A Rapid Assessment of Sediment Delivery from Clearcut Timber Harvest Activities in the Battle Creek Watershed, Shasta and Tehama Counties, California

November, 2011

CAL FIRE · California Department of Fish & Game · California Water Boards · California Geological Survey

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Report prepared at the request of

The California Resources Agency

by staff from

The California Department of Forestry and Fire Protection (CAL FIRE)

The California Department of Fish and Game (DFG)

The Central Valley Regional Water Resource Control Board (CV RWQCB)

and

The California Geological Survey (CGS)

Executive Summary:

The Battle Creek Salmon and Steelhead Restoration Project is a cornerstone for the recovery of listed salmonid species in the Sacramento Valley, northern California. The spring-dominated, relatively cold waters of Battle Creek provide important potential refugia for salmon and steelhead in the event of rising global temperature. As restoration activities focus on the removal of downstream barriers for salmonid migration, much of the headwaters of Battle Creek are being managed for high-yield timber production by the largest private landowner in the watershed – Sierra Pacific Industries (SPI). SPI's use of clearcutting, coupled with the rate of harvest in the upper watershed, has alerted local environmental stakeholders to the potential for water quality impacts from these harvest practices. These concerns have garnered State-wide attention with the recent publishing of several stories in the Sacramento Bee detailing the potential for clearcut-related impacts to the success of the restoration in Battle Creek. In response to public concern, staff from the Timber Harvesting Plan (THP) Review Team agencies formed the interagency Battle Creek Task Force (Task Force). The Task Force performed a rapid assessment to determine if timber operations associated with SPI clearcut harvesting in Battle Creek had resulted in observable erosion and subsequent delivery of sediment which has resulted in violation of state law or observable negative impact to fisheries.

Over a five-day field period in September 2011, the Task Force assessed the potential for water-quality impacts at 135 sites they determined to have a high risk for sediment delivery to waters of the state. Of these sites, 55 were clearcut harvest units, 39 were road crossings of watercourses, 24 were watercourse-adjacent road segments, 6 were watercourse-adjacent landings, 5 were tractor crossings of watercourses, and 3 were associated with other sources of erosion. Despite assessing approximately 16 miles of riparian buffers directly adjacent to clearcut harvest units (i.e., 47 percent of the total buffer-zone length adjacent to harvested clearcuts), the Task Force only found one instance of low-magnitude sediment delivery (less than 1 cubic yard) directly associated with a clearcut. However, sediment delivery associated with this site resulted from a Forest Practice Rules (FPRs) violation (encroachment of a tractor into an equipment-limitation zone adjacent to a watercourse), rather than from erosion generated within the adjacent clearcut unit.

The Task Force field study found the likelihood of sediment delivery in the assessment area to be highest for tractor crossings, road crossings, watercourse-adjacent road segments, and watercourse-adjacent landings, respectively. All 5 tractor crossings delivered sediment, but were generally delivering only a low-magnitude of sediment to waters of the state. Road crossings and watercourse-adjacent road segments delivered sediment 69 percent and 67 percent of the time, respectively. The magnitude of sediment delivery from road crossings and watercourse-adjacent road segments with implemented Best Management Practices (BMPs) was generally low or unobservable. The highest magnitudes of sediment delivery from roads were associated with poor BMP implementation (e.g., poor road drainage) and/or poor location (e.g., road segments

within 30-50 feet of a watercourse). Poor BMP implementation was commonly associated with county-managed roads or SPI-managed roads with public access. Watercourse-adjacent landings associated with recent Timber Harvesting Plans (THPs) delivered no sediment, and the lack of delivery was attributed to the protective ground cover provided by application of a wood–chip mulch.

Overall, the Task Force saw no significant direct water quality impact related to clearcut harvesting in the assessment area. Most observed timber-harvest-related water-quality impacts were found to be associated with publicly and privately managed roads. These roads are used for all types of timber harvesting in the watershed, whether clearcutting, selection, or some intermediate silvicultural method. Due to the limited time period of the assessment, the Task Force was unable to evaluate the potential for indirect water-quality impacts that may result from clearcut harvesting (such as possible increases in suspended sediment and turbidity associated with logging-induced increases in peak flows). Recommendations developed by the Task force are provided herein to improve the water-quality-related performance of forest roads and to further evaluate the potential for logging-induced water quality impacts in the Battle Creek watershed.

Battle Creek Task Force Team Members

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Mr. Mathew Boone, **RPF**, Environmental Scientist, Central Valley Regional Water Quality Control Board, Timber Harvest Regulatory Unit, Redding. Mr. Boone has a BS in Forestry and Natural Resources Management from California Polytechnic State University (Cal Poly) in San Luis Obispo. Mr. Boone, a Registered Professional Forester, has worked in the forestry and natural resources field since 1997, and has been working in the Water Board's Timber program since 2006 with a focus on timber-harvest review, forest roads and crossings, Basin Plan compliance inspections, and water quality monitoring.

Ms. Jennifer Bull, Environmental Scientist, California Department of Fish and Game (DFG), Yreka. Ms. Bull has a BS in Biological Sciences from UC Davis. Ms. Bull has worked in the DFG Interior Timberland Program dealing with forestry issues for the past 12 years, focusing primarily on aquatic issues in Siskiyou County, and is currently the Siskiyou County DFG District Fisheries Biologist.

Mr. Drew Coe, Central Valley Regional Water Quality Control Board, Timber Harvest Regulatory Unit, Redding. Mr. Coe holds a BS in Forestry from Humboldt State University and a MS in Watershed Science from Colorado State University. Mr. Coe has worked on forestry and watershed issues since 1993, specializing in the hydrologic and geomorphic impacts of forest roads, and upstream-downstream interactions in forested watersheds.

Mr. Donald Lindsay, PG, CEG, PE, Engineering Geologist, California Geological Survey (CGS), Redding. Mr. Lindsay is a State-registered Professional Geologist, State-certified Engineering Geologist, and State-registered Professional Civil Engineer. Mr. Lindsay has BS and MS degrees in Geology as well as over 11 years of professional experience performing geologic, hydrologic, and geotechnical engineering work and has been a member of the Redding Inter-Agency Timber-Harvesting-Plan Review Team since 2008.

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Dr. Michael Wopat, PG, CEG, CHG, Senior Engineering Geologist, California Geological Survey, Redding. Dr. Wopat is a State-registered Professional Geologist and a State-certified Hydrogeologist and Engineering Geologist. Dr. Wopat holds BS, MS, and PhD degrees in Geology and has been a member of the Redding Inter-Agency Timber Harvesting Plan Review Team since 1999, focusing mainly on issues related to geomorphology (mass movement and erosion) and hydrology.

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Acknowledgements

All Battle Creek Task Force members contributed to this report. We thank especially Drew Coe who wrote most of the analytical parts of the report and Michael Wopat who did the bulk of the editing. Matt Boone provided tremendous GIS and analytical support for Drew. In addition to Drew, Stacey Stanish, Don Lindsay, Michael Wopat, Adam Wyman, Bruce Beck, and Duane Shintaku all prepared parts of the manuscript. Kelly Dreesman, Curt Babcock, Mark Stopher, Pete Cafferata, Angela Wilson, and Bill Short all reviewed and commented upon various drafts of the manuscript – we thank them for their insightful comments. We thank Christy Gilbreath and Whitney Brown for supporting the field phase by taking pictures and recording site notes for the Task Force teams and providing good cheer during those endeavors. We also thank Mike Mitzel and Ted James for their help in accessing and traveling about SPI property. GIS specialists Nancy Magner, Mami Odaya, and Suzanne Lang prepared excellent maps for use in scoping and in the field and very useful information regarding the extent of geologic units. Cheryl Hayhurst and Anita Carney prepared detailed geologic and soils maps of the 5-planning-watershed-assessment area.

We thank you all for your contributions to this report!

Acronyms

ASP – Anadromous Salmonid Protection

BCWC – Battle Creek Watershed Conservancy

BCWG – Battle Creek Working Group

BLM – Unites States Bureau of Land Management

BMP – Best Management Practice

CAL FIRE – California Department of Forestry and Fire Protection

CEG – California Certified Engineering Geologist

CGS – California Geological Survey

CHG – California Certified Hydro Geologist

CVRWQB – Central Valley Regional Water Quality Control Board

DFG – California Department of Fish and Game

DWR – California Department of Water Resources

ELZ – Equipment Limitation Zones

ESA – Endangered Species Act

FPR – California Forest Practice Rules

LTO – Licensed Timber Operator

MOU – Memorandum of Understanding

THP – Timber Harvest Plan

PE – California Professional Civil Engineer

PG – California Professional Geologist

RFF – Regional Flood-Frequency

RPF – California Registered Professional Forester

SPI – Sierra Pacific Industries, Inc.

TPZ – Timber Production Zone

USBR – United States Bureau of Reclamation

USDA – United States Department of Agriculture

USGS – United States Geological Survey

WLPZ – Watercourse and Lake Protection Zone

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1.0. Introduction

Battle Creek supports important populations of Chinook salmon (*Oncorhynchus tshawytscha)* and Central Valley steelhead (*Oncorhynchus mykiss*). It is one of the northernmost major tributaries to the Sacramento River downstream of Keswick and Shasta dams, which are complete barriers to upstream fish passage. Springs on North Fork Battle Creek supply cold water for deep pool habitat while South Fork Battle Creek receives much of its water from snow melt and spring runoff. In particular, the predominance of colder springs in Battle Creek make the watershed an important potential refugia for salmonids in the event of rising global temperatures. As populations of salmon and steelhead have declined, Battle Creek has become a cornerstone for the survival and restoration of these anadromous species in the Sacramento Valley.

Over the last century, Battle Creek has been subject to extensive hydropower development that has impacted salmonid populations and their habitat. Hydropower development has altered and diverted watercourse flows beginning in the early 1900s, reducing natural flows and blocking access to spawning habitat. In 1942, the Coleman National Fish Hatchery was established to raise steelhead and salmon as mitigation for the loss of access to upstream spawning areas by the construction of Shasta Dam. The weir at Coleman was at one time a seasonal barrier to salmonids, further reducing access to spawning habitat. These hydromodifications, and a variety of other likely factors, have resulted in declining populations of these salmonid species.

Recognizing the important role Battle Creek plays in salmonid recovery, a memorandum of understanding (MOU) was developed and signed by federal and state agencies and PG&E in 1999 to implement the Battle Creek Salmon and Steelhead Restoration Project. The project has collaborated with the Battle Creek Watershed Conservancy and is a 128-million-dollar multi-phased effort that mainly focuses on modifying and adjusting existing hydroelectric facilities so as to balance hydroelectric energy production with protecting and restoring salmonid populations and their habitat (USBR, 2011a) (see Figure 6 of this report for project major components).

Historically, the Battle Creek watershed has been subjected to a variety of land uses. In addition to hydroelectric power generation, forestry and agriculture are the primary land uses, with parcels designated as Timber Production Zone (TPZ) comprising 38 percent of the watershed area. The major owner of timber-producing lands in the watershed is privately-owned Sierra Pacific Industries (SPI), which owns 31 percent of the watershed area and 82 percent of the private TPZ land. In the past decade SPI has been increasingly reliant on using clearcut silviculture to manage its forest lands in the Battle Creek watershed.

Clearcutting is a silvicultural practice where essentially all trees are removed from the harvested area. Clearcutting has also been shown to result in adverse environmental impacts depending upon the extent of its use and its spatial application (Keenan and Kimmins, 1993; Moore and others, 2005). There are also strong social perceptions regarding clearcutting, and there is significant public disdain for clearcutting as a silvicultural tool (Bliss, 2000). The rate of clearcutting in the basin has been alarming to some of the environmental stakeholders (e.g., Battle Creek Alliance) in the Battle Creek watershed, and has prompted numerous lawsuits to halt logging. Some of these stakeholders have also undertaken water-quality monitoring to attempt to demonstrate water quality violations from timber harvest activities (see Appendix A).

On June 19, 2011 the Sacramento Bee published an article by Matt Weiser (http://www.sacbee.com/2011/06/19/3711308/troubled-waters-of-battle-creek.html) that implies clearcut harvesting by SPI has resulted in water-quality impacts contrary to the goals and objectives of the *Battle Creek Salmon and Steelhead Restoration Project*, a $128 million project to remove Pacific Gas & Electric dams and open up 48 miles of additional habitat for listed salmon species. The article was followed by an editorial calling for logging restrictions in the Battle Creek watershed (http://www.sacbee.com/2011/06/21/3715189/governor-needs-to-keep-pledge.html).

After release of the initial article, Natural Resources Agency Secretary John Laird and members of his staff met with CAL FIRE management to discuss SPI's clearcut harvesting in the Battle Creek watershed. CAL FIRE was asked to coordinate an interagency group (the Battle Creek Task Force) consisting of the state agency experts normally involved in environmental review of commercial logging operations; these included CAL FIRE forest-practice inspectors, Central Valley Water Board staff, DFG biologists, and CGS engineering geologists. The agency experts were asked to rapidly assess if the claims of clearcut-induced water-quality impacts in the Battle Creek watershed were supported by evidence observed in the field of sediment delivery to Battle-Creek watercourses from harvested clearcut units.

Given public concern over clearcutting in the Battle Creek watershed, the agency participants developed the following purpose statement for the Task Force:

> **Evaluate whether timber operations associated with SPI clearcut harvesting in Battle Creek has resulted in observable erosion and subsequent delivery of sediment which has resulted in violation of state law or observable negative impact to fisheries.**

This report attempts to answer the various questions posed by this statement. In particular, we focus on the issue of whether observable water quality impacts are originating from clearcut areas. Because of the rapid nature of this assessment, the Task force focused on the 5 planning watersheds with the most clearcut activities (see Section 4 for additional detail).

2.0. Background

Despite the fact that timber-harvest activities can increase erosion rates by several orders of magnitude over natural erosion rates (MacDonald and Coe, 2007) these erosional impacts may not always translate into water-quality impacts. A key concept to consider when evaluating potential water-quality impacts from land use activities is the following:

> Significant Water-Quality Impacts = Significant Erosion + **Significant Delivery to a Waterbody**

This concept is critical because it acknowledges that erosion will not affect water quality as long as it does not deliver[1] to a waterbody.

The potential for sediment delivery from timber-harvest activities strongly depends on the interaction between the location of the activity relative to a waterbody and the erosion potential of the activity (Croke and Hairsine, 2006) (Figure 1). The location of the activity is important because eroded sediment from a disturbed site can rapidly settle as it discharges onto undisturbed forest floor and the further an activity is from a watercourse the more likely it will be that eroded material will deposit before it reaches the water and causes a water-quality impact. In fact, the ability of the undisturbed forest floor to filter sediment is a fundamental concept used in forestry-related "Best Management Practices[2] (BMPs), and the California Forest Practice Rules rely heavily on riparian buffer strips to prevent sediment delivery from timber-harvest activities. Hence, the likelihood of sediment delivery generally decreases as distance from the watercourse increases.

The erosion potential of an activity is an important consideration because the ability of the sediment to reach a waterbody is dependent upon the magnitude of erosion from the disturbed area (Megahan and Ketcheson, 1996). In short, sites with high rates of erosion have a higher likelihood of delivering to water bodies than sites with low rates of erosion. While erosion is strongly dependent on site factors such as geology, soils, slope steepness, climate, and vegetation, the various components of timber harvesting (e.g., roads, forest harvest) each have a characteristic erosion potential. Erosion potential from these various activities is generally related to the degree of disturbance summarized by the following:

- **Soil compaction** – Lower-permeability compacted soils have an increased potential to generate erosive runoff;
- **Surface cover removal** – Soils lacking surface cover are subject to rain-splash erosion and higher runoff rates through soil sealing. The flow resistance offered by cover also slows runoff and reduces its erosion capability;
- **Flow-path modification** – Roads and skid trails can collect, redistribute, and concentrate runoff, increasing the erosion capability of runoff and increasing the likelihood of landsliding;
- **Soil/earth movement** – Displaced or heavily disturbed soil from heavy equipment operation can be dislodged and transported by rainfall, moving water, and/or landsliding;

[1] The likelihood of sediment delivery is also referred to in terms of "connectivity" and "linkage."

[2] Best Management Practices are "operational practices that prevent or reduce the amount of nonpoint source pollution in keeping with water quality objectives" (Singer and Maloney, 1977).

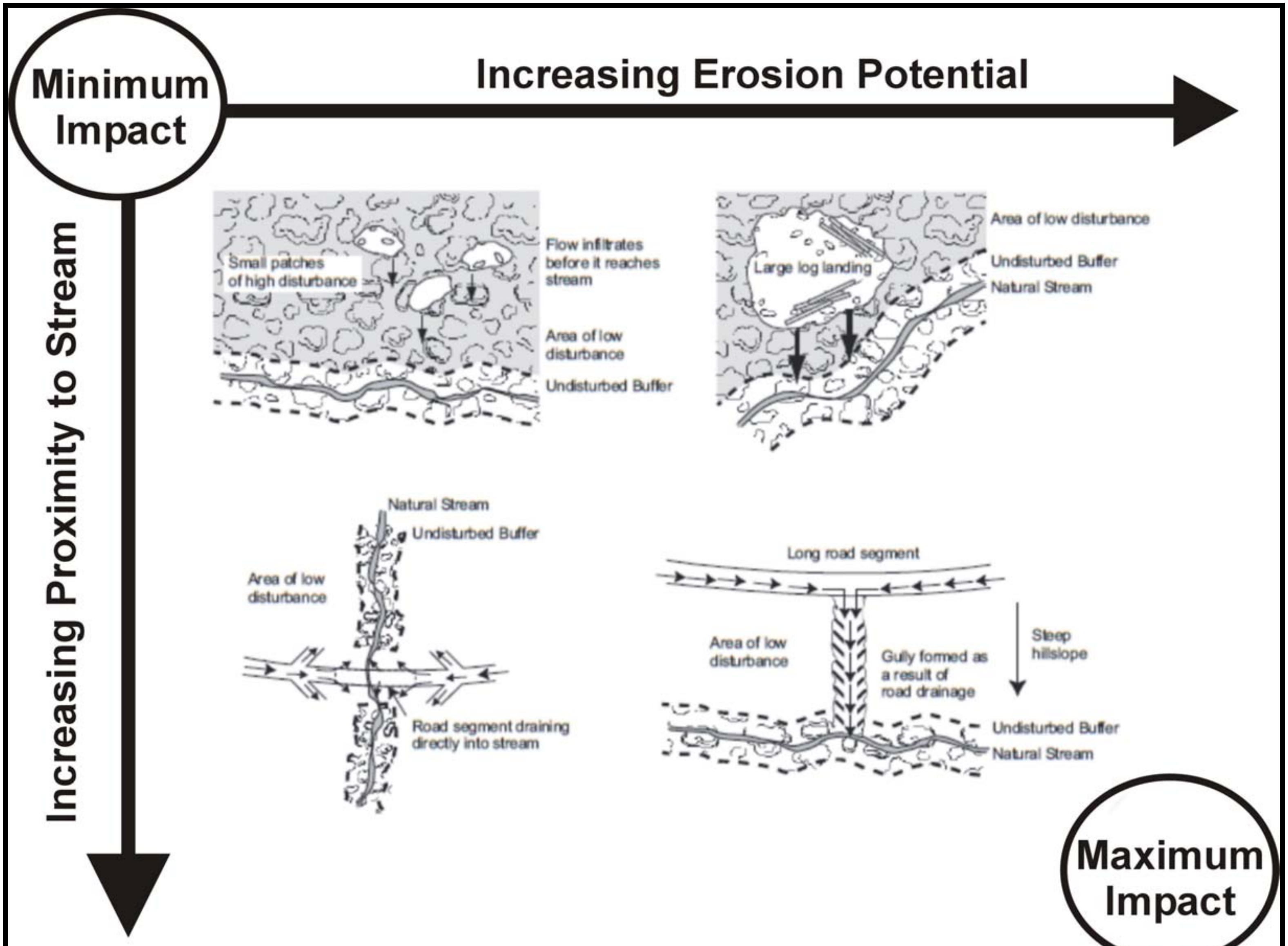

Figure 1. A conceptual schematic demonstrating how water quality impacts depend on the relationship between erosion potential and location of disturbance relative to a stream (adapted from Croke and Hairsine, 2006).

