2017 Ponderosa Way Road Assessment and Sediment Reduction Plan, Tehama County, California

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Central Valley Regional Water Quality Control Board (CVRWQCB)
Proposition 1 Timber Fund Grants Program

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Photo 1: Debris flows impacted the project area roads after the 2012 Ponderosa Fire. PWA field crews assessed the conditions of the roads in 2016-2017 to identify potential future road related erosion and sediment delivery sources.

Photo 2: PWA field crews identify road related sediment sources and the impacts caused by the road after the 2012 Ponderosa Fire. The majority of the forest understory and dominate overstory was lost in a notably high intensity wildfire that burned 27,676 acres in the Battle Creek Watershed, Tehama County, CA.

1 EXECUTIVE SUMMARY

The Ponderosa Way Road Assessment and Sediment Reduction Plan area is located approximately 27 miles northeast of Red Bluff, California and 35 miles southeast of Redding, California. Ponderosa Way (14.0 miles) was constructed in the early 1930s and maintained to support land use, public and private access, and wildfire management (Peterson, 2009). Spur roads (8.1 miles) upslope and downslope of Ponderosa Way within the project area were constructed in the 1960s and 1980s for PG&E diversion works in the South Fork Battle Creek. The South Fork Battle Creek in the Ponderosa Way assessment area is underlain by highly erodible and locally unstable geologic substrate, and both field observations and analysis of aerial photographs suggest that roads have been a significant source of historic accelerated sediment production, especially following the recent Ponderosa Fire. Once the area burned, sediment production and downstream delivery from roads greatly increased.

Battle Creek is a salmonid stream located in the foothills of the Mt. Lassen. Researchers have found that most native salmonid species are adapted to natural patterns and processes of disturbance and recovery in the landscape, including occasional wildfire, and that preventing additional human disturbance (and reducing the effects of past land use disturbances) will generally provide the best management strategy for regional ecological conservation and recovery (Beschta et al., 2004; Beschta et al., 1995). Erosion and sediment delivery from forest roads is a recognized environmental threat to the Battle Creek watershed, which provides important habitat for anadromous salmonids.

In 2016, the Pacific Watershed Associates (PWA) received a personal services agreement from Tehama County Resource Conservation District (TCRCD) to conduct a road related sediment source assessment and generate a treatment action plan for Ponderosa Way and several of its spurs. The project was funded by the California Water Resources Control Board, Prop 1 Timber Fund Grants Program, and the California Department of Fish and Wildlife Fisheries Restoration Grant Program (FRGP). Timber Fund grant oversight is provided by the Central Valley Regional Water Quality Control Board (CVRWQCB). The project deliverables included a prioritized plan-of-action for cost-effective erosion prevention and erosion control for roads in a portion of the South Fork Battle Creek Watershed. Techniques for performing watershed-scale forward-looking erosion assessments and prioritized, cost-effective sediment control programs have been in practice for several decades (Harr and Nichols 1993; CDFG 2003; Burroughs and King, 1989; Weaver and Hagans; 1994; Weaver and Hagans, 1999).

PWA assessment teams conducted a rapid “forward-looking” erosion assessment of forest roads in the 2012 Ponderosa Fire area to identify the nature and magnitude of post-fire road related erosion and sediment delivery. The field data provides quantitative estimates, or ranges, of how much sediment could be eroded and delivered to streams in the future if no erosion control or erosion prevention work is performed. Finally, we identified potential treatment opportunities, prioritized treatment sites, and developed a detailed cost estimate for the recommended erosion prevention and sediment control work.

The Ponderosa Way road erosion assessment and demonstration project is divided into 3 main parts or phases:

Part 1 of the project consisted of two components: (1) a complete field inventory to document all current and potential road related sediment delivery sources along 22.1 miles of project roads in the Ponderosa Fire area, specifically along Ponderosa Way and several spur roads; and (2) development of a prioritized action plan for cost-effective erosion control and erosion prevention treatments, including site-specific recommendations for road upgrading and road decommissioning, various storm-proofing treatments at stream crossings, road surface drainage features, fillslope failures and instabilities, and other sediment delivery sites (see Appendix B for site-specific recommendations). Part 1 is the subject of this report.

Part 2 will report the selection a demonstration sediment control project to be implemented in 2018 (see Part 2 of the report for the selection of the demonstration project). The demonstration project will be constructed at selected site(s) or road reach(es) along Ponderosa Way, as approved by the TAC. The implementation "demonstration project" will include a variety of restoration techniques described in the Handbook for Forest, Ranch, and Rural Roads (Weaver et al., 2015) and the California Salmonid Stream Habitat Restoration Manual, Part X (Weaver et al., 2006).

Part 3 will report the findings of the Ponderosa Fire post-fire watershed analysis, including: 1) Air photo analysis will be used to identify relevant land use and road construction histories, visible post-fire impacts from the 2012 Ponderosa Fire burn area, historic erosion events as evidenced from air photo analysis, and visible road related sediment source problems; 2) A GIS-based Erosion Hazard Rating (EHR) for soils in the 2012 Ponderosa Fire burn area will be developed using vegetative cover statistics and other site factors, as based on the procedure described in the California Forest Practice Rules (Board Technical Rule Addendum #1); and 3) A GIS-based model of post-fire hillslope erosion in the 2012 Ponderosa Fire burn area will be developed using GeoWEPP (Geographical interface for the Water Erosion Prediction Project).

This summary report describes Part 1 of the project and serves as a prioritized general plan-of-action for cost-effective erosion control and erosion prevention treatments for inventoried roads in the project area. During the field inventory, PWA field crews identified a total of 111 sites and 10.6 miles of the 22.1 miles of Ponderosa Way and spur roads that are hydrologically connected to local streams. These road segments have the potential to deliver sediment directly to South Fork Battle Creek and its tributaries. We recommend that 107 of the inventoried existing and potential sediment delivery features, and all of the 10.6 miles of hydrologically connected road segments, be treated for sediment control and erosion prevention. When erosion and sediment control treatments are implemented in combination with protective land use practices, the proposed projects will contribute to the long-term protection and improvement of beneficial uses (water quality and salmonid habitat) in the watershed. The estimated total cost to implement the recommended erosion control and erosion prevention treatments for 22.1 miles of Ponderosa Way and spurs is approximately $1,832,000.

The implementation of erosion control and erosion prevention work is an important step towards protecting and restoring watersheds and their anadromous fisheries, especially where excessive and/or anthropogenic sediment inputs are a limiting or potentially limiting factor to fisheries production, as is thought to be the case for many of streams with extensive land use histories and dramatic post-fire impacts in the Sacramento River Basin. Unlike many watershed improvement and restoration activities, erosion prevention and "storm-proofing" of forest and rural road systems has an immediate benefit to the stream’s water quality and aquatic habitat. It helps ensure that the biological productivity of the watershed's streams is minimally impacted by future human-caused erosion, and that future storm runoff can cleanse the streams of accumulated coarse and fine sediment, rather than depositing additional sediment from managed activities and areas. Sites targeted for immediate implementation in the Ponderosa Way project area have been identified as priority sites for treatment so that fill failures, stream crossing wash outs and stream diversions do not continue to degrade South Fork Battle Creek.

The expected benefit of completing the erosion control and prevention planning work for 22.1 miles of project roads outlined in this report lies in the reduction of long term sediment delivery to the South Fork Battle Creek. With this prioritized plan-of-action for addressing sediment inputs and impacts, cooperating watershed stakeholders (i.e., PG&E, SPI, BLM and other private landowners) have the ability to seek and obtain funding and implement the erosion remediation identified for the project area in future State Water Board Prop 1 Timber Fund Grants Program and Fisheries Restoration Grant Program (FRGP). California Department of Fish and Wildlife FRGP annual grant proposal for upslope erosion control and instream habitat restoration are especially suitable for this project area, but other grant sources are also available. The erosion control and erosion prevention treatments recommended in this assessment, if implemented and employed in combination with protective land use practices, will significantly improve and protect water quality and salmonid habitat in downstream watershed areas.

2 CERTIFICATION AND LIMITATIONS

The report entitled *Ponderosa Way Road Assessment and Sediment Reduction Plan, Tehama County, California* was prepared by or under the direction of a licensed professional geologist at Pacific Watershed Associates (PWA), and all information herein is based on data and information collected by PWA staff. Sediment-source inventory and analysis for the project, as well as erosion and sediment control treatment prescriptions, were similarly developed by or under the responsible charge of a California licensed professional geologist at PWA.

The interpretations and conclusions presented in this report are based on a study of inherently limited scope. Observations are qualitative, semi-quantitative and quantitative, and are confined to surface expressions of limited extent and artificial exposures of subsurface materials. Interpretations of problematic geologic and geomorphic features (such as unstable hillslopes) and erosion processes are based on the information available at the time of the study and on the nature and distribution of existing features we observed.

The conclusions and recommendations contained in this report are professional opinions derived in accordance with current standards of professional practice, and are valid as of the submittal date. No other warranty, expressed or implied, is made. PWA is not responsible for changes in the conditions of the property with the passage of time, whether due to natural processes or to the works of man, or changing conditions on adjacent areas. PWA is not responsible for any erosion control treatments that may have been improperly or inadequately implemented in the Ponderosa Way project area during the course of this assessment for which PWA was not informed and did not provide construction management services or complete post-implementation reviews. Furthermore, to be consistent with existing conditions, information contained in this report should be reevaluated after a period of no more than three years, and it is the responsibility of the landowner to ensure that all recommendations in the report are reviewed and implemented according to the conditions existing at the time of construction. Finally, PWA is not responsible for changes in applicable or appropriate standards beyond our control, such as those arising from changes in legislation or the broadening of knowledge, which may invalidate any of our findings.

Certified by:

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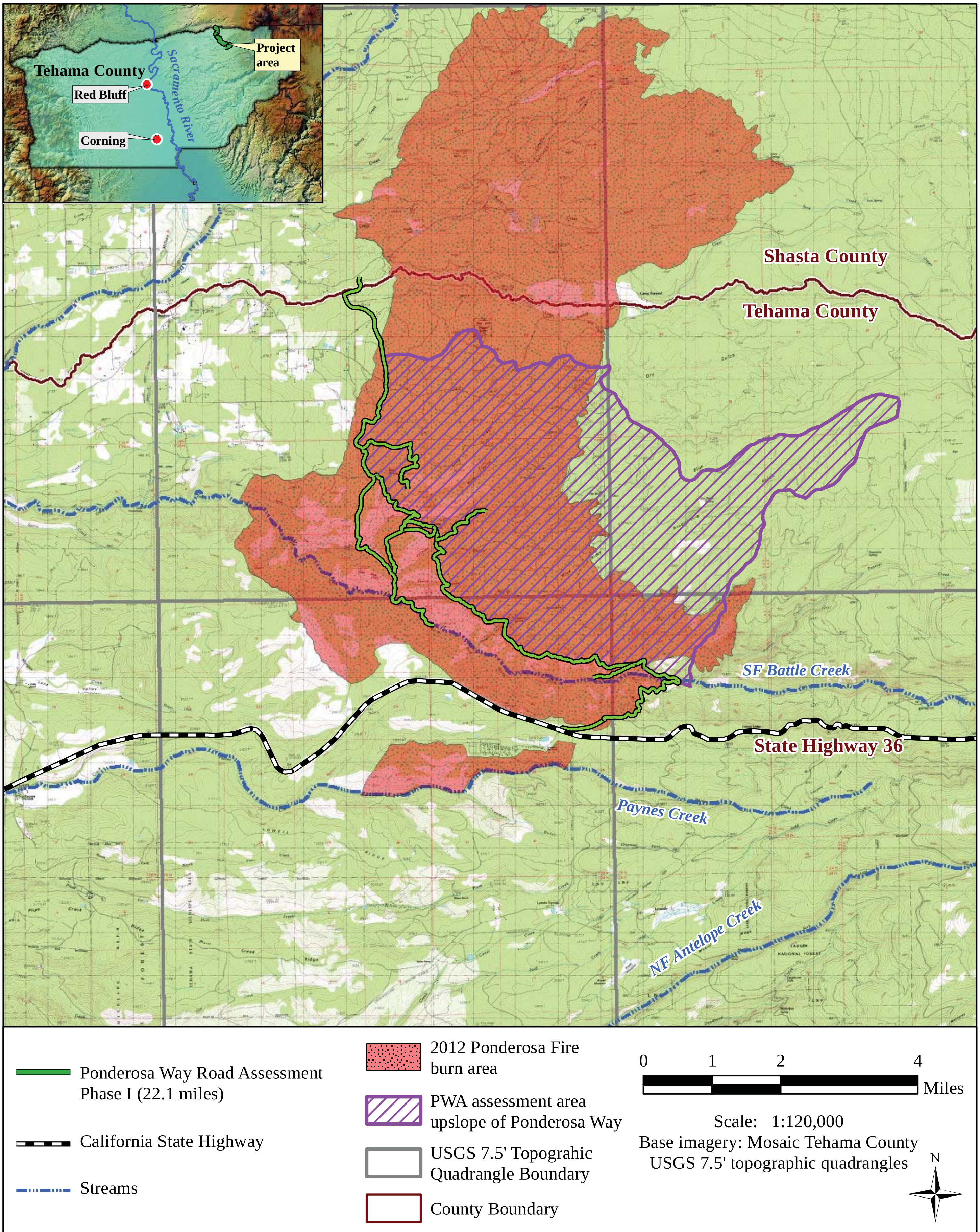
3 INTRODUCTION

The 2012 Ponderosa Fire burned 27,676 acres of forest and range land that was subsequently salvage logged between 2013 and 2015. The wildfire was ignited by a lighting strike very close to Ponderosa Way and South Fork Battle Creek (Wilson, 2015). The fire quickly burned the northern slope of the watershed at a very high intensity due to the dry, extreme fuel and weather conditions. The fire completely destroyed the forest and vegetated understory along the northern slope of the watershed and the subject reach of Ponderosa Way and its spurs. Erosion originating from forest road systems is a common and significant accelerated anthropogenic sediment source input to streams in managed watersheds affected by wildfire and forest management throughout Northern California. Road related sediment production includes storm-triggered episodic erosion (fluvial and mass wasting) and chronic surface erosion of fine sediment from the road alignment, both of which impact aquatic and salmonid habitat. In the project area, post-fire runoff, erosion and downstream sedimentation rates have increased and caused significant impacts in the South Fork Battle Creek watershed (Map 1). Storm-proofing roads that access private residences and salvage logging areas, or decommissioning unwanted roads in burned areas, provides an opportunity to protect and improve aquatic habitat and long term water quality through the reduction of ongoing and future sediment delivery to affected streams.

Two of the most important elements of long-term restoration and maintenance of beneficial uses (water quality and fish habitat) from forested and wildland watersheds is the reduction of on-going and future impacts from upland anthropogenic (human caused) erosion and sediment delivery associated with roads, trails, and other land management activities and disturbed areas. Sediment delivery to stream channels from roads and road networks has been extensively documented in managed steepland watersheds and is recognized as a significant impediment to water quality and the health of salmonid and aquatic habitat (Furniss et al., 1991; Higgins et al., 1992; Harr and Nichols, 1993; Flosi et al., 2010; NMFS, 2000, 2001). Roads modify natural drainage networks and accelerate erosion processes. These changes can alter physical processes in streams, leading to impaired streamflow regimes, sediment transport and storage, channel bank and bed configurations, substrate composition, and stability on slopes adjacent to streams. These changes can have important biological consequences, and they can negatively affect the aquatic ecosystem (Furniss et al., 1991).

Unlike many watershed improvement and restoration activities, erosion prevention through "storm-proofing" rural, ranch, and forest roads provides both immediate and long term benefits to the streams and aquatic habitat of a watershed (Weaver et al., 2015; Weaver and Hagans, 1999; Weaver et al., 2006). Storm-proofing is a geomorphic approach that is based on an understanding of hillslope position and how the road influences geomorphic processes. At the site, storm-proofing treatments are sized to manage and balance the current sediment regime and accelerated erosion rates. It measurably diminishes the impact of road related erosion on the biological productivity of the watershed's streams, and allows future storm runoff to cleanse the streams of accumulated coarse and fine sediment, rather than permitting continued sediment delivery from the current conditions of the road network in the project area.



Map 1. Location of the Ponderosa Way Road Assessment and Sediment Reduction Plan Project, Part 1, Tehama County, California.

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The project roads are located approximately 27.0 miles northeast of Red Bluff, California (Map 1). This section of Ponderosa Way is a 14.0 mile road reach that transverses the slopes of South Fork Battle Creek watershed, a tributary to Battle Creek, which is a large tributary to the Sacramento River basin. The California Department of Fish and Wildlife (CDFW) Fisheries Restoration Grant Program (FRGP) provided funding for the erosion assessment and treatment plan for a 12.0 mile reach of Ponderosa Way. The State Water Resources Control Board Proposition 1 Timber Funds Grant Program funded the assessment of a 2.0 mile reach of Ponderosa Way and 8.1 miles of spur roads upslope and downslope of main Ponderosa Way road alignment. The entire 14.0 mi of Ponderosa Way was originally assessed by the TCRCD in 2010. The results of the *WUI and Watershed Protection/Emergency Access Assessment,* between the Tehama/Shasta County line and State Route 36E, initiated a series of CVRWQCB inspections in 2014 and 2015. A portion of the road was reviewed by the Regional Board in 2015 and resulted in mandated mitigation of a 2.0 mile road reach owned by PG&E (Wilson, 2015).

South Fork Battle Creek contains two species of anadromous salmonids, including steelhead trout and Chinook salmon. Historically, South Fork Battle Creek was one of the most important Chinook salmon spawning streams and spring-run Chinook salmon in the Sacramento Valley in response to being blocked from migration from the construction of the Shasta-Keswick dam complex. This steep, 106.0 mi^2 watershed drains slopes located in Tehama County, California (Map 1). The South Fork has approximately 28.0 miles of blue-line stream from the headwaters to its confluence with the Sacramento River. The upper 10.0 miles of the South Fork are not accessible to anadromous salmon and steelhead due to natural barriers (boulder-clusters at milepost 18.9) which blocks fish migration near Panther Creek (Kier, 1999). The South Fork Battle Creek watershed is composed primarily of mixed evergreen forests, oak woodlands and grasslands, both privately and federally managed for different resource values. The Coleman National Fish Hatchery staff report that in recent years since the wildfire there has been extremely elevated levels of very fine sediment clogging their filtration system, with some of the finest sizes making it through (Jameson, 2015). The hatchery, which raises millions of fish to mitigate the effects of habitat degradation and declining fisheries populations, was temporarily closed in 2015 due to the effects of flooding and sedimentation (USFWS, 2015).

Part 1: Specifically, Part 1 of this project include the road erosion assessment and development of a prioritized sediment control plan for the inventoried roads. PWA will produce a detailed erosion prevention and erosion control plan that is designed to protect and improve habitat for salmonids by preventing or minimizing controllable erosion and downstream sedimentation. The prioritized action plan will include data from the complete field inventory of current and future erosion and sediment delivery sites, the prioritized plan for erosion and sediment control treatment prescriptions, and an estimated budget for heavy equipment, labor, and materials to cover all recommended treatments for the 22.1 miles of project area roads.

In this summary report, PWA will present the Action Plan and cover the field techniques and data collection process that led to the results of the road related sediment source assessment and proposed treatment plan. On our data forms and summarized in Appendix B, we provide detailed site evaluations and treatment prescriptions for all significant sediment delivery sites. By 2016-

2017, five years after the Ponderosa Fire, significant erosion has already occurred. Our inventory and analysis is forward-looking and focuses on current and future road related erosion and sediment delivery that is preventable; not on processes that have already occurred and delivered their sediment to downslope and downstream areas. Thus, we do not provide detailed analysis of past processes and rates of erosion and sediment delivery. Site specific problems, site prioritization, and recommended treatments and materials needed to implement the project are included in Appendix B.

<u>Part 2:</u> Part 2 of this project will develop a discrete sediment reduction demonstration project that will treat sediment source sites and associated road segments where sediment delivery is occurring or is expected. The demonstration project will include site-specific treatment recommendations that are prioritized for implementation in 2018. PWA and the TCRCD will work together, using this summary report, tables and maps, with the Central Valley Regional Water Quality Control Board to select the road related erosion sites or a specific road segment for implementation.

<u>Part 3:</u> Part 3 of this project will report the results of our watershed analysis for the 2012 Ponderosa Fire burn area that will be submitted to the Regional Board in December 2017. The post-fire watershed analysis will include an analysis of historic photographs to develop a road-construction history and erosion source history for the watershed. The post-fire watershed analysis will also include the development of an erosion hazard rating map that includes a watershed analysis model (GEOWEPP) that was employed to estimate post-fire soil movement.

The post-fire watershed analysis describes the effects of storms and post-fire erosional events which have occurred in the watershed over about the last 40 year period. Battle Creek has a recorded history of wildfire dating back to 1911. The Ponderosa Fire occurred in 2012, burning an area of 27,676 acres of mixed confer forest encompassing ~ 9% of the watershed in both main tributaries (Jameson, 2015). The burned areas were subsequently salvage logged. The historic aerial photos from 1952 document the earliest conditions of the watershed from which there are somewhat complete records. Stereo aerial photography from later decades was used to identify changes which have occurred in the watersheds as a result of over four decades of storms and land management. Analysis of historic photos and current satellite imagery is useful for identifying the nature, location, magnitude and potential significance of the changes which have occurred.

A critical step in the overall risk-reduction process for an impacted watershed is the development of a long-term transportation plan. In developing this plan, all roads in an ownership or sub-watershed are considered for either upgrading or permanent closure (i.e., decommissioning), depending on the risk of erosion and sediment delivery to streams and the importance of the road in overall transportation and resource management. The TCRCD and Regional Water Board can use this plan to inform landowners of site specific treatments and estimated costs, or to apply for grant funding for the recommended sediment control treatments. The road related erosion assessment and prioritized treatment action plan can be used as a planning tool to pinpoint sites or road segments with a high risk of erosion and sediment delivery.

Good land stewardship requires that if roads are going to be used, they must be designed to minimize erosion and be maintained in good condition. If no longer needed, they should be properly decommissioned and converted to a naturally functioning landscape condition, not simply abandoned. The outdated practice of abandoning roads, either by installing barriers to traffic (logs, tank traps, or gates) or simply letting them naturally revegetate, is usually generally unacceptable in all but the most stable of landscape locations. Abandoned roads typically continue to fail, and may contribute to erosion and sediment delivery problems for decades.

At the same time, not all road segments are high risk, and those that pose a low risk of degrading aquatic habitat in the watershed may not need immediate attention. It is therefore important to rank and prioritize roads in a watershed based on their potential to impact downstream resources, as well as their importance to the overall transportation system and for resource management needs. We assert that the erosion control and erosion prevention treatments recommended in this assessment report, if implemented and employed in combination with protective land use practices, will significantly improve and protect water quality and salmonid habitat in this ecologically significant watershed.

4 FIELD DESCRIPTION OF THE ASSESSMENT AREA

4.1 Climate and Terrain

The climate of northeast California in the South Fork Battle Creek watershed is characterized by dry-summer subtropical climate, mild-to-hot summers and cool winters with periods of intense rainfall that produce distinct, seasonal floods. This region experiences a moderate mean annual precipitation compared to the rest of the state (40+ in.), with most of the rainfall occurring between October and April. Winters are dominated by convective rainfall at low elevations and snowfall at high elevations with an elevation band experiencing rain-on-snow between 3,600 and 5,000 feet. Although snow can fall at any elevation, high elevations above 5,000 feet may receive the dominant amount of precipitation as snowfall, and receive increased precipitation due to orographic lifting.

Summers experience occasional high intensity short duration thunderstorms. However, soil moisture conditions are low in summer months, which results in the infiltration of precipitation before ponding and surface runoff are large enough to influence stream levels during summer storms. Snow fields persist on Lassen Peak during the dry season providing a constant inflow of groundwater to support perennial baseflow in the mainstem South Fork Battle Creek.

The South Fork of Battle Creek is located at the southern end of the Cascade Range, in the northern Central Valley, and flows into the main stem of Battle Creek and then the Sacramento River at RM 272 (Ward and Kier, 1999). The South Fork Battle Creek is geologically significant due to cold water springs, which occur due to porous bedrock and snowpack in the higher elevations. The creek carves through basalt canyons and foothills before it joins the Battle Creek mainstem and Sacramento River.

The project area is located in steep, mountainous terrain, with hillslope gradients frequently exceeding 70% along inner gorges of tributary stream channels. Vegetation attests to abundant water and fertile soil. Deciduous, evergreen and mixed forests consist primarily of oaks and Douglas fir; shrub, herbaceous, and pasture units are also present within the watershed. Battle Creek has a recorded history of wildfire dating back to 1911. The recent Ponderosa Fire occurred in 2012, approximately 12,864 acres burned in the South Fork Battle Creek watershed. High burn intensities were vast encompassing 45% of the burn area (CAL FIRE, 2012). The Ponderosa Fire was a natural disturbance severely impacting the watershed by removing vegetation cover, increasing the hydrophobicity of soils, and increasing the susceptibility of the landscape to surface erosion. Post-fire salvage logging added to soil disturbances in most of the burned areas.

Anadromous salmonids, including spring and fall run Chinook, and steelhead trout are present in the South Fork Battle Creek; the cold water tributaries are especially important for these salmonid species. Brown trout, Brook trout and rainbow trout have also been stocked repeatedly in this watershed (Kier, 1999). Of significance for salmonid and steelhead trout habitat, the terrain of the upper tributary subwatersheds are underlain by volcanically derived rhyolitic bedrock and poorly indurated and weathered volcanic tuffs that are particularly susceptible to erosion and mass wasting during periods of sustained or heavy rainfall. The rhyolitic bedrock is moderately weathered to decomposed, forming shallow soils that lack cohesive strength and are predominately fine to course sized sand particles (Jameson, 2015). The lack of cohesive strength leads to high erosion rates and difficulties in recovery of natural vegetation after wildfire and large-scale salvage logging.

The project area has well developed and incised drainage pattern with bedrock gorges with steep and unstable slopes, and low-gradient areas where sediment deposition and accumulation is typical of stream morphology. But whereas salmonid populations have evolved and flourished with the natural processes of rainfall and erosion in the area, the impact of the wildfire and anthropogenically induced erosion (e.g., from logging and road construction) has resulted in high rates of runoff, soil loss, erosion, numerous debris flows, and accelerated sediment delivery to streams and a major degradation of salmon and steelhead trout habitat (see *Post Ponderosa Fire Sediment Impacts to Coleman NFH*, staff memo from U.S. Fish and Wildlife Service, dated 24 June 2015). As it exists today, PG&E’s Battle Creek Hydroelectric Project (FERC No. 1121) has also had historic impacts on salmonid habitat in the watershed. Their project works consist of three diversions on South Fork Battle Creek (South, Inskip, and Coleman), numerous tributary and spring diversions, and a network of some 10 canals, ditches, flumes and pipelines (Kier, 1999).

5 ROAD RELATED SEDIMENT SOURCE ASSESSMENT

There are two broad categories of road related sediment sources along the 22.1 miles of Ponderosa Way and inventoried spur roads. These include (1) sediment that is eroded and delivered from discrete sites along the road alignments, and (2) fine sediment that is eroded from bare road surfaces, cutbanks, and ditches of varying lengths that are hydrologically connected[1] and directly deliver to local streams that form the stream network.

5.1 Ponderosa Way and Spurs Road related Sediment Source Assessment (22.1 miles)

In the project area, Ponderosa Way (14.0 miles) was constructed in the early 1930s and maintained to support forest land use, landowner access, and wildfire management (Photo 1). Ponderosa Way is a continuous "firebreak" that, when it was built, extended for 800 miles along the length of the Sierra Nevada Mountains and into the southern Cascades, ending north of Redding, California. It was intended to be a permanent defensive line between the lower foothill regions and the higher elevation National Forest lands to the east. It was funded by the Emergency Conservation Work (ECW) program, which was established in April 1933 and almost immediately became known as the Civilian Conservation Corps (CCC) (Peterson, 2009). Spur roads (8.1 miles total) located downslope of Ponderosa Way were constructed in the 1960s and 1980s for PG&E diversion works in the South Fork Battle Creek and upslope of Ponderosa Way for access to adjacent timberlands.

Photo 1. Ponderosa Way in the project area traverses the South Fork Battle Creek Watershed 27 miles northeast of Red Bluff, CA (see mid-slope road trace). The road was constructed in the 1930s in a middle hillslope position prior to more modern wildland road standards such as those defined by the California Forest Practice Rules. The road intercepts hillslope runoff, intermittently fails during storm events, and has caused downstream channel degradation.

The Project Areas roads for the sediment source assessment and treatment action plan are located in Tehama County between Rock Creek Road to the north and Highway 36 to the south (Map 1;

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1 *Hydrologically connected* describes sites or road segments from which surface runoff and eroding sediment is directly delivered to stream channels (Furniss et al., 2000).

Table 1). Seasonal travel along the mainline Ponderosa Way was still possible until the 2012 Ponderosa Fire and subsequent post-fire erosion closed the route (personal communication Regional Water Board, 2017). Most of the road had been constructed before California Forest Practice Rules in the 1970s using low standard road construction techniques and designs standards. Most of the road does not meet today's generally accepted standards for a "storm-proofed" and upgraded road system (see details in Appendix A, Weaver et al., 2015 and California Forest Practice Rules, 2017).

Table 1. Ownership and road lengths inventoried for the Ponderosa Way road related sediment source assessment, Tehama County, California.

Road	Landowner(s)[1]	Length (mi)	Map (#)
Ponderosa Way	Private, SPI, PG&E, BLM	13.77	All maps
Spur 1	PG&E	1.93	3b/4b
Spur 2	Private, BLM, PG&E	3.19	¾ b, c and d
Spur 3	Private, BLM, PG&E	1.60	3c/4c
Spur 4	SPI	0.99	3c/4c
Spur 5	SPI	0.66	3e/4e
Total		**22.14**	

[1] SPI = Sierra Pacific Industries; PG&E = Pacific Gas and Electric Company; BLM = U.S. Bureau of Land Management

In winter 2016 and spring 2017, PWA inventoried 22.1 miles of maintained and abandoned road sections, as well as several adjacent spur roads that provide access to the PG&E diversion tunnels, canals, and waterlines located in the South Fork Battle Creek watershed. Short segments (< 5.0 miles) of Ponderosa Way near Rock Creek Road to the north and Highway 36 to the south is still maintained and has a partially rocked running surface. The majority of the road which is abandoned and unmaintained between these maintained sections has a native (unrocked) road surface (< 9.0 miles), and several miles of Ponderosa Way are covered with colluvial rock and debris from upslope areas and with woody plants. Road reaches that are rocked and maintained, or overgrown with vegetation, have less of an impact on water quality. An unrocked road surface has the greatest potential for surface erosion, especially where there is high use with frequent vehicular traffic.

The most significant existing and potential erosion problems and sediment delivery sites are located along the abandoned, unmaintained section of Ponderosa Way, where upslope wildfire has accelerated erosion processes that now impact Ponderosa Way. In general, the inventoried road system in the project area has culverts installed at most stream crossings, and its surface is poorly drained through the use of road surface insloping, inboard ditches, and a few ditch relief culverts. Most of the stream crossing culverts are old and undersized metal or concrete pipes with concrete sills built to stabilize the oversteepened fillslope (Photo 2). Some of these stream crossings have failed, several of the culverts have been intentionally removed as a management measure and others are partially plugged and threatening to fail and wash out in the near future. Eroded sediment has been transported to the road alignment from upslope areas via fluvial in-stream transport, debris flows from burned areas, rill erosion from bare slopes that are now revegetating, and cutbank failures and colluvial raveling processes. These processes have effectively made the road impassible and the weakest points along Ponderosa Way have either failed or are in the process of failing as the road continues to deteriorate with time.

Photo 2. On the abandoned sections of Ponderosa Way, stream crossing culverts are undersized and many have plugged due to the magnitude of storm runoff during the post-fire period. Stream crossing washouts occur when culverts plug, sending the streamflow over the top of the stream crossing fill. Most washed out stream crossings, such as the one in this photo, have delivered the eroded sediment downstream and degraded the offsite channel.

Erosion problems along the project roads are frequent (5.0 inventoried sites/mile) largely because the road has altered the natural post-fire runoff patterns and hillslope processes. Only a few stream crossing structures on Ponderosa Way still function to pass high flows. Nearly all of the stream crossing culverts are undersized for 100 year peak flow (the current design standard), with the exception of the bridges located on Digger Creek to the North (Site #1) and South Fork Battle Creek to the south (Site #75).

PWA observed that along many of the road segments, excessively long lengths of road surface and inboard ditches are hydrologically connected to stream channels. Years of road use and maintenance grading has created a berm along the outside edge the road that continues to collect and concentrate road surface runoff during storms, directing the water and eroded sediment into local streams and preventing it from being dispersed onto the adjacent hillslope. There are only a few road segments over the 22.1 miles of inventoried roads that have road surface drainage structures designed to disperse concentrated road runoff and prevent the runoff from being directly connected to the South Fork Battle Creek stream network. Project area roads have altered the natural geomorphic and hydrologic processes, including direct rainfall interception by the road surface, accelerated erosion from increased road surface erosion processes, concentrated runoff on the road surface and in the ditches affecting channel structure and geometry, altered surface flow paths, diverted hillslope runoff patterns, and culvert plugging with woody debris and sediment at stream crossing culverts. These erosion mechanisms involve different physical processes, have various effects on erosion and sedimentation rates and are not uniformly distributed on the landscape. The hydrologically connected road surfaces often drain directly into culverted stream crossings or to ditch relief culverts that feed into the stream network. As a result, interception of accelerated hillslope runoff and fine sediment derived from road surface runoff, ditch incision, and cutbank ravel are being delivered directly to the stream system. These types of sedimentation issues were greatly accelerated by the 2012 wildfire and subsequent salvage logging. Many of these impacted road reaches have been noted as a high priority for treatment and remediation.

5.2 Field Techniques and Data Collection

Methods - Field inventory work was completed by trained field personnel experienced and knowledgeable in forest and watershed geomorphology, hydrology, and road management and use. The inventory staff is also skilled and experienced in identifying ongoing or potential road erosion problems, evaluating the potential for erosion and sediment delivery, and developing and implementing road treatment prescriptions designed to be both effective and cost-effective. The field crew included 2-4 people so that problems and treatments could be jointly reviewed and discussed. Problematic features were identified for review by the project manager and/or the professional geologist in responsible charge of geologic components of the project.

All field and GIS data collected and compiled into the relational database were checked by PWA staff for consistency and accuracy. This process of “database cleaning” ensures that all project roads and treatment features are properly recorded, and that all assigned treatments are adequate and consistent with the needs of the forest manager or landowner. The PWA project manager used database queries to identify locations needing final field checking at the close of the project, including features with high treatment immediacy (priority) ratings, features with unclear or missing data, sites with large sediment volumes, and complex sites that required additional review of erosion potential and sediment delivery calculations and treatment prescriptions.

PWA verified the accuracy of GIS data by cross-checking the mapped features in the GIS database and the features in the field assessment database to ensure that all feature locations were correctly identified. This process reveals any feature that was mapped in the field that is missing a GPS data point. A data point for the feature can then be digitized using the field mapped location. In rare instances in which a feature is neither mapped in the field nor recorded with GPS coordinates, PWA uses sketches on the field data forms from the same vicinity to reconstruct the feature location and add it to the GIS and field databases.

<u>*Sediment source assessment*</u> – Part 1 of the road related sediment source assessment project consisted of two components: (1) a complete field inventory to document all current and potential road related sediment delivery sources along approximately 22.1 miles of roads; and (2) the development of a prioritized action plan for cost-effective erosion control and erosion prevention treatments, including site-specific recommendations for road upgrading and decommissioning, various storm-proofing treatments at stream crossings, road drainage features, potential fillslope failures, and other sediment delivery sites (see Appendix B for site-specific recommendations). Part 2 will include the selection of a demonstration project for implementation in 2018.

Road related features are defined as current or potential erosion locations along a road, or caused by the road, where eroded sediment is, or could be, delivered to a watercourse. Sediment source sites inventoried as part of the *Ponderosa Way Road Assessment and Sediment Reduction Plan* primarily consist of stream crossings, potential and existing fillslope instabilities, ditch relief culverts, areas of streambank erosion, and various road surface discharge points (e.g., roadside gullies, berm breaks, waterbars or low points) where road surface and/or inboard ditch flow is discharged to tributaries of the South Fork Battle Creek (Photo 3). For sites and road segments identified as a potential or existing source of sediment delivery to the stream system, PWA staff plotted its location on laminated 1:3,000 scale GIS-generated field maps with Mylar overlays.

Photo 3. On a spur road, a washed out stream crossing and fillslope failure deliver sediment to Soap Creek (Sites #106 and #107). The road is impassable beyond this point.

PWA staff recorded a series of field observations and measurements for each inventoried erosion and sediment delivery site and hydrologically connected road segment on data forms. These forms included: (1) detailed description of the erosion site; (2) nature and magnitude of existing and potential erosion problems; (3) likelihood of erosion or slope failure; (4) length of hydrologically connected road surface, cutbank, and inboard ditch associated with the erosion site; and (5) treatments needed to prevent or minimize future sediment delivery. Field crews used GPS units to acquire accurate location data for features, and downloaded treatment feature data points to be converted to GIS spatial data.

Due to the 2012 Ponderosa Fire, increased surface runoff caused numerous areas containing hillslope rills and gullies, including sheetwash, and shallow hillslope and channelized debris flows during long duration, high intensity rainfall events. Many of the hydrologically connected road segments intercepted rejuvenated and increased upslope surface runoff and sediment movement, which increased site density along the roads. Subsequently, the road runoff volume and magnitude increased causing increased rates and volumes of runoff, soil loss, road surface erosion and sediment delivery.

For each existing or potential erosion feature along the roads (with the exception of stream crossings), PWA technical staff evaluated the potential for future erosion and sediment delivery, and collected field measurements (length, width, and depth of the potential erosion area) to derive a likely erosion volume. The field crew then estimated the proportion (percent) of the eroded sediment that would likely be delivered to a watercourse if no erosion prevention or erosion control treatments were applied. Field notes, treatment prioritization, site specific erosion volumes and field measurements are noted on our data forms and presented in Appendix B.

At each stream crossing site, field crews defined the limits of expected disturbance area. Treatments areas for stream crossing upgrade work were defined and flagged at both the upstream and downstream extent of the proposed stream crossing treatment site. A flag with a written site number was also hung along the road at each proposed treatment site. Most stream crossings in the project area were Type 1 or Type 2, with a few more complex Type 3 stream crossings[2]. PWA field crews used tape and clinometer surveying techniques at all stream crossings to develop longitudinal profiles and cross sections, and then compiled the data necessary to calculate potential sediment delivery volumes as derived from the PWA Stream[3] computer program. This proprietary software, developed by PWA, provides accurate and reproducible estimates of the potential volume of erosion at a stream crossing, whether over time or during any possible catastrophic, storm-generated wash outs. The program is also used to calculate excavation, removal, and endhaul volumes, including stream crossing reconstruction geometries and volumes for road upgrading and decommissioning projects.

An evaluation of treatment immediacy (priority) was also completed for each proposed treatment site and hydrologically connected road segment(s), based on the potential or likelihood of sediment delivery from the feature to stream channels in the project area, the expected volume and rate of sediment to be delivered to the streams, the ease and cost of accessing the feature for treatment, recommended treatments, logistics, costs, and the level of urgency for addressing erosion problems at that location. In addition, field crews measured the lengths of hydrologically

[2] Definitions for Types 1-3 stream crossings are from Weaver et al., 2006.
[2] PWA Stream for Windows v. 2.0, June 2001 / Enhancement copyright 2001; Pacific Watershed Associates Inc. / Portion copyright U.S. Department of the Interior National Park Service.

connected road surfaces and ditches to derive estimates for chronic fine sediment delivery, on a decadal basis. Field crews assigned increased site priority for road segments with evidence of significant past erosion or signs of pending failure, as well as those road reaches with the greatest length of hydrologically connected road. Some of the assessed road segments are feeding over 5,500 feet of undrained road and ditch to the stream network. Stream crossing features were additionally evaluated for potential fish barriers and passage.

5.3 Results of the Road related Sediment Source Assessment

The purpose of the field assessment was to identify and quantify all existing or potential road related features that are currently eroding and delivering sediment to streams in the Ponderosa Way project area, or show a potential to do so in the future. Features with evidence of active or potentially active erosion were individually judged as having an increased treatment priority, such as a diverted stream or long length of connected road and ditch runoff. Any on-going or potential erosion features identified in the field that did not show evidence for sediment delivery to a stream were not included in the inventory, or prescribed and prioritized for treatment. They were considered maintenance issues and not threats to water quality or aquatic habitat. However, since most of the road system is hydrologically connected to the stream network, a significant part of the road (48%) has been prescribed for road drainage improvements and sediment control treatments.

5.3.1 Summary of field data and analyses

PWA field crews identified a total of 111 erosion sites and 10.6 miles of the 22.1 miles of Ponderosa Way and spurs hydrologically connected, these road segments have the potential to deliver sediment directly to South Fork Battle Creek and its tributaries (Map 1; Table 2). We recommend that 107 of the inventoried erosion features and all of the 10.6 miles of hydrologically connected road segments be treated for sediment control and erosion prevention. Sites with a high likelihood for future erosion, such as a plugged culvert or long lengths of uncontrolled road runoff, were judged as having a high priority for treatment. Understanding the relation between the magnitude and frequency of sediment erosion and delivery and comparing that erosion to other features assessed in the watershed is the best way to determine the treatment immediacy at a sediment source site.

