spread footing ☐ Pile Extension ☐ Footing on Piles ☐ Unknown

b. **Foundation Material** ☒ Known _Timber logs w/dirt backfill_ ☐ Unknown

Scour Review: Done By: Gerhard Panuschka Date: 04Nov2009

Structural Assessment: Done By: Date:
Critical Elevation: ________________

Geotechnical Assessment: Done By: Date:
Critical Elevation: ________________

2. NBIS CODING INFORMATION	
	Most Recent
Inspection date	
Item 113 Scour	3
Item 60 Substructure	5
Item 61 Channel & Channel Protection	6
Item 71 Waterway Adequacy	7

3. COUNTERMEASURE RECOMMENDATION

A. Completed Countermeasures:

No countermeasures are currently in place.

B. Proposed Countermeasures:

☐ **Countermeasures Not Required. (Please explain)**

☒ **Install Scour Countermeasures** (See 4 and 5)

	Estimated Cost
_X_ Riprap with monitoring program	$ 80,000
___Guide bank	$
___Spurs / Bendway weirs / Barbs	$
___Relief bridge / Culvert	$
___Channel improvements	$
___Monitoring	$
___Monitoring device	$
___Check Dam	$
___Substructure Modification	$
_X_ Bridge replacement	$ 750,000
___Other ____	$

☐ **Close Bridge** (See 6)

4. COUNTERMEASURE IMPLEMENTATION SCHEDULE

Countermeasure Implementation Project Type:

☒ Proposed Construction Project

Lead Agency _State Parks_

☒ Maintenance Project

Advertised Date: NA

Other scheduling information: **Bridge was added to Project Identification Data (PID) list for replacement as soon as budget becomes available.**

5. MONITORING PLAN

Monitoring Plan Summary:

State Parks maintenance personnel will monitor structure several times a year, and after main runoff events. Maintenance personnel will be trained in observing and identifying scour, how to minimize scour (removal of debris, filling of scour holes, etc.), and what steps to take when significant scour occurs. Bridge may be closed after significant scour events pending evaluation of structural integrity of bridge by engineer.

State Parks personnel will inspect the bridge in early winter for debris. Another inspection is planned in spring. In consultation with the District's Environmental Coordinator and the California Department of Fish and Game, woody debris may be removed or manipulated.

Monitoring Authority: **State Parks – North Coast Redwoods District Trail Maintenance**

☒ **Regular Inspection Program of _____6_mo.** ☐w/surveyed cross sections
Items to Watch: undermining the footing
☒ **Increased Inspection Interval of ____3_ mo.** ☐w/surveyed cross sections
Items to Watch: **Erosion on South approach embankment.**
☐ **Underwater Inspection Program** **Frequency _______ mo.**
Items to Watch:
☐ **Fixed Monitoring Device**
Type of Instrument:
Installation location(s):
Sample Interval: ☐ 30 min. ☐ 1 hr. ☐ 6 hrs. ☐ 12 hrs.
☐ Other _________
Frequency of data logger downloading: ☐ Weekly ☐ Bi-weekly ☐ Monthly
☐ Other _________
Scour-critical discharge:_________
Action required if scour-critical elevation detected:

☒ **Other Monitoring Program**
Type: ☒ Visual
☐ Instrument
☐ Portable ☐ Geophysical ☐ Sonar
☐ Other gages
Flood monitoring required: ☐ Yes ☒ No
Flood monitoring event defined by:
☐ Discharge over _________
☐ Stage _______
☐ Elev. measured from _______
Frequency of flood monitoring: ☐1 hr. ☐3 hr. ☐6 hrs. ☐ Other
Scour critical elevation:
Action required if scour-critical elevation detected:

6. BRIDGE CLOSURE PLAN			
Bridge ADT: 10	**Built:** 1950	**% Trucks:** 10	**Bridge Length (ft):** 90

Closure Plan Summary
State Parks Maintenance will report significant scour events to management. State Parks engineer or geologist will immediately inspect bridge condition and, if required, close bridge by setting up barricades and signs. State Parks engineer/geologist will determine countermeasures to protect the bridge from further damage. Bridge will be re-opened upon completion of countermeasures and if it is considered structurally sound.