- **Overstory (tree) removal** – Timber harvest can both increase the amounts of rainwater and snowmelt entering the soil and decrease the amount of groundwater utilization by trees. These effects can increase pore-water pressures in soils and increase peak flows in relatively small watercourses. Removing trees can increase the likelihood of landsliding in marginally-stable areas by temporarily decreasing rooting strength and raising groundwater levels. These process alterations have the potential to increase in-channel erosion, channel extension, and/or increase the risk of landsliding in marginally-stable areas.

In general, roads affect these factors much more dramatically than harvested areas (Croke and Hairsine, 2006). Theoretically, this means that the unit area erosion potential from roads should exceed that of harvested areas. This assertion is confirmed by published studies, which find erosion rates from roads can be one or more orders of magnitude higher than erosion rates found on skid trails and non-compacted portions of the harvested areas (Croke and others, 1999; MacDonald and others, 2004).

Given this framework for understanding the potential water quality impacts from timber harvest activities, we postulate that activities closest to the watercourses and with the highest erosion potential would have the highest likelihood for sediment delivery to waters of the state. Furthermore, we hypothesize that road crossings (where a road crosses a watercourse) and watercourse-adjacent (within the riparian buffer) roads and landings would have the highest likelihood for sediment delivery. Although the literature suggests that overland sediment delivery from harvested areas is rare when BMPs are implemented and riparian buffers are in place (Rashin and others, 2006; Litschert and MacDonald, 2009), some studies have demonstrated instances of sediment delivery associated with clearcutting (Rivenbark and Jackson, 2004; Litschert and MacDonald, 2009). Since the public perception is that clearcutting is causing water quality impacts in Battle Creek, the Task Force placed a primary emphasis on assessing the frequency of direct sediment delivery from clearcut harvest units to waters of the state. The Task also recognized that because the assessment was conducted during the fall season, they would not be able to directly assess all potential mechanisms of sediment delivery, such as potential increases in suspended sediment and turbidity associated with harvest-related increases in peak flows.

3.0. Site Description

3.1. Physiography and Relief

The Battle Creek Watershed drains an area of about 370 square miles on the east side of the Sacramento River in Shasta and Tehama Counties in northern California. The watershed extends westward about 35 miles from its highest point of 10,457 feet at the top of Lassen Peak at the south end of the High Cascades downstream to its confluence with the Sacramento River at about 335 feet elevation near the town of Cottonwood in the northeast end of the Sacramento Valley (Figure 2). It is at its widest near its east end, where it extends about 23 miles northward from Turner Mountain south of Mineral to Huckleberry Mountain about 8 miles north of Viola.

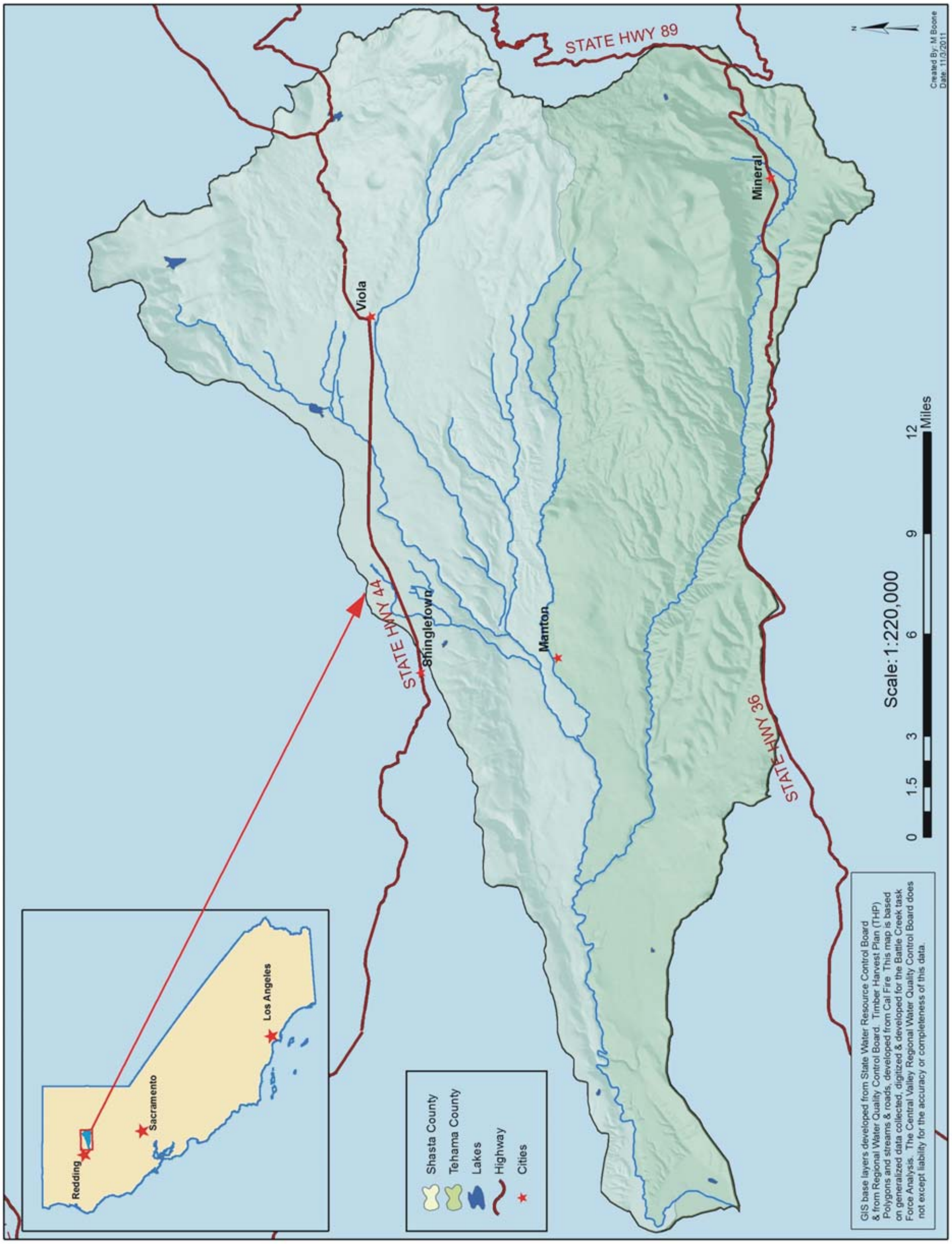

Figure 2. Overview of the Battle Creek watershed.

East of Manton, the south edge of the watershed is largely defined by the deep canyon eroded by South Fork Battle Creek (the actual watershed boundary is the ridge south of the canyon followed by Highway 36). In contrast to the deeply incised canyon of South Fork Battle Creek in the southeastern part of the watershed, the northeastern part of the watershed east of Shingletown shows relatively minor evidence of significant fluvial erosion and this results in a relatively low drainage density for this portion of the watershed. Further east, local topographic relief increases with proximity to the Lassen Peak volcanic center.

3.2. Geology

Almost the entire 370 square-mile Battle Creek watershed lies in the Cascade Range geomorphic province (Bailey, 1966; CGS, 2002), characterized by widespread andesitic volcanism that formed stratovolcanos like Mt. Shasta and abundant associated flows of basalt, basaltic andesite, dacite, and rhyolite that locally form volcanic edifices such as Lassen Peak, a dacite plug dome. As a result, most of the watershed is underlain by volcanic deposits that include lava flows, ash flows, and volcanic mudflows (lahars) (Figure 3).

In the 5-planning-watershed study area (see section 4.0 – Selection and Methods for discussion), the proportions of the volcanic lithologies differ from that of the watershed as a whole in that basalt is less common in the study area than elsewhere in the watershed. In the study area, andesite (36%), basaltic andesite (17.5%), and basalt (1.3%) together make up about 55 percent of the outcrop area. Less prevalent are outcrops of dacite (7%), rhyolitic ash flow (7%), rhyolite (7%), and rhyodacite (1%). Glacial till and outwash make up about 17 percent of the area, with a large ancient debris-flow deposit[3] and alluvium covering another 6 percent. See Appendix C for detailed geologic maps of the 5 planning watersheds in the assessment area.

3.3 Soils

Soils in the 5-planning-watershed study area can be roughly grouped into two soil associations, 1) the Cohasset-Windy-McCarthy association and 2) the Jiggs-Lyonsville-Forward association, based on differences related to physiography and parent rock (USDA 1967, 1974). The Cohasset-Windy-McCarthy soil association consists of thin to moderately-thick soils that mantle gentle-sloping to rolling ridges capped by lava flows and very steep slopes on mountains of volcanic rock. The soils are generally dark brown to dark reddish brown, derived from andesitic to basaltic rock, and known to support vegetation that includes ponderosa pine, Douglas-fir, white fir, sugar pine, and black oak. These soils are mostly north of the west-flowing Digger Creek, in the Lower Manzanita Creek, Bailey Creek, and Canyon Creek planning watersheds.

[3] The debris-flow deposit covers more than 4,000 acres in the Upper Digger Creek (2500 ac.), Canyon Creek (955 ac.), Lower Digger Creek (500 ac.), and Panther Creek (80 ac.) planning watersheds and is prehistoric - it is interpreted to have resulted from a massive failure of part of Brokeoff Mountain about 340 to 350 thousand years ago (Clynne and Muffler, 2010).

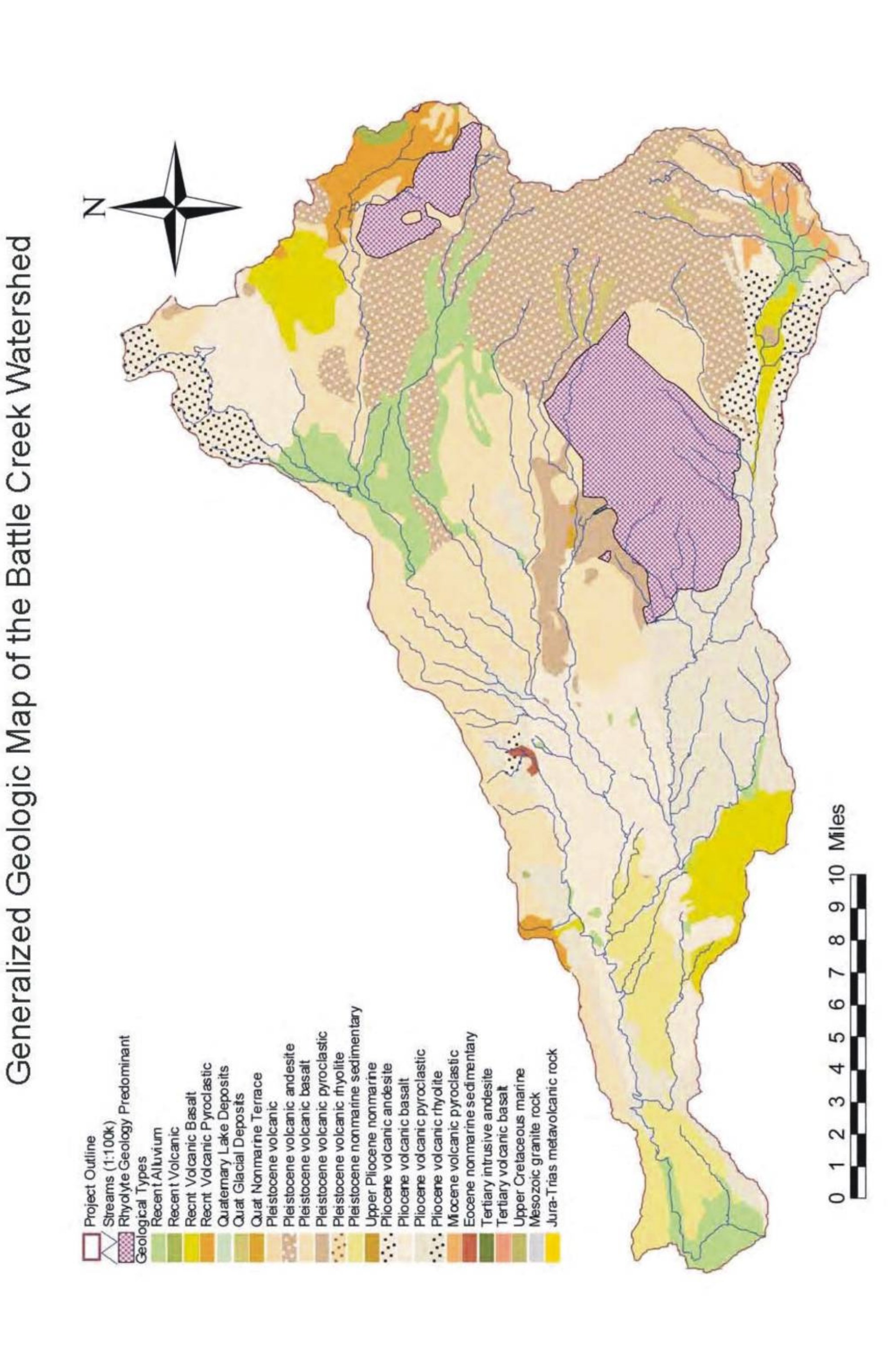

Figure 3. Simplified geologic map of the Battle Creek watershed (from Ward and Moberg, 2004).

The Jiggs-Lyonsville-Forward soil association mantles broad, gentle-sloping ridges and steep slopes that flank incised watercourses. The soils are mostly light gray, are derived from rhyolitic to dacitic rock, and support vegetation that includes ponderosa pine, white fir, sugar pine, Douglas-fir, and incense cedar. These soils are mostly south of Digger Creek, in the Upper Digger Creek and Panther Creek planning watersheds.

Although most soils in the study area are grouped into the two major soil associations, there are isolated areas where other soils occur. A prominent example is around Viola where soils of the Nanny Series, consisting of gravelly to cobbly glacial outwash alluvium, are present on gently-sloping ground. Table 1 provides a partial list of the prominent soil types (series) found within the study area and their associated properties. See Appendix D for detailed soil maps of the 5 planning watersheds in the assessment area.

Although most of the soils in the assessment area are similar in texture, drainage, and erosion hazard, the Jiggs soils, which are derived from a rhyolitic parent material, are unique in that they are the only soil described in the soil surveys as being sensitive to ground disturbance resulting from logging (USDA, 1964, 1967).

Table 1. Prominent soil types in 5-watershed study area (adapted from USDA 1967, 1974)

Soil Series	Texture	Parent Material	Drainage	Erosion Hazard
Cohasset	Yellowish-red, loam to gravelly clay loam, non to slightly plastic.	Andesite	Well drained	Slight to High
Windy	Dark grayish-brown, sandy loam to gravelly sandy loam, nonplastic.	Basalt	Well drained	High to Very High
McCarthy	Dark brown, gravelly sandy loam to very cobbly sandy loam, nonplastic.	Basalt	Well drained	Moderate to High
Jiggs	Light-gray, gravelly sandy loam to gravelly coarse sandy loam, nonplastic.	Rhyolite	Excessively drained	Moderate
Forward	Light brownish-gray, sandy loam, nonplastic	Rhyolitic tuff	Well drained	Moderate to High
Lyonsville	Pale-brown, gravelly sandy loam, non to slightly plastic	Dacite and Rhyolite	Well drained	Moderate
Nanny	Very dark grayish-brown stony and gravelly sandy loam, nonplastic	Glacial outwash	Well drained	Slight

3.4 Climate

The Battle Creek watershed, like most of California, is subject to a wet-winter Mediterranean climate, in which most precipitation falls in the winter and summer is relatively dry. In the middle elevations of the watershed between about 2,000 feet and approximately 5,000 to 6,000 feet, the climate is temperate and humid, with a mean annual precipitation of about 30 to 60 inches, with much of the precipitation falling as snow. Mean annual temperature is about 46° to 58° F, with a mean freeze-free period is about 100 to 175 days (Miles and others, 1998). Most of the sites inspected during the Battle Creek field effort were in these middle elevations.

The middle elevations described above include the rain-on-snow zone, an elevational zone that is high enough to develop an extensive snowpack, but low enough to potentially get rain from a warm winter storm on an existing snowpack. The combination of the rain and melting of the snowpack from the rain and associated warm winds has caused most of California largest and most damaging floods (Kattelman and others, 1991; Kattelman, 1997, see also Harr, 1981). Ward and Moberg (2004) considered the rain-on-snow zone in the Battle Creek watershed to be the elevation band between 3,500 feet to 5,000 feet, which coincides with much of the area managed for timber production.

3.5. Hydrology:

The hydrology of the Battle Creek watershed is heavily dependent upon the relatively recent volcanic nature of the eastern part of the watershed. A large proportion of the rainfall and snowmelt in the uplands infiltrates into the relatively permeable volcanic rocks and emerges in a number of springs that feed Battle Creek and its tributaries. The high proportion of spring water provides a stable base level of cold water compared to most other streams that derive a major proportion of their runoff from surface and shallow-subsurface runoff. Some of the larger springs west of Manton are captured to provide a reliable source of water for nearby fish hatcheries. Average daily flow of Battle Creek since 1940 is in the range of 1,000 cfs and dry-season summer flows are rarely less than 200 cfs (Heiman and Knecht, 2010).

A 48-year record (1962-2010) of Battle Creek peak flows from the U.S. Geological Survey station 11376550 at Coleman Fish Hatchery is available from National Water Information System website (NWIS-Web) at http://nwis.waterdata.usgs.gov/usa/nwis/peak?search_site_no=11376550[4]. Additional peak-flow data from 1941 through 1962 are available from Goodridge (2000). The 35,000 cfs peak flow of record for this station occurred in December 1937 (Waananen and Crippen, 1977). Analysis of these combined peak-flow data with the USGS PeakFQ program (USGS, 2007) shows the Bulletin-17B estimate of the 100-year return-period peak flow to be 27,530 cfs.

Relatively limited-duration stream-flow records are available from California Department of Water Resources (DWR) stream gages on North Fork Battle

[4] This record is missing a peak-flow data point from 1997. For completeness, the 1997 peak flow of 17,636 cfs measured on January 1, 1997 at a stream gage at Coleman National Fish Hatchery (Stanish, 2011, personal communication) has been added to the peak-flow data used in this report.

Creek (BNF) and South Fork Battle Creek (BAS) where stream-flow records are available starting in 2000 (the record for BAS appears to end in late 2007)[5]. In addition, Waananen and Crippen (1977) summarize peak-flow estimates for a 13-year record of peak flows measured on Summit Creek (1.8 mi^2 watershed) near Mineral (station number 11376200)[6].

Regional flood-frequency equations (RFF's) developed by Waananen and Crippen (1977) were used to estimate the 100-year and 2-year return-period flood flows for watersheds where gaged data are not available. The ratio of the 100-year return-period flood flow to the 2-year return-period flood flow (i.e., Q_{100}/Q_2) can be used as a measure of the relative "flashiness" of a stream, with smaller values denoting less flashiness. The Q_{100}/Q_2 ratio obtained for Battle Creek from PeakFQ processing of its 70-year record of measured peak flows is 4.44. In contrast, the Q_{100}/Q_2 ratio obtained for the Battle Creek watershed using USGS regional flood-frequency equations is 5.75. The 23-percent smaller Q_{100}/Q_2 ratio obtained from the Battle Creek measured peak flows shows the Battle Creek peak flows to be demonstrably less flashy than peak flows on most of similar watershed area, elevation range, and average annual precipitation in the Sierra flood-frequency region. The relatively diminished flashiness of Battle Creek is interpreted to result in part from the significant role spring water plays in its hydrologic budget. These results are similar in kind to those obtained by Tague and Grant (2004) in their study of Cascade streams in Oregon.