Stream crossings represent the majority (76%) of recommended treatment features, by number, for the assessment area (Table 2). We estimate that approximately 8,730 yd^3 of future road related sediment delivery will originate from erosion at stream crossings if they are left untreated. This represents 90% of total episodic and chronic future sediment delivery documented for the entire project area (Table 3). PWA also recommends treatment for 8 ditch relief culverts, 8 discharge points for road drainage, 6 potential fill failures, 3 springs related to the road system and 1 uncontrolled hillslope gully (Table 2). Total estimated potential episodic and chronic sediment delivery for all recommended treatment features is estimated at 9,706 yd^3 (Table 3).

Table 2. Site specific sediment delivery sites and hydrologically connected road segments recommended for treatment to reduce sediment delivery on a total of 22.1 miles of road, Ponderosa Way Road Assessment and Sediment Reduction Plan Project, Tehama County, California.

Site type	Road erosion assessment sites identified (#)	Sites recommended for treatment (#)	Hydrologically connected road segments treated (mi)
Stream crossings	85	81	8.64
Ditch relief culverts	8	8	0.90
Discharge points for road drainage	8	8	0.83
Fill failures	6	6	0.00
Springs	3	3	0.14
Hillslope gully	1	1	0.06
Total	**111**	**107**	**10.57**

Table 3. Estimated future sediment delivery for erosion sites and road surfaces recommended for treatment, Ponderosa Way Road Assessment and Sediment Reduction Plan Project, Tehama County, California.

Sediment sources	Estimated sediment savings (yd^3)	Percent of total
1. Episodic sediment delivery from road related erosion sites (indeterminate time period)		
Stream crossings	8,730	90%
Ditch relief culverts	167	2%
Discharge point for road drainage	160	2%
Fill failures	626	6%
Springs	13	< 1%
Hillslope gully	10	< 1%
Total episodic sediment delivery	**9,706**	**100%**
2. Chronic sediment delivery from road surface erosion (estimated for a 10 yr period)[a]		
Total chronic sediment delivery	**5,980**	**100%**
[a] Sediment delivery is calculated for a 10 yr period using field-measured road, ditch, and cutbank contributing areas and 1 of 10 empirical values for road surface lowering and cutbank retreat rates based on field observations and analyses by PWA staff.		

The 2012 Ponderosa Fire burned the dominate canopy cover and altered landscape conditions, which decreased rainfall interception and increased rainfall runoff rates. Of the 85 inventoried stream crossings, we identified 27 that experienced debris flows caused by increased surface runoff and elevated surface erosion rates originating in upslope burned areas. Debris flows are geological phenomena in which water-laden masses of soil and fragmented rock rush down mountainsides, funnel into stream channels, entrain objects in their paths, and form thick layers of deposition on valley floors. Stream crossings on Ponderosa Way and its spurs did not perform well during post-fire rainfall and runoff events largely because the roads were constructed to a much lower standard than is currently required for forest roads, and the crossings were inundated by water and sediment in the form of concentrated fluvial flows and viscous debris flows.

Of the 85 inventoried stream crossings in the project area, 40 stream crossings currently have the potential to divert in the future; 14 of these streams are currently diverted out of their natural stream channels. Of the 41 culverted stream crossings, 38 (93%) of the culverts are undersized and not sufficiently designed for the 100-yr peak streamflow and 27 are identified as having a high potential to become plugged by sediment and debris.

PWA field crews measured 10.6 miles of road surfaces and/or ditches that currently drain to stream channels, either directly to stream crossings or via hillslope gullies. All these connected reaches (10.6 miles) have been recommended and prescribed for treatment (Table 2). From these hydrologically connected road segments, we estimate that approximately 5,980 yd^3 of sediment could be delivered to the South Fork Battle Creek stream network, downstream of Ponderosa Way, during the next decade if no efforts are made to change road drainage patterns and disperse road surface runoff (Table 3). We emphasize that this estimate is for a 10 yr period, and over longer time periods, for example the average 30-50 yr lifespan of a stream crossing culvert, this number could be considerably greater. In addition, sediment production associated with hydrologically connected roads is predominately fine grained sediment generally less than 10mm in size. This grain size is well documented to adversely impact most instream spawning and rearing habitats utilized by salmonids.

Of the 107 inventoried erosion features that PWA has recommended for treatment, we designate 28 with priority rating of high or high-moderate (Table 4 and Maps 2, 4A-4E). For example, a high priority stream crossing (Site #63) has a plugged culvert as well as over 1,125 feet of hydrologically connected road surface contributing road runoff and eroded fine sediment to the stream. We estimate that treating this high priority erosion feature could prevent the episodic delivery of 671 yd^3 of sediment to streams, which is approximately 7% of the total site-specific, episodic sediment delivery projected for the project area. In addition to episodic sediment delivery, PWA estimates that 75 yd^3 of fine sediment chronically eroded from the adjacent road surfaces and ditches could be delivered to the stream crossing site during the next 10 years.

Most of the erosion features on Ponderosa Way and its spurs were classified as having a moderate or moderate-low treatment immediacy or priority. These included 68 sites (Table 4; Maps 2, 4A-4E) with an estimated 4,586 yds^3 of future sediment delivery, if and when they fail. Fine sediment delivery from surface erosion on the adjacent hydrologically connected road surfaces and ditches to these 68 sites recommended for treatment represents another 3,383 yds^3 of sediment delivery over the next decade. This represents about 47% of the total estimated site-specific sediment delivery, and 56% of the total estimated chronic sediment delivery, from roads in the entire project area (Table 4).

Finally, we assigned a low priority to 11 road upgrading features, including 4 stream crossings, 2 potential fill failures, one road runoff discharge point and one spring site (Table 4). We estimate that implementing erosion control and erosion prevention treatments for these features could prevent 487 yd^3 of sediment delivery to streams in the project area during the coming decades, as well as 173 yd^3 of sediment delivery during the next 10 year period from adjacent segments of eroding, hydrologically connected road, ditch, and cutbank surfaces (Table 4).

5.4 Potential stream crossing barriers to fish and aquatic organism passage

Culverts pose the most common migration barriers associated with road networks (Furniss, 1991). A total of 2 of the 111 stream crossings were identified as being on fish-bearing streams, based on existing biologic data and PWA field observations. These sites have well-built engineered bridges and do not inhibit migration of juvenile or adult salmonids.

5.5 Unusually Problematic or Complex Erosion Sites

5.5.1 Erosion sites requiring immediate treatment

Based on field data and analyses, PWA recommends treating several high priority features in the project area as soon as feasible to avoid imminent erosion and sediment delivery (Table 4, Maps 2, 3a-3e, 4a-4e). Below we present a few of the typical problems associated with high priority sites recommended for treatment:

1. Sites #26 and #27 are filled (unculverted) stream crossings with undersized concrete sills that are failing to function properly (Photos 4 and 5). Instead of having culverts, the streams flow over the road surface and spill over a concrete sill at the outside edge of the road. Both of these “wet crossings” were identified as having a high treatment immediacy. The stream crossings are located in the Soap Creek sub-basin, a major perennial tributary to South Fork Battle Creek. The slightly dipped concrete sills at these stream crossings are undersized for the design flow stream channel widths and peak flow volumes. The wet crossings are low gradient through the roadbed to allow for traffic, but also greatly reduce the natural stream channel gradient, thereby causing bedload or debris flow deposition on the road. During storm events, streamflow spreads out on the roadbed flanks the concrete sills causing gully erosion along their lateral margins. At the base of the concrete sills at the two stream crossing sites, scour holes are undermining the concrete and exposing the underlying channel bed material beneath the structures. This type of structural undermining and lateral breaching at stream crossing fills with concrete sills is common throughout the length of Ponderosa Way.

Table 4. Treatment immediacy ratings for sediment delivery sites and associated lengths of hydrologically connected road, Ponderosa Way Road Assessment and Sediment Reduction Plan Project, Tehama County, California.

Treatment immediacy	Sites and hydrologically connected road lengths proposed for treatment				Estimated future sediment delivery from inventoried erosion sites[b]		Estimated future sediment delivery from road, ditch, and cutbank surfaces[c]	
	Upgrade sites	Road length (ft)[a]	Decommission sites	Road length (ft)[a]	Volume (yd^3)	Relative percentage	Volume (yd^3)	Relative percentage
High	2 stream crossings	920	11 stream crossings, 1 ditch relief culvert	10,099	3,352	*34%*	1,259	*21%*
High-moderate	6 stream crossings, 1 hillslope gully	5,215	7 stream crossings	4,867	1,281	*13%*	1,165	*20%*
Moderate	17 stream crossings, 3 ditch relief culverts, 1 spring	13,103	13 stream crossings, 4 fill failures, 2 discharge points, 1 spring	7,602	3,549	*36%*	2,046	*34%*
Moderate-low	5 stream crossings, 3 ditch relief culverts, 1 discharge point	7,056	13 stream crossings, 1 ditch relief culvert, 4 discharge points	5,062	1,037	*11%*	1,337	*22%*
Low	2 stream crossings, 1 fill failure, 1 spring	255	5 stream crossings, 1 fill failure, 1 discharge point	1,629	487	*5%*	173	*3%*
Total	**43 upgrade sites[e]**	**26,549**	**64 decommission sites[f]**	**29,259**	**9,706**	**100%**	**5,980**	**100%**

[a] *Road length* refers to hydrologically connected road reaches adjacent to recommended treatment sites.
[b] Episodic sediment delivery for road related sites (indeterminate time period).
[c] Chronic sediment delivery from adjacent hydrologically connected roads and cutbanks (estimated for a 10 yr period).
[e] Upgrade sites (43 total): 32 stream crossings, 6 ditch relief culverts, 2 springs, 1 discharge point, 1 fill failure, 1 hillslope gully.
[f] Decommission sites (64 total): 49 stream crossings, 7 discharge points, 5 fill failures, 2 ditch relief culverts, 1 spring.

Photo 4. The concrete sill at this stream crossing (Site #26) is undersized for the peak storm flow. High flow flanks the stream crossing on the right and left hingeline. The stream has a 13.0 foot plunge off the center of the sill that has caused a scour hole and is subsequently undermining the concrete sill.

Photo 5. The concrete sill at this stream crossing (Site #27) is also undersized for the peak flows that occur at the site. High flow flanks the stream crossing on the left hingeline (right side of photo). The stream has a 14.0 foot plunge off the sill that has caused a scour hole and subsequently undermined the concrete sill.

The watershed drainage areas are relatively large (Site #26, 4.1 mi^2; Site #27, 2.8 mi^2), and peak flows impede vehicular passage in the winter (Q_{100} = 650 cfs to 910 cfs). Driving over the crossings in the winter during high flow is complex, dangerous and could pose great difficulty to navigate safely (Map 2, 3c, and 4c). There is a limited amount of driving surface over one of the eroded stream crossings (Site #26). PWA field crews repositioned a large boulder and rock and were able to crawl across the crossing in 4wd in February, 2017 (Site #27). Upgrading these stream crossings would require construction of two engineered bridges.

In addition, long lengths of hydrologically connected road surface and ditch deliver concentrated surface runoff and eroded fine sediment to the steam at these crossing sites. Hydrologically connected road lengths range from 90 feet to over 4,000 feet. The road surface and inboard ditches leading to the crossings are eroded and actively downcutting, delivering coarse sediment to the stream crossings during each runoff event.

These stream crossings should be decommissioned to reduce the threat of episodic erosion. The connected road approaches should be treated to disperse concentrated road surface runoff and to convey minor hillslope gullies directly across the decommissioned road prism. Importantly, during decommissioning the widths of the excavated (decommissioned) stream crossing channels should mimic the 100-year flow widths of the natural stream channel both upslope and downslope of the site. The road surfaces on the right and left road approaches should be treated by constructing frequently spaced cross road drains and ripping (decompacting) the roadbed to decrease concentrated road runoff and to prepare the road surface for placement of excavated fill and/or facilitate infiltration and revegetation.

Proper treatment of these high priority road reaches could prevent an estimated 340 yd^3 of chronically eroded sediment from being delivered to the stream system. Decommissioning the stream crossings includes removing the concrete sills, road fill, debris, and stored sediment upstream of each crossing. PWA field crews estimated a wash out volume for each crossing that may occur if the crossings continue to actively erode and are not treated. Site #26 is estimated to deliver 668 yd^3 and Site #27 estimated to deliver 1,209 yd^3 if no erosion control work is implemented.

2. Site #63 is a culverted (48 inch diameter) stream crossing that has washed out and is impassible by vehicular traffic (Photo 6). The culvert installed at the stream crossing was undersized for the volume of runoff, sediment, and organic debris it experienced after the 2012 Ponderosa Fire. Subsequently, the culvert plugged, due to a debris flow, forcing water over the road prism. A debris flow also caused the stream crossing to wash out. Debris flows originating from upslope burn areas have degraded long lengths of streams (2,000 to 5,500 ft) in the project area.

   The stream crossing at Site #63 is classified as having a high treatment immediacy. PWA field crews estimated that 336 yd^3 of sediment (past erosion) have washed out and already been delivered to the stream system. The estimated future sediment delivery at this location is another 671 yd^3 if the crossing remains washed out. Treating the 1,125 feet of hydrologically connected road surface with improved, dispersed drainage treatments will prevent an estimated 75 yd^3 of sediment delivery. Altogether, decommissioning the stream crossing, removing the stored sediment upstream of the culvert, and treating the road approaches will prevent an estimated 746 yd^3 of potential future erosion from entering the stream system and adding to the ongoing sedimentation and habitat degradation problems.

Photo 6. A post-fire debris flow plugged the culvert inlet at this stream crossing (Site #63). Flow overtopped the stream crossing and downcut through the road prism, washing out a large volume of sediment. Stream flow and large wood at the stream crossing culvert inlet continues to threaten the remaining, uneroded fill. Large boulders and cobbles have deposited on top of the former roadbed. Downstream, the stream channel is degraded by sediment delivered from the washed out crossing and debris flow.

3. Feature #56 is a plugged culvert (15 inch diameter) on a stream crossing that is partially washed out (Photo 7). The culvert inlet was plugged by a debris flow that overtopped the road and gullied the road prism before reentering the watercourse channel. This stream crossing has an undersized 15 inch diameter steel culvert which is currently plugged by an abundance of coarse and fine sediment. The culvert outlet is set flat and high in the fill with an 8.0 foot drop at the outlet. In general at project site stream crossings, a dramatic change (reduction) in channel gradient is one of the factors that has caused culvert plugging and subsequent stream crossing failure. This site has been evaluated as having a high treatment immediacy because a large volume of erodible road fill (future erosion) that remains at the site. It displays a high potential for complete, catastrophic failure next winter. On the right road approach, the road surface and adjacent hillslope have also been deeply eroded (gullied) by a diverted stream from Site #55.

Decommissioning this priority stream crossing by excavating and removing the remaining road fill will require approximately 8.0 hours of excavator and bulldozer work. Treating the adjacent road approaches with improved road surface drainage can be accomplished by ripping the road surface and constructing frequent cross road drains. Decommissioning this site will prevent approximately 365 yd^3 of sediment from entering the stream system.

Photo 7. A debris flow plugged the culvert inlet (note person sitting next to plugged culvert inlet) at this stream crossing (Site #56). Flow overtopped the stream crossing and deposited sediment on the surface of the road. Streamflow diverted to the left and eroded approximately 20 yd^3 of road fill before reentering the watercourse. The remaining volume of erodible material at the stream crossing is a priority for treatment (excavation) before next winter's storm events.

5.5.2 Features restricting access

PWA identified 3.3 miles of road between erosion sites #37 and #63, that are largely washed out because of debris flows (Maps 3d/4d and 3e/4e). Debris flows originating from upslope burned areas occurred within a majority of the steep, high gradient channels (22 stream crossings) that cross Ponderosa Way. Channel gradients ranged from 33% to 80% at the stream reach upslope of the road crossing, and have the capacity to transport large sized boulders, sediment and organic debris a considerable distance downstream when they are entrained in a fast moving slurry of water and mud. Where they encountered the road, nearly every culvert was plugged and engulfed with deposits of rock, sediment, debris, and wood (Photo 8). Concrete sills were overtopped by streams and flow flanked the structures along their hinglines (Photo 9). Streams were either diverted out of their natural watercourse or the crossing fill material was washed out entirely. In some cases, debris flow lag deposits replaced the road prism material, washing the culvert and concrete headwall downstream (Photo 10). Stream diversions caused the greatest amount of road related post-storm erosion, first downcutting the road alignment then

Photo 8. A debris flow plugged the culvert inlet at this stream crossing (Site #38, looking upstream at culvert inlet headwall). Flow overtopped the stream crossing, washed out (eroded) approximately 50% of the road fill material, diverted down the road alignment causing road surface gullies and hillslope erosion, and then reentered its original watercourse.

Photo 9. A debris flow plugged the culvert inlet and flanked the concrete sill at this stream crossing (Site #37). Flow overtopped the stream crossing and washed out approximately 25% of the road fill material that was then delivered to the steep stream channel. The road is impassible with vehicles or ATV's beyond this site; access to the south can be obtained only on foot.

Photo 10. A debris flow plugged the 12 inch diameter culvert and washed out this stream crossing (Site #49). Flow overtopped the stream crossing and washed out almost 100% of the road crossing fill material. Debris flow material and boulders now reside at the stream crossing. Several of the mobilized large boulders are over 5.0 feet diameter. Crossings like this should have been strongly dipped and designed to accommodate intermittent debris flows from the upslope watershed.

gullying the hillside before reentering the stream network some distance downslope. PWA field crews identified 14 stream channels currently diverted out of their natural watercourses. An enormous volume of erosion has occurred along this abandoned road segment and vehicular access was permanently terminated by the erosion events.

5.5.3 Erosion sites with a large fill volume

As previously mentioned, Sites #26 and #27 are filled (unculverted) stream crossings with large fill volumes (Photos 2 and 3). Both of these wet crossings have relatively large volumes of fill remaining at the crossing site. The large concrete sills at the outside edge of the road are overtopped and flanked during high flow events. For example, Site #26 influences the stream channel for 100 feet upstream of the roadbed with an estimated 640 yd^3 of potential future erosion and Site #27 influences the stream channel for 105 feet upstream, of the crossing with an estimated 1,199 yd^3 of potential future erosion. These sites were identified as having a high treatment immediacy because they pose a significant threat to beneficial uses and water quality.

One feature in the project area has a future chronic and episodic sediment delivery volume greater than 500 yd^3 (Site #34; Photo 11). Feature #34 is a relatively large intermittent stream with an armored fill (no culvert) that was recently reopened and maintained to gain access further south onto Ponderosa Way. The road's outer fillslope is protected with large boulders and rocks that were intended to protect the crossing fill from eroding and washing out.

Photo 11. An armored fill at a stream crossing (Site #34) was recently reopened and maintained to gain access south on Ponderosa Way. The armored fill at the stream crossing was not constructed properly, is currently slumping, and shows signs of potential failure and imminent sediment delivery. This stream crossing has the 4th largest volume of potential erosion and sediment delivery for the project area (501 yd^3).

Another large fill volume site in the project area that has an estimated future chronic and episodic sediment delivery volume greater than 278 yd^3 is Site #22 (Photo 12). Site #22 is an intermittent Class II watercourse with a concrete sill protecting the road fill. The current culvert (24 inch diameter) is set high and short in the fill and it plugged with sediment following the post-fire flooding (not visible in photo). The stream crossing's outer fillslope is protected with a concrete apron that was undersized and nonfunctional during high flows. There was also evidence of gully erosion and downcutting of the fill prism. At the base of the concrete apron high flows have created a scour hole and eroded the stream channel below its natural grade; the sill has also been undermined. The road surface at this site is unrocked and built on a low gradient road approach that has eroded and delivered fine sediment to the stream system at the crossing. Upgrading this stream crossing will prevent approximately 278 yd^3 of sediment from entering the stream system, if it were to fail entirely.

Photo 12. A debris flow plugged the 24 inch diameter culvert and flanked this stream crossing (Site #22). Stream flow then overtopped the stream crossing fill and washed out approximately 10% of the crossing material. Downstream the channel is degraded and incised.

Site #29, is a large perennial stream with a poorly installed, rusted culvert (48 inch diameter) with a concrete headwall at the inlet, a concrete outer fill (wall) for outlet stability, and a concrete apron for energy dissipation (Photo 13). The culvert is undersized for the drainage area (576 acres) and flood flows are estimated to peak at 235 cfs (Q_{100}). The culvert invert (bottom) has rusted through and there are holes derived from both rust and from sediment transport (wear) from the channel's mobile bedload. The culvert is set at a low gradient compared to the natural stream channel upstream and is set high in the road fill. In addition, the pipe is shorter than the constructed road prism and higher than the natural channel gradient. Below the outlet, the stream plunges off the concrete apron, causing stream bank erosion and a large scour hole into the original channel bed that is undermining the structure. Assuming eventual culvert and stream crossing failure, we estimate approximately 280 yd^3 of sediment would be eroded and delivered to the stream channel.

Long lengths of uncontrolled road runoff also deliver fine sediment to the stream crossing at a low point in the road. At Site #29, PWA field crews measured 2,170 feet of contributing road, of which approximately 20% is hydrologically connected to the stream network. We estimate that 107 yd^3 of potential future erosion and sediment delivery will occur from the connected road surface in the next decade if no work is done to disperse road surface runoff. We recommend decommissioning the stream crossing, decompacting the road surface, and constructing cross-road drains to prevent sediment from entering the stream system.

Photo 13. A Class II watercourse with a 48 inch diameter culvert and concrete wall protecting the culvert inlet and outlet. This is one of a few stream crossing that did not experience a debris flow. However, the culvert is undersized for the drainage area's estimated peak flows. At the outlet of the culvert, a plunge off the flow dissipation apron creates a scour hole, erosion, and sediment delivery.

5.5.4 Erosion sites with a long lengths of contributing road surface erosion

Since the 2012 Ponderosa Fire, much of the road system requires careful navigation to pass in a 4wd vehicle and is impassable by 2wd vehicles. Many sites contain uncontrolled road surface runoff that collects and concentrates on the road bed and has created locally deep and continuous gullies down the center of the road while delivering turbid, sediment-rich runoff to local streams (Photo 14). Road surface gullies are relatively large and have downcut deeply into the road surface, exposing the erodible road bed. Rills convey surface runoff and fine sediments, much of which is eventually delivered to the stream network. Ditches intercept hillslope runoff and transport sediment to streams. In areas with high vehicular use, erosion and sedimentation rates can increase and also impact the stream network wherever the road or ditch is hydrologically connected to a stream.

A through-cut road will collect a large volume of rainfall (Site #4). Berms or cuts on both sides of the road trap road surface runoff until it eventually forms rills and gullies. At Site #4, PWA field crews measured 5,000 feet of hydrologically connected road and estimate that 300 yd^3 of potential future erosion and sediment delivery will occur in the next decade if no road drainage improvements are performed. This road segment has been recommended for road upgrading. In general, especially on high use road segments, road surfaces will need to be upgraded by reshaping and construction of road drainage structures (e.g., rolling dips and ditch relief culverts) to disperse road surface runoff sufficient to prevent road surface and fillslope gullying and to improve long term, dispersed road drainage. Road upgrading techniques are described in

Photo 14. Road surfaces, berms and ditches capture and transport hillslope runoff and direct rainfall during storms. Road surface and ditch runoff often flow down the road grade and directly into stream crossing culvert inlets. This photo shows a long road segment with uncontrolled road runoff during a rainfall event. The road surface is unrocked and sediment is eroded and transported in several rills and gullies down the road. This road segment is without a drainage point for over 5,900 feet. The sediment that is in transport and eventually delivers fine road related material to a stream crossing located at Site #4.

Appendix A, site-specific treatments recommendations are shown in Appendix B, and typical design drawings are shown in Appendix C.

Significant end-goals of the project are to achieve more normalized hillslope drainage and to hydrologically disconnect Ponderosa Way and its spurs from tributaries to South Fork Battle Creek to the extent feasible. Reducing the length of hydrologically connected road (currently 10.6 miles) will directly and immediately improve water quality in South Fork Battle Creek. Improving and dispersing road surface runoff will also protect the integrity of the roadbed and minimize erosion and off-site, downstream sediment pollution and habitat degradation. For example, at Site #27, road surface runoff on an approach to a stream crossing exits the road at a waterbar, flows over the steep road fill, and thereby directly delivers eroded sediment to the stream channel downslope (Photo 15). This road segment has over 4,000 ft of hydrologically connected road surface and an estimated 235 yd^3 of potential chronic erosion and sediment delivery over the next decade if no erosion control and road drainage improvements are implemented.

Photo 15. At Site #27, a long road segment concentrates road runoff inside the ditch on the inside of the road. During storms, the road surface and inboard ditch transports runoff and sediment to the stream network. Concentrated road surface and ditch runoff flows down the road with increasing velocity and discharge, creating surface erosion, rills and small gullies. In this photo, the runoff is focused in the ditch along the inside of the road; when it encounters a waterbar, the runoff exits road delivering fine sediment to Soap Creek at the base of the road fill.

Many of the road segments identified as a problem in the project area intercept hillslope runoff from slopes burned in the 2012 Ponderosa Fire (Photos 16 and 17; Site #39). Wherever a hydrologic connection exists, road surface runoff and fine sediment is delivered to streams every time there is a rainfall event sufficient to produce surface runoff and cause erosion of bare soil areas. Concentrated runoff on compacted surfaces and ditches results in erosion and road related sediment transport to nearby streams. At Site #39, PWA field crews measured 270 feet of hydrologically connected road and estimate that 36 yd^3 of potential future erosion and sediment delivery will occur if no work is done. This road segment is recommended for road decommissioning.

Photo 16. Roads that are flat in cross section, with an outside berm and inside ditch, intercept upslope runoff and do not allow the runoff to leave the road. At Site #39, a long road segment intercepts hillslope runoff that has increased due to the 2012 Ponderosa Fire. Uncontrolled road runoff during a storm eroded the road surface and transports concentrated runoff and eroded sediment to the nearby stream network. In this photo, the runoff is trapped by a berm on the outer edge of the road and sediment is transported in several large rills and gullies down the roadbed until it leaves the road prism.

Photo 17. On Ponderosa Way, a berm has formed after years of routine grading and road surface erosion. The berm captures and concentrates road runoff, preventing it from being dispersed onto the hillside, and accelerates road surface and ditch erosion rates. Rills and gullies have formed in the roadbed and increase in size each storm. Sediment delivered from these gullies can be prevented by dispersing runoff in more frequent locations through road surface outsloping or construction of rolling dips and ditch relief culverts.

5.5.5 Erosion sites with post fire effects

The 2012 Ponderosa Fire burned 27,676 acres of steep, mountainous forest lands causing widespread effects that accelerated surface runoff and increased hillslope erosion rates. Flames and the heat from the wildfire had a high intensity that burned the tree canopy and woody plant understory; whole trees were burned to the ground, including low growing woody plants and grasslands, thereby exposing the underlying, erodible soils and weathered parent materials. The loss of vegetative cover is evident in post-fire aerial photos and digital imagery. Tree canopy and vegetated understory were lost in the fire, which decreased rainfall interception and thereby increased hillslope runoff rates and fine scale drainage densities. This, coupled with salvage logging, in turn, caused increases in peak flows at the landscape scale upslope of Ponderosa Way. Increased peak flows and high rates of surface runoff and erosion eventually triggered debris flows, caused culverts to plug, and initiated uncontrollable hillslope gullying, fillslope failures and an overall increase in the magnitude of erosion and sediment delivery.

Site #104 is a filled (unculverted) stream crossing that was constructed without a culvert and that subsequently washed out after recent storm events. Without a culvert, the stream crossing site could never function properly (Photo 18). Site #103 is a fillslope failure (shallow debris slide) that was triggered by accelerated runoff and hillslope gullying from upslope runoff. Both of these sites were identified as having a moderate treatment immediacy. The stream crossing is located in the Soap Creek sub-basin, a major tributary to South Fork Battle Creek. This type of post-fire effect on hillslopes, stream crossings, and unstable fillslopes are common throughout the length of Ponderosa Way and its spur roads in the project area.

Photo 18. Site #104 is a washed out stream crossing that delivered approximately 110 yd^3 of eroded sediment to the Soap Creek stream system. This spur road has a buried 12 inch diameter waterline that diverted stream flow in the past, before the failure occurred. In the photo's foreground, two upslope gullies caused fillslope erosion and eventual failure of the fill along the outer edge of the road prism, causing an estimated 84 yd^3 of erosion and sediment delivery.

Perhaps the most insidious source of sediment from road systems in the Ponderosa Fire area is surface erosion and fine sediment delivery from road surface runoff and road drainage, as well as from the high rate of upslope surface runoff and sheet erosion that is intercepted by the road alignment. Road surface erosion is a chronic source of sediment supply to streams in all the affected watersheds, and it occurs wherever roads are drained to stream channels through road surfaces, ditches or other drainage features (Photo 19). It occurs not just during large storms, but every time there is surface runoff from the roads and ditches (Photo 20). In addition, where roads are insloped or bermed, road drainage released on steep hillslopes causes gullying and sediment delivery (e.g., gullying below ditch culverts). Although some roads are properly outsloped and frequently drained, 48% (10.6 miles) of the inventoried road network is currently "hydrologically connected" to the stream network and currently delivering road runoff and eroded fine sediment to watercourses. Over the next decade, unless road surface drainage treatments are applied, we estimate that well over 6,000 yd^3 of fine sediment will be delivered to the stream system from these "connected" road reaches, thereby continuing to degrade downstream salmonid spawning and rearing habitat. Proposed treatments are straight forward and relatively inexpensive, consisting of installing road drainage structures that disperse runoff and "disconnect" the road drainage system from the natural stream channel network.

Photo 19. Ditches convey road surface runoff and intercept hillslope runoff from burned and unburned slopes. Ditches transport concentrated runoff directly to watercourses, increasing stream channel peak flows and sedimentation rates. These hydrologically connected road segments increase the magnitude and duration of turbidity and fine sediment delivery during both high and low intensity runoff events.

Photo 20. The roads in the Ponderosa Fire area are underlain by highly erodible and locally unstable geologic substrate, and both field observations and analysis of aerial photographs suggest that roads have been a significant source of accelerated sediment production from the burned areas. Wherever maintenance of road drainage features is lacking in the burned area, sediment production from roads is likely to stay at relatively high levels.

Major sources of upslope sediment production and delivery from the Ponderosa Fire area include widespread rilling of bare soil areas, gullying, channel incision, and channelized debris flows from the burn area that was salvage logged after the fire. The debris flows are an episodic source of sediment supply to streams in all the affected sub-watersheds. The denudation caused by both wildfire and ground disturbance by salvage logging and fuel break construction appear to be causative factors. These were especially important where they occurred immediately upslope from Ponderosa Way and were located on steep, bare hillslopes (Photo 21). Most erosion and debris flow activity occurred during large storms between 2012 and 2016 (Photos 21-27). In addition, where roads intercepted (blocked) the path of a debris flows, stream diversions occurred wherever sediment and debris plugged culvert inlets and diverted streamflow to one side or another. Although some roads and stream crossings are completely washed out, some of the debris flow fans and fan deposits remain on the road surface (Photo 21).

Photo 21. A debris flow deposited on the road at the abrupt change in channel grade (Site #57). The debris fan deposit on the road surface blocks vehicular access. Most of the material is composed of small angular material mixed with fines from post fire runoff. Flow overtopped the stream crossing and washed out approximately 20% of the road crossing material. Subsequent streamflow down these channels will either be diverted down the adjacent road bench and create a new channel (gully) down the hillslope, or it will eventually erode through the remaining road fill and debris flow deposit as it exhumes and reestablishes the original stream bed.

Photo 22. A Class III watercourse with a washed out 15 inch diameter culvert. The culvert was plugged by a small debris flow that subsequently caused overtopping and the erosion of the road fill (Site #40). The road is impassible beyond this site. We estimate that there is an estimated 161 yd^3 of future erosion associated with the site.

Photo 23. A Class III watercourse that experienced a debris flow that overtopped the road and caused channel incision and deleterious downstream effects (Site #57). Approximately, 20 yd^3 of road fill eroded and washed downstream. We estimate that there is approximately 62 yd^3 of future erosion associated with this site.

Photo 24. A debris flow containing very large boulders washed out Ponderosa Way and made it impassible beyond this point (Site #55; note person for scale). The undersized culvert at the crossing was plugged and the stream diverted down the road, causing significant hillslope gullies and sediment delivery. It was estimated that 80% of the road prism was washed away and replaced with debris flow materials, including very large boulders.

Photo 25. A debris flow washed out Ponderosa Way at this site and made it impassible beyond this point (Site #52). The undersized culvert was engulfed by the debris flow deposit and quickly plugged. It was estimated that 15% of the road prism washed away. PWA field crews measured the crossing geometry and estimated that 174 yd^3 of potential future erosion and sediment delivery is likely to occur if decommissioning the crossing is not completed in a timely manner.

Photo 26. A Class II watercourse with an undersized culvert and stone revetment work (Site #51). A debris flow in this steep channel flowed over a 75 foot tall cliff. We estimated that 25% of the crossing washed out and 76 yd^3 of future potential erosion and sediment delivery remain at the site if it is not decommissioned.

Photo 27. A debris flow with very large boulders washed out Ponderosa Way at Site #53. The original, undersized culvert plugged and failed. The stream diverted down the road, causing hillslope gullies and additional sediment delivery. PWA field crews estimated that 75% of the road prism was washed away by the debris flow.

6 RECOMMENDED TREATMENTS

PWA recommends 21 different types of erosion control and erosion prevention treatments for the 22.1 miles of the Ponderosa Way project area. A long term transportation plan has not been developed for the project area so a preferred alternative was tentatively selected. The preliminary overall design plan calls for 9.4 miles of road upgrading and 12.7 miles of road decommissioning. For Ponderosa Way, approximately 1.9 miles to the north and 3.1 miles to the south has been recommended for road upgrading; the remainder of the route has been recommended for decommissioning. All spur roads (8.4 miles) were recommended for road decommissioning. The higher initial costs of designing and upgrading a road that weathers well or decommissioning unused or unmaintained road segments can be amortized by lower future maintenance costs (Furniss, 1991). Treatments for Ponderosa Way and its spur roads are organized into 2 categories (site-specific treatments (e.g., stream crossings) and road surface drainage treatments (see Table 5). In addition to the treatment summaries in Table 5, detailed treatment information is included in the assessment database. Site-specific treatment recommendations, data, and overviews of construction and installation techniques for Ponderosa Way and the spur roads in the project area are provided in Appendixes A, B, and C.

Unlike many watershed improvement and restoration activities, erosion prevention through “storm-proofing” and decommissioning forest roads provides immediate benefits to the streams and aquatic habitat of a watershed. Road decommissioning measurably diminishes the impact of road related fine sediment erosion on the biological productivity of the watersheds’ streams while protecting streams from catastrophic road failures and sediment inputs during flood events.

Table 5. Recommended erosion control and erosion prevention treatments, Ponderosa Way Road Assessment and Sediment Reduction Plan Project, Tehama County, California.

Treatment type			No.	Comments
Site feature specific treatments	Stream crossing treatments	Culvert (install)	2	Install 2 culverts at unculverted fills (Site #: 73, 93)
		Culvert (replace)	13	Replace 13 undersized, poorly installed, or worn out culvert (Site #: 3, 13, 14, 15, 16, 17, 64, 65, 75, 95, 96, 97, 98)
		Bridge installation	1	Install 1 bridge to prevent crossing failure (Site #18)
		Wet crossing	14	Install 2 ford crossings (Site #: 6, 7) and 12 armored fill crossings using 409 yd^3 of riprap and rock armor (Site #: 4, 5, 8, 9, 10, 11, 12, 19, 21, 22, 23, 71)
		Decommission crossing	49	Decommission stream crossing by removing all fill and wood material and restoring natural channel morphology and function to convey 100-year storm flow.
		Critical dip	11	Install 11 critical dips to prevent stream diversions.
	Other	Rock (armor)	17	At 17 sites, add a total of 593 yd^3 of rock armor on headcuts and inboard and outboard stream crossing fillslopes.
		Clean culvert	1	At 1 site, clean the culvert inlet to regain inlet capacity and pass stream flow (Site # 17)
		Soil excavation	85	At 85 sites, excavate and remove a total of 21,801 yd^3 of sediment, primarily at fill failures and stream crossings.
Road surface treatments		Outslope road and remove ditch	23	At 23 locations, outslope the road and remove or fill the inboard ditch for a combined treatment length of 15,222 feet.
		Inslope road	3	At 3 locations, inslope the road for a combined treatment length of 525 feet.
		Crown road	2	At 2 locations, inslope the road for a combined treatment length of 3,825 feet.
		Ditch relief culvert	3	At 3 locations, replace the current ditch relief culverts with properly installed ditch relief culverts.
		Ditch relief culvert downspout	1	Install 1 downspout on a ditch relief culvert outlet to prevent fillslope erosion.
		Remove berm	24	At 24 locations, remove the berm on the outboard edge of the road for a length of 14,865 feet.
		Remove ditch	1	At 1 location, remove the inboard ditch for a length of 1,450 ft.
		Rolling dip	134	Install 134 rolling dips on hydrologically connected roads to improve road surface drainage.
		Clean and cut ditch	4	At 4 locations, clean and cut inboard ditch for a combined treatment length of 2,050 feet.
		Cross-road drain	624	Install 624 cross-road drains to improve and disperse surface runoff on decommissioned roads.

Table 5. Recommended erosion control and erosion prevention treatments, Ponderosa Way Road Assessment and Sediment Reduction Plan Project, Tehama County, California.

Treatment type		No.	Comments
	Rock road surface	8	At 8 locations, rock the specified road length using 126 yd^3 road rock
	Rip road surface	12.70 mi	Decompact approximately 12.70 mi of existing road surface with bulldozer rippers to prepare the road surface for placement of excavated fill and/or facilitate water infiltration and revegetation.

These treatments allow future storm runoff to cleanse the streams of accumulated coarse and fine sediment under improved habitat conditions, rather than allowing continued sediment delivery from managed areas to impaired watercourses. Utilizing the upslope road assessment and treatment action plan, the Regional Board and watershed stakeholders can work together to use the treatment action plan to prioritize extensive restoration and sediment control activities within the watershed that would greatly accelerate rates of downstream water quality improvement and habitat recovery.

6.1.1 Site-Specific Treatments

Stream crossing upgrade treatments are primarily implemented to reduce the risk of catastrophic failure and sediment delivery resulting from gullying, headcut migration, stream diversion and stream crossing failure (washout). Stream crossings should be designed (or redesigned) to minimize impacts to water quality and to handle peak runoff and flood waters. There are three basic subcategories of permanent stream crossings; 1) bridges and arches, 2) fords and armored fills, and 3) culverts. PWA recommends that 43 inventoried erosion features (sites) be upgraded and 64 inventoried erosion features (sites) be decommissioned (Map 2; Table 5). Each recommendation is dependent on a number of factors and elements that were considered before selecting the preferred alternative, final treatment prescriptions and comprehensive treatment action plan. New stream crossing upgrades are designed to follow current standards and make future failures less likely to occur. Treatments will reduce the vulnerability of stream crossings to failure (overtopping and washout) and eliminate the risk of stream diversion.

Recommended treatments for road upgrading include replacing (upsizing) undersized culverts at 13 stream crossings and installing 2 culverts at unculverted (filled) stream crossings. In these locations, our treatment recommendations are suitable and have the appropriate design geometry for installing a new culvert or replacing the current culvert with a new culvert. All new stream crossing culvert installations should be properly sized for the 100-year recurrence interval design streamflow discharge (Table 5; Appendix A). As previously mentioned, stream crossings that are designed to meet the minimum standards and basic design criteria will significantly reduce the risk of catastrophic failure and sediment delivery.

Road upgrading treatments also include constructing 2 ford crossings and 12 armored fills in locations that are suitable for wet crossing construction. A ford is built to convey stream flow across the roadbed with no fill to the natural channel below the roadbed, and an armored fill crossing is built to convey stream flow directly across the roadbed and down an armored fillslope to the natural channel below. Generally, a ford and an armored fill crossing is intended for low-volume traffic areas, such as remote wildland roads and parklands experiencing little use. Fords and armored fills are a good design for small ephemeral and intermittent streams when the majority of the traffic will be crossing during low flow or dry conditions (Weaver et al., 2015). When designed and properly built, fords and armored fill crossings are a good option for low volume, low maintenance, low use routes, such as Ponderosa Way and the associated spur roads.

Stream crossings that display a diversion potential occur wherever the road climbs through the crossing site and where the road approach slopes away from the stream crossing. If the culvert plugs, the backed up flood waters will be diverted out of the channel, down the road alignment and eventually onto adjacent, unprotected hillslopes. A major dip in the roadbed is critical, in the case of a plugged culvert, to direct flow over the low point (dip) in the fill and back into the natural channel. A total of 11 critical dips or dipped fills are proposed for construction at stream crossings to prevent future stream diversions.

