Golden Gate National Recreation Area
Redwood Creek Watershed, Muir Woods
Road and Trail Re-evaluation and Assessment
Marin County, California

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Prepared for:
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1 EXECUTIVE SUMMARY

Redwood Creek is an 8.76 mi^2 watershed that drains directly to the Pacific Ocean at Muir Beach, 6.5 miles southwest of Mill Valley (Map 1). Land owners and land managers in the watershed include Marin County (County), Marin Municipal Water District (MMWD), Mt. Tamalpais State Park (MTSP), National Park Service (NPS), Green Gulch Farm (GGF) and Muir Beach Community Services District (MBCSD). Highway 1 is managed by Cal Trans; Muir Woods Road and Panoramic Highway are managed by Marin County. Therefore, it is important to note that the other adjacent land owners/land managers do not have jurisdiction to work on the drainage structures associated with these roads.

The primary goal for this project was to assess selected sites within the watershed; update observations based on current conditions; compile information on work completed and planned; and provide updated prioritized recommendations for short and long term erosion control and erosion prevention implementation strategies in order to assist GGNRA with their ultimate goal of land stewardship, protection of sensitive species and their habitats.

In 2002, 67 miles of roads and trails were assessed by PWA within the Redwood Creek watershed. The 2002 assessment locations, hereafter referred to as the "Project Area", identified 500 sites where sediment was being delivered, or had the potential to deliver, to the Redwood Creek watershed. Of the 500 sites identified, 383 were recommended for treatment. The 2002 assessment was developed as a tool for landowners and land managers responsible for maintenance, preservation, restoration and/or conservation within the Project Area.

It is important to note that PWA's 2002 study identified only sources of sediment related to roads and trails. While sediment delivery to stream channels from road/trail networks are significant, they are not the only contributor of fine sediment in the watershed. In 2003, Golden Gate National Recreation Area (GGNRA) retained Stillwater Sciences (Stillwater) to prepare a sediment budget (looking at all sources of potential sediment) for Redwood Creek Watershed. Stillwater recognized that it is difficult to isolate the impacts of human disturbance in the watershed sediment budget. However, of all sediment sources, Stillwater estimated about 32% was related to roads and trails, about 41% is related to tributary bank erosion/incision, and about 27% is related to hillslope erosion (Table 21D, Stillwater Sciences, 2004).

Since 2002, agency staff have implemented recommended treatments and/or maintenance at 67 of the 383 sites (17%) recommended in the 2002 assessment as available funding and/or opportunities presented themselves. Of these 67 sites, 18 were given a high or high-moderate treatment immediacy (2 on MTSP, 13 on MMWD, and 3 on GGNRA/Muir Woods National Monument (MWNM) property); 27 were originally assigned a moderate or moderate-low treatment immediacy (13 on GGNRA/MWNM, 12 on MTSP, and 1 on GGF); 13 were assigned a low treatment immediacy (10 on MTSP and 3 on GGNRA/MWNM property); and 9 sites were not recommended for treatment (8 on MTSP and 1 on MWNM property).

In addition, MTSP, GGNRA, and MWNM have currently identified 64 sites with work planned for the near future along Deer Park Fire Road, Dipsea Trail, Fern Creek Trail, Heather Cutoff Trail, Lost Trail, Miwok Trail, Canopy View Trail, Redwood Creek Trail, Ben Johnson Trail, and Muir Woods Road. MTSP currently plan to treat 59 sites (3 assigned a high or high-moderate treatment immediacy, 35 moderate or moderate-low rating, 19 low rating, and 2 were identified as not

recommended for treatment in 2002). GGNRA/MWNM currently plan to treat 5 sites (3 assigned moderate or moderate-low and 2 low treatment immediacy in 2002).

In 2016-2017, NPS staff retained PWA to conduct a re-evaluation of approximately 9% of the original sites identified in the 2002 assessment. Of the 44 sites, 8 were located along Muir Woods Road, 10 on Panoramic Highway, 7 on Conlon Avenue, 12 on Camino Del Canyon, 2 on Muir Woods Old Service Road, and 5 on Dipsea Trail; managed by NPS, MTSP, and Marin County (Map 1). Using field inventories and data analysis consistent with California Department of Fish and Wildlife (CDFW) approved protocols (Weaver et al., 2006, 2015), PWA re-characterized a total of 44 sites along 6 separate road/trail segments with the potential to deliver sediment to streams within the 8.76 mi^2 Redwood Creek watershed area.

Of the 44 sediment source assessment sites that were re-evaluated, 40 sites were recommended to be treated for erosion control and erosion prevention. It is estimated that treating these sites will prevent approximately 6,160 yd^3 of *episodic*, primarily storm-driven sediment delivery to streams in the Redwood Creek watershed in the next 30 years. In addition to individual erosion sites, field crews confirmed approximately 2.99 miles of eroding road surfaces, ditches, and/or cutbanks were hydrologically connected[1] (adjacent) to assessment sites that are currently draining fine sediment to nearby stream channels, either directly through the inboard ditch or via gullies. Treatment of these hydrologically connected road surfaces could prevent the *chronic* (annual) additional delivery of approximately 2,090 yd^3 of fine sediment delivery to nearly streams on a decadal basis. Therefore, if assessment sites and their associated hydrologically connected road reaches are treated, an estimated total of 8,250 yd^3 of sediment could be prevented from entering the main stem and tributaries of Redwood Creek over the coming decades.

[1] Hydrologically connected describes sites or road segments from which eroding sediment is delivered to stream channels via surface and gully erosional processes occurring along the road (Furniss et al., 2000).

2 CERTIFICATION AND LIMITATIONS

This report, entitled *Redwood Creek Watershed, Muir Woods Road Re-Assessment*, was prepared under the direction of a licensed professional geologist at Pacific Watershed Associates Inc. (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 control treatment prescriptions, were similarly conducted 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, or semi-quantitative, and 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.

The recommendations included 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.

Furthermore, to ensure proper applicability to existing conditions, the information and recommendations contained in this report shall be reevaluated after a period of no more than 3 years, and it is the responsibility of the landowner to ensure that no recommendations are inappropriately applied to conditions on the property that have changed since the recommendations were developed. 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:

Tara Zuroweste, California Professional Geologist #8418
Pacific Watershed Associates Inc.

3 INTRODUCTION

The primary goal for this project was to assess selected sites within the watershed; update observations based on current conditions; compile information on work completed and planned; and provide updated prioritized recommendations for short and long-term erosion control and erosion prevention implementation strategies in order to assist GGNRA with their goal of land stewardship, protection of sensitive species and their habitats.

In 2002, Muir Beach Community Services District (MBCSD), California Department of Fish and Wildlife (CDFW), MMWD, and NPS worked with Pacific Watershed Associates (PWA) to complete a sediment source assessment and prepare a prioritized erosion prevention plan for 67 miles of roads and trails within the Redwood Creek watershed (PWA, 2002). The assessment was focused on identifying sources of sediment delivery and providing recommendations to reduce impact on nearby streams. The original assessment did not include specific recommendations for treating impacts from other pollutants, such as petroleum products, etc. However, hydrologically disconnecting road lengths through improved road drainage, sediment basins, etc. would effectively reduce sediment delivery, as well as impacts from other pollutants.

Following the 2002 assessment, land managers in the Redwood Creek watershed implemented treatments at a number of sites identified by PWA. Following treatment guidelines developed and provided by PWA, Marin Municipal Water District (MMWD) performed erosion control work on 10 sites between 2004 and 2008, refer to report entitled *Redwood Creek Watershed Sediment Control on Marin Municipal Water District Lands* (MMWD, 2008) for more details. In addition, MTSP replaced culverts on Alice Eastwood Road and at Kent Canyon, and did significant work on Dias Ridge Trail, Bootjack Trail, and Old Mine Trail. NPS decommissioned an old service road at Muir Woods, replaced culverts on Banducci Road, and did significant work on their portion of Dias Ridge Trail and Middle Green Gulch Road and Trail. Land managers are currently working on planning for other projects in the watershed which will address PWA sites such as a Marin County project on Muir Woods Road, MTSP improvements to Heather Cut Off and Miwok Trail, NPS improvements to Conlon Ave, and NPS and MTSP are working together on improvements to Deer Park Fire Road and Dipsea Trail. Refer to Table 5 for a summary of completed and planned work at PWA sites assessed in 2002.

Sediment delivery to stream channels from roads and road networks has been extensively documented, and is recognized as a significant impediment to the health of salmonid habitat (Furniss et al., 1991; Higgins et al., 1992; Harr and Nichols, 1993; Flosi et al., 1998; NMFS, 2000, 2001; Cafferata et al., 2007). Unlike many watershed improvement and restoration activities, erosion prevention and sediment reduction through "storm-proofing" state, county, rural, ranch, and forest roads provides immediate benefits to the streams and aquatic habitat of a watershed (Weaver and Hagans, 1999; Weaver et al., 2006, 2015). 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 fine sediment, rather than allowing continued sediment delivery from managed areas.

One of the purposes of this project is to reevaluate road related sources of erosion and sediment delivery at selected sites, and develop recommendations with an immediacy rating, for implementing a plan of actions to reduce sediment delivery to Redwood Creek that can be included within future Management Plan(s). In this report, we provide results of the field assessment and data analysis, and an immediacy rating for implementing short and long-term erosion control and erosion prevention treatments to reduce

road related erosion in the project area. All treatment prescriptions follow guidelines described in the *Handbook for Forest Ranch and Rural Roads* (Weaver et al., 2015), as well as *Parts IX* and *X* of the California Department of Fish and Wildlife (CDFW)[2] *Salmonid Stream Habitat Restoration Manual* (Taylor and Love, 2003; Weaver et al., 2006).

PWA's reassessment data is summarized in Tables 1-4; Map 1; and Appendix A. Details regarding all 2002 identified sediment delivery sites and their current re-assessed status are found in Appendix B. Construction and installation techniques for the recommended erosion control and erosion prevention treatments are provided in Appendix C. For an overview of terminology and techniques used in road related erosion assessment, see Appendix D: Supplementary Information.

Erosion assessment and data collection methods employed in the field generally followed those outlined in Part IX and X of the CDFW Salmonid Stream Habitat Restoration Manual (Taylor and Love, 2003; Weaver et al., 2006) for conducting upslope sediment source assessments. Using these California-approved PWA standard erosion inventory and assessment protocols, staff confirmed existing erosion and sediment delivery data and developed updated treatment prescriptions and a prioritization scheme based on current conservation and management values. The same protocols were used during the 2016-2017 reassessment as was used in the 2002 assessment. Refer to Table 1 below for a complete list of the sites selected for re assessment.

Based on the results from field investigations, as well as communications with GGNRA and Conservancy staff, PWA has prepared this report of findings and recommendations with an immediacy rating for implementing short term and long term sediment reduction from roads and trails.

4 FIELD DESCRIPTION OF THE ASSESSMENT AREA

4.1 Location of the Field Area

The Project Area is located in southwestern Marin County. Properties within the Project Area include MWNM, MMWD, NPS, MTSP, GGNRA, GGF, and MBCSD. All sites reassessed in 2016-2017 are located in Redwood Creek watershed. Redwood Creek drains directly to the Pacific Ocean, with the mouth located at Muir Beach, 6.5 miles southwest of Mill Valley (Map 1).

4.2 Roads and Trails Re-Assessed in Redwood Creek Watershed

The 44 sites reassessed as part of the 2016-2017 scope of work are located along: Muir Woods Road and Panoramic Highway, owned by Marin County; Conlon Avenue, owned by NPS; and Camino Del Canyon, Muir Woods Old Service Road, and Dipsea Trail, located on NPS and MTSP property (Table 1, Map 1). Road and trail uses include year round paved access, seasonal unpaved road access, abandoned road reaches and trail. Most sites can be accessed by a 4x4 vehicle or an all-terrain vehicle (ATV). However, Conlon Ave is currently impassable due to a failure and its' repair at stream crossing Site #204. In addition, Muir Woods Old Service Road has been decommissioned and segments of Dipsea Trail are only accessible to foot traffic.

Roads and trails within the Project Area contain outdated, unstable, undersized, and/or unmaintained culverted stream crossings; insufficient, ineffective, and/or unmaintained ditch relief culverts; and

[2] California Department of Fish and Wildlife, formerly known as California Department of Fish and Game.

Table 1. Sediment delivery sites re-evaluated by PWA in 2016-2017*

Site #	Road Name	Site Type
78	Muir Woods Road	Ditch relief culvert
79	Muir Woods Road	Stream crossing
90	Muir Woods Road	Road surface discharge point
92	Muir Woods Road	Stream crossing
93	Muir Woods Road	Ditch relief culvert
94	Muir Woods Road	Stream crossing
118	Panoramic Highway	Ditch relief culvert
119	Panoramic Highway	Ditch relief culvert
127	Panoramic Highway	Ditch relief culvert
129	Panoramic Highway	Stream crossing
137	Panoramic Highway	Stream crossing
139	Panoramic Highway	Ditch relief culvert
141	Panoramic Highway	Stream crossing
143	Panoramic Highway	Ditch relief culvert
152	Panoramic Highway	Stream crossing
154	Panoramic Highway	Stream crossing
159	Muir Woods Road	Stream crossing
180	Camino Del Canyon	Stream crossing
181	Camino Del Canyon	Road surface
182	Camino Del Canyon	Stream crossing
183	Camino Del Canyon	Road surface
184	Camino Del Canyon	Ditch relief culvert
185	Camino Del Canyon	Stream crossing
186	Camino Del Canyon	Road surface
187	Camino Del Canyon	Stream crossing
187.1*	Camino Del Canyon	Stream crossing
188	Camino Del Canyon	Stream crossing
189	Camino Del Canyon	Landslide
190	Camino Del Canyon	Stream crossing
193	Muir Woods Old Service Road	Landslide
194	Muir Woods Old Service Road	Stream crossing
199	Conlon Ave	Stream crossing
200	Conlon Ave	Stream crossing
201	Conlon Ave	Stream crossing
202	Conlon Ave	Ditch relief culvert
203	Conlon Ave	Stream crossing
204	Conlon Ave	Stream crossing
205	Conlon Ave	Stream crossing
216	Muir Woods Road	Ditch relief culvert
517	Dipsea Trail	Stream crossing
518*	Dipsea Trail	Stream crossing
520*	Dipsea Trail	Stream crossing
521.1	Dipsea Trail	Stream crossing
522.1	Dipsea Trail	Stream crossing
*Additional sites were included in the re-evaluation based on the discretion of PWA field crew. Sites include: #187.1 (SC); #518 (SC); and 520 (SC).		

significant hydrologically connected[3] road lengths with inadequate drainage structures and/or road shaping to properly disperse road runoff. Concentrated runoff and erosion of these road/trail surfaces, ditches, and/or cutbanks has resulted in fine sediments being transported and delivered directly into the streams within the Redwood Creek watershed. However, selected road/trail reaches have already been effectively storm-proofed as per 2002 PWA recommendations and further improvements are planned.

5 FIELD TECHNIQUES AND DATA COLLECTION METHODS

The project consisted of a re-evaluation of 44 select sites included in the 2002 original assessment. Based on the field inventory of existing conditions, recommendations were classified by immediacy rating for effective erosion control and erosion prevention in the Redwood Creek watershed (Map 1).

To facilitate the field inventory, GIS data layers were combined with NAIP imagery (USDA, 2016) and 10 m contour interval layers to produce field maps at a 1:3,600 scale. These maps were used to confirm the locations of sediment delivery sites and used in the development of the final project maps.

Inventoried sites for the road related sediment source reassessment primarily consist of stream crossings, potential and existing landslides related to the road system, gullies below ditch relief culverts, and road surface drainage discharge points (e.g., swales, roadside gullies, low spots in the road, berm breaches, etc.) for uncontrolled road surface and/or inboard ditch runoff.[4] For each site, PWA staff plotted its location on a GIS-generated base map; collected a GPS waypoint using a Garmin GPSMap 60Cx handheld GPS unit (where possible based on satellite reception); and recorded changes in field observations.

The data collected for each site also includes a reevaluation of *treatment immediacy* based on the potential or likelihood of sediment delivery from the site to a stream channel, and the level of urgency for addressing erosion problems at that location.

Based on current conditions and information from NPS staff about realistic needs for future road use, PWA personnel analyzed the inventory results to develop short and long term effective erosion control and erosion prevention prescriptions for the re-evaluated sites and assigned treatment immediacy of “High”, “High-moderate”, “Moderate”, “Moderate-low, and “Low” for each treatment site. These designations are intended to provide staff with prioritized prescriptions for storm-proofing treatment sites and hydrologically connected road segments, and are PWA’s best recommendations for the most efficient and cost-effective methods to accomplish this goal.

6 PWA ROAD AND TRAIL RELATED SEDIMENT DELIVERY SITE RE-ASSESSMENT RESULTS

PWA field crews re-evaluated a total of 44 sites and confirmed the associated 3.12 miles of hydrologically connected road/trail surfaces have the potential to deliver sediment to the Redwood Creek watershed (Map 1; Tables 1 and 2; Appendix A). Of the 44 sediment delivery sites re-evaluated along the 6 different segments of road/trail, we recommend that 40 of these sites and 2.99 miles of the connected road segments be treated for erosion control and erosion prevention (Tables 2 and 3).

[3] Hydrologically connected describes sites or road segments from which eroding sediment is delivered to stream channels (Furniss et al., 2000).
[4] Detailed definitions of sediment delivery sites are provided in Appendix D.

Table 2. Inventory results for sediment delivery sites and hydrologically connected road and trail segments re-evaluated by PWA in 2016-2017 by site type.

Sources of sediment delivery	Sediment delivery sites		Hydrologically connected road/trail adjacent to sites	
	Inventoried (#)	Recommended for treatment (#)	Inventoried (mi)	Recommended for treatment (mi)
Stream crossings	28	25	1.79	1.66
Ditch relief culverts	10	10	0.93	0.93
Road drainage discharge points	4	4	0.40	0.40
Landslides	2	1	0.00	0.00
Total	**44**	**40**	**3.12**	**2.99**

Table 3. Inventory results for sediment delivery sites and hydrologically connected road and trail segments re-evaluated by PWA in 2016-2017 by road and trail.

Road/Trail	Sediment delivery sites		Hydrologically connected road/trail adjacent to sites	
	Inventoried (#)	Recommended for treatment (#)	Inventoried (mi)	Recommended for treatment (mi)
Muir Woods Road	8	8	0.59	0.59
Panoramic Highway	10	9	0.94	0.84
Camino Del Canyon	12	12	0.76	0.76
Muir Woods Old Service Road	2	0	0.03	0
Conlon Avenue	7	6	0.26	0.26
Dipsea Trail	5	5	0.54	0.54
Total	**44**	**40**	**3.11**	**2.99**

Field data shows that treating the 40 sites will prevent the future *episodic* delivery of approximately 6,160 yd^3 of sediment to streams in the Redwood Creek watershed, and that treating the 2.99 miles of connected road segments could prevent *chronic* delivery of approximately 2,090 yd^3 of fine sediment during the next decade alone (Table 4).

Of the 28 stream crossing sites re-evaluated, 25 sites are recommended for treatment (Table 2). Approximately 5,596 yd^3 of future *episodic* road/trail related sediment delivery will originate from the 25 stream crossings if they are left untreated, which is approximately 91% of total future *episodic* sediment delivery from sites recommended for treatment in the project area (Table 4).

Ditch relief culverts included in the original assessment were inventoried if they showed the potential to deliver future, site-specific sediment, or were currently functioning as conduits for delivery of road surface sediment. Treatment for all 10 re-evaluated ditch relief culvert sites in the Project Area is recommended (Table 2). Treating the 10 ditch relief culverts represent projected potential future *episodic* sediment delivery of approximately 343 yd^3 (Table 4).

Discharge points for road surface drainage are locations along poorly drained road segments where accumulated concentrated flow from road surface/ditch/cutbank erosion exits the road to be delivered to a stream. The accumulation and subsequent discharge of large quantities of road surface runoff frequently results in the erosion of a length of native hillside or fillslope between the road and the receiving stream channel. In addition, these sites are also commonly found along streamside roads in close proximity to a stream channel. Of the 4 discharge points re-evaluated in the Project Area, all are recommended for treatment (Table 2). Estimated site-specific future *episodic* sediment delivery from these sites totals 110 yd^3 (Table 4).

Field crews re-evaluated 2 road related landslides (Tables 1 and 2). Site 193 was treated by MWNM in 2003 when Muir Woods Old Service Road was closed and decommissioned. Continued maintenance and road surface treatments are recommended at Site 189 along Camino Del Canyon Road with a total estimated future *episodic* sediment delivery volume of 111 yd^3 (Table 4).

Table 4. Estimated future sediment delivery for re-evaluated sites and road/trail surfaces recommended for treatment.