A major rain-on-snow event affected northern California in early 1997, causing widespread landsliding and peak flows that were the largest on record at 106 of 292 streamflow gaging stations that were evaluated in central and northern California (Hunrichs and others, 1998). A 2001 to 2002 assessment of the Battle Creek watershed considered the storm event to be ". . . the primary sediment source factor affecting aspects of stream condition (Ward and Moberg, 2004). The 17,636 cfs flow measured January 1, 1997 at Coleman National Fish Hatchery is the 5th largest annual peak flow recorded on Battle Creek since the peak flow of record in 1937. Comparison to flood flows estimated using PeakFQ shows the 17,636 cfs 1997 peak flow to have an annual .exceedance probability of about 5.5 percent, with a corresponding return interval of about 18 years. Ward and Moberg indicate the 1997 storm ". . . disturbed stream reaches at high elevations . . ." (2004, p. 63) (emphasis added), whereas the Battle Creek peak-flow data were collected at Coleman National Fish Hatchery just a few miles above the mouth of the Battle Creek watershed at an elevation of 415 feet (see Figure 4 for Hatchery location).

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[5] These records can be accessed at the DWR Data Exchange Center at http://cdec.water.ca.gov/cgi-progs/staSearch using the appropriate 3-letter station ID and referring to sensor 20 to get stream flow.

[6] The 13-year peak-flow record for this site is available on the Internet from NWIS-Web at: http://nwis.waterdata.usgs.gov/usa/nwis/peak?search_site_no=11376200.

3.6. Vegetation Types

Starting at the confluence of Battle Creek and the Sacramento River, at about 350 feet above sea level, the vegetation types transition eastward from river riparian to perennial grassland and grass and oak woodland in the lower foothills,

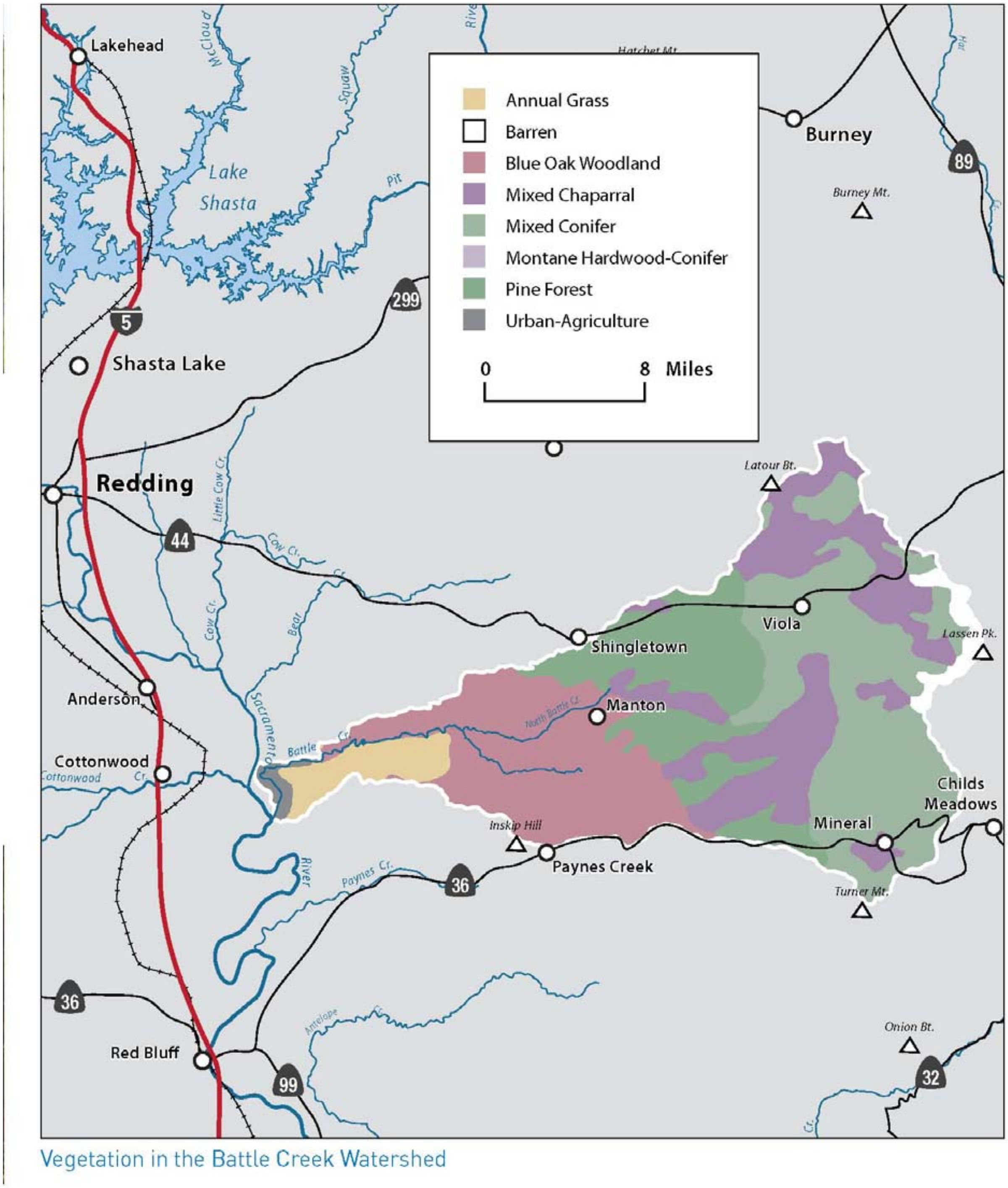


Figure 4. Vegetation in the Battle Creek watershed (from Heiman and Knecht, 2010).

with increasing brush and pine species mixing in with increasing elevation. As the elevation increases to 3,500 feet, Sierran mixed conifer forest dominates the landscape. At 5,000 feet, high mountain meadows with riparian vegetation are interspersed with lodgepole pine, cottonwood, and aspen trees. True fir conifer forests dominate above 5,000 feet elevation. The highest elevation in the Battle Creek watershed is Lassen Peak at 10,457 feet, well above timberline. Figure 4 (previous page) shows vegetation types in the Battle Creek watershed,

3.7. Battle Creek Fisheries

Salmon and steelhead are economically and socially important species to California that provide recreational and commercial opportunities. Central Valley steelhead trout (Oncorhynchus mykiss) and four runs of Chinook salmon (Oncorhynchus tshawytscha) have historic and existing populations within the Sacramento River watershed. The fall, late-fall, winter, and spring runs of Chinook are defined by the season in which they begin their upstream migration (Moyle, 2002). Under the Endangered Species Act (ESA), Sacramento River winter-run Chinook are listed as Endangered, Central Valley spring-run Chinook are listed as Threatened, Central Valley fall- and late fall-run Chinook are listed as Species of Concern, and Central Valley steelhead are listed as Threatened (NOAA Fisheries, 2011),

There are 250 miles of fish-bearing streams within the Battle Creek Watershed. Historically, 87 of those miles provided spawning access to anadromous steelhead and Chinook (Terraqua, 2008). The extent of historical anadromy in Battle Creek existed three miles upstream of Volta powerhouse and up to Whispering Falls on the North Fork, around the vicinity of Manton on Digger Creek, and to Angel Falls on the South Fork (Yoshiyama 1996) (Figure 5). Flows from the abundant springs n the Battle Creek watershed ensure continuous flow throughout the year while consistently providing cold water habitat (Ward and Kier, 1999). The spring hydrology of Battle Creek is what makes the watershed so important to anadromous salmonids which have specific requirements for cold water to complete their life cycle.

Central Valley steelhead enter freshwater in the fall and hold until flows increase and stream temperatures decrease before they move into the tributaries to spawn (Moyle, 2002). Steelhead young remain in the tributary streams to rear from one to three years before migrating out to sea. Fall-run Chinook enter freshwater in the fall and spawn in the late fall. The fall-run juveniles can rear in streams from one to seven months (Yoshiyama and others, 1998). Peak migration for spring-run Chinook occurs in the spring months where they then hold in the cool tributary streams over the summer. Spawning occurs in early fall and spring-run juveniles can rear up to a year in freshwater. Winter-run peak migration occurs around March and spawning occurs during the spring. Winter-run juveniles remain in stream from five to ten months before out-migrating to the ocean. The complex and variable life histories of steelhead and the various runs of Chinook in Battle Creek can result in any one of the species being in the watershed at any given time of the year.

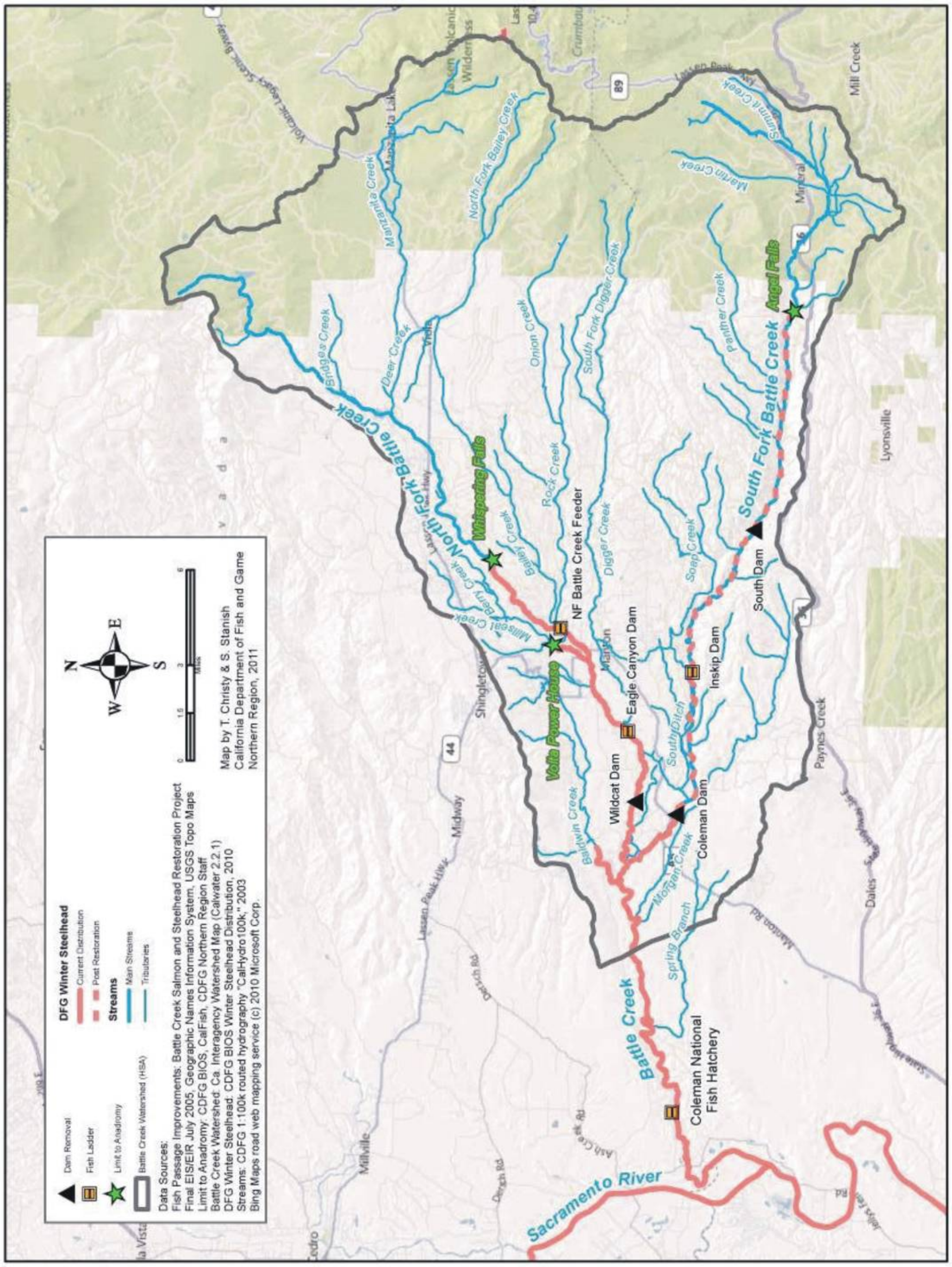


Figure 5. Steelhead and Chinook distribution in the Battle Creek watershed.

Steelhead and Chinook have experienced declining populations over the last century (Yoshiyama and others, 1998). Some of the main factors contributing to this decline are the construction of dams and water diversion. This results in a drastic elimination of access to natal spawning grounds and reduces the available of water volume necessary for spawning and rearing while modifying natural hydrology regimes. Battle Creek watershed is among those areas where stream flow has been modified, specifically for the purpose of hydropower generation.

The first hydropower facilities were constructed in the Battle Creek watershed in the early 1900s, beginning with the Volta Powerhouse (Jensen, 1975). More powerhouses were constructed on Battle Creek for the next ten years with the last one being Coleman Powerhouse only a few miles upstream from the confluence with the Sacramento River. As a result, much of the access, both seasonally and spatially, to native spawning grounds for steelhead and Chinook was effectively reduced. Construction of the Shasta Dam began in the 1930s, thereby eliminating anadromous access on the Sacramento River north of Redding.. As mitigation for the loss of spawning access and to preserve steelhead and Chinook populations, the Coleman National Fish Hatchery was constructed in 1942, very near the site of the Coleman Powerhouse. A weir was constructed on Battle Creek to capture upstream, migrating salmonids to meet the production needs of the hatchery. The weir has been a seasonal migration barrier to upstream fish passage (USBR 2005, 2011). Seasonally high flows and access to a fish ladder have allowed some upstream migration of salmon and steelhead. Once upstream of Coleman, fish could only migrate as far as the upstream hydropower dams.

Recognizing the significance of Battle Creek’s anadromous fish and the need to balance the interests of existing water users, the Greater Battle Creek Working Group (BCWG), which includes state and federal agencies and other stakeholders, was organized in 1995. In 1997, the Battle Creek Watershed Conservancy (BCWC) was formed by a group of private landowners and stakeholders to address and protect the economic and environmental interests in the watershed. In 1999, the Battle Creek Salmon and Steelhead Restoration Plan was completed with collaboration from the BCWG and BCWC, providing the technical basis for the Battle Creek Salmon and Steelhead Restoration Project.

United States Bureau of Reclamation heads the restoration project in collaboration with other federal and State agencies, and private landowners (USBR 2005). The $128-million-dollar restoration project incorporates multiple phases of progress that include installing fish screens and ladders and ultimately removing several dams from the watershed. (Figure 6) The main goal of the project is to restore spawning access for salmon and steelhead.

Concurrently with the restoration project various groups are conducting monitoring efforts throughout the watershed. The BCWC secured funding to assess stream habitat conditions beginning in 2001 to monitor trends in sedimentation, pool-riffle habitat, and temperature, among other variables (Terraqua 2008, KrisWeb 2011). The United States Fish and Wildlife Service is currently monitoring anadromous fish population trends of adult and juvenile salmonids – the monitoring includes collecting stream-temperature and turbidity data (Newton and others, 2007, Whitton and others, 2010).

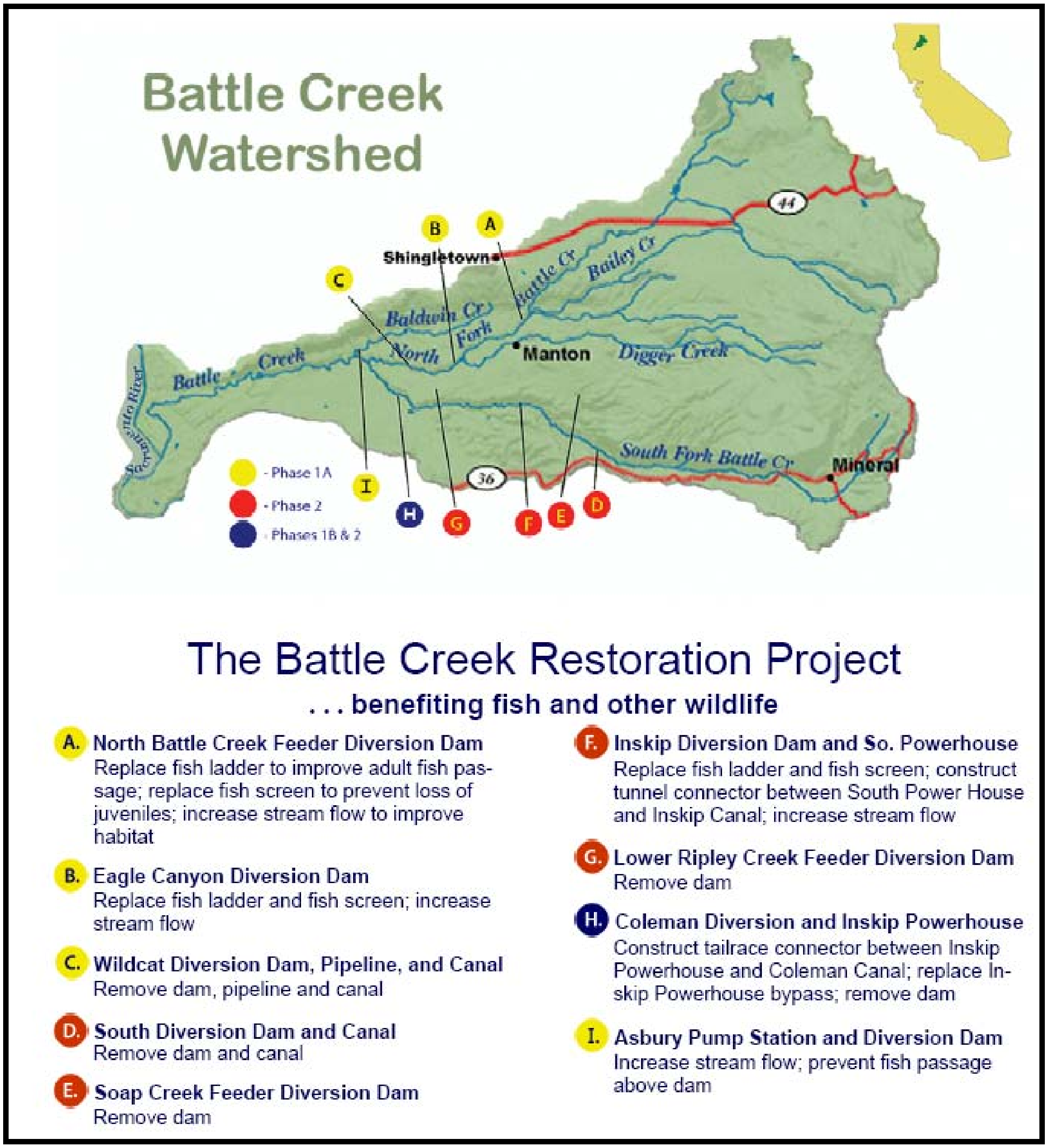


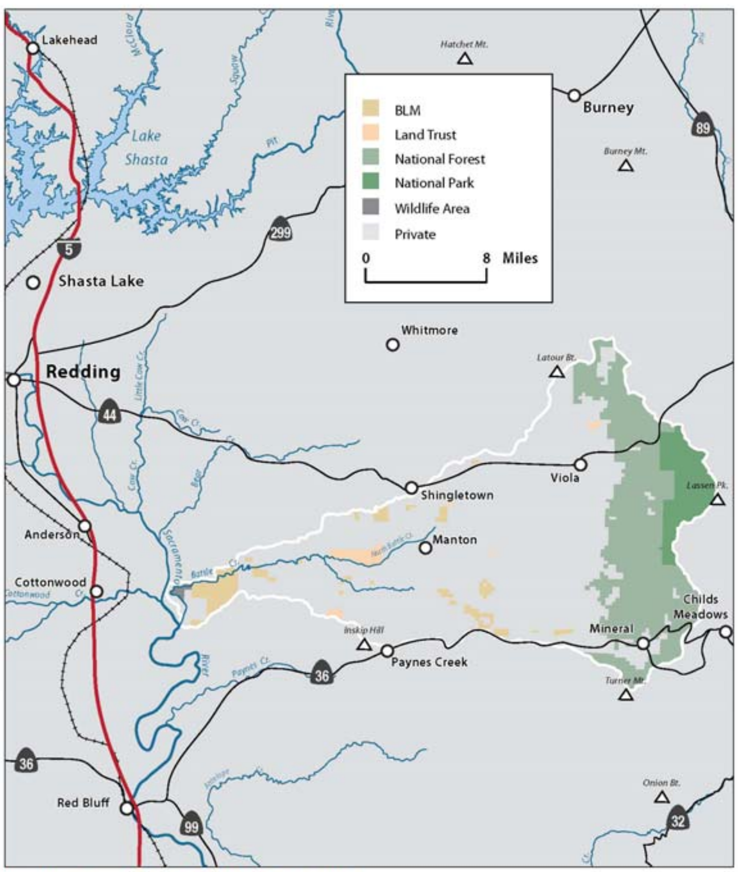
Figure 6. Battle Creek salmon and steelhead restoration project components.