A total of 17 stream crossing fills that were designed with fillslope angles greater than 50% (2:1) will be armored using 593 yd^3 of riprap and rock armor to provide increased fillslope stability and erosion prevention. Compaction of the fillslope face and slope gradient is one of the key factors that influence the stability of fillslopes. On fillslope angles steeper than 50% (2:1), riprap is used as a stabilization measure as well as a non-erodible erosion control “mulch” on fillslopes that lack vegetation. Used as mulch, riprap prevents raindrop erosion, rilling and gullying that could be caused by direct rainfall or concentrated road surface runoff. Fillslope riprap armor has been sized according to expected stream velocities and slope gradients, it should consist of well-graded mixture of hard, large to smaller rock sizes to minimize void space and create a dense layer of interlocking angular rock fragments.

Recommended treatments to decommission sites on roads that are to be closed include: decompacting and/or outsloping the former road bed and installing cross road drains to prevent collection, concentration or diversion of surface runoff; removing (excavating) unstable or potentially unstable fill (sidecast materials) that could fail and deliver sediment to a steam; excavating stream crossing fills and exhuming the original stream channel bed and stable sideslopes; removing concrete sills; and applying erosion control (seeding and mulching) to bare soil areas disturbed by the work.

Decommissioning stream crossings follows the following standards and provides certain benefits: (1) complete removal of stream crossing road fills and stored sediment that has impacted the natural stream channel morphology (see typical drawing for stream crossing decommissioning), (2) excavated channel bottom widths sized for the 100-year storm flood flow and at least as wide as the undisturbed natural stream channel, (3) stable channel grades and streamside hillslopes, (4) elimination of stream diversion potential, and (5) prevention of future stream crossing wash outs and gullying of abandoned stream crossing fills.

In addition, we propose treating 6 unstable fillslope (landslide) features which represent existing and pending road fill failures. We estimate that, if left untreated, approximately 626 yd^3 of sediment would be mobilized and delivered to the stream channel from these potential fillslope failures. This represents 6% of the projected future sediment delivery from all point source erosoin features for the project area (Table 3).

Most of the Class II watercourses proposed for upgrading or decommissioning will require dewatering, using either gravity fed flex pipe or a gas powered pump and coffer dams. CDFW standards detailed in the CDFG Salmonid Habitat Restoration Manual, Part X: *Upslope Erosion Inventory and Sediment Control Guidance* will be followed.

6.1.2 Road Surface Treatments

Significant goals of the project are to achieve more normalized hillslope drainage and, to the extent feasible, to hydrologically disconnect Ponderosa Way and its spur roads from tributaries to South Fork Battle Creek. A "hydrologically connected" road or road segment has been defined as: "Any road segment that has a continuous surface flow path to a natural stream channel during a runoff event" (Furniss et al., 2000).

Wherever a hydrologic connection exists, road surface runoff and fine sediment is delivered to streams every time there is a rainfall event sufficient to produce surface runoff and cause erosion of bare soil areas. Concentrated runoff on compacted road surfaces and ditches results in erosion and road related sediment transport to nearby streams. The most common road related bare surface areas include unpaved road surfaces, as well as bare (unvegetated) fillslopes, cutbanks, ditches, gullies and landslide surfaces. PWA identified and mapped 48% of Ponderosa way and spurs (10.6 miles) as being hydrologically connected to local stream channels.

The road surface drainage treatments PWA has proposed for upgraded roads are designed to control, direct and disperse road surface runoff and ditch flow onto adjacent hillslopes by reshaping the roadbed and constructing relatively frequent road surface drainage structures (e.g., rolling dips). Road segments proposed for decommissioning are designed based on the same principals of dispersing road surface runoff by constructing cross road drains and increasing infiltration rates by decompacting the road surface. These techniques act to disperse road surface runoff and reduce or prevent delivery of concentrated road runoff and fine sediment to streams (Weaver et al., 2015).

Road surface upgrading treatments are designed to redirect and disperse surface runoff off the road bed as frequently as feasible. Road upgrading recommendations include outsloping, insloping, berm removal, and installing rolling dips and ditch relief culverts to more frequently discharge runoff along segments of Ponderosa Way. For each recommended road surface drainage treatment where ground disturbance will occur, we also estimated the volume and trucking cost to apply road rock to stabilize the road surface. This will curtail road surface erosion by fortifying the road surface and reducing the rate of vehicle abrasion, downwearing, surface erosion, and resultant fine sediment production and delivery. A total of nearly 8,882 yd^3 of base rock will be used to treat the road surface where road upgrading (reshaping and/or drainage structure construction) has been recommended.

Road surface decommissioning treatments are designed to prevent surface runoff by ripping the road surface to an average depth of 18 inches to 24 inches to increase infiltration rates and improve revegetation. In addition, road drainage will be dispersed by constructing frequent cross road drains to convey upslope runoff quickly across the road and to more frequently discharge runoff along segments of Ponderosa Way.

Reducing the length of road (decommissioning 10.6 miles) and number of road segments that are hydrologically connected to streams will directly and immediately improve water quality in South Fork Battle Creek. The basic principles of road surface drainage design calls for dispersing runoff as frequently as possible, protecting the integrity of the road and minimizing erosion and sediment pollution. As shown in Table 5 and Appendix C, the primary recommended road surface drainage treatments for upgrading Ponderosa Way include:

1) Outsloping 15,222 feet of road by removing the inboard ditch.
2) Crowning 3,825 feet of road by directing surface runoff to the outer edges of the road.
3) Installing 134 rolling dips.
4) Removing the outside road berm for a total of 14,865 feet.

For Ponderosa Way, outsloped roads with rolling dips and no ditch or berms along the outside edge of the road are considered the best, most preferred road shape and drainage configuration for the majority of road upgrading circumstances. Over 15,200 feet of Ponderosa Way is suitable and has been recommended for road outsloping (Figure 7). Each segment of outsloped road will have the outside berm removed and will be resurfaced with road rock. An outsloped road cross section is likely to capture and disperse road surface runoff. It has less environmental impact and lower maintenance costs than other designs. Outsloping high priority road segments of Ponderosa Way will minimize flow volumes and the magnitude of runoff in the inside ditch, as well as reduce the potential for erosion, hydrologic connectivity and sediment delivery from the upgraded road surface. An outsloped road ensures that turbid road runoff and fine sediment eroded from the roadbed will be quickly drained to the outside edge of the road where it can be safely discharged onto vegetation and into undisturbed slopes (see Appendix C for typical design drawings).

However, outsloping is not always enough to get surface runoff out of wheel ruts and off the road rapidly. In this case, in addition to outsloping and berm removal, rolling dips will be necessary to disperse surface runoff from outsloped roads. Rolling dips and a smooth, outsloped road surface are critical to maintaining a well-drained, outsloped road. A total of 134 rolling dips are recommended to treat high priority, hydrologically connected road segments on Ponderosa Way. Rolling dips are smooth, angled depressions constructed in the road bed that drain the surface runoff to the outside of the road and disperse it onto the native hillside. Dips should be constructed deep enough into the road subgrade with an outsloped dip axis and long, shallow approach on their up-road side and a more abrupt rise, or reverse grade, on their down-road side (Weaver et al., 2015). PWA designed rolling dip spacing dependent on the grade of the road, length of uncontrolled runoff, the erodibility of the road surface (e.g., rocked or native) and the proximity of the nearest stream channel.

In addition secondary recommended road surface treatments for upgrading selected portions of Ponderosa Way are shown in Table 5 and Appendix C, and include:

1) Installing 3 ditch relief culverts and installing 1 ditch relief culvert downspout.
2) Insloping 525 feet of road in 3 locations.
3) Cutting and cleaning 2,050 feet of existing inboard ditch in 4 locations.
4) Applying a total of 126 yd^3 of road rock at 8 sites on existing rocked roads.

As shown in Table 5 and Appendix C, the primary recommended road surface treatments for decommissioning Ponderosa Way and the spur roads include:

1) Installing 624 cross road drains to improve and disperse drainage.
2) Ripping (decompacting) 12.7 miles of road to reduce (eliminate) surface runoff and encourage native revegetation.

6.2 Heavy Equipment and Labor Requirements

Equipment needs for erosion control treatments in the assessment area are detailed in the project database and summarized, based on treatment prioritization, in Table 6. Most treatments require the use of heavy equipment, including an excavator, bulldozer, dump trucks, grader, roller, water truck and others. Some hand labor is required for installing culverts and applying seed and mulch to ground disturbed during heavy equipment operations. Equipment needs are reported as equipment times, in hours, to treat all features and road segments. These estimates only include the time needed for the actual treatment work, and do not include additional construction activities such as constructing temporary access at washed out stream crossings, staging equipment and materials at work sites, installing temporary erosion control measures, sediment barriers and traps, or traveling between work sites.

PWA estimates that erosion control and erosion prevention remediation on Ponderosa Way and the spur roads will require 821 hr. of excavator time and 1,112 hr. of bulldozer time (Table 6). Dump truck operators will require almost 377 hr. to transport excavated fill to appropriate spoil disposal locations, as well as time for importing 8,882 yd^3 of road rock and 1,002 yd^3 of riprap to specific locations proposed for road upgrading. Water truck operators will require approximately 83 hr. for stream crossing backfill compaction and 34 hr. for dust abatement during final road grading. Finally, approximately 452 hr. of labor time will be required for feature-specific tasks and an additional 341 hr. for various tasks, including transporting materials, spreading straw mulch and erosion control seed, and final stabilization (not included).

Table 6. Estimated heavy equipment and labor requirements based on treatment immediacy, Ponderosa Way Road Assessment and Sediment Reduction Plan Project, Tehama County, California.

Treatment immediacy	# of sites	Excavated volume[a] (yd^3)	Excavator (hr)	Bulldozer (hr)	Labor (hr)	Water truck (hr)	Dump trucks (hr)
High or High moderate	28	8,805	320	377	110	17	226
Moderate or moderate-low	68	11,729	463	680	179	63	147
Low	11	1,267	38	55	163	3	4
Total	**107**	**21,801**	**821**	**1,112**	**452**	**83**	**377**

Note: Equipment and labor times do not include hours necessary for logistics, opening or ripping roads, traveling between sites, unloading culvert materials, hauling road rock or riprap, or spreading seed, straw and mulch. These hours are included as line items in Table 7.

[a] Excavated volume includes material permanently removed and stored.

To minimize post-construction erosion, all bare soil areas not on the road bed or ditch will be seeded with native grasses appropriate for the area. In addition, bare soil areas with any risk of sediment delivery should be mulched with weed-free straw to prevent post-construction surface erosion and sediment delivery until vegetation is established. As a final step in the completion of this project, approximately 1,743 trees and native woody plants will be planted within the disturbed work area. These trees will be planted to replace trees lost during the upgrading process, stabilize the freshly excavated fillslopes and stream banks, and provide future riparian cover over tributary streams to South Fork Battle Creek.

6.3 Final Upslope Implementation Budget

Estimated Road Treatment Implementation Costs

The estimated total cost to implement the recommended erosion control and erosion prevention treatments for 22.1 miles of Ponderosa Way and spurs is approximately $1,832,000 (Table 7). Approximately $366,400, or 18% of the total project cost, is projected for contracting, coordination, treatment layout, construction management, data analysis and cost tracking, implementation monitoring and final reporting. Costs detailed in Table 7 also include expenses for the use of lowboy trucks to haul construction equipment to and from the work area (footnote "6"); truck/trailer time for delivering straw mulch and culverts to work features (footnote “8”); Water truck time required for road upgrading treatments, including final road grading (footnote “9”); and labor time for seeding and spreading straw mulch for erosion control (footnote “10”).

Most of the treatments listed in the treatment action plan are not complex or difficult for equipment operators with experience in road upgrading and decommissioning operations on forestlands and rangelands. The costs in Table 7 are assumed reasonable if work is performed by experienced private sector contractors, and there is no added overhead for contract administration and pre- and post-project surveying. It is assumed contractors will be used on a time (hourly rental rates) and materials basis, as this will reduce pre-construction survey staking and contract development while at the same time increasing flexibility in adapting treatments, as needed, based on specific site conditions. The use of inexperienced operators or the wrong combination of heavy equipment would require additional technical oversight and supervision in the field, as well as an escalation of the costs to implement the work. To help insure success of the project, it is imperative that only the most experienced and reliable heavy equipment operators be employed under the supervision of a professional geologist or erosion control specialist experienced in road upgrading and decommissioning treatments and construction management, and that the project coordinator is on-site full time at the beginning of the project and intermittently after equipment operations have begun.

Table 7. Estimated logistic requirements and costs for road related erosion control and erosion prevention work on all inventoried sites with future sediment delivery, Ponderosa Way Road Assessment and Sediment Reduction Plan Project, Tehama County, California.

Cost Category[1]		Cost Rate[2] ($/hr)	Estimated Project Times			Total Estimated Costs[5] ($)
			Treatment[3] (hours)	Logistics[4] (hours)	Total (hours)	
Move-in; move-out[6] (Low Boy expenses)	Excavator	135	12	-	12	1,620
	Bulldozer	135	12	-	12	1,620
	Pilot car	60	24	-	24	1,440
	Dump truck	155	24	-	24	3,720
	Roller	135	12	-	12	1,620
	Water truck	145	12	-	12	1,740
	Grader	135	12	-	12	1,620
	Truck/trailer	95	12	-	12	1,140
Road opening[7]	Excavator	218	44	-	18	9,592
	Bulldozer	190	44	-	18	8,360
Heavy Equipment[8] requirements for feature specific treatments	Excavator	218	786	236	1,022	222,796
	Bulldozer	190	689	207	896	170,240
	Dump truck	155	396	119	515	79,825
	Roller	150	12	4	16	2,400
	Water truck	145	29	9	38	5,510
	Truck/trailer	95	147	44	191	18,145
Heavy Equipment[9] requirements for road drainage treatments	Excavator	218	61	18	79	17,222
	Bulldozer	190	489	147	636	120,840
	Roller	150	142	43	185	27,750
	Water truck	145	88	26	114	16,530
	Grader	176	34	10	44	7,744
Laborers[10]		85	793	238	1,031	87,635
Mulch and seed materials for 12.6 acres of disturbed ground[11]						10,322
Rock costs (8,882 yd^3 of road rock and 1,002 yd^3 of riprap)						494,220
Culvert costs (120' of 18", 530' of 24", 220' of 30", 40' of 36", and 500' of 6" flex pipe, including costs for couplers etc.)						38,841

Bridge (40 ft) for Bluff Springs (Site #18) plus materials	50,000
Permit fees [13]	40,000
Riparian replanting costs[12]	12,590
Erosion control material and small equipment rental (geofabric, silt fence, vibratory compactor, pressure washer, pumps, etc.)	10,460
PWA Technical Oversight, including Layout, Coordination, Supervision, Reporting and associated costs[14]	366,386
Total Estimated Costs	**$1,831,928**

[1]Costs excluded from the list are for (1) tools and miscellaneous materials and (2) variable TCRCD administration and contracting expenses.

[2]Heavy equipment costs include operator and fuel. Costs listed are estimates based on favorable local private sector prevailing wage equipment rental and labor rates.

[3]Treatment times refer to equipment hours expended explicitly for erosion control-and-prevention work at all project sites, roads and opening access.

[4]Logistics times for heavy equipment (30%) include all equipment hours expended for opening access to sites on maintained and abandoned roads, travel time for equipment to move from feature to feature, and conference times with equipment operators to convey treatment prescriptions and strategies. Logistic times for laborers (30%) include estimated daily travel time to project area.

[5]Total estimated project costs for equipment rental and labor are based on local private sector prevailing wage equipment rental and labor rates. Materials costs are subject to change.

[6]Move in/move out costs are based on specific sub-contractor conditions at individual work areas for excavator, bulldozer, grader, roller, dump trucks, water truck, and truck/trailer.

[7]Road opening costs are applied to open access for dump trucks, clearing spoil areas and brushing alignments where earth moving is slated to take place.

[8]An additional 140 hr of truck and trailer time are added for delivering straw to sites. A total of 7 hr of excavator and truck and trailer time are added for loading and delivering culverts. An additional 19 hr of excavator and dump truck time are added to generate and deliver fill required to backfill culvert upgrades.

[9]An additional 34 hr of water truck, grader, and roller time are added for dust abatement and final grading on selected roads. In addition, 66 hr of dozer time is added for ripping decommissioned roads.

[10]An additional 341 hr of labor time are added for spreading straw mulch and seeding. This includes 140 hr of labor for initial delivery of straw to all work sites.

[11]Seed costs are based on 50 lb of erosion control seed per acre at $12/lb. Straw needs are 50 bales per acre at $8/bale. Labor time for straw mulching and seeding is $50/hr.

[12]The CDFW Fisheries Restoration Grant Program programmatic General Regional Permit requires replanting within the “riparian corridor” along disturbed work sites. Estimated costs are included to replant disturbed and compacted riparian areas after heavy equipment work is completed.

[13] Grant programs require state, county and federal applications and permit fees.

[14]Supervision time includes detailed layout (flagging, staking, etc.) prior to equipment arrival, training of equipment operators, supervision during equipment operations, supervision of labor work, and post-project documentation and reporting.

7 CONCLUSIONS

At the request of Central Valley Regional Water Quality Control Board and Tehama County Resource Conservation District, PWA has completed Part 1 of the Ponderosa Way Road Assessment and Sediment Reduction Plan. It includes a comprehensive sediment source assessment and treatment action plan for road related erosion and sediment delivery to South Fork Battle Creek and its tributaries, in Tehama County, California. The purpose of this road erosion inventory and treatment plan project was to assess current and future erosion problems along 22.1 miles of Ponderosa Way and selected spur roads in the South Fork Battle Creek watershed, and to develop a prioritized erosion control and erosion prevention treatment plan to diminish or prevent future sediment delivery to the severely impacted South Fork Battle Creek and its tributaries.

Each recommended treatment is consistent with the conservation goals and objectives written into the implementation strategies and guidelines of the Basin Plan for the Central Valley Region (revised April 2016) to protect beneficial uses and water quality. All upslope road treatment recommendations follow guidelines described in the *Handbook for Forest, Ranch and Rural Roads* (Weaver et al., 2015), *Part X* of the CDFG *Salmonid Stream Habitat Restoration Manual* (Weaver et al., 2010), and California Forest practice Rules (CAL FIRE, 2017). The recommendations and costs contained in this final summary report reference current road "storm-proofing" standards of erosion prevention and sediment control and local private sector heavy equipment rental and labor rates.

Ultimately, we found that the current post-fire conditions of project area roads have modified the natural runoff regime and stream network, and accelerated road related erosion rates and hillslope processes. The 2012 Ponderosa Fire, past construction practices, salvage logging, fuel break construction, ineffective or poor road drainage, and deferred or locally ineffective maintenance activities has led to altered hillslope drainage patterns, increased runoff, debris flows and accelerated hillslope and road erosion. It has also likely resulted in correlative off-site impacts including downstream channel instability, bank erosion, water quality impacts, and degraded aquatic habitat.

To assist in future road and resource management, this road related sediment source assessment and prioritized action plan provides field-based data needed to cost-effectively treat existing and potential sources of erosion and sediment delivery from 107 individual erosion sites along 22.1 miles of roads in the project area. In addition to specific erosion sites, we have included treatment prescriptions for 10.6 miles of hydrologically connected road surfaces and ditches that are currently eroding and delivering fine sediment and road runoff to tributaries of the South Fork Battle Creek. The prescribed treatments will prevent approximately 9,706 yd^3 of projected sediment delivery from individual erosion features during the coming several decades, and at least 5,980 yd^3 of fine sediment delivery from the chronic erosion of road surfaces, cutbanks and ditches during the next decade. These pending and potential impacts can be prevented as soon as the proposed road upgrading and decommissioning work is undertaken.

An evaluation of treatment immediacy (priority) has been completed for all 107 existing and potential erosion sites recommended for treatment. This priority ranking is based on the likelihood of erosion and sediment delivery, the expected magnitude (volume) and rate of sediment to be delivered, and the sensitivity of resources at risk. Most of the erosion features on the road (56%) were classified as having a moderate treatment immediacy, and these typically included undersized and plugged culverts, and gullies on the road surface and in the ditch. Only two (2) of the 85 stream crossing that were identified were fish bearing streams. The erosion assessment identified a few generalized problem sites that require immediate treatment, including site features judged as having a high priority for treatment, features restricting Ponderosa Way access, stream crossings with large fill volumes, as well as specific locations or road reach(es) where there the proposed demonstration project will be Implemented in 2018.

An integral part of this assessment is the prioritized plan of action for cost-effective erosion prevention and control, employing the proposed preliminary design plan treatments for 9.4 miles of road upgrading and 12.7 miles of road decommissioning treatments on Ponderosa Way and its spurs. The expected benefit from employing these treatments lies in the reduction of both chronic and episodic sediment erosion and sediment delivery to streams, as well as managing the current sediment regime (e.g. accelerated post fire runoff, sol loss, erosion, and debris flows). The increased initial costs of redesigning and reshaping specific road sections to withstand storms and visitor traffic should be balanced by lower long term maintenance costs and reduced downstream impacts. The estimated total cost to implement the entire plan for Ponderosa Way and its spurs, as detailed here, is approximately $1,832,000. When implemented and employed in combination with protective land management and post-fire land improvements, the treatment prescriptions outlined in this action plan may be expected to significantly improve road conditions (drivability and access) for users, reduce long term road maintenance costs, and provide for long-term protection and improvement of water quality and salmonid habitat in the South Fork and main stem Battle Creek.

Overall, PWA estimates that erosion control and erosion prevention remediation on the project area roads will require approximately 22-30 weeks for a heavy equipment team to implement, including labor hours needed to complete the treatment prescriptions. To help insure success of the project, we recommend that only the most experienced and reliable heavy equipment operators be employed under the supervision of a professional geologist experienced in road upgrading treatments and construction management, and that the project coordinator is on-site full time at the beginning of the project and intermittently once equipment operations have begun.

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APPENDIX A

Terminology and techniques used in road related erosion control and erosion prevention projects

1. Sources of road related erosion
2. Overview of storm-proofing roads
3. Road maintenance (once the recommended erosion control and erosion prevention treatments for road upgrading are implemented)

1 SOURCES OF ROAD RELATED EROSION

Sources for erosion and sediment delivery are divided into two categories: (1) sediment from specific treatment sites, and (2) sediment from the surfaces of road segments of varying lengths—and their associated cutbanks and inboard ditches—that are hydrologically connected[1] to streams.

Site-specific erosion is termed *episodic* because it is projected to occur during storm events that may occur over an indeterminate time. Some sites, such as unstable fillslope landslides on steep hillslopes, may show evidence for imminent failure, erosion, and sediment delivery. But typically, individual sites can only be evaluated in terms of their likelihood to fail during the next severe storm or runoff event, with plans designed to prevent erosion and sediment delivery as a result of that eventuality.

In contrast to site-specific episodic erosion, erosion from road surfaces is termed *chronic* because it occurs on an on-going basis, during every rainfall event that results in surface runoff. Chronic road surface erosion is primarily dependent on the level of road usage, the erodibility of the road surface, the steepness of the road, and the amount of surface runoff that is collected, concentrated, and discharged from the road. PWA provides estimates of chronic erosion and sediment delivery for a 10-year period, based on empirical calculations for fine sediment generation from hydrologically connected road surfaces and associated bare cutbanks and ditches (Weaver et al., 2006). The amount of fine sediment delivered to stream channels from these eroding road surfaces can be substantial over time, and in many watersheds may represent the greater detriment to fish habitat and the aquatic ecosystem.

1.1 Site-Specific Erosion Sources

1.1.1 Stream crossings

A stream crossing is the location where a road crosses a stream channel (Weaver and Hagans, 1994). Drainage structures used in stream crossings include bridges, fords, armored fills, culverts, and a variety of temporary crossing structures. When they erode, sediment delivery from stream crossings is always assumed to be 100%, because any sediment eroded from the crossing site is delivered directly to the stream (Furniss et al., 1997; Weaver et al., 2006). The size of the stream affects the rate of sediment mobilization and movement, but any sediment delivered to small ephemeral streams will eventually be transported to downstream fish-bearing stream channels. Because of this, it is important to identify all stream crossings and evaluate the potential for erosion and sediment delivery from the site.

Common features of stream crossings that lead to erosion problems include (1) fill crossings without culverts, (2) crossings with undersized culverts, (3) crossings with culverts susceptible to being plugged, (4) crossings with culvert outlet erosion, (5) crossings with logs or debris buried in the fill intended to convey streamflow (i.e., *Humboldt crossings*), (5) crossings with a potential for stream diversion, and (6) crossings that have currently diverted streams.

[1] *Hydrologically connected* describes sites or road segments from which eroding sediment is delivered to stream channels (Furniss et al., 2000).

A *fill crossing* is a stream crossing without a culvert or other drainage structure to carry the flow through the road prism. At such sites, stream flow either crosses the road and flows over the fillslope, or is diverted down the road via the inboard ditch. Most fill crossings are located at small Class II or III streams[2] that only have flow during larger runoff events. *Armored fill crossings* and *ford crossings* are designed to be functional, unculverted stream crossings. A properly constructed armored fill crossing is based on a site-specific design, using a mix of riprap-sized rock to minimize erosion while allowing the stream to flow across the road prism (Weaver et al., 2006). A ford crossing may use rock armor to stabilize the roadway, but the road is built essentially on the natural streambed and fill is not used.

Humboldt crossings are constructed from logs or woody debris, usually laid parallel to flow, which are then covered with fill. Humboldt crossings are susceptible to plugging, gullying, and washout during storm flows (Weaver et al., 2006). Older Humboldt log crossing structures beneath more recently installed culverts are often found in rural northern California road networks.

Large volumes of erosion may occur at stream crossings when culverts are too small for the drainage area and storm flows exceed culvert capacity, or when culverts become plugged by sediment and debris. In these instances, flood runoff will spill across the road, allowing erosion of the stream crossing fill and development of a *washout crossing*. Washout crossings will remain highly problematic as the streambed and banks continue to erode and adjust to a stable grade.

Serious erosion problems may also occur where a stream crossing has a *diversion potential*. Stream diversions occur at stream crossings that are unculverted, or have culverts that plug during a flood event, allowing water to spill out onto the road surface or into the ditch, and flow down the road and onto adjacent hillslopes or into nearby stream channels. When this occurs, the roadbed, hillslope, and/or stream channel that receives the diverted flow may become deeply gullied or destabilized. Road and hillslope gullies can develop and enlarge quickly and deliver large quantities of sediment to stream channels (Hagans et al., 1986; Furniss et al., 1997). Streamflow that is diverted onto steep or unstable slopes may also trigger hillslope landslides and large debris flows.

To be considered adequately sized, culverts at stream crossings must have the capacity to convey a 100-year peak storm flow[3] with sediment and organic debris in transport (USDA Forest Service, 2000; Weaver et al., 2006). In areas where large woody debris may lodge against the culvert, trash racks should be installed slightly upstream from culvert inlets as an additional precaution against plugging. Substandard stream crossing culverts include those that are not large enough to convey a 100-year flow, or are installed at too low of a gradient through the stream crossing fill. Installing a culvert at a shallower grade than the natural upstream channel will cause sediment and debris to be deposited at and immediately upstream of the culvert inlet,

[2] In general, Class I streams are waterways containing viable or restorable fish habitat, or are the source of domestic water supplies. Class II streams are those that support non-fish aquatic species. Class III streams are defined as channels with a defined bed and banks and showing evidence for sediment transport. Class IV streams are man-made watercourses.
[3] The *100-year peak storm flow* for a location is the discharge that has a 1% probability of occurring at that location during any given year.

which promotes plugging and decreases the culvert's capacity to carry streamflow. The outdated practice of installing culverts at insufficiently low gradients was once employed as a cost-cutting measure, because it requires a shorter length of pipe to convey flow through the road. In the long run, however, this practice often proves detrimental to erosion control and maintenance efforts because it allows the culvert to discharge water onto unconsolidated road fill rather than into the preexisting stream channel, resulting in pronounced erosion of the outboard, downstream fill face.

1.1.2 Landslides

Landslides with the potential to fail during periods of intense and prolonged rainfall events are identified in the field by tension cracks, scarps showing vertical displacement, corrective regrowth on trees (i.e., pistol butt trees) and perched, hummocky fill indicating surface instability. As a standard practice, PWA maps all existing and potential landslides observed in the field, but only inventories those that are associated with roads and show a potential to deliver sediment to a watercourse. Types of landslides in a road related erosion assessment typically include (1) road fill failures, (2) landing fill failures, (3) hillslope debris slides, and (4) deep-seated, slow landslides. The majority of treatable landslides in an assessment area are often the result of failure of unstable fill and sidecast material from earlier road construction. Preemptive excavation of small, current or potential landslides is an effective technique for erosion control, achieved by removing the unstable material and redepositing it in a stable, designated location either at or near the treatment site. Conversely, large, deep-seated landslides are usually found to be technically infeasible to treat.

1.1.3 Ditch relief culverts

A *ditch relief culvert* (DRC) is a plastic, metal, or concrete pipe installed beneath the road surface to convey flow from an inside road ditch to an area beyond the outer edge of the road fill. When properly spaced, DRCs limit the quantity of water available to cause erosion at any single location, allowing flow to disperse and reducing the likelihood of gullies forming at their outlets. It is sometimes necessary to install downspouts or rock armor at DRC outlets to further dissipate energy and prevent erosion.

1.1.4 Discharge points for road surface, cutbank, and ditch erosion.

Unpaved road surfaces, and their associated cutbanks and inboard ditches, are major sources for erosion and delivery of fine sediment to stream channels. For paved roads, ditches, cutbanks, and unpaved turnouts may still represent active sediment sources. Road surface, cutbank, and ditch erosion is termed "chronic" because it occurs throughout the year, and may include one or more of the following processes: (1) mechanical pulverizing and wearing down of road surfaces by vehicular traffic; (2) erosion of unpaved road surfaces by rainsplash and runoff during periods of wet weather; (3) erosion of inboard ditches by runoff during wet weather; and (4) erosion of cutbanks by dry ravel, rainfall, slope failures, and brushing/grading practices. *Discharge points for road surface, cutbank, and ditch erosion* are locations where sediment-laden flow from poorly drained road/cutbank/ditch segments exits the roadway to be delivered into the stream system. Discharge points are often in the form of roadside gullies or waterbars, but on some low gradient or streamside roads may simply be low spots where concentrated flow exits the road and is delivered directly to a stream without gully formation.

1.1.5 Additional site-specific sediment sources

Additional, less frequent sources of sediment delivery that may be found in an assessment area include:

Point source springs. Point source springs refer to sites where spring flow is entering the roadbed and causing erosion. Flow from multiple springs may become concentrated along a road with inadequate drainage structures, creating roadside gullies or fillslope failures.

Sites of bank erosion. Bank erosion sites refer to locations of streambank erosion caused or exacerbated by emplacement of a nearby road.

Swales. Swales are channel-like depressions that only carry minor flow during periods of extreme rainfall.

Channel scour. Channel scour refers to the widening or deepening of stream channels as a result of increased flow levels.

Non-road related upslope gullies. These are sites of focused runoff that form upslope from a roadway, and may exacerbate erosion at the roadway or contribute sediment to the system during high discharge.

1.2 Evaluation of Hydrologically Connected Road Segments

PWA measures the lengths of hydrologically connected road segments adjacent to sediment delivery sites, such as on either side of a stream crossing, ditch relief culvert, or discharge point, to derive an estimate for total potential sediment delivery from connected road surfaces in the project area. In addition, because the adjacent hydrologically connected road segments contribute to the overall erosion and sediment delivery problem at a site, PWA considers the treatment site and adjacent road segments as a unit when estimating future sediment delivery and developing treatment prescriptions for that location.

2 OVERVIEW OF STORM-PROOFING ROADS (ROAD UPGRADING AND DECOMMISSIONING)

Forest and rural roads may be storm-proofed by one of two methods: upgrading or decommissioning (Weaver and Hagans, 1994, 1999; Weaver et al., 2006). Upgraded roads are kept open, and are inspected and maintained. Their drainage facilities and fills are designed or treated to accommodate the 100-year peak storm flow. Conversely, properly decommissioned roads are closed and no longer require maintenance. Whether through upgrading or decommissioning, the goal of storm-proofing is to make the road as "hydrologically invisible" as possible, that is, to minimize the hydrologic effects of the road and to reduce or prevent future sediment delivery to the local stream system. A well-designed storm-proofed road includes specific characteristics (Table A1), all proven to contribute to long-term improvement and protection of watershed hydrology and aquatic habitat.

2.1 Road upgrading

Road upgrading involves a variety of treatments used to make a road more resilient to large storms and flood flows. The most important of these include upgrading stream crossings (especially culvert upsizing to accommodate the 100-year peak storm flow and debris in transport, and treatments to correct or prevent stream diversion); removing unstable sidecast and fill materials from steep slopes; and applying road drainage techniques (e.g., installing ditch relief culverts, removing berms, constructing rolling dips, insloping or outsloping the road) to improve dispersion of surface runoff. Road upgrading often also includes adding road rock or riprap as needed to fortify roads and crossings. The treatments are fully described by Weaver et al. (2006).

2.1.1 Installing rolling dips

Rolling dips are installed on low- to moderate-gradient, hydrologically connected roads to disperse surface runoff and discharge it onto the native hillslope below the road. Rolling dips may extend from the inboard edge to the outboard edge of a road prism, or just on the roadbed, and are constructed at intervals as needed to control erosion (typically 100, 150, or 200 ft). They are effective in reducing year-round ("chronic") sediment delivery from road surfaces, and are designed to be easily drivable and not impede vehicular traffic.

2.1.2 Road shaping

Road shaping changes the existing geometry or orientation of the road surface, and is accomplished through insloping (sloping the road toward the cutbank), outsloping (sloping the road toward the outside edge), or crowning (creating a high point near the center axis of the road so that it slopes both inward and outward). Like rolling dips, road shaping is used to prevent uncontrolled delivery of road surface runoff by dispersing it into the inside ditch or onto the hillslope below the road. This is also effective in preventing the formation of gullies at the edge of the road, and localized slope instability below the road. Road shaping is almost always used in concert with rolling dips to disperse surface runoff.

Table A1. Characteristics of storm-proofed roads (*from* Weaver et al., 2006).

Storm-proofed stream crossings • All stream crossings have a drainage structure designed for the 100-year peak storm flow (with debris). • Stream crossings have no diversion potential (functional critical dips are in place). • Stream crossing inlets have low plug potential (trash barriers installed). • Stream crossing outlets are protected from erosion (extended beyond the base of fill; dissipated with rock armor). • Culvert inlet, outlet, and bottom are open and in sound condition. • Undersized culverts in deep fills (greater than backhoe reach) have emergency overflow culvert. • Bridges have stable, non-eroding abutments and do not significantly restrict 100-year flood flow. • Fills are stable (unstable fills are removed or stabilized). • Road surfaces and ditches are "hydrologically disconnected" from streams and stream crossing culverts. • Class I stream crossings meet CDFG and NMFS fish passage criteria (Taylor and Love, 2003).
Storm-proofed fills • Unstable and potentially unstable road and landing fills are excavated or structurally stabilized. • Excavated spoil is placed in locations where it will not enter a stream. • Excavated spoil is placed where it will not cause a slope failure or landslide.
Road surface drainage • Road surfaces and ditches are "hydrologically disconnected" from streams and stream crossing culverts. • Ditches are drained frequently by functional rolling dips or ditch relief culverts. • Outflow from ditch relief culverts does not discharge to streams. • Gullies (including those below ditch relief culverts) are dewatered to the extent possible. • Ditches do not discharge (through culverts or rolling dips) onto active or potential landslides. • Decommissioned roads have permanent drainage and do not rely on ditches. • Fine sediment contributions from roads, cutbanks, and ditches are minimized by utilizing seasonal closures and implementing a variety of surface drainage techniques including berm removal, road surface shaping (outsloping, insloping, or crowning), road surface decompaction, and installing rolling dips, ditch relief culverts, waterbars, and/or cross-road drains to disperse road surface runoff and reduce or eliminate sediment delivery to the stream.

2.1.3 Installing ditch relief culverts

A ditch relief culvert is a drainage structure (usually an 18 in. pipe) installed across a road prism to move water and sediment from the inboard ditch so that it can be dispersed on native hillslope downslope from the road. Ditch relief culverts are used to drain ditch flow on roads that are too steep for rolling dips or outsloping, as well as at sites with excessive flow from springs or seepage from cutbanks.

2.1.4 Excavating unstable fillslope

The fillslope, the sloping part of the road between its outboard edge and the natural ground surface below, may fail or show signs of potential failure. As a preventative measure, unstable fillslope sediment is excavated and relocated (endhauled or pushed) to a permanent, stable spoil disposal site.

2.1.5 Upgrading stream crossings

Techniques used to remediate road related erosion at a stream crossing are dependent on the size of the stream channel, and specific physical characteristics at the crossing site. Class I and large stream crossings may require a bridge, or, if their banks are small or low gradient, a ford crossing may be suitable, particularly if seasonal use is anticipated. A common approach to upgrading moderate-sized crossings of Class II and III streams is to construct a culverted fill crossing capable of withstanding the 100-year flood flow. Techniques for upgrading small and moderate-size stream crossings include:

Installing or replacing culverts. A culvert capable of withstanding the 100-year peak storm flow is installed or replaced in the fill crossing. Culverts on non fish-bearing streams are placed at the base of fill, in line and on grade with the natural stream channel upstream and downstream of the crossing site. Backfill material, free of woody debris, is compacted in 0.5-1.0 ft thick lifts until 1/3 of the diameter of the culvert has been covered. At sites where fillslopes are steeper than 2:1, or where eddying currents might erode fill on either side of the inlet, rock armor is applied as needed.

Installing an armored fill. Armored fills are installed on smaller stream crossings with relatively small fill volume, but where debris torrents are common, channel gradients are steep, or inspection and maintenance of a culverted crossing is impossible or unlikely to occur. The roadbed is heavily rocked and a keyway at the base of the outboard fillslope is excavated and backfilled with interlocking rock armor of sufficient size to resist transport by stream flow. Armored fill crossings are constructed with a dip in the axis of the crossing to prevent diversion of the stream flow, and focus the flow over the part of the fill that is most densely armored.

Installing secondary structures. A variety of secondary structures may be used to increase the function of small stream crossings by allowing uninterrupted stream flow, decreasing plugging, and controlling erosion. Where a culvert has been improperly installed too high in the fill, a *downspout* may be added to its outlet to release the flow close to the ground surface, rather than letting it cascade from the height of the culvert. *Rock armor* may be used to buttress steep fillslopes, as well as to prevent erosion of inboard or outboard fillslopes by eddying currents. A *trash rack* placed in the channel above a culvert inlet will trap debris and reduce plugging. To prevent stream diversion should the culvert become plugged or its capacity exceeded, a *critical dip* (essentially a rolling dip constructed on the down-road hingeline of the fill) may be installed to ensure that stream flow will be directed across the road and back into the natural channel. Finally, an *overflow culvert* may be a necessary addition at a culverted crossing where, because of site conditions, plugging or capacity exceedence of the primary culvert is anticipated.

2.2 Road decommissioning

In essence, decommissioning is “reverse road construction,” although complete topographic obliteration of the roadbed is not usually required to achieve cost-effective erosion prevention. In most cases, serious erosion problems are confined to a few, isolated locations along a road (perhaps 10% to 20% of the full road network to be decommissioned) where stream crossings need to be excavated, unstable sidecast on the downslope side of a road or landing needs to be removed before failure, or the road crosses unstable terrain and the entire road prism must be removed. But typically, lengths of road beyond the extent of individual treatment sites usually require simpler, permanent improvements to surface drainage, such as surface decompaction, additional cross-road drains, and/or partial outsloping. As with road upgrading, the heavy equipment techniques used in road decommissioning have been extensively field tested and are widely accepted (Weaver and Sonnevil, 1984; Weaver et al., 1987, 2006; Harr and Nichols, 1993; Pacific Watershed Associates, 1994).

2.2.1 Road ripping or decompaction

Road ripping is a technique in which the surface of a road or landing is disaggregated or "decompacted" to a depth of at least 18 in. using mechanical rippers. This action reduces or eliminates surface runoff and usually enhances revegetation.

2.2.2 Installing cross-road drains

Cross-road drains (also called “deep waterbars”) are large ditches or trenches excavated across a road or landing surface to provide drainage and prevent runoff from traveling along, or pooling on, the former road bed. They are typically installed at 50, 75, 100 or 200 ft intervals, or as necessary at springs and seeps. In some locations (e.g., streamside zones), partial outsloping may be used instead of cross-road drain construction.

2.2.3 In-place stream crossing excavation (IPRX)

IPRX is a decommissioning treatment used for roads or landings that are built across stream channels. The fill (including the culvert or Humboldt log crossing) is completely excavated and the original streambed and side slopes are exhumed. Excavated spoil is stored at nearby, stable locations where it will not erode. In some cases, this may necessarily be as far as several hundred feet, or more, from the crossing. An IPRX typically involves more than simply removing a culvert, as the underlying and adjacent fill material must also be removed and stabilized. As a final measure, the sides of the channel may be cut back to slopes of 2:1, and mulched and seeded for erosion control.

2.2.4 Exported stream crossing excavation (ERX)

ERX is a decommissioning treatment in which stream crossing fill material is excavated and the spoil is hauled off-site for storage (the act of moving spoil material off-site is called “endhauling”). This procedure is necessary when large, stable storage areas are not available at or near the excavation site. It is most efficient to use dump trucks to endhaul the spoil material.