Scour Monitoring Criteria for Consideration of Bridge Closure:

- ☐ Water surface elevation reaches ________________
- ☐ Overtopping road or structure
- ☒ Scour Measurement Results / Monitoring Device
- ☒ Loss of Riprap
- ☒ Observed amount of Settlement
- ☒ Loss of Road Embankment
- ☒ Debris Accumulation
- ☐ Other _________________

Person / Area Responsible for Closure: **Jeff Bomke, Sector Superintendent, North Coast Redwoods District**

Contact People (Name & Phone No.): **Gerhard Panuschka: 916-445-8680**

Responsible for re-opening after inspection: **Jeff Bomke**

7. DETOUR ROUTE

Detour route description (route number, from - to, etc.) – attach map.

Average ADT: 10	**Year:** 2003	**% Trucks:** 10	**Length:** 123.7 miles

Bridges on Detour Route:

Bridge Number	Waterway	Sufficiency Rating/ Load limitations	Scour 113 code

BRIDGE SCOUR EVALUATION - PLAN OF ACTION				
Br. No. 01P0016	**Owner** Parks	**Location** Mill Creek	**Facility Carried** West Branch Rd	**Name** Kelly Creek [1)]
Plan of Action Completed By: Gerhard Panuschka			**Date of Completion:** 30Nov2009	

1. SCOUR VULNERABILITY RATING

Scour Evaluation Summary:

At the time of this inspection, no debris was observed. A slight flow of water was passing through the channel beneath the bridge. This bridge is of concern because the SW abutment bank is severely eroded under the log supporting the flatcar superstructure. Furthermore, there is evidence that road runoff is causing additional abutment bank erosion at both abutments. A slack cable is hanging across the channel on the upstream side; the cable needs to be removed.

This watershed is vegetated with small trees only. Consequently, there is minimal chance for large debris in the channel.

Scour History:

A cut in the embankment beneath Abutment 1 was noted during previous investigations in 2003 and 2006. Work recommendations dated 10/23/2008 called for providing scour counter measures along the embankments at both abutments.

a. **Foundation Type** ☒ Spread footing ☐ Pile Extension ☐ Footing on Piles ☐ Unknown

b. **Foundation Material** ☒ Known _Timber logs w/dirt backfill_ ☐ Unknown

Scour Review: Done By: Gerhard Panuschka Date: 04Nov2009

Structural Assessment: Done By: Date:
Critical Elevation: ________________

Geotechnical Assessment: Done By: Date:
Critical Elevation: ________________

2. NBIS CODING INFORMATION

	Most Recent
Inspection date	
Item 113 Scour	3
Item 60 Substructure	6
Item 61 Channel & Channel Protection	6
Item 71 Waterway Adequacy	6

Note 1: Caltrans database shows "Chewy Creek" under Structure Name. The correct Structure Name is "Kelly Creek".

3. COUNTERMEASURE RECOMMENDATION

A. Completed Countermeasures:

No countermeasures are currently in place.

B. Proposed Countermeasures:

☐ **Countermeasures Not Required. (Please explain)**

☒ **Install Scour Countermeasures** (See 4 and 5)

	Estimated Cost
_X_ Riprap with monitoring program	$ 80,000
___Guide bank	$
___Spurs / Bendway weirs / Barbs	$
___Relief bridge / Culvert	$
___Channel improvements	$
___Monitoring	$
___Monitoring device	$
___Check Dam	$
___Substructure Modification	$
_X_ Bridge replacement	$ 500,000
___Other ____	$

☐ **Close Bridge** (See 6)

4. COUNTERMEASURE IMPLEMENTATION SCHEDULE

Countermeasure Implementation Project Type:

☒ Proposed Construction Project

Lead Agency State Parks

☒ Maintenance Project

Advertised Date: NA

Other scheduling information: **Bridge will be added to Project Identification Data (PID) list for replacement as soon as budget becomes available.**

5. MONITORING PLAN

Monitoring Plan Summary:

State Parks maintenance personnel will monitor structure several times a year, and after main runoff events. Maintenance personnel will be trained in observing and identifying scour, how to minimize scour (removal of debris, filling of scour holes, etc.), and what steps to take when significant scour occurs. Bridge may be closed after significant scour events pending evaluation of structural integrity of bridge by engineer.

State Parks personnel will inspect the bridge in early winter for debris. Another inspection is planned in spring. In consultation with the District's Environmental Coordinator and the California Department of Fish and Game, woody debris may be removed or manipulated.