Private timberlands compose a large portion of the Battle Creek watershed. Timber-harvesting operations on private lands are subject to the California Forest Practice Act. As part of the Act, rules exist to protect and conserve watercourses, from perennial fish-bearing streams to headwater streams. In 2009, the California Board of Forestry adopted the Anadromous Salmonid Protection (ASP) rules for the protection of anadromous salmonids. The intent of the ASP rules is to maintain and improve aquatic habitat and contribute to restoration of listed anadromous salmonids. The ASP rules replaced the Threatened or Impaired Watershed rules which had the same intent. Among the

ASP rules are additional measures to address sediment runoff in watersheds that are directly upstream of ASP-designated watersheds.

3.8. Land Ownership

Land ownership in the Battle Creek Watershed includes small private single-family residential lots and homes, small private non-industrial timberland and ranchettes, and private large-industrial timberland that is primarily owned and managed by SPI, with some owned or managed by W.M. Beaty & Associates and by PG&E. There is a small component of county- and State-owned lands, and vast areas of federal land in the upper-elevation areas consisting of mostly of Lassen National Forest, smaller amounts of Lassen National Park, and minor BLM ownership (Figure 7). Timber Production Zone (TPZ) makes up 38 percent of the watershed area, and Sierra Pacific Industries owns 82 percent of the land zoned as TPZ.. The distribution of land ownership in the watershed is illustrated in Figure 7.



Land ownership in the Battle Creek Watershed

Figure 7. Land ownership in the Battle Creek Watershed (after Heiman and Knecht, 2010)

3.9. Land-Use Impacts and Activities

Within the Battle Creek watershed, the most recognizable activities occurring within the watershed are: cattle grazing, land conversion (from timber to non-timber uses, subdivision, community development), timber harvesting, agriculture (farming, orchards, vineyards, and grazing), watershed restoration projects, State, federal and private fish hatcheries, wildfire suppression, rights-of-way (for roads, utilities, power lines, gas lines, etc.), water diversions (water dams, historic ditches, penstocks, and flumes), fuel-reduction projects, and dispersed recreation (fishing, hunting, hiking, camping, etc.). Since forestland comprises a significant portion of the Battle Creek watershed, forest management is one of the dominant land uses. While the United States Forest Service has currently stopped intensive management of federally owned forests, SPI and other timberland owners have continued to actively manage their private forestland. SPI is responsible for approximately 79 percent of the 33,100 acres under THP within the watershed during the time period spanning from 1997 to 2010. Approximately 67 percent of the total THP area has been harvested using even-aged silviculture (i.e., clearcut, seed tree, and/or shelterwood). Fifty-four percent of the even-aged harvesting is within the five planning watershed assessment area.

3.10 Roads

Road classifications in the Battle Creek Watershed comprise State Highways (44 and 36), county managed roads and privately managed roads that cross public, private and federal lands. The State Highways are surfaced with asphalt, while county and private roads are surfaced with asphalt, rock, or native material. A qualitative evaluation of the road network within the Battle Creek watershed suggests that the majority of the road density consists of native-surfaced roads, followed by gravel- and asphalt-surfaced roads.

The present road network within the Battle Creek watershed used for forest operations has largely been in existence for decades with only minor road segments being abandoned or constructed in the last decade. Road maintenance for any given road is generally the responsibility of the owner. However, in some cases, particularly where a road crosses mixed private and public ownership or is shared, determining the party responsible for road maintenance becomes more complex and maintenance duties are often shared. In some instances privately managed roads are gated to prevent public access, and roads that are not gated are often subject to all weather use.

3.11 General Summary of Compliance with FPR’s

The standard Forest Practice Rules for CAL FIRE’s Northern Forest District, including the 2010 ASP Rules (14 CCR 936.9 et seq.), apply within the Battle Creek Watershed. Of the 222,363-acre Battle Creek watershed (not including the valley floor), SPI owns 72,606 acres (about 33% of the watershed) and 82 percent of the land zoned as TPZ. Of SPI’s 72,606 acres, the complete 2010 ASP Rule package applies to only 30,234 acres. Of the remaining 42,372 acres of SPI land, 35,830 acres are immediately upstream of and contiguous to watersheds with listed anadromous salmonids and thus are subject to only the road-maintenance and erosion-control parts of the ASP Rules [i.e., 936.9(k) through 936.9(q)]. The 6,542 acres of SPI land not addressed above do not meet the definition of listed watersheds with listed anadromous salmonids and thus are not subject to the ASP Rules.

Within the last 13 years, a total of 15 SPI timber harvesting plans (THPs) with proposed clearcut silviculture have been filed in the 5 planning watersheds (Lower Manzanita Creek, Bailey Creek, Canyon Creek, Upper Digger Creek, and Panther Creek) that make up the study area. Collectively, the 15 THPs have been subject to 115 different Forest-Practice inspections to date. The 115 inspections resulted in CAL FIRE issuing 10 violations of the Forest Practice Rules and Act and filing 2 Civil Penalty cases, one against SPI for silvicultural issues and the other against a licensed timber operator (LTO) working for SPI for discharging sediment into a watercourse along with other infractions. A summary of status and violations for these 15 THPs is included as Appendix E.

4.0. Site Selection and Methods

4.1. Site Selection

The Task Force focused on assessing timber harvest activities in 5 CalWater planning watersheds with the majority of clearcutting activities in the Battle Creek watershed (Figure 8). The CalWater names, ID numbers, and acreages for these planning watersheds, listed from north to south, are shown in Table 2:

Table 2. CalWater[7] planning watersheds in assessment area.

Watershed name	Watershed ID Number	Acreage
Lower Manzanita Creek	5507.120102	9,976
Bailey Creek	5507.120201	13,670
Canyon Creek	5507.120202	15,360
Upper Digger Creek	5507.120402	13,227
Panther Creek	5507.120602	10,996

The assessment area defined by these five planning watersheds encompasses approximately 63,229 acres (i.e., 98.8 mi^2) (Figure 8), or 28 percent of Battle Creek watershed area. Bailey Creek, Canyon Creek, and Upper Digger Creek also coincide with the watersheds monitored for turbidity by the Battle Creek Alliance (see Appendix A for BCA turbidity data and review of data). Hence, results from the assessment can be compared to available turbidity data to determine potential causal relationships between timber-harvest activities and turbidity.

Sites were not sampled in areas above Lake McCumber because sediment from these sites is mostly deposited in the lake rather than traveling to downstream

[7] Information about CalWater is available on the Internet at http://cain.ice.ucdavis.edu/calwater/.

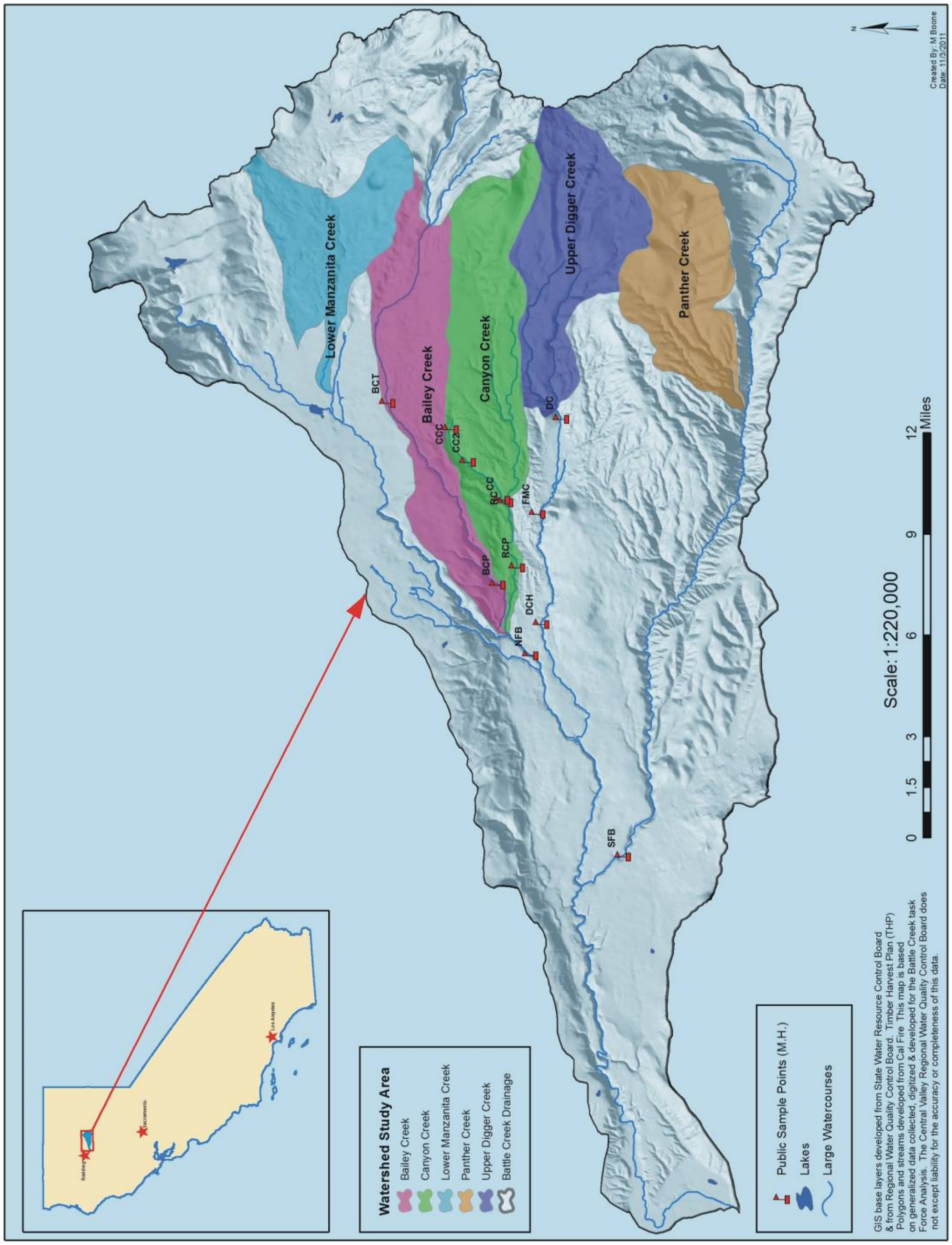


Figure 8. Overview of the assessment area defined by the 5 CalWater planning watersheds and the Battle Creek Alliance's turbidity sampling locations.

salmonid habitat. Three sites were sampled in the Bear Creek planning watershed which is outside the primary assessment area.

Within the assessment area, the Task Force focused on the following potential sediment sources likely to be sources of logging-related erosion:

- **Clearcut harvest units** – Clearcut units (areas where most or all vegetation is removed) have the potential for compaction of soils by heavy equipment use, disturbed surface soils, reduced surface and tree cover, and flow concentration by skid trails.
- **Road segments** – Road segments have highly compacted travel surfaces, are often surfaced with native soil that can be a source of fine sediment, and can intercept, redistribute, and concentrate runoff. Road fillslopes and cutslopes are subject to surface erosion and landsliding.
- **Road crossings and water drafting sites** – Road crossings of watercourses and drafting sites (sites where water is removed [drafted] from a water body by a water truck) have highly compacted travel surfaces, and can have large volumes of erodible fill material placed in the watercourse channel. In some instances, undersized drainage structures associated with these features (e.g., culverts) can lead to catastrophic failure of the crossing during large runoff events. Crossing approaches, the relatively short stretches of road immediately adjacent to the crossing, typically slope toward the crossing and can be major sources of sediment to the watercourse. Previous studies indicate that all road crossings deliver at least a low magnitude of sediment to watercourses (Longstreth and other, 2008).
- **Tractor crossings –** Tractor crossings are where ground-based logging machinery crosses a watercourse within a harvest unit. To prepare the crossing, fill material is placed in the watercourse so that machines can drag logs across the watercourse. Tractor crossings are most common on lower-order streams (intermittent streams). Temporary culverts or log bridging (e.g., “Humboldt-” or “Spittler-“type crossings) are sometimes used if water is present within the watercourse. Once logging ends, the fill material is removed from the watercourse and the crossing typically is treated for erosion control. Most water quality impacts from tractor crossings are associated with the temporary placement of fill material in the watercourse because the finer material cannot be completely removed by mechanical means.
- **Landings** – Landings are enlarged parts of the road network where logs are processed and loaded onto log trucks and typically are within or adjacent to clearcut units. Landings can be one-quarter of an acre in size or more, so the potential for runoff generation is increased due to the relatively large compacted area. Furthermore, networks of skid trails converging to and terminating at the landing have the potential to concentrate runoff onto the landing. The large disturbed surface area

and potentially substantial amount of fill material associated with landings make them a potential sediment source.

- **Other** – This category encompasses other potential sediment sources associated with land use on TPZ lands. Examples of this include erosion from grazing and from off-highway vehicle use.

Sites selected from this list had to have undergone at least one year of overwintering, so that sites would be subject to erosion processes associated with stressing winter storms.

Since the likelihood of sediment delivery strongly depends on the location of the erosion source relative to surface waters of the State, we focused on assessing potential sediment sources closest to watercourses, and those associated with watercourses with the highest potential of linkage to beneficial uses[8]. In a Forest Practice setting, a natural watercourse is generally classified according to its relation to beneficial uses and this guided our site selection process. Table 3 explains this watercourse classification, its linkage to beneficial uses and its relative priority in the site selection process.

Given these criteria, the Task Force placed the highest priority on sampling non-randomly-chosen clearcut harvest units, road crossings, road segments, and landings with potential linkage to Class I watercourses. The next highest priority was to assess potential sediment sources adjacent to Class II and III watercourses.

Further, because a 100-percent sample was not feasible given the time allotted for the rapid field assessment, the Task Force also prioritized the above sites using the following additional criteria:

- Time since operation – Indicators of sediment delivery are most visible immediately following sediment delivery. Recently-operated sites with at least one year of overwintering were given highest priority;
- Logging system[9] – Tractor-logged units were prioritized higher than cable-yarded units due to tractor-logging's higher potential for soil compaction and drainage modification;

[8] Beneficial uses of California's waters include ". . . domestic; municipal; agricultural and industrial supply; power generation; recreation; aesthetic enjoyment; navigation; and preservation and enhancement of fish, wildlife, and other aquatic resources or preserves" Water Code Section 13050(f) (CVRWQCB, 2009, p. II-1.00).

[9] Logging system = yarding system = means by which logs are moved from the stump to the landing where the logs are loaded on to trucks for transport. Tractor-logging uses ground-based equipment to drag the logs or one end of the logs across the ground to the landing. In the process, the weight of the equipment tends to compact the underlying soil. Cable-yarding moves the logs using cables that may, depending upon the cable system, (a) drag the log or one end of the log along the ground as it is moved or, less commonly (b) fully suspend the log above the ground as it is moved to the landing. Cable logging does not have the same potential to compact the soil as tractor logging.

Table 3. California FPRs watercourse classification, beneficial uses, and relative priority for assessment.

Watercourse Classification	Beneficial Use or Key Characteristic	Relative Priority for Assessment Based on Linkage to Downstream Salmonid Waters
Class I	1) Fish always or seasonally present; 2) Domestic water supply on site or within 100 feet of timber harvest.	**High –** Potential for direct observable sedimentary impacts to resident fish and/or salmonid fish habitat.
Class II	1) Fish always or seasonally present offsite within 1000 feet downstream; 2) Aquatic habitat available for nonfish aquatic species;	**Moderate –** Potential for sedimentary impacts to translate or disperse downstream to fish habitat. Fine sediment can be readily delivered to downstream salmon habitat. Coarse sediment has low/moderate linkage to downstream fish habitat.
Class III	No aquatic life present, but watercourse shows evidence of being capable of sediment transport to Class I and II waters under normal high water flow conditions.	**Moderate –** Potential for sedimentary impacts to translate or disperse downstream to fish habitat. Fine sediment can be readily delivered to downstream salmon habitat when watercourses are flowing. Coarse sediment has low/moderate linkage to downstream fish habitat.
Class IV	Man-made watercourses, usually downstream, established domestic, agricultural, hydroelectric supply, or other beneficial use.	**Low** – Potential for sedimentary impacts to translate or disperse downstream to fish habitat is low. Fine sediment can possibly be delivered to downstream salmon habitat when watercourses are flowing. Coarse sediment has low linkage to downstream fish habitat.

- Steeper slopes – Sites on steeper slopes were given higher priority than those on gentle slopes;
- Erodible soils – Soils derived from rhyolite were given higher priority due to their higher apparent erosion potential.

By following this prioritization scheme, the Task Force concentrated on sites assumed to have the highest risk of delivering sediment to waters of the State.

Using the above-described criteria, the Task Force selected potential assessment sites on Tuesday, September 13, 2011. The potential assessment sites were recorded on maps and lists that were used during the ensuing rapid field assessment to prioritize and plan each day's field work. Figures used to help scope the field investigations and select potential assessment sites are compiled in Appendix B.

4.2. Methodology

A rapid-assessment methodology was created to capture the relative impacts to water quality by logging operations (skid trails, clearcut harvest units, and landings) and associated infrastructure (roads and watercourse crossings). The method is implemented in a step-wise format by prompting field personnel to: 1) identify if sediment was delivered to a watercourse, then, only if sediment appeared to have been delivered, 2) evaluate the relative magnitude of sediment delivered to the watercourse; 3) identify the type of erosion that delivered as surface erosion, fluvial erosion, mass wasting, or other; and 3) describe the erosion source as being clearcut units, watercourse crossings, tractor crossings, roads, landings, or other. The method also includes determining if any regulations were violated - such regulations include the Forest Practice Rules, the State Fish and Game Code, and the Porter-Cologne Water Quality Control Act.

A critical part of the methodology was determining the relative magnitude of sediment delivery to waters of the state. This involved estimating sediment volume in cubic yards (yd^3) from observed erosion features. The sediment volume was estimated by relating the erosion void to a simple geometric shape (e.g., wedge, rectangle, etc). The estimated sediment volume was then transformed into a relative estimate of sediment delivery using the following criteria:

- Low – Less than 1 cubic yard;
- Moderate – One to 10 cubic yards; and
- High – Greater than 10 cubic yards.

Field inventory datasheets were developed specifically for the work completed to assist field personnel in collecting the required information for each type of sediment delivery site encountered. The benefits of using the datasheets include: 1) prompting field personnel to evaluate key conditions in the field and record the necessary data, 2) providing consistence in the data collected, 3) providing the added security of a hard copy of the data that can be later converted into digital form, such as in a spreadsheet or database, that could be queried, 4) and allowing the flexibility to gather field sketches and other non-database type information. Information from the datasheets were entered into a spreadsheet. If information was missing from the datasheet, the additional information was gathered, when feasible, through the GIS and/or through consultation with Task Force members. Appendix F provides a copy of a blank data sheet and an example of a completed one. Appendix G provides copies of all data sheets that were filled out to record field conditions at assessment sites during the rapid field assessment.