Sources of sediment delivery	Estimated future sediment delivery (yd^3)	Percent of total
1. *Episodic* sediment delivery from road related erosion sites (indeterminate time period)		
Stream crossings	5,596	91%
Ditch relief culverts	343	6%
Discharge points for road surface drainage	110	2%
Landslides	111	2%
Total *episodic* sediment delivery	**6,160**	**100%**
2. *Chronic* sediment delivery from road surface erosion (estimated for a 10 yr period)[a]		
Total *chronic* sediment delivery[b]	**2,090**	
Total estimated future sediment delivery	**8,250**	

[a] *Chronic* sediment delivery calculated for a 10 yr period. Calculations assume a combined width of 15-25 ft for the road, ditch, and cutbank contributing area, and a uniform empirical value of 0.2 ft/10 yr for road/ditch surface lowering/cutbank retreat.
[b] Estimated total *chronic* sediment delivery is approximately 25% of the projected future sediment delivery of 8,250 yd^3 for the entire project area.

During the original 2002 assessment, PWA field crews measured approximately 3.12 miles of road surfaces and/or ditches currently draining to stream channels, either directly or via gullies at these re-evaluated sites (Tables 2 and 3). Field crews confirmed that these surfaces remain hydrologically connected and should be treated. Our 2016-2017 field data shows that treating the recommended hydrologically connected road reaches could prevent 2,090yd^3 of fine sediment from being delivered to stream channels in the Project Area over the next decade.

Of the 44 total sites reassessed, 4 sites were not recommended for treatment. Of these "no treat" sites, all have had work completed in some respect since initially assessed in 2002 (Site 129, 193, 194, and 204). Of the remaining 40 sites, treatment immediacy ratings were re-assigned in 2016-2017 (Appendix A; Map 1).

7 OBSERVATIONS, EROSION CONTROL AND EROSION PREVENTION RECOMMENDATIONS FROM PWA 2016-2017 RE-EVALUATION

Based on the results of field assessment of 44 re-evaluated sites along 6 road segments within the Project Area, treatment immediacy was designated for erosion control and erosion prevention treatments at 40 sites. The observations are based on field investigations conducted between May 2016 and February 2017. Recommendations provided are intended to be implemented in the next 6 months to 2 years. However, some recommendations for treatment include measures that could require more planning, funding, and permitting to implement and are, therefore, highlighted as long-term treatment recommendations. Based on communications with land managers, both short and/or long-term treatment recommendations were identified for six re-evaluated sites (#94 and #200-204), see Section 8. Short term treatments are categorized as intermediate storm-proofing measures prior to completing long-term remediation (i.e. decommission or road-to-trail conversion) of identified road segments. Both short-term and long-term treatment options are also included (where applicable) within Appendix A

In addition to the provided recommendations, *routine observation* and *as-needed maintenance* are considered the most crucial element in any short-term erosion control and erosion prevention plan. Included in Appendix B is a comprehensive summary table of sediment delivery sites from PWA's original 2002 report with location maps provided by NPS staff. It is recommended routine monitoring be conducted along all roads and at stream crossings annually prior to the onset of winter rains and after each large storm event. As these road reaches and stream crossing sites, surveyors should identify the need for and conduct any minor hand labor work to reduce either the failure potential or extent of ongoing sediment delivery that may be occurring.

The following sub-sections detail the results of field observations during PWA's 2016-2017 re-evaluation outlined by road or trail sections. In addition, re-designated treatment immediacy ratings were assigned, as well as short and/or long-term treatment recommendations updated from the original 2002 report. Refer to Appendix A for a summary of field observations and treatment recommendations; Map 1 depicts 2016-2017 re-evaluated site locations within the Project Area.

Map 1. Road related sediment delivery sites re-evaluated 2016-2017 by site type and treatment immediacy.
Redwood Creek Watershed, Muir Woods Road Re-Assessment, Marin County, California

Site types

- Stream crossing
- Road surface discharge point
- Landslide
- Ditch relief culvert

Site priority

- High; High-moderate
- Moderate; Moderate-low
- Low
- No treatment recommended

- PWA assessed paved roads
- PWA assessed unpaved roads and trails
- Other roads
- Other unpaved roads
- Trails
- Streams
- Redwood Creek Watershed boundary

Property ownership

- Muir Woods National Monument
- Mt. Tamalpais State Park
- Golden Gate National Recreation Area
- Marin Municipal Water District

0 300 600 1,200 Feet

Scale 1 : 7,200 1 in = 600ft
Contour interval: 10m

Imagery: 3m DEM hillshade (USDA 2016)
Note: Streams generated from 3m DEM and selectively edited based on field mapping and aerial photo interpretation

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Spike Buck Creek
Boojack Creek
Fern Creek
Redwood Creek
Conlon Creek
Panoramic Highway
Old Service Road
Muir Woods Road
Dipsea Trail
Camino Del Canyon
Conlon Ave.
State Highway 1
PACIFIC OCEAN
Marin Municipal Water District
Mt. Tamalpais State Park
Muir Wood National Monument
Golden Gate National Recreation Area

127 141 139 143 137 129 119 118 152 154 79 78 518 517 185 184 182 183 186 194 193 90 520 181 180 187 187.1 199 200 92 93 522.1 521.1 201 188 202 189 203 205 204 190 94 159 216

San Rafael 37122h5
Bolinas 37122h6
Point Bonita 37122g5
Muir Beach

Petaluma
Marin County
Novato
San Rafael
Project location
Mill Valley
Bolinas
Muir Beach
San Francisco
0 2.5 5 10 Miles

0 0.5 1 2 Miles

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7.1.1 Muir Woods Road (Sites # 78, 79, 90, 92-94, 159, and 216)

Site #78

Description of Problem: Site #78 is an 18” diameter DRC that receives 105' of spring fed inboard ditch along the upper section of Muir Woods Road as you descend into the basin from Panoramic Highway. The outlet of the culvert is shotgun causing a gully on the fillslope. The culvert outlets of DRC Sites #77, 78, and 80 all deliver to the stream crossing Site #79 (Photos 1-3). The gullies at the outlets of the DRC sites have eroded down to more competent, rocky material. In addition, the trail below these sites is constructed with rock protection.

Treatment Immediacy: Moderate-Low

Description of Recommended Treatment: Install 20’-30’ of full-round downspouts at the DRC outlets to the trail and/or stream at DRC Sites #77, 78, and 80.

Photo 1. Photo taken from the trail looking upslope at the outlet of Site #78. We recommend installing a full round downspout to connect the outlet of this DRC to the armored trail crossing.

Photos 2 and 3. Photos taken from the left and right road approaches[5] (top and bottom photos, respectively) looking at where Site #78 hits the armored trail crossing. Note the outlet of DRC Sites #77, 78, and 80 all deliver to stream crossing Site #79.

[5] Left and right are defined as the road approaches to your left and right when looking downstream from the site.

Site #79

Description of Problem: Site #79 is a 20" diameter CMP draining a 5' x 1.5' class 2 stream. The culvert is undersized, set shallow in the fill, and has a *High* plug potential due to woody debris in the channel and poor culvert installation. The site also receives ~70' of spring fed left ditch that is hydrologically connected, draining directly to the existing culvert inlet. See photos 4 and 5 below.

Treatment Immediacy: High-Moderate

Description of Recommended Treatment: Replace the existing culvert with a properly sized 42" diameter culvert, set at natural stream grade and at the base of the fill. Install a flared inlet and a trash rack 42" above the culvert inlet to decrease plug potential.

Photos 4 and 5. Photos taken of stream crossing Site #79. Photo 4 (left) taken upstream of the 20" diameter CMP inlet. Photo 5 (right) taken downstream of the CMP outlet. This 5' x 1.5' class 2 stream flows through an undersized culvert set shallow in the fill with a high plug potential. PWA recommends replacing this culvert with a properly sized and installed culvert.

Site #90

Description of Problem: Site #90 is a road surface discharge point resulting from ~730' of road related ditch runoff that exits Muir Woods Road onto an Abandoned Service Road causing gullying and past landsliding resulting in sediment delivery to a class 2 stream located below the abandoned road. Since the 2001 assessment, a fence has been installed and posts located at the entrance of the abandoned road to restrict access. Ditch flow from Muir Woods Road has been directed into a 12" diameter DRC with a flared inlet and flex pipe downspout (Photo 6) for >100' to protect the fill and hillslope from further erosion and sediment delivery. As of April 2016, there were straw bales staged along the backside of the fence blocking flow from the ditch to the DRC (Photo 7).

Treatment Immediacy: Moderate

Description of Recommended Treatment: Move or spread the straw bales as erosion control material. Clean the inlet of the DRC and use spoils to create a berm to direct flow from inboard ditch (IBD) of Muir Woods Road to DRC flared inlet and prevent future diversion down the abandoned road.

Photos 6 and 7. Photos taken at road surface discharge point Site #90. Photo 6 (left) taken at newly installed 12" DRC collecting flow from 730' of ditch along Muir Woods Road. DRC has a flared inlet and flex pipe for >100' down the hillslope. Photo 7 (right) is taken from Muir Woods Road looking at newly installed fence and stack of straw bales. We recommend that straw bales are moved to the outboard edge of the road so as not to impede flow onto abandoned road and to clean the inlet of the DRC.

Site #92

Description of Problem: Site #92 is a stream crossing. Flow from a Class 2 stream is conveyed through an oval culvert (41” wide x 30" tall) placed at the axis of a switchback on the road. The switchback is at the entrance to Muir Woods National Monument. This culvert appears to be functioning well. See photos 8 and 9 below.

Treatment Immediacy: Low

Description of Recommended Treatment: Clean out the stream channel downstream of the culvert outlet for 5' to the step in the channel and install a rock grade control structure at the culvert outlet to act as energy dissipation. Maintain the DRC up the right road approach and clean the plugged DRC to the left of the site and remove 60' of bermed road. If you are concerned about road-related pollutants, consider installing a filter above the inlets of contributing DRCs.

Photos 8 and 9. Photos taken at stream crossing Site #92. The stream is carried through an oval 41” wide by 30” tall culvert. Photo 8 (left) is taken from above the inlet of the culvert looking downstream. Photo on the left is view looking upstream at the outlet.

Site #93

Description of Problem: Site #93 is a 12" diameter DRC receiving input from multiple areas (parking lot at park maintenance from left, plugged DRC at hairpin turn, and likely received diverted flow from Site #94 during high flows. See photos 10 and 11 below.

Treatment Immediacy: Moderate-Low

Description of Recommended Treatment: Define the channel by removing accumulated stored sediment prior to entering the culvert inlet to prevent plugging. Clean accumulated sediment at the culvert outlet for 15' long x 2' wide x 1' deep. Note that this is not a stream site, but a ditch relief culvert that carries flow only in response to immediate rainfall.

Photos 10 and 11. Photos taken at DRC Site #93. Photo above on left is taken from above the inlet of the 12” DRC. Photo to the right is taken below the outlet of the 12” culvert showing half plugged culvert.

Site #94:

Description of Problem: Site #94 is sediment delivery site with a very complicated stream crossing and surface runoff drainage pattern within a well-developed area of the property. A 4' x 2' class 2 stream exits a narrow and steep canyon and enters a 24" diameter culvert above a developed parking lot and building area. The culvert is undersized with a high plug potential evident by the presence of several buried trash racks (Photo 12). The culvert is plumbed beneath a parking lot where it connects to an 18"diameter somewhere beneath a paved surface, crosses Muir Woods Road and outlets to Redwood Creek. This is a very large stream crossing because the stream valley is buried by buildings, parking lot and Muir Woods Road. As is, this culvert plugs regularly and can overtop and divert overland to a 12" DRC which crosses an old roadbed currently utilized as a trail and then outlets into a rocked ditch before popping out onto Muir Woods Road. A portion of this diverted stream overflow crosses the road into another parking lot with another portion entering the IBD and entering the next DRC. A portion of the flow eventually delivers to Redwood Creek (Photo 13). Improving this crossing with installation of a properly sized and located culvert would require a major excavation including working around several outbuildings and large amount of pavement. This crossing is likely to continue plugging and cause erosional problems in various locations.

Treatment Immediacy: High-Moderate.

Description of Treatment Recommendation: Based on field discussions with NPS staff, properly treating this site by upgrading the culverted crossing with all the infrastructure is not realistic at this juncture. However, the road and parking lot area(s) are currently being redesigned. Therefore, we are providing short and long term recommendations.

Short-term recommendation: recommend improving the existing overflow channel by increasing capacity and directing flow into the DRC along Muir Woods Road. In addition, we recommend installing some rip rap at the outlet of the existing 18" diameter CMP to reduce the potential for erosion at the culvert outlet and sediment delivery to Redwood Creek.

Long-term recommendation: If the road and parking lots are being redesigned, we recommend that a permanent solution be designed. PWA is available for consultation and/or review of any proposed plans. The existing culverts should be located and evaluated for structural integrity. Based on location and condition, drainage structures should be replaced, decommissioned, and/or removed. In addition, based on the location and extent of the improvements, we recommend that a new, properly sized culvert section(s), designed to accommodate the 100-year design flood flow along with organic debris that will be in transport, should connect the class 2 stream to Redwood Creek. Finally, any lengths of culvert that will be located under paved road/parking lot(s) greater than 60 ft in length and/or that may include elbows should have risers installed with cleanouts for future maintenance and trouble shooting.

Photos 12 and 13. Photos taken at complicated stream crossing Site #94. Photo 12 (left) is taken from the inlet of the uppermost culvert looking upstream. The stream is carried through an undersized 24" diameter culvert from this point where the stream valley becomes buried by buildings, parking lot, and Muir Woods Road. The 24" culvert regularly plugs and flows across pavement and through a DRC. Flows from the 24" culvert are plumbed into an 18" culvert which outlets into Redwood Creek. Photo 13 (right) is taken below the outlet of the undersized 18" culvert delivering to Redwood Creek.

Site #159:

Description of Problem: Site #159 is a class 2 stream crossing through an undersized 24" diameter steel culvert. The outlet and bottom of the pipe is rusted. The culvert outlet is shot-gunned, which is causing erosion of the fillslope and streambank. There is a ~20' drop from the outlet to the gully below. The outboard edge of fill (OBF) is failing as a result of the erosion. Redwood Creek is located ~75' below the culvert outlet. The right IBD is nearly flat; therefore, there is diversion potential to the right if the stream overtops. Underground telephone cables exist at this location. See photos 14 and 15 below.

Treatment Immediacy: High Moderate

Description of Treatment Recommendation: Replace the existing stream crossing with a properly sized 30" diameter CMP installed at a 30% gradient with a downspout installed to the bottom of the fill. Eliminate diversion potential to the right. Maintain ditch capacity; however, keep ditches vegetated in between maintenance to promote filtration.

Photos 14 and 15. Photos taken of the hydrologically connected road and inboard ditch draining to stream crossing inlet at Site #159. Note that ditches are well vegetated, which promotes filtration of road surface runoff (sediment and pollutants).

Site #216:

Description of Problem: Site #216 is a 15” diameter DRC that receives 290' of left and 70' of right hydrologically connected ditch flow. There is a concrete headwall and the culvert outlets 6’ from pavement to an existing 7’ wide x 6’ deep x 100’ long average gully delivering sediment to the stream located 100’ below. Both IBD’s and cutbanks are well vegetated and the DRC receives little flow (Photo 16). The erosional threat is contained to that at the outlet.

Treatment Immediacy: Moderate Low

Description of Treatment Recommendation Pack armor around the existing culvert outlet to offer additional support and protect the OBR against further erosion.

Photo 16. Photo taken along the outboard edge of the road across at the inlet of DRC Site #216 and the well vegetated inboard ditch.

7.1.2 Panoramic Highway (Sites # 118, 119, 127, 129, 137, 139, 141, 143, 152, and 154)

Site #118

Description of Problem: Site #118 is an 18" diameter DRC that receives excessive drainage from a hydrologically connected fire road and non-paved ridge spur road. This excessive drainage has caused a gully at the DRC outlet that delivers to site #100. Since 2001, a ~30' long downspout has been installed at the DRC outlet. Although the downspout does not extend the entire way to Site #100, the remaining gully below the downspout has eroded to bedrock and now stable (Photo 17).

Treatment Immediacy: Moderate Low

Description of Treatment Recommendation: Install 3 rolling dips up ridge spur road and one DRC on paved fire station road.to disconnect hydrologically connected road surface runoff draining to the site.

Photo 17. Photo taken of DRC Site #118 view of recently installed full round downspout attached to outlet to protect the fillslopes from further gullying.

Site #119

Description of Problem: Site #119 is an 18" diameter DRC that receives IBD, cutbank and road surface runoff contribution. The excess flow has caused a gully that connects to site #104 on Alice Eastwood Rd. There is a concrete retaining wall at the culvert outlet. This wall has multiple drains that also contributes flow to site. A small gully comes off the cutbank and contributes flow and sediment to site. Since 2001, a full round downspout has been installed at the outlet extending the entire way to Site #104. The downspout outlet is slightly crushed and needs maintenance, but is functioning well as installed.

Treatment Immediacy: Low

Description of Treatment Recommendation: Open up and maintain downspout to ensure flow is not restricted.

Photo 18. Photo taken of DRC Site #119 view of recently installed full round downspout attached to outlet to protect the fillslopes from further gullying.

Site #127

Description of Problem: Site #127 is an 18" diameter DRC that receives flow from 600' of IBD from the right. This is causing a gully that delivers to sites on Alice Eastwood Rd. The existing gully is covered with duff with dimensions of approximately 2-4' wide x 2' deep at the top tapering to 6"-1' deep near the bottom (Photo 19). No cutbank slide or headcut is visible from the road. However, there is evidence of flow in IBD from small headwall stream that also contributes flow to #127, located ~50' to the right[6].

Treatment Immediacy: High Moderate[7]

Description of Treatment Recommendation: Install 2 DRCs to the right and build up down-road berms at DRCs to cut off diversion potential and flow from the right.

Photo 19. Photo taken from outboard edge of road looking downslope at the outlet of DRC Site #127. Note that the existing gully below the DRC outlet is stable and covered with duff.

[6] Description of "right" and left" is the direction when standing on the road looking downstream.
[7] Need to access Alice Road to determine if there should be a change to treatment immediacy.

Site #129

Description of Problem: Site #129 is a class 2 stream crossing that has been treated since 2001. The previously plugged 12" CMP was recently replaced with an 18" pipe with a 57"wide x 43" high concrete headwall (Photo 20). The pipe is shot-gunned and drains to a stable headwall swale. The pipe is clear and functioning ok as installed.

Treatment Immediacy: Not Applicable

Description of Treatment Recommendation: None, already treated. However, the inlet will require ongoing maintenance to keep inlet clear and open as the pipe diameter is smaller than recommended and the installation is not at channel grade with a shot-gunned outlet. Installation may inhibit proper self-cleaning and/or result in outlet erosion. Finally, if erosion is observed at the shot-gunned outlet, rip rap and/or a downspout should be installed for energy dissipation and prevent further erosion.

Photo 20. Photo taken from above the inlet of stream crossing Site #129. Note that the pipe has been recently upgraded with an 18" diameter culvert and 57" wide x 43" high concrete headwall. This site will require ongoing maintenance.

Site #137

Description of Problem: Site #137 is a large class 2 stream (Spike Buck Creek) crossing through a 36" concrete culvert with a downspout. The stream crossing has functioned well in the past but is undersized for 100yr flow. Based on orientation we presume there is an elbow (bend) in the 36" pipe within the fillslope. Road runoff exits at the OBF resulting in some fillslope erosion and sediment delivery. See photos 21 and 22 below.

Treatment Immediacy: High Moderate

Description of Treatment Recommendation: Install an overflow pipe with a downspout to reach the base of fill. Locate the elbow of the existing 36" pipe and install a riser for cleaning out debris.

Photos 21 and 22. Photos taken from above the inlet (top) and from the left road approach (bottom) looking at the stream crossing Site #137. Based on the orientation, we presume there is an elbow within the fillslope. We recommend installing an overflow pipe with a downspout and a riser for cleanout.

Site #139

Description of Problem: Site #139 is a 24" steel DRC that drains nearly 800 feet of hydrologically connected road and ditch directly to Rattlesnake Creek 200' below the DRC outlet. The culvert outlet projects through a cement retaining wall and onto the fillslope. There is a clump of bay trees at the outlet that will make it difficult to attach a downspout (Photo 23).

Treatment Immediacy: Moderate

Description of Treatment Recommendation: Install 4 DRCs to the right road to reduce hydrologic connectivity to the site. Connect a flexpipe downspout to the existing DRC outlet, navigating around bay trees to base of fill.

Photo 23. Photo taken from the outboard edge of the road looking downslope at the DRC outlet at Site #139. We recommend installing a downspout to the culvert outlet to protect the fillslope from future erosion.