2.2.5 In-place outsloping (IPOS)

IPOS (also called "pulling the sidecast") calls for excavation of unstable or potentially unstable sidecast material along the outside edge of a road prism or landing, and placement of the spoil on the roadbed against the corresponding, adjacent cutbank or within several hundred feet of the site. As a further decommissioning measure, the spoil material is placed against the cutbank to block vehicular access to the road.

2.2.6 Export outsloping (EOS)

EOS is a technique comparable to IPOS, except that spoil material is moved off-site to a permanent, stable storage location. EOS is required when it is not possible to place spoil material against the cutbank, e.g., where the road prism is narrow or where there are springs along the cutbank. EOS usually requires dump trucks to endhaul the spoil material. This technique is used for both decommissioning and upgrading roads, but as the roadbed is partially or completely removed, EOS is more commonly used for decommissioning.

3 ROAD MAINTENANCE

Once the recommended erosion control and erosion prevention treatments for road upgrading are implemented, maintenance inspections will need to occur annually, at a minimum. Regular maintenance is required to keep roads in good condition and to identify and correct problems promptly (Furniss, 1991). Ponderosa Way maintenance inspections can identify and treat erosion problems before erosion and sediment delivery become significant, or before complete failure occurs. It is beneficial to conduct stream crossing culvert inspections during the summertime, so that there is ample time to request heavy equipment to remove sediment deposits, large rocks or floatable debris at the culvert inlet which block flow or threaten to plug the culvert before winter rains. In addition to the annual, pre-winter road and drainage structure inspections, personnel need to perform emergency inspections and maintenance during and following large storms and floods.

Poorly maintained road surfaces will channel water, reduce road life and increase erosion and sedimentation to streams. Over years of continued road use and repeated maintenance grading, road surface materials have broken down and have been graded to the side of the road, thereby creating berms and preventing proper road surface drainage. Inadequate or improper maintenance activities can lead to substantial increases in road surface runoff, road erosion, stream sedimentation and off-site stream channel erosion (Furniss, 1991). Dispersing and maintaining dispersed road surface runoff is critically important to reducing and minimizing these impacts.

Ponderosa Way is “through-cut” (trench-like with berms or cuts on both sides) and flat in cross section. As a result, the road exhibits poor road drainage and actively eroding ditches. Steep road segments experience the highest rates of wear. Road outsloping and road surface drainage structures are needed to lessen the flow volumes in the ditch and further disperse surface runoff. As is common on many unpaved roads here and elsewhere, routine road surface maintenance (smoothing) activities are contributing to the slightly through-cut road and berm development; it is a common result of annual maintenance grading and consequent gradual lowering of the road surface (Figure 8). Poor road surface drainage will not improve until the road berm is removed or the road is outsloped, raised and crowned, or paved.

Serious damage to the road structure and road surfaces have been identified with the loss of road drainage, erosion of road surfacing materials and excess standing water on the surface. Ruts and mud indicate that road strength is deteriorating (Weaver et al., 2015). This bermed and through-cut road has locally led to the development of rills and gullies where the road is steep, and to potholes and mud puddles where it is gentle. Outside berms created by maintenance grading have unintentionally concentrated road runoff during winter storms and need to be removed from the outside edge of the road wherever they are preventing proper road drainage.

The first rule of maintaining a stable road surface is to minimize unrestricted visitor traffic and grading during the wet weather season or when the road is vulnerable to damage. We understand roads benefit greatly by closing vehicle access for several days during the wet weather season. In locations on Ponderosa Way where there are potholes, washboarding, or exposed base materials maintenance grading can regrade the road by cutting deeply into the road surface and ripping the roadbed so loose material on the regraded surface will mix, compact, and bind with underlying material. Otherwise, individual potholes and tire ruts from vehicles that are patched will quickly reform in the same sections of road.

Road surface grading and maintenance grading of ditches should not happen along the entire road on an annual basis. Road surfaces and ditches should be graded where prioritized as necessary and only when needed to maintain a stable, smooth running surface to retain the most effective, dispersed surface drainage (Weaver et al., 2015). PWA recommends that prioritized road segments be ripped or deeply scarified and new loads of graded rock aggregate spread, mixed, and compacted in the existing road surface materials. Berms with good surfacing materials along the outside edge of the road can be retrieved and worked back into the roadbed. Over grading often results in unnecessary erosion and increases road surface rock wear. Steep road segments will quickly lose their running surfaces with frequent grading so operators should raise the blade wherever grading is not needed. The implementation of proper and protective road management and maintenance is key to minimizing road damage, minimizing a road’s impact to water quality and reducing maintenance needs and costs.

In general, ditches should not be carrying large volumes of water. Additional rolling dips connected to the inside ditch and a few more ditch relief culverts can be installed to drain ditches more frequently. Rock armor can be installed to protect ditches from downcutting on steep sections of road or in through cut road sections where the road cannot be drained. Ditch erosion can be kept to a minimum by retaining vegetation and adding seed to promote fast growing erosion control vegetative cover. Hydrologically connected ditches should be viewed as sediment filtering and trapping structures used to encourage sediment deposition. Once ditches are regraded and maintained they can be seeded to reestablish a vegetation cover and control sediment.

Once the road has been treated (reshaped and drained more effectively), annual inspections and regular road maintenance is essential to protect the road, prevent sedimentation of streams and protect downstream water quality and aquatic habitat. Maintenance inspections are conducted to determine which road surfaces and drainage structures are in need of repair or maintenance so they function as originally designed and constructed. All roads should be regularly inspected and maintained prior to the beginning of the rainy season, whether they are mainline arterial routes or local, dead end spur roads receiving minimal traffic. Inspections should be performed on the most-at-risk features and structures first, and then low priority road segments and sites second.

During annual inspections, road inspectors can take down information in the field by noting the current conditions and maintenance requirements that should be addressed before the next wet weather season. Overtime, each existing drainage structure or problematic maintenance site should be inventoried and placed on a master list for quick reference. Road maintenance should address the road surface, stream crossings, cutbanks and fillslopes, as well as drainage structures and erosion control measures. Maintained culverts should be cleaned from floating debris or rocks that impede flow capacity. Armored fills can be cleaned-up and evaluated to determine if rock sizes are appropriate for high flows or if additional or larger rock needs to be added after flood flows. Rocked surfaced roads that are permanent can be inspected to evaluate if the traffic types and intensities are damaging the road and additional surfacing needs to be added.

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Site #	Treatment Immediacy	Problem	Left road length (ft)	Left road delivery (%)	Right road length (ft)	Right road delivery (%)	Total estimated sediment delivery (yd^3)	Comment on Problem	Comment on treatment
1	HM	Stream crossing	1200	100	1370	100	278	Class I stream crossing with a bridge over Digger Creek. Entire right road length is delivering fine sediment. This part of Ponderosa Way has high traffic use. Left road is outsloped with rills and fine sediment. PWA estimates that 278 yd^3 of road surface material will erode and deliver to the stream system in the next 10 years, if the road is not upgraded to meet forest road standards. This problem is a high priority for treatment, the bridge is sound and well- engineered. There is a water trough above right road (11 ft- 6 inch clearance). There is ponded water on the far right road that are up to 2 ft. deep. The ponded water is filled with fines when driven through. A moderately-sized gully turns into a larger gully as the road grade gets steeper on right road approach; there is sediment delivery in three distinct locations. First delivery point is at the trough and goes into a Class III stream, tributary to Digger Creek. The second delivery point goes onto the Digger Creek bridge then off the sides into the stream. The third delivery point travels along a skid road that terminates into the stream bank. Bridge is 100 ft. wide with wooden decking atop a steal frame. The bridge is supported by cement. A portion of the road approach is paved. The wooden decking is deteriorating and needs to be replaced. Other than the decking the bridge seems sound.	1. Construct 1 rolling dip at 8+30 ft. to the right on right road approach, outslope and rock road surface for 130 ft. using 1.5 inch minus road base. 2. Rock right road and outslope through-cut section of road from 8+30 ft. to 5+00 ft. 3. Remove berm and outslope 500 ft. of right road approach from 5+00 ft. to 0+00 ft. 4. Outslope right road approach 138 ft. to bridge. 5. Construct 4 rolling dips on left road approach. 6. Outslope on left road approach for 1,200 ft. 7. All reshaped road sections will be rocked with 1.5 inch diameter minus base rock. 8. Spoil locally.
2	M	Ditch relief culvert	3700	30	215	100	121	Ditch relief culvert (DRC) with chronic rilling and gullying on road surface is a priority for treatment. There is a large road reach with no breaks and a ditch the entire way (except for some local landowner's driveways). There is a deep rill at the DRC outlet that delivers fine sediment to Digger Creek. It is 250 ft. from the outlet of the DRC to the creek with the hill steepening as it gets closer to the creek. Left road is long with multiple buried DRC's and private driveways. There were 7 working outs that allow for some sediment to layout off the road; it is estimated that 30% of the road makes it down to the DRC. There are periodic berms, cutbacks, driveways, and through cuts on the left road. Treating this road surface erosion problem may be difficult due to the private driveways and road easement.	1. Construct 8 rolling dips on left road approach (see original field map for specific locations). 2. Outslope 1,000 ft. of the left road approach, cut ditch for 1000 ft. and install 150 yd^3 of 0.25 - 0.75 ft. diameter rock to inboard ditch. 3. Crown 1,150 ft. of the left road approach. 4. All reshaped road sections will be rocked with 1.5 inch diameter minus base rock. 5. Spoil locally.

Site #	Treatment Immediacy	Problem	Left road length (ft)	Left road delivery (%)	Right road length (ft)	Right road delivery (%)	Total estimated sediment delivery (yd^3)	Comment on Problem	Comment on treatment
3	M	Stream crossing	2425	100	0	0	241	A manmade irrigation ditch/canal crosses the road via a 30 inch corrugated metal pipe (CMP). Strong flow was present when surveyed. Inlet is crushed some, otherwise CMP is fine. Very shallow matrix above CMP, with some CMP exposed on road bed. There is a 15 inch ditch relief culvert ~125 ft. left of crossing that carries ditch flow and discharges onto fairly gentle ground and spreads out across access road next to the canal with no delivery. Long ditch and road to left with two more 15 inch ditch relief culverts; one is plugged and neither deliver. PWA estimates that 229 yd^3 of road surface material will erode and deliver to or past the site in the next 10 years, if the road is not upgraded to meet forest road standards.	1. Construct 6 rolling dips on left road approach. 2. Outslope 800 ft. of the left road approach and cut new ditch, then armor new ditch with 120 yd^3 of rock. All reshaped road sections will be rocked with 1.5 inch diameter minus base rock. 3. Replace current CMP with a 36 inch diameter culvert, best to utilize a 4 ft. wide metal box culvert that has similar flow capacity. Pumping this volume of water may be difficult during construction. 4. All reshaped road sections will be rocked with 1.5 inch diameter minus base rock. 5. Spoil locally.
4	M	Stream crossing	2510	25	5925	35	313	Class III stream with a recently upgraded crossing using a repurposed CMP. The upgrading was new rock and a critical dip was installed. There is a total of 9,510 ft. of road intersecting at this site. Ponderosa Way has 7,000 ft. (right road). The right road has ditch runoff contributing fine sediment for the entire road length. The road reach has a slight through cut from long term grading, which formed a berm that concentrated road runoff. The cutbank on the inside of the road and the berm on the outside of the road has mature trees growing on them intermittently; there are a few outs for road runoff. The left road is 2,500 ft. of PG&E Spur 1. The left road has a locked green gate; beginning of road has a slight grade with rilling and large rocks; road gets steeper wit rolling dips and outs; road surface rills and delivers fine sediment into the adjacent creek; overland/hillslope runoff from the recent burn is creating most of the erosion; soil and road surface seems highly erodible. PWA estimates that nearly 300 yd^3 of road surface material will erode and deliver to the stream system in the next 10 years, if the road is not upgraded to meet forest road standards.	1. Construct dip by lowering road 1.0 ft. and remove CMP (40 ft- wide x 1 ft- deep x 15 ft- long = 27 yd^3). 2. Excavate keyway (15 ft- wide x 2 ft- deep x 11 ft- long = 15 yd^3). 3. Install armor with 0.5 - 1.5 ft. diameter rock (15 ft- wide x 2 ft- deep x 11 ft- long = 15 yd^3). Rock that is located onsite can be used for riprap (8.0 yd^3 onsite) 4. Rock 80 ft. of road. 5. Outslope 2,550 ft. of right road; remove berm on outer edge of road when applicable. All reshaped road sections will be rocked with 1.5 inch diameter minus base rock. 6. Crown road for 2,675 ft. 7. Construct 17 rolling dips to the right road. 8. Construct 4 rolling dips to the left PG&E road. 9. Spoil locally.

Site #	Treatment Immediacy	Problem	Left road length (ft)	Left road delivery (%)	Right road length (ft)	Right road delivery (%)	Total estimated sediment delivery (yd^3)	Comment on Problem	Comment on treatment
5	M	Stream crossing	200	100	219	100	41	Road surface delivers fine sediment via small gully into stream in two locations. Berm along outboard road keeps water on the road until this breach in the berm. Many fines and sands deliver to an already choked channel. Site is downstream from a confluence. There are some functional rolling dips on the left road approach. The road surface is not as much of the problem as the berm and water that is concentrating, creating an active, downcut gully. With further exploration, a 2.0 x 0.5 foot stream was identified 40 ft. right of gully on the inboard edge of the road fill. This stream is low energy. This stream has not been properly addressed. Due to the stream being altered by the road and fire, any new channel will have to be directed down the outboard fill. Also because of the alterations to the natural channel we recommended aligning the stream down the road 50 ft. to a natural dip in the road surface.	1. Construct dip by lowering road 1 ft. (50 ft- wide x 1 ft deep x 14 ft long = 31 yd^3). 2. Excavate keyway (10 ft- wide x 2 ft- deep x 8 ft- long = 7 yd^3). 3. Install armor with 0.5-1.5 ft. diameter rock (8 ft- wide x 2 ft- deep x 10 ft- long = 6 yd^3). 4. Rock dip for 50 linear ft (50 ft- wide x 0.5 ft- deep x 14 ft- long = 13 yd^3). 5. Construct 1 rolling dip to right road approach. 6. Outslope and remove berm and install 1 rolling dip on left road approach. 7. All reshaped road sections will be rocked with 1.5 inch diameter minus base rock. 8. Spoil locally.
6	ML	Stream crossing	140	100	750	100	101	A shallow armored fill crossing. Outboard fill is only 6 ft. long. Outboard armor is nonfunctional (not wide enough) and some of the flow flanks the structure causing minor past erosion (<1 yd^3); future erosion is estimated to be ~1-2 yd^3. Road surface was rocked at the stream crossing with base rock, but the rock size (class) used was too small and easily washed into the stream. Right road surface delivers fine sediment via a small gully to the right 50 ft.	1. Construct dip by lowering road 1 foot and excavate outboard fill = 10 yd^3. 2. Excavate to create a ford crossing (25 ft- wide x 3 ft- deep x 20 ft- long = 67 yd^3). 3. Rock road with 0.5-0.75 ft. diameter rock (50 ft- wide x 0.5 ft- deep x 15 ft- long = 14 yd^3). 4. Outslope right road 500 ft. 5. Construct 3 rolling dips on right road. 6. All reshaped road sections will be rocked with 1.5 inch diameter minus base rock. 7. Spoil locally.
7	L	Stream crossing	50	100	50	100	22	A shallow armored fill crossing on low gradient stream that was recently installed. Armored fill crossing is washed-out and nonfunctional. Imported rock has been plucked from high flow channel path. Rock on outboard fill seems small and undersized; larger rock should be installed, if this road is upgraded. Left road approach is at 1% and is functionally outsloped, well drained. There is a small Class III stream or uncontrollable hillslope gully crossing the road 50 ft. to the right with a nonfunctional drainage structure.	1. Construct dip by lowering road 1 ft. (40 ft- wide x 1 ft- deep x 13 ft- long = 24 yd^3). 2. Construct a wet ford. Excavate and remove 75 yd^3 and remove imported rocks. 3. Develop an eight foot wide channel bottom. 4. Spoil locally.

Site #	Treatment Immediacy	Problem	Left road length (ft)	Left road delivery (%)	Right road length (ft)	Right road delivery (%)	Total estimated sediment delivery (yd^3)	Comment on Problem	Comment on treatment
8	M	Stream crossing	0	0	700	100	86	Class III stream that currently has a nonfunctional rolling dip as a structure at the crossing. There is a 1.0 foot tall head cut starting on the inboard side edge of the road. The inboard side of the road also has intermittent bedrock exposed. This channel connects with channel (site # 7) on the outboard side. There is an active gully with a small head cut on the outboard side of the channel. The right road has three rolling dips; outsloped; with berm. There is a lot of hillslope runoff collecting on the road surface. The berm is concentrating and intercepting the hillslope runoff, until the rolling dips, where the runoff then delivers fine sediment to the creek.	1. Construct dip by lowering road 1 ft. (40 ft- wide x 1 ft- deep x 21 ft- long = 38 yd^3) 2. Excavate keyway (10 ft- wide x 2 ft deep x 13 ft long = 12 yd^3). 3. Install armor with 0.5 - 1.5 ft. diameter rock (10 ft- wide x 2 ft- deep x 13 ft- long = 10 yd^3). 4. Remove berm on the right road. 5. Enhance rolling dips (4) up right road approach. 6. Spoil locally.
9	M	Stream crossing	265	100	1500	100	294	A low gradient Class III stream fill crossing, on a tight u-bend. There is an erosional scar from an abandoned road alignment that went up the right cutbank that now has the stream running down it for 100 ft. above the stream crossing. The road is rocked, but there is no armored fill along the outboard fill for protection against erosion. The stream flows on the right hingeline with two gullies down the outboard fill. Road on the left approach has fairly steep grade with rolling dips and outsloping. Hillslope runoff from the burn contributes a lot of fines delivered to the road, where the runoff intercepts runoff which collects at the rolling dips and then create rills down to the stream where they deliver fines; berm and weak outsloping contribute to concentration of runoff. Right road approach is outsloped with small intermittent berms. Runoff on burned hillslope, upslope of road, is creating rills and cut bank failures leading to deep gullies on the outboard fill then delivering to a Class III stream.	1. Construct dip by lowering road 1 ft. (60 ft- wide x 2 ft- deep x 40 ft- long = 107 yd^3). 2. Excavate keyway (20 ft- wide x 2 ft- deep x 24 ft- long = 43 yd^3). 3. Install armor with 0.5 - 1.5 ft. diameter rock (15 ft- wide x 2 ft- deep x 24 ft- long = 30 yd^3). 4. Rock road surface for 40 linear ft (40 ft- wide x 0.5 ft- deep x 20 ft- long = 10 yd^3). 5. Construct a dip at the hillslope gully 80 ft. to the left and rock (30 ft- wide x 0.5 ft deep x 15 ft- long = 10 yd^3). 6. Excavate keyway (10 ft- wide x 2 ft- deep x 15 ft- long = 14 yd^3). 7. Install armor with 0.5 - 1.5 ft. diameter rock (10 ft- wide x 2 ft- deep x 15 ft- long = 12 yd^3) 8. Outslope road for and remove berm for 250 ft. on left road approach. 9. Install 5 rocked rolling dips to the right. 10. All reshaped road sections will be rocked with 1.5 inch diameter minus base rock. 11. Spoil locally. Note: use outer fillslope material and taper hillslope to control flow on right approach.

Site #	Treatment Immediacy	Problem	Left road length (ft)	Left road delivery (%)	Right road length (ft)	Right road delivery (%)	Total estimated sediment delivery (yd^3)	Comment on Problem	Comment on treatment
10	HM	Stream crossing	345	100	414	100	118	A Class III stream crossing with a 12 inch diameter plugged CMP (not plugged in 2017). Road has a rocked overflow spillway on the left hingeline that is actively eroding. Ditch delivers fine sediment to stream crossing from right road approach. Hillslope gullies on left road approach are frequent, cross the road and gully hillslope to channel. Channel is chocked with sediment downstream of the stream crossing.	1. Construct dip by lowering road 1 ft. (50 ft- wide x 1 ft- deep x 15 ft- long = 34 yd^3). 2. Excavate keyway (15 x 4 x 11 = 30 yd^3). 3. Install armor with 0.5 - 1.5 ft. diameter rock (11 ft- wide x 4 ft - deep x 15 ft- long = 10 yd^3). 4. Rock the crossing; 60 linear ft. to the left and 40 linear ft. to the right. 5. Outslope 215 ft. of right road approach. 6. Outslope 345 ft. of left road approach. 7. Construct 2 rolling dips on the right road, rock rolling dips (other treatment). 8. Construct 3 rocked rolling dips on the left road at 235 ft., 515f t., and 825 ft. 9. Inslope road for 200 ft. on right road approach near culvert. 10. Cut and rock newly cut ditch for 200 ft., use 8 yd^3 of 2.0-3.0 inch diameter rock. 11. All reshaped road sections will be rocked with 1.5 inch diameter minus base rock. 12. Spoil locally.
11	M	Stream crossing	360	100	0	0	96	Class III stream, low gradient, with weak power, drains through an old 12 inch diameter CMP that is undersized. There is a rock wall at the stream crossing inlet. There is a ditch relief culvert 290 ft. up the right road approach that is open at the inlet and plugged at the outlet; inlet has a concrete wall; hillslope gully just above inlet. 140 ft. up the right road there is a hillslope gully that goes into the ditch; incising and widening ditch. There is a berm along the road with a larger berm on the right hinge outboard road. This berm is concentrating runoff and eroding the road surface and ditch and causing sediment delivery. This crossing has not been upgraded since the fire in 2012, though it does look like someone cleaned out the inlet recently.	1. Construct dip by lowering road 1 ft. and remove CMP/wall (40 ft- wide x 1 ft- deep x 13 ft- long = 116 yd^3). 2. Excavate keyway (10 ft- wide x 2 ft- deep x 10 ft- long = 10 yd^3). 3. Install armor with 0.5 - 1.5 ft. diameter rock (10 ft- wide x 2 ft- deep x 10 ft- long = 10 yd^3). 4. Construct 2 rocked rolling dips 140 ft. and 290 ft. up right road. 5. Outslope 360 ft. of right road; remove berm when applicable. 6. All reshaped road sections will be rocked with 1.5 inch diameter minus base rock. 7. Spoil locally.

Site #	Treatment Immediacy	Problem	Left road length (ft)	Left road delivery (%)	Right road length (ft)	Right road delivery (%)	Total estimated sediment delivery (yd^3)	Comment on Problem	Comment on treatment
12	M	Stream crossing	0	0	250	100	49	A Class III stream crossing with and undersized 12 inch diameter CMP. Evidence of culvert plugging and clogging in the past. Road is insloped, with hillslope runoff from the burned area, with an actively eroding inboard ditch. Road surface runoff exits at the outboard fill and inboard fill with 100% delivery of fines to the stream. The inlet area has a rock wall.	1. Construct dip by lowering road 1 ft. and remove CMP/wall (50 ft- wide x 1 ft- deep x 15 ft- long = 34 yd^3). 2. Excavate keyway (10 ft- wide x 2 ft- deep x 10 ft- long = 10 yd^3) 3. Install armor with 0.5 - 1.5 ft. diameter rock 10 ft- wide x 2 ft- deep x 10 ft- long = 10 yd^3) 4. Rock 40 linear ft. of road near inlet or wherever out slope id not feasible 5. Outslope 250 ft. of right road. 6. Construct 2 rolling dip on right road. 7. All reshaped road sections will be rocked with 1.5 inch diameter minus base rock. 8. Spoil locally.
13	M	Stream crossing	0	0	290	100	124	Class III stream with low energy transport. The inlet has a concrete/rock wall. Right road approach is insloped with major rilling and gulling that deliver sediment at the inlet via the inboard ditch. Surface and uncontrollable hillslope runoff are creating moderate/high erosion and deterioration of the landing, road, and cutbank. Inboard ditch located on the right approach of the stream crossing inlet has evidence of past erosion and a 4 ft tall headcut.	1. Excavate from the top flag to the bottom flag. 2. Install a 24 inch diameter culvert (CMP). 3. Construct a critical dip on the left hinge line. 4. Outslope and remove berm for 100 ft. beyond landing to right. Keep insloped road surface through landing 175 ft. of right road approach; remove berm when applicable. 5. Construct 1 rolling dip on right road up road from landing. 6. Install 200 yd^3 of 0.25 - 0.75 ft. diameter road rock to right road approach and 20 yd^3 to inboard ditch through landing. 7. Install 5 yd^3 of 1.5-1.5 ft diameter rock armor to head cut in inboard ditch close to culvert inlet. 8. All reshaped road sections will be rocked with 1.5 inch diameter minus base rock. 9. Spoil locally.
14	M	Stream crossing	0	0	200	100	69	A Class III stream crossing with an undersized 12 inch diameter CMP. Small rock wall above inlet protects fill. Two small low powered streams merge just before the stream crossing inlet. Inlet of culvert is torn, giving evidence that the inlet has been cleaned in the past. Short road reach on the right road approach with hillslope runoff, erosion downcut cutbank into the inboard ditch, then delivery to the stream. Right road approach is insloped with a berm caused by long term grading. The road reach has a section of through cut in the middle of the reach that concentrates road runoff.	1. Excavate from the top flag to the bottom flag (TOP to BOT). 2. Install a 24 inch diameter culvert. 3. Construct a critical dip on the left hinge line. 4. Construct 1 rolling dip to immediate right. All reshaped road sections will be rocked with 1.5 inch diameter minus base rock. 5. Spoil locally.

Site #	Treatment Immediacy	Problem	Left road length (ft)	Left road delivery (%)	Right road length (ft)	Right road delivery (%)	Total estimated sediment delivery (yd^3)	Comment on Problem	Comment on treatment
15	M	Stream crossing	0	0	175	100	171	Class III stream with low energy. Two small streams converge just before culvert inlet. Outlet downstream of the crossing is steep and long. Right creek and ditch approach have 4 ft. head cuts upstream of the inlet. Inlet has a concrete/rock wall. Gully from outlet is 2 ft wide x 2 ft deep. Chunk of concrete is broken and nonfunctional at the outlet. Right road approach is insloped with a deep incising inboard ditch. The cutbank was sprayed with herbicide and the plants are dead. Some of the right road approach is through cut.	1. Excavate from the top flag to the bottom flag. 2. Install a 24 inch diameter by 40 foot long culvert at base of fill. 3. Construct a critical dip on the left hinge line. 4. Inslope right road for 150 ft. All reshaped road sections will be rocked with 1.5 inch diameter minus base rock. 5. Install 10 yd^3 of 0.25 - 0.75 ft. diameter rock armor to inboard ditch. 6. Install 5 yd^3 0.5 - 1.5 ft. diameter rock armor to IBF slope (between inboard ditch and new inlet). 7. Spoil locally.
16	HM	Stream crossing	0	0	260	100	128	Class III stream crossing with an undersized 12 inch diameter CMP. Culvert inlet is torn, giving evidence of past plugging and maintenance. The stream crossing was recently rocked around the inboard fill and outboard fill. Channel upstream of the top flag has recent incision. Right road approach is insloped and delivers fine sediment to the crossing.	1. Excavate from the top flag to the bottom flag (TOP to BOT). 2. Install a 24 inch diameter culvert (CMP) set to grade. There is a good rock supply onsite including 2.0 - 3.0 ft. diameter rip rap. 3. Construct a critical dip on the left hinge line. 4. Outslope where possible to 260 ft. of right road; remove berm where applicable. 5. Construct 1 rolling dip on right road. 6. All reshaped road sections will be rocked with 1.5 inch diameter minus base rock. 7. Spoil locally.
17	H	Stream crossing	0	0	500	100	69	An active canal diverts stream flow from a Class II stream (looks like about half the volume of water is diverted into the canal). The canal makes a hard right turn at the bottom flag. The culvert is undersized and the inlet has a mature tree growing onto of it and has relic barbwire around the berm atop the inlet. The canal seems to be in disrepair in some sections with THICK blackberry. The canal is entrenching in some areas and shallow in others. Road is flat and has been recently mulched with wood chips (when it rains it turns road into mud with traction). The crossing has lowered through years of use and has rocks unearthing. Due to the slope of the road a critical dip is not suggested.	1. Clean inlet of CMP (High Immediacy). 2. Excavate from top flag to bottom flag and remove existing culvert. Remove large oak tree at inlet to access area of excavation. 3. Install a 30 inch diameter culvert 30 ft. long. 4. Outslope 500 ft. of the right road approach. 5. Construct 2 rolling dips to the right road approach. 6. All reshaped road sections will be rocked with 1.5 inch diameter minus base rock. 7. Spoil locally.

Site #	Treatment Immediacy	Problem	Left road length (ft)	Left road delivery (%)	Right road length (ft)	Right road delivery (%)	Total estimated sediment delivery (yd^3)	Comment on Problem	Comment on treatment
18	M	Stream crossing	85	100	280	100	63	A Class II stream crossing at Bluff Springs with an undersized and mitered 24 inch diameter CMP. Large drainage area with a high volume of runoff, shallow streambed with a high velocity, looks like this area has been modified through the years. A diversion canal begins upslope, where water is taken from a spring and possibly the main channel (thick blackberry block the view of the diversion origin). Inlet has a small flare added to the CMP, but is undersized. Blackberry cover the entire outlet area. Outlet is 3 ft. high in the fill with a deep plunge hole. Shallow crossing with outboard fill ~10 ft. down and can't divert. Culvert is rust, but there was no sign of holes. The interior is crushed/bent 20%. Road surface contributed fine sediment at the crossing.	1. Excavate crossing from top flag to bottom flag. 2. Establish a 10 ft. wide channel bottom with 2:1 side slopes through the crossing. 3. Install a 40 ft. long bridge; ensure road approaches are drained prior to bridge installation. 4. Construct 1 rolling dip on right road. 5. All reshaped road sections will be rocked with 1.5 inch diameter minus base rock. 6. Spoil locally.
19	ML	Stream crossing	85	80	425	100	82	Class II stream with and old but functioning concrete and rocked armored fill. Small Class III stream converges on the left hinge line that goes on the road and to the main spillway. Spillway has ~35 foot apron. There is some undercutting on the bottom of the apron and step. Right bank is eroding and undercutting. Inlet and upstream of inlet are buried in blackberry. There are large boulders at the outlet and below. Native vegetation is coming back from the burn, with patches that were not burned. Some puddling and rutting on the left road. Left road has a through cut; no outsloping. Right road has recently applied wood chips on road surface.	1. Construct dip by lowering road 1 ft. (50 ft- wide x 1 ft- deep x 15 ft- long = 34 yd^3). 2. Excavate keyway (40 ft- wide x 5 ft- deep x 13 ft- long = 116 yd^3). 3. Install armor with 2.0 – 3.0 ft. diameter rock (22 ft- wide x 5 ft- deep x 13 ft- long = 53 yd^3). 4. Outslope 425 ft. of right road; remove berm when applicable. 5. Construct 2 rolling dips on right road approach. 6. Rock 20 ft. of right road. 7. Buildup 85 ft. of left road. 8. Rock 30 linear ft. of left road. 9. Endhaul half the spoils 600 ft. to the right and use the other half for road construction. 10. Use bull prick to demolish cement structure. 11. All reshaped road sections will be rocked with 1.5 inch diameter minus base rock.
20	HM	Other	165	100	145	100	47	A hillslope gully (no defined swale) crosses road, is eroding outboard fill, and is headcutting into roadbed and drivable road surface. Gully is 2 ft- wide x 1 ft- deep. Recent rains have laid out a sediment fan deposit on the road surface. Flow has run down the left road approach (0% grade to the left for 60 ft.) and has eroded outboard fill in a couple of locations delivering erosion in the past. Large areas of ponded water are located on left road approach. The stream diversion is active and also causing gullies in two locations.	1. Construct a rolling dip at the site. 2. Rock the rolling dip. 3. Excavate the outboard fill (20 ft- wide x 2 ft- deep x 10 ft- long = 20 yd^3). 4. Armor the outboard fill at the outlet of the rolling dip (20 ft- wide x 2 ft- deep x 15 ft- long = 15 yd^3). 5. Outslope 165 ft. of left road approach. 6. Outslope 145 ft. of right road approach. 7. All reshaped road sections will be rocked with 1.5 inch diameter minus base rock. 8. Spoil locally.

Site #	Treatment Immediacy	Problem	Left road length (ft)	Left road delivery (%)	Right road length (ft)	Right road delivery (%)	Total estimated sediment delivery (yd^3)	Comment on Problem	Comment on treatment
21	M	Stream crossing	850	20	0	0	92	Class III stream that is steep, rocked, and has an undefined swale. Recent sediment fan at inlet of stream crossing; lots of mixed clays-small gravels. CMP looks like it is undersized and plugs often, but water cuts through aggraded sediment deposited at the stream crossing inlet area. CMP is currently open. Outlet is shotgunned. Approximately, 100 ft. above inlet the channel splits for 8 ft. then rejoins at the stream crossing inlet. Another split in the stream is 30 ft. above inlet; right channel is gullying and eroding hillside. There is some ditch erosion on the right side of the inlet. Rilling is present on the outboard fill above CMP; water is eroding the hillside around the CMP. Downstream is fairly close to Union Creek confluence. Even though there is a long bottom, an armored fill is the most appropriate treatment recommendation, if upgrading this stream crossing. There are four gullies on the hillslope that we suggest placing rock to fortify the outlet areas of recommended rolling dips. The second gully and third gully should flow towards the same rolling dip.	1. Construct dip by lowering road 1 ft. (40 ft- wide x 4 ft- deep x 10 ft- long = 71 yd^3). 2. Excavate keyway (20 ft- wide x 2 ft- deep x 10 ft- long = 18 yd^3). 3. Install armor with 0.5 - 1.5 ft. diameter rock (20 ft- wide x 2 ft- deep x 10 ft- long = 15 yd^3). 4. Outslope 850 ft. of left road; remove berm when applicable. 5. Construct 4 rolling dips on the left road approach. 6. Rock 3 rolling dips at hillslope gullies. 7. Armor outboard fill at rocked rolling dips (10 ft- deep x 2 ft- deep x 15 ft- long x 3= 33 yd^3). 8. Spoil locally. 9. Remove old piece of culvert located near top flag. 10. All reshaped road sections will be rocked with 1.5 inch diameter minus base rock.
22	HM	Stream crossing	400	50	125	100	278	A larger Class II stream crossing with a 24 inch CMP that is 100% plugged with evidence of a concrete inboard fill wall. PWA estimates that 233 yd^3 of material will wash-out at the stream crossing in the next catastrophic event or overtime, if no work is done. After plugging an armored fill type crossing was installed with a concreate apron spillway sown outboard fill. A mature tree is growing at the inlet. Concrete apron is nonfunctional and being flanked on both sides by the stream, with ongoing erosion down outboard fill. Directly below the apron there is a big boulder and bedrock at the bottom flag. Concrete apron is 12 ft. wide and 10 ft. long. Left road has hillslope gully issues with eroding cut bank rills gullies down the outboard fill that are head cutting into the road. The crossing has a high sediment transport regime.	1. Construct dip by lowering road 1 ft. (60 ft- wide x 3 ft- deep x 15 ft- long = 120 yd^3). 2. Excavate keyway (20 ft- wide x 5 ft- deep x 35 ft- long = 156 yd^3). 3. Install armor with 0.5 - 3.0 ft. diameter rock (20 ft- wide x 5 ft- deep x 35 ft- long = 130 yd^3). 4. Outslope 125 ft. of right road; remove berm when applicable. 5. Outslope 400 ft. of left road; remove berm for 300 ft. or when applicable. 6. Construct 2 rolling dips to the left road; one at 75 ft. and one at 225 ft. left from center line, first rolling dip to right in a Type III rolling dip. 7. Rock rolling dips (15 ft- wide x 20 ft- ft long = 11 x 2= 22 yd^3). 8. Armor outboard fill at the rolling rocks (10 ft wide x 2 ft- long x 15 ft- deep = 11 x 2= 22 yd^3). 9. End haul the spoils to the right 1,500 ft. 10. Use bull prick to remove concrete apron. 11. All reshaped road sections will be rocked with 1.5 inch diameter minus base rock.

Site #	Treatment Immediacy	Problem	Left road length (ft)	Left road delivery (%)	Right road length (ft)	Right road delivery (%)	Total estimated sediment delivery (yd^3)	Comment on Problem	Comment on treatment
23	HM	Stream crossing	6	100	322	100	119	Class II stream cascades onto a dipped and fortified armored fill. Water is turbid upstream of the crossing. A gully has formed where the stream crosses road surface. The right road approach has an actively eroding ditch the entire way with little standing water. Outboard fill of right road approach has a rill 30 ft. from centerline that delivers sediment to outlet. Some sediment deposits and is fanning before inboard road. Road surface is saturated. Creek splits at the outlet around a Ponderosa Pine. Concrete sill was exposed in 2017 storm events.	1. Construct armored fill, remove cement sill with bull prick, construct dip by lowering road 1 ft. (40 ft- wide x 1 ft- deep x 26 ft- long = 47 yd^3). 2. Excavate keyway (32 ft wide x 4 ft- deep x 14 ft- long = 80 yd^3). 3. Install armor with 1.0 – 3.0 ft. diameter rock (32 ft- wide x 4 ft- deep x 14 ft- long = 66 yd^3). 4. Outslope 322 ft. of right road; remove berm when applicable. 5. Construct 2 rolling dips to the right road. 6. Endhaul to spoil pile at landing. 7. Remove rock and sediment in road/channel near top flag. 8. All reshaped road sections will be rocked with 1.5 inch diameter minus base rock.
24	M	Stream crossing	0	0	1250	50	91	A near origin Class III stream crossing with a 12 inch diameter CMP in a broad drainage. Flow splits upstream and the two channels are separated by 6 ft down to the inlet where they converge. There is a rock wall at the stream crossing inlet to protect the fill. The right road approach has surface erosion and sediment delivery problems. Past diversion gullies from site #23 have caused past gullies down the right road outboard fill.	Decommission: 1. Remove all road fill and decommission stream crossing 2. Construct a 4.0 ft. wide channel bottom. 3. Lay back sideslopes 2:1. 4. Rip and drain right road approach for 1,250 ft. and add 12 cross road drains.
25	H	Stream crossing	0	0	245	100	64	Class III stream with 2 springs emerge out of the cutbank right of inlet. The stream channel is diverted, culvert is plugged. CMP is 99% plugged at inlet and exposed on the road. Upstream and cut bank area are erodible soil (soft bedrock). Plugged culvert has caused a diversion which caused large outboard fill erosion 80 ft. left road. Parts of the road have eroded and delivered sediment to the creek. When diverted stream flow goes over outboard fill, it delivers to a larger stream via a gully that has cut down to Cr in some places. A majority of the continual water at the outlet is from the springs and road runoff, with the main channel in recent rain events. The outlet has a gully and a rock wall. This site is active, exhibiting extreme erosional behavior, during mild fall precipitation. This Class III stream looks like it was an on gully scar that has grown over decades.	Decommission: 1. Remove all road fill and decommission stream crossing. 2. Construct a 4 ft. wide channel bottom. 3. Lay back sideslopes 2:1. 4. Rip and drain right road approach for 245 ft. 5. Add 2 cross road drains,

Site #	Treatment Immediacy	Problem	Left road length (ft)	Left road delivery (%)	Right road length (ft)	Right road delivery (%)	Total estimated sediment delivery (yd^3)	Comment on Problem	Comment on treatment
26	H	Stream crossing	450	100	505	100	784	A large, rowdy Class II stream with an armored fill/concrete apron spillway that is nonfunctional. PWA estimates that 668 yd^3 of material will wash-out at the stream crossing in the next catastrophic event or overtime, if no work is done. Stream is flanking spillway on both sides and is causing active erosion and sediment delivery with left side threatening to washout road. Spillway built into some natural existing rock features. Concreate apron is short of bottom by 7 ft. and flow is seeping under fill and undercutting apron. Right road approach had diverted stream from site #26, which is eroding road surface and outboard fill. There is also hillslope runoff gullies that impact cut bank and road surface. Apron is 30 ft- wide x 15 ft. deep x 5 ft thick. Inlet width and overall area is restricted by cutbanks.	Decommission: 1. Excavate cement sill and remove stored sediment to decommission stream crossing. 2. Excavate a 40 ft. wide channel bottom at grade. 3. Lay back side slopes 2:1 from top flag to bottom flag. 4. End haul spoils offsite to nearest landing. 5. Remove 60 ft. of right hinge to remove risk of fill slope overburden and potential failure (444 yd^3). 6. Decommission right hinge line for 60 ft. (444 yd^3).
27	H	Stream crossing	6,265	35	92	100	1,444	Class II stream crossing with a nonfunctional concrete fill and spillway that is a potential fish barrier. PWA estimates that 1,209 yd^3 of material will wash-out at the stream crossing in the next catastrophic event or overtime, if no work is done. PWA is unsure of the fish status of this stream, but frogs and other aquatic species were seen. Water has a blue/brown color upstream of the crossing. The concrete wall at the outboard fill is 87 ft. wide, 2 ft. thick, and 10 ft. down. The road and stream are creating gullies, which actively flank the concrete wall, creating a fillslope failure, and undercutting the concrete wall causing sediment delivery. We found a CMP sticking out at the outlet position that is completely crushed. The inlet is buried due to aggradation up to the top of inlet wall. The inboard wall is visible for 40 ft. wide, 1 foot tall, and 1 foot thick. The site has experienced moveable bedload with sizes that range from fines to large boulders. The top flag is located at a knick point, but the stream is altered by debris flow deposition that we were unsure of its original configuration. Some armoring on the right outboard edge has been done to help reduce the volume of erosion and sediment delivery. The left road approach is lacking road drainage features; very long with rills, actively eroding ditch, failing ditch relief culverts, and springs. Only a few road segments contain site insloped/outsloped road reaches and rolling dip features. An active spring on left approach erodes hillslope downstream of road. PWA estimates that 235 yd^3 of road surface material will erode and deliver to the stream system in the next 10 years, if the road is not upgraded to meet forest road standards.	Decommission: 1. Decommission stream crossing from top flag to bottom flag 2. Lay back streamside hillslopes to base of cut bank on right and left. 3. Construct a 40 ft. wide channel bottom on grade. 4. Remove all concrete off site- use bull prick. 5. End haul spoils off site to stable disposal area(s). 6. Construct 63 cross road drains to left and 1 cross road drain to right road approach. 7. Remove left and right hinge lines, 60 ft. each= a total of 888 yd^3.