5.0. Results

5.1. General Results

The Battle Creek Task Force performed five days of field assessments over the period spanning from 14 September, 2011 through 22 September, 2011. The Task Force split into two assessment teams based on the county where timber harvest activities occurred (Tehama and Shasta County teams). This was done to take advantage of the local knowledge of the CAL FIRE Forest-Practice inspectors, whose areas of responsibility are typically separated by county boundaries.

Altogether the two assessment teams surveyed 135 sites (Figure 9). Of these sites:

- 58 were clearcut harvest units or functional equivalents of clearcut units[1];
- 6 were landings;
- 39 were road crossings of watercourses;
- 5 were tractor-watercourse crossings;
- 24 were watercourse-adjacent road segments; and
- 3 sites were classified as “other” sediment sources.

In total:

- 43 percent of the sites were associated with Class I watercourses,
- 14 percent of the sites were associated with Class II watercourses, and
- 40 percent were associated with Class III watercourses.

Two of the sites were associated with unchanneled swales that displayed no evidence of recently flowing water and/or sediment, but were still classified as watercourses. These two sites were included in further analyses, since swales can be subject to periodic overland flow which can deliver sediment to downstream watercourses.

Three of the 58 clearcut harvest units (sites SU072-1, 2, and 3) were shown to be adjacent to watercourses on the THP maps, but no watercourses or swales were found adjacent to the harvest units by the Task Force. These three sites were subsequently removed from further analyses, leaving 55 assessed clearcut units and 132 total assessed sites associated with watercourses and swales.

Of the 132 sites associated with watercourses and swales:

- Thirty-nine percent (39%; n=51) delivered sediment to waters of the state. For two sites, the assessment team could not definitively assess whether

[1] For example, one of the clearcut harvest units was identified as an alternative prescription harvest unit. However, because essentially the entire canopy was removed during harvest, the assessment team determined that the unit was functionally equivalent to a clearcut and included it in the analysis as a clearcut.

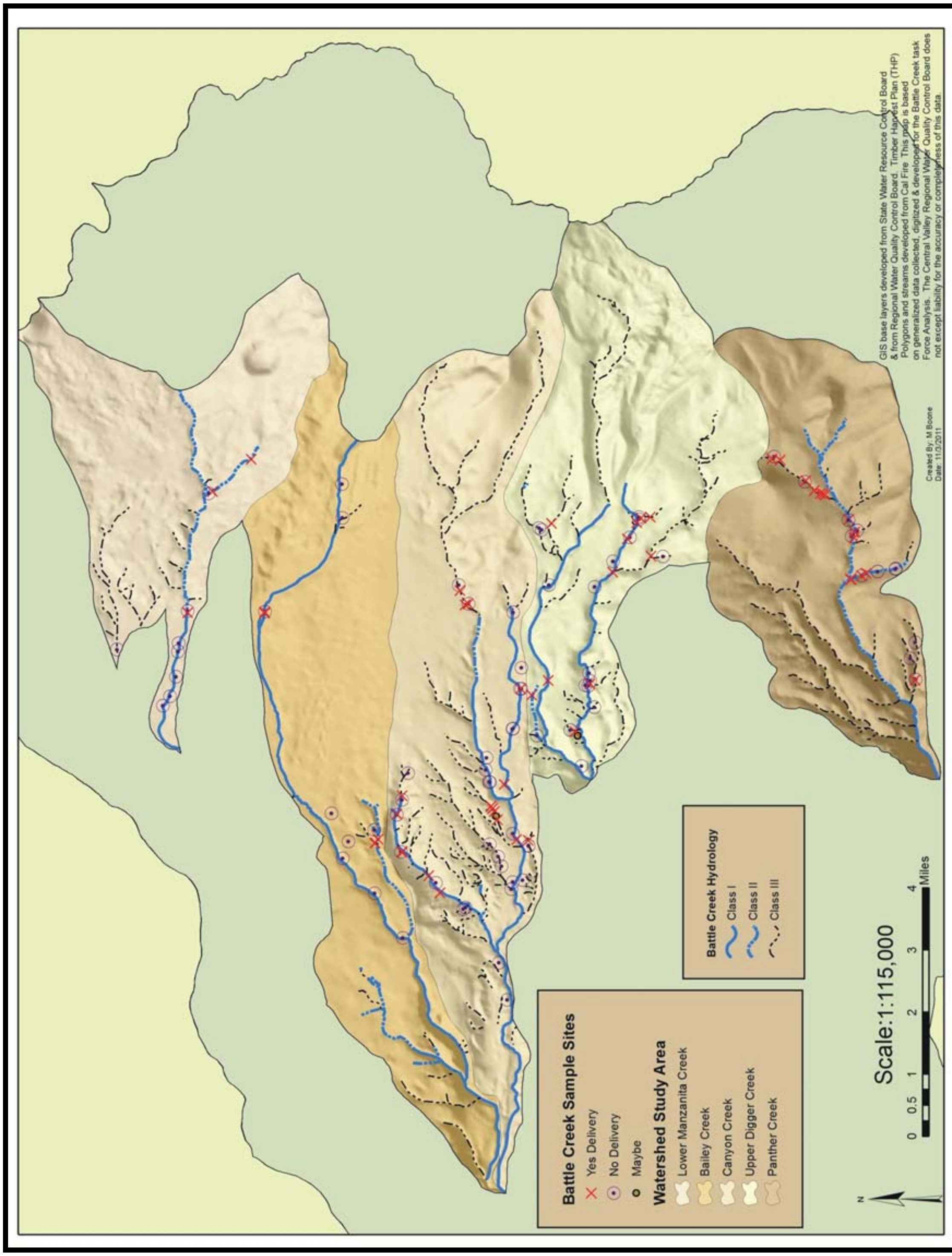


Figure 9. Location of assessment sites by planning watershed.

sediment delivery occurred or not, and these sites were labeled as "maybe" delivering sediment. "Maybe" sites were treated conservatively as sites with sediment delivery in subsequent analyses, resulting in 40 percent of the assessed sites delivering sediment to waters of the state (n=53);

- Only one (1) of the 55 harvest units (i.e., < 2%) was determined to have delivered sediment (Figures 10 and 11);
- Sixty-nine percent (69%) of road crossings delivered sediment (Figure 11);
- Sixty-seven percent (67%) of watercourse-adjacent road segments delivered sediment (Figure 11);
- All 5 tractor crossings (100%) displayed evidence of sediment delivery (Figures 10 and 11);
- Only one (1) of the six landings (17%) delivered sediment (Figure 10).

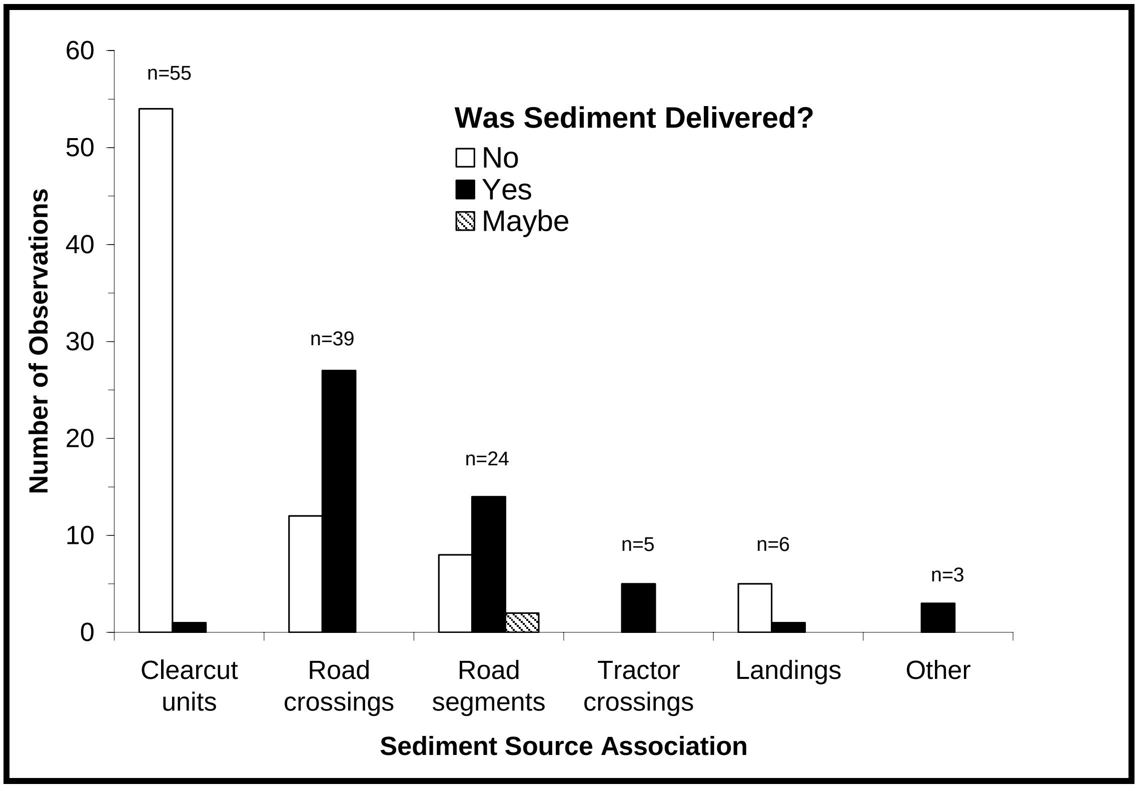


Figure 10. Number of observations of sediment delivery by sediment source association.

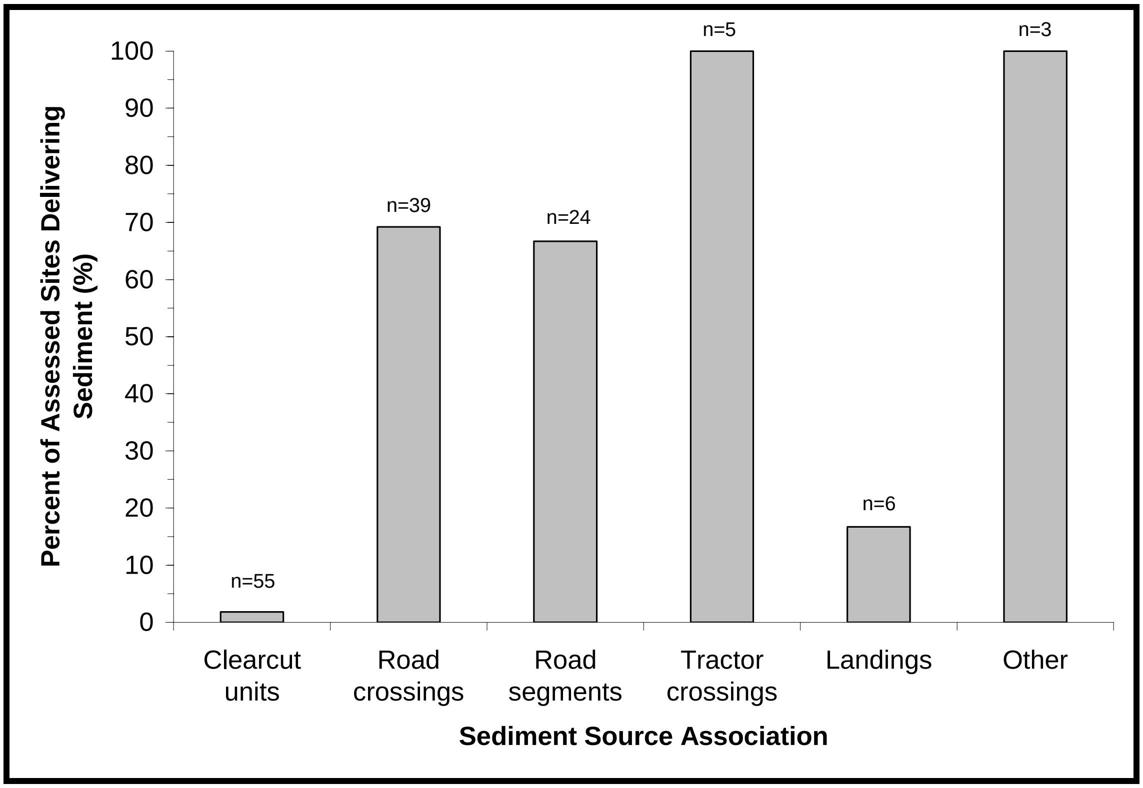


Figure 11. Percentage of sites delivering sediment by sediment source association.

For purposes of data presentation and discussion in this report, the magnitude of observed delivered sediment is divided into three categories: (1) **Low** (less than 1 cubic yard), (2) **Moderate** (1 to 10 cubic yards), and (3) **High** (more than 10 cubic yards).

The magnitude of observed sediment delivery was found to vary by sediment source (Figure 12):

- Of the 55 assessed clearcut units, 1 (1.8%) displayed evidence of sediment delivery; the magnitude of sediment delivery from this site was estimated to be low;
- Of the 39 assessed road crossings of watercourses, 12 (31%) displayed no evidence of sediment delivery, 16 (41%) displayed evidence of low magnitudes of sediment delivery, and 10 (28 %) displayed evidence of moderate magnitudes of sediment delivery;
- Of the 24 assessed watercourse-adjacent road segments, 8 (33%) displayed no evidence of sediment delivery, 3 (13%) showed low magnitudes of sediment delivery, 11 (46%) showed moderate magnitudes of sediment delivery, 2 (8%) delivered high magnitudes of sediment to waters of the state;

- Of the 5 assessed tractor crossings of watercourses, 4 (80%) delivered a low magnitude of sediment, while 1 (20%) showed evidence of delivering a moderate magnitude of sediment;
- Of the 6 assessed landings, 1 (17%) showed signs of sediment delivery, and the magnitude of delivered sediment was low.

The distribution of observed sediment delivery to types of watercourses was found to vary as follows (Figures 13 and 14):

- Class III watercourses constituted the highest proportion of sediment-delivery sites (56%). Of the Class-III sediment-delivery sites,
    - o Road crossings constituted almost half (48%),
    - o Road segments accounted for 30 percent, and
    - o Tractor crossings accounted for 15 percent, respectively (Figure 14).
- Class I watercourses made up the next highest proportion of sediment-delivery sites (29%; n=14), and sediment delivered to these watercourses was associated solely with road crossings and watercourse-adjacent road segments.
- Class II watercourses constituted only 13 percent of the sediment delivery-sites – these sites occurred primarily in association with road crossings and road segments (Figures 13 and 14).
- Unclassified swales constituted only 2 percent of sediment-delivery sites.

The magnitude of sediment delivery to Class I sediment-delivery sites was estimated as low (<1 cy) (i.e., 56 percent) to moderate (1 to <10 cy) (i.e., 44 percent).

Although the absolute numbers of documented sediment delivery to Class II watercourses were low (n=6), 3 (50%) of the Class II sites had moderate magnitudes of sediment delivery, with 2 (33%) and 1 (17%) having low and high magnitudes of sediment delivery, respectively.

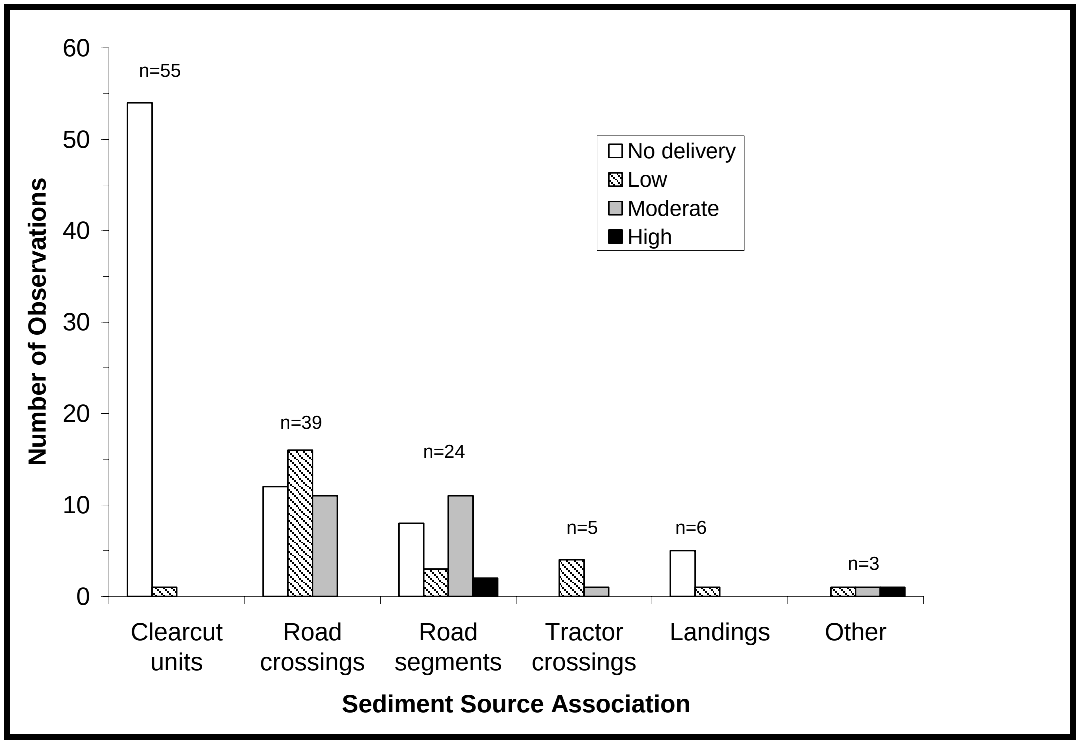


Figure 12. Magnitude of sediment delivery by sediment source association.

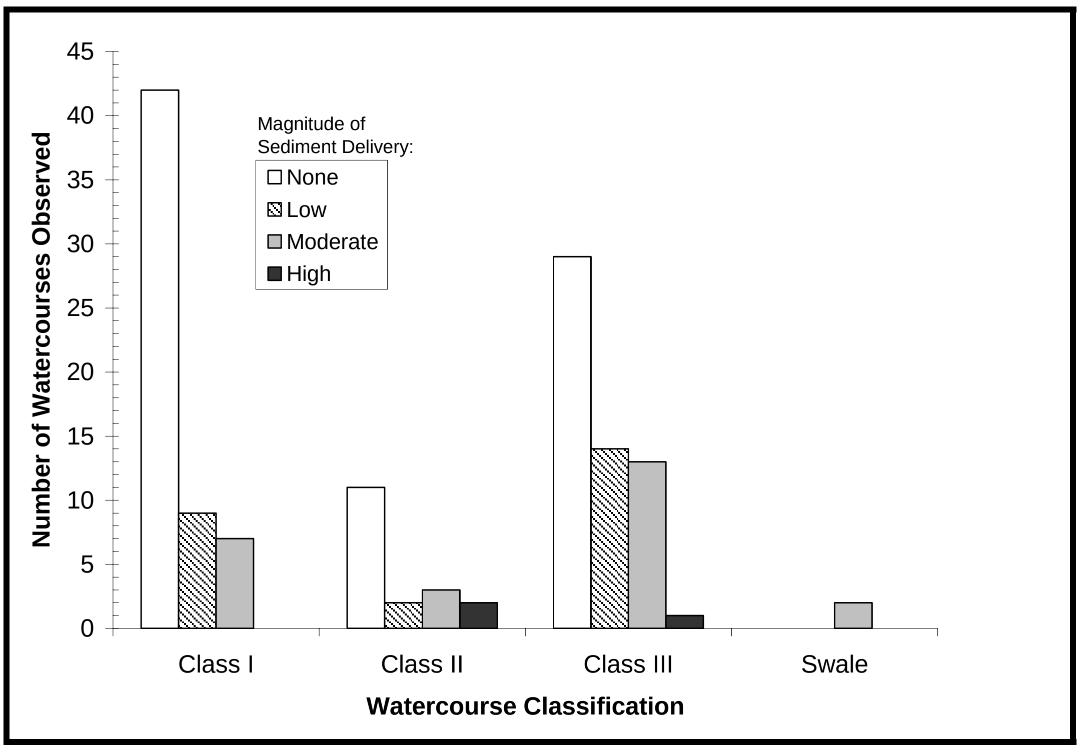


Figure 13. Magnitude of sediment delivery by watercourse classification.