Monitoring Authority: **State Parks – North Coast Redwoods District Trail Maintenance**

☒ **Regular Inspection Program of _____6_mo.** ☐ w/surveyed cross sections

Items to Watch: undermining the footing

☒ **Increased Inspection Interval of ____3_ mo.** ☐ w/surveyed cross sections

Items to Watch:.

☐ **Underwater Inspection Program** **Frequency _______ mo.**

Items to Watch:

☐ **Fixed Monitoring Device**

Type of Instrument:

Installation location(s):

Sample Interval: ☐ 30 min. ☐ 1 hr. ☐ 6 hrs. ☐ 12 hrs.

☐ Other __________

Frequency of data logger downloading: ☐ Weekly ☐ Bi-weekly ☐ Monthly

☐ Other __________

Scour-critical discharge:__________

Action required if scour-critical elevation detected:

☒ **Other Monitoring Program**

Type: ☒ Visual

☐ Instrument

☐ Portable ☐ Geophysical ☐ Sonar

☐ Other gages

Flood monitoring required: ☐ Yes ☒ No

Flood monitoring event defined by:

☐ Discharge over __________

☐ Stage _______

☐ Elev. measured from _______

Frequency of flood monitoring: ☐ 1 hr. ☐ 3 hr. ☐ 6 hrs. ☐ Other

Scour critical elevation:

Action required if scour-critical elevation detected:

6. BRIDGE CLOSURE PLAN

Bridge ADT: 10	Built: 1950	% Trucks: 10	Bridge Length (ft): 40

Closure Plan Summary

State Parks Maintenance will report significant scour events to management. State Parks engineer or geologist will immediately inspect bridge condition and, if required, close bridge by setting up barricades and signs. State Parks engineer/geologist will determine countermeasures to protect the bridge from further damage. Bridge will be re-opened upon completion of countermeasures and if it is considered structurally sound.

Scour Monitoring Criteria for Consideration of Bridge Closure:

- ☐ Water surface elevation reaches _______________ ☐ Overtopping road or structure
- ☒ Scour Measurement Results / Monitoring Device ☒ Loss of Riprap
- ☒ Observed amount of Settlement ☒ Loss of Road Embankment
- ☒ Debris Accumulation
- ☐ Other _______________

Person / Area Responsible for Closure: **Jeff Bomke, Sector Superintendent, North Coast Redwoods District**

Contact People (Name & Phone No.): **Gerhard Panuschka: 916-445-8680**

Responsible for re-opening after inspection: **Jeff Bomke**

7. DETOUR ROUTE

Detour route description (route number, from - to, etc.) – attach map.

Average ADT: 10	**Year:** 2003	**% Trucks:** 10	**Length:** 123.7 miles

Bridges on Detour Route:

Bridge Number	Waterway	Sufficiency Rating/ Load limitations	Scour 113 code

BRIDGE SCOUR EVALUATION - PLAN OF ACTION				
Br. No. 01P0017	**Owner** Parks	**Location** Mill Creek	**Facility Carried** West Branch Rd	**Name** West Branch Mill Creek
Plan of Action Completed By: Gerhard Panuschka			**Date of Completion:** 30Nov2009	

1. SCOUR VULNERABILITY RATING

Scour Evaluation Summary:

At the time of this inspection, no scour and no debris was observed. A slight flow of water was passing through the channel beneath the bridge. The South abutment sits on two massive logs with perpendicular smaller logs extending into the abutment fill (interlocked). This abutment is getting undermined. Road runoff is causing additional erosion at the abutments.

Recommendation: 1) cut ditches on the road on both sides of the bridge to divert road runoff off the side; 2) provide RSP to protect the eroded abutment fill.

Scour History:

Observations: Work recommendations dated 10/23/2008 called for placing scour countermeasures at Abutment 1 until the abutment is replaced.

a. **Foundation Type** ☒ Spread footing ☐ Pile Extension ☐ Footing on Piles ☐ Unknown

b. **Foundation Material** ☒ Known _**Timber logs w/dirt backfill**_ ☐ Unknown

Scour Review: Done By: **Gerhard Panuschka** Date: **04Nov2009**

Structural Assessment: Done By: NA Date:
Critical Elevation: ________________

Geotechnical Assessment: Done By: NA Date:
Critical Elevation: ________________

2. NBIS CODING INFORMATION

		Most Recent
Inspection date		
Item 113	Scour	3
Item 60	Substructure	5
Item 61	Channel & Channel Protection	7
Item 71	Waterway Adequacy	5

3. COUNTERMEASURE RECOMMENDATION

A. Completed Countermeasures:

No countermeasures are currently in place.