Site #	Treatment Immediacy	Problem	Left road length (ft)	Left road delivery (%)	Right road length (ft)	Right road delivery (%)	Total estimated sediment delivery (yd^3)	Comment on Problem	Comment on treatment
28	HM	Stream crossing	30	100	625	100	236	A small Class III stream with a filled stream crossing that is not functioning properly. There is no rock armor on outboard fill. There is an apron on the left approach. The stream flow goes over the road causing erosion on the outboard fill, as well as creating active headcutting. There are two straw bales in the head cut, lengthwise. There is a fallen oak down the outboard fill that is holding back fill temporarily.	Decommission: 1. Decommission stream crossing from top flag to bottom flag. 2. Lay back streamside hillslopes to base of cut bank on right and left. 3. Construct a 4 ft. wide channel bottom at grade. 4. Stockpile material locally. 5. Construct 6 cross road drains on right road approach.
29	HM	Stream crossing	1750	20	420	100	385	Class II stream with a 48 inch diameter CMP that had a cement wall at the inlet and outlet. There is a Class III ephemeral stream that intersects the road to the right of the inlet. This site was not directly affected by the fire; high amount of lush vegetation are present, however there is evidence of higher than normal sediment transport in recent years. Stream is rowdy, with a lot of boulders and scour scars from recent (last) winter. Approximately, 210 ft. to the right road approach is a swale but no sign of channel. Inlet was cleaned out in the past few years with evidence of sediment plugging up to 5 ft.; spoil site just left of the inlet. Inlet wall has a crack above the CMP; it is possible that the wall may break off and plug inlet. Left side of the inlet has a wing wall. Outlet had a cement step that is cracking and undercutting. There are two trees flanking the outlet that are dangerously undercut. Water overtops road. PWA estimates that 278 yd^3 of material will wash-out at the stream crossing in the next catastrophic event or overtime, if no work is done. Most of the road drains off, but the first 300 ft. has delivering gullies. Just left of the hinge line is a cut bank failure that has piled into the ditch (13 tall x 2 deep x 10 wide).	Decommission: 1. Decommission stream crossing from top flag to bottom flag. 2. Layback streamside hillslopes 2:1. 3. Construct a 12 ft. wide channel bottom on grade. 4. Spoil material locally. 5. Construct 18 cross road drains on left and 5 cross road drains on right road approach.
30	ML	Stream crossing	500	15	50	100	31	Class III stream crossing that has been upgraded an armored fill with shallow rock. There was a 12 inch diameter CMP with a concrete wall on the inboard side that was removed. Road was dipped but the keyway was not excavated and armored properly, and is nonfunctional. Not too steep of a slope, but most of the fill was removed with some rock armor at the outboard fill, two straw bales at the center of the crossing at the outlet that splits flow into two channels running does the fill. Low powered stream with low erosion potential. Left road is highly erodible with gullies forming along short road sections. Left road has several water bars outs and a recent rolling dip constructed at a pulled 12 inch diameter ditch relief culvert. The erosion potential has increased to ML due to left road surface. Most is not connected, but the water bars are broken down and shallow dips are breaching. Enhancement to left road drainage is needed ASAP.	Decommission: 1. Decommission stream crossing from top flag to bottom flag. 2. Lay back streamside slopes 2:1. 3. Excavate a 4 ft. wide channel bottom on grade. 4. Spoil material locally. 5. Construct 5 cross road drains on left road approach.

Site #	Treatment Immediacy	Problem	Left road length (ft)	Left road delivery (%)	Right road length (ft)	Right road delivery (%)	Total estimated sediment delivery (yd^3)	Comment on Problem	Comment on treatment
31	ML	Stream crossing	131	100	20	100	20	Class III stream with a filled crossing that has had a CMP recently removed. To remedy the problem, there are two hay bales at the outlet that are splitting flow and creating a temporary sediment catch that is nonfunctional. Ultimately, the crossing is dipped but nonfunctional with stream flow actively flanking berms on the outboard fill. Some grasses and shrubs have grown back with some tree retention in the riparian area. Crossing is near origin. There is a sediment wedge at the inlet that the stream has cut through. The sediment wedge/deposit is made of coarse sand. The road matrix is highly erodible with gullies on the left and right hinge on the dip.	Decommission: 1. Decommission stream crossing from top flag to bottom flag. 2. Lay back streamside hillslopes 2:1. 3. Construct a 4 ft. wide channel bottom on grade. 4. Spoil locally. 5. Construct 2 cross road drains on left road approach.
32	M	Stream crossing	45	100	45	100	19	A Class III stream with a dip that had a 12 inch diameter CMP removed recently. This crossing was not decommissioned properly. Small near origin stream with low power. Immediate treatment is necessary to arrest active erosion, excavate keyway and armor. Small stream with small drainage area and shallow swale below road but sediment transport evident and continuous to where step break in slope occurs ~250 ft. below road. Right road surface is highly erodible with riling.	Decommission: 1. Decommission stream crossing from top flag to bottom flag. 2. Lay back streamside hillslopes 2:1. 3. Construct a 4 ft. wide channel bottom. 4. Spoil locally.
33	M	Stream crossing	0	0	1,079	20	185	A Class III stream that has a filled stream crossing. Stream crossing is on right hinge line of an additional stream crossing site (armored fill crossing site #34). Stream is diverted and flows down inboard edge of road down to site #34, where it converges. Erosion occurring along inboard road and is undercutting cut bank. PWA estimates that 163 yd^3 of material will wash-out at the stream crossing in the next catastrophic event or overtime, if no work is done. Outboard fill has recent spoils, making for an overhanging berm that is being undercut by a Class II stream crossing (site #34). Armor for site #34 does not extend to this site.	Decommission: 1. Decommission stream crossing top flag to bottom flag. 2. Lay back streamside slopes 2:1. Excavate a 4 ft. wide channel bottom at grade. 4. Spoil locally. 5. Construct 11 cross road drains on right road approach.

Site #	Treatment Immediacy	Problem	Left road length (ft)	Left road delivery (%)	Right road length (ft)	Right road delivery (%)	Total estimated sediment delivery (yd^3)	Comment on Problem	Comment on treatment
34	M	Stream crossing	2,300	10	76	100	542	Class II stream that was recently upgraded without proper design or permits. PWA estimates that 501 yd^3 of material will wash-out at the stream crossing in the next catastrophic event or overtime, if no work is done. There was a concrete wall on the outboard fill that was removed. It looks like there was a large sediment storage behind the concrete wall before it was removed. In addition the road was dipped, and the culvert inlet was cleaned out. The concrete wall was broken up and used as armor for the outlet. Inlet area is a knick point/waterfall. The water seems turbid and there are pools upstream of the road that are green. The slopes on the outboard fill flanking the outlet are perched and deteriorating, delivering sediment to the stream. There has already been some failure since the unpermitted upgrade. There is a Class III stream from a stream crossing (site #33) that delivers into this stream crossing (site #34). There is a landing/spoil site 400 ft. to the left. Left road long with ditch relief culverts, rolling dips, and outs. Soil is very erodible pebbles-fines. There is a lot of hillslope runoff creating gullies, but not streams. Some swales too, but they lack bed and banks. There are 4 ditch relief culverts that were pulled and left sloppily. We suggest rocking each of these sites. Some seem to be near origin streams, downstream from sites there are channels, but not upstream.	Decommission: 1. Decommission stream crossing from top flag to bottom flag. 2. Lay back stream side slopes to base of cut bank. 3. Construct a 12 ft. wide channel bottom. 4. End haul spoils to landing. 5. Install a total of 23 cross road drains on left and on right. 6. Remove perched fills on left (40 ft. long x 80 ft. wide x 6 ft. deep = 711 yd^3). 7. Remove perched fills on left (40 ft. long x 80 ft. wide x 6 ft. deep = 711 yd^3).
35	M	Stream crossing	370	100	12	100	128	Class III stream crossing with an undersized 15 diameter inch CMP. Inlet has nonfunctional concrete wall and outlet has concrete apron acting as a spillway if CMP plugs. Channel upstream is braided and spills over fairly rocky, but erodible cut bank over a broad area. CMP likely plugged in the past and diverted. Spoils to left indicate past cleaning. Even if culvert plugs 100%, stream will flow across road and down concrete apron. If critical dip fails along the right hingeline, the stream has the potential to divert again. Left road approach has bedrock cut bank and road is perched on a steep cliff. Concrete wall is present (12 ft- wide x 5 ft- tall).	Decommission: 1. Decommission stream crossing from top flag to bottom flag. 2. Excavate a 5 ft. channel bottom at grade. 3. Lay back stream side slopes to base of cut bank or 2:1. 4. Stockpile locally. 5. Install 4 cross road drains on left approach.
35.1	M	Road surface	270	100	0	0	53	Spring and road runoff cause gully on road surface and hillslope downstream of road. Site delivers sediment to the headwall of a Class III stream.	1. Rip and drain 270 ft. use 3 cross road drains.
35.2	ML	Road surface	850	100	0	0	135	Road surface erosion exits road at water bar and delivers sediment to the headwall of a Class III stream. PWA estimates that 135 yd^3 of road surface material will erode and deliver to the stream system in the next 10 years, if the road is not decommissioned.	1. Rip and drain 850 ft. of road, use 9 cross road drains.
35.3	ML	Road surface	150	100	0	0	30	Road surface erosion exits road at water bar and delivers sediment to the headwall of a Class III stream.	1. Rip and drain 150 ft. of road, use 2 cross road drains.

Site #	Treatment Immediacy	Problem	Left road length (ft)	Left road delivery (%)	Right road length (ft)	Right road delivery (%)	Total estimated sediment delivery (yd^3)	Comment on Problem	Comment on treatment
35.4	ML	Road surface	100	100	0	0	20	Road surface erosion exits road at water bar and delivers sediment to the headwall of a Class III stream.	1. Rip and drain 100 ft. of road, use 2 cross road drains.
36	ML	Stream crossing	870	15	20	100	75	Class III stream and steep cascade, all rock face inlet, and recently removed CMP that has active erosion. Very steep outboard fill and lower end stake. Stream is low power and near origin. Spoils were side casted on the left hinge outboard fill and flanking outlet. Armoring of outlet is one of the better jobs that we've seen but still needs work to function properly. Left road is well drained. Towards the end of the left road there is a gully that will need rocking.	Decommission: 1. Decommission stream crossing from top flag to bottom flag. 2. Lay back stream side slopes to base of cut bank. 3. Construct a 4 ft. wide channel bottom. 4. Spoil locally 5. Construct 9 cross road drains on left road approach.
37	H	Stream crossing	160	100	0	0	96	Class II stream crossing with and undersized 18 inch diameter CMP that is 100% plugged. Steep boulder cascade above stream crossing inlet. Inlet has small concrete wall at the inboard fill. Stream flow splits at inlet with road washed out on the left hinge line. Some flow runs over concrete apron (15 x 2) on right and has flanked in the past on the right as well. Some flow splits upstream of top flag and has diverted down the road to the right for 125 ft. This stream diversion combines with the hillslope runoff and has caused erosion down the outboard fill where crossing will continue to flank concrete and washed out. There is a potential for continued stream diversion to the right.	Decommission: 1. Decommission stream crossing from top flag to bottom flag. 2. Lay back stream side slopes to base of cut bank. 3. Construct a 4 ft. wide channel bottom. 4. Spoil locally 5. Construct 1 cross road drains on left road approach.
38	HM	Stream crossing	0	0	943	80	122	Class II stream and steep cascade has filled the inlet of the CMP with a debris flow deposit and washed out the right hinge. Then the stream diverted down the left road alignment. There are a lot of moderately sized rills off of the hillslope that contribute to the diverted channel. The diversion is 35 ft. down the left road. It goes down the outboard fill for 100 ft. before reentering original channel. This entire reach of road (from turn to turn) has hillslope scaring from long-term erosion that appears accelerated. Approximately, 50 ft. left road there is a large gully from the hillslope creating a large (7 ft. wide) gully down road and out the outboard fil. There are three major gullies from uncontrollable hillslope runoff on the right road approach. Right road is rock outcrop with bedrock cutbanks. Gullies create a waterslide effect when water hits road. High velocity and concentrated water from bedrock cutbank. PWA estimates that 98 yd^3 of road surface material will erode and deliver to the stream system in the next 10 years, if the road is not decommissioned.	Decommission: 1. Decommission stream crossing from top flag to bottom flag. 2. Lay back stream side slopes to base of cut bank. 3. Construct a 4 ft. wide channel bottom. 4. Spoil locally 5. Construct 9 cross road drains on right road approach.

Site #	Treatment Immediacy	Problem	Left road length (ft)	Left road delivery (%)	Right road length (ft)	Right road delivery (%)	Total estimated sediment delivery (yd^3)	Comment on Problem	Comment on treatment
39	H	Ditch relief culvert	0	0	270	90	74	A 24 inch diameter ditch relief culvert drains ditch on the inside edge of road intercepts runoff from ditch/road and cutbank and delivers sediment to a Class III stream downstream. The right road surface approach is heavily impacted by a diversion gully (site #38) and several hillslope rills and gullies. Road is gullied with several erosion gullies downstream of outboard fill that deliver to the stream below. The ditch is plugged up the road and most of the flow of the outboard fill with some still making it to the inlet. The inlet area has a brick wing wall. Inlet of culvert is ~10% plugged. Erodible soil mixed with erodible bedrock and rock.	Decommission: 1. Excavate DRC and create a large cross road drain. 2. Rip and drain 270 ft. of right road, use 3 cross road drains.
40	M	Stream crossing	0	0	1083	15	182	Class III stream with an undersized and washed out 15 inch diameter CMP. Stream has eroded and incised the channel bed down to bedrock. PWA estimates that 161 yd^3 of material will wash-out at the stream crossing in the next catastrophic event or overtime, if no work is done. The stream reaches near the culvert inlet and outlet are boulders cascades. There is some sediment that has overtopped the crossing, but a lot of the sediment delivery is from 3 major uncontrollable hillslope gullies on the right road approach. Currently, most of the right road approach water runoff diverts off via the previously mentioned gullies before delivering sediment to the stream at the crossing. Soil is sandy, very erodible, and there are many rock falls from upslope cliffs that have deposited on the road surface. CMP is shotgunned and 80% unearthed and exposed.	Decommission: 1. Decommission stream crossing from top flag to bottom flag. 2. Lay back stream side slopes to base of cut bank. 3. Construct a 10 ft. wide channel bottom. 4. Spoil locally. 5. Construct 11 cross road drains on right road approach. 6. Rip 1,083 ft. of road on right approach. 7. Remove fill slope (80 ft- wide x 8 ft- deep x 25 ft- long).
41	M	Stream crossing	0	0	500	100	92	Class III stream with a filled stream crossing. Stream is near origin. Rocky steep channel reach upstream of the road. Stream flow mostly washes over outboard fill downstream through rocky material. Some stream flow diverts to the left down the road approach. Site will continue to wash out over time but has rocky cut bank and native rocks on the road surface. Right road approach has a spring 375 ft. up right road approach. Stream flow overtops the site and flows over uncompacted fill on the outer edge of the road. There is a concrete outlet down the outboard fill on the right hinge line; it must have drained the right road approach in the past. This section of road is perched and steep rocky inner gorge section, it may be difficult to maintain in the future.	Decommission: 1. Decommission stream crossing from top flag to bottom flag. 2. Lay back stream side slopes to base of cut bank. 3. Construct a 6 ft. wide channel bottom. 4. Spoil locally. 5. Construct 5 cross road drains on right road approach.

Site #	Treatment Immediacy	Problem	Left road length (ft)	Left road delivery (%)	Right road length (ft)	Right road delivery (%)	Total estimated sediment delivery (yd^3)	Comment on Problem	Comment on treatment
42	L	Stream crossing	150	100	460	30	220	Class II stream with a culvert and a brick inboard fill wall and a concrete wall on the outer edge of the road (outboard fill wall). Stream has a large drainage area and channel is wide with lots of rock and exposed bedrock. There is a stream diversion pipe on the right road and a concrete housing station on the right bank. Crossing seems fine except for large rock on the road surface. Large trees have fallen onto the right and left roads. Stream is naturally in a step styled morphology (cascade, pool, cascade). Left road has vegetation taking over. There is a spring 150 ft. up the left road approach. Although this site has low erosion potential, PWA estimates that 199 yd^3 of material will wash-out at the stream crossing in the next catastrophic event or overtime, if no work is done.	Decommission: 1. Decommission stream crossing from top flag to bottom flag. 2. Lay back stream side slopes to base of cut bank. 3. Construct a 40 ft. wide channel bottom. 4. Spoil locally, IPOS 80 ft. wide x 40 ft. long x 6 ft. deep to left. 5. Rip and drain 450 ft. of road, construct 5 cross road drains on left road approach. 6. Remove concrete waste 50 yd^3.
43	ML	Ditch relief culvert	1250	10	0	0	19	A strong flowing spring emerges from undercut cutbank and flows down road for 35 ft. to a plugged 36 inch diameter ditch relief culvert. Culvert is plugged with berry vines and rock. Still has a good amount of flow exiting the culvert outlet with a past gully, erosion and sediment delivery down the fillslope. Gully flows over rocky material. Stable CMP rusty with no holes. Some of the stream flow overtops the road and outboard fill just up road from ditch relief culvert inlet at water bar. Future erosion was identified under vines.	Decommission: 1. Decommission springs from top flag to bottom flag in 4 locations. 2. Lay back excavated side slopes to base of cut bank. 3. Construct a 4 ft. wide channel bottom at each spring. 4. Spoil locally. 5. Rip and drain road, construct 9 cross road drains on left road approach.
44	ML	Stream crossing	220	100	440	100	116	Class III near origin with cut bank failure that plugged inlet creating aggradation. Upstream is bedrock. Cement apron. Pile of sediment stored on the road with the stream later cutting a little channel through the fan.	Decommission: 1. Decommission stream crossing from top flag to bottom flag. 2. Lay back stream side slopes to base of cut bank. 3. Construct a 4 ft. wide channel bottom. 4. Spoil locally 5. Construct 2 cross road drains on left road approach, and 4 on the right.
45	HM	Stream crossing	860	80	0	0	108	Class III stream crossing with a 12 inch plugged CMP. There is a concrete spillway at the outboard fill that was built over top of plugged CMP. There is 15 ft. of exposed CMP below the cement; wash out. Concrete is undercut and cracking with pieces fallen into the stream. Concrete is (25 x 0.5 x 10). Past debris torrent from stream channel above deposited debris on the road and the channel below.	Decommission: 1. Decommission stream crossing from top flag to bottom flag. 2. Lay back stream side slopes to base of cut bank. 3. Construct a 4 ft. wide channel bottom. 4. Spoil locally 5. Construct 8 cross road drains total.

Site #	Treatment Immediacy	Problem	Left road length (ft)	Left road delivery (%)	Right road length (ft)	Right road delivery (%)	Total estimated sediment delivery (yd^3)	Comment on Problem	Comment on treatment
46	ML	Stream crossing	375	90	0	0	125	Class II stream with a CMP that has a concrete outboard fill wall with a formed concrete step. There is a rock deposit on the right hinge line from a rock fall/debris flow. Approximately 50 ft. to the right of the stream crossing is a cutbank failure. The stream crossing is filled with sediment and rock, water is carving a channel though the road prism. Approximately 50 ft. above the top flag is a 75 foot tall waterfall. It is possible that the channel went 20 ft. to the left of center line before carving its current channel through the sediment (deceiving because of the waterfall and rock debris).	Decommission: 1. Decommission stream crossing from top flag to bottom flag. 2. Lay back stream side slopes to base of cut bank. 3. Construct a 6 ft. wide channel bottom. 4. Spoil locally. 5. Rip and drain, construct 4 cross road drains on left road approach.
47	H	Stream crossing	1875	90	0	0	267	A Class III stream crossing with an 18 inch diameter CMP. CMP is plugged 100% at inlet and stream flow overtops the road surface and erodes outboard fill in several places, The stream flow emerges just below bottom flag. Outlet is set high in the fill. Long left road approach with three uncontrollable hillslope gullies that cross the road and delivered in the past. Percentage of road surface delivery is high, connection via hillslope gullies and past gullies with sediment delivery erode outboard fill. Cutbank seeps and springs along the road diverted in the past causing sediment delivery. PWA estimates that 237 yd^3 of road surface material will erode and deliver to the stream system in the next 10 years, if the road is not upgraded to meet forest road standards. The crossing has a high treatment immediacy.	1. Excavate from top flag to bottom flag with 2:1 side slopes and a 4 ft. wide channel bed. 2. Spoil locally on left. 3. Construct 5 cross road drains to the left road= 1) Rip road surface 18" to 24" deep for 1,875 ft. on left road approach using rippers on bulldozer 2) Construct 5 cross road drains on the left road approach at the hill slope gullies and ditch relief culverts (be sure they are deep and wide). 4. Spoil locally.
48	M	Stream crossing	200	100	0	0	138	A steep, cascading Class III stream with no culvert and a rock wall that stabilizes the outlet area. Stream has a small drainage area, but looks like it can get power behind it (flashy). Bottom flag is a 7 foot headcut approximately 20 ft. downstream from outer wall. There is a sediment deposit on the left hingeline of the crossing. The outboard fill along the right hingeline has a large amount of overburden and is waiting to fail. Steep country. Cutbank is seeping water.	1. Excavate from top flag to bottom flag with 2:1 side slopes and a 6 foot wide channel bed. 2. Spoil locally on left road approach. 3. Construct 4 cross road drains to the left road= 1) Rip road surface 18" to 24" deep for 200 ft. on left road approach using rippers on bulldozer 2) Construct 4 cross road drains on the left road approach. 4. Spoil locally.
49	M	Stream crossing	840	80	40	100	147	A Class III stream crossing with an undersized 12 inch diameter CMP. The culvert inlet is 100% plugged by a debris torrent in the past, big boulders and sediment are deposited on road surface. Stream may have been washed out pre debris slide and now lots of rock deposits on road surface. Stream splits at the inboard road due to rock and is undercutting left and right road approaches. This will continue to undercut sideslopes on the left and right of the crossing. Otherwise, rocky material fills eroded void in crossing. Right road has an uncontrollable hillslope gully that crosses road approximately 50 ft. left of the stream crossing. We identified springs and a weeping cutbank on the left road approach as well as insloped sections of road, exit outboard fill and connect road surface to stream below via past gullies down outboard fill.	1. Excavate from top flag to bottom flag with 2:1 side slopes and a 9 foot wide channel bed. 2. Construct 5 cross road drains= 1) Rip road surface 18" to 24" deep for 840 ft. on left road approach using rippers on bulldozer 2) Construct 3 cross road drains to the left road 50 ft. apart and 2 more at 100 ft. apart to drain spring. 3. Spoil locally.

Site #	Treatment Immediacy	Problem	Left road length (ft)	Left road delivery (%)	Right road length (ft)	Right road delivery (%)	Total estimated sediment delivery (yd^3)	Comment on Problem	Comment on treatment
50	L	Stream crossing	550	90	0	0	163	Class II stream that had a major debris flow erode the crossing. Now the entire crossing has incised and eroded down to bedrock with boulder lag. There are whole dead trees at the top of crossing and bottom of the crossing. From top flag to bottom flag this is only on change in slope where there is a 7 foot knick point (bedrock edge and contact point). There is an active diversion 80 ft down the right road. Approximately, 150 ft. up the left road approach is a road runoff gully that delivered; may have been exasperated by past stream diversion form site #51. Approximately, 85% future delivery; not 100% due to onsite landslide behavior. Cutbank is seeping water and there are a lot of rocks creeping down the slope upslope of the road.	1. Pull perched outboard fill left from washout (50 ft- wide x 3 ft- deep x 12 ft- long = 67 yd^3). 2. Pull perched outboard fill right from washout (40 ft- wide x 2 ft- deep x 20 ft- long = 60 yd^3). 3. Spoil locally on left, out slope road and fill ditch for 550 ft. to decommission road alignment. 4. Construct 11 cross road drains to the left road= 1) Rip road surface 18" to 24" deep for 550 ft. on left road approach using rippers on bulldozer 2) Construct 11 cross road drains on the left road approach. 5. Spoil locally.
51	H	Stream crossing	500	100	0	0	146	A Class II stream crossing with and undersized 12 inch CMP. Steep rocky 75 ft. cliff upstream of the top flag about 25 ft. the stream crossing is washed out with recent erosion evidence and failed outboard fill. Stream experienced a debris torrent as well as hillslope gullies just up road approach from left of hinge line and run down to road and gully across outboard fill also. Outlet of CMP encased in concrete wall with rock armor. Stream and hillslope gullies are undercutting fill and flank rock armor and concrete outlet. More hillslope gullies on the left road approach; there is are 6 gullies in a 500 ft. reach of road. Steep erosive top soil layer prone to debris flows. Burned with steep hills upslope of road. This site has a high treatment immediacy.	1. Excavate from top flag to bottom flag with 2:1 side slopes and a 4 foot wide channel bed. 2. Spoil locally on left, out slope road and fill ditch for 320 ft. to decommission road alignment. 3. Construct 6 cross road drains to the left road= A) Rip road surface 18" to 24" deep for 320 ft. on left road approach using rippers on bulldozer B) Construct 6 cross road drains on the left road approach. 4. Spoil locally.
52	H	Stream crossing	740	100	50	100	270	Class II stream with two undersized culverts (18 and 12 inch diameter). Site has a nonfunctional concrete fillslope on the outer edge of road. Evidence of past debris flow upstream and downstream of stream crossing. Stream crossing is washed-out, but could easily be made passable by machinery. PWA estimates that 174 yd^3 of material will wash-out at the stream crossing in the next catastrophic event or overtime, if no work is done. There is a 6.0 ft DBH burnt Ponderosa Pine on the right hingeline. Stream, erosion and gullies are flanking concrete wall, but wall is still intact. However, the concrete step is deteriorating. Uncontrollable, upslope hillslope gullies on left road approach have past and future erosion. In addition to the estimated catastrophic erosion, PWA estimates that 96 yd^3 of road surface material will erode (chronic erosion) and deliver to the stream system in the next 10 years, if the road is not decommissioned. This site has a high treatment immediacy.	1. Excavate from top flag to bottom flag with 2:1 side slopes and a 6 foot wide channel bed; remove concrete and CMP. 2. Spoil locally on left, out slope road and fill ditch for 740 ft. to decommission road alignment. 3. Construct 14 cross road drains to the left road = 1) Rip road surface 18" to 24" deep for 740 ft. on left road approach using rippers on bulldozer 2) Construct 14 cross road drains on the left road approach. 6. Other Treatment: Construct 2 cross road at hillslope gullies at 230 ft. left road and at 400 ft. left road at spring. Remove 35 to 60 yd^3 at each gully location. 5. Spoil locally.

Site #	Treatment Immediacy	Problem	Left road length (ft)	Left road delivery (%)	Right road length (ft)	Right road delivery (%)	Total estimated sediment delivery (yd^3)	Comment on Problem	Comment on treatment
53	ML	Stream crossing	0	0	650	50	64	A Class II stream crossing that had a 12 inch diameter CMP. Culvert was undersized for the drainage area at the stream crossing. A debris torrent from upslope completely washed-out the stream crossing and CMP. We identified extreme hydraulic power and deposition by boulders crossing washout. Most of the road has washed away completely. Stream undercuts outboard fill which will continue to layback side slopes. Otherwise lots of rock from debris torrent covers and has deposited at crossing and stream swale below road cut to steep break in slope. No profile or cross section shot at the site since most fill is washed-away. Right road approach has hillslope gully that transports surface runoff and delivers to stream below. Also an active spring to right of stream crossing contributes to runoff.	1. Layback outboard fill on right hinge (25 ft- wide x 3 ft- deep x 10 ft- long) = 34 yd^3 and left outboard fill (15 ft- wide x 3 ft- deep x 6 ft- long) = 12 yd^3; total= 46 yd^3. 2. Spoil locally on right, out slope road and fill ditch for 650 ft. to decommission road alignment. 3. Construct 2 cross road drains to the left road= A) Rip road surface 18" to 24" deep for 650 ft. on left road approach using rippers on bulldozer B) Construct 2 cross road drains on the left road approach with on at the hillslope gully and another at the spring. 4. Spoil locally.
54	HM	Stream crossing	0	0	300	100	122	Class III stream crossing with a rock wall that stabilizes and fortifies the outboard fill. Downstream of the wall there is erosion at cross section #3.Upslope from road has pines and oaks that made it through the fire and are alive. It looks like some armoring was placed on parts of the outboard fill where failure had occurred; it looks like work was done by hand. Stream splits over a debris fan and goes mostly right (75%) but some goes left (25%).	1. Excavate from top flag to bottom flag with 2:1 side slopes and a 4 foot wide channel bed. 2. Spoil locally on right, out slope road and fill ditch for 300 ft. to decommission road alignment. 3. Construct 6 cross road drains to the left road= 1) Rip road surface 18" to 24" deep for 300 ft. on left road approach using rippers on bulldozer 2) Construct 6 cross road drains on the left road approach. 4. Spoil locally.
55	HM	Stream crossing	0	0	875	80	161	A washed out stream crossing on a big, rowdy Class II stream. The existing culvert has plugged. The undersized CMP was not designed or constructed properly. A steep boulder channel with large 5.0 – 6.0 foot diameter boulders. Crossing is washed out in a wide area and is undercutting lest approach and outboard fill. Otherwise big rocks in fill, stable right approach has more rock. Right road runoff enters at outboard fill also. There is a hillslope gully to right that combined with some flow diverted for from site #54, that diverted down road in the past, more recent hillslope gullies cut across road and deliver sediment to stream below. Big rocks on road approach right. This stream also has a debris flow, lots of debris deposits on road. Stream continues to divert flow down the left road approach with several past diversion gullies down outboard fill. PWA estimates that 88 yd^3 of road surface material will erode and deliver to the stream system in the next 10 years, if the road is not decommissioned. Future erosion evaluated for left approach, otherwise stable washout. Very large boulder in channel will make stream crossing with equipment very challenging.	1. Excavate left approach 120 ft- wide x 4 ft- deep x 9 ft- long = 160 yd^3. 2. Armor left approach 60 ft- wide x 3 ft- deep x 9 ft- long = 60 yd^3. 3. Lay back right approach 50 ft- wide x 3 ft- deep x 10 ft- long = 56 yd^3. 4. Rip and drain right road approach for 875 ft. 5. Install drainage swale at hillslope gully 575 ft. to right (+2 hours excavator/dozer). 6. Remove berm to right 40 ft. 7. Spoil locally.

Site #	Treatment Immediacy	Problem	Left road length (ft)	Left road delivery (%)	Right road length (ft)	Right road delivery (%)	Total estimated sediment delivery (yd^3)	Comment on Problem	Comment on treatment
56	H	Stream crossing	110	100	1932	90	365	Class II stream with bedrock steps and waterfall at inlet. Large sediment fan laid out on road that pushed channel to the left hinge line. CMP is burrier under the fan; inlet has a piece of metal sticking up. Outlet is shotgunned with a trickle of water coming out. Hillslope seems to be creeping and saturated. Right road has a diversion gully from site #55 and has burnt fallen trees crossing the road. Due to site #55 active stream diversion there are four prominent gullies on the outboard fill right road. However, the washed out crossing will not divert in the future. All diversion erosion is past erosion. PWA estimates that 228 yd^3 of road surface material will erode and deliver to the stream system in the next 10 years, if the road is not decommissioned. This site has a high treatment immediacy.	1. Excavate from top flag to bottom flag with 2:1 side slopes and a 6 foot wide channel bed. 2. Spoil locally on left, out slope road and fill ditch for 110 ft. to decommission road alignment. 3. Spoil locally on right, out slope road and fill ditch for 1,932 ft. to decommission road alignment. 3. Construct 40 cross road drains to the left road= A) Rip road surface 18" to 24" deep for 1,932 ft. on left road approach using rippers on bulldozer B) Construct 40 cross road drains on the left road approach. 4. Spoil locally.
57	HM	Stream crossing	0	0	1000	100	137	A washed out fill crossing on a stream that is experiencing undercutting, hillslope runoff, and sediment delivery. There may not have been much erosion before the fires and major runoff events. There are multiple hillslopes swales that experienced runoff and crossed the road 70 ft. to the right. Lots of material fanned out on right road approach from hillslope gullies. Stream is down cutting, incised down through debris and fill. Area prone to hillslope gully/debris slides and debris flows. PWA estimates that 94 yd^3 of road surface material will erode and deliver to the stream system in the next 10 years, if the road is not decommissioned. This site has a moderately-high treatment immediacy.	1. Excavate from top flag to bottom flag with 2:1 side slopes and a 4 foot wide channel bed. 2. Construct a drainage swale at the hillslope gullies 100 ft. to the right. 3. Rip and drain road to right for 1,000 ft. 4. Install 10 cross road drains to right road past newly constructed drainage swale. 5. Spoil locally.
58	H	Stream crossing	0	0	80	100	70	Class III stream that recently had a debris flow. Upslope from road this watercourse is a straight gully, starting from the cliffs. Recently there was a debris flow that flowed onto the road, eroded the road surface and created channels. A lot of debris has deposited on the stream crossing with a split channel across to the outboard fill (around tree). Area is mixed with burnt snags and large trees. The uphill side of road is failing onto the road. Road is acting like a bench/shelf that is catching a lot of sediment and rock. Outboard fill has two deep head cuts where the channel was split and then go back into a single channel at the lower end stake on bedrock. This site has a high treatment immediacy.	1. Excavate from top flag to bottom flag with 2:1 side slopes and a 5 foot wide channel bed. 2. Spoil locally on right, out slope road and fill ditch for 80 ft. to decommission road alignment. 3. Construct 1 cross road drains to the left road= 1) Rip road surface 18" to 24" deep for 80 ft. on left road approach using rippers on bulldozer 2) Construct 1 cross road drains on the left road approach. 4. Spoil locally.

Site #	Treatment Immediacy	Problem	Left road length (ft)	Left road delivery (%)	Right road length (ft)	Right road delivery (%)	Total estimated sediment delivery (yd^3)	Comment on Problem	Comment on treatment
59	H	Stream crossing	0	0	900	20	54	Class III stream crossing and debris flow with a debris deposit on the road that happened during the last big rain event. Debris flow incised channel upstream of road in partially burned forest located in an upper hillslope position. Right road approach has a series of three hillslope gullies that crosses the road and deposited large sediment fans on the road. This site has a high treatment immediacy.	1. Excavate from top flag to bottom flag with 2:1 side slopes and a 4 foot wide channel bed. 2. Spoil locally on right, out slope road and fill ditch for 900 ft. to decommission road alignment. 3. Excavate to decommission. Construct 3 drainage swales to the right road to convey hillslope drainage at 3 gullies across the road. 4. Construct 6 cross road drains to the left road= 1) Rip road surface 18" to 24" deep for 900 ft. on left road approach using rippers on bulldozer 2) Construct 6 cross road drains on the left road approach. 5. Spoil locally.
60	ML	Stream crossing	700	100	0	0	106	Class III stream that is incised with a sediment fan deposit on the road surface, there is no real distinctive channel upslope. Water splits into at least three different channels across the depositional fan. Sediment fan is 50 ft. wide along the road. The sediment flow regime is altered by the road alignment.	1. Excavate from top flag to bottom flag with 2:1 side slopes and a 4 foot wide channel bed. 2. Spoil locally on left, out slope road and fill ditch for 700 ft. to decommission road alignment. 3. Construct 14 cross road drains to the left road= 1) Rip road surface 18" to 24" deep for 700 ft. on left road approach using rippers on bulldozer 2) Construct 14 cross road drains on the left road approach. 4. Spoil locally.
61	M	Stream crossing	750	35	275	30	87	A Class III stream crossing with a filled stream crossing and channel. There was a debris flow and debris deposit on left and right road approach. Left road approach has hillslope gullies from upslope. The gullies the road in several sections and deposit sediment on road surface. The hillslope gullies from upslope seem to be diminishing in size and power compared to site #60, slope gradient decreases at this road crossing. Outboard fill at this site has a 5 foot head cut and will continue to erode and migrate through crossing, with a high potential for future sediment delivery. Hillslope gullies on right road approach are located 100 ft. to the left. Several gullies cross the road and have deposited on the road and gullied through the road prism.	1. Excavate from top flag to bottom flag with 2:1 side slopes and a 5 foot wide channel bed. 2. Spoil locally on left, out slope road and fill ditch for 750 ft. to decommission road alignment. 3. Spoil locally on right, out slope road and fill ditch for 275 ft. to decommission road alignment. 4. Construct 15 cross road drains to the left road= 1) Rip road surface 18" to 24" deep for 750 ft. on left road approach using rippers on bulldozer 2) Construct 15 cross road drains on the left road approach. 5. Construct 5 cross road drains to the left road= 1) Rip road surface 18" to 24" deep for 275 ft. on left road approach using rippers on bulldozer 2) Construct 5 cross road drains on the left road approach. 6. Spoil locally.

Site #	Treatment Immediacy	Problem	Left road length (ft)	Left road delivery (%)	Right road length (ft)	Right road delivery (%)	Total estimated sediment delivery (yd^3)	Comment on Problem	Comment on treatment
62	M	Stream crossing	2000	100	100	100	207	Class II stream with a washed out CMP and past erosion. Top flag is located where the stream goes subsurface and is not seen again. The drainage area and stream size is hard to quantify. Upper end stake is a waterfall over bedrock. There are two large trees that have fallen across the stream crossing. There is a bit of an overflow gully and diversion that runs from the top flag to the outboard fill when there are high flows. There is a constructed rock wall at the bottom flag. PWA estimates that 119 yd^3 of road surface material will erode and deliver to the stream system in the next 10 years, if the road is not decommissioned.	1. Excavate from top flag to bottom flag with 2:1 side slopes and a 6 foot wide channel bed. 2. Spoil locally on left, out slope road and fill ditch for 2,000 ft. to decommission road alignment. 3. Spoil locally on right, out slope road and fill ditch for 100 ft. to decommission road alignment. 4. Construct 40 cross road drains to the left road= 1) Rip road surface 18" to 24" deep for 2,000 ft. on left road approach using rippers on bulldozer 2) Construct 40 cross road drains on the left road approach. 5.Construct 1 cross road drains to the left road= 1) Rip road surface 18" to 24" deep for 100 ft. on left road approach using rippers on bulldozer 2) Construct 1 cross road drains on the left road approach. 6. Spoil locally.
63	H	Stream crossing	375	100	750	100	746	A big rowdy Class II stream with a plugged undersized 48 inch CMP and washed out left side of crossing. Field technicians measured 336 yd^3 of past erosion. PWA estimates that 671 yd^3 of material will wash-out at the stream crossing in the next catastrophic event or overtime, if no work is done. Culvert is still intact under fill inlet to mid road and receives 20% of current stream flow. CMP is 50% plugged. There was a large storm event in the recent past that carried a debris flow. Torrent deposited 1.0 -2.0 foot diameter rock on the right road approach. CMP inlet has a brick wall and a tree growing on top of it. Crossing will continue to erode and washout side slopes. Walk from here, decommission road from here to site #26. This site has a high treatment immediacy.	1. Excavate CMP and wall; layback side slopes to a stable angle. Remove stored sediment on right bank upstream of top flag (50 yd^3). 2. Spoil locally on right, out slope road and fill ditch for 750 ft. to decommission road alignment. 3. Construct 15 cross road drains to the right road= 1) Rip road surface 18" to 24" deep for 750 ft. on right road approach using rippers on bulldozer 2) Construct 15 cross road drains on the right road approach. 4. Outslope 375 ft. of left road; remove berm when applicable, by upgrading left road approach. 5. Construct 3 rolling dips to the left road. 6. Endhaul spoils 600 ft. to the left at the big flat

Site #	Treatment Immediacy	Problem	Left road length (ft)	Left road delivery (%)	Right road length (ft)	Right road delivery (%)	Total estimated sediment delivery (yd^3)	Comment on Problem	Comment on treatment
64	M	Stream crossing	500	100	50	100	232	Class III stream with a small drainage area and low power. This crossing has two separate CMPs. The stream inlet is plugged, goes to the ditch where there is the outlet at a brick wall, a 1.0 foot gap, and then a second CMP inlet that goes across the road and is open. The first CMP has a turn-around driveway that has been cut off by the main ditch; this CMP can be removed unless the land owner wants to keep the turn-around. The second CMP drains the stream CMP and the ditch; we will upgrade this CMP. The brick wall at CMP 1 outlet and CMP 2 inlet is being flanked and overtopped by the stream. Two culverts drain this site (see sketch) both are open and functioning, yet undersized. Culvert Q calculated a 42 inch diameter culvert is suitable for this site's drainage area. PWA estimates that 181 yd^3 of material will wash-out at the stream crossing in the next catastrophic event or overtime, if no work is done.	1. Excavate from top flag to bottom flag and remove brick wall. 2. Layback side slopes 2:1 and create a 4 foot wide channel after removing CMP 1. 3. Install a 30 inch diameter culvert across the main road. 4. Outslope 500 ft. of left road; remove berm when applicable. 5. Outslope 50 ft. of right road; remove berm when applicable. 6. Construct 2 rolling dips to the left road, connected to inboard ditch. 7. All reshaped road sections will be rocked with 1.5 inch diameter minus base rock. 8. Spoil locally.
65	HM	Stream crossing	0	0	1325	50	205	A relatively small Class II stream diverts out of its natural watercourse and down road surface and inboard ditch to the left approximately 200 ft.; some flow enters CMP down road, and the remaining runoff exits outboard fill left of CMP and delivers sediment to the stream. PWA estimates that 122 yd^3 of material will wash-out at the stream crossing in the next catastrophic event or overtime, if no work is done. The existing culvert is 100% plugged. This 15 inch diameter CMP is undersized at this stream crossing. Outlet of CMP is shotgunned and high in the fill. Right road approach slightly insloped with small berms which traps and concentrates runoff on the road surface. Road is partially/lightly rocked in spots. There is a plugged ditch relief culvert with sediment delivery to the right (750 ft.); the DRC no longer receives much runoff, connect to ditch but ditch is grassy with not a lot of runoff to ditch relief culvert evident, 100% plugged. Lower power stream, but is actively eroding road surface and outboard fill. PWA estimates that 83 yd^3 of road surface material will erode and deliver to the stream system in the next 10 years, if the road is not decommissioned.	1. Excavate fill from top flag to bottom flag. 2. Install a 24 inch CMP at base of fill, across the main road. 3. Construct a critical dip to the left hinge line. 5. Construct 6 rolling dips to the right road connected to inboard ditch. 6. Armor outer fillslope with 20 yd^3 of 0.5 to 1.5 ft. diameter rip rap. 7. End haul spoils 2,250 ft. to right. 8. All reshaped road sections will be rocked with 1.5 inch diameter minus base rock.
66	M	Spring	0	0	185	100	21	A moderate powered spring over a cascade with a brick inlet. Site #65 is up right road approach and is diverted past this site 50 ft. to the left, where it goes over the outboard fill and delivers sediment to the creek. Culvert inlet has an inboard ditch that is hydrologically connected from right road approach, where most of the water from site #65 meet with this inlet. Inlet had brick wall. No effect from fire; lots of ferns and lush vegetation; black berry. CMP replacement instead of armored fill due to year-round traffic and a possible year-round spring so close to main stem South Fork Battle Creek.	1. Excavate from top flag to bottom flag and remove brick wall. 2. Install an 18 inch diameter CMP x 30 ft. long. 3. Outslope 185 ft. of right road; remove berm when applicable. 4. Construct 1 rolling dips to the right road. 5. Spoil locally.