Site #141

Description of Problem: Site #141 is 8’ x 3’ class 2 stream crossing through a 48” diameter CMP. The stream channel is steep with 2' diameter boulders present. The site also receives significant runoff from a spring to right. The culvert is set fairly well in the crossing; the inlet is on bedrock and outlet set low in fill. The stream converges with Site #140 below the road. A 5’ headwall exists with logs and boulders. The culvert is functioning well as installed. However, it is undersized. See photos 24 and 25 below.

Treatment Immediacy: High Moderate

Description of Treatment Recommendation: Install a 48” overflow pipe at 20% gradient along the left side of the crossing with a downspout to the bottom of the fill, left of redwoods. Remove ~ 25 yd^3 of fill, dipping the surface 3’deep x 30’ long x 10’ wide with 2:1 sideslopes in a “U” shape between Sites #140 and #141 for extra protection against stream diversion at Site #141.

Photos 24 and 25. Photos taken from upstream looking at the stream crossing inlets at Site #140 (left) and #141 (right). The culvert at Site #141 is undersized; therefore, we recommend installing an overflow pipe and excavating material between Sites #140 and #141 for additional protection against diversion.

Site #143

Description of Problem: Site #143 is a DRC with a 12"diameter concrete inlet and 18" aluminum outlet shot-gunned over steep fill. The gully that developed at the DRC outlet delivers to Rattlesnake Creek ~300' below. Since 2001, continued erosion has occurred down to bedrock, reducing the future potential for future gully erosion and sediment delivery. Approximately 595' of right ditch is hydrologically connected and contributes flow and sediment to this site (Photo 26). The right cutbank is highly erodible and ditch is filled with accumulated material. The hydrologically connected road is insloped and a 2nd DRC located 375' to the right is being bypassed by ditch flow. Additionally, the stream crossing at Site #144 has diversion potential and may have diverted to this site in the past.

Treatment Immediacy: Moderate

Description of Treatment Recommendation: Install a 10' downspout on the existing DRC, clean DRC inlet, and install a ditch plug to prevent diversion. Install 1 new DRC to right road with a ditch plug to prevent diversion. Install ditch plug on 2nd existing DRC to right to prevent diversion. Cutbank failures will need future maintenance to clean out IBD and DRC inlet.

Photo 26. Photo taken along the inboard ditch looking down road at the inlet of DRC Site #143.

Site #152

Description of Problem: Site #152 is a class 2 stream crossing through an undersized 18” diameter culvert (Photo 27). It was found to be 60% plugged at the inlet in 2001 with a large sediment fan extending 30' up the right ditch due to continued plugging and ponding. Flow also appeared to divert to the left down the ditch. Channel above is a very steep cascade down bedrock steps. During the 2016 evaluation, the inlet, while still undersized, was open and sediment fan above inlet has been cleared.

Treatment Immediacy: Moderate Low

Description of Treatment Recommendation: Replace the existing culvert with 24" diameter CMP at natural channel grade. Remove any aggraded sediment above the inlet.

Photo 27. Photo taken of the armored outlet at stream crossing Site #152. The culvert is undersized, but at time of re-evaluation, the inlet was open and the pre-existing sediment fan above inlet had been cleared.

Site #154

Description of Problem: Site #154 is a small class 3 stream crossing through an 18" diameter CMP (Photo 28). The outlet has a 20' full-round downspout outlet onto armored fillslope (Photo 29). Site delivers to swale. The existing pipe is functioning well as installed and the once plugged DRC to the right has been cleaned.

Treatment Immediacy: Moderate Low

Description of Treatment Recommendation: Install ditch plug at the existing DRC to prevent diversion. Install an 18" DRC to right with ditch plug. Remove berm for 500' to the right *(unless installed for safety as it is current access to bus stop).*

Photos 28 and 29. Photos taken of stream crossing Site #154. The small class 3 stream is conveyed through an 18” diameter culvert with an open inlet (top) and outlet with downspout onto an armored fillslope (bottom). Existing pipe is functioning well as installed. But, hydrologically connected road needs to be addressed with improved road drainage.

7.1.3 Conlon Avenue (Sites # 199 to #205)

We understand that access is required beyond the gate for the next 3-5 years in order to demolish existing infrastructure further up the road. However, once the infrastructure has been removed, there will be no need to maintain vehicular access along this road. Therefore, we have provided 2 treatment prescriptions at each site (short-term and long-term). In the short-term, recommendations are made to stormproof the site in order to allow some protection against full site failure until the long-term recommendation is implemented.

Site #199

Description of Problem: Site #199 is a class 2 stream crossing conveyed through a rusted 36" diameter culvert (Photos 30, 31). There is an active overflow channel along the axis of the crossing, and the fill near the inlet is disaggregating. Also, tributary valley to the right has been completely filled in and has a very long culvert. These channels have been completely altered from their natural state all the way downstream due to road and home building activities.

Treatment Immediacy: High-Moderate

Short and long-term recommendation: Decommission the road and stream crossing by removing all road fill from the crossing and establishing a natural channel bottom and banks and disconnecting hydrologically connected road by ripping the road surface to promote native revegetation and installing cross road drains.

Photos 30 and 31. Photos taken of stream crossing Site #199. A Class 2 stream crossing with a poorly installed 36" CMP with fill near the inlet (above, left) showing active erosion to and its' capacity being exceeded. The outlet is placed well (right); but there is an active overflow channel along the axis of the crossing. Stream valley was filled to create building space for home to the left of the site.

Site #200

Description of Problem: Site #200 is a class 2 stream crossing conveyed through a 30" concrete culvert (Photos 32 and 33). The channel above inlet has been altered by mechanical activities and it appears as though the stream has been pushed over towards the left side of the valley. The 30" culvert appears sufficient except under peak flow conditions, where plugging has occurred and flow has diverted to the left down high flow channel.

Treatment Immediacy: Moderate

Short-term recommendation: Clean the inlet area and install a flared inlet to existing culvert inlet. Install new trash rack above the culvert inlet and maintain a critical dip[8] to left that can act as an overflow channel.

Long-term recommendation: Reestablish the original watercourse along its natural axis to restore the natural riparian functionality. Decommission the road and stream crossing by removing all road fill from the crossing and establishing a natural channel bottom and banks and disconnecting hydrologically connected road by ripping the road surface to promote native revegetation and installing cross road drains.

Photos 32 and 33. Photos taken of stream crossing Site #200. Stream valley has been filled and altered by both ancient debris fan deposits as well as mechanical disturbance. A debris trash rack has been installed above the 30" concrete culvert inlet (left) in an attempt to reduce plugging potential. Outlet seen in the photo above.

[8] A *critical dip* is essentially a rolling dip constructed on the down-road hingeline of the fill. Hingeline is defined as the intersection between the approaching roadbed and the full fill of a culverted stream crossing. Typically, roads go from a cut-and-fill or full bench cross section on a hillside to a full fill cross section where fill material has been used to "fill" the stream crossing during road construction. There are two hinge lines on a stream crossing fill; one on the left and one on the right.

Site #201

Description of Problem: Site #201 is a class 2 stream crossing conveyed through a 36" concrete culvert. Crossing conveys flow under the driveway to a house. The crossing is functional, but it is undersized for 100 year flow. The fillslopes are constructed out of rock and concrete and are vertical. There is right and left road flow contribution as well as diversion potential down road to the right.

Treatment Immediacy: Moderate-Low

Short-term recommendation: Construct critical dip to right to eliminate diversion potential. Install a rolling dip just up the right road that is connected to the IBD in order to convey stream flow into the crossing. Key in rock armor along the outboard edge of the road at the outlet of the rolling dip.

Long-term recommendation: Decommission the road and stream crossing by removing all road fill from the crossing and establishing a natural channel bottom and banks and disconnecting hydrologically connected road by ripping the road surface to promote native revegetation and installing cross road drains.

Photos 34 and 35. Photos taken of stream crossing Site #201. Flow is conveyed via an undersized 36" concrete culvert under the driveway to house (above, left). Representative photo of right and left road contribution (right) as well as diversion potential down road to right.

Site #202

Description of Problem: Site #202 is a DRC along a streamside road with an incised IBD draining to a rusted 10” diameter DRC (Photo 36). Flow delivers directly to the nearby channel contributing lots of road surface and ditch fine sediment directly to the stream.

Treatment Immediacy: High-Moderate

Short-term recommendation: Outslope the road and retain the IBD for 400’. Install 3 rolling dips along road reach not connected to the IBD. Replace the two existing DRCs with new 18” diameter culverts installed at or near the base of fill. Install 2 new DRC’s long the road reach to further disconnect the very wet IBD.

Long-term recommendation: Decommission the road by ripping the road surface and installing cross road drains every 50’.

Photo 36. Photo taken of DRC Site #202. A 400’ streamside road with an incised IBD drains to 10” rusted DRC. This delivers directly to the nearby channel.

Site #203

Description of Problem: Site #203 is a 6’ x 2’ class 2 stream flowing through a failing 36” diameter pipe that was repaired by installing a newer 30” pipe within the old culvert. Currently, flow leaks 2’ before the 30” outlet through slots in the pipe. Stream flow is constricted at the inlet by the road and cement headwall on the left. Past diversion and plugging is indicated by dilapidated sand bags above inlet. The crossing was already undersized before the insert was installed further reducing capacity by 30%. In addition, the installation was too short, causing fill to collapse around the outlet. Culvert is aligned nearly perpendicular to the natural channel. The new culvert should be realigned with natural channel. This site is also receiving 150' of runoff from driveway to the right. See photos 37 and 38 below.

Treatment Immediacy: High

Short-term recommendation: Install a trash rack above the culvert inlet to reduce plug potential, apply 10 yd^3 of 1’ to 2.5’ mixed rip-rap to the outlet to provide energy dissipation, and a critical dip at the crossing to eliminate diversion potential. Outslope and remove IBD 150' along the driveway to the right. Install cross road drains at top of driveway to capture spring flow.

Long-term recommendation: Decommission the road and stream crossing by removing all road fill from the crossing and establishing a natural channel bottom and banks and disconnecting hydrologically connected road by ripping the road surface to promote native revegetation and installing cross road drains.

Photos 37 and 38. Photos taken of undersized, 30” culvert installed within failing 36” culvert at stream crossing Site #203. Photo 37 (left) is taken from the right road approach, note the blue arrow denotes the direction of flow. Photo 38 (right) shows the concrete crib wall protecting the road above the inlet at the bend in the channel.

Site #204

Description of Problem: Site #204 is a 6' x 2' class 2 stream crossing that failed during the 2015-2016 winter rains. The site was temporarily repaired by installing armor through the crossing to prevent further erosion of remaining road fill (Photos 39-41). The concrete inlet and outlet headwalls remain in place. Although the emergency erosion control appears effective. A permanent repair is required.

Treatment Immediacy: Low

Short-term recommendation: Remove the headwalls remaining in the crossing. Re-distribute the armor currently placed within the crossing to construct an armored fill crossing utilizing the existing armor onsite to serve as a grade control structure to armor the headcut that is developing along the left bank at the outlet and stream tributary confluence immediately below the Site #204 crossing.

Long-term recommendation: Decommission the road and stream crossing by removing all road fill from the crossing and establishing a natural channel bottom and banks and disconnecting hydrologically connected road by ripping the road surface to promote native revegetation and installing cross road drains.

Photo 39. Photo taken from the right road approach in 2017 of failed stream crossing with subsequent adequate emergency repaired measures installed at Site #204.

Photo 40. Photo taken looking downstream of failed and emergency repaired stream crossing at Site #204 at the remaining concrete headwall of the inlet and the installation of a temporary rock armored crossing.

Photo 41. Photo taken looking upstream at failed and emergency repair at stream crossing Site #204 looking at the remaining concrete headwall at the outlet and the installation of a temporary rock armored crossing.

Site #205

Description of Problem: Site #205 was a 6’ x 2’ class 2 stream crossing through a 36” diameter CMP identified in 2001. During the 2016 re-evaluation, the culvert was not present. Either the culvert has been removed or blown out. A steel 1” diameter pipe still remains in the stream channel, along with evidence of accumulated sediment along the right stream bank from a possible failure of the stream crossing (Photo 42).

Treatment Immediacy: Not Applicable

Description of Treatment Recommendation: None. Crossing no longer exists.

Photo 42. Photo taken looking upstream at the presumed location of the decommissioned or blown out stream crossing site #205. No future treatments at this site.

7.1.4 Camino Del Canyon (Sites # 180 to #190)

Site #180

Description of Problem: Site #180 is class 2 stream crossing through a 100% plugged 12" diameter culvert. The culvert is installed short and high in the fill. Stream flow is currently being conveyed through the fill beneath the culvert and is exiting the fill 12' downstream of the existing culvert outlet. Site receives 400' of road runoff from the right road approach. Site also receives runoff from Panoramic Rd. and Dipsea Trail (Photo 43).

Treatment Immediacy: High

Description of Treatment Recommendation: Replace the existing culvert with a new 24"x 40’ CMP installed at the base of fill with stable fill slopes (use armor as needed) and define the stream channel to upstream to the culvert inlet. Install a critical dip on the left hinge-line to prevent future stream diversion. Outslope the hydrologically connected road approaches and install a rolling dip to the right road with an armored outlet. Re-rock the surface after construction as needed for future management.

Photo 43. Photo taken of stream crossing Site #180. An undersized, 12” culvert is currently 100% plugged and not conveying flow through the pipe but underneath and through the fill. The site also receives significant runoff from the connected road reaches as well as Panoramic Rd. and Dipsea Trail above.

Site #181

Description of Problem: Site #181 is a road surface discharge point with 700’ of hydrologically connected road (with berm on outboard edge of road) concentrating road runoff to exit the road at this low spot causing a gully that delivers to Class 2 stream channel ~175’ downslope (Photo 44). The gully will continue to enlarge and continued erosion could potentially cause a significant portion of road to fail.

Treatment Immediacy: High-Moderate

Description of Treatment Recommendation: Outslope the 700’ of hydrologically connected right road approach, remove the ditch, and install 2 rolling dips.

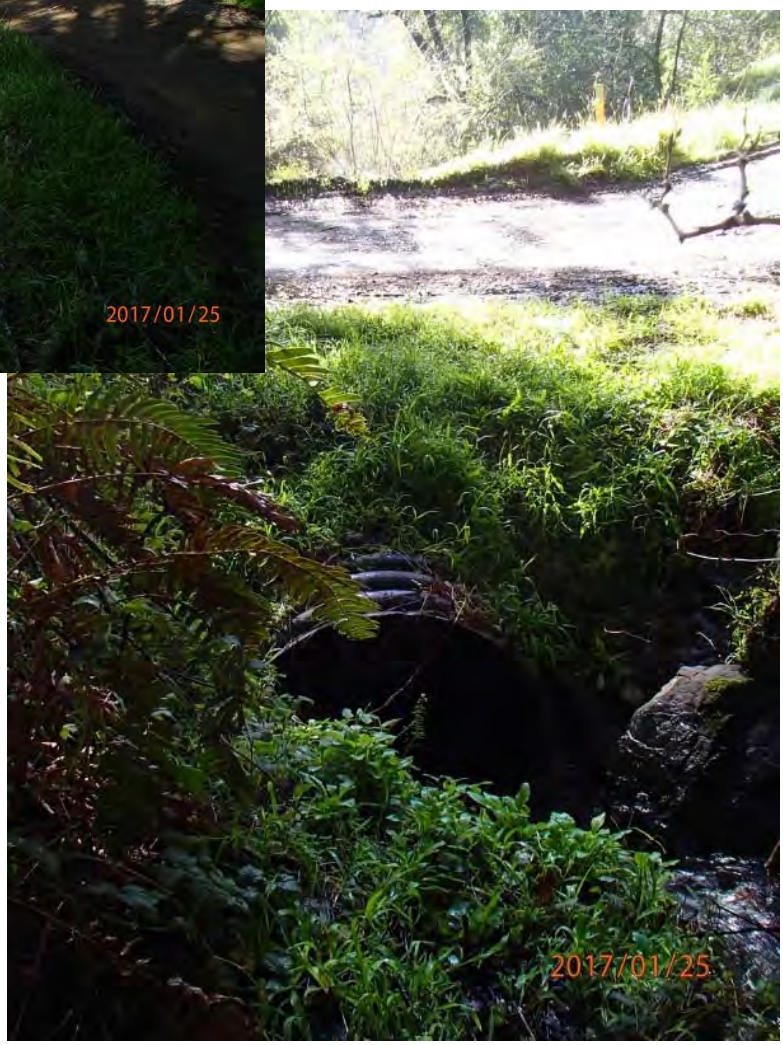
Photo 44. Photo taken of road surface discharge point Site #181. 700’ of concentrated road runoff exits road at a low point in the road. Concentrated road run off has eroded a gully that delivers to Class II stream channel below.

Site #182

Description of Problem: Site #182 is a stream crossing with flow from a class 2 stream conveyed through a 42" diameter HDPE plastic culvert, installed after the original assessment. Culvert is set at a shallow grade, and high and short in the fill. There is a 3' drop at the culvert outlet and subsequent splash zone erosion. There is an active spring in the right IBD area that is being conveyed to the culvert inlet. See photos 45 and 46 below.

Treatment Immediacy: Moderate

Description of Treatment Recommendation: Install a rock grade control structure at the culvert outlet utilizing 5yd^3 of mixed 1' to 2.5' diameter rip-rap to act as energy dissipation. Treat the hydrologically connected road by outsloping the road and installing a rolling dip to the right at the existing outboard drain location with a rocked outlet keyed into the road surface to prevent headward erosion into the road bed. Maintain the active IBD to drain the spring flow to the right for 20' but remove the ditch through the remaining outsloped portion.



Photos 45 and 46. Photos taken of stream crossing Site #182. The culvert is set high in the fill with a 3' drop at the outlet (above, left). An active spring along the right inboard ditch is being effectively conveyed into a recently installed 42" diameter culvert.

Site #183

Description of Problem: Site #183 is a road surface discharge point within a section of insloped and bermed road accumulating water at 2 low spots 165’ apart (Photos 47 and 48). Along this section, ponded water exits the road at OBF forming gullies along the OBF slope that deliver to class 2 streams ~45’- 200’ downslope.

Treatment Immediacy: Moderate-Low

Description of Treatment Recommendation: Outslope the hydrologically connected road approaches and remove the ditch.

Photos 47 and 48. Photos taken of road surface discharge point Site #183. A section of insloped and bermed road accumulates water at 2 low spots 165’ apart. At both sites ponded water exits road at OBF and is actively gullying the OBF slope.

Site #184

Description of Problem: Site #184 is an 18" diameter DRC that drains hydrologically connected right road and springy cutbank (Photo 49). The DRC is 30% plugged, installed at a shallow grade with the outlet shot-gunned, and a 5' drop at the outlet (Photo 50). Additional runoff is exiting the road at the OBF, and gullying down to the class 2 stream ~150' downslope.

Treatment Immediacy: Moderate-Low

Description of Treatment Recommendation: Replace the existing DRC with a new 18" diameter DRC installed to the base of fill to promote self-cleaning with rock armor at the outlet to act as energy dissipation. Outslope the hydrologically connected road approaches maintaining the 25' of active IBD draining to the DRC to the right.

Photos 49 and 50. Photos taken of DRC Site #184. An 18" diameter DRC drains the connected right road approach and springy cutbank (left). The DRC is 30% plugged and is installed at a shallow grade, and the outlet is shot-gunned with a 5' drop at the outlet (below).

Site #185

Description of Problem: Site #185 is a rowdy (rough) class 2 stream conveyed through an undersized 36” diameter HDPE plastic culvert with aluminum flared inlet set high in the fill with a shot-gunned outlet. There is also a 24” diameter CMP ~26’ to the right of the stream crossing that conveys flow to site #185 from a failing network of 24” diameter plastic culverts intended to convey flow to bypass an existing gully generated by road surface runoff coming from Muir Woods Road. The culvert is separated and disconnected in several locations. The combined hillslope runoff and breached culvert flow have exacerbated the existing gully. There is a~ 10’ drop at the culvert outlets exacerbating erosion and destabilizing the outboard fillslope. See photos 51 and 52 below.

Treatment Immediacy: High

Description of Treatment Recommendation: Replace the existing culvert with a new 72" diameter culvert installed in line with the natural channel alignment and at the base of fill with stable fill slopes (use armor as needed). Construct a critical dip on the left hinge to eliminate diversion potential, install a galvanized single post trash rack 72” above the culvert inlet, and install rock armor at the culvert outlet for energy dissipation. Replace the DRC to the right of the main crossing with a 30” diameter culvert at the base of fill and outlet onto the armored fillslope of site #185. Re-rock the surface after construction as needed.