B. Proposed Countermeasures:

☐ **Countermeasures Not Required. (Please explain)**

☒ **Install Scour Countermeasures** (See 4 and 5)

	Estimated Cost
_X_ Riprap with monitoring program	$ 80,000
___Guide bank	$
___Spurs / Bendway weirs / Barbs	$
___Relief bridge / Culvert	$
___Channel improvements	$
___Monitoring	$
___Monitoring device	$
___Check Dam	$
___Substructure Modification	$
_X_ Bridge replacement	$ 350,000
___Other ________________________________	$

☐ **Close Bridge** (See 6)

4. COUNTERMEASURE IMPLEMENTATION SCHEDULE

Countermeasure Implementation Project Type:

☒ Proposed Construction Project

Lead Agency _State Parks

☒ Maintenance Project

Advertised Date: NA

Other scheduling information: **Bridge will be added to Project Identification Data (PID) list for replacement as soon as budget becomes available.**

5. MONITORING PLAN

Monitoring Plan Summary:

State Parks maintenance personnel will monitor structure several times a year, and after main runoff events. Maintenance personnel will be trained in observing and identifying scour, how to minimize scour (removal of debris, filling of scour holes, etc.), and what steps to take when significant scour occurs. Bridge may be closed after significant scour events pending evaluation of structural integrity of bridge by engineer.

State Parks personnel will inspect the bridge in early winter for debris. Another inspection is planned in spring. In consultation with the District's Environmental Coordinator and the California Department of Fish and Game, woody debris may be removed or manipulated.

Monitoring Authority: **State Parks – North Coast North District Trail Maintenance**

☒ **Regular Inspection Program of _____6_mo.** ☐ w/surveyed cross sections
Items to Watch: undermining the footing
☒ **Increased Inspection Interval of ____3_ mo.** ☐ w/surveyed cross sections
Items to Watch: Extent of undermining at South abutment.
☐ **Underwater Inspection Program** **Frequency _______ mo.**
Items to Watch:
☐ **Fixed Monitoring Device**
Type of Instrument:
Installation location(s):
Sample Interval: ☐ 30 min. ☐ 1 hr. ☐ 6 hrs. ☐ 12 hrs.
☐ Other _________
Frequency of data logger downloading: ☐ Weekly ☐ Bi-weekly ☐ Monthly
☐ Other _________
Scour-critical discharge:_________
Action required if scour-critical elevation detected:

☒ **Other Monitoring Program**
Type: ☒ Visual
☐ Instrument
☐ Portable ☐ Geophysical ☐ Sonar
☐ Other gages
Flood monitoring required: ☐ Yes ☒ No
Flood monitoring event defined by:
☐ Discharge over _________
☐ Stage _______
☐ Elev. measured from _______
Frequency of flood monitoring: ☐ 1 hr. ☐ 3 hr. ☐ 6 hrs. ☐ Other
Scour critical elevation:
Action required if scour-critical elevation detected:

6. BRIDGE CLOSURE PLAN

Bridge ADT: 10	Built: 1950	% Trucks: 10	Bridge Length (ft): 58

Closure Plan Summary

State Parks Maintenance will report significant scour events to management. State Parks engineer or geologist will immediately inspect bridge condition and, if required, close bridge by setting up barricades and signs. State Parks engineer/geologist will determine countermeasures to protect the bridge from further damage. Bridge will be re-opened upon completion of countermeasures and if it is considered structurally sound.

Scour Monitoring Criteria for Consideration of Bridge Closure:

- ☐ Water surface elevation reaches ________________
- ☐ Overtopping road or structure
- ☒ Scour Measurement Results / Monitoring Device
- ☒ Loss of Riprap
- ☒ Observed amount of Settlement
- ☒ Loss of Road Embankment
- ☒ Debris Accumulation
- ☐ Other _________________

Person / Area Responsible for Closure: **Jeff Bomke, Sector Superintendent, North Coast Redwoods District**

Contact People (Name & Phone No.): **Gerhard Panuschka: 916-445-8680**

Responsible for re-opening after inspection: **Jeff Bomke**

7. DETOUR ROUTE

Detour route description (route number, from - to, etc.) – attach map.