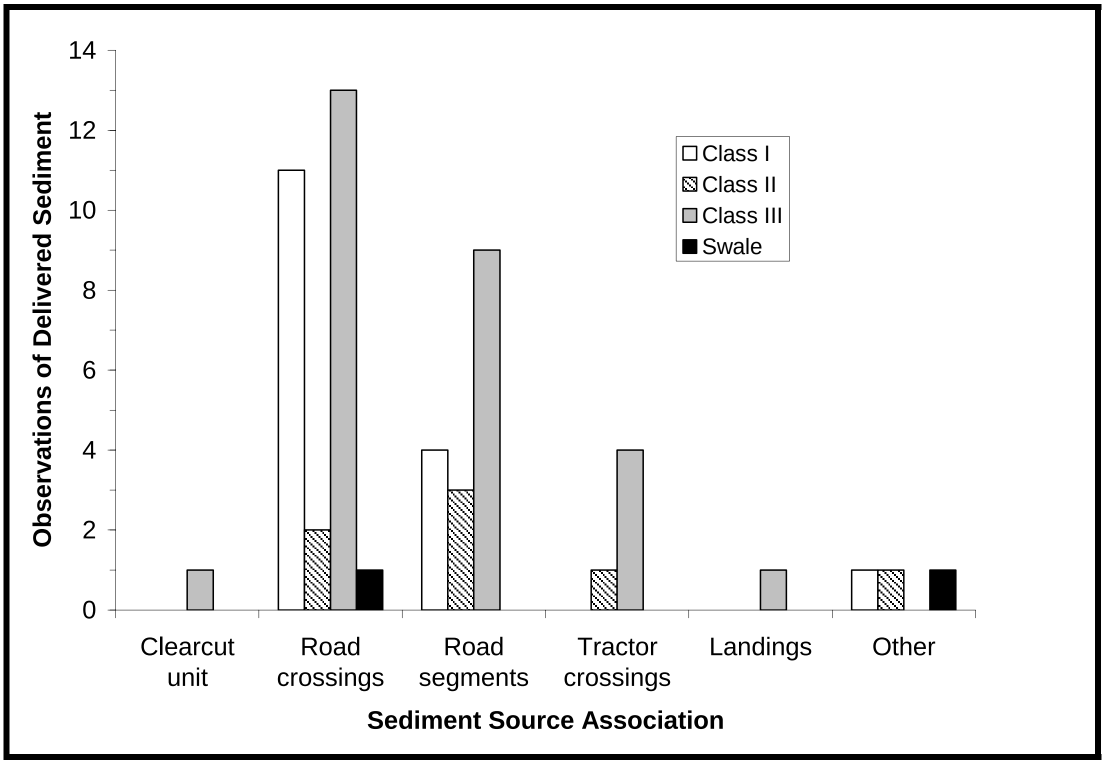


Figure 14. Sediment delivery to Class I, II, and III watercourses by sediment source association.

5.2. Clearcut Harvest Units

Overall, there were 405 clearcut units from the 15 THPs in the assessment area (Figure 15). Of the 405 units, 140 were adjacent to Class I, II, or III watercourses. The Task Force assessed 39 percent of the units with riparian buffers. The 55 units assessed by the Task Force accounted for 16.1 miles, or 47 percent of the 34.4 miles of operated riparian buffer length in the assessment area (Table 4). Approximately, 6.8 miles or 88 percent of the Class I buffers were assessed. Thirty-three (33) percent and 35 percent of the operated riparian buffers were assessed for Class II and Class III watercourses, respectively. Out of the entire 16.1 miles assessed, only one instance of sediment delivery was observed to be associated with a clearcut unit.

Table 4. Summary table of the total operated riparian buffer length adjacent to clearcuts versus the assessed operated buffer length adjacent to clearcuts for the five planning watersheds.

Watercourse Classification	Total Length of Operated Buffer (miles)	Total Length of Assessed Buffer (miles)	Percent Assessed
Class I:	7.7	6.8	88
Class II:	5.1	1.7	33
Class III:	21.6	7.6	35
Total:	34.4	16.1	47

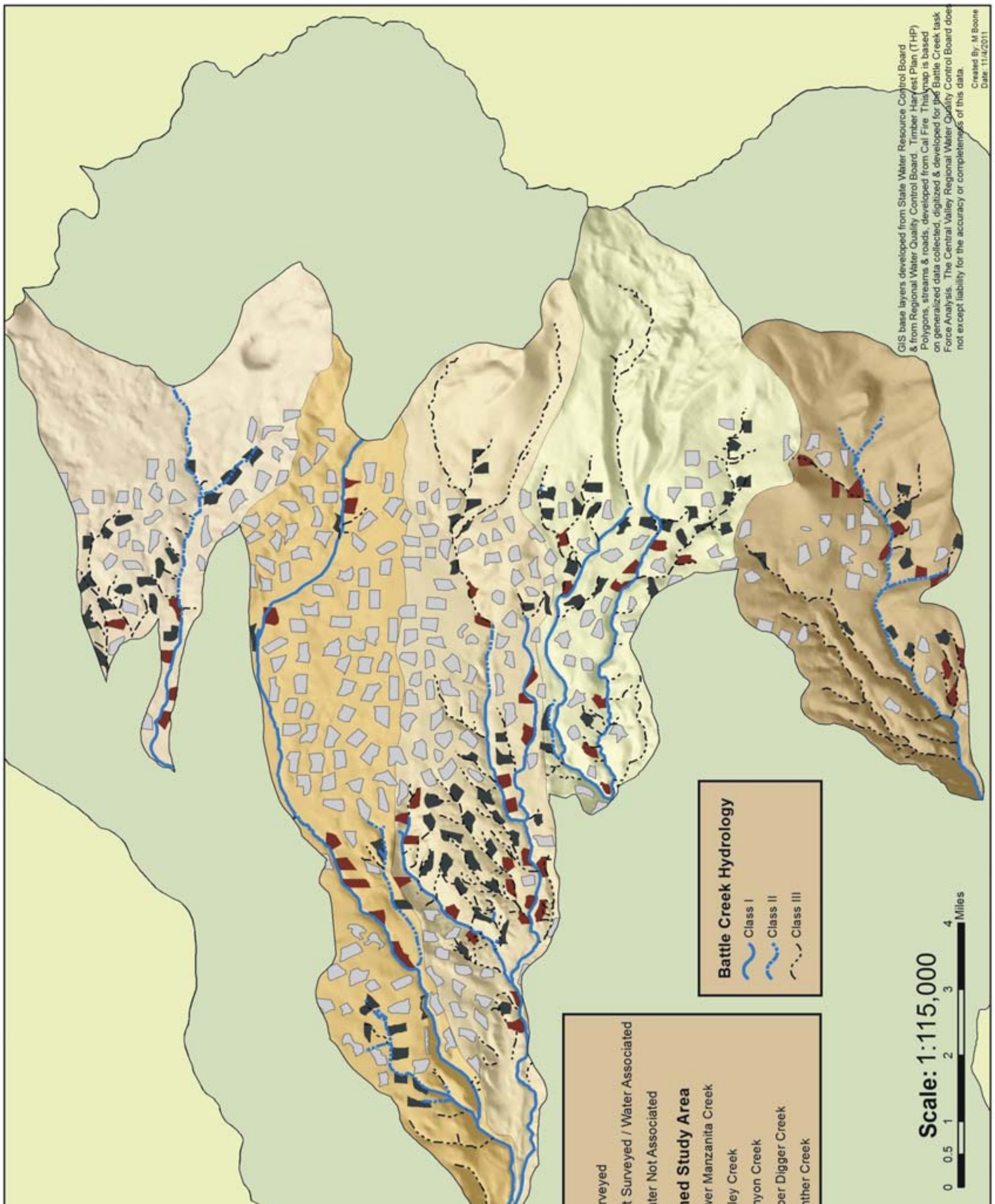


Figure 15. Total clearcut harvest units within the assessment area. Red shading indicates surveyed units, green shading indicates non-surveyed units, and the gray shading indicates units not adjacent to watercourses.

The single case of sediment delivery associated with a clearcut unit was resulted from encroachment of a tractor into the equipment limitation zone (ELZ) of a Class III watercourse, and was not a result of erosion generated within the unit. The tractor entered the ELZ and constructed a waterbar/berm within 15 feet of a Class III watercourse (Figure 16). Substantially less than a cubic yard of soil (i.e., less than 1 cubic foot of sediment) from the waterbar/berm deposited within the high water mark of the Class III. Although the encroachment of the tractor into the ELZ constitutes a violation of the Forest Practice Rules, the violation was not identified during previous inspections.

Figure 16. A clearcut harvest-unit site where sediment was observed to deliver to waters of the state. The tractor encroached within the equipment limitation zone (ELZ) and constructed a waterbar/berm. A small volume of soil from the waterbar/berm deposited within the high water mark of the Class III watercourse.

5.3. Road Crossings

The Battle Creek Task Force assessed 39 road crossings of watercourses, or approximately 12 percent of the 328 road crossings identified in the assessment area by GIS methods. The 39 assessed road crossings consisted of 18 culverted crossings, 13 dips/fords, 5 bridges, and 3 pulled crossings (where the crossing and the crossing fill have been removed). Twenty (51%) of the crossings were on SPI-managed roads behind locked gates, 6 (15%) were on ungated SPI-managed roads and therefore accessible to the public, and 12 (31%) on county-managed roads. Of the 39 crossings, 27 (69%) delivered sediment to watercourses.

All 5 (100%) of the bridge crossings delivered sediment to watercourses. Sediment delivery from 3 of the 5 bridges was associated with sheetwash from the crossing approaches, whereas the remaining two bridges delivered sediment derived from bank failure. Sediment delivery from the bridge approaches was chronic in nature, while sediment delivery associated with bank failure was episodic in nature. The magnitude of sediment delivery associated with bridges was determined to be low for 3 of the sites and moderate for the remaining 2 sites.

All 3 (100%) of the pulled crossings (sites where the crossing and associated crossing fill was removed and the crossing abandoned) delivered sediment to the watercourse. Sediment delivery from the 3 pulled crossings was due to post-abandonment bank erosion (n=3) and some associated sheetwash erosion of the pulled-back watercourse banks (n=1). The magnitude of sediment delivery was moderate for 2 of the pulled crossings and low for the other.

Eleven (11) of the 14 dipped or ford crossings (79%) delivered sediment to watercourses. Sediment delivery at 10 of the 11 dips/fords was associated with chronic sheetwash from the crossing approaches. The average combined length of the 2 approaches leading to each of the dip/ford crossings with sediment delivery was approximately 200 feet. For 2 of the 11 dips/fords, the delivered sediment was derived from gullies eroded into the road surface where the watercourse crossed the road. The magnitude of sediment delivery from dips/fords was low for 8 of the sites, and moderate for 3 of the sites.

Sediment was delivered to watercourses at 9 of the 18 culverted crossings (50%). The 9 crossings that did not deliver sediment all had rocked approaches. Of the 9 culverted crossings where sediment delivery occurred, 8 delivered sediment associated with chronic sheetwash and rilling of the crossing approaches, and 2 delivered sediment associated with crossing-related bank failure and erosion of the crossing fill. The average combined length of the 9 culverted-crossing approaches with sediment delivery was 400 feet. The magnitude of sediment delivery was low for 5 of the culverted crossings and moderate for 4 of the culverted crossings.

Seven (7) of the 11 road crossings with a moderate magnitude of sediment delivery were on roads that were accessible to the public (county roads and ungated SPI-managed roads with public access) (Figure 17). Altogether, 37 percent of road crossings subject to public access had moderate magnitudes of sediment delivery. Four of the 20 crossings (20%) on SPI-managed roads had moderate magnitudes of sediment delivery. However, 2 of the 4 sites with a moderate magnitude of sediment delivery were associated with pulled crossings on a Class I and II watercourse, respectively.

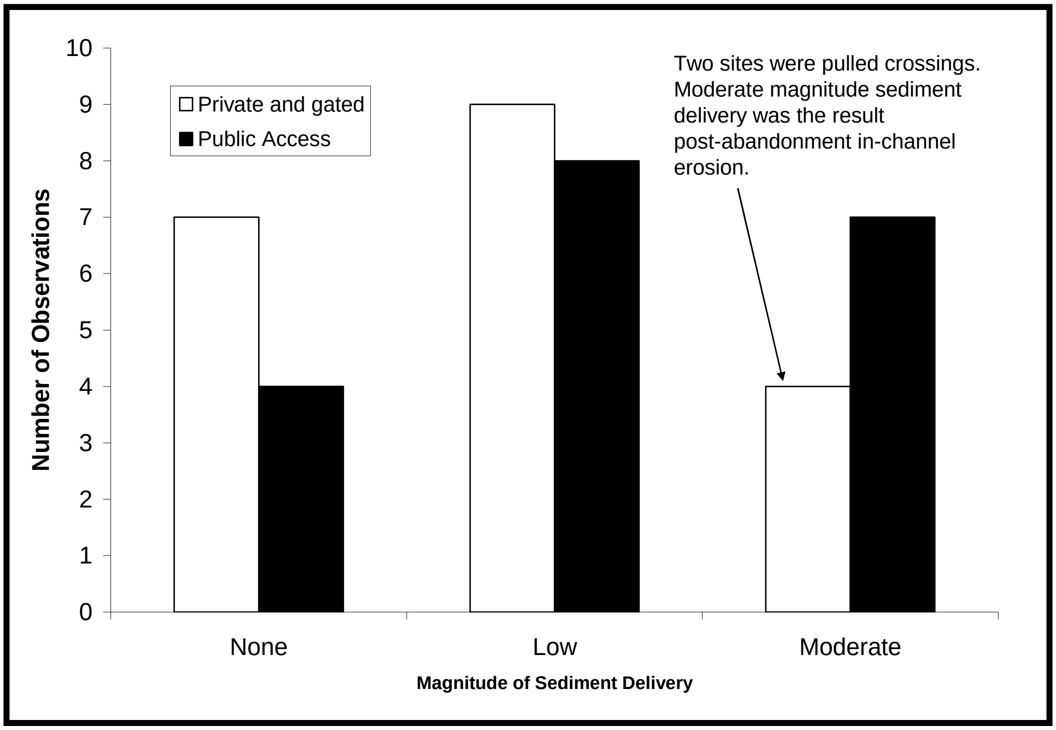


Figure 17. Magnitude of sediment delivery for road crossings by road ownership and use designation. Private and gated refers to crossings on SPI-managed roads that are behind locked gates. Public access refers to crossings on roads managed by the county or ungated SPI-managed roads that are accessible to the public.

5.4. Watercourse-Adjacent Road Segments

Sixteen (16) of the 24 watercourse-adjacent road segments assessed by the Task Force (67%) exhibited evidence of sediment delivery to waters of the state. Sediment delivery at 15 of the 16 sites these sites was associated with sheetwash and/or rilling. One (1) of these 15 road segments also exhibited gully erosion below a waterbreak outlet from road drainage that had combined with an intercepted and rerouted Class III watercourse (Figure 18). One (1) road segment delivered sediment from failure of the road fillslope. The fillslope appeared to have failed from oversteepening by bank erosion from the adjacent Class II watercourse.

The magnitude of sediment delivery for watercourse-adjacent road segments was low for 3 road segments, moderate for 11 road segments, and high for 2 road segments. The two sites with a high magnitude of sediment delivery were associated with a road fillslope failure (Figure 19) and with a road segment that was directly adjacent to a Class III watercourse for approximately one-quarter of

Figure 18. Gully erosion below a road segment. Runoff from a long length of undrained road combined with an intercepted Class III watercourse to initiate a gully below the road. The gully eventually delivered to a Class III watercourse.

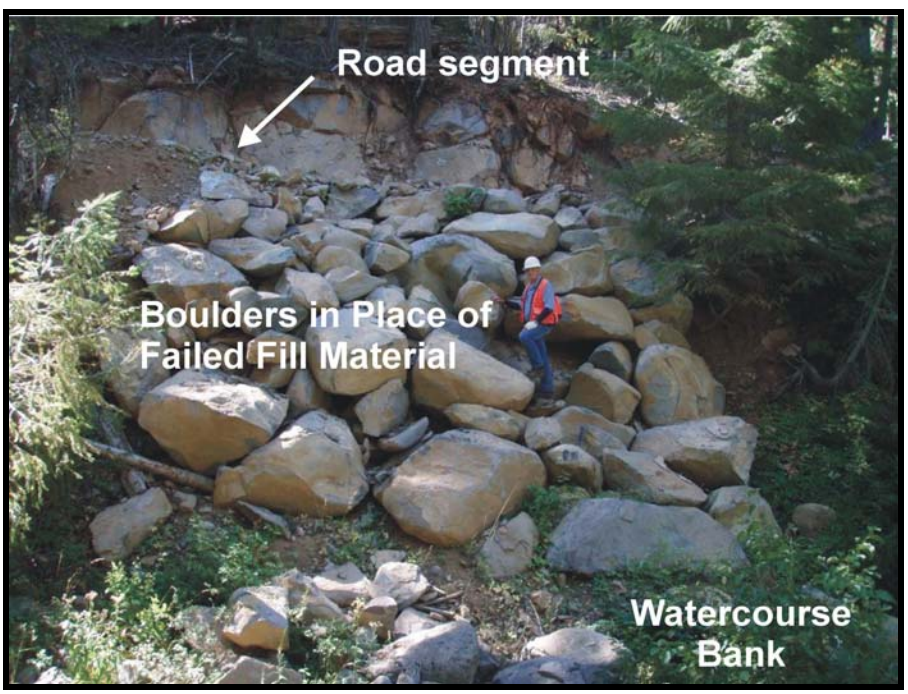


Figure 19. A watercourse-adjacent road segment that delivered a high magnitude of sediment to a Class II watercourse. The road fillslope appeared to have been undermined by bank erosion and the failed fill material delivered to the adjacent watercourse via landsliding. Large boulders have been placed in the slide scar to support the road and prevent further erosion and sliding.

a mile (Figure 20). The road fillslope failure was not associated with recent harvest activity. However, the road segment adjacent to the Class III was subject to a Forest Practice Rules violation and civil penalty in 2006.

Seventy percent (70%) of the watercourse-adjacent road segments were on SPI-managed roads that were behind locked gates (n=17). The remaining 30 percent of road segments were either on county roads (n=6), or were on SPI-managed roads with public access (n=1). The majority (10 of 13) of watercourse-adjacent road segments with moderate and high magnitudes of sediment delivery were on SPI-managed roads that were behind locked gates (Figure 14).