Photos 51 and 52. Photos taken of stream crossing Site #185. A rowdy Class 2 stream is conveyed through this crossing via an undersized 36” diameter HDPE plastic culvert with an aluminum flared inlet (left). There is a 24” diameter CMP ~26’ to the right of the stream crossing that conveys flow from a failing downspout network upslope (right).

Site #186

Description of Problem: Site #186 is a road surface discharge point causing a gully that delivers to a class 2 stream ~100' downslope. Accumulated runoff exits at this low point in the road from the hydrologically connected road reaches (Photos 53 and 54).

Treatment Immediacy: Moderate-Low

Description of Treatment Recommendation: Disconnect hydrologically connected road by outsloping the road approaches.

Photos 53 and 54. Photos taken of road surface discharge point Site #186. The concentrated RSDP run off is actively eroding a gully that delivers to Class 2 stream 100' downslope.

Site #187

Description of Problem: Site #187 is class 2 stream crossing through a plugged 12" diameter culvert. A downspout was installed, but it is not functioning properly. Water is ponding on the road surface resulting in a gully along the outboard fillslope (Photos 55 and 56).

Treatment Immediacy: High

Description of Treatment Recommendation: Replace the existing culvert with a new 24" diameter culvert installed at the base of fill with stable fill slopes (use armor as needed). Stabilize the headcut above the culvert inlet by installing a grade control structure utilizing 5yd^3 of mixed 0.5' to 1.5' diameter rip-rap. Outslope the hydrologically connected road approaches. Transition the bottom of excavation at this site into the top of the excavation at site #187.1. Re-rock the surface after construction as needed.

Photos 55 and 56. Photos taken of stream crossing Site #187. A plugged 12" diameter CMP conveys Class 2 stream flow through this crossing. A downspout was installed at the lower cutbank (right), but it is not functioning. Water is ponding on road and evacuating the RSDP via an OBF gully (above, left).

Site #187.1

Description of Problem: Site #187.1 is a non-culverted fill crossing conveying flow from the class 2 stream (Site #187) above eroding through an abandoned road prism (Photos 57 and 58).

Treatment Immediacy: High

Description of Treatment Recommendation: Decommission the abandoned road and fill crossing by pulling road fill through the crossing to establish a natural channel grade with stable sideslope angles, rip the road surface for natural revegetation and disconnect the hydrologically connected road approaches by installing cross road drains.

Photos 57 and 58. Photos taken of stream crossing Site #187.1. Stream flow from site #187 on Camino Canyon Road outlets onto this relict road prism (left). Stream flow is actively eroding through the fill and delivering sediment to the Class 2 stream downslope (below).

Site #188

Description of Problem: Site #188 is class 2 stream crossing being conveyed through a partially plugged 24" diameter culvert (Photos 59 and 60). There is a significant amount of sediment deposited at the outlet due to a large debris slide to left from Site #189 that has buried the channel below the crossing in the past.

Treatment Immediacy: High

Description of Treatment Recommendation: Replace the existing culvert with a new 36" diameter culvert installed at the base of fill with stable fill slopes (use armor as needed). Excavate sediment within the channel to establish a consistent gradient through the crossing and transition the stream channel above and below the new crossing. Take care not to undercut the toe of the slide deposit at Site #189. Construct a critical dip along the left hinge line to eliminate diversion potential, install a single post trash rack 36" above the new culvert inlet, and install 5yd^3 of mixed 1' to 2.5' diameter rip-rap rock armor at the culvert outlet for energy dissipation and/or as grade control. Outslope the hydrologically connected road approaches and install rolling dips. Re-rock the surface after construction as needed.

Photos 59 and 60. Photos taken of stream crossing Site #188. Class 2 stream flow is conveyed through this crossing via an undersized 24" diameter aluminum culvert. The inlet is 50% plugged (left) and in need of a proper installation to reduce plug and failure potential. There is a significant amount of deposition at outlet due to a past debris slide (Site #189) to the left of site that delivered sediment to the channel below the crossing.

Site #189

Description of Problem: Site #189 is a large debris slide that has deposited sediment into the stream channel below Site #188. Since failure, the road has been rebuilt over and through the slide deposit; therefore difficult to detect in photos 61 and 62 below. Potential future sediment delivery is still very likely towards the right side and lower to the left of the feature as well as continued road surface (*chronic*) contribution.

Treatment Immediacy: Moderate

Description of Treatment Recommendation: This feature will require continued future road maintenance. As the slide feature continues to fail and deliver upslope sediment to the road, slide material will need to be incorporated into the road. Spread material along the road surface to continue building up the road surface to buttress the toe of the slide and reduce cutbank heights. Maintain the DRC to the left keeping the ditch functional and open. Remove the section of disconnected downspout and establish a rocked outfall for the DRC to prevent future gully erosion.

Photos 61 and 62. Photos taken of road beneath landslide Site #189. A large debris slide has deposited into channel below stream crossing site #188. Since failure, road has been rebuilt thru deposit with a maintained inboard ditch and DRC draining hillslope and feature seepage as well as road surface runoff.

Site #190

Description of Problem: Site #190 is a class 3 stream crossing being conveyed through an undersized 18" aluminum culvert. The culvert is installed short and high in the fill and at a very shallow gradient. The culvert is 50% plugged with aggraded bedload, and shows evidence of recent overtopping (Photos 63 and 64).

Treatment Immediacy: High-Moderate

Description of Treatment Recommendation: Replace the existing undersized culvert with a new 30" diameter culvert at the base of fill and install a critical dip on the left hinge to prevent diversion. Outslope hydrologically connected road reaches and install 3 rolling dips on the right road approach.

Photos 63 and 64. Photos taken of stream crossing Site #190. Flow from a Class 3 stream is conveyed through this crossing via an undersized 18" aluminum culvert. The culvert is 50% plugged with aggraded bedload, and shows evidence of recent overtopping.

7.1.5 Muir Woods Old Service Road (Sites # 193 and 194)

Site #193

Description of Problem: Site #193 was identified as a landslide feature in the 2002 assessment. Since 2002, the remaining perched road fill has been excavated during road decommissioning and appears to be stable.

Treatment Immediacy: N/A

Description of Treatment Recommendation: No treatment recommended.

Photos 65 and 66. Photos taken of landslide Site #193. The road was decommissioned by NPS in 2003 when remaining perched fill was excavated. Currently, road and feature appear to be stable.

Site #194

Description of Problem: Site #194 is a decommissioned stream crossing. The majority of the road fill has been removed. Road approaches and stream channel appear stable (Photo 67).

Treatment Immediacy: N/A

Description of Treatment Recommendation: No treatment recommended.

Photo 67. Photo taken of stream crossing Site #194. The road and stream crossing was decommissioned by NPS in 2003 when remaining fill was excavated from the crossing. Currently, stream appears to be stable.

7.1.6 Dipsea Trail (Sites # 517, 518, 520, 521.1, and 522.1)

Site #517

Description of Problem: Site #517 is a near origin class 3 stream crossing conveyed by a poorly constructed armored fill. A gully formed from Muir Woods Road runoff contributes to this site (Photo 68).

Treatment Immediacy: Moderate

Description of Treatment Recommendation: Install a properly sized and installed armored fill crossing utilizing 15 yd^3 of mixed 0.5' to 2' diameter rip rap and define the stream channel 4' wide with 2:1 sideslopes from the base of the armored fill crossing to the bedrock step ~26' downstream.

Photo 68. Photo taken of poorly installed and inadequately sized armored fill stream crossings at Site #517 (left) and Site #518 (right). Note the two blue arrows indicating flow at each crossing.

Site #518

Description of Problem: Site #518 is a near origin class 3 stream crossing conveyed by a low volume fill/ford crossing. Combined hillside drainage and flow from a gully off Muir Woods Road contributes to this site (Photo 68).

Treatment Immediacy: Moderate-Low

Description of Treatment Recommendation: Install a properly sized and installed armored fill crossing utilizing 11 yd^3 of mixed 0.5' to 1.5' diameter rip rap capturing stream and gully flow. Disconnect the hydrologically connected trail lengths by installing trail drains (waterbars).

Site #520

Description of Problem: Site #520 is a near origin class 3 stream crossing conveyed by a low volume fill/ford crossing (Photo 69). Combined hillside drainage and flow from a gully off Muir Woods Road contributes to this site.

Treatment Immediacy: Low

Description of Treatment Recommendation: Install a properly sized and installed armored fill crossing utilizing 11 yd^3 of mixed 0.5' to 1.5' diameter rip rap capturing stream and gully flow. Disconnect the hydrologically connected trail lengths by installing trail drains (waterbars).

Photo 69. Photo of stream crossing Site #520. This near origin class 3 stream needs a properly sized and installed armored fill.

Site #521.1

Description of Problem: Site #521.1 is a class 3 stream crossing conveyed by a 50% plugged 12" diameter culvert (Photos 70 and 71). The channel is incised. This part of the trail is an old road bed and is not needed anymore for use as a road. 1500' of steep trail contributes to this site. There are actually 2 trails (one stairs and one gullied). There is also an abandoned section of road to the left, which does not appear to have any drainage problems.

Treatment Immediacy: Moderate

Description of Treatment Recommendation: Complete a road-to-trail conversion if possible. Either re-establish channel width to 4' and layback slopes to 2:1 or construct a small armored fill trail crossing utilizing 15 yd^3 of mixed 0.5’ to 2.5’ diameter rip rap. Outslope the hydrologically connected road and install trail drains (waterbars). Decommission the abandoned trail to the left and install cross road drains where possible, revegetate other sections.

Photos 70 and 71. Photos of stream crossing Site #521.1. Culvert inlet is buried by sediment fan (left) and outlet of very undersized and poorly installed clay pipe is visible below the road (below).

Site #522.1

Description of Problem: Site #522.1 is a class 3 stream crossing conveyed by a 12" clay pipe at inlet and 18" aluminum pipe at outlet (Photo 72).

Treatment Immediacy: Moderate

Description of Treatment Recommendation: Complete a road-to-trail conversion if possible. Either re-establish channel width to 4' and layback slopes to 2:1 or construct a small armored fill trail crossing utilizing 15 yd^3 of mixed 0.5’ to 2.5’ diameter rip rap. Outslope the hydrologically connected road and install trail drains (waterbars). Decommission the abandoned trail to the left and install cross road drains where possible, revegetate other sections.

Photo 72. Photo of stream crossing site #522.1. Stream flow is being conveyed through a poorly installed, undersized and high plug potential 12" clay pipe at inlet and 18" aluminum pipe at outlet.

7.1.7 Road Drainage Observations and Recommendations

During field investigations, PWA observed the majority of hydrologically connected road reaches were via inboard ditches associated with generally flat to insloped road beds with fill berms along the OBR. Many ditches were well vegetated and therefore, pose less risk of delivering sediment from road surface runoff to the adjacent streams. However, in general, we recommend that the following guidelines be considered and employed.

1. Maintain ditch capacity and allow vegetation to thrive which will assist in filtering out sediment which the road related pollutants (oil, etc.) stick to.
2. Where there are long ditches (> 250') that are directly connected to stream crossing culverts, if room allows, excavate a linear sediment basin (20' long x 2' wide x 1-2' deep with 1:1 sideslopes) before the culvert inlet to settle out fine sediment which may contain other highway pollutants. Maintain the capacity of these linear sediment basins on an annual basis, or as-needed.
3. Along non-paved roads, employ road shaping design techniques to achieve an outsloped road cross section with or without an inboard ditch, so as to evenly distribute and not concentrate road runoff, and install frequent rolling dips to protect the roadbed from rutting during winter use. If possible, once permanent drainage features (i.e. rolling dips) are installed and/or road shaping techniques implemented (i.e. outsloping), allow the road/trail segment to revegetate and mow rather than grade the surface during maintenance.

8 SITES WITH TREATMENTS COMPLETED OR PLANNED

Of the 500 sites identified in the 2002 assessment, 383 were recommended for treatment (Table 5). Of these 383 sites, 98 sites are on land and roads managed by Cal Trans or Marin County. Of the 285 sites on GGNRA/MWNM, MTSP, MMWD and GGF land, 67 (about 24%) have had some work completed at the site[9]. Completed work was initiated by land managers at GGNRA, MWNM, MMWD, MTSP, and GGF over the last 2 decades. Of these 67 sites, 18 were given a high or high-moderate treatment immediacy (2 on MTSP, 13 on MMWD, and 3 on GGNRA/MWNM property); 27 were originally assigned a moderate or moderate-low treatment immediacy (13 on GGNRA/MWNM, 12 on MTSP, and 1 on GGF); 13 were assigned a low treatment immediacy (10 on MTSP and 3 on GGNRA/MWNM property); and 9 sites were not recommended for treatment (8 on MTSP and 1 on MWNM property).

In addition, 64 sites have been identified with work planned for the near future. MTSP has identified 59 sites along Deer Park Fire Road, Dipsea Trail, Fern Creek Trail, Heather Cutoff Trail, Lost Trail, Miwok Trail, Canopy View Trail, Redwood Creek Trail and Muir Woods Road. Of these 59 sites, 3 were assigned a high or high-moderate treatment immediacy in 2002, 35 were assigned a moderate or moderate-low rating, 19 assigned a low rating, and 2 were identified as not recommended for treatment in 2002. GGNRA/MWNM identified 5 sites along Ben Johnson Trail and Muir Woods Road; 3 were assigned moderate or moderate low treatment immediacy and 2 with low treatment immediacy during PWA's 2002 assessment.

In addition to Table 5 below, refer to Appendix B for a summary table and location maps of all 500 treatment sites from the original 2002 assessment.

[9] Please note that some of the implemented and planned sites were not recommended for treatment in 2002.

Table 5. Sediment delivery sites inventoried in PWA's original 2002 assessment that have had work completed or have plans to apply treatment recommendations at the site as of 2017[1].

Site #	Responsible Agency[2]	Road Name	Problem Type[3]	TI[4]	Future Erosion[5]	Work Completed or Plans to Apply Treatment Recommendations[6]	
						Date	Treatment Notes Provided by Appropriate Landowner Staff
WORK COMPLETED							
13	Cal Trans/GGNRA	HWY 1	DRC	ML	8		Contractor removed fire road
40	MMWD	Old RR Grade	SC	H	402	2007	
41	MMWD	Old RR Grade	SC	H	204	2007	
50	MMWD	West Point	SC	HM	1822	2007	
52	MMWD	West Point	SC	H	402	2007	
56	MMWD	Old Stage Rd	SC	HM	99	2007	
57	MMWD	Old Stage Rd	SC	HM	94	2007	
58	MMWD	Old Stage Rd	SC	HM	80	2007	
59	MMWD	Old Stage Rd	SC	HM	104	2007	
63	MMWD	Old Stage Rd	SC	HM	56	2007	
66	MMWD	Old Stage Rd	SC	HM	21	2007	
106	MTSP	Alice Eastwood Rd	DRC	HM	59	2013	Removed debris and constructed headwalls on the 24" DRC; install grates to prevent future clogging; reshape the inboard drain to catch road and hillside (off Panoramic Drive) flow
108	MTSP	Alice Eastwood Rd	SC	HM	4873	2005	Installed 160LF of 48" of Galvanized CSP; install with 48" tapered inlet, 2 48" elbows
110	MTSP	Alice Eastwood Rd	SC	M	3762	2005	Installed 120 LF of 60" Galvanized CSP, with 60" tapered inlet, and 2 60" elbows
118	Marin County/MMWD	Panoramic Highway	DRC	HM	34		County downspout
119	Marin County/MMWD	Panoramic Highway	DRC	HM	88		County downspout
129	Marin County/MMWD	Panoramic Highway	SC	HM	372		County headwall
161	MTSP	Muir Woods Rd	SC	ML	253	2007	Replaced in 2007 to allow for fish passage
170	MTSP	Dias Ridge Rd	RSDP	ML	24	2008-2009	Dias Ridge Road to Trail Conversion in MTSP was completed in 2008-2009. Ditches removed, trail narrowed and out-sloped, realigned, and armored crossings installed.

Table 5. Sediment delivery sites inventoried in PWA's original 2002 assessment that have had work completed or have plans to apply treatment recommendations at the site as of 2017[1].

Site #	Responsible Agency[2]	Road Name	Problem Type[3]	TI[4]	Future Erosion[5]	Work Completed or Plans to Apply Treatment Recommendations[6]	
						Date	Treatment Notes Provided by Appropriate Landowner Staff
171	MTSP	Dias Ridge Rd	RSDP	L	13	2008-2009	Dias Ridge Road to Trail Conversion in MTSP was completed in 2008-2009. Ditches removed, trail narrowed and out-sloped, realigned, and armored crossings installed.
172	MTSP	Dias Ridge Rd	RSDP	ML	99	2008-2009	Dias Ridge Road to Trail Conversion in MTSP was completed in 2008-2009. Ditches removed, trail narrowed and out-sloped, realigned, and armored crossings installed.
174	GGNRA	Dias Ridge Rd	RSDP	M	24	2008-2009	Dias Ridge Road to Trail Conversion in MTSP was completed in 2008-2009. Ditches removed, trail narrowed and out-sloped, realigned, and armored crossings installed.
175	MTSP	Coastal Fire Rd	RSDP	ML	25	2005	State Parks Completed a Road to Trail Conversion in 2005 and removed the road and associated facility at this site.
193	MWNM	Muir Woods Old Service Rd	LS	M	417	2003	Muir Woods Old Service Road closed and decommissioned
194	MWNM	Muir Woods Old Service Rd	SC	H	432	2003	Muir Woods Old Service Road closed and decommissioned
195	MWNM	Muir Woods Old Service Rd	LS	ML	347	2003	Muir Woods Old Service Road closed and decommissioned
196	MWNM	Muir Woods Old Service Rd	DRC	L	10	2003	Muir Woods Old Service Road closed and decommissioned
204	MWNM	Conlon Ave	SC	H	91	2016	NPS installed rip rap at failed culvert; rip rap installation will be upgraded for stability and vehicle passage.
237	GGNRA	Banducci Rd	SC	ML	8	2015	Replaced culvert, bermed drainage ditch to direct water into Redwood Creek floodplain.
238	GGNRA	Banducci Rd	SC	M	26	2004?	NPS Roads Crew replaced culvert
239	GGNRA	Banducci Rd	DRC	L	4	2004?	NPS Roads Crew replaced culvert
241	MTSP	Coastal Fire Rd	RSDP	L	0	2005	State Parks Completed a Road to Trail Conversion in 2005 and removed the road and associated facility at this site.
252	GGNRA	Coastal South Rd	SC	ML	114		Contractor
253	GGNRA	Coastal South Rd	RSDP	M	111		Contractor
254	GGNRA	Coastal South Rd	RSDP	M	0		Contractor
256	GGNRA	Middle Green Gulch Rd	SC	M	40	2012	GOGA Trail Crew; Middle Green Gulch repairs

Table 5. Sediment delivery sites inventoried in PWA's original 2002 assessment that have had work completed or have plans to apply treatment recommendations at the site as of 2017[1].

Site #	Responsible Agency[2]	Road Name	Problem Type[3]	TI[4]	Future Erosion[5]	Work Completed or Plans to Apply Treatment Recommendations[6]	
						Date	Treatment Notes Provided by Appropriate Landowner Staff
257	GGNRA	Middle Green Gulch Rd	Spring	M	18	2012	GOGA Trail crew Middle Green Gulch repairs
258	GGNRA	Middle Green Gulch Rd	SC	HM	78	2012	GOGA Trail crew Middle Green Gulch repairs
259	GGNRA	Middle Green Gulch Rd	LS	ML	185	2012	GOGA Trail crew Middle Green Gulch repairs
260	GGNRA	Middle Green Gulch Rd	SC	ML	26	2012	GOGA Trail crew Middle Green Gulch repairs
261	GGNRA	Middle Green Gulch Rd	SC	ML	217	2012	GOGA Trail crew Middle Green Gulch repairs
268	GGF	Green Gulch Driveway	SC	M	258	2011-12	Contractor working with Green Gulch Farm-treatment may be different than PWA recommendations
270.1	GGNRA	Middle Green Gulch Rd	SC	L	23	2010	Removed culvert plus entire eroding trail segment. Armored rock crossings installed.
343	MTSP	Boot Jack Trail	SC	L	3	2014	The Bootjack Trail Rehabilitation Project was completed in 2014. It included installing new bridges, armored crossings, repairing retaining structures and bringing all the facilities up to current DPR trail standards.
344	MTSP	Boot Jack Trail	SC	ML	1	2014	The Bootjack Trail Rehabilitation Project was completed in 2014. It included installing new bridges, armored crossings, repairing retaining structures and bringing all the facilities up to current DPR trail standards.
369	MTSP	Bootjack Trail	SC		17	2014	The Bootjack Trail Rehabilitation Project was completed in 2014. It included installing new bridges, armored crossings, repairing retaining structures and bringing all the facilities up to current DPR trail standards.
370	MTSP	Bootjack Trail	SC	ML	1	2014	The Bootjack Trail Rehabilitation Project was completed in 2014. It included installing new bridges, armored crossings, repairing retaining structures and bringing all the facilities up to current DPR trail standards.