Site #	Treatment Immediacy	Problem	Left road length (ft)	Left road delivery (%)	Right road length (ft)	Right road delivery (%)	Total estimated sediment delivery (yd^3)	Comment on Problem	Comment on treatment
67	L	Spring	50	100	325	10	10	A 12 inch diameter ditch relief culvert with a concrete wall at the inlet. This stream crossing delivers almost directly into South Fork Battle Creek, just below a large bridge. There is a 1.0 x 0.5 foot past erosion gully down the outboard fill/bank from the culvert outlet to the creek below. Inlet is 35% plugged. Crossing drains a strong spring flow from the bedrock cut bank for 50 ft. The road and ditch are slightly reverse, the flow of water goes to the right puddle on the road and runs off outboard fill onto old road below. Will continue to slowly gully down slope below outlet.	1. Replace ditch relief culvert with an 18 inch diameter CMP. 2. Install a 20 foot long 18 inch diameter downspout. 3. Clean ditch for 50 ft. to the right. 4. Install 2 rolling dips to right road 5. All reshaped road sections will be rocked with 1.5 inch diameter minus base rock. 6. Spoil locally.
68	L	Stream crossing	45	100	20	100	8	Class I stream; South Fork Battle Creek bridge crossing. Bridge with 2 cement pylons and wood decking. Bridge is outsloped. Some of the decking and bolts have been recently replaced. Right bank footing is getting undercut. The sloping of the bridge mixed with wet wood is slippery. There is a side channel to the right outboard side. There are 2 access roads on the downstream side coming from Ponderosa Way. Bridge is 100 ft. long, 14 ft. wide. Wooden guard rails are starting to rot.	1. Replace railing on both sides of bridge (other treatment).
69	L	Landslide	0	0	150	5	43	Side cast fill is perched on steep slope right above South Fork Battle Creek. Leaning conifers and saturated (soft) outboard fill from road and past road runoff have likely triggered past failure. (12 x 3 x 20) of past failure on right side, with more perched on left and right, with undercutting from the stream during high flows. Some bedrock base may protect some fill from failure. Right side road ponded where road grade near 0%. We estimate that over 40 yd^3 of material will deliver to the stream if this site is not treated.	1. Excavate outboard fill (50 ft- wide x 3 ft- deep x 15 ft- long = 100 yd^3-27 yd^3; past erosion= 73 yd^3). 2. Endhaul spoils 3,000 ft. right to big flat
70	ML	Road surface	1250	100	160	100	254	Nonfunctioning ditch relief culvert. Right of crossing is where most of the road runoff is going over outboard fill and delivering to the floodplain of side channel of South Fork Battle Creek. A ditch runs the entire length of road both ways. Ditch is vegetated with trees and grass. Water ponds on the road surface where the gully goes off. PWA estimates that 229 yd^3 of road surface material will erode and deliver to the stream system in the next 10 years, if the road is not upgraded to meet forest road standards. This part of the road gets minimal to no sunlight (NNW aspect) with lush tree canopy.	1. Construct 7 rolling dips to the left road, connected to ditch. 2. Construct 1 rolling dip to the right road, connected to ditch. 3. All reshaped road sections will be rocked with 1.5 inch diameter minus base rock. 4. Spoil locally.

Site #	Treatment Immediacy	Problem	Left road length (ft)	Left road delivery (%)	Right road length (ft)	Right road delivery (%)	Total estimated sediment delivery (yd^3)	Comment on Problem	Comment on treatment
71	ML	Stream crossing	225	100	0	0	77.2	Class III stream crossing with a 24 inch diameter CMP. Stream crossing is just down road from an intersection with a spur road above, and there is an armored fill crossing on that spur crossing. Top of the site is at the inlet and the bottom for the armored fill is just upstream. Inlet has a rock wall with larger rock above the inlet in the channel (1.0 - 1.5 ft. diameter). These larger rocks could plug the culvert inlet, but the stream doesn't look like it has the power to move the larger size class rock (debris flow). Culvert is undersized, surface erosion flows past crossing and delivers sediment via outer fillslope.	1. Install an armored fill at the crossing. a) Excavate a broad dip through the road: 60 ft- wide x 1 ft- deep x 18 ft- long = 48 yd^3. b) Excavate a keyway: 30 ft- wide w x 2 ft- deep x 15 ft- long = 40 yd^3. c) Install 35 yd^3 of 0.5 - 2.5 ft. diameter rip rap to keyway 2. Construct 1 rolling dips to the left road. 3. All reshaped road sections will be rocked with 1.5 inch diameter minus base rock. 4. Spoil locally.
72	ML	Ditch relief culvert	1125	50	0	0	60	Gully is delivering sediment to stream from ditch relief culvert. Outlet of CMP is shotgunned and high in the fill. Ditch relief culvert is 18 inch diameter. Left road is insloped at the turn. Ditch and berm run the length of the left road. There are two ditch relief culverts and a broad swale on the left road. We recommend a rocked rolling dip at the broad swale.	1. Construct a rocked rolling dip at broad swale 530 ft. to the left, rock road surface. 2. Construct 4 additional rolling dips to the left road connected to the inboard ditch. 3. All reshaped road sections will be rocked with 1.5 inch diameter minus base rock. 4. Spoil locally.
73	ML	Stream crossing	800	100	0	0	194	A near origin stream in broad head water swale, runs down rocky cut bank on the left side of the swale into an 18 inch diameter CMP. Inlet has brick wall and a wing wall on the right, which is collapsing due to a 24 inch diameter fir tree and root. Drainage area is relatively small for this low power stream.	1. Install a 24 inch diameter x 60 ft long culvert at base of fill, armor fill slope using 20 yd^3 of rock. 2. Install a critical dip to right hinge line of the crossing. 4. Construct 3 rolling dips to the left road. 5. All reshaped road sections will be rocked with 1.5 inch diameter minus base rock. 6. Spoil locally.
74	ML	Ditch relief culvert	900	75	0	0	132	Ditch relief culvert with a deeply incised ditch that looks like there was recent sediment delivery. There is a brick wall at the inlet. Ditch looks recently cleaned. Cutbank is actively eroding, dropping rocks into the ditch and onto the road surface. The cutbank starts to excessively seep water 600-900 ft. up left road.	1. Construct 5 rolling dips to the left road, connected to the inboard ditch. 2. All reshaped road sections will be rocked with 1.5 inch diameter minus base rock.

Site #	Treatment Immediacy	Problem	Left road length (ft)	Left road delivery (%)	Right road length (ft)	Right road delivery (%)	Total estimated sediment delivery (yd^3)	Comment on Problem	Comment on treatment
75	ML	Stream crossing	600	100	0	0	221	A Class III stream crossing with an 18 inch diameter CMP incased in a brick wall at the inlet. Stream is near origin upslope and runs down bedrock cut bank via a 12 inch diameter 10 foot long CMP that was connected like a downspout to funnel the flow to the inlet, probably has past plugging issues. Springy and rocky cut bank left and right of the stream crossing. If inlet plugged, a diversion would occur, water would flow down right road approach. Outlet of CMP is shotgunned and discharges onto hard rock. Bottom and lower end stake has lots of garbage (small as beer cans, large as cars) and rock. Right road is saturated from springy/seeping cut bank; ditch recently cleaned. Road is rocked at the crossing. Locked gate 100 ft. up left road. Ditch to left connected for a long distance with evidence of a good amount of sediment delivery and runoff.	1. Construct dip by lowering road 1 ft. and remove CMP (60 ft- wide x 1 ft- deep x 35 ft- long = 94 yd^3). 2. Install a 24 inch diameter culvert at base of fill, armor fill slope using 20 yd^3 of rip rap. 3. Add a critical dip to the right hinge line. 4. Remove trees on outer fillslope. 5. Construct 3 rolling dips to the left road, connected to inboard ditch. Remove berm for 600 ft. 6. All reshaped road sections will be rocked with 1.5 inch diameter minus base rock. 7. Spoil 22 yd^3 locally and endhaul the remaining material to a stable spoil storage area.
76		Stream crossing	950	2	30	1	1	A PG&E powerline access road. Crossing is shallow low gradient wetland like ford. Appears to be a Class II watercourse. Supports wetland plants and frogs. Grassy low gradient approaches. Channel braided upstream. Right approach to stream crossing runs down the stream for about 7o ft. and road could easily be aligned so that stream crossing crosses to right bank and out of channel much sooner. Very seldom used access road. Very little, if any erosion potential.	1. No treatment recommended.
77	ML	Stream crossing	200	10	0	0	7	PWA field technicians identified 350 ft. of road is within the high-flow flood channel of stream. Some flow diverts right for approximately 50 ft. Stream channel to left is upstream of the road, and that flow drains into road below along this length. Moving the road up the hillslope out of the stream channel would be best here. A small headcut within stream channel to right of crossing doesn't threaten the road.	1. Decommission site by removing all road fill. 2. Dip the road at existing crossing to convey surface flow to stream channel and prevent diversion (60 ft- wide x 1 ft- deep x 20 ft- long = 53 yd^3).
78		Stream crossing	50	0	50	0	10	Old road section crossed a Class II stream which is washed out and has been for quite a while. Rocky boulder channel. Mostly washed out with little potential future erosion, no treatment recommended. Site has well vegetated banks and grassy road approach. Sideslopes will continue to adjust through stream crossing but slowly over time and difficult to even discern crossing shallow stream crossing. Road not digitized on map correctly (road on map follows powerline cut instead).	1. No treatment recommended.

Site #	Treatment Immediacy	Problem	Left road length (ft)	Left road delivery (%)	Right road length (ft)	Right road delivery (%)	Total estimated sediment delivery (yd^3)	Comment on Problem	Comment on treatment
79		Stream crossing	175	100	35	100	46	Washed out stream crossing blocks access to this site. Stream meanders gently before abrupt drop over armored outer fillslope. Rock is native and a boulder field is localized here. Well rocked channel below confluences with Main Battle Creek tributary, approximately 150 ft. Road alignment up the hillslope seems to be in better shape and avoids crossing this stream here and at site #78. Armored fill has decent u-shape and looks solid. Bedrock is 7.0 ft. from the outer edge of road.	1. No treatment recommended.
80		Stream crossing	0	0	300	0	0	A washed out crossing blocks access to this site. Old bridge crossing on Soap Creek was ripped out by past debris flow many years ago. Don't need this crossing since there is access to both sides of demolished bridge. Concrete abutment sat on bedrock and bridge was probably 25 - 30 ft. above stream flow, so was big flood/torrent event that like ripped out bridge. Right and left road approaches covered and protected from erosion by grass.	1. No treatment recommended.
81	M	Road surface	300	100	3125	25	154	Long road reach has trapped flow and is causing gullying and rilling down road, with several discharge points, including the one at site up just above main stream Soap Creek. Naturally rocky geology, past gullies downslope to Soap Creek, gullies split with recent erosion and sediment delivery. Erosion will be ongoing and sediment delivery of road surface and road gullying will continue through shallow layer of erodible soils. Steep rough road to right, has steep switch back that is shallowly eroded down to bedrock and has been paved in short sections through switch backs. Road continues up to drainage break 3,125 ft. up road. There are 8 discharge points along road, that don't deliver. Berm up road contains flow along upper section of road, with two drainage points that disperse into meadow below, but don't capture all of runoff.	1. Decommission road segment by ripping and draining road in frequent locations. 2. Install 31 cross road drains. 3. Remove 2.000 ft. long berm that concentrates runoff on road.

Site #	Treatment Immediacy	Problem	Left road length (ft)	Left road delivery (%)	Right road length (ft)	Right road delivery (%)	Total estimated sediment delivery (yd^3)	Comment on Problem	Comment on treatment
82	M	Spring	75	100	1350	30	63	Small spring emerges 50 ft. upstream of road surface and is conveyed across road where it pools and joins road surface flow from left and right. Multiple rills convey flow from outer fillslope to hillslope and spring beyond. There is another road crossing below on private property. No fill in road prism here. Main source of erosion is active gully to right where road is through cut beyond the right approach. Origin of stream begins 50 ft. downhill. Right road approach is long (1,350 ft). Surface runoff and stormwater flow is trapped on the road surface for most of its length due to a combination of long deep berms, through-cut sections, and incision of the road surface into the hillslope it's constructed on. Surface of road is in bad shape; long gullies and rills, potholes and ponded water. Road is rocky along most of its length. Road will require a combo of rolling dips, berm removal, outsloping, and potentially minor realignment where appropriate.	1. Excavate a broad dip in the road at spring. 80 ft- wide x 1 ft- deep x 25 ft- long = 75 yd^3. 2. Treat right road surface w/ berm removal, ripping road surface and 14 cross road drains where appropriate and feasible for 1,350 ft.
83	ML	Road surface	0	0	750	25	45	Road runoff delivers sediment to abandoned canal and Battle Creek. This road is the main access road to canal and to road along outboard/berm edge of canal. Flow currently at this point in canal. Road runoff also bypasses canal on road and delivers to Battle Creek via small gully. Though canal is nonfunctional it carries enough residual flow to transport sediment which ultimately will deliver sediment to Battle Creek. Road has eroded down to bedrock in spots and also paved in places. Road to right has a consistent berm that is broken at several spots but delivers back onto road below. Also partial section of road has pavement along steeper grade section. Average future delivery 2.0 x 0.5 ft. down road and down fillslopes.	1. Remove berm and stock pile against cut bank. 2. Outslope road for 750 ft. on right road approach. 3. Rip and drain 750 ft. of road and add 7 cross road drains.
84	M	Stream crossing	50	100	27	100	41	A washed out stream blocks access to this site. This is a large drainage area and stream crossing. Fairly well built armored fill excepting diversion potential left down a weak dip with discharge from road surface gully 25 ft. left at drainage break. Good u-shape design application, appropriate rock size used here is key. Dip needs to be wider and deeper. There's a spring with a small gully 50 ft up left road approach that can be treated with a deep cross road drain.	1. Excavate fill from top flag to bottom flag. 2. Lay back side slopes 2 to 1 and establish a 12 ft- wide channel bottom. 3. Install 1 cross road drain 50 ft. left of crossing at spring. 4. Spoil locally.
85	L	Stream crossing	0	0	75	100	37	A washed out crossing blocks access to this site. This Class III stream crossing has a constructed armored fill. Keyway of armored fill has 1.0 -4.0 ft diameter rocks. Some of the stream flow diverts to left due to sediment fan on road from recent high flows. Shallow soils erode down to bedrock and deliver sediment to stream. Future erosion due to diversion low, this area has already eroded to bedrock. Lots of rocky material in fill. Low erosion potential due to bedrock features underlying shallow soil.	1. Excavate crossing from top flag to bottom flag. Lay back side slopes 2 to 1 or to natural grade and establish a 4.0 ft wide channel bottom. 2. Install 1 cross road drain to right road approach. 3. Spoil locally.

Site #	Treatment Immediacy	Problem	Left road length (ft)	Left road delivery (%)	Right road length (ft)	Right road delivery (%)	Total estimated sediment delivery (yd^3)	Comment on Problem	Comment on treatment
86	L	Road surface	310	85	45	100	14	A washed out crossing blocks access to this site. There is a canal/flume beneath the road surface here (Union Canal). Two small gullies discharge water down slope to a steep cliff overlooking South Fork Battle Creek. Left gully is 30 ft. long, gully to right is 20 ft. long. Insloped berm along left road traps water along most of its length. Left road fill eroded down to bedrock. Not much future erosion at this site. Rightward gully discharges primarily hillslope runoff with small right road contribution. Most of the fill here already eroded away.	1. Remove berm to left for 310 ft. 2. Rip and drain 310 ft of road and add 3 cross road drains.
87	L	Stream crossing	0	0	1450	25	103	A washed out crossing on Soap Creek, a large Class I tributary to South Fork Battle Creek. Recent past debris flow deposited a large amount of boulders/rocks and sand on left road approach to stream crossing. No drainage structure or bridge remain, it washed-away. Left bank of stream at crossing appears to have been built of up with rocks and could have been a bridge at this site. Left and right banks will erode some and lay back slowly over time. Also long road reach to right delivers via gully to this site. PWA field technician estimated the stream crossing future erosion (3 ft- wide x 2 ft- deep x 12 ft- long) = 27 x 2 = 54 yd3. PWA field technician also estimated future erosion at the gully (2 ft- wide x 0.5 ft- deep x 100 ft- long). 2 ft x 1 ft past gully down right road approach. Steep gullied right road has several discharge points that do not deliver sediment to the system. Persistent outbound berm and well established wheel ruts capture and concentrate right road runoff.	1. Lay back side slopes at crossing (30 ft- wide x 2 ft- deep x 12 ft- long = 27 yd^3) x 2 = 54 yd^3. 2. Remove berm to right. 2 ft- wide x 1 ft- deep x 1,450 ft- long. Spoil berm along inboard road against cut bank 3. Rip road surface, then out slope right road for 1,450 ft, and construct 14 cross road drains.
88	ML	Stream crossing	1000	25	20	100	35	Small near origin stream crosses spur road downslope of Ponderosa Way. Long left road gully 1.0 x 0.5 ft discharges and delivers sediment to the stream in this location. Some rock has been placed to armor headcut at OBR. Channel below is naturally rocky. Barbed wire fence from left ends at stream crossing. Cutbanks are composed of bedrock. Road is naturally rocked as well.	1. Excavate fill from top flag to bottom flag. Lay back channel side slopes 2:1 with a 4.0 ft channel bottom. 2. Rip and drain 1,000 ft of road and construct 10 cross road drains. 3. Spoil locally.
89	ML	Stream crossing	30	100	450	20	47	Dramatic road surface erosion and long term deterioration prevents access to this stream crossing site. A Class III stream crossing with a filled channel. Low power 2 x 0.5 ft. gully crosses road with very little erosion (native rock) at stream crossing and with thick blackberry vines on outer edge of road. PWA field technicians estimated length and past erosion visible through briars.	1. Excavate crossing from top flag to bottom flag with 2 to 1 side slopes and a 4.0 ft channel bottom. 2. Rip and drain 450 ft of road, add 4 cross road drains.

Site #	Treatment Immediacy	Problem	Left road length (ft)	Left road delivery (%)	Right road length (ft)	Right road delivery (%)	Total estimated sediment delivery (yd^3)	Comment on Problem	Comment on treatment
90	ML	Stream crossing	66	100	3250	20	87	Small stream crossing splits just before crossing. Approaches are native rocky fill. Not much erosion here. Small gully on outer edge of road may migrate headward with time. Right road surface runoff and erosion not bad here. We identified a 2 ft-wide x 0.5 ft-deep x 350 ft long located approximately 2,100 ft. up right road that delivers sediment to the stream system. We also identified a 2 ft-wide x 0.5 ft- deep x 500 ft long located approximately 2,250 ft up the right road approach that delivers sediment to the stream system. Multiple ditch relief culverts in various stages of being plugged, buried, or crushed don't deliver over the long outer fillslope. The two that points that do discharge sediment to the stream system are included with site forms estimated future erosion.	1. Excavate fill from top flag to bottom flag. Lay back channel side slopes 2:1 with a 4 ft wide channel bottom. 2. Rip and drain 3,250 ft of road, add 32 cross road drains. 3. Spoil locally.
91	L	Stream crossing	0	0	2000	5	24	A Class II stream crossing with two culverts. Stream drains low gradient prairie and over flow from small pond. There is a 36 inch diameter CMP set on right side of crossing and a 24 inch diameter CMP set on left side of crossing, culverts sit side by side. Culverts are showing signs of rust, but no holes, good life still exists in CMP bottoms. Outlet of CMP's set near natural grade.	1. Excavate crossing from top to bot with a 10.0 ft wide channel bottom and 2:1 side slopes. 2. Install 40 cross road drains on right approach.
92	ML	Ditch relief culvert	2000	70	0	0	168	Long length of uncontrollable road surface runoff and erosion. Weeping cutbank adds flow to inside ditch. Gullies below road erode hillslope and deliver sediment to headwall and ephemeral streams.	1. Construct 10 rolling dips connected to inboard ditch along left road. 2. Remove berm for 2,000 ft. Side cast material.
93	M	Stream crossing	450	100	0	0	185	A Class III stream crossing with a filled crossing. Stream diverts down road to right 160 ft to site #94. Steep rocky channel upstream of crossing with steep slopes downstream. Weepy cu bank with different layers of erodible material mixed with bedrock. Erosion down rocky ditch will continue in future. DRC at site #94 has shotgunned outlet, with big past gully, erosion and sediment delivery downslope.	1. Excavate crossing from top flag to bottom flag. 2. Install 24 inch diameter x 60 ft long culvert set to grade. 3. Install 25 yd^3 of 0.5-2.0 ft. diameter rip rap to outer fillslope. 4. Install a critical dip on left hinge line of the crossing. 5. Install 3 rolling dips to right road. 6. Rock all shaped section of road with 1.5 inch diameter road base x 15 ft wide. 7. Spoil locally.

Site #	Treatment Immediacy	Problem	Left road length (ft)	Left road delivery (%)	Right road length (ft)	Right road delivery (%)	Total estimated sediment delivery (yd^3)	Comment on Problem	Comment on treatment
94	M	Ditch relief culvert	160	100	0	0	38	Diverted stream at stream crossing site #94 diverts out of its natural water course to a ditch relief culvert which gullies hillslope and delivers sediment to stream channel headwall, approximately 100 ft. downslope of Ponderosa Way. Cutbank unstable in some locations with active cutbank landslides. Cutbank landslide deposits are eroded by active stream diversion and deliver sediment to the stream system. Lag material remains in ditch on inside edge of road and all fine sediment has washed away and delivered to the stream. Gully downhill of road is large. Road surface runoff is evident and 100% delivers to this ditch relief site. PWA field technicians estimated 117 yd^3 of erosion occurred here in the past.	1. Construct 1 rolling dip to left road. 2. Leave DRC in place. 3. Leave ditch in place. Note: By fixing the diverted stream crossing (site #93), future erosion at this site will be decreased significantly.
95	M	Stream crossing	95	50	0	0	210	A Class III stream crossing with filled channel. Stream diverts down inside ditch for 130 ft. to site #96. Steep rocky stream channel down to wide road at crossing with steep outer edge of road also and steep channel below bottom flag. Nearly 100 ft of ditch and road surface are hydrologically connected to this site. We estimated nearly 200 yd^3 of future erosion if the stream crossing washes out.	1. Excavate crossing from top flag to bottom flag. 2. Install a 30 inch diameter x 60 ft. long culvert set to grade. 3. Install critical dip on right hinge line of crossing. 4. Install 20 yd^3 of 0.5 - 2.0 ft. diameter rip rap to outer fillslope. 5. Spoil locally.
96	M	Stream crossing	130	100	0	0	134	Approximately, 130 ft of inside ditch to left conveys a diverted stream from site #95. This near origin Class II stream crosses road via a 24 inch diameter culvert. Inlet has cemented retaining wall. Culvert shotgunned, high within road fill. Cutbank to right on inboard side may fail and plug culvert in near future. Retaining wall of inlet is failing w time. Cutbank along left and right road is failing and filling ditch with highly erodible material. Road reach here is insloped with ditch sources of sediment. At this site PWA identified 5 yd^3 of estimated past erosion and 111 yd^3 of erosion if the crossing washes-out in the future.	1. Excavate fill from top flag to bottom flag. 2. Replace CMP with a 24 inch diameter x 60 ft long culvert at base of fill. 3. Install critical dip to right hinge line of crossing. 4. Install 20 yd^3 of 0.5 - 2.0 ft. diameter rip rap to outer fillslope. 5. Spoil locally.
97	H	Stream crossing	420	100	0	0	162	Class II stream crossing with an undersized 18 inch diameter CMP that is 100% plugged and stream is diverting down road to right for 160 ft. to site #98. Outlet of culvert is shotgunned and discharges onto mossy rock armor, with very little past erosion. Currently strong flow emerging from outlet. Active diversion eroding ditch down to undersized culvert at stream crossing site #98. Diversion could run onto road and erode road surface.	1. Excavate crossing from top flag to bottom flag. 2. Install 30 inch diameter culvert by 60 ft. long at base of fill. 3. Armor outer fillslope with 40 yd^3 of 0.5 - 2.0 ft. diameter rip rap. 4. Install a critical dip on right hinge line of crossing. 5. Remove berm to left for 420 ft. 6. Install 3 rolling dips to left road. 7. Spoil local.

Site #	Treatment Immediacy	Problem	Left road length (ft)	Left road delivery (%)	Right road length (ft)	Right road delivery (%)	Total estimated sediment delivery (yd^3)	Comment on Problem	Comment on treatment
98	M	Stream crossing	165	100	0	0	123	Small near origin stream descends steep hillslope to cross through undersized steel culvert. Diversion potential to right, culvert has shotgunned configuration, high and short within fill. Road is insloped and ditched along this reach. Cemented brick retaining wall at inlet seems fine now but is degrading with time. Left road ditch conveys flow 165 ft. from diverted 5 x 1 ft stream (site #97). Main source of erosion here is diverted stream flow left via inboard itch. Bottom area is rocky so incision is low but right bank erosion below bottom flag is active and ongoing. Scour hole in channel caused by culvert outlet contributes to past erosion volume and channel degradation. Cutbank erosion high moderate but distance between crossings (road lengths) small. Inside ditch currently delivers fine sediment to the stream system; lag retained in ditch. Past diversion gully 80 ft to the right of stream crossing adds to past erosion volume.	1. Excavate fill from top flag to bottom flag. 2. Replace 18 inch diameter culvert with new 24 inch diameter x 60 ft. long culvert set to grade 3. Install critical dip to right hinge line of crossing. 4. Install 35 yd^3 of 0.5 - 2.0 ft. diameter rip rap to outer fillslope.
99	M	Ditch relief culvert	270	100	0	0	47	A 15 inch diameter ditch relief culvert drains 200 ft. of inboard ditch and weepy cut banks located on left road approach. Inlet of ditch relief culvert is encased in brick. There is a past 2 ft- wide x 1 ft- deep x 150 ft-long gully that delivers sediment to a Class III stream. Culvert outlet has a shotgunned configuration. Future erosion in ditch on inside of road and down gully to Class I stream is extremely long (1 ft- wide x 0.5 ft- deep x 350 ft- long).	1. Replace ditch relief culvert with 18 inch diameter x 40 ft. long ditch relief culvert. 2. Install 1 rolling dip to left road. Rock rolling dip with 10 yd^3 of road base.
100	M	Landslide	0	0	0	0	72	A washed out stream crossing blocks access to this site. This section of road features a steep hillslope above the road actively delivering water initiating gully development along outer edge of road. Cracks in road surface indicate failure of outer fillslope. Past failure with delivery to Soap Creek (Class 1) below is evident. Recent fires and denuded hillslopes will alter and increase hillslope runoff and erosion in this location. Approximately, 8 - 10 gullies along the outer edge of road, cracks and sheet wash, as well as the highly erodible rhyolitic, ashy soils indicate that the perched road fill here will continue to fail and deliver downstream.	1. Remove all road fill and store on cutbank (IPOS road) for 260 ft. between flags. Be careful with placement of fill material near active discharge points on the hillslope above.

Site #	Treatment Immediacy	Problem	Left road length (ft)	Left road delivery (%)	Right road length (ft)	Right road delivery (%)	Total estimated sediment delivery (yd^3)	Comment on Problem	Comment on treatment
101	M	Landslide	0	0	0	0	74	Washed out crossing blocks access to this site. Similar to site #100. Gullies in hillslope upslope and downslope of the road are more developed. Highly erodible dacitic volcanic soils and fill material combined with greater sheet flow of water from steep hillslopes and recent denudation of vegetation due to the most recent wildfire, coupled with the presence of nearby Soap Creek. Rills and gullies as well as cracks developed in outer edge of road. Cutbank failures along road length here especially where associated with gullies upslope. A 12 inch diameter plastic flex pipe exposed along outer road failures. Not sure about intended function. Some smaller pipe as well. A 12 inch diameter pipe is also threaded through the length of this entire road, an abandoned nonfunctional diversion of Soap Creek. Intake of diversion pipe is not in the stream but may be active at high flow. Pipe remains intact at two washed out crossings downhill. It will be important to remove this pipe and dispose of the waste properly upon stormproofing this road.	1. Excavate and remove the road for 400 ft. between flags. Be careful with placement of fill material along cut bank near active gullies on hillslope above.
102	L	Landslide	0	0	0	0	18	The washed out crossing blocks access to this site. Similar situation as sites #101 and #100. However, the distance from stream has increased and hillslope grade is much mellower (57% slope). Hillslopes are sparsely vegetated with many burnt trees (loss of canopy). Highly erodible rhyolitic volcanic soils and greater surface runoff on steep slopes due to wildfire. Soap Creek is about 400 ft. downhill, there is perched road fill along this length of road with imminent sediment delivery. Gullies upslope of road and within outer edge of road, as well as across its breadth in places. Plenty of evidence of recent debris flows in the stream crossings.	1. Excavate and remove the road for 250 ft. between flags. Be careful with placement of fill material along cut bank where active gullies are present on hillslope above.

Site #	Treatment Immediacy	Problem	Left road length (ft)	Left road delivery (%)	Right road length (ft)	Right road delivery (%)	Total estimated sediment delivery (yd^3)	Comment on Problem	Comment on treatment
103	M	Landslide	0	0	0	0	311	Washed out crossing blocks access to this site. PWA estimates that 311 yd^3 of material will fail at the site in the next catastrophic event or overtime, if no work is done. Large sections of fill have collapsed and moved downslope where two hillslope gullies above convey water to cracks in road surface here. Bedrock cliffs above channel water to these gullies. Failure scarps are steeply concave; sub vertical sidewalls. Stream channel below displays wreckage from recent debris torrent failure of crossing site #104. Special care/consideration will need to be given the two gullies above road prism. Developing a small drainage swale at these spots may prevent head cutting and continued failure of fill slope. Recent fires, hillslope denudation, regional dacitic igneous geology and associated highly erodible soils and road fill material; along steep slopes w increased sheet wash from lack of vegetation. The steeply perched road fill is failing and washing downslope almost anywhere it interacts with water conveyed by hillslopes above along this entire road.	1. Excavate and remove road for 100 ft between flags = 497 yd^3. 2. Construct two drainage swales below the gullies within the hillslope above road to convey water across fill face 15 ft- wide x 2 ft- deep x 10 ft- long = 11 yd^3 x 1.2 = 13 yd^3. 13 yd^3 x 2 = 26 yd^3.
104	M	Stream crossing	150	20	50	50	150	A washed out crossing blocks access to this site. Here a washed out stream crossing with no drainage structure was identified. A steep boulder filled channel is upstream of top flag. Washout has exposed the two 12 inch diameter water diversion pipes that are buried under the entire length of this road. Logs and rocks in fill exposed. Crossing side slopes are highly likely to continue to erode and adjust over time. There is a hillslope gully on right approach near hinge line that has washed out outer edge of road and will continue to headcut into road with an estimated 10 yd3 future erosion and sediment delivery.	1. Lay back side slopes at 2:1 with a 10 ft. wide channel width. 2. Remove water diversion pipes. 3. Install drainage swale at hillslope gully to right 50 ft., that 15 ft- wide x 3 ft- deep x 20 ft- long = 33 yd^3. 4. End haul spoils. 5. Add 2 cross road drains, rip and drain road surface.
105	M	Landslide	0	0	0	0	109	Washed out stream crossing blocks access to this site. Fresh cracks within road surface to right of past debris flow (recent). Maybe sheet wash from fire denuded hillslope above caused the failure here. No obvious gully or other erosion feature above road surface on hillslope. Past cut bank slide associated with debris flow downslope of road.	1. Excavate and remove road fill between flags for 425 ft.

Site #	Treatment Immediacy	Problem	Left road length (ft)	Left road delivery (%)	Right road length (ft)	Right road delivery (%)	Total estimated sediment delivery (yd^3)	Comment on Problem	Comment on treatment
106	ML	Stream crossing	0	0	425	5	11	Washed out crossing blocks access to this site. A Class III stream crossing with filled channel. Stream is near origin, upslope in broad swale that is very steep. Stream flows across road and is eroding the outer edge of road and head cutting back into road prism. Low power near origin stream with small drainage areas. Past erosion ~(2 ft- wide x 2 ft- deep x 30 ft- long) x 2 = 9 yd^3. Right road includes hillslope gullies from burned slopes upslope that have caused failure along outer edge of road.	1. Excavate crossing from top flag to bottom flag, lay back slopes 2:1. 2. Establish a 4 ft wide channel bottom. 3. Rip and drain right road approach for 425 ft. Add 4 cross road drains
107	ML	Stream crossing	140	2	50	100	113	Partially washed out stream crossing supported at top and bot by large boulders filling the channel. Small stream is adjacent to right (site #106). There is a functional gate on the left road just before stream crossing failure. Stream crossing will continue to wash out along steep sidewalls through time and deliver sediment and rocks to Soap Creek far downstream. Active gully erosion of left approach is delivering sediment to this stream. Cutbank failures just above outer edge of road, here the gullies are actively continuing to erode but probably don't deliver sediment to the stream system. This road surface is wide (18 ft). Local dacitic soils have degraded here into quartz rich sands, highly erodible and largely incompetent. Even with decommissioning, the road may continue to deliver some sediment due to the conditions upslope. Natural hillslopes in region are prone to debris flows. Recent fires and associated hillslope denudation may increase sheetwash and associated surface erosion as well.	1. Excavate remaining fill from top flag to bottom flag. 2. Lay back side slopes 2:1 or natural grade, with a 4 ft. wide channel bottom. 3. Spoil locally on left and right road approach. 4. Rip and drain 140 ft of road add 2 cross road drains.