Average ADT: 10	Year: 2003	% Trucks: 10	Length: 123.7 miles

Bridges on Detour Route:

Bridge Number	Waterway	Sufficiency Rating/ Load limitations	Scour 113 code

BRIDGE SCOUR EVALUATION - PLAN OF ACTION				
Br. No. 01P0019	**Owner** Parks	**Location** Mill Creek	**Facility Carried** Child's Hill RD	**Name** Jane Creek
Plan of Action Completed By: Gerhard Panuschka			**Date of Completion:** 30Nov2009	

1. SCOUR VULNERABILITY RATING

Scour Evaluation Summary:

At the time of this inspection, no scour and no debris was observed. A slight flow of water was passing through the channel beneath the bridge. The channel has a steep slope and is armored with naturally occurring big boulders. Some erosion was noted at the abutments.

Scour History:

Observations: A cut in the embankment beneath Abutment 1 was noted during previous investigations in 2003, 2006, and 2008. Development of a scour hole near Abutment 1 was also reported in the 2008 inspection report. The scoured area of the embankment was approximately 10 feet long and 6 feet long.

a. **Foundation Type** ☒ Spread footing ☐ Pile Extension ☐ Footing on Piles ☐ Unknown

b. **Foundation Material** ☒ Known _**Timber logs w/dirt backfill**_ ☐ Unknown

Scour Review: Done By: **Gerhard Panuschka** Date: **04Nov2009**

Structural Assessment: Done By: NA Date:
Critical Elevation: ________________

Geotechnical Assessment: Done By: NA Date:
Critical Elevation: ________________

2. NBIS CODING INFORMATION

		Most Recent
Inspection date		
Item 113	Scour	3
Item 60	Substructure	5
Item 61	Channel & Channel Protection	7
Item 71	Waterway Adequacy	6

3. COUNTERMEASURE RECOMMENDATION

A. Completed Countermeasures:

No countermeasures are currently in place.

B. Proposed Countermeasures:

☐ **Countermeasures Not Required. (Please explain)**

☒ **Install Scour Countermeasures** (See 4 and 5)

	Estimated Cost
_X_Riprap with monitoring program	$ 80,000
___Guide bank	$
___Spurs / Bendway weirs / Barbs	$
___Relief bridge / Culvert	$
___Channel improvements	$
___Monitoring	$
___Monitoring device	$
___Check Dam	$
___Substructure Modification	$
_X_Bridge replacement	$ 500,000
___Other ____	$

☐ **Close Bridge** (See 6)

4. COUNTERMEASURE IMPLEMENTATION SCHEDULE

Countermeasure Implementation Project Type:

☒ Proposed Construction Project

Lead Agency State Parks

☒ Maintenance Project

Advertised Date: NA

Other scheduling information: **Bridge will be added to Project Identification Data (PID) list for replacement as soon as budget becomes available.**

5. MONITORING PLAN

Monitoring Plan Summary:

State Parks maintenance personnel will monitor structure several times a year, and after main runoff events. Maintenance personnel will be trained in observing and identifying scour, how to minimize scour (removal of debris, filling of scour holes, etc.), and what steps to take when significant scour occurs. Bridge may be closed after significant scour events pending evaluation of structural integrity of bridge by engineer.

State Parks personnel will inspect the bridge in early winter for debris. Another inspection is planned in spring. In consultation with the District's Environmental Coordinator and the California Department of Fish and Game, woody debris may be removed or manipulated.