Table 5. Sediment delivery sites inventoried in PWA's original 2002 assessment that have had work completed or have plans to apply treatment recommendations at the site as of 2017[1].

Site #	Responsible Agency[2]	Road Name	Problem Type[3]	TI[4]	Future Erosion[5]	Work Completed or Plans to Apply Treatment Recommendations[6]	
						Date	Treatment Notes Provided by Appropriate Landowner Staff
371	MTSP	Bootjack Trail	SC	ML	2	2014	The Bootjack Trail Rehabilitation Project was completed in 2014. It included installing new bridges, armored crossings, repairing retaining structures and bringing all the facilities up to current DPR trail standards.
372	MTSP	Bootjack Trail	SC	ML	1	2014	The Bootjack Trail Rehabilitation Project was completed in 2014. It included installing new bridges, armored crossings, repairing retaining structures and bringing all the facilities up to current DPR trail standards.
408	MTSP	Bootjack Trail	SC		0	2014	The Bootjack Trail Rehabilitation Project was completed in 2014. It included drainage improvements along the trail from Panoramic Hwy to Muir Woods. The project removed culverts, installed new bridges, armored crossings, repaired retaining structures and brought the trail up to current DPR trail standards.
409	MTSP	Bootjack Trail	SC	L	2	2014	The Bootjack Trail Rehabilitation Project was completed in 2014. It included drainage improvements along the trail from Panoramic Hwy to Muir Woods. The project removed culverts, installed new bridges, armored crossings, repaired retaining structures and brought the trail up to current DPR trail standards.
410	MTSP	Bootjack Trail	SC		0	2014	The Bootjack Trail Rehabilitation Project was completed in 2014. It included drainage improvements along the trail from Panoramic Hwy to Muir Woods. The project removed culverts, installed new bridges, armored crossings, repaired retaining structures and brought the trail up to current DPR trail standards.
411	MTSP	Bootjack Trail	SC	L	1	2014	The Bootjack Trail Rehabilitation Project was completed in 2014. It included drainage improvements along the trail from Panoramic Hwy to Muir Woods. The project removed culverts, installed new bridges, armored crossings, repaired retaining structures and brought the trail up to current DPR trail standards.

Table 5. Sediment delivery sites inventoried in PWA's original 2002 assessment that have had work completed or have plans to apply treatment recommendations at the site as of 2017[1].

Site #	Responsible Agency[2]	Road Name	Problem Type[3]	TI[4]	Future Erosion[5]	Work Completed or Plans to Apply Treatment Recommendations[6]	
						Date	Treatment Notes Provided by Appropriate Landowner Staff
414	MTSP	Bootjack Trail	RSDP	M	12	2014	The Bootjack Trail Rehabilitation Project was completed in 2014. It included drainage improvements along the trail from Panoramic Hwy to Muir Woods. The project removed culverts, installed new bridges, armored crossings, repaired retaining structures and brought the trail up to current DPR trail standards.
415	MTSP	Bootjack Trail	SC	ML	1	2014	The Bootjack Trail Rehabilitation Project was completed in 2014. It included drainage improvements along the trail from Panoramic Hwy to Muir Woods. The project removed culverts, installed new bridges, armored crossings, repaired retaining structures and brought the trail up to current DPR trail standards.
416	MTSP	Bootjack Trail	SC	L	1	2014	The Bootjack Trail Rehabilitation Project was completed in 2014. It included drainage improvements along the trail from Panoramic Hwy to Muir Woods. The project removed culverts, installed new bridges, armored crossings, repaired retaining structures and brought the trail up to current DPR trail standards.
417	MTSP	Bootjack Trail	SC	L	1	2014	The Bootjack Trail Rehabilitation Project was completed in 2014. It included drainage improvements along the trail from Panoramic Hwy to Muir Woods. The project removed culverts, installed new bridges, armored crossings, repaired retaining structures and brought the trail up to current DPR trail standards.
418	MTSP	Bootjack Trail	SC		0	2014	The Bootjack Trail Rehabilitation Project was completed in 2014. It included drainage improvements along the trail from Panoramic Hwy to Muir Woods. The project removed culverts, installed new bridges, armored crossings, repaired retaining structures and brought the trail up to current DPR trail standards.
419	MTSP	Bootjack Trail	SC		0	2014	The Bootjack Trail Rehabilitation Project was completed in 2014. It included drainage improvements along the trail from Panoramic Hwy to Muir Woods. The project removed culverts, installed new bridges, armored crossings, repaired retaining structures and brought the trail up to current DPR trail standards.

Table 5. Sediment delivery sites inventoried in PWA's original 2002 assessment that have had work completed or have plans to apply treatment recommendations at the site as of 2017[1].

Site #	Responsible Agency[2]	Road Name	Problem Type[3]	TI[4]	Future Erosion[5]	Work Completed or Plans to Apply Treatment Recommendations[6]	
						Date	Treatment Notes Provided by Appropriate Landowner Staff
420	MTSP	Bootjack Trail	SC		0	2014	The Bootjack Trail Rehabilitation Project was completed in 2014. It included drainage improvements along the trail from Panoramic Hwy to Muir Woods. The project removed culverts, installed new bridges, armored crossings, repaired retaining structures and brought the trail up to current DPR trail standards.
421	MTSP	Bootjack Trail	SC	L	2	2014	The Bootjack Trail Rehabilitation Project was completed in 2014. It included drainage improvements along the trail from Panoramic Hwy to Muir Woods. The project removed culverts, installed new bridges, armored crossings, repaired retaining structures and brought the trail up to current DPR trail standards.
422	MTSP	Bootjack Trail	SC		0	2014	The Bootjack Trail Rehabilitation Project was completed in 2014. It included drainage improvements along the trail from Panoramic Hwy to Muir Woods. The project removed culverts, installed new bridges, armored crossings, repaired retaining structures and brought the trail up to current DPR trail standards.
423	MTSP	Bootjack Trail	SC		0	2014	The Bootjack Trail Rehabilitation Project was completed in 2014. It included drainage improvements along the trail from Panoramic Hwy to Muir Woods. The project removed culverts, installed new bridges, armored crossings, repaired retaining structures and brought the trail up to current DPR trail standards.
427	MWNM	Ben Johnson Trail	SC		0	2015	Replaced in-kind puncheon style bridge elevated above bank and removed abutment
470	MTSP	Old Mine Trail	SC	L	1	2009	The Old Mine Trail was converted to an ADA Trail in 2009. This project addressed drainage along the length of the trail with outsloping, a bridge, and other standard trail features consistent with the current State Parks Trail standards.
471	MTSP	Old Mine Trail	SC	L	1	2009	The Old Mine Trail was converted to an ADA Trail in 2009. This project addressed drainage along the length of the trail with outsloping, a bridge, and other standard trail features consistent with the current State Parks Trail standards.

Table 5. Sediment delivery sites inventoried in PWA's original 2002 assessment that have had work completed or have plans to apply treatment recommendations at the site as of 2017[1].

Site #	Responsible Agency[2]	Road Name	Problem Type[3]	TI[4]	Future Erosion[5]	Work Completed or Plans to Apply Treatment Recommendations[6]	
						Date	Treatment Notes Provided by Appropriate Landowner Staff
472	MTSP	Old Mine Trail	SC	ML	1	2009	The Old Mine Trail was converted to an ADA Trail in 2009. This project addressed drainage along the length of the trail with outsloping, a bridge, and other standard trail features consistent with the current State Parks Trail standards. At this location a 10" culvert and headwalls were installed along roadside and the drainage was cleared and a 12' footbridge was install below to eliminate erosion caused by mechanical wear
WORK PLANNED							
92	Marin County/MWNM	Muir Woods Rd	SC	L	92	TBD	1) Clean plugged DRC to left. 2) Remove 60' of bermed road shown on sketch. 3) Clean out the channel downstream of the culvert outlet for 5' to the step in the channel. 4) Install a rock grade control structure at the culvert outlet to act as energy dissipation. Define the grade control structure 5' wide x 3' long x 2' deep, armor the GCS with 2yd^3 of 0.5-1.5' diameter rock armor. 5) Maintain the DRC up the right road approach.
93	Marin County/MWNM	Muir Woods Rd	DRC	ML	4	TBD	1) Define the culvert inlet to prevent plugging. 2) Clean the culvert outlet and the associated downstream channel reach for 15' long x 2' wide x 1' deep.
95	Marin County/MWNM	Muir Woods Rd	SC	M	14	TBD	1. Replace existing with 24" CMP.
96	Marin County/MWNM	Muir Woods Rd	SC	L	20	TBD	1. Install DRC ~300' to left of site 95.
97	Marin County/MTSP	Muir Woods Rd	DRC	L	2	TBD	1. Clean inlet.
98	Marin County/MTSP	Muir Woods Rd	DRC	L	2	TBD	clean DRC
99	Marin County/MTSP	Muir Woods Rd	DRC	L	1	TBD	1. clean inlet
155	Marin County/MTSP	Muir Woods Rd	SC	ML	14	TBD	1. Excavate xing 2. Replace with 30" CMP. 3. Rolling dip fire trail so that is drains to no delivery DRC to right.

Table 5. Sediment delivery sites inventoried in PWA's original 2002 assessment that have had work completed or have plans to apply treatment recommendations at the site as of 2017[1].

Site #	Responsible Agency[2]	Road Name	Problem Type[3]	TI[4]	Future Erosion[5]	Work Completed or Plans to Apply Treatment Recommendations[6]	
						Date	Treatment Notes Provided by Appropriate Landowner Staff
156	Marin County/MTSP	Muir Woods Rd	DRC	ML	7	TBD	1. Clean existing DRC inlet. 2. Install one DRC to the left.
157	Marin County/MTSP	Muir Woods Rd	SC	M	238	TBD	1. Excavate xing. Replace with 48" CMP. Excavate old xing 40" up channel. Store spoils locally (~40 yds) (easy access to left, move 3 large boulders).
158	Marin County/MTSP	Muir Woods Rd	DRC		6	TBD	No treatment.
159	Marin County/MTSP	Muir Woods Rd	SC	HM	104	TBD	1) Replace the existing stream crossing with a properly sized 30" diameter CMP installed at a 30% gradient with a downspout installed to the bottom of the fill. 2) Eliminate diversion potential to the right.
160	Marin County/MTSP	Muir Woods Rd	DRC		2	TBD	No treatment
162	Marin County/MTSP	Muir Woods Rd	DRC	L	2	TBD	clean inlet and outlet
163	Marin County/MTSP	Muir Woods Rd	SC	M	103	TBD	1. Excavate top to Bot. 2. Replace culvert with 24' at base of fill.
164	Marin County/MTSP	Muir Woods Rd	SC	ML	38	TBD	1. Excavate xing top to Bot. 2. Replace pipe with 24" CMP lower in fill.
166	Marin County/MTSP	Muir Woods Rd	DRC	L	2	TBD	clean inlet
167	Marin County/MTSP	Muir Woods Rd	SC	M	205	TBD	1. Excavate crossing top to Bot. 2. Replace culvert with 60" at base of fill. *entered as 166
176	MTSP	Deer Park Rd	DRC	ML	4	TBD	1. Install a rolling dip a current DRC location. 2. Outslope road with no IBD as shown on sketch.
178	MTSP	Deer Park Rd	RSDP	L	5	TBD	1. Install 1 rolling dip at existing DRC. 2. Install 3 rolling dips to right road.
206	MTSP	Deer Park Fire Rd	DRC	ML	32	TBD	1. Maintain ditch for first 350' to right. 2. Outslope and remove ditch for 1360' to right road. 3. Replace existing DRC with 18". 4. Install 3 rolling dips to right.

Table 5. Sediment delivery sites inventoried in PWA's original 2002 assessment that have had work completed or have plans to apply treatment recommendations at the site as of 2017[1].

Site #	Responsible Agency[2]	Road Name	Problem Type[3]	TI[4]	Future Erosion[5]	Work Completed or Plans to Apply Treatment Recommendations[6]	
						Date	Treatment Notes Provided by Appropriate Landowner Staff
207	MTSP	Deer Park Fire Rd	RSDP	L	17	TBD	1. Outslope and remove ditch for 500' to right road. 2. Install rolling dip to right road. 3. Start outslope treatment 150' right road.
208	MTSP	Deer Park Fire Rd	DRC	ML	29	TBD	1) Replace DRC with 18" 2) Install rolling dips to 1480' left road. 3) Dips across Dipsea Tr.
209	MTSP	Deer Park Fire Rd	SC	M	7	TBD	1) Excavate top to Bot. 3) Replace culvert with 24" at base of fill. 3) Install critical dip to left. 4) Install 3 rolling dips to right. 5) Excavate 20' above top to create stable transition, remove berm on rebuild. Raise road 1' on rebuild. Stock
210	MTSP	Deer Park Fire Rd	DRC	ML	5	TBD	1) Replace existing DRC with 18". 2) Outslope road and retain IBD for 100' to right retain ditch for another 50' to capture spring into IBD. **This outsloping will involve significant berm removal. Some of this material can be side casted but special ca
211	MTSP	Deer Park Fire Rd	DRC	ML	12	TBD	1) Install rolling dip instead of DRC. 2) Install 2 dips to left road.
212	MTSP	Deer Park Fire Rd	DRC	M	28	TBD	1) Outslope road and remove IBD on left approach. (This will involve removal of 4 DRCs) (4 backhoe hours). 2) Install 4 rolling dips to the left.
213	MTSP	Deer Park Fire Rd	DRC	M	44	TBD	1) Replace 18" DRC with 18" lower in fill. 2) Install 2- 18" DRCs low in fill to left of road. 3) Outslope and retain ditch for 400' of left road.
214	MTSP	Deer Park Fire Rd	DRC	ML	10	TBD	1) Outslope and remove IBD for 280' left. 2) Install a rolling dip at DRC.
215	MTSP	Deer Park Fire Rd	SC	HM	52	TBD	1) Excavate crossing top to Bot. 2) Replace culvert with 36" at base of fill. 3) Install critical dip to right. 4) Outslope road with no IBD to left. 5) Install 2 rolling dips left. (import 9 yds for 30 degree fillslopes)
216	MTSP	Muir Woods Rd	DRC	HM	13	TBD	1) Pack armor around the existing culvert outlet to offer additional support and protect the OBR against further erosion.
217	MTSP	Muir Woods Rd	SC	L	40	TBD	1) Excavate top to Bot. 2) Replace culvert with 24" at base of fill.
218	MTSP	Muir Woods Rd	SC	ML	36	TBD	1) Excavate top to Bot. 2) Replace culvert with 24" at base of fill. 3) Install an 18" DRC to the right. (rebuild with existing fillslopes

Table 5. Sediment delivery sites inventoried in PWA's original 2002 assessment that have had work completed or have plans to apply treatment recommendations at the site as of 2017[1].

Site #	Responsible Agency[2]	Road Name	Problem Type[3]	TI[4]	Future Erosion[5]	Work Completed or Plans to Apply Treatment Recommendations[6]	
						Date	Treatment Notes Provided by Appropriate Landowner Staff
383	MWNM	Dipsea Trail	RSDP	M	44	TBD	1) Install up to 12 trail drains or dips to the right of outlet gully. 2) Install 3 more dips to the left to disperse trail drainage before reaching swale.
384	MTSP	Dipsea Trail	RSDP	M	27	TBD	1) Install up to 10 trail dips to the right of delivery location. 2) Install one to the left. (Bobcat work)
385	MTSP	Dipsea Trail	RSDP	ML	10	TBD	1) Install 7 trail drains or dips to the right and one at site.
387	MTSP	Fern Creek Trail	SC	ML	2	TBD	1) Use hand labor to excavate larger critical dip just beyond armored fill to prevent any high flow diversion. 2) Use hand labor to redistribute alluvial sediments in channel below bot. Currently flow is forced to the left and right causing bank erosion
430	MWNM	Ben Johnson trail	SC	M	1	TBD	Above the site, where the flow splits, trench to direct as much flow as possible to the bridge. Plug, pull or put an elbow on the metal pipe to stop or direct flow into channel. Excavate 6" clay pipe and replace with 12" CMP at base of fill. Direct all
458	MTSP	Miwok trail	RSDP	L	6	TBD	Use hand labor to install up to 11 trail dips especially one at swale crossing.
459	MTSP	Miwok trail	SC	L	1	TBD	1) Use hand labor to excavate broader, deeper dip, removing fill along OBF and being sure flow is captured from above. Use spoils locally to build up left inboard trail to help prevent diversion. * use gavel size rock to rock trail surface thru crossing
460	MTSP	Miwok trail	RSDP	M	15	TBD	1) Enhance dips across 3 swale crossings by excavating fill using hand labor (4 hrs each). 2) Install up to 8 trail dips at approaches to these swales (2 hrs each).
461	MTSP	Miwok trail	SC	L	1	TBD	1) Install gravel size rock thru crossing (4x12=48ft2). 2) Install 3 rolling trail dips right.
462	MTSP	Miwok trail	SC	L	1	TBD	Rebuild or enhance dips to the right.
463	MTSP	Miwok trail	SC	ML	2	TBD	1) Use hand labor to remove top row of rock at OBF and create broad, stable, more pronounced dip thru crossing. 8x1x10 removal. 2) Install 3 trail dips to the right.
466	MTSP	Redwood Creek Trail	SC	L	3	TBD	1) Install 6 trail dips to the right.

Table 5. Sediment delivery sites inventoried in PWA's original 2002 assessment that have had work completed or have plans to apply treatment recommendations at the site as of 2017[1].

Site #	Responsible Agency[2]	Road Name	Problem Type[3]	TI[4]	Future Erosion[5]	Work Completed or Plans to Apply Treatment Recommendations[6]	
						Date	Treatment Notes Provided by Appropriate Landowner Staff
469	MTSP	Redwood Creek Trail	SC	M	4	TBD	Install armored fill crossing. Currently only foot access but could build short access for bobcat.
482	MTSP	Lost Trail	SC	ML	1	TBD	1) Use hand labor to remove boulder at CLP and create dip for channel, 5x2x7 dirt removal. Use local rock to re-armor fillslope and channel.
486	MTSP	Canopy View Trail	SC	L	1	TBD	1) Use hand labor to excavate a better defined dip. 5x2x7 approximate removal.
487	MTSP	Canopy View Trail	SC	M	3	TBD	1) Excavate fill removing old CMP and replace with armored fill crossing. This will be done with hand labor. 2) Install 3 trail dips right.
500	MTSP	Redwood Creek Tr.	SC	ML	52	TBD	1) Excavate Top to Bot. 2) Replace existing with a 72" CMP.
502	MTSP	Redwood Creek Tr.	SC	M	1	TBD	1) Install 8' footbridge sturdy enough to support horse traffic. 2) Rock 9' to the left. 3) Rock 7' to the right.
503	MTSP	Redwood Creek Tr.	SC	L	1	TBD	Armor 4' right and 4' left approach. Average bedload 6"
505	MTSP	Redwood Creek Tr.	RSDP	M	6	TBD	1) Install 10 cross road drains to 300' left trail where possible.
508	MTSP	Redwood Creek Tr.	SC	M	1	TBD	1) Notch top tie to allow drainage. 2. Rock road (4x4) with large rock.
509	MTSP	Redwood Creek Tr.	SC	ML	1	TBD	1) Notch top of railroad tie to allow drainage. 2) Excavate channel from Top to OBF.
510	MTSP	Heather Cutoff Trail	SC	L	6	TBD	1) Install 50 cross road drains 1500' to right. From fire road down to crossing.
511	MTSP	Heather Cutoff Trail	SC	L	1	TBD	1) Excavate crossing Top to OBF. 2) Install ford.
512	MTSP	Heather Cutoff Trail	SC	M	1	TBD	1) Rock ford 4x2. 2) Install ford at spring 75' to right. 3) Install cross road drains to 120' right trail.
513	MTSP	Heather Cutoff Trail	SC	L	42	TBD	1) Notch wood to allow drainage. 2) Rock through crossing. 3) Install 10 drains to left trail.
514	MTSP	Heather Cutoff Trail	SC	ML	1	TBD	1) Install rock ford (3x15). 2) Install 10 cross road drains to 450' right trail.

Table 5. Sediment delivery sites inventoried in PWA's original 2002 assessment that have had work completed or have plans to apply treatment recommendations at the site as of 2017[1].