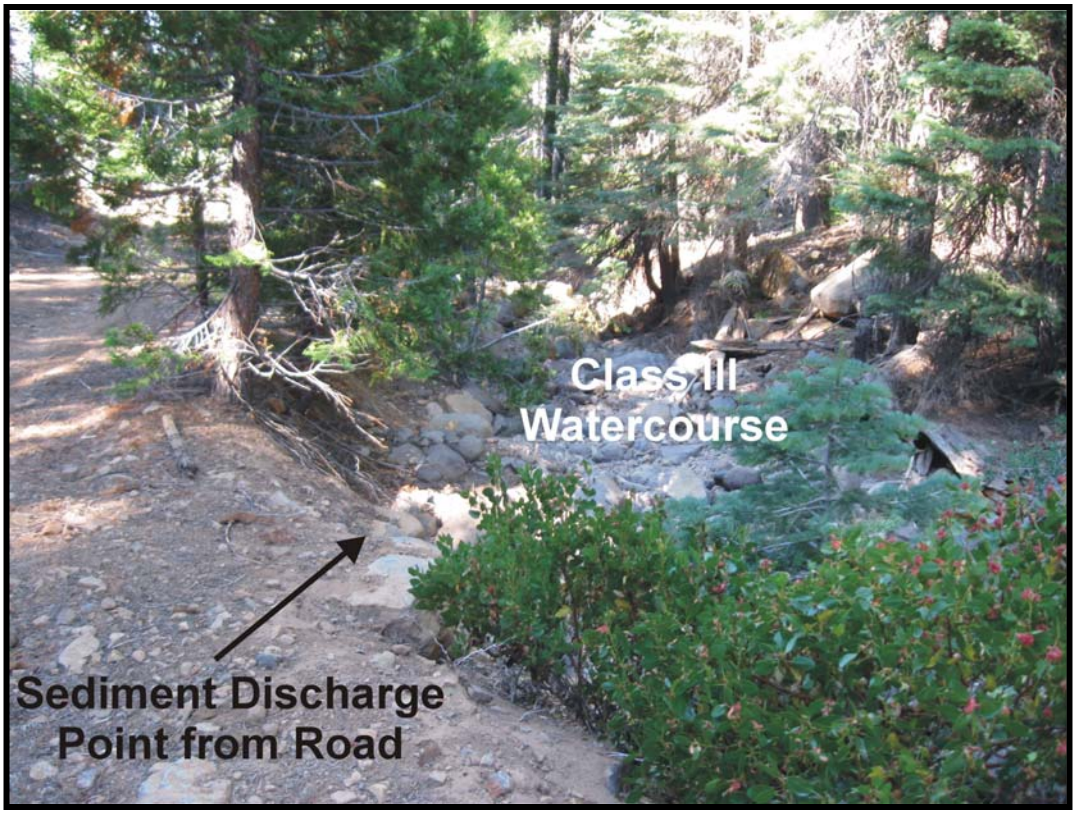


Figure 20. A road segment directly adjacent to a Class III watercourse. Sediment delivery is difficult to mitigate here because of the lack of buffer strip between the road and watercourse. This road segment was subject to a violation and civil penalty in 2006.

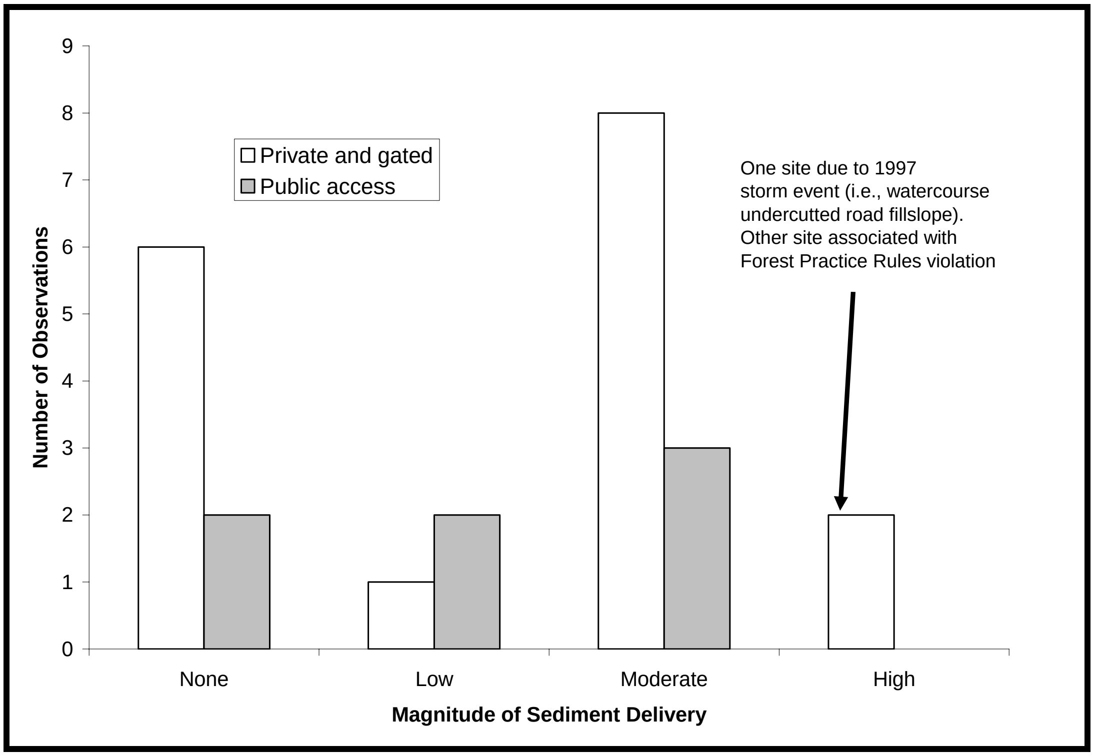


Figure 21. Magnitude of sediment delivery for watercourse-adjacent road segments by road ownership and use designation.

5.5. Tractor Crossings and Landings

All 5 of the tractor crossings assessed by the Task Force showed evidence of sediment delivery. Four (4) of the crossings (80%) were on Class III watercourses and 1 (20%) was on a Class II watercourse. All 5 of the tractor crossings showed evidence of in-channel erosion of the residual fill material left behind in the watercourse after the crossing was abandoned. Four (4) of the 5 crossings (80%) displayed low magnitudes of sediment delivery, while 1 (20%) showed evidence of moderate-magnitude inputs of sediment to a Class III watercourse. The tractor crossing with the highest magnitude of sediment delivery had crossing approaches that appeared to be untreated with mulch or slash (Figure 22). Despite the fact the watercourse was a Class III, the active width of the watercourse was 10-12 wide and 2-3 feet deep. The relatively large dimensions of the channel and coarse-grained substrate meant that more residual fill material was left behind in the relatively large crossing area after crossing removal.

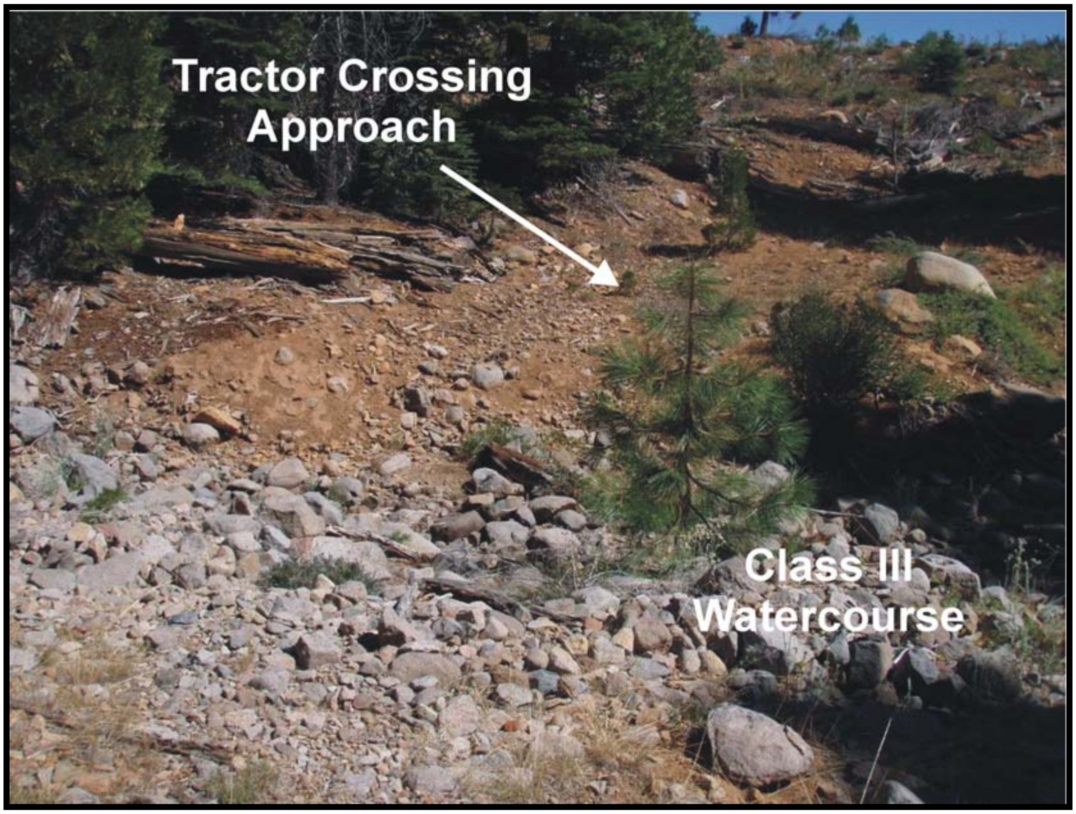


Figure 22. Pulled tractor crossing on a large Class III watercourse. The crossing delivered a moderate magnitude of sediment.

Only 1 of the 6 landings (17%) assessed by the Task Force delivered sediment to waters of the state. All 6 assessed landings were within WLPZs or ELZs. The 5 landings showing no evidence of sediment delivery were associated with relatively recent THPs, while the one site associated with sediment delivery was an older landing not associated with a recent THP. The older landing contributed a low magnitude of sediment delivery to a Class III watercourse.

6.0. Discussion

Results from the assessment indicate that observable sediment delivery within the assessed portion of the watershed is primarily derived from road crossings and road segments located directly adjacent to watercourses. Only one of the 55 assessed clearcut harvest units (less than 2 percent) displayed evidence of observable sediment delivery to waters of the state – the sediment delivery resulted from a tractor pushing soil into the watercourse buffer zone and not from erosion of soil from the harvest unit. In contrast, observable sediment delivery to waters of the state occurred 67 to 69 percent of the time for assessed road crossings and watercourse-adjacent road segments. Although the small quantity of assessed tractor watercourse crossings and watercourse-adjacent landings limit the robustness of the following conclusions, the assessment findings suggest that all tractor crossings deliver at least a low magnitude of sediment delivery, and that watercourse-adjacent landings associated with recent SPI THPs have a low likelihood of delivering sediment.

6.1 Sediment Delivery from Clearcut Harvest Units

The low level of sediment delivery from clearcut harvest units is attributed to two factors: (1) by the physical characteristics within and immediately adjacent to the clearcut units; and (2) the relatively low stream density in the assessment area.

The observed lack of large-scale erosion on clearcut harvest units deemed by the Task Force as having a high potential risk for sediment delivery can be attributed to a variety of physical characteristics within and immediately adjacent to the clearcut units. Generally, the clearcut units had more than 50 percent surface cover[2], with many units having surface cover in excess of 75 percent (Figure 16). Surface cover protects the soil from rainfall impact, and reduces the potential for erosive runoff generated through soil-sealing (Larsen and others, 2007). Surface cover consisting of vegetation and logging slash also provides surface roughness that increases infiltration, slows down runoff, and increases the likelihood of sediment deposition (Croke and Hairsine, 2006). Although some erosion features were observed on skid trails, waterbars were observed to be effective in discharging sediment-laden runoff off of the skid trails onto less-compacted portions of the harvest unit. Runoff discharged onto uncompacted and hydraulically rough portions of the units appeared to infiltrate rapidly, resulting in sediment deposition just below the waterbreak outlet.

The practice of contour ripping[3] commonly seen on many of the units was also effective in preventing erosion from leaving the clearcut units. Contour ripping reduces soil compaction from skidding activities and disrupts the continuity of skid-trail networks, thereby increasing infiltration and reducing the potential for generating and concentrating erosive runoff. Contour ripping also reduces the slope length for generating runoff, and the furrows provide settling basins for sediment deposition.

Where sediment from an erosion feature was observed to leave the clearcut unit, the sediment was observed to rapidly deposit within the adjacent riparian buffer. Riparian buffers generally have higher infiltration rates and denser surface cover than the harvested clearcut units. Hence, runoff quickly infiltrates and sediment is rapidly deposited on the forest floor in the buffer zone. In general, the Task Force found the Forest-Practice-Rules-mandated buffer zones for Class I, II, III watercourses to be sufficient to filter observable sediment from the clearcut units. The minimum buffer zones implemented in the assessment area were 25 feet wide for Class III watercourses on relatively gentle slopes (<30% slope), and the Task Force found no evidence of sediment from the clearcut units traveling

[2] Surface cover is the percent of the ground covered by live vegetation, litter, rock, ash, or wood.
[3] Contour ripping is the tilling of soil by a tractor equipped with a winged subsoiler. The ripping is done on contour to prevent the concentration of runoff and facilitate infiltration.

through the riparian buffers in excess of this distance. Members of the Task Force did see one instance where rill-derived sediment traveled approximately 20 feet into the riparian buffer.

Figure 23. The interface between a clearcut harvest unit and a riparian buffer zone for a Class I watercourse in the assessment area. Surface cover and hydraulic roughness provided by dense surface cover limits runoff generation and erosion within the unit. If sediment leaves the unit, runoff is dispersed and sediment is quickly deposited within the riparian buffer.

The lack of sediment delivery from clearcut harvest units is consistent with the results of other studies done in Mediterranean climates. Litschert and MacDonald (2009) assessed 200 harvest units on National Forestland in the Sierra Nevada and southern Cascades, and walked approximately 180 miles of riparian buffer zone looking for evidence of sediment delivery from timber harvest (i.e., selection, thinning, and clearcuts). Despite this relatively large sample size, they only found 6 erosion features that delivered to watercourses. In southeastern Australia, Croke and others (1999) found that sediment from skid trails rarely traveled more than 16 feet once sediment-laden discharge was routed onto areas with dense surface cover and hydraulically rough surfaces. Another study in southeastern Australia (Lacey, 2000) found that 33-foot-wide stream buffers were effective in trapping almost 100 percent of the sediment generated by timber harvest.

Altogether, the observations indicate that the suite of BMPs used in association with clearcut harvest units are effective in preventing sediment delivery via overland flowpaths within the assessment area. On unit practices such as the waterbarring of skid trails, the maintenance of high surface cover and surface roughness, and contour ripping serve to minimize erosion and/or the travel distance of sediment on site. In the rare instances that sediment leaves the units, the eroded material is quickly deposited within the dense surface cover of the riparian zone. These observations are consistent with the recently-published studies regarding overland sediment delivery from timber-harvest units.

The majority of the clearcuts in the assessment area have a very low likelihood of delivering sediment to waters of the state due to the relatively low stream density in the assessment area. Stream density is the total length of streams within a given area. Low stream density means there will be low stream length per unit area and therefore less opportunity for potential linkage of timber-harvest units to the streams. Of the 396 clearcut units in the assessment area, 63 percent had no association with Class I, II, and/or III watercourses (Figure 15). For these clearcut units, eroded sediment must travel long distances (miles in some cases) to result in a water-quality impact. The Task Force rarely observed sediment from a clearcut traveling more than 20 feet, and these sites were typically associated with runoff from skid trails.

6.2. Sediment Delivery from Road Crossings and Watercourse-Adjacent Road Segments

The watercourse-adjacent road segments and road crossings identified as having a high risk of water-quality impacts delivered sediment to watercourses 67 to 69 percent of the time, respectively. While the assessment was not intended to provide a sediment-budget estimate on sediment delivery from road crossings and road segments, the results suggest that roads are one of the larger human-caused sediment sources in the assessment area. To provide perspective on the possible water quality impacts due to roads, Table 5 provides an overview of the GIS-determined number of watercourse crossings and length of watercourse-adjacent road in the assessment area.

Most of the sediment delivery at road crossings of watercourses was found to be associated with a lack of observable best-management-practice (BMP) implementation on the road approaches to the crossings. Some effective BMPs at road crossings include hydrologically disconnecting the road approaches so that the length of road draining to the watercourse is minimized, and surfacing the remaining connected road approaches with non-erodible materials. Road crossings on gated SPI-managed roads generally employed these types of BMPs, and as a result 80 percent of the SPI road watercourse crossings had no sediment delivery or a low magnitude of sediment delivery. Approaches draining to watercourse crossings on county-managed roads were almost twice as long on the average as those on SPI-managed roads (370 feet versus 190 feet). Because of the longer hydrologically-connected approaches, the magnitude of sediment delivery to crossings on county-managed roads was disproportionately larger than it was for gated SPI roads. Crossing approaches with rocked surfaces generally had a lower likelihood of delivering sediment and a lower magnitude of sediment delivery in general. The lower magnitude of sediment delivery from rocked roads is consistent with the literature that suggests that rock surfacing can reduce erosion from roads by up to an order of magnitude (Burroughs and King, 1989; Coe, 2006).

Table 5. A summary of road crossings and watercourse-adjacent road segments for the assessment area.

Planning Watershed	Watercourse Classification	Number of Road Crossings	Road Crossing Density (crossings per sq mi)	Roads Within 50' of Watercourse (miles of road)
Lower Manzanita Creek	I	8	0.5	0.5
	II	13	0.8	0.6
	III	27	1.7	1.4
	Total:	**48**	**3.1**	**2.5**
Bailey Creek	I	10	0.5	0.3
	II	15	0.7	0.8
	III	12	0.6	0.4
	IV	2	0.1	0.2
	Total:	**39**	**1.8**	**1.7**
Canyon Creek	I	23	1.0	1.2
	II	4	0.2	0.2
	III	102	4.3	4.6
	IV	1	0.0	0
	Total:	**130**	**5.4**	**6.0**
Upper Digger Creek	I	4	0.2	0.6
	II	6	0.3	0.4
	III	51	2.5	1.8
	Total:	**61**	**3.0**	**2.8**
Panther Creek	II	9	0.5	0.4
	III	41	2.4	2.0
	Total:	**50**	**2.9**	**2.4**
Assessment Area	I	45	0.5	2.6
	II	47	0.5	2.4
	III	233	2.4	10.2
	IV	3	0.0	0.2
	Total:	**328**	**3.3**	**15.4**

Watercourse-adjacent road segments were more likely to deliver sediment when they were within 30 feet of the watercourse, and road segments with moderate to high levels of sediment delivery were often within 5 to 20 feet of a watercourse. There were no observable differences in the likelihood or magnitude of sediment delivery for SPI-managed watercourse-adjacent road segments versus watercourse-adjacent road segments managed by the county. The Task Force observed that the SPI-managed road segments closest to streams (within 5 to 20 feet) were drained according to the Forest Practice Rules, but that there was insufficient sediment filtering capacity between the road and watercourse. Hence, the standard BMPs were generally insufficient for preventing sediment delivery from roads this close to the watercourse.

While the assessment did not explicitly try to assess the differences between SPI and county-managed roads, the Task Force members did observe that county roads generally had higher rates of sediment delivery than private roads. Uncontrolled traffic on roads with public access also created ruts along road surface, which concentrate runoff and increase erosion. Publicly managed roads also exhibited signs of frequent grading (for example, visible berms on outboard edge of road), and grading significantly increases erosion rates on roads (Luce and Black, 2001; Ramos-Scharron and MacDonald, 2005).

6.3. Sediment Delivery from Tractor Crossings and Landings

Although all of the assessed tractor watercourse crossings delivered sediment to associated watercourses, the magnitude of sediment delivery was generally low. Tractor watercourse crossing typically deliver a low magnitude of sediment following removal because it is very difficult to remove all of the crossing fill using mechanical means, and post-logging adjustment of the crossing and flushing of the small amount of remaining fill commonly occurs. Four of the five tractor crossings exhibited only trace amounts of sediment delivery. The one tractor crossing that displayed a moderate magnitude of sediment delivery was associated with a crossing on an unusually large Class III watercourse. The large dimensions of this watercourse meant that the crossing fill covered a larger area than it would in a smaller watercourse, the amount of fill remaining after crossing removal was correspondingly larger, and some of this material appeared to have been eroded/flushed from the crossing. In addition, the crossing approaches were not treated sufficiently to reduce erosion.

Five of the six watercourse-adjacent landings did not deliver sediment, despite some of them being as close as 20 feet to a watercourse. The only instance of observable sediment delivery from a landing was attributed to an older landing that had not been utilized for recent timber-harvest activities. The lack of sediment delivery from more recent landings was attributed to the high surface cover provided by application of wood-chip mulch. These landings were utilized for biomassing activities, so an abundant supply of wood chips was available onsite. The woodchips provided protection against rainsplash erosion and associated soil sealing. No runoff was visible across the surface of the chipped landings (Figure 24).