Monitoring Authority: **State Parks – North Coast Redwoods District Trail Maintenance**

☒ **Regular Inspection Program of _____6_mo.** ☐w/surveyed cross sections
Items to Watch: undermining the footing
☐ **Increased Inspection Interval of _______ mo.** ☐w/surveyed cross sections
Items to Watch:.
☐ **Underwater Inspection Program** **Frequency _______ mo.**
Items to Watch:
☐ **Fixed Monitoring Device**
Type of Instrument:
Installation location(s):
Sample Interval: ☐ 30 min. ☐ 1 hr. ☐ 6 hrs. ☐ 12 hrs.
☐ Other _________
Frequency of data logger downloading: ☐ Weekly ☐ Bi-weekly ☐ Monthly
☐ Other _________
Scour-critical discharge:_________
Action required if scour-critical elevation detected:

☒ **Other Monitoring Program**
Type: ☒ Visual
☐ Instrument
☐ Portable ☐ Geophysical ☐ Sonar
☐ Other gages
Flood monitoring required: ☐ Yes ☒ No
Flood monitoring event defined by:
☐ Discharge over _________
☐ Stage _______
☐ Elev. measured from _______
Frequency of flood monitoring: ☐1 hr. ☐3 hr. ☐6 hrs. ☐ Other
Scour critical elevation:
Action required if scour-critical elevation detected:

6. BRIDGE CLOSURE PLAN			
Bridge ADT: 5	**Built:** 1950	**% Trucks:** 10	**Bridge Length (ft):** 63

Closure Plan Summary

State Parks Maintenance will report significant scour events to management. State Parks engineer or geologist will immediately inspect bridge condition and, if required, close bridge by setting up barricades and signs. State Parks engineer/geologist will determine countermeasures to protect the bridge from further damage. Bridge will be re-opened upon completion of countermeasures and if it is considered structurally sound.

Scour Monitoring Criteria for Consideration of Bridge Closure:

- ☐ Water surface elevation reaches ________________
- ☐ Overtopping road or structure
- ☒ Scour Measurement Results / Monitoring Device
- ☒ Loss of Riprap
- ☒ Observed amount of Settlement
- ☒ Loss of Road Embankment
- ☒ Debris Accumulation
- ☐ Other _________________

Person / Area Responsible for Closure: Jeff Bomke, Sector Superintendent, North Coast Redwoods District

Contact People (Name & Phone No.): Gerhard Panuschka: 916-445-8680

Responsible for re-opening after inspection: Jeff Bomke

7. DETOUR ROUTE			
Detour route description (route number, from - to, etc.) – attach map.			
Average ADT: 5	**Year:** 2003	**% Trucks:** 10	**Length:** 123.7 miles

Bridges on Detour Route:

Bridge Number	Waterway	Sufficiency Rating/ Load limitations	Scour 113 code

BRIDGE SCOUR EVALUATION - PLAN OF ACTION

Br. No.	Owner	Location	Facility Carried	Name
01P0021	Parks	Mill Creek	Child's Hill RD	East Fork Mill Creek

Plan of Action Completed By: Gerhard Panuschka	**Date of Completion:** 30Nov2009

1. SCOUR VULNERABILITY RATING

Scour Evaluation Summary:

At the time of this inspection, no debris was observed. A slight flow of water was passing through the channel beneath the bridge. The log supports at the abutments are starting to get undermined, and the logs are rotting. However, no settlement of the superstructure was noted.

Scour History:

Observations: A cut in the embankment along the Abutment 1 timber crib wall was noted during previous investigations in 2003, 2006, and 2008. Undermining of the bottom transverse log of the Abutment 1 crib wall was also noted during an investigation in 2008. The undermining was up to 2 feet below the log and 2 feet back from the face along a distance of 7 feet on the downstream side. Work recommendations dated 10/23/2008 called for the repair of the undermining along the bottom of the crib wall at Abutment 1.

a. **Foundation Type** ☒ Spread footing ☐ Pile Extension ☐ Footing on Piles ☐ Unknown

b. **Foundation Material** ☒ Known _**Timber logs w/dirt backfill**_ ☐ Unknown

Scour Review: Done By: **Gerhard Panuschka** Date: **04Nov2009**

Structural Assessment: Done By: Date:
Critical Elevation: ________________

Geotechnical Assessment: Done By: Date:
Critical Elevation: ________________

2. NBIS CODING INFORMATION

		Most Recent
Inspection date		
Item 113	Scour	3
Item 60	Substructure	5
Item 61	Channel & Channel Protection	6
Item 71	Waterway Adequacy	7

3. COUNTERMEASURE RECOMMENDATION

A. Completed Countermeasures:

No countermeasures are currently in place.