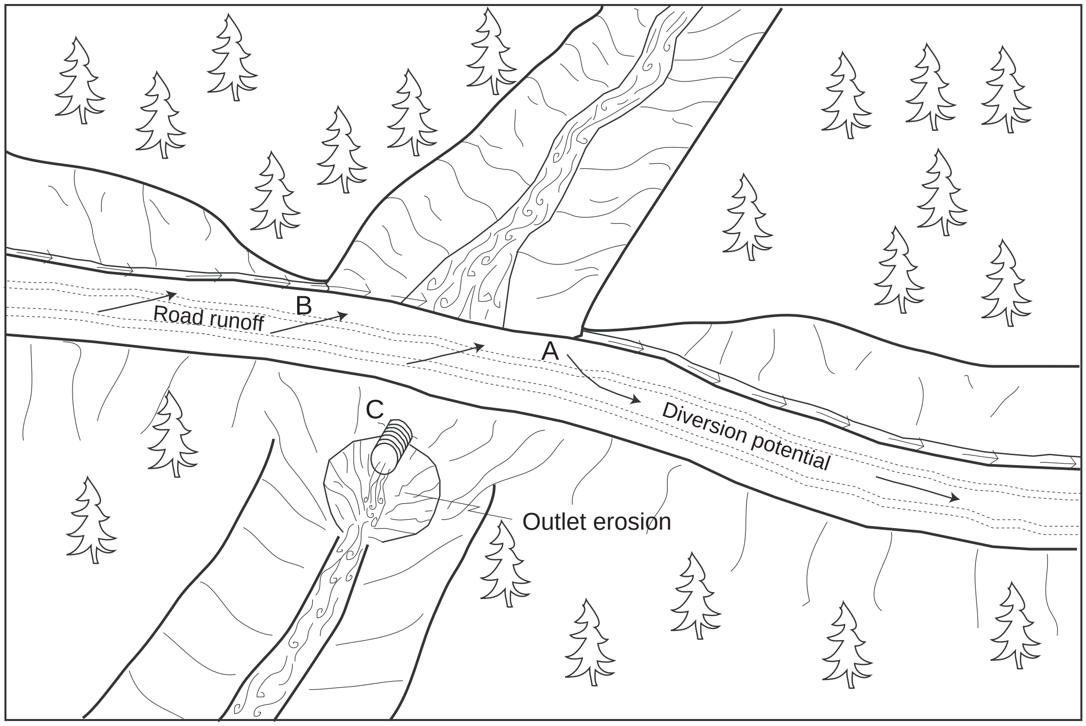
Typical Problems and Applied Treatments for a Non-fish Bearing Upgraded Stream Crossing

Problem condition (before)

A - Diversion potential

B - Road surface and ditch drain to stream

C - Undersized culvert high in fill with outlet erosion

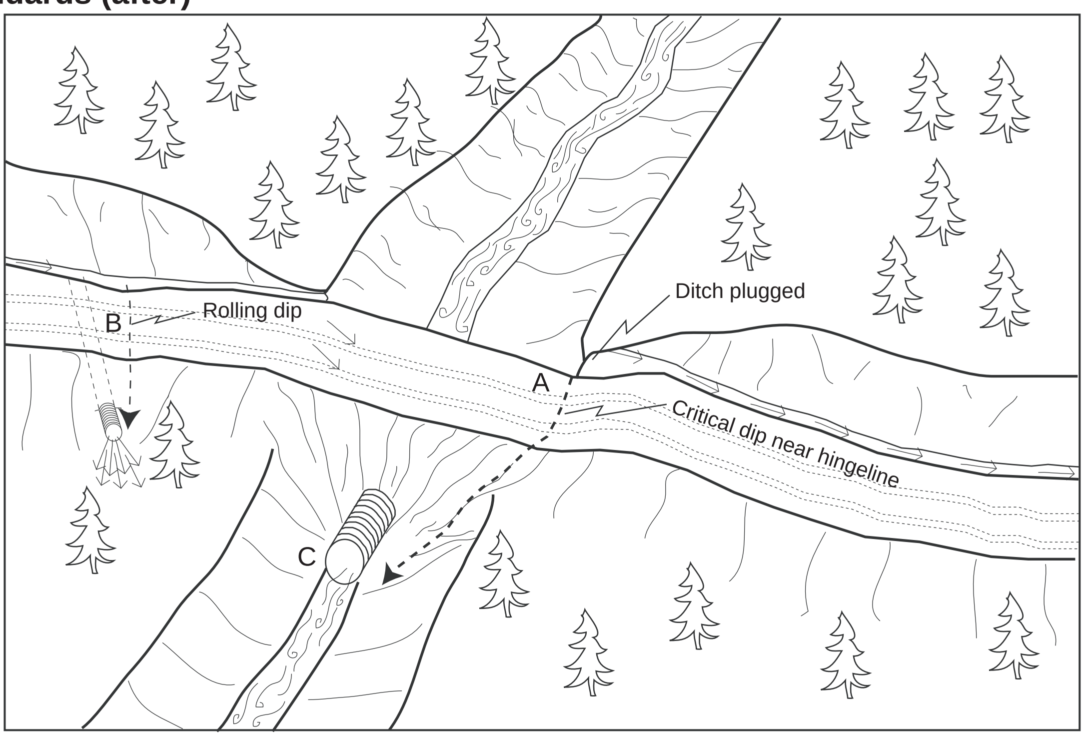


Treatment standards (after)

A - No diversion potential with critical dip installed near hingeline

B - Road surface and ditch disconnected from stream by rolling dip and ditch relief culvert

C - 100-year culvert set at base of fill



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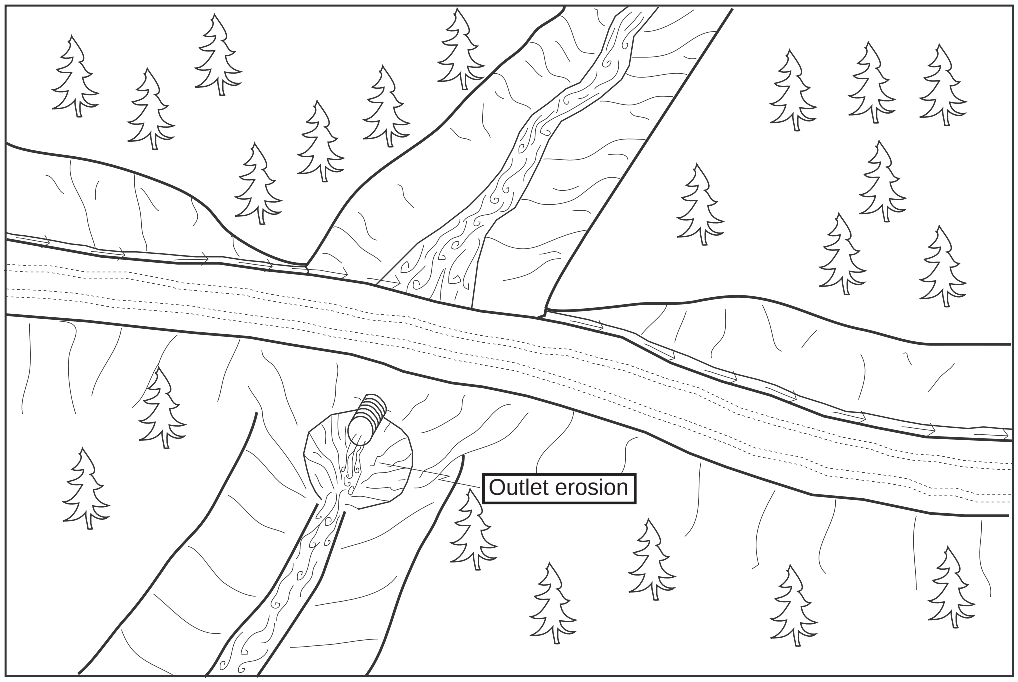
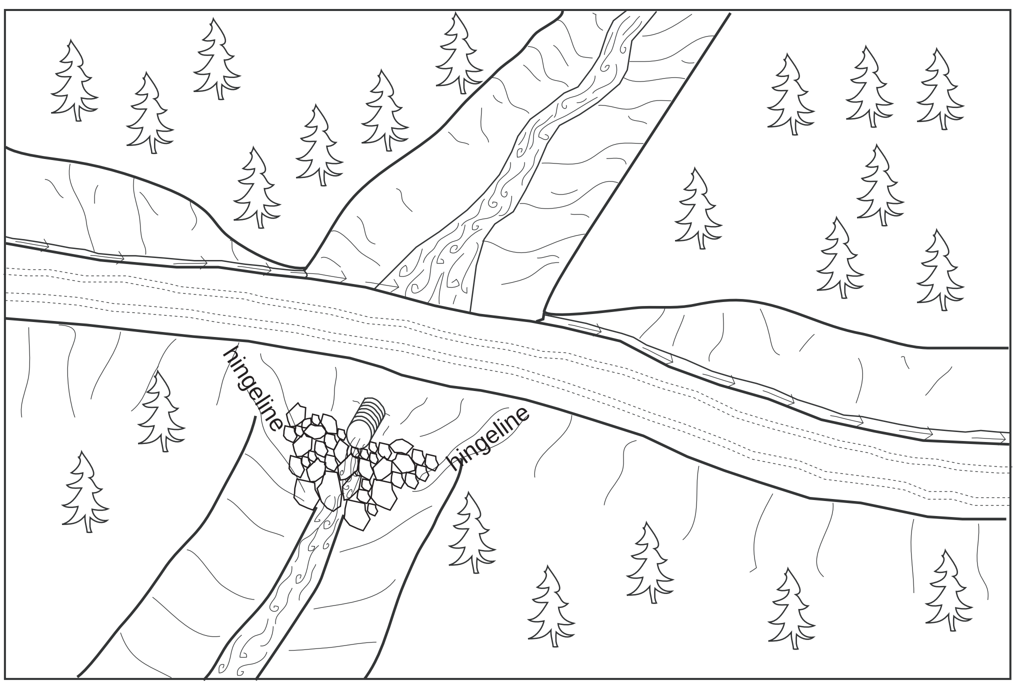
PWA Typical Drawing #1a

Armoring Fill Faces to Upgrade Stream Crossings



Problem: Culvert set high in outboard fill has resulted in scour of the outboard fill face and natural channel.
Conditions: The existing stream crossing has a culvert sufficient in diameter to manage design stream flows and has a functional life.



Action: The area of scour is backfilled with rip-rap to provide protection in the form of energy dissipation for the remaining fill face and channel.

Treatment Specifications:

1) Placement of rip-rap should be between the left and right hingelines and extend from a keyway excavated below the existing channel base level at the base of the fill slope up and under the existing culvert.
2) Rock size and volume is determined on a site by site basis based on estimated discharge and existing stream bed particle size range (See accompanying road log).

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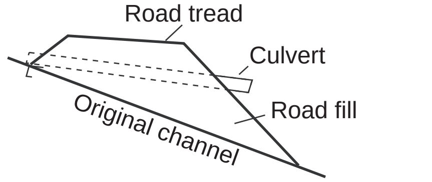
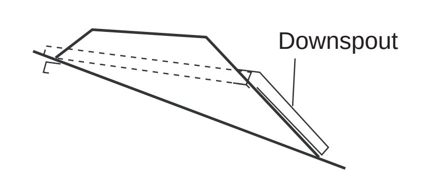
Typical Design of a Non-fish Bearing Culverted Stream Crossing

Existing



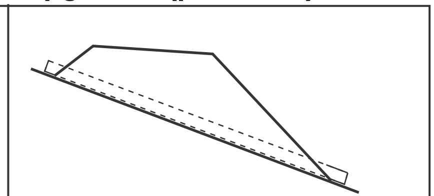
1. Culvert not placed at channel grade.
2. culvert does not extend past base of fill.

Upgraded



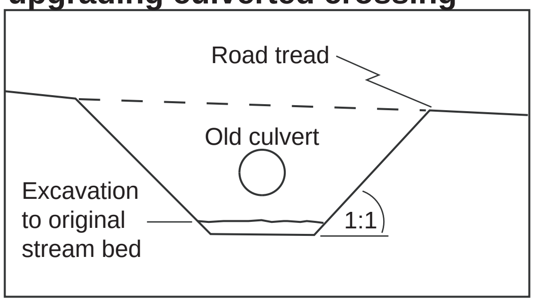
1. Culvert not placed at channel grade.
2. Downspout added to extend outlet past road fill.

Upgraded (preferred)

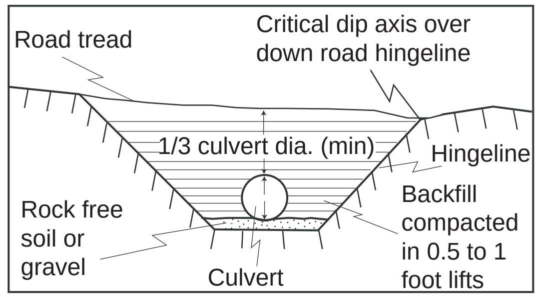


1. Culvert placed at channel grade.
2. Culvert inlet and outlet rest on, or partially in, the originial streambed.

Excavation in preparation for upgrading culverted crossing



Upgraded stream crossing culvert installation



Note:
Road upgrading tasks typically include upgrading stream crossings by installing larger culverts and inlet protection (trash barriers) to prevent plugging. Culvert sizing for the 100-year peak storm flow should be determined by both field observation and calulations using a procedure such as the Rational Formula.

Stream crossing culvert Installation

1. Culverts shall be aligned with natural stream channels to ensure proper function, and prevent bank erosion and plugging by debris.
2. Culverts shall be placed at the base of the fill and the grade of the original streambed, or downspouted past the base of the fill.
3. Culverts shall be set slightly below the original stream grade so that the water drops several inches as it enters the pipe.
5. To allow for sagging after burial, a camber shall be between 1.5 to 3 incher per 10 feet culvert pipe length.
6. Backfill material shall be free of rocks, limbs or other debris that could dent or puncture the pipe or allow water to seep around pipe.
7. First one end then the other end of the culvert shall be covered and secured.;The center is covered last.
8. Backfill material shall be tamped and compacted throughout the entire process:
   - Base and side wall material will be compacted before the pipe is placed in its bed.
   - Backfill compacting will be done in 0.5 - 1 foot lifts until 1/3 of the diameter of the culvert has been covered. A gas powered tamper can be used for this work.
9. Inlets and outlets shall be armored with rock or mulched and seeded with grass as needed.
10. Trash protectors shall be installed just upstream from the culvert where there is a hazard of floating debris plugging the culvert.
11. Layers of fill will be pushed over the crossing until the final designed road grade is achieved, at a minimum of 1/3 to 1/2 the culvert diameter.

Erosion control measures for culvert replacement

Both mechanical and vegetative measures will be employed to minimize accelerated erosion from stream crossing and ditch relief culvert upgrading. Erosion control measures implemented will be evaluated on a site by site basis. Erosion control measures include but are not limited to:

1. Minimizing soil exposure by limiting excavation areas and heavy equipment distrubance.
2. Installing filter windrows of slash at the base of the road fill to minimize the movement of eroded soil to downslope areas and stream channels.
3. Retaining rooted trees and shrubs at the base of the fill as “anchor” for the fill and filter windrows.
4. Bare slopes created by construction operations will be protected until vegetation can stabilize the surface. Surface erosion on exposed cuts and fills will be minimized by mulching, seeding, planting, compacting, armoring, and/or benching prior to the first rains.
5. Excess or unusable soil will be stored in long term spoil disposal locations that are not limited by factors such as excessive moisture, steep slopes greater than 10%, archeology potential, or proximity to a watercourse.
6. On running streams, water will be pumped or diverted past the crossing and into the downstream channel during the construction process.
7. Straw bales and/or silt fencing will be employed where necessary to control runoff within the construction zone.

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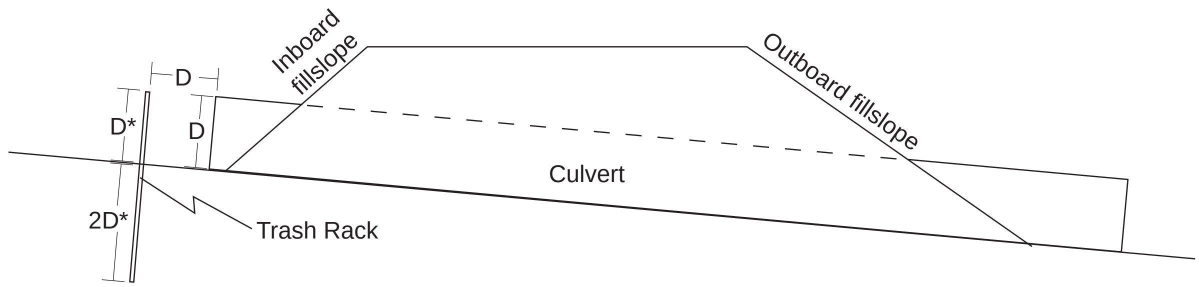
Typical Design of a Single-post Culvert Inlet Trash Rack

Cross section view



D - Culvert diameter

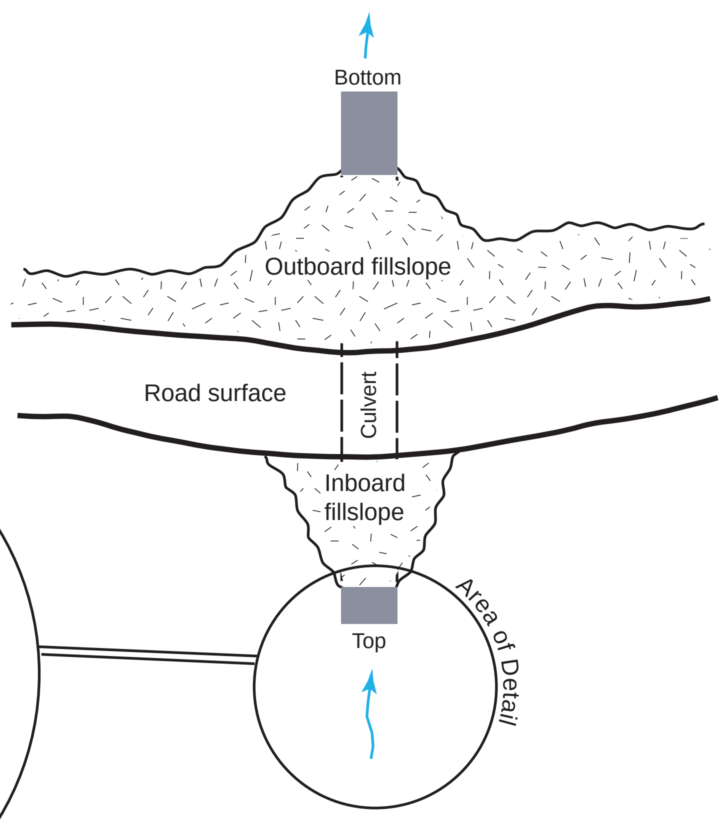
D* - If the culvert is designed for the 100-year peak storm flow, the trash rack height above the streambed should equal D.
If the culvert is undersized, then the trash rack needs to be extended vertically above the streambed to match or exceed the expected headwall height.

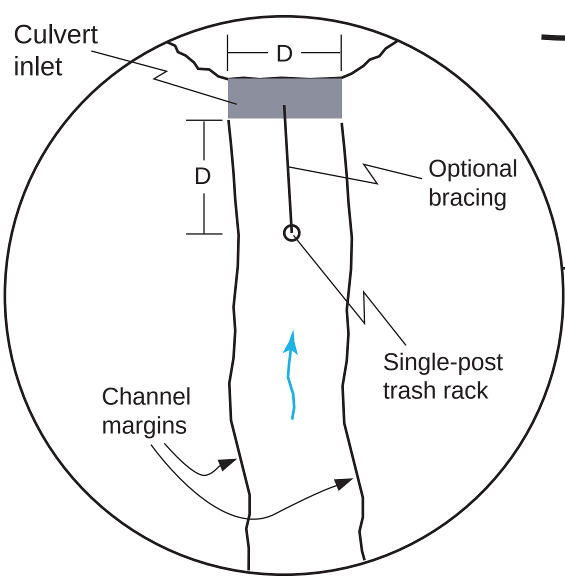
Plan view

Notes:

1. Many materials can be used for a single-post trash rack including old railroad track, galvanized pipe, and fence posts.

2. The diameter of single-post trash racks should be sized based on the size of expected woody debris. As a basic rule of thumb, the diameter of the trash rack should be equal to the diameter of the expected woody debris up to 4 inches.





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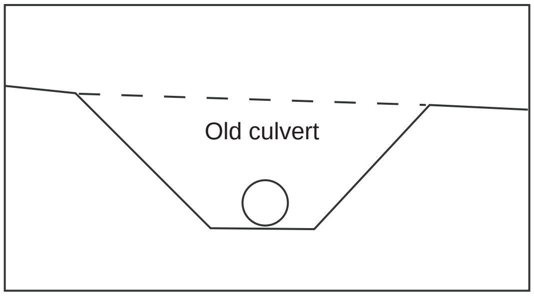
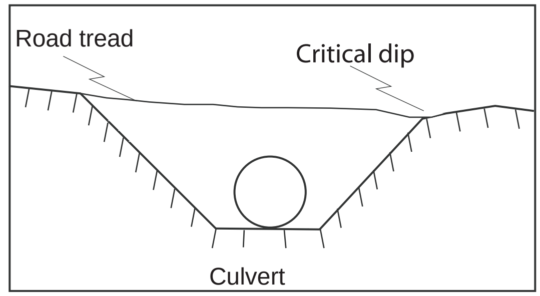
Typical Design of Upgraded Stream Crossings





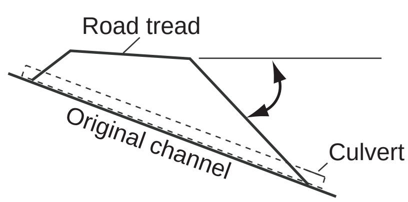
Stream crossing culvert Installation

1. Culverts shall be aligned with natural stream channels to ensure proper function, and prevent bank erosion and plugging by debris.
2. Culverts shall be placed at the base of the fill and the grade of the original streambed or downspouted past the base of the fill.
3. Culverts shall be set slightly below the original stream grade so that the water drops several inches as it enters the pipe.
5. To allow for sagging after burial, a camber shall be between 1.5 to 3 incher per 10 feet culvert pipe length.
6. Backfill material shall be free of rocks, limbs or other debris that could dent or puncture the pipe or allow water to seep around pipe.
7. First one end and then the other end of the culvert shall be covered and secured. The center is covered last.
8. Backfill material shall be tamped and compacted throughout the entire process:
   - Base and side wall material will be compacted before the pipe is placed in its bed.
   - backfill compacting will be done in 0.5 - 1 foot lifts until 1/3 of the diameter of the culvert has been covered. A gas powered tamper can be used for this work.
9. Inlets and outlets shall be armored with rock or mulched and seeded with grass as needed.
10. Trash protectors shall be installed just upstream from the culvert where there is a hazard of floating debris plugging the culvert.
11. Layers of fill will be pushed over the crossing until the final designed road grade is achieved, at a minimum of 1/3 to 1/2 the culvert diameter.

Note:
Road upgrading tasks typically include upgrading stream crossings by installing larger culverts and inlet protection (trash barriers) to prevent plugging. Culvert sizing for the 100-year peak storm flow should be determined by both field observation and calculations using a procedure such as the Rational Formula.

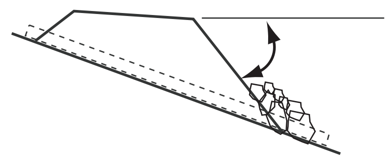
Armoring fill faces

Fill angles ≤ 2:1



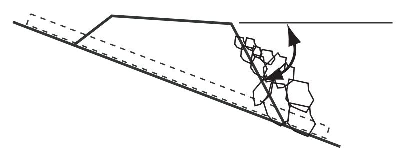
No rock armor needed

Fill angles (between 2:1 & 1.5:1)



Armor 1/4 up fill face

Fill angles (between 2:1 & 1.5:1)



Armor 3/4 way up fill face

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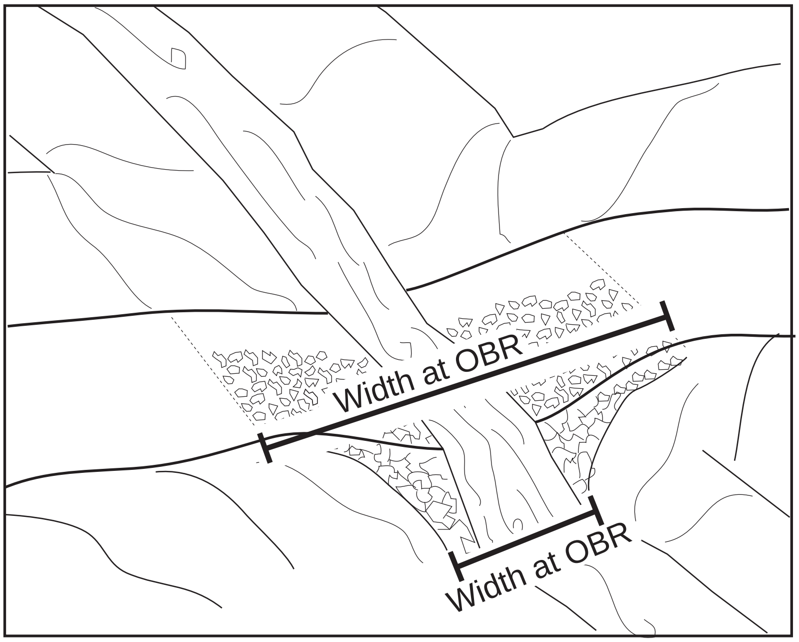
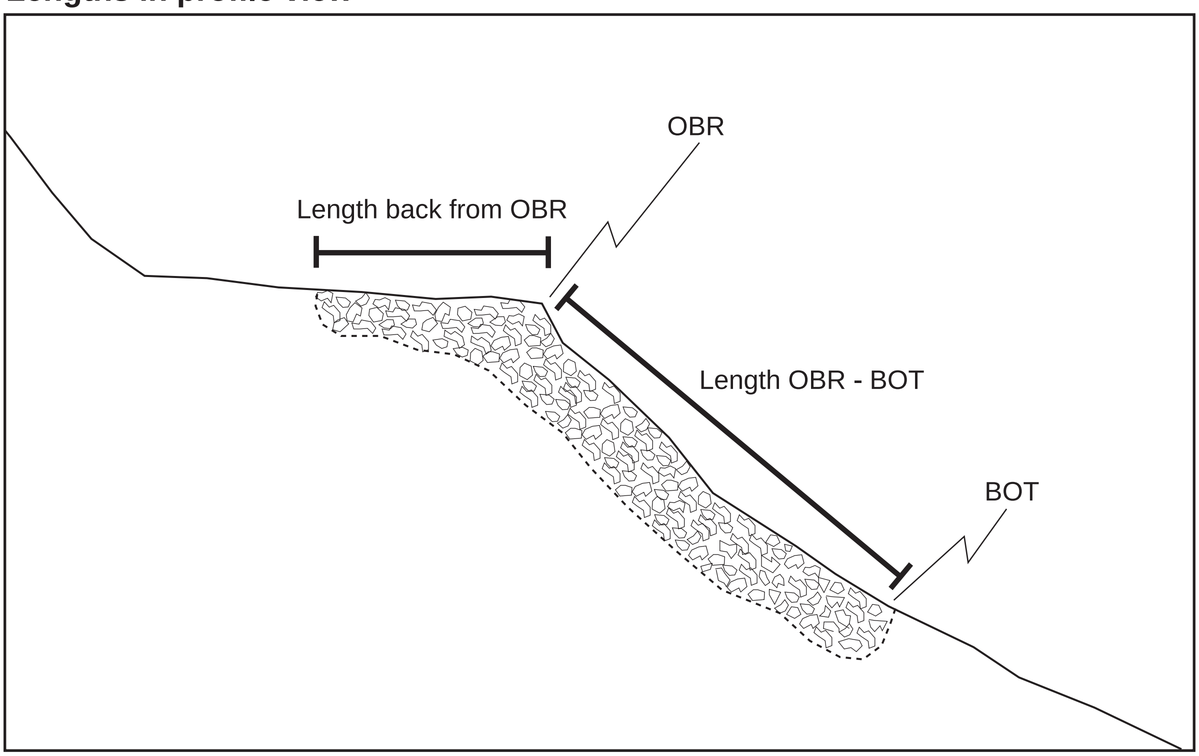
Typical Dimensions Refered to for Armored Fill Crossings

Widths in oblique view



OBR - Outboard edge of road

Lengths in profile view



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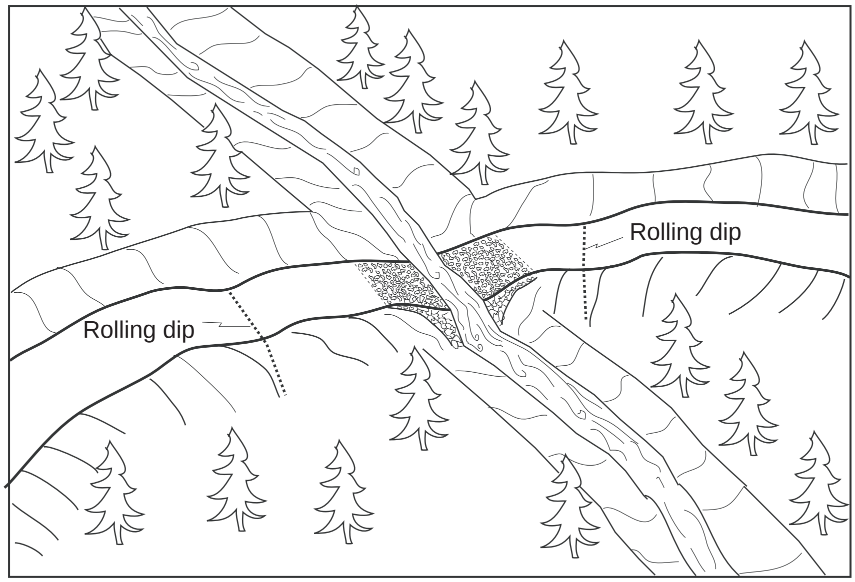
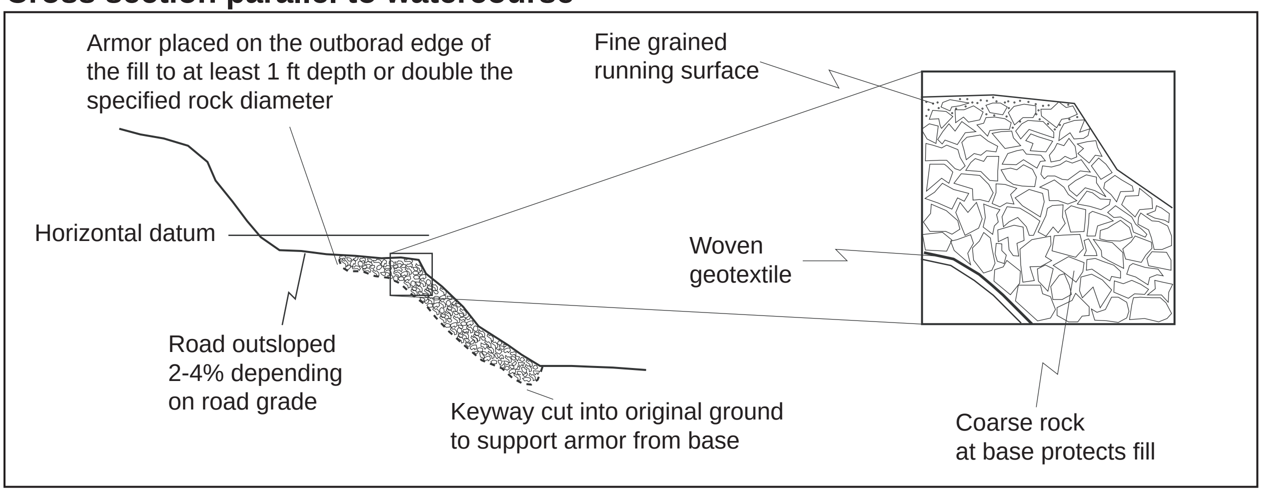
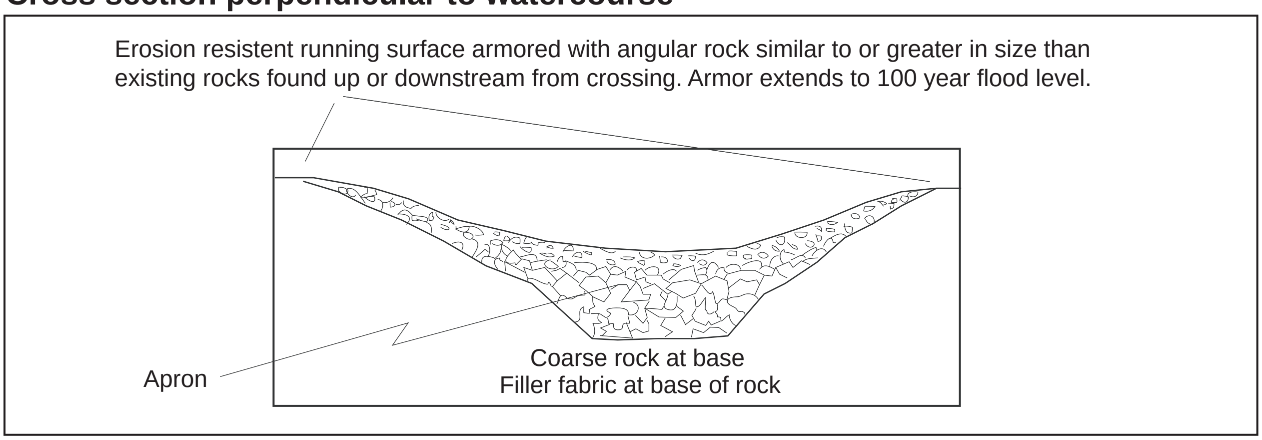
Typical Armored Fill Crossing Installation



Cross section parallel to watercourse



Cross section perpendicular to watercourse



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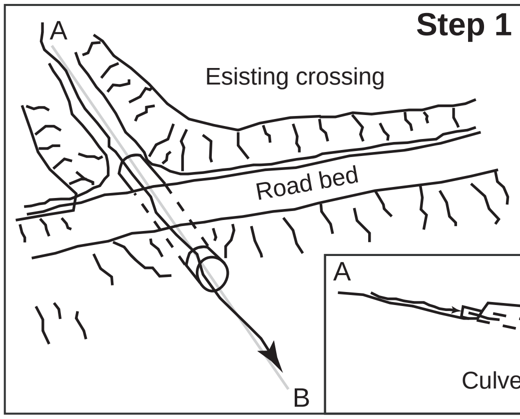
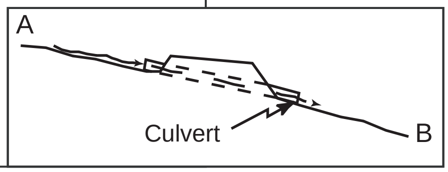
Ten Steps for Constructing a Typical Armored Fill Stream Crossing

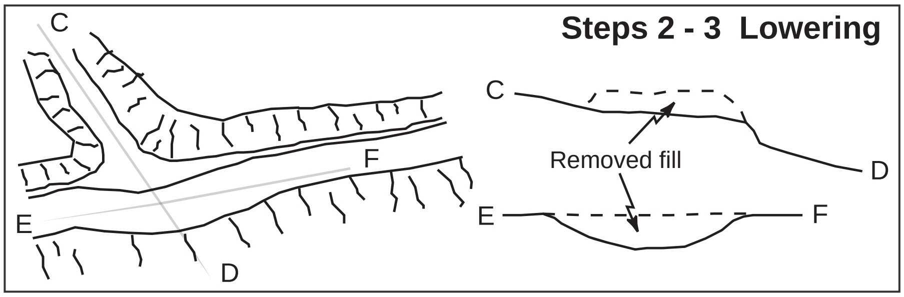




1. The two most important points are:

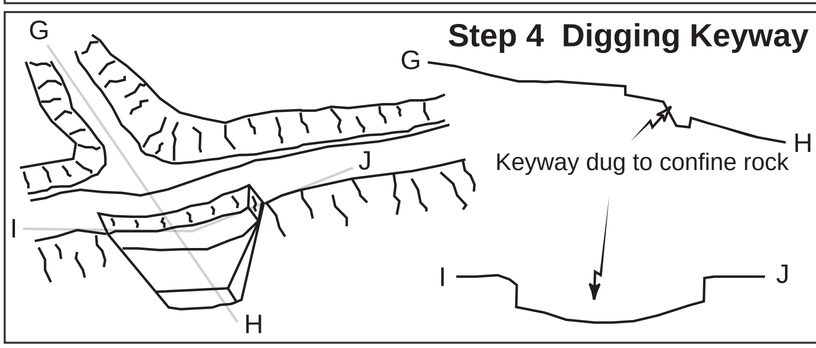
A) **The rock must be placed in a “U” shape across the channel to confine flow within the armored area.** (Flow around the rock armor will gully the remaining fill. Proper shape of surrounding road fill and good rock placement will reduce the likelihood of crossing failure).

B) **The largest rocks must be used to buttress the rest of the armor in two locations:** (i) The base of the armored fill where the fill meets natural channel. (This will butress the armor placed on the outboard fill face and reduce the likelihood of it washing downslope). (ii) The break in slope from the road tread to the outer fill face. (This will butress the fill placed on the outer road tread and will determine the “base level” of the creek as it crosses the road surface).



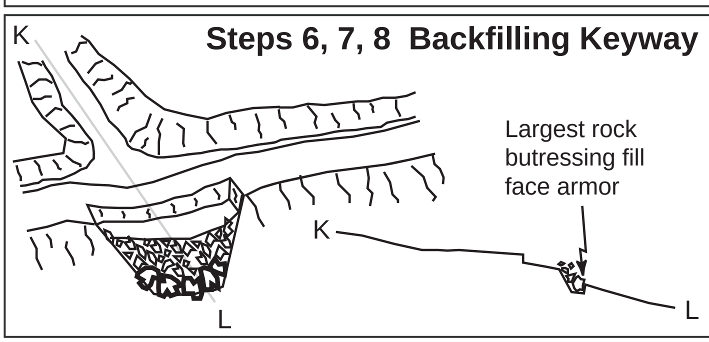
2. Remove any existing drainage structures including culverts and Humboldt logs.

3. Construct a dip centered at the crossing that is large enough to accomodate the 100-year peak storm flow and prevent diversion (C-D, E-F).



4. Dig a keyway (to place rock in) that extends from the outer 1/3 of the road tread down the outboard road fill to the point where outbaord fill meets natural channel (up to 3 feet into the channel bed depending on site specifics) (G-H, I-J).

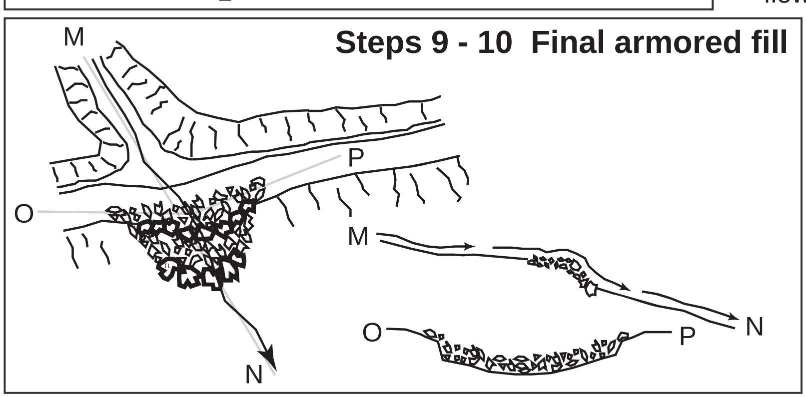
5. Install geofabric (optional) within keyway to support rock in wet areas and to prevent winnowing of the crossing at low flows.



6. Put aside the largest rock armoring to create 2 buttresses in the next step.

7. Create a buttress using the largest rock (as described in the site treatments specifications) at the base of fill. (This should have a “U” shape to it and will define the outlet of the armored fill.)

8. Backfill the fill face with remaining rock armor making sure the final armored area has “U” shape that will accomodate the largest expected flow (K-L).



9. Install a second buttress at the break in slope between the outboard road and the outboard fill face. (This should define the base level of the stream and determine how deep the stream will backfill after construction). (M-N)

10. Back fill the rest of the keyway with the unsorted rock armor making sure the final armored area has a “U” shape that will accommodate the largest expected flow (O-P).

Typical Drawing #7

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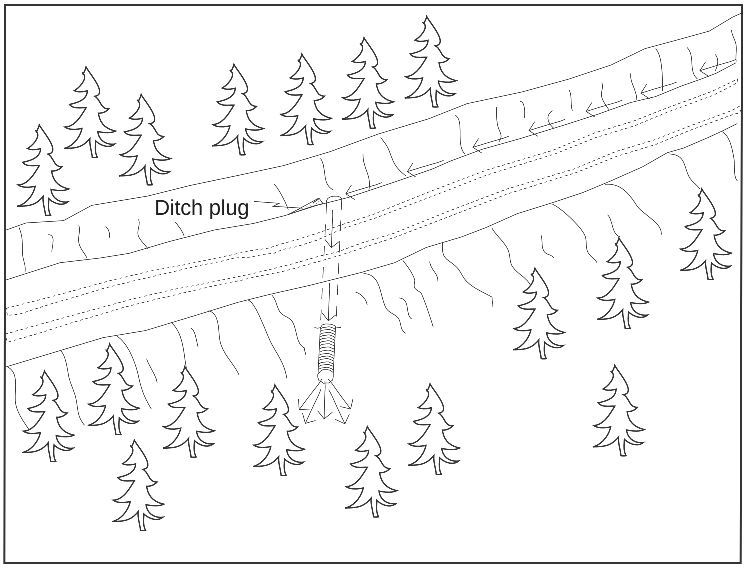
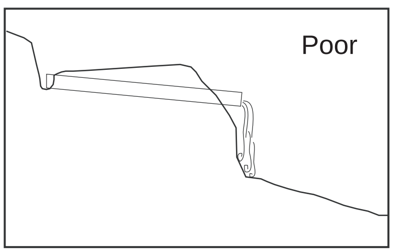
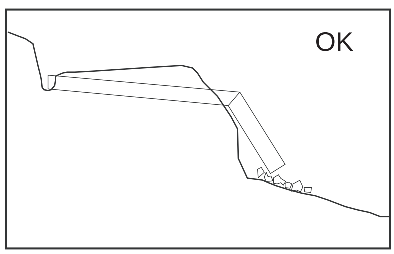
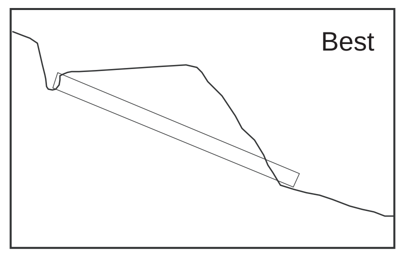
Typical Ditch Relief Culvert Installation









Ditch relief culvert installation

1) The same basic steps followed for stream crossing installation shall be employed.
2) Culverts shall be installed at a 30 degree angle to the ditch to lessen the chance of inlet erosion and plugging.
3) Culverts shall be seated on the natural slope or at a minimum depth of 5 feet at the outside edge of the road, whichever is less.
4) At a minimum, culverts shall be installed at a slope of 2 to 4 percent steeper than the approaching ditch grade, or at least 5 inches every 10 feet.
5) Backfill shall be compacted from the bed to a depth of 1 foot or 1/3 of the culvert diameter, which ever is greater, over the top of the culvert.
6) Culvert outlets shall extend beyond the base of the road fill (or a flume downspout will be used). Culverts will be seated on the natural slope or at a depth of 5 feet at the outside edge of the road, whichever is less.