Site #	Responsible Agency[2]	Road Name	Problem Type[3]	TI[4]	Future Erosion[5]	Work Completed or Plans to Apply Treatment Recommendations[6]	
						Date	Treatment Notes Provided by Appropriate Landowner Staff
524	MTSP	Canopy View Trail	SC	L	1	TBD	1. Install 1 trail drain to right trail.
525	MTSP	Canopy View Trail	SC	M	1	TBD	Excavate TOP to BOT. Install ford with hand labor.
527	MTSP	Canopy View Trail	SC	ML	1	TBD	Excavate channel 10' above and 10' below crossing at bridge. Spoil locally. Move bridge downstream and replace with 9' with new footings.
529	MTSP	Canopy View Trail	SC	ML	1	TBD	Excavate xing TOP to BOT. Install ford with 3' channel width. Rock (2*4) 1-2" bedload. Spoil locally

[1] All information included in this table was provided by responsible agency.
[2] Responsible Agencies are abbreviated as follows: MMWD = Marin Municipal Water District; MTSP = Mt. Tamalpais State Park; GGNRA = Golden Gate National Recreation Area; MWNM = Muir Woods National Monument, part of GGNRA.
[3] Site Types are abbreviated as follows: SC = stream crossing, DRC = ditch relief culvert, RSDP = road surface discharge point, and LS = landslide.
[4] TI - Treatment Immediacy. Ratings are abbreviated as follows: L= low, ML= moderate low, M= moderate, HM=high-moderate, H=high, and NA – not applicable.
[5] Future erosion includes only the estimated "*episodic*" future sediment delivery for site specific volumes based on a 30-year interval with no rounding.
[6] Details regarding work completed and planned was provided by the responsible agency. PWA did not review the completed work.

9 POST PROJECT MONITORING RECOMMENDATIONS

As the Erosion Control and Erosion Prevention Recommendations in this report are implemented, post-project monitoring should be completed to evaluate and document performance[10]. This should at a minimum include establishing multiple permanent and reproducible photo point locations at each site. Annual monitoring and following significant storm events with >5 year return interval peak flows should be performed to assess treatment effectiveness through visual inspections of the sites and comparing post-construction photographic documentation.

During visual inspections, evaluate the effectiveness of the treatments by: (1) identifying any instability along treated road/trail segments; (2) documenting the structural integrity of implemented treatments; (3) identifying any areas with potential for erosion/sediment delivery; (4) quantifying sediment delivery due to any significant adjustments to the implemented treatments; and (5) recording turbidity detected at any of the treatment sites.

Inspections should be conducted yearly after implementation, in particular during the wet weather season (October through April) after the first major rainfall event and then later in the season within 48 hours after a large storm event where greater than 2” of rainfall is recorded within a 24 hours period.

Minor adjustments following treatments can be expected and are normal; therefore, annual monitoring of implemented treatment plans will not only evaluate project performance, but it will also identify where adaptive management actions are warranted to fine tuning or perform maintenance before becoming a significant problem.

10 CONCLUSIONS

This assessment includes a re-evaluation of road related erosion and sediment delivery sources to the Redwood Creek watershed at 44 sites along 6 road and trail segments in the southwestern region of Marin County, California. This report provides a summary of analyzed field data that describes current observations (with photo documentation) and treatment recommendations re-classified by treatment immediacy along selected roads. In addition, the report provides a summary of all 500 sites included in the 2002 report with an update noting work completed or where plans have been prepared or are underway to complete additional recommended treatments.

An integral part of this assessment is inclusion of treatment recommendations classified by treatment immediacy for cost-effective erosion control and erosion prevention for the 44 selected sites, including both short and long term recommendations, where necessary.

[10] It is understood that there are additional monitoring protocols for most of these actions as they are permitted by regulatory agencies and that those agencies have their own monitoring requirements.

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Appendix A

2016-2017 Field observations and treatment recommendations for road/trail related sediment delivery sites

Redwood Creek Watershed, Muir Woods Road/Trail Re-Assessment Marin County, California

Table 1. 2016-2017 Field observations and treatment recommendations for road related sediment delivery sites.

Site #	Road	TI[a]	Site[b] Type	Hydro[c]		Estimated future sediment delivery[d]			Comment on Problem[e]	Recommended Treatments[e]
				Left (ft)	Right (ft)	Chronic (yd^3)	Episodic (yd^3)	Sum (yd^3)		
78	Muir Woods	ML	DRC	105	0	8	17	25	Site #78 is an 18" diameter DRC that receives 105' of spring fed inboard ditch. The outlet of the culvert is shotgun causing a gully on the fillslope. The culvert outlets of DRC sites #77, 78, and 80 all deliver to the stream crossing Site #79. The gullies at the outlets of the DRC sites have eroded down to more competent, rocky material. In addition, the trail below these sites is constructed with rock protection.	1) Install 20'-30' of full-round downspouts at the DRC outlets to the trail and/or stream at DRC Sites #77, 78, and 80.
79	Muir Woods	HM	SC	70	0	5	150	155	Site #79 is a 20" diameter CMP draining a 5' x 1.5' Class 2 stream. The culvert is undersized, set shallow in the fill, and has a *High* plug potential due to woody debris in the channel and poor culvert installation. The site also receives ~70' of spring fed left ditch that is hydrologically connected, draining directly to the existing culvert inlet.	1) Replace the existing culvert with a properly sized 42" diameter culvert, set at natural stream grade and at the base of the fill. 2) Install a flared inlet. 3) Install a single post trash rack 42" above the culvert inlet to decrease plug potential.
90	Muir Woods	M	RSDP	730	0	54	22	76	Site #90 is a RSDP discharge point resulting from ~730' of road related ditch runoff that exits Muir Woods Road onto an Abandoned Service Road causing gullying and past landsliding resulting in sediment delivery to a class 2 stream located below the abandoned road. Since the 2001 assessment, a fence has been installed and posts located at the entrance of the abandoned road to restrict access. Ditch flow from Muir Woods Road has been directed into a 12" diameter DRC with a flared inlet and flex pipe downspout for >100' to protect the fill and hillslope from further erosion and sediment delivery. As of April 2016, there were straw bales staged along the backside of the fence blocking flow from the ditch to the DRC.	1) Move or spread the straw bales as erosion control material. 2) Clean the inlet of the DRC and use spoils to create a berm to direct flow from inboard ditch (IBD) of Muir Woods Road to DRC flared inlet and prevent future diversion down the abandoned road.

Table 1. 2016-2017 Field observations and treatment recommendations for road related sediment delivery sites.

Site #	Road	TI[a]	Site[b] Type	Hydro[c]		Estimated future sediment delivery[d]			Comment on Problem[e]	Recommended Treatments[e]
				Left (ft)	Right (ft)	Chronic (yd^3)	Episodic (yd^3)	Sum (yd^3)		
92	Muir Woods	L	SC	575	0	106	92	198	Class 2 stream flow is conveyed through this crossing via an oval culvert (41" wide x 30" tall) placed at the axis of a switchback on road. The switchback is at entrance to Muir Woods National Monument. This culvert appears to be functioning well.	1) Clean plugged DRC to left. 2) Remove 60' of bermed road shown on sketch. 3) Clean out the channel downstream of the culvert outlet for 5' to the step in the channel. 4) Install a rock grade control structure at the culvert outlet to act as energy dissipation. Define the grade control structure 5' wide x 3' long x 2' deep, armor the GCS with $2yd^3$ of 0.5-1.5' diameter rock armor. 5) Maintain the DRC up the right road approach.
93	Muir Woods	ML	DRC	225	500	134	4	138	12" DRC is receiving input from multiple areas (parking lot at park maintenance from left, plugged DRC at hairpin turn). Not much can be done to disperse runoff from parking lot. This site has likely received diverted flow from site 92 during high flows.	1) Define the culvert inlet to prevent plugging. 2) Clean the culvert outlet and the associated downstream channel reach for 15' long x 2' wide x 1' deep.

Table 1. 2016-2017 Field observations and treatment recommendations for road related sediment delivery sites.

Site #	Road	TI[a]	Site[b] Type	Hydro[c]		Estimated future sediment delivery[d]			Comment on Problem[e]	Recommended Treatments[e]
				Left (ft)	Right (ft)	Chronic (yd^3)	Episodic (yd^3)	Sum (yd^3)		
94	Muir Woods	HM	SC	250	0	19	677	696	Site #94 is sediment delivery site with a very complicated stream crossing and surface runoff drainage pattern within a well-developed area of the property. A 4' x 2' class 2 stream exits a narrow valley and enters a 24" diameter culvert above a developed parking lot and building area. The culvert is undersized with a high plug potential evident by the presence of several buried trash racks. The culvert is plumbed beneath a parking lot where it connects to an 18" diameter somewhere beneath a paved surface, crosses Muir Woods Road and outlets to Redwood Creek. This is a very large stream crossing because the stream valley is buried by buildings, parking lot and Muir Woods Road. As is, this culvert plugs regularly and can overtop and divert overland to a 12" DRC which crosses an old roadbed currently utilized as a trail and then outlets into a rocked ditch before popping out onto Muir Woods Road. A portion of this diverted stream overflow crosses the road into another parking lot with another portion entering the IBD and entering the next DRC. Improving this crossing with installation of a properly sized and located culvert would require a major excavation including working around several outbuildings and large amount of pavement. This crossing is likely to continue plugging and cause erosional problems in various locations.	1) Based on field discussions with NPS staff, properly treating this site by upgrading the culverted crossing with all the infrastructure is not realistic at this juncture. Therefore, we recommend improving the existing overflow channel by increasing capacity and directing flow into the DRC along Muir Woods Road. In addition, we recommend installing some rip rap at the outlet of the existing 18" diameter CMP to reduce the potential for erosion at the culvert outlet and sediment delivery to Redwood Creek.

Table 1. 2016-2017 Field observations and treatment recommendations for road related sediment delivery sites.

Site #	Road	TI[a]	Site[b] Type	Hydro[c]		Estimated future sediment delivery[d]			Comment on Problem[e]	Recommended Treatments[e]
				Left (ft)	Right (ft)	Chronic (yd^3)	Episodic (yd^3)	Sum (yd^3)		
118	Panoramic Highway	ML	DRC	500	270	57	34	91	Site #118 is an 18" diameter DRC that receives excessive drainage from a hydrologically connected fire road and non-paved ridge spur road. This excessive drainage has caused a gully at the DRC outlet that delivers to site #100. Since 2001, a ~30' long downspout has been installed at the DRC outlet. Although the downspout does not extend the entire way to Site #100, the remaining gully below the downspout has eroded to bedrock and now stable.	1) Install 3 rolling dips up ridge spur road and one DRC on paved fire station road to disconnect hydrologically connected RSDP runoff draining to the site.
119	Panoramic Highway	L	DRC	180	200	28	88	116	Site #119 is an 18" diameter DRC that receives IBD, cutbank and RSDP runoff contribution. The excess flow has caused a gully that connects to site #104 on Alice Eastwood Rd. There is a concrete retaining wall at the culvert outlet. This wall has multiple drains that also contributes flow to site. A small gully comes off the cutbank and contributes flow and sediment to site. Since 2001, a full round downspout has been installed at the outlet extending the entire way to Site #104. The downspout outlet is slightly crushed and needs maintenance, but is functioning well as installed.	1) Open up and maintain downspout to ensure flow is not restricted.

Table 1. 2016-2017 Field observations and treatment recommendations for road related sediment delivery sites.

Site #	Road	TI[a]	Site[b] Type	Hydro[c]		Estimated future sediment delivery[d]			Comment on Problem[e]	Recommended Treatments[e]
				Left (ft)	Right (ft)	Chronic (yd^3)	Episodic (yd^3)	Sum (yd^3)		
127	Panoramic Highway	HM	DRC	0	600	44	41	85	Site #127 is an 18” diameter DRC that receives flow from 600' of IBD from the right. This is causing a gully that delivers to sites on Alice Eastwood Rd. The existing gully is covered with duff (~2-4’ wide x 2’ deep at top tapering to 6”-1’ deep near the bottom). No cutbank slide or headcut is visible from the road. However, there is evidence of flow in IBD from small headwall stream that also contributes flow to #127, located ~50’ to the right.	1) Install 2 DRCs to the right and build up down-road berms at DRCs to cut off diversion potential and flow from the right.
129	Panoramic Highway	NA	SC	10	480	36	372	408	Site #129 is a class 2 stream crossing that has been treated since the 2002 assessment. The previously plugged 12” CMP was recently replaced with an 18” pipe with a 57” wide x 43” high concrete headwall. The pipe is shotgunned and drains to a stable headwall swale. The pipe is clear and functioning ok as installed.	1) None, already treated.
137	Panoramic Highway	HM	SC	0	480	36	1713	1749	Site #137 is a large class 2 stream (Spike Buck Creek) crossing through a 36" concrete culvert with a downspout. The stream crossing has functioned well in the past but is undersized for 100yr flow. Based on orientation we presume there is an elbow (bend) in the 36” pipe within the fillslope. Road runoff exits at the OBF resulting in some fillslope erosion and sediment delivery.	1) Install an overflow pipe with a downspout to reach the base of fill. 2) Locate the elbow of the existing 36” pipe and install a riser for cleaning out debris at the elbow.

Table 1. 2016-2017 Field observations and treatment recommendations for road related sediment delivery sites.

Site #	Road	TI[a]	Site[b] Type	Hydro[c]		Estimated future sediment delivery[d]			Comment on Problem[e]	Recommended Treatments[e]
				Left (ft)	Right (ft)	Chronic (yd^3)	Episodic (yd^3)	Sum (yd^3)		
139	Panoramic Highway	M	DRC	0	730	54	30	84	Site #139 is a 24" steel DRC that drains nearly 800 feet of hydrologically connected road and ditch directly to Rattlesnake Creek 200' below the DRC outlet. The culvert outlet projects through a cement retaining wall and onto the fillslope. There is a clump of bay trees at the outlet that will make it difficult to attach a downspout.	1) Install 4 DRCs to the right road to reduce hydrologic connectivity to the site. 2) Connect a flexpipe downspout to the existing DRC outlet, navigating around bay trees to base of fill.
141	Panoramic Highway	HM	SC	0	150	11	394	405	Site #141 is 8’ x 3’ class 2 stream crossing through a 48” diameter CMP. The stream channel is steep with 2' diameter boulders present. The site also receives significant runoff from a spring to right. The culvert is set fairly well in the crossing; the inlet is on bedrock and outlet set low in fill. The stream converges with Site #140 below the road. A 5’ headwall exists with logs and boulders. The culvert is functioning well as installed. However, it is undersized.	1) Install a 48” overflow pipe at 20% gradient along the left side of the crossing with a downspout to the bottom of the fill, left of redwoods. 2) Remove ~ 25 yd^3 of fill, dipping the surface 3’deep x 30’ long x 10’ wide with 2:1 sideslopes in a “U” shape between Sites #140 and #141 for extra protection against stream diversion at Site #141.

Table 1. 2016-2017 Field observations and treatment recommendations for road related sediment delivery sites.

Site #	Road	TI[a]	Site[b] Type	Hydro[c]		Estimated future sediment delivery[d]			Comment on Problem[e]	Recommended Treatments[e]
				Left (ft)	Right (ft)	Chronic (yd^3)	Episodic (yd^3)	Sum (yd^3)		
143	Panoramic Highway	M	DRC	0	595	44	59	133	Site #143 is a DRC with a 12"diameter concrete inlet and 18" aluminum outlet shotgunned over steep fill. The gully that developed at the DRC outlet delivers to Rattlesnake Creek ~300' below. Since 2001, continued erosion has occurred down to bedrock, reducing the future potential for future gully erosion and sediment delivery. Approximately 595' of right ditch is hydrologically connected and contributes flow and sediment to this site. The right cutbank is highly erodible and ditch is filled with accumulated material. The hydrologically connected road is insloped and a 2nd DRC located 375' to the right is being bypassed by ditch flow. Additionally, the stream crossing at Site #144 has diversion potential and may have diverted to this site in the past.	1) Install a 10' downspout on the existing DRC, clean DRC inlet, and install a ditch plug to prevent diversion. 2) Install 1 new DRC to right road with a ditch plug to prevent diversion. Install ditch plug on 2nd existing DRC to right to prevent diversion. NOTE: Cutbank failures will need future maintenance to clean out IBD and DRC inlet.
152	Panoramic Highway	ML	SC	0	210	16	234	250	Site #152 is a class 2 stream crossing through an undersized 18” diameter culvert. It was found to be 60% plugged at the inlet in 2001 with a large sediment fan extending 30' up the right ditch due to continued plugging and ponding. Flow also appeared to divert to the left down the ditch. Channel above is a very steep cascade down bedrock steps. During the 2016 evaluation, the inlet, while still undersized, was open and sediment fan above inlet has been cleared.	1) Replace the existing culvert with 24" diameter CMP at natural channel grade. 2) Remove any aggraded sediment above the inlet.

Table 1. 2016-2017 Field observations and treatment recommendations for road related sediment delivery sites.

Site #	Road	TI[a]	Site[b] Type	Hydro[c]		Estimated future sediment delivery[d]			Comment on Problem[e]	Recommended Treatments[e]
				Left (ft)	Right (ft)	Chronic (yd^3)	Episodic (yd^3)	Sum (yd^3)		
154	Panoramic Highway	ML	SC	0	540	40	215	255	Site #154 is a small class 3 stream crossing through an 18" diameter CMP. The outlet has a 20' full-round downspout outlet onto armored fillslope. Site delivers to swale. The existing pipe is functioning well as installed and the once plugged DRC to the right has been cleaned.	1) Install ditch plug at the existing DRC to prevent diversion. 2) Install an 18" DRC to right with ditch plug. 3) Remove berm for 500' to the right *(unless installed for safety as it is current access to bus stop).*
159	Muir Woods	HM	SC	310	0	23	104	124	Site #159 is a class 2 stream crossing through an undersized 24" diameter steel culvert. The outlet and bottom of the pipe is rusted. The culvert outlet is shotgunned, which is causing erosion of the fillslope and streambank. There is a ~20' drop from the outlet to the gully below. The outboard edge of fill (OBF) is failing as a result of the erosion. Redwood Creek is located ~75' below the culvert outlet. The right IBD is nearly flat; therefore, there is diversion potential to the right if the stream overtops. Underground telephone cables exist at this location.	1) Replace the existing stream crossing with a properly sized 30" diameter CMP installed at a 30% gradient with a downspout installed to the bottom of the fill. 2) Eliminate diversion potential to the right.

Table 1. 2016-2017 Field observations and treatment recommendations for road related sediment delivery sites.

Site #	Road	TI[a]	Site[b] Type	Hydro[c]		Estimated future sediment delivery[d]			Comment on Problem[e]	Recommended Treatments[e]
				Left (ft)	Right (ft)	Chronic (yd^3)	Episodic (yd^3)	Sum (yd^3)		
180	Camino Del Canyon	H	SC	10	400	76	55	131	A 100% plugged 12"culvert on a Class 2 stream conveys stream flow through this crossing. The culvert is installed short and high the fill. Stream flow is currently being conveyed through the fill beneath the culvert and is exiting the fill 12' downstream of the existing culvert outlet. Site receives 400' of road runoff from the right road approach. Site also receives runoff from Panoramic Rd. and Dipsea Trail upslope.	1) Excavate TOP to BOT and replace the existing culvert with a new 24"x 40' CMP installed at the base of fill. 2) Define the stream approach to the newly installed culvert inlet. 3) Armor the lower 3/4 of the OBF slope with $15yd^3$ of 2'-3' diameter rock armor. 4) Armor the lower 1/2 of the IBF slope with $4yd^3$ of 1'-2' diameter rock armor. 5) Outslope road from rolling dip to CLP. 6) Outslope road to right. 7) Install critical dip on left hinge. 8) Rerock road through crossing with $15yd^3$ of road rock. 9) Install one type 1 rolling dip to right road with an armored keyway at the outlet. Excavate a keyway 6' wide at the top x 5' wide at the base x 8' long x 2' deep, and armor the keyway with $5yd^3$.
181	Camino Del Canyon	HM	RSDP	80	700	144	52	196	700' of concentrated road runoff exits road at a low. Concentrated road run off has eroded a gully that delivers to Class II stream channel 175' downslope. Gully will continue to increase and continued erosion could potentially cause a significant portion of road to fail at the IBF transitions. Entire connected road length is bermed.	1) Outslope road remove ditch for 700' to right. 2) Install 2 type 1 rolling dips to right.

Table 1. 2016-2017 Field observations and treatment recommendations for road related sediment delivery sites.