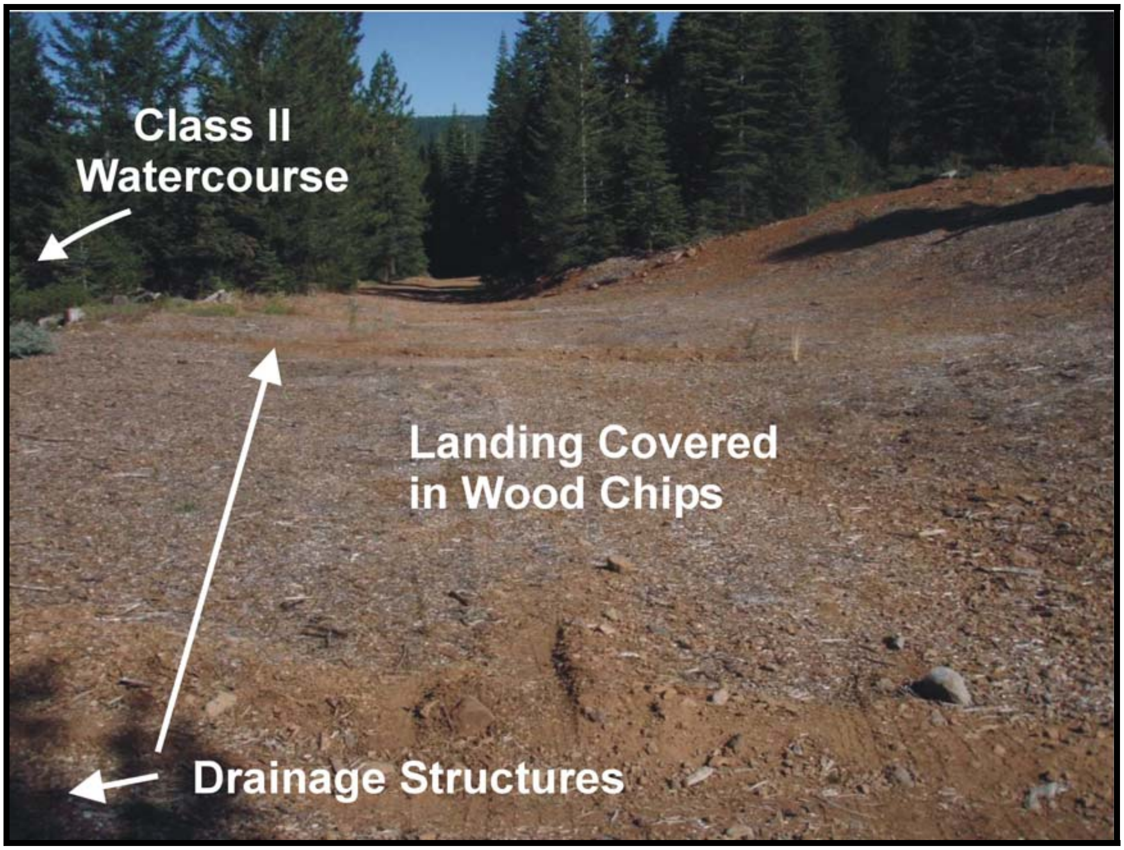


Figure 24. A landing located within 20 feet of a Class II watercourse. No observable sediment was delivered from this site due to the high level of surface cover provided by wood chips.

6.4 Other Sources of Sediment Delivery

In addition to sites identified as having a high risk of sediment delivery in the site selection process, the Task Force also documented "other" sediment delivery sites on an opportunistic basis. In particular, one site on a private in-holding (i.e., non-SPI) in the Bailey Creek planning watershed that was responsible for the highest magnitude of sediment delivery (an estimated 500 cubic yards or approximately 50 dump-truck-loads worth of sediment) found during the assessment. The site appeared to have been graded (i.e., flattened) to build a homestead or lumber mill, and displayed historic evidence of human habitation. A Class II watercourse currently flows through the site, and has significantly incised through the graded surface (Figure 25). The bank erosion associated with channel incision in this graded surface is responsible for the large magnitude of sediment delivery. Sediment delivery from the site is ongoing as the channel is still exhibiting signs of headward incision.

Cattle grazing and or deer/elk browsing within the assessment area is also a source of sediment delivery to waters of the state. The Task Force witnessed several instances where grazing/browsing animals had trampled watercourse banks, including banks associated with pulled crossings. Bank trampling directly contributes sediment to the watercourse, and the reduction in bank vegetation can lead to increased bank erosion (Trimble and Mendel, 1995). However, it is difficult to evaluate the significance of grazing and deer/elk browsing on water quality without further assessments.

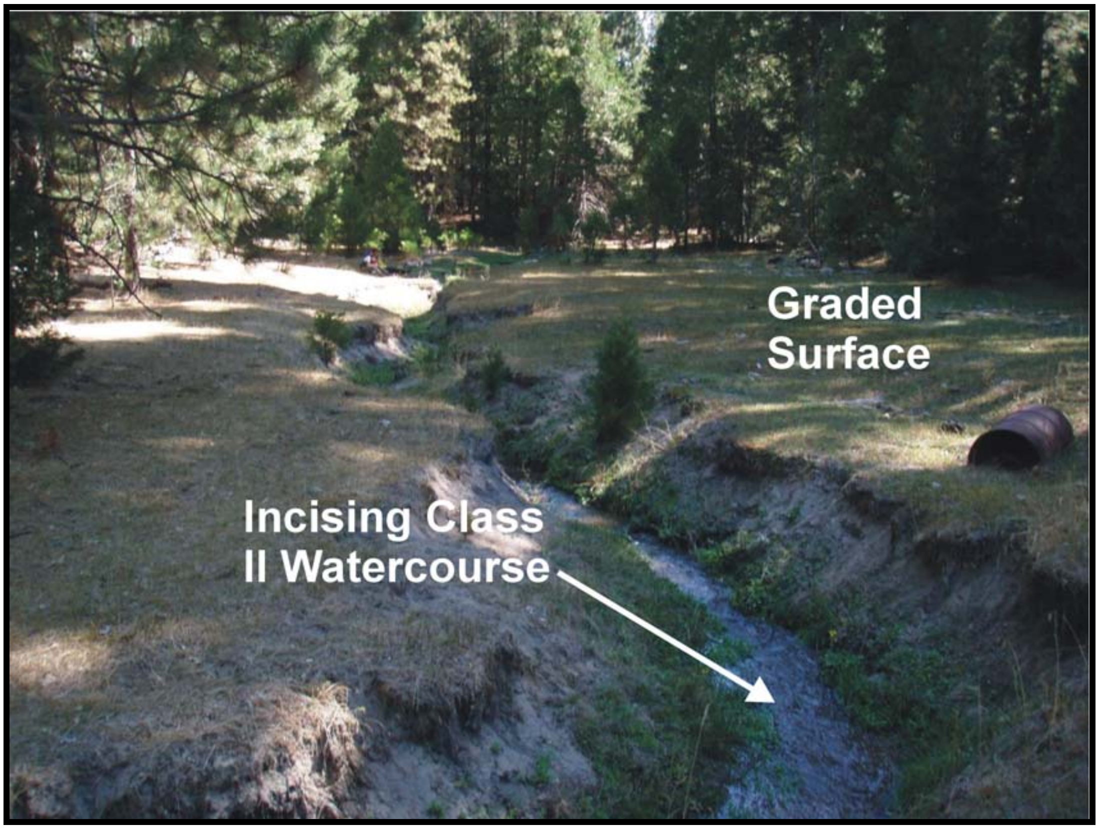


Figure 25. Extensive channel incision at a legacy sediment site in the Bailey Creek planning watershed. This location had the highest magnitude of sediment delivery of all the surveyed sites.

The Task Force noted several instances of road-related sediment delivery believed to be associated with the January storm event of 1997. Although not directly assessed, anecdotal observations indicate that the sediment delivery associated with this event was significant. For instance, the Task Force observed historical evidence of cutbank failures, fillslope failures, crossing failures, and inside-ditch incision attributed to the 1997 storm event. These observations are consistent with other accounts of significant road-related sediment delivery from the 1997 storm (Wemple and others, 2001; Ward and Moburg, 2004).

Bank erosion is considered one of the primary sources of sediment in small forested watersheds (Hassan and others, 2005). The Task Force saw ample evidence of sedimentation from bank erosion within the assessment area. Much of the bank erosion appears to have been associated with the 1997 storm event and this observation is consistent with previous studies in the watershed (Ward and Moberg, 2004).

6.5. Role of Clearcutting-Associated Harvesting in Sediment Delivery

The Task Force saw no evidence that clearcut harvest units were directly delivering significant volumes of observable sediment to waters of the state. Although tractor crossings, road crossings, and watercourse-adjacent road segments had the highest risk of delivering sediment to watercourses, these features are associated with all forms of timber harvest, including selection harvesting. Each type of silvicultural system (i.e., clearcutting, selection logging, etc) has its own characteristic rate of entry, and the rate of use and harvest entry has direct implications for the duration and magnitude of erosion from road surfaces and skid trails (Reid and Dunne, 1984; Hood and others, 2010). Clearcut logging does have the potential to increase rates of road erosion below a harvest unit (La Marche and Lettenmaier, 2001), due to increased runoff intercepted by road cutslopes. However, this cause-and-effect mechanism could not be evaluated using a rapid assessment methodology.

6.6. Linkage to Fish Habitat

Fine sediment can impact the physiology, behavior and habitat of salmonids. Increased suspended sediment and turbidity can affect feeding behavior (Sigler and others, 1984), influence migration, and reduce spawning and rearing habitat, among others (Newcombe and MacDonald, 1991; Bash and others,. 2001). The magnitude of impacts, however, depends on the duration and severity of sediment exposure, as well as the natural background levels within the system. In 2001, Terraqua initiated a stream-habitat monitoring program for the Battle Creek Watershed Conservancy (BCWC). Ward and Moberg (2004) determined that fine sediment levels in Battle Creek were high, but consistent with other watersheds with private and federally managed timberlands. They also acknowledged that the January 1997 storm event played a significant role in delivering fine sediment within the watershed. In addition, they stated from their studies that roads and other land uses, while a source of sediment, were not likely causing significant impacts on a watershed scale. Tussing and Ward (2008) analyzed five years of continuous Battle Creek monitoring data and found that all salmonid habitat metrics, including fine sediment, particle size, pool frequency and pool depth were improving since the 1997 storm event and conditions for salmonid production are “likely favorable.”

As discussed in Section 4.1, the clearcut units chosen for assessment were identified based on a higher-risk probability that sediment may be delivered. Of the 52 clearcut units assessed, only one had an instance of observable delivery, and that resulted from encroachment into the Class III ELZ by a tractor and not from erosion of sediment from the clearcut. Results of the assessment indicate that direct delivery of observable sediment from clearcuts is not causing an observable negative impact to fisheries habitat or to fisheries populations in the Battle Creek watershed. The California Forest Practice Rules that apply to watercourse protection appear to be providing adequate safeguards to prevent direct sediment delivery to watercourses from clearcut units.

The Task Force identified that sediment delivery was generated from 67 to 69 percent of the assessed watercourse-adjacent road and road watercourse crossing sites. In most cases the amount of sediment delivered was low. Class III watercourses had the highest proportion of sediment–delivery sites, but the delivery magnitudes were mostly quantified as low. The impact to downstream fish and their habitat from these sites depends on whether the delivery is chronic or episodic (MacDonald and Coe 2007), as fish have evolved to cope with episodic disturbance and not with chronic low-level disturbance (Yount and Niemi, 1990). Sediment from roads and crossings is typically a chronic input, whereas the January 1997 storm event is an example of an episodic input. Sediment delivery from roads and crossings may result in impacts to anadromous salmonids and their habitat, but given the relatively low inputs, the significance is uncertain. A more detailed and intensive monitoring program and data analysis would need to be conducted to determine the impact to the fisheries.

6.7. Assessment Limitations

The assessment only looked at direct impacts of clearcutting-related timber-harvest activities. The effects of timber harvest on increased suspended sediment yields is well noted in the literature, with much of it being attributed to harvest-induced increases in the duration and magnitude of sediment-mobilizing flows or the upslope extension of the channel network (Gomi and others, 2005; Hassan and others, 2005; Reid and others, 2010). Less certain is the role of harvest-induced flow increases on in-channel processes such as bank erosion and/or bedload transport (Grant and others, 2008). As such, the lack of documented water quality impacts from clearcutting only applies to direct sediment delivery from overland flowpaths, and not the potential indirect impacts caused by harvest-induced changes in hydrology. It should be noted that the effects of timber harvest on the duration and magnitude of streamflow remains an open question in the spring-dominated young volcanic terrane of Battle Creek (Grant, 1997).

The assessment of sediment delivery is limited by the forensic evidence observable in the field. The Task Force focused on finding erosion features generated by timber harvest activities, but these features may be transient in nature. For examples, rill networks and small gullies generated by clearcutting can fill in and disappear within 5 years (Rivenbark and Jackson, 2004). Erosion features on clearcut units can also be obscured by dense vegetation or slash. Evidence of road erosion may be obliterated during road-grading activities, or by post-storm reconstruction. Furthermore, the timber harvest activities assessed by the Task Force have likely not been subjected to a high magnitude, low frequency storm event. Flow records from the Coleman Fish Hatchery indicate that the largest flow event in the assessment area during the last 10 years of timber harvest activity (2001 to 2011) was approximately a 3.85-year return-period flow (January, 2006). The apparent lack of recent stressing storm events suggests the sediment delivery the Task Force observed is minimal, although relevant to the interpretation of the BCA turbidity data because of the similar time frames in which both studies were conducted.

7.0. Recommendations

The results from the assessment allow the Task Force to make several recommendations regarding forest-related land use activities in the Battle Creek watershed.

Recommendation 1:

Because clearcut harvest units were generally not found to be sources of direct sediment delivery to adjacent watercourses, the Task Force believes that Review Team should maintain their current emphasis on field review of road crossings, tractor crossings, watercourse-adjacent road segments, landings, and timber-management activities in the WLPZ. More emphasis should be placed on interagency THP completion inspections to evaluate the adequacy and effectiveness of road-related BMPs. CGS should continue to evaluate the potential impacts of clearcutting on slope stability.

Recommendation 2:

Encourage road and landowners in the watershed to develop road management plans for the roads on their property and/or roads that they control. Guidelines and contents of road management plans on timberland are provided in Article 6.9, Sec. 1093 of the FPRs. Encourage the development of a watershed-wide road inventory to identify and prioritize the treatment of road-related sediment sources.

Recommendation 3:

Managers of public and private roads should focus on implementing BMPs that hydrologically disconnect road surfaces from watercourses. The Task Force noted relatively long stretches of roads draining into watercourses on county-managed roads and SPI-managed roads that were accessible to the public. While SPI-managed roads generally delivered less sediment from watercourse-crossing approaches than county-managed roads, watercourse crossings on both public and private roads would benefit from strategic placement of waterbreaks (e.g., rolling dips, waterbars, or cross-drain culverts) so sediment filtering by the riparian zone is maximized while the length of road draining to the stream is appropriately minimized. Limiting access during the rainy season through gating or use limitations would help ensure that these drainage features would remain functional over longer time periods and would help protect native-surface roads from wet-season rutting and erosion. The concept of hydrological disconnection on timberland roads is a centerpiece in the proposed “Road Rules Package” currently being discussed by the Board of Forestry and Fire Protection. Currently, there is no mechanism requiring hydrologic disconnection of publicly-maintained roads.

Recommendation 4:

Managers of public and private roads should evaluate the need for treating road surfaces for erosion control (e.g., rocking road surfaces) particularly at road crossing approaches and on roads within 50 feet of a watercourse. This is being discussed as part of the proposed "Road Rules Package" for timberlands by the Board of Forestry and Fire Protection.

Recommendation 5:

Managers of public and private roads should evaluate the need to abandon and/or relocate watercourse-adjacent roads. Road segments within 30-50 feet of a watercourse were typically found to be responsible for the largest magnitude of sediment delivery to waters of the state.

Recommendation 6:

Support passage of a comprehensive "Road Rules Package" by the Board of Forestry and Fire Protection. The current version of the "Road Rules Package" requires the implementation of Recommendations 2 and 3 for roads managed by non-federal timberland owners.

Recommendation 7:

The Central Valley Regional Water Quality Control Board and the Department of Fish and Game will coordinate with the counties to develop programs that focus on fish-friendly BMP implementation for county road systems. An example of this type of program would be the 5 Counties Program found in the North Coast region (http://www.5counties.org/). The Central Valley Regional Water Quality Control Board will also explore potential regulatory mechanisms that will help county public works departments achieve water quality objectives on county roads.

Recommendation 8:

Provide a road and road crossing BMP component for Licensed Timber Operator (LTO) training.

Recommendation 9:

Encourage outreach workshops for LTOs, local landowners, and county public works supervisors and equipment operators to inform them of state-of-the-art road-related BMPs, and how their application will reduce both road maintenance costs and sediment delivery to nearby watercourses.

Recommendation 10:

Engage in a follow-up study to relate the results of the assessment to water column data (i.e., turbidity) and in-channel physical habitat characteristics (e.g., particle size, pool fining, etc). A follow-up study should also address the potential for timber harvest associated peak-flow induced increases to suspended sediment, turbidity, bedload transport, and/or channel alterations.

8.0. Conclusions

Over a five day period in September 2011, the Task Force assessed the potential for water quality impacts from 132 sites they determined to have a high risk for sediment delivery to surface waters. Of these sites, 55 were clearcut harvest units, 39 were road crossings, 24 were watercourse-adjacent road segments, 6 were watercourse-adjacent landings, 5 were tractor crossings, and 3 were associated with other sources of erosion. Despite assessing approximately 16 miles of riparian buffers directly adjacent to clearcut harvest units (i.e., 47 percent of the total operated buffer zone adjacent to clearcuts), the Task Force only found one observable instance of low magnitude sediment delivery (i.e., less than one cubic foot of sediment) associated with a clearcut. Sediment delivery associated with this site resulted from a Forest Practice Rules violation (encroachment of a tractor into an equipment-limitation zone), rather than erosion generated within a clearcut unit.

The likelihood of sediment delivery was found to be highest for tractor crossings, road crossings, watercourse-adjacent road segments, and watercourse-adjacent landings, respectively. All 5 tractor crossings delivered sediment, but were generally delivering only a low magnitude of sediment to waters of the State. Road crossings and watercourse-adjacent road segments delivered sediment 69 percent and 67 percent of the time, respectively. The magnitude of sediment delivery from road crossings and watercourse-adjacent road segments with implemented Best Management Practices (BMPs) was generally low or unobservable[1]. The highest magnitudes of sediment delivery from roads were associated with substandard design or maintenance practices (e.g., poor road drainage) and/or poor location (for example, road segments within 30-50 feet of a watercourse). Watercourse-adjacent landings associated with recent THPs delivered no sediment, and the lack of delivery was attributed to the protective ground cover provided by wood-chip mulch applications.

[1] These results are consistent with results reported from past monitoring programs conducted statewide on non-federal timberlands in California (Cafferata and Munn, 2002; Brandow and others, 2006).

The Task Force observed violations of the California Forest Practice Rules during the assessment. However, violations were generally rare and appeared to be of relatively minor significance at the scales relevant to salmonids.

Overall, the Task Force saw no significant direct water quality impacts related specifically to harvest within clearcut units in the assessment area. Most observed timber-harvest-related water-quality impacts were related to roads, which are used all kinds of timber harvesting (clearcutting, selection, and intermediate silvicultural methods), and in some cases for public access.
The Task Force was unable to evaluate the potential for indirect water quality impacts due to clearcut harvesting (for example, potential channel modifications and increases in suspended sediment and turbidity associated with logging-induced increases in peak flows), but the issue of timber-harvest-induced changes in hydrology in ground-water dominated, young volcanic terranes such at Battle Creek watershed remains an open question.

Recommendations are given to improve the water quality related performance of forest roads and to further evaluate the potential for logging-induced water quality impacts in the Battle Creek watershed.

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