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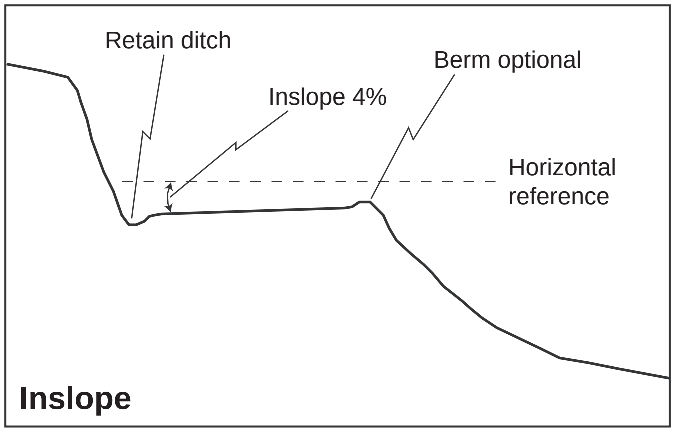
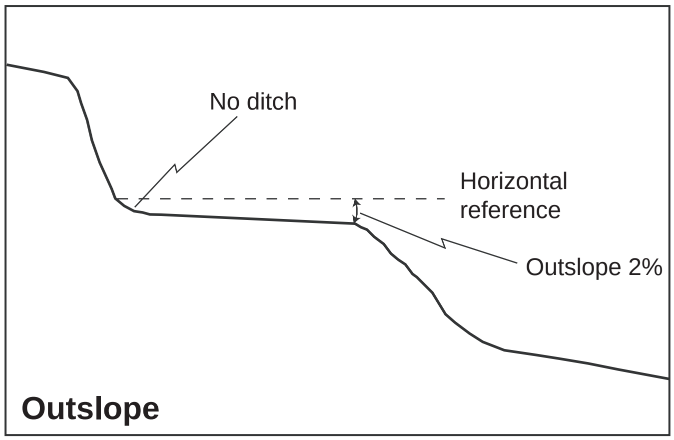
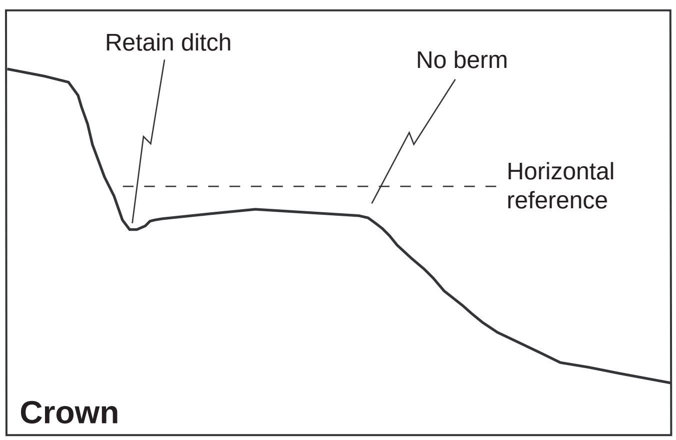
Typical Designs for Using Road Shape to Control Road Runoff







Outsloping Pitch for Roads Up to 8% Grade		
Road grade	**Unsurfaced roads**	**Surfaced roads**
4% or less	3/8" per foot	1/2" per foot
5%	1/2" per foot	5/8" per foot
6%	5/8" per foot	3/4" per foot
7%	3/4" per foot	7/8" per foot
8% or more	1" per foot	1 1/4" per foot

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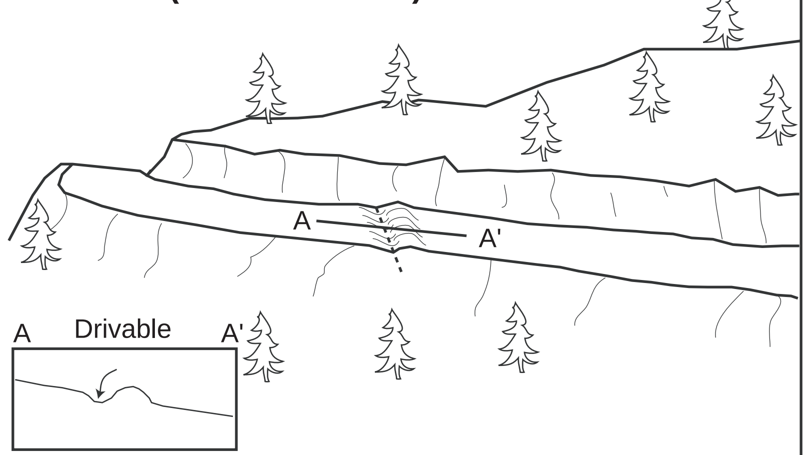
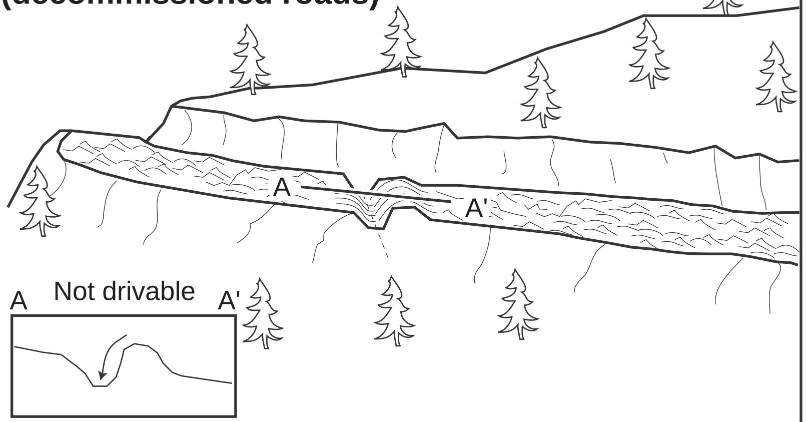
Typical Methods for Dispersing Road Surface Runoff with Waterbars, Cross-road Drains, and Rolling Dips

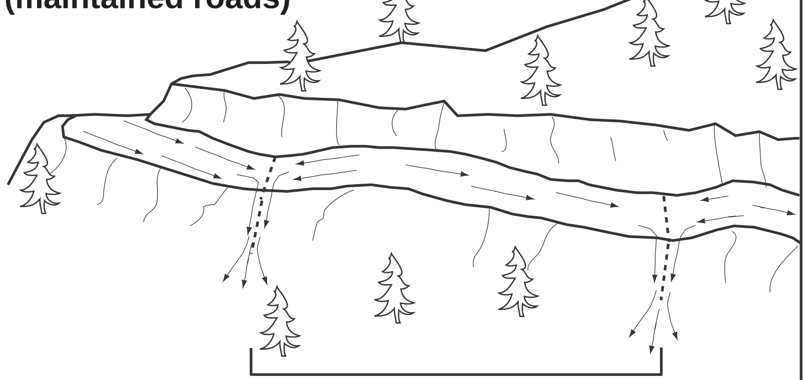
Waterbars (seasonal roads)



Cross-road drain and decompaction (decommissioned roads)



Rolling dips (maintained roads)



Rolling dip spacing dependent on road grade,
soil erodibility, and proximity to stream

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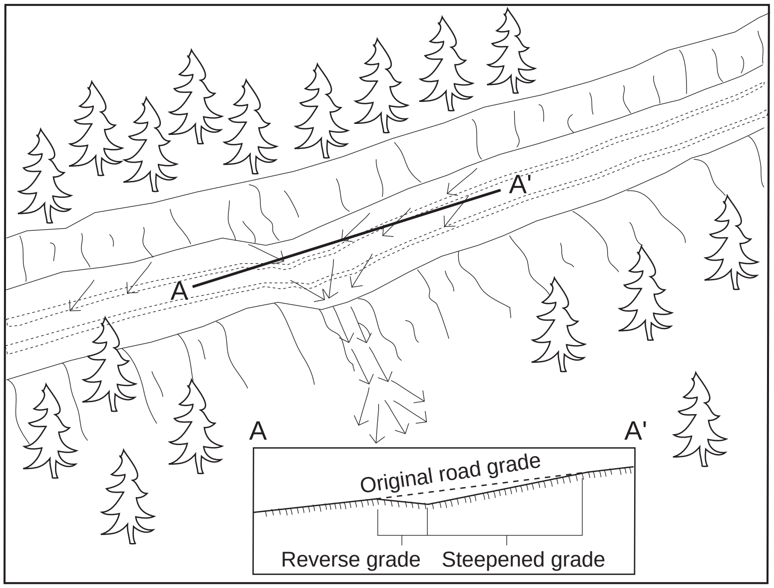
Typical Road Surface Drainage by Rolling Dips



Rolling dip installation:

1. Rolling dips will be installed in the roadbed as needed to drain the road surface.
2. Rolling dips will be sloped either into the ditch or to the outside of the road edge as required to properly drain the road.
3. Rolling dips are usually built at 30 to 45 degree angles to the road alignment with cross road grade of at least 1% greater than the grade of the road.
4. Excavation for the dips will be done with a medium-size bulldozer or similar equipment.
5. Excavation of the dips will begin 50 to 100 feet up road from where the axis of the dip is planned as per guidelines established in the rolling dip dimensions table.
6. Material will be progressively excavated from the roadbed, steepening the grade unitl the axis is reached.
7. The depth of the dip will be determined by the grade of the road (see table below).
8. On the down road side of the rolling dip axis, a grade change will be installed to prevent the runoff from continuing down the road (see figure above).
9. The rise in the reverse grade will be carried for about 10 to 20 feet and then return to the original slope.
10. The transition from axis to bottom, through rising grade to falling grade, will be in a road distance of at least 15 to 30 feet.

Table of rolling dip dimensions by road grade

Road grade %	**Upslope approach distance** (from up road start to trough) ft	**Reverse grade distance** (from trough to crest) ft	**Depth at trough outlet** (below average road grade) ft	**Depth at trough inlet** (below average road grade) ft
<6	55	15 - 20	0.9	0.3
8	65	15 - 20	1.0	0.2
10	75	15 - 20	1.1	0.01
12	85	20 - 25	1.2	0.01
>12	100	20 - 25	1.3	0.01

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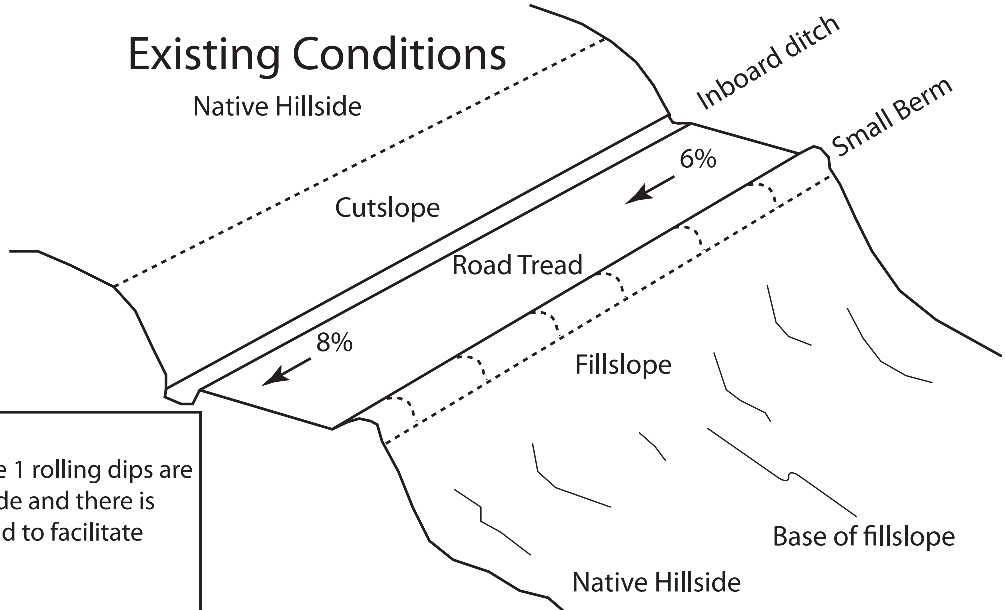
Standard (Type 1) Rolling Dip Construction

Existing Conditions



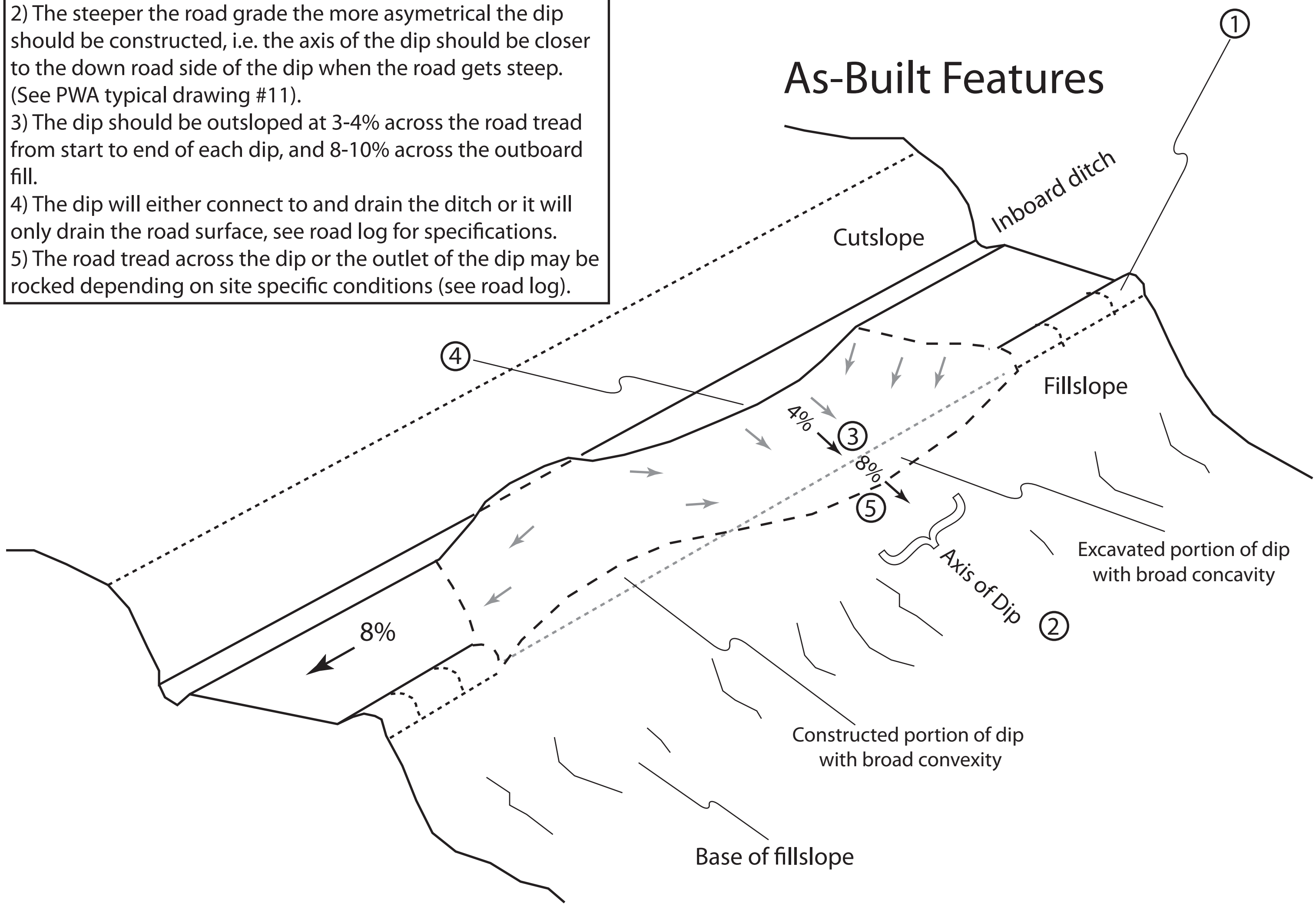
Notes

Rolling dip type 1 existing conditions: Type 1 rolling dips are utilized when roads are less than 12-14% grade and there is proximal outfall adjacent to the outboard road to facilitate road drainage.

Design Notes:

1) The berm should be removed for the entire length of the dip.
2) The steeper the road grade the more asymetrical the dip should be constructed, i.e. the axis of the dip should be closer to the down road side of the dip when the road gets steep. (See PWA typical drawing #11).
3) The dip should be outsloped at 3-4% across the road tread from start to end of each dip, and 8-10% across the outboard fill.
4) The dip will either connect to and drain the ditch or it will only drain the road surface, see road log for specifications.
5) The road tread across the dip or the outlet of the dip may be rocked depending on site specific conditions (see road log).

As-Built Features



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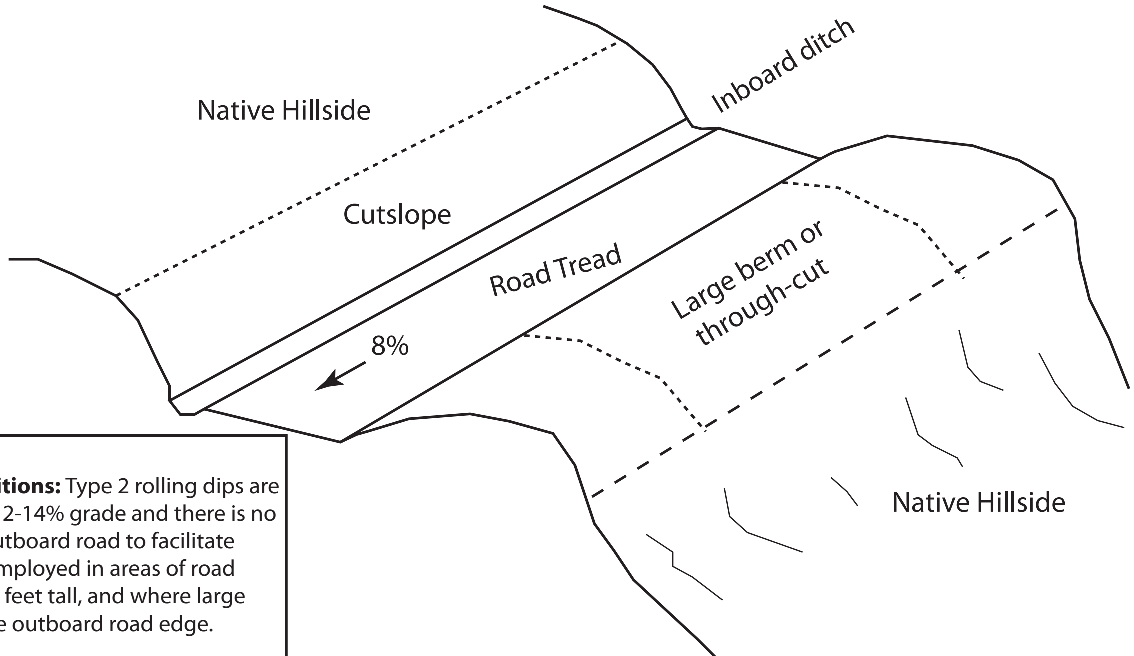
Type 2 Rolling Dip Construction

(Through-cut or thick berm road reaches)



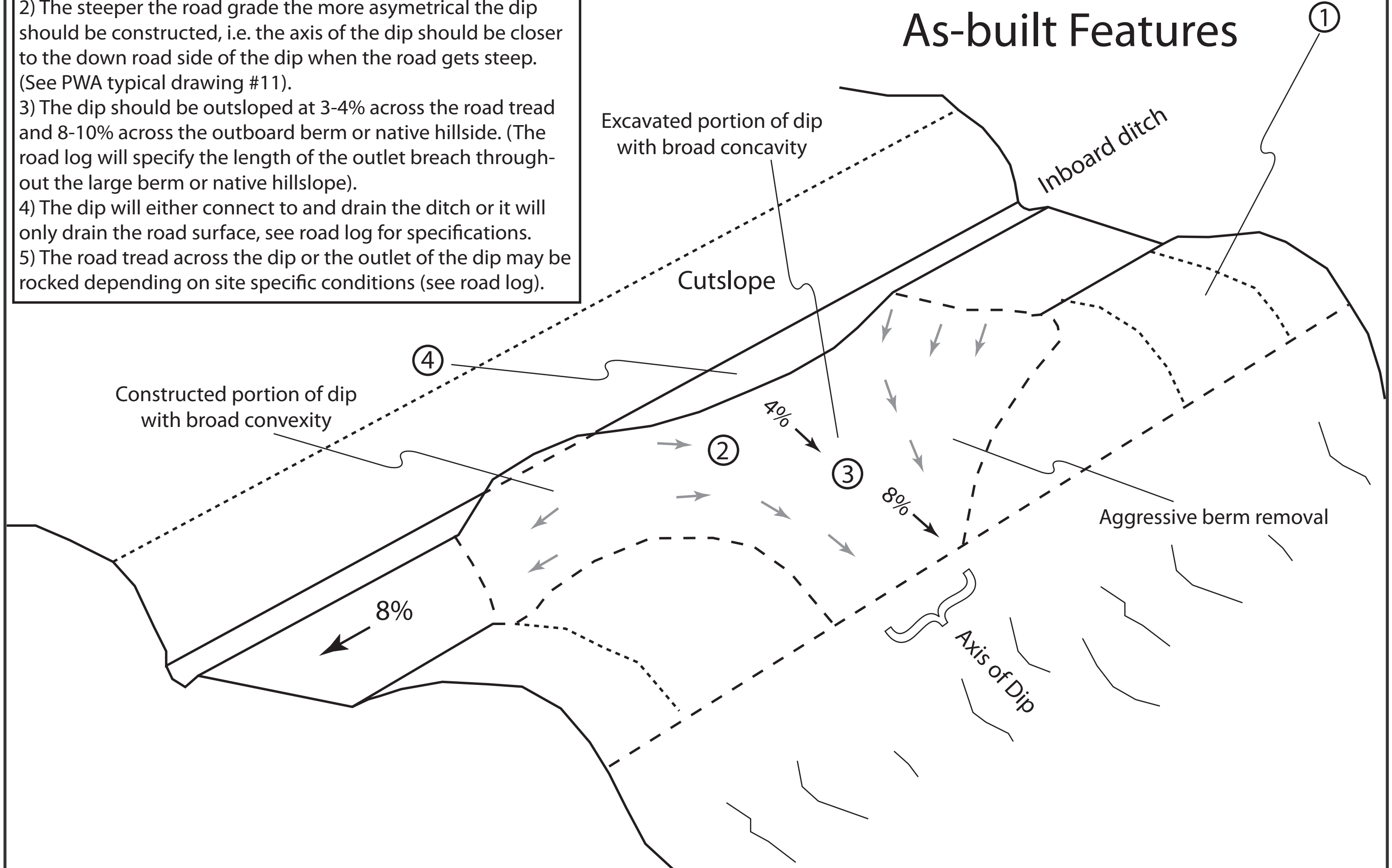
Notes

Rolling dip type 2 existing conditions: Type 2 rolling dips are utilized when roads are less than 12-14% grade and there is no proximal outfall adjacent to the outboard road to facilitate road drainage. These should be employed in areas of road through-cuts generally less than 3 feet tall, and where large wide and/or tall berms exist on the outboard road edge.

Design Notes:

1) The berm or native hillside should be removed for the entire length of the excavated portion of the dip, or, at a minimuim through the axis of the dip.
2) The steeper the road grade the more asymetrical the dip should be constructed, i.e. the axis of the dip should be closer to the down road side of the dip when the road gets steep. (See PWA typical drawing #11).
3) The dip should be outsloped at 3-4% across the road tread and 8-10% across the outboard berm or native hillside. (The road log will specify the length of the outlet breach throughout the large berm or native hillslope).
4) The dip will either connect to and drain the ditch or it will only drain the road surface, see road log for specifications.
5) The road tread across the dip or the outlet of the dip may be rocked depending on site specific conditions (see road log).

As-built Features



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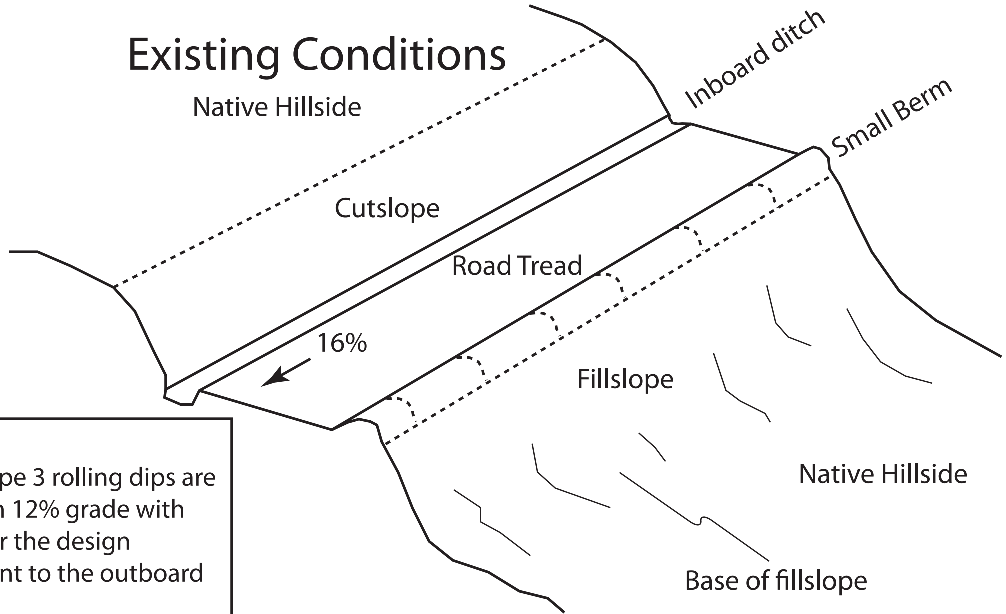
Type 3 Rolling Dip Construction
(steep slope outslope)

Existing Conditions

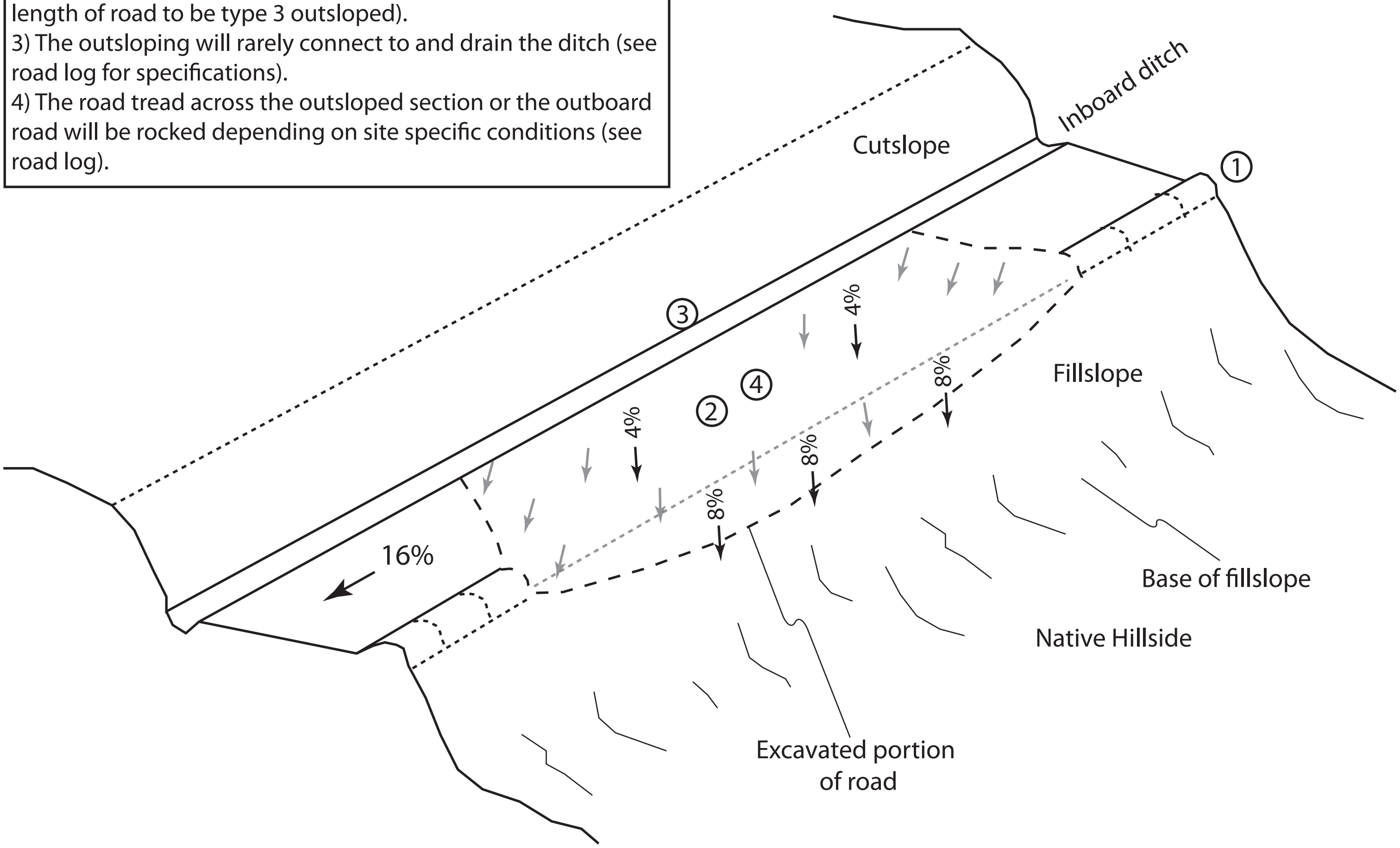


Notes

Rolling dip type 3 existing conditions: Type 3 rolling dips are utilized when roads grades are steeper than 12% grade with little opportunity to create reverse grade for the design vehicle, and there is proximal outfall adjacent to the outboard road to facilitate road drainage.

Design Notes:

1) The berm should be removed for the entire length of the outsloped section.
2) The dip should be outsloped at 2-4% across the road tread and 4-8% across the outboard fill. (The road log will specify the length of road to be type 3 outsloped).
3) The outsloping will rarely connect to and drain the ditch (see road log for specifications).
4) The road tread across the outsloped section or the outboard road will be rocked depending on site specific conditions (see road log).



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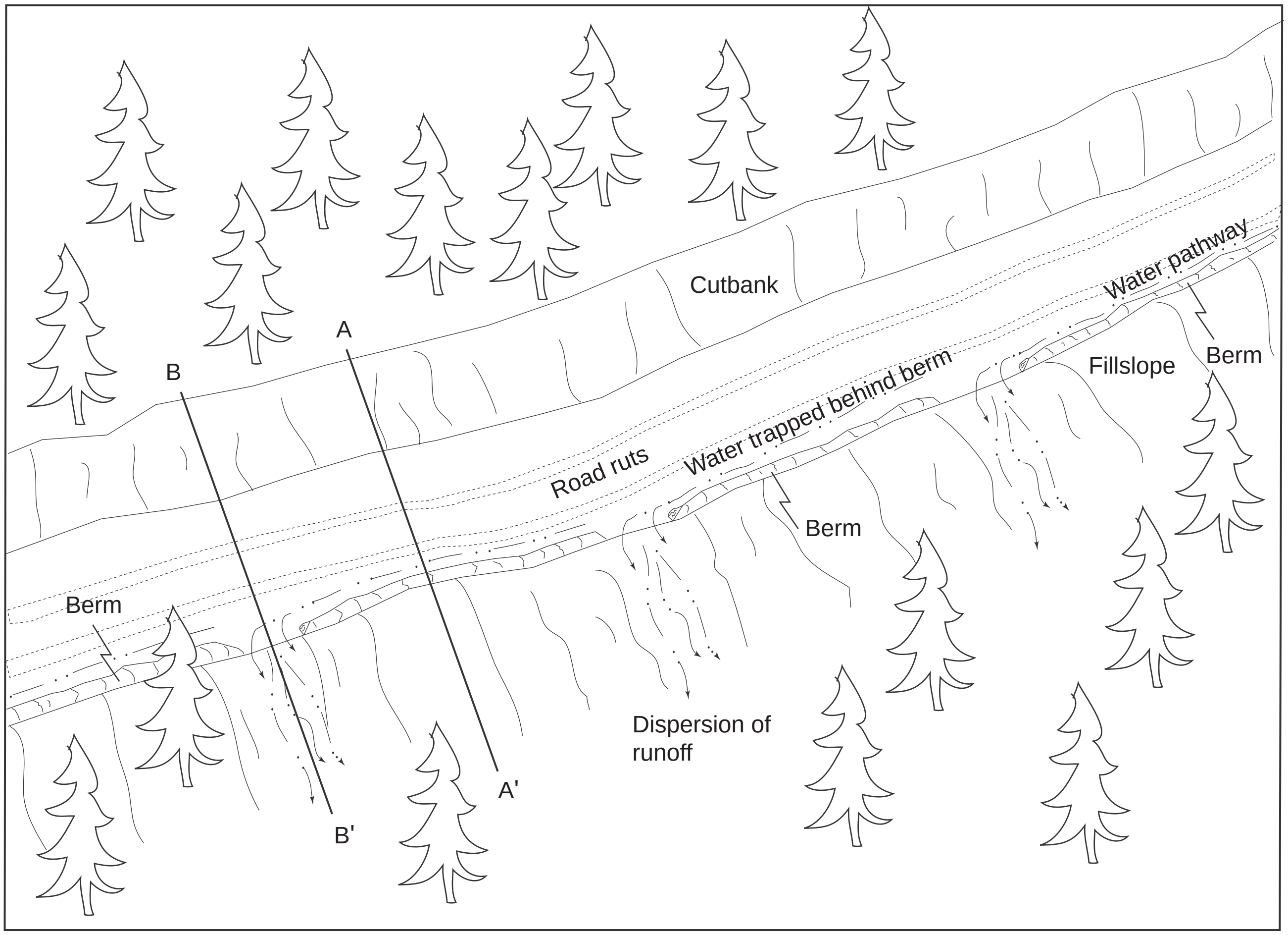
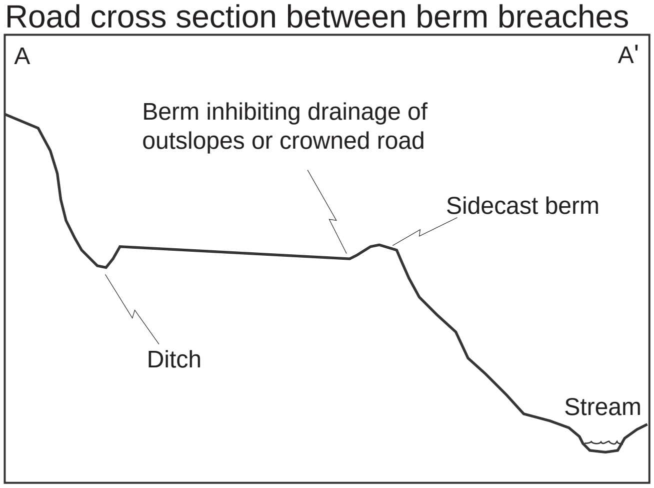
Typical Sidecast or Excavation Methods for Removing Outboard Berms on a Maintained Road

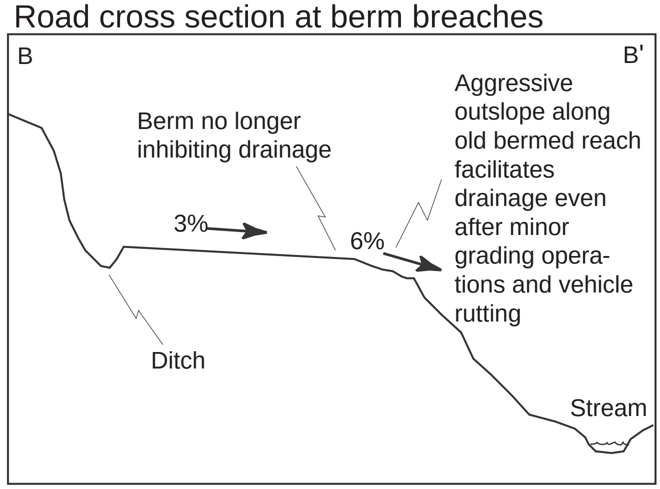
1. On gentle road segments berms can be removed continuously (see B-B').
2. On steep road segments, where safety is a concern, the berm can be frequently breached (see A-A' & B-B') Berm breaches should be spaced every 30 to 100 feet to provide adequate drainage of the road system while maintaining a semi-continuous berm for vehicle safety.



Road cross section between berm breaches



Road cross section at berm breaches



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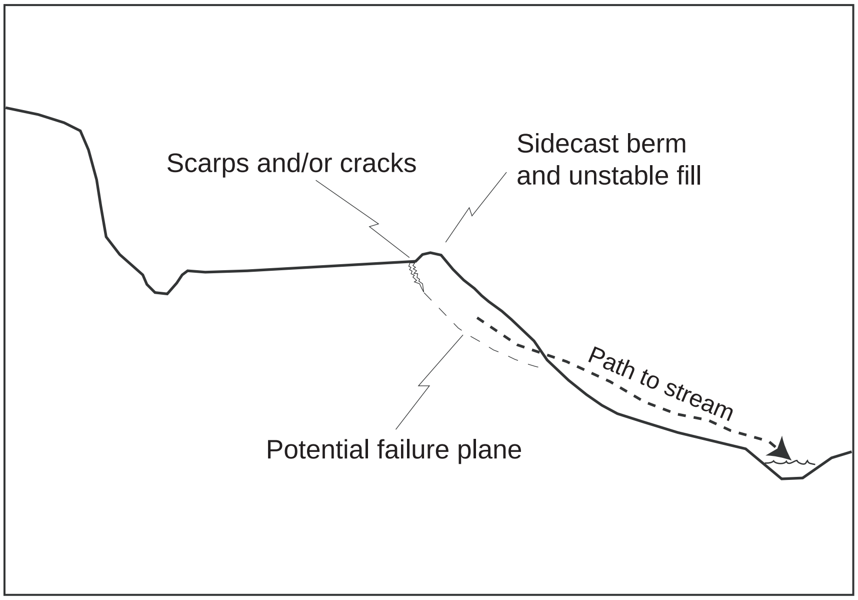
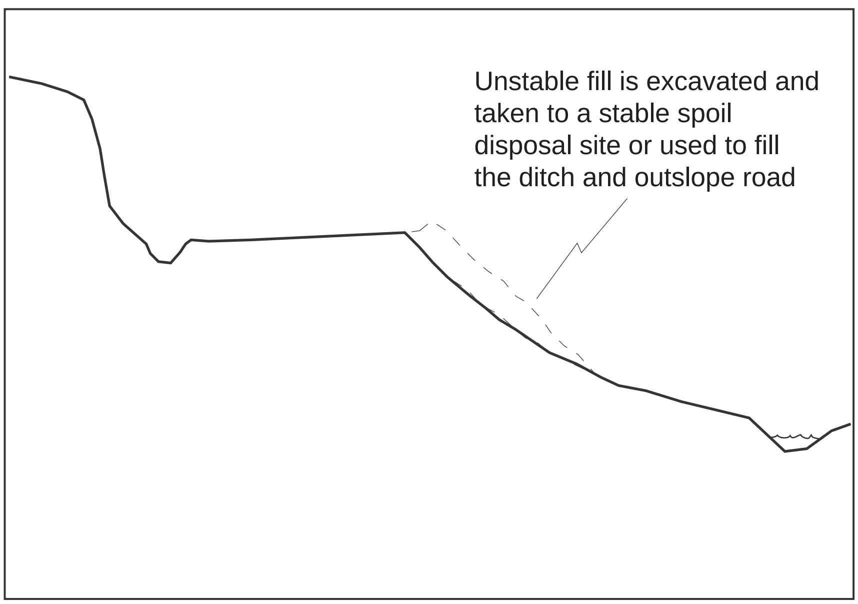
Typical Excavation of Unstable Fillslope on an Upgraded Road

Before



After



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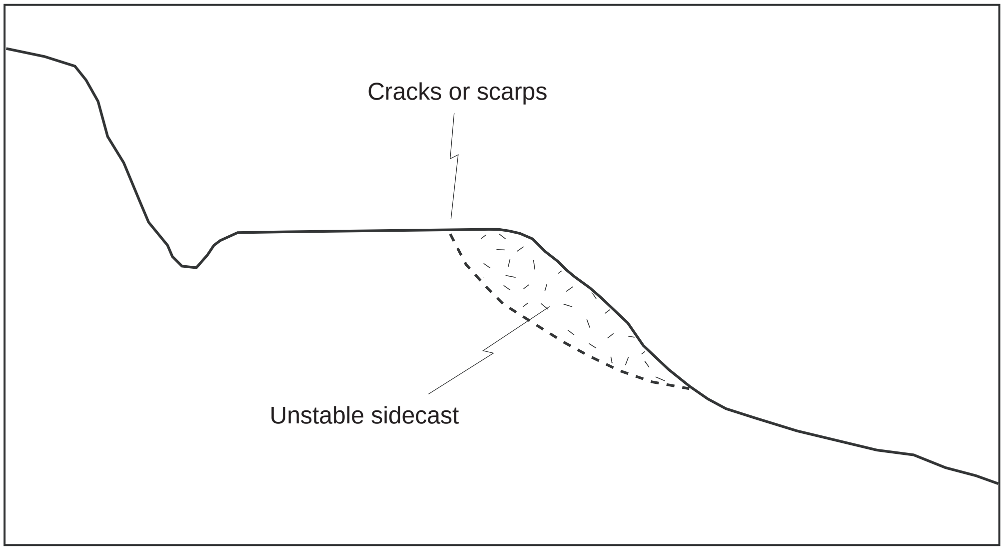
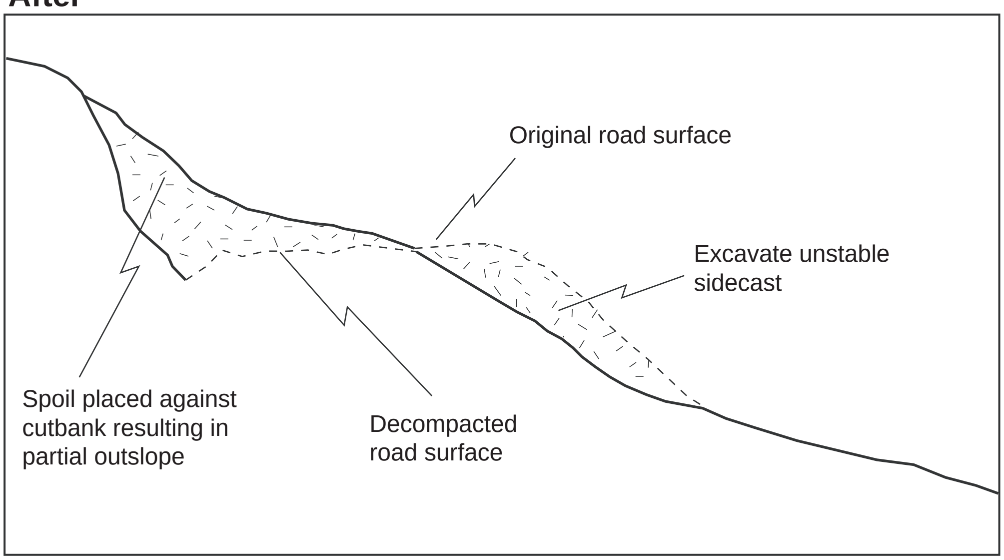
Typical Excavation of Unstable Fillslope on a Decommissioned Road

Before



After



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