Site #	Road	TI[a]	Site[b] Type	Hydro[c]		Estimated future sediment delivery[d]			Comment on Problem[e]	Recommended Treatments[e]
				Left (ft)	Right (ft)	Chronic (yd^3)	Episodic (yd^3)	Sum (yd^3)		
182	Camino Del Canyon	M	SC	55	180	44	113	157	A crossing on a Class 2 stream. Stream flow is conveyed through the crossing via a recently installed 42" diameter HDPE plastic culvert. Culvert is set at a shallow grade, and high and short in the fill. There is a 3' drop at the culvert outlet and subsequent splash zone erosion. There is an active spring in the right IBD area that is being conveyed to the culvert inlet.	1) Install a type 1 rolling dip on the right road approach at existing outboard drain location. 2) Install a rocked keyway at the outlet of the rolling dip to prevent headward erosion into the road bed. Excavate a keyway 6' wide at the top x 5' wide at the base x 8' long x 2' deep, and armor the keyway with $5yd^3$. 3) Outslope right approach with no IBD. 4) Maintain the active IBD to drain the spring flow to the right for 20'. 5) Install a rock grade control structure at the culvert outlet to act as energy dissipation. Define the grade control structure 11' wide x 8' long x 2.5' deep, armor the GCS with $5yd^3$ of 1-2.5' diameter rock armor.
183	Camino Del Canyon	ML	RSDP	190	150	63	21	84	A section of insloped and bermed road accumulates water at 2 low spots 165' apart. At both sites ponded water exits road at OBF and is actively gullying the OBF slope. Site A delivers to Class 2 stream 45' downslope. Future erosion volumes are based on continued gullying of road, fillslope. Site B delivers to a Class 2 stream, 200' downslope.	1) Outslope the road and fill ditch for 340' to the left and right.

Table 1. 2016-2017 Field observations and treatment recommendations for road related sediment delivery sites.

Site #	Road	TI[a]	Site[b] Type	Hydro[c]		Estimated future sediment delivery[d]			Comment on Problem[e]	Recommended Treatments[e]
				Left (ft)	Right (ft)	Chronic (yd^3)	Episodic (yd^3)	Sum (yd^3)		
184	Camino Del Canyon	ML	DRC	105	120	42	27	69	An 18" diameter DRC drains the connected right road approach and springy cutbank. The DRC is 30% plugged and is installed at a shallow grade, and the outlet is shotgunned with a 5' drop at the outlet. Additionally, water is evacuating the road at the OBF, and has eroded a gully down to the Class 2 stream 150' downslope.	1) Replace the existing DRC with a new 18" x 50' CMP installed at grade to establish a self-cleaning DRC. 2) Install 1yd3 of 0.5-1' diameter rock armor at the outlet of the newly installed DRC to act as energy dissipation. 3) Outslope right road fill ditch for 225' (no ditch), but maintain the active IBD for 25'just to the right of the site.
185	Camino Del Canyon	H	SC	0	0	0	147	147	A rowdy Class 2 stream is conveyed through this crossing via an undersized 36" diameter HDPE plastic culvert with an aluminum flared inlet. There is a 24" diameter CMP ~26' to the right of the stream crossing that conveys flow from a failing downspout network upslope. The network of 24" diameter plastic culverts is intended to convey flow down the existing gully, however the culvert is disconnected in several locations. The combined hillslope runoff and breached culvert flow have eroded a gully beneath the plastic culvert. Both culverts are shotgunned and outlet very high in the fill with a subsequent 10' drop at the culvert outlet. The splash zone below the culvert outlets is actively eroding the toe of the outboard fillslope, and destabilizing the outboard fillslope. There is active slumping visible on the left OBF slope.	1) Excavate TOP to BOT, and replace the existing 36" diameter plastic culvert with a 72"x70' CMP installed at the base of fill. 2) Replace the CMP to the right of the main crossing with a 30" x 60' culvert installed at the base of fill. Incorporate this culvert outlet into the armored fillslope for the mainstream crossing. 3) Upon fill rebuild construct the outboard fill at 35 degrees, and armor the lower ½ of the OBF slope with 45yd^3 of 2'-3' diameter rock armor. 4) Construct a critical dip on the left hinge of the crossing. 5) Install a galvanized single post trash rack at the 72" culvert inlet. 6) Install 8yd^3 of 1'-2.5' diameter rock armor at the newly defined culvert outlet to act as energy dissipation.
186	Camino Del Canyon	ML	RSDP	100	160	48	15	63	Accumulated road drainage from right and left road approaches exits the RSDP at an existing low in the road alignment. The concentrated RSDP run off is actively eroding a gully that delivers to Class 2 stream 100' downslope.	1) Outslope road to the right and left.

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Site #	Road	TI[a]	Site[b] Type	Hydro[c]		Estimated future sediment delivery[d]			Comment on Problem[e]	Recommended Treatments[e]
				Left (ft)	Right (ft)	Chronic (yd^3)	Episodic (yd^3)	Sum (yd^3)		
187	Camino Del Canyon	H	SC	55	100	29	211	240	A plugged 12" diameter CMP conveys Class 2 stream flow through this crossing. A downspout was installed at the lower cutbank, but it is not functioning. Water is ponding on road and evacuating the RSDP via an on OBF gully.	1) Excavate crossing TOP to BOT, and install a new 24"x60' diameter CMP at the base of fill. 2) Upon fill rebuild armor the outboard fillslope with 45yd^3 of 1.5'-3' diameter rock armor to buttress the steep outboard fillslope. 3) Install 2ys^3 of 1'-2' diameter rock armor at the outlet of the newly installed culvert to act as energy dissipation. 3) Blend the TOP of Site #187.1 into the BOT of this site. 4) OSRFD the right road approach for 155'. 5) Lay back the headcut above the culvert inlet and construct a grade control structure, excavate a keyway 8' wide x 9' long x 2' deep, and armor the GCS with 5yd^3 of 0.5'-1.5' diameter rock armor.
187.1	Camino Del Canyon	H	SC	125	0	23	100	123	Stream flow from site #187 on Camino Canyon Road outlets onto this relict road prism. Stream flow is actively eroding through the fill and delivering sediment to the Class 2 stream downslope.	1) Decommission the stream crossing. Excavate from TOP to BOT and establish a 4' wide channel bottom, lay back slopes 2:1. 2) Store spoils locally on left road approach landing. Disconnect the through cut left road approach via spoils storage. 3) Install 3 XRD on the left road approach.

Table 1. 2016-2017 Field observations and treatment recommendations for road related sediment delivery sites.

Site #	Road	TI[a]	Site[b] Type	Hydro[c]		Estimated future sediment delivery[d]			Comment on Problem[e]	Recommended Treatments[e]
				Left (ft)	Right (ft)	Chronic (yd^3)	Episodic (yd^3)	Sum (yd^3)		
188	Camino Del Canyon	H	SC	80	540	115	76	191	Class 2 stream flow is conveyed through this crossing via a 24" diameter aluminum culvert. The inlet is 50% plugged. There is a significant amount of deposition at outlet due to a large debris slide to left of site that buried the channel below the crossing.	1) Excavate TOP to BOT, and replace the existing undersized CMP with a new 36"x50' CMP installed at the base of fill. 2) Upon fill rebuild; lower the axis of the crossing by 1', construct the OBF slope at 30-32 degrees, and armor the lower ¼ of the outboard fillslope with 7yd^3 of 2'-2.5' diameter rock armor. 3) Excavate the stream channel and establish a stable transition below culvert outlet. 4) Endhaul any excess spoil materials to the right 400' to turnout. 5) Outslope road with no inboard ditch 540' to right. 6) Install 2 rolling dips to right. 7) Install a single post trash rack. 8) Maintain/install a critical dip on the left hinge of the crossing. 9) Install 5yd3 of 1'-2.5' diameter rock at the culvert outfall to act as energy dissipation.

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Site #	Road	TI[a]	Site[b] Type	Hydro[c]		Estimated future sediment delivery[d]			Comment on Problem[e]	Recommended Treatments[e]
				Left (ft)	Right (ft)	Chronic (yd^3)	Episodic (yd^3)	Sum (yd^3)		
189	Camino Del Canyon	M	LS	0	0	0	111	111	A large debris slide has deposited into channel below site #188. Since, road has been rebuilt thru deposit. This has left the channel buried, with some perched material failing into channel. Delivery is very high towards the right side and lower to the left. This feature will be a future road maintenance issue, and will have to be ramped over as the feature progresses downslope.	1) When treating Stream crossing #188 use caution and do not undercut this large earthflow feature. 2) Maintain the DRC on the left lateral drainage, and keep the ditch functional and open. 3) Remove the section of disconnected downspout and establish a rocked outfall for the DRC to prevent erosion. Excavate a 4’ wide at the top x 3’ wide at the base x 5’ long x 1.5’ deep keyway and install 2yd3 of 0.5’-1.0’ rock armor. Ensure the keyway has adequate capacity to convey flow down the axis of the grade control structure.
190	Camino Del Canyon	HM	SC	0	870	161	105	266	Flow from a Class 3 stream is conveyed through this crossing via an undersized 18” aluminum culvert. The culvert is installed short and high in the fill and at a very shallow gradient. The culvert is 50% plugged with aggraded bedload, and shows evidence of recent overtopping.	1) Replace the existing undersized CMP, excavate from TOP to BOT and install a new 30”x60’ CMP at the base of fill. 2) OSRFD (outslope road and fill ditch) 870’ of right road. 3) Install critical dip on the left hinge. 4) Install 3 rolling dips on the right road approach.
193	Old Service Road	NA	LS	0	0	0	292	292	Identified as a future road fill failure feature which had scarps up to 8’ back from OBF and up to 6” vertical displacement. The remaining perched fill has been excavated back during road decommissioning and appears to be stable.	No treatment recommended.

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Site #	Road	TI[a]	Site[b] Type	Hydro[c]		Estimated future sediment delivery[d]			Comment on Problem[e]	Recommended Treatments[e]
				Left (ft)	Right (ft)	Chronic (yd^3)	Episodic (yd^3)	Sum (yd^3)		
194	Old Service Road	NA	SC	150	0	28	432	460	A decommissioned stream crossing on an abandoned road. This site has been effectively decommissioned in the past decade. The majority of the road fill has been excavated through the crossing. The slopes and channel appear to be stable.	No treatment recommended.
199	Conlon Avenue	HM	SC	0	150	28	252	280	A Class 2 stream crossing with a 36" rusted CMP. Stream Valley was filled to create building space for home to left. This really, should be a decommission site, full treatment may involve decommissioning the house in the valley to the left of the crossing. There is an active overflow channel along the axis of the crossing, and the fill near the inlet is disaggregating. Also, tributary valley to the right has been completely filled in and has a very long culvert. These channels have been completely altered from their natural state all the way downstream due to road and home building activities.	1) Decommission the stream crossing, excavate crossing from TOP to BOT. Establish a 6' wide channel bottom and lay back banks 2:1. The left bank will have to be steeper than 2:1 if the building is to be retained. 2) Lay back the right stream bank upstream of the culvert inlet for at least 45'. Lay the bank back to 2:1 or to stable native ground material. 3) Spoil locally on the roads, and to the right on the landing.

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Site #	Road	TI[a]	Site[b] Type	Hydro[c]		Estimated future sediment delivery[d]			Comment on Problem[e]	Recommended Treatments[e]
				Left (ft)	Right (ft)	Chronic (yd^3)	Episodic (yd^3)	Sum (yd^3)		
200	Conlon Avenue	M	SC	0	0	0	624	624	Stream valley has been filled and altered by both ancient debris fan deposits as well as mechanical disturbance. A 4' x 1.5' Class 2 stream has been placed into 30" concrete culvert. The channel above inlet has been altered by mechanical activities and it appears as though the stream has been pushed over towards the left side of the valley. The 30" culvert appears sufficient except under peak flow conditions, where plugging has occurred and flow has diverted to the left down high flow channel. It would be best to reestablish the original watercourse along its natural axis, and decommission the entire area to restore the natural riparian functionality.	*Short term:* 1) Clean the inlet area and install a flared inlet to existing CMP inlet. 2) Install new trash rack. 3) Maintain dip to left that acts as overflow channel. *Long term:* 1) Reestablish the original watercourse along its natural axis to restore the natural riparian functionality. 2) Decommission the road and stream crossing by removing all road fill from the crossing and establishing a natural channel bottom and banks and disconnecting hydrologically connected road by ripping the road surface to promote native revegtation and installing cross road drains.

Table 1. 2016-2017 Field observations and treatment recommendations for road related sediment delivery sites.

Site #	Road	TI[a]	Site[b] Type	Hydro[c]		Estimated future sediment delivery[d]			Comment on Problem[e]	Recommended Treatments[e]
				Left (ft)	Right (ft)	Chronic (yd^3)	Episodic (yd^3)	Sum (yd^3)		
201	Conlon Avenue	ML	SC	100	100	37	31	68	A Class 2 stream is conveyed through this crossing via a 36" concrete culvert. Crossing conveys flow under the driveway to house. The crossing is functional, but it is undersized for 100-year flow. The fillslopes are constructed out of rock and concrete and are vertical. There is right and left road contribution as well as diversion potential down road to right.	*Short term:* 1) Construct critical dip to right. 2) Install a rolling dip just up the right road that is connected to the IBD in order to convey stream flow into the crossing. 3) Rock armor the OBF transition at the axis of the RD outlet with $5yd^3$ of 0.5'-1.0' diameter rock armor. *Long term:* Decommission the road and stream crossing by removing all road fill from the crossing and establishing a natural channel bottom and banks and disconnecting hydrologically connected road by ripping the road surface to promote native revegtation and installing cross road drains.

Table 1. 2016-2017 Field observations and treatment recommendations for road related sediment delivery sites.

Site #	Road	TI[a]	Site[b] Type	Hydro[c]		Estimated future sediment delivery[d]			Comment on Problem[e]	Recommended Treatments[e]
				Left (ft)	Right (ft)	Chronic (yd^3)	Episodic (yd^3)	Sum (yd^3)		
202	Conlon Avenue	HM	DRC	400	0	74	30	104	A 400' streamside road with an incised IBD drains to 10" rusted DRC. This delivers directly to the nearby channel. This contributes lots of road surface and ditch fines directly to channel. Upgrade treatment will be unlikely to reduce majority of erosion due to road being built next to channel. This road really should be decommissioned to prevent long term sediment delivery. It is also possible that this is a historic anadromous stream channel, however numerous check dams have formed steps in the channel ranging up to 4' in height. Disturbances to the unstable upslope area should be minimized to prevent further destabilizing the saturated hillslope.	*Short-term:* 1) Outslope road and retain the IBD for 400'. 2) Install 3 rolling dips along road reach not connected to the IBD. 3) Replace the Two existing DRC with new 18" diameter culverts installed at or near the base of fill. There are several wooden retaining walls that will have to be worked around. 4) Install 2 new DRC's long the road reach to further disconnect the very wet IBD. Install 1st new 18" diameter DRC just down the right road from the driveway ~20' from the intersection at site #210. And install an additional new 18" diameter DRCs in between the existing DRC locations. *Long-term:* 1) Decommission the road by ripping the road surface and installing cross road drains.

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Site #	Road	TI[a]	Site[b] Type	Hydro[c]		Estimated future sediment delivery[d]			Comment on Problem[e]	Recommended Treatments[e]
				Left (ft)	Right (ft)	Chronic (yd^3)	Episodic (yd^3)	Sum (yd^3)		
203	Conlon Avenue	H	SC	0	150	11	45	56	Site #203 is a 6’ x 2’ class 2 stream crossing through a failing 36” diameter pipe that was repaired by installing a newer 30” pipe within the old culvert. Currently, flow leaks 2’ before the 30” outlet through slots in the pipe. Stream flow is constricted at the inlet by the road and cement headwall on the left. Past diversion and plugging is indicated by dilapidated sand bags above inlet. The crossing was already undersized before the insert was installed further reducing capacity by 30%. In addition, the installation was too short, causing fill to collapse around the outlet. Culvert is aligned nearly perpendicular to the natural channel. The new culvert should be realigned with natural channel. This site is also receiving 150' of runoff from driveway to the right.	*Short-term:* 1) Install a trash rack above the culvert inlet to reduce plug potential, apply 10 yd^3 of 1’ to 2.5’ mixed rip-rap to the outlet to provide energy dissipation, and a critical dip at the crossing to eliminate diversion potential. 2) Outslope and remove IBD 150' along the driveway to the right. 3) Install cross road drains at top of driveway to capture spring flow. *Long-term:* 1) Decommission the stream crossing by removing all road fill from the crossing and establish a 6’ wide natural channel bottom and lay back banks 2:1. 2) Decommission the road by ripping the road surface to promote native revegtation and installing cross road drains to disconnect hydrologically connected road reaches.

Table 1. 2016-2017 Field observations and treatment recommendations for road related sediment delivery sites.

Site #	Road	TI[a]	Site[b] Type	Hydro[c]		Estimated future sediment delivery[d]			Comment on Problem[e]	Recommended Treatments[e]
				Left (ft)	Right (ft)	Chronic (yd^3)	Episodic (yd^3)	Sum (yd^3)		
204	Conlon Avenue	L	SC	450	0	33	91	124	Site #204 is a 6' x 2' class 2 stream crossing that failed during the 2015-2016 winter rains. The site was temporarily repaired by installing armor through the crossing to prevent further erosion of remaining road fill. The concrete inlet and outlet headwalls remain in place. Although the emergency erosion control appears effective. A permanent repair is required.	*Short term:* 1) Remove the headwalls remaining in the crossing. 2) Remove the armor currently placed within the crossing. Construct an armored fill crossing utilizing the existing armor onsite. 3) Install a grade control structure to armor the headcut developing along the left bank at the outlet and stream tributary confluence immediately below the Site #204 crossing. *Long-term:* 1) Decommission the stream crossing by removing all road fill (and rock armor) from the crossing and establish a 6' wide natural channel bottom and lay back banks 2:1. 2) Decommission the road by ripping the road surface to promote native revegtation and installing cross road drains to disconnect hydrologically connected road reaches.
205	Conlon Avenue	NA	SC	0	0	0	172	172	Site #205 was a 6' x 2' class 2 stream crossing through a 36" diameter CMP identified in 2001. During the 2016 re-evaluation, the culvert was not present. Either the culvert has been removed or blown out. A steel 1" diameter pipe still remains in the stream channel, along with evidence of accumulated sediment along the right stream bank from a possible failure of the stream crossing.	None. Crossing no longer exists.

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Site #	Road	TI[a]	Site[b] Type	Hydro[c]		Estimated future sediment delivery[d]			Comment on Problem[e]	Recommended Treatments[e]
				Left (ft)	Right (ft)	Chronic (yd^3)	Episodic (yd^3)	Sum (yd^3)		
216	Muir Woods	ML	DRC	290	70	27	13	40	Site #216 is a 15” diameter DRC that receives 290' of left and 70' of right hydrologically connected ditch flow. There is a concrete headwall and the culvert outlets 6’ from pavement to an existing 7’ wide x 6’ deep x 100’ long average gully delivering sediment to the stream located 100’ below. Both IBD’s and cutbanks are well vegetated and the DRC receives little flow. The erosional threat is contained to that at the outlet.	1) Pack armor around the existing culvert outlet to offer additional support and protect the OBR against further erosion.
517	Dipsea Trail	M	SC	280	5	53	2	55	Gully off Muir Woods Rd. contributes flow to this stream crossing on a near origin Class 3 Stream on Dipsea Trail. Stream flow is conveyed through the crossing via a poorly installed armored fill.	1) Install an armored fill crossing, lower the axis of the crossing by 1’, excavate a keyway 15’ wide at the top x 8’ wide at the base x 14’ long x 2.5’ deep, armor the keyway with 15yd^3 of 0.5-2’ diameter rock armor. 2) Define the stream channel 4’ wide with 2:1 sideslopes from the base of the armored fill crossing to the bedrock step ~26’ downstream.
518	Dipsea Trail	ML	SC	90	0	10	2	12	A near origin Class III stream crossing. Combined hillslope drainage and flow from a gully off of Muir Woods Rd are conveyed across the road prism via a dip. The crossing is functioning as a low volume fill/ford crossing.	1) Install an armored fill on the gully/ near origin stream crossing to the left, lowering the axis of the crossing by 1', excavate a keyway 13' wide at the top x 8' wide at the base x 14' long x 2' deep, armor the keyway with 11yd^3 of 0.5-1.5' diameter rock armor. 2) Install 2 trail drains (waterbars) along the left 90'

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Site #	Road	TI[a]	Site[b] Type	Hydro[c]		Estimated future sediment delivery[d]			Comment on Problem[e]	Recommended Treatments[e]
				Left (ft)	Right (ft)	Chronic (yd^3)	Episodic (yd^3)	Sum (yd^3)		
520	Dipsea Trail	L	SC	700	165	96	8	104	A near origin Class 3 stream crossing with contributing flow from a DRC on Muir Woods Rd.	1) Install an armored fill on the gully/ near origin stream crossing to the left, lowering the axis of the crossing by 1', excavate a keyway 13' wide at the top x 8' wide at the base x 14' long x 2' deep, armor the keyway with 11yd^3 of 0.5-1.5' diameter rock armor. 2) Install 12 trail drains (waterbars) along the left 700'. 3) Install 4 trail drains (waterbars) along the right 165'.
521.1	Dipsea Trail	M	SC	1500	0	278	56	334	12" culvert (clay pipe) 50% plugged on (2x1) Class 3 stream. The channel is incised. This part of the trail is an old road bed and is not needed anymore for use as a road. This site is easily accessible by large equipment and a large amount of fill should be removed. Additionally, 100' of left approach can be outsloped. 1500' of steep trail contributes to this site. There are 2 trails (one stairs and one gullied). The section of gullied trail should be decommissioned, drained, and revegetated. The stair section needs permanent draining as well. There is also an abandoned section of road to the left, it does not appear to have any drainage problems, but may be possible spoil site and decommissioning of old road by outsloping.	1) Complete a road-to-trail conversion if possible. 2) Excavate crossing TOP to BOT. Re-establish channel width to 4', layback slopes to 2:1. OR install a small armored fill crossing utilizing 15 yd^3 of mixed 0.5' to 2.5' diameter rip rap. 3) Use spoil to outslope abandoned road to left (up to 2000') and install trail drains (waterbars). 4) Decommission abandoned trail to left 1000' and install cross road drains where possible, revegetate other sections.