B. Proposed Countermeasures:

☐ **Countermeasures Not Required. (Please explain)**

☒ **Install Scour Countermeasures** (See 4 and 5)

	Estimated Cost
_X_ Riprap with monitoring program	$ 80,000
___Guide bank	$
___Spurs / Bendway weirs / Barbs	$
___Relief bridge / Culvert	$
___Channel improvements	$
___Monitoring	$
___Monitoring device	$
___Check Dam	$
___Substructure Modification	$
_X_ Bridge replacement	$ 500,000
___Other ________________________________	$

☐ **Close Bridge** (See 6)

4. COUNTERMEASURE IMPLEMENTATION SCHEDULE

Countermeasure Implementation Project Type:

☒ Proposed Construction Project

Lead Agency State Parks

☒ Maintenance Project

Advertised Date: NA

Other scheduling information: **Bridge will be added to Project Identification Data (PID) list for replacement as soon as budget becomes available.**

5. MONITORING PLAN

Monitoring Plan Summary:

State Parks maintenance personnel will monitor structure several times a year, and after main runoff events. Maintenance personnel will be trained in observing and identifying scour, how to minimize scour (removal of debris, filling of scour holes, etc.), and what steps to take when significant scour occurs. Bridge may be closed after significant scour events pending evaluation of structural integrity of bridge by engineer.

State Parks personnel will inspect the bridge in early winter for debris. Another inspection is planned in spring. In consultation with the District's Environmental Coordinator and the California Department of Fish and Game, woody debris may be removed or manipulated.

Monitoring Authority: **State Parks – North Coast Redwoods District Trail Maintenance**

☒ **Regular Inspection Program of _____6_mo.** ☐ w/surveyed cross sections
Items to Watch: undermining the footing

☐ **Increased Inspection Interval of _______ mo.** ☐ w/surveyed cross sections
Items to Watch:.

☐ **Underwater Inspection Program** **Frequency _______ mo.**
Items to Watch:

☐ **Fixed Monitoring Device**
Type of Instrument:
Installation location(s):
Sample Interval: ☐ 30 min. ☐ 1 hr. ☐ 6 hrs. ☐ 12 hrs. ☐ Other _________
Frequency of data logger downloading: ☐ Weekly ☐ Bi-weekly ☐ Monthly ☐ Other _________
Scour-critical discharge:_________
Action required if scour-critical elevation detected:

☒ **Other Monitoring Program**
Type: ☒ Visual
☐ Instrument
☐ Portable ☐ Geophysical ☐ Sonar
☐ Other gages

Flood monitoring required: ☐ Yes ☒ No
Flood monitoring event defined by:
☐ Discharge over _________
☐ Stage _______
☐ Elev. measured from _______

Frequency of flood monitoring: ☐ 1 hr. ☐ 3 hr. ☐ 6 hrs. ☐ Other
Scour critical elevation:
Action required if scour-critical elevation detected:

6. BRIDGE CLOSURE PLAN			
Bridge ADT: **10**	**Built:** **1950**	**% Trucks:** **15**	**Bridge Length (ft):** **59**

Closure Plan Summary

State Parks Maintenance will report significant scour events to management. State Parks engineer or geologist will immediately inspect bridge condition and, if required, close bridge by setting up barricades and signs. State Parks engineer/geologist will determine countermeasures to protect the bridge from further damage. Bridge will be re-opened upon completion of countermeasures and if it is considered structurally sound.

Scour Monitoring Criteria for Consideration of Bridge Closure:

- ☐ Water surface elevation reaches ________________ ☐ Overtopping road or structure
- ☒ Scour Measurement Results / Monitoring Device ☒ Loss of Riprap
- ☒ Observed amount of Settlement ☒ Loss of Road Embankment
- ☒ Debris Accumulation
- ☐ Other ________________

Person / Area Responsible for Closure: **Jeff Bomke, Sector Superintendent, North Coast Redwoods District**

Contact People (Name & Phone No.): **Gerhard Panuschka: 916-445-8680**

Responsible for re-opening after inspection: **Jeff Bomke**

7. DETOUR ROUTE

Detour route description (route number, from - to, etc.) – attach map.

Average ADT: 10	**Year:** 2003	**% Trucks:** 15	**Length:** 123.7 miles

Bridges on Detour Route:

Bridge Number	Waterway	Sufficiency Rating/ Load limitations	Scour 113 code

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