Table 1. 2016-2017 Field observations and treatment recommendations for road related sediment delivery sites.

Site #	Road	TI[a]	Site[b] Type	Hydro[c]		Estimated future sediment delivery[d]			Comment on Problem[e]	Recommended Treatments[e]
				Left (ft)	Right (ft)	Chronic (yd^3)	Episodic (yd^3)	Sum (yd^3)		
522.1	Dipsea Trail	M	SC	20	75	18	99	117	12" clay pipe at inlet and 18" aluminum pipe at outlet. Site is a great candidate for decommissioned.	1) Complete a road-to-trail conversion if possible. 2) Excavate crossing TOP to BOT. Re-establish channel width to 4', layback slopes to 2:1. OR install a small armored fill crossing utilizing 15 yd^3 of mixed 0.5' to 2.5' diameter rip rap. 3) Use spoil to outslope abandoned road to left (up to 2000') and install trail drains (waterbars).

[a] TI - Treatment Immediacy. Ratings are abbreviated as follows: L= low, ML= moderate low, M= moderate, HM=high-moderate, H=high, and NA – not applicable.
[b] Site Types are abbreviated as follows: SC = stream crossing, DRC = ditch relief culvert, RSDP = road surface discharge point, and LS = landslide.
[c] Hydro – Hydrologically connected road reaches. Hydrologically connected describes sites or road segments from which eroding sediment is delivered to stream channels (Furniss et al., 2000). *Left* and *right* are defined as looking downstream from the site.
[d] Estimated future sediment delivery for episodic (site specific) volumes based on a 30-year interval with no rounding. Estimated future sediment delivery is for chronic (road surface/ditch lowering and cutbank retreat) volumes based on a 10-year interval with rounding.
[e] Refer to Appendix C (Typical Drawings) and Appendix D (Supplementary Information) for terminology, definitions, and more details regarding problem and treatment types.

Appendix B

Field observations, treatment recommendations, And status maps for 2002 road/trail related sediment delivery sites

Redwood Creek Watershed, Muir Woods Road/Trail Re-Assessment Marin County, California

Table 1. Summary table of all sediment delivery sites inventoried in PWA's original 2002 assessment[1]

Site #	Responsible Agency[2]	Road	Site Type[3]	FE[4]	TI[5]	Comment on treatment[6]	Work[7] Completed
1	Cal Trans/MTSP	HWY 1	DRC	6	L	1. Install 18" DRC to left road about 90'. 2. Install I dip to trail. 3. Repave road.	
2	Cal Trans/MTSP	HWY 1	SC	65	L	1. Excavate crossing TOP to BOT. 2. Install 24" CMP at natural channel grade. 3. Install 18" DRC to left road. 4. Ensure secondary channel (10' to right) drains to new CMP. 5. Breach left berm at 5 locations. 6. Repave road.	
3	Cal Trans/MTSP	HWY 1	DRC	0		No treatments recommended.	
4	Cal Trans/MTSP	HWY 1	SC	1608	ML	1. Excavate xing TOP to excavation BOT. 2. Install 30" CMP at with 50' fullround downspout. 3. Install 30: flared inlet. 4. Breach berm at 7 locations along 500' of left road (store spoils ~10yds3 locally, without contributing sediment to site). 5. Install 2 ditch relief culverts to left road. 6. Reinstall outboard drop inlet. 7. Repave road.	
5	Cal Trans/MTSP	HWY 1	SC	319	M	1) Excavate Top to excavation Bot. 2) Replace culvert with 24". 3) Install flared inlet. 4) Install 2 DRCs to the left. 5) Install 30' full round downspout. Site requires engineer for fill reconstruction.	
6	Cal Trans/MTSP	HWY 1	SC	458	M	1) Excavate crossing Top to Bot. 2) Install 36" CMP at base of fill. 3) Breach berm for 700' left road every 50'. 4) Be sure to capture flow from right.	
6.1	Cal Trans/MTSP	HWY 1	LS	367	ML	*engineer to reconstruct fill.	
7	Cal Trans/MTSP	HWY 1	DRC	23	ML	1) Clean inlet basin 2) Install trash rack 3) Install two DRC's to the left 4) Breech berm every 50' to left	
8	Cal Trans/MTSP	HWY 1	SC	817	ML	1) Excavate crossing TOP to 25' down OBF. 2) Install 24" CMP. 3) Install 40' full round downspout. 4) Breach 360' of left road berm at least every 50'.	
8.1	Cal Trans/MTSP	HWY 1	LS	481	M	Engineer to reconstruct fill.	
9	Cal Trans/GGNRA	HWY 1	SC	500	L	1) Install 1 DRC to left road. 2) clean inlet	
10	Cal Trans/GGNRA	HWY 1	SC	386	M	1) Excavate top to 25' down fillslope. 2) Replace culvert with 24". 3) Install 20' downspout. 4) Install 2 DRCs to the left. 5) Clean and cut IBD for 40' to the right to the left. 5) Clean and cut IBD for 40' to the right to drain spring/swale to inlet of this site.	
10.1	Cal Trans/GGNRA	HWY 1	LS	167	ML	Engineer to reconstruct fill.	
11	Cal Trans/GGNRA	HWY 1	DRC	13	ML	1. Install 3 DRC to left road.	
12	Cal Trans/GGNRA	HWY 1	SC	84	ML	1) Excavate crossing top to Bot. 2) Replace culvert with 24" at channel grade. 3) Install one DRC to the left.	
13	Cal Trans/GGNRA	HWY 1	DRC	8	ML	1. Install 5 rolling dips up fire road to right.	Y
14	Cal Trans/GGNRA	HWY 1	SC	59	L	1) Clean culvert. 2) Install 1 DRC 700' to left.	
20	MMWD	Ridgecrest	DRC	6	L	1. Replace DRC with 18" deeper in fill. 2. Repave road.	
20.1	MMWD	Ridgecrest	RSDP	27	M	1. Install 3 rolling dips to left. Repave. OR 2. Install 3 DRC to left.	
21	MMWD	Ridgecrest	DRC	11	ML	1. Replace DRC with 18" deeper in fill. 2. Install additional DRC to right.	
22	MMWD	Ridgecrest	DRC	4	L	1. Replace existing DRC with 18" deeper in fill and move 5' to the right.	
23	MMWD	Ridgecrest	DRC	6	L	1. Replace existing DRC with 18" deeper in fill. 2. Install one DRC to the right.	

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Site #	Responsible Agency[2]	Road	Site Type[3]	FE[4]	TI[5]	Comment on treatment[6]	Work[7] Completed
24	MMWD	Ridgecrest	DRC	2	L	1. Replace existing DRC with 18" with outlet lower in fill and inlet shallower in fill.	
25	MMWD	Ridgecrest	RSDP	10	L	1. Remove 100' of left berm. Store spoils locally.	
26	MMWD	Ridgecrest	DRC	2	L	1. Replace existing DRC with 18".	
27	MMWD	Ridgecrest	DRC	16	ML	1. Replace existing DRC with 18" deeper in fill at outlet.	
28	MMWD	Ridgecrest	DRC	15	M	1. Replace existing DRC with 24". 2. Install 20' downspout to DRC. 3. Maintain left IBD.	
29	MMWD	Ridgecrest	DRC	6	M	1. Replace existing DRC with 18". 2. Remove perched sidecast material (5*2*40= 15 yds3)	
30	MMWD	Ridgecrest	SC	416	M	1. Excavate crossing TOP to 25' down fillslope 2. Replace existing CMP with 24", be sure to capture spring flow to right of stream channel. 3. Install 30' downspout to BOT. 4. Install 2 ditch relief culverts to left.	
31	MMWD	Ridgecrest	DRC	44	M	1. Replace existing DRC with 18".	
32	MMWD	Ridgecrest	DRC	14	ML	1. Replace existing DRC with 18" culvert.	
33	MMWD	Ridgecrest	SC	136	M	1. Excavate TOP to 35' down fillslope. 2. Replace with 30"CMP in line with stream centerline. 3. Install 20' downspout to BOT. 4. Excavate 10' above concrete box to capture flow from swale. 5. Repave road.	
34	MMWD	Ridgecrest	SC	84	ML	1. Excavate TOP to BOT. 2. Replace culvert with 24" at channel grade. 3. Install 2 DRC to left road. 4. Remove asphalt berm to disperse drainage to berm drain.	
35	MMWD	Ridgecrest	DRC	6	L	1. Replace existing DRC with 18" deeper in fill. 2. Install 18" DRC to left road.	
36	MMWD	Ridgecrest	DRC	17	M	1. Replace existing DRC with 18" (Place inlet 30' left of current location). 2. Install DRC to the left of Ridge Crest Dr. 3. Install 10 rolling dips to left on seasonal road (dips should intersect inboard ditch)	
37	MMWD	Old RR Grade	SC	133	M	1. Remove 500' of left road berm (5*3*500=278 yds3) place spoils along cutbank. 2. Install 3 rolling dips to left road. 3. Excavate xing TOP to BOT. 4. Replace CMP with 24" at natural channel grade and align with channel. 5. Install critical dip on right hingeline.	
38	MMWD	Old RR Grade	DRC	4	L	1. Install 3 rolling dips to 990' of left road.	
39	MMWD	Old RR Grade	SC	102	M	1. Excavate crossing TOP to BOT. 2. Install 30" culvert at natural channel grade. 3. Install critical dip to right. 4. Install 7 rolling dips to left road.	
40	MMWD	Old RR Grade	SC	402	H	1) Excavate Top to Bot (will involve removal of log retaining wall). 2) Install 42" CMP at natural grade, along CLP. 3) Install critical dip at right hinge line. 4) Install 2 rolling dips to 480' of left road.	Y
41	MMWD	Old RR Grade	SC	204	H	1. Excavate crossing TOP to BOT. 2. Replace culvert with 42" at natural channel grade. 3. Install critical dip to right. 4. Endhaul spoils to unknown site.	Y
42	MMWD	Old Stage Rd	RSDP	15	M	1. Install rolling dip at site. 2. Install 5 dips to left road.	
43	MMWD	Old Stage Rd	DRC	9	ML	1. Replace existing DRC with 18", deeper in fill. 2. Install rolling dip at swale 190' to left. 3. Install a rolling dip ~30' to left where runoff currently exits road, rock dip with 10 yds3.	
44	MMWD	Old Stage Rd	DRC	3	L	1. Install 20' downspout on existing 18" DRC. 2. Install rolling dip to right of DRC.	
45	MMWD	Old Stage Rd	DRC	33	M	1. Replace DRC with 18", deeper in fill. 2. Install 3 rolling dips to left road.	
46	MMWD	West Point	SC	295	M	1. Excavate crossing TOP to 20' down outboard fill (excavation BOT). 2. Replace with 30" culvert. 3. Install 30" fluorine downspout to BOT. 4. Install critical dip to left. 5. Install rolling dip to right. 6. Lower road 2' on back fill. 7. Stockpile soils locally.	
47	MMWD	West Point	SC	118	ML	1. Excavate crossing TOP to BOT. 2. Install 24" CMP at natural channel grade in centerline. Be sure to capture spring flow at new inlet. 3. Lower road 1' on back fill. 4. Rebuild with 40degree fillslope. 5. Install critical dip to left.	
48	MMWD	West Point	SC	97	M	1. Excavate crossing TOP to BOT. 2. Replace culvert with 30" at natural channel grade. 3. Install critical dip to left. 4. Install one rolling dip to right.	
49	MMWD	West Point	DRC	11	M	1. Install 8 rolling dips to right (be sure to intersect inboard ditch). 2. Install 1 dip 50' to left of site 49 to catch spring flow.	

Table 1. Summary table of all sediment delivery sites inventoried in PWA's original 2002 assessment[1]

Site #	Responsible Agency[2]	Road	Site Type[3]	FE[4]	TI[5]	Comment on treatment[6]	Work[7] Completed
50	MMWD	West Point	SC	1822	HM	1) Excavate crossing Top to base of culvert. 2) Replace culvert with 54". 3) Install 30' full round downspout. 4) Install 3 rolling dips to the right.	Y
51	MMWD	West Point	SP	4	L	1. Replace existed DRC with 18" deeper infill. 2. Cut ditch for 40' to the right to capture all spring flow in DRC. 3. Install 3 rolling dips to right.	
52	MMWD	West Point	SC	402	H	1. Excavate crossing TOP to BOT. Install 60" CMP at natural channel gradient. 2. Install critical dip to left hinge line.	Y
53	MMWD	West Point	SC	34	M	1) Excavate TOP to BOT. 2) Install 24" culvert. 3) Install critical dip to left. ** Installation at site #52 should build up fill enough to prevent dip to the right. **use some of spoils from site 52 to raise road to allow for CVMP installation. ** Keep same footprint (narrow road surface and keep footprint)	
54	MMWD	West Point	SC	45	L	1. Install 4 rolling dips to right road. 2. Excavate TOP to BOT. 3. Replace with 24" CMP at channel grade.	
55	MMWD	West Point	SC	29	M	1. Excavate crossing TOP to BOT. 2. Replace culvert with 24". 3. Install critical dip to left hingeline. 4. Outslope road and retain ditch for 90' to right (capture spring flow). 5. Install one rolling dip right (just beyond spring). 6. Import 89 yards to rebuild fillslope.	
56	MMWD	Old Stage Rd	SC	99	HM	1. Excavate crossing TOP to BOT. 2. Replace culvert with 48" at natural channel grade. 3. Install critical dip to right. 4. Install 4 rolling dips to left. 5. Import 27 yds3. (+1 hr excavator labor)	Y
57	MMWD	Old Stage Rd	SC	94	HM	1) Excavate crossing Top to Bot install 30" CMP at natural channel grade 2) Install critical dip to right hinge Note- need to import 118 yds., replace retaining wall with 35 degree fillslope on backfill	Y
58	MMWD	Old Stage Rd	SC	80	HM	1) Excavate crossing Top to Bot. 2) Install 54" pipe at natural channel grade. 3) Install 2 rolling dips to 275' of right road. 4) Install 1 critical dip along right hinge. 5) Raise road 1' on back fill. Note- need 84 yds. to rebuild.	Y
59	MMWD	Old Stage Rd	SC	104	HM	1) Excavate crossing Top to Bot. 2) Replace culvert with 42" culvert at channel grade. 3) Install critical dip to right. 4) Enhance existing outslope to left approach. 5) Install 2 rolling dips left. 6) Clear/maintain IBD 30' left to capture springs from serpentine outcrop. 6) Store spoil locally (use some to outslope road).	Y
60	MMWD	Old Stage Rd	SC	35	M	1) Excavate crossing Top to Bot. 2) Install 24" CMP at channel grade. 3) Install critical dip to right just beyond swale to right. 4) Install 1 rolling dip to left road.	
61	MMWD	Old Stage Rd	SC	49	ML	1) Excavate fill along apex of crossing to create dip through road (average) 50x1x25= 46 yds. 2) Rock road surface through crossing 50x20= 1000 square feet. 3) Armor fillslope with 6" diameter rock 10x5= 50 square feet, will be minimal depth of fill after excavation. 4) Outslope road with no IBD to the left. 5) Install 3 rolling dips left.	
62	MMWD	Old Stage Rd	SC	20	M	1) Excavate crossing Top to Bot. 2) Install 24" CMP at channel grade. 3) Install 2 rolling dips to left road. 4) Raise road 1' on backfill, spoil locally. 5) Install critical dip to right hinge	
63	MMWD	Old Stage Rd	SC	56	HM	1) Excavate crossing Top to Bot. 2) Replace culvert with a 60" at channel grade. 3) Maintain existing DRCs to left. 4) Outslope road with no IBD for 400' beyond second DRC. 5) Install one rolling dip to the left. 6) Outslope left road and retain ditch for first 100'.	Y
64	MMWD	Old Stage Rd	SC	40	ML	1. Excavate xing TOP to BOT. 2. Replace existing with 24" CMP at natural channel grade. 3. Install critical dip to right. 4. Import 10 yds3 fill.	
65	MMWD	Old Stage Rd	SC	29	ML	1. Excavate xing TOP to BOT. 2. Replace culvert with 24". 3. Install critical dip to right. 4. Outslope road and retain inboard ditch for first 50'. 5. Outslope road with no inboard ditch for 70' between swale and site 64. 6. Spoil locally.	
66	MMWD	Old Stage Rd	SC	21	HM	1) Excavate TOP to BOT. 2) Install armored fill crossing. 3) Rock road surface 375 ft2. 4) Rock fill face with 6"-1' riprap. 5) Outslope with no ditch for 415' of left road.	Y
67	MMWD	Old Stage Rd	SC	30	L	1. Excavate crossing TOP to BOT. 2. Replace culvert with 24". 3. Install critical dip to right. 4. Outslope road with no inboard 260' to left. 5. Install 1 rolling dip to left. 6. Stockpile locally.	
68	MTSP	Old Stage Rd	SC	141	M	1. Excavate xing TOP to BOT. 2. Replace with 54" CMP. 3. Install critical dip to left. 4. Install 4 rolling dips to left road. 5. Raise road 1' backfill.	

Table 1. Summary table of all sediment delivery sites inventoried in PWA's original 2002 assessment[1]

Site #	Responsible Agency[2]	Road	Site Type[3]	FE[4]	TI[5]	Comment on treatment[6]	Work[7] Completed
68.1	MTSP	Old Stage Rd	DRC	12	M	1. Replace existing DRC with 18" deeper in fill. 2. Install 1 DRC to right.	
69	MTSP	Old Stage Rd	DRC	5	L	1. Replace existing DRC with 18" deeper in fill. 2. Clear/cut /maintain inboard ditch 30' to left. 3. Install over flow shutoff valve on water trough (if possible).	
70	MTSP	Old Stage Rd	DRC	1	L	1. Clean existing DRC. 2. Install 2 DRC to left. 3. Remove 50' left berm, do not sidecast materials.	
71	MTSP	Old Stage Rd	SC	31	ML	1. Excavate crossing TOP to BOT. 2. Replace culvert with 24". 3. Reconstruct retaining wall.	
72	MTSP	Old Stage Rd	DRC	7	L	1. Replace with 18" DRC.	
73	MTSP	Old Stage Rd	DRC	2	L	1. Replace existing DRC with 18" deeper in fill.	
74	Marin County/MTSP	Muir Woods Rd	DRC	51	M	1. Install DRC to left.	
75	Marin County/MTSP	Muir Woods Rd	DRC	7	ML	1. Install 30' downspout to existing culvert.	
76	Marin County/MTSP	Muir Woods Rd	DRC	2	L	1. Install DRC to left with 20' fullround downspout. 2. Install 10' fullround downspout to existing DRC (1hr additional labor for installation).	
77	Marin County/MTSP	Muir Woods Rd	DRC	6	ML	1. Replace with 18" DRC lower in fill with 30' fullround downspout.	
78	Marin County/MTSP	Muir Woods Rd	DRC	17	HM	1. Replace existing DRC with 18" deeper in fill at outlet. 2. Install 10' fullround downspout.	
79	Marin County/MTSP	Muir Woods Rd	SC	150	HM	1. Excavate TOP to BOT. 2. Replace culvert with 48" at base of fill. 3. Install flared inlet. 4. Spoil locally if needed.	
80	Marin County/MTSP	Muir Woods Rd	SC	117	M	1. Excavate crossing TOP to BOT. 2. Replace culvert with 24" at base of fill.	
81	Marin County/MTSP	Muir Woods Rd	DRC	267	ML	1. Install I DRC to left road.	
82	Marin County/MTSP	Muir Woods Rd	DRC	19	ML	1. Install 20' fullround downspout to existing DRC. 2. Clean existing DRC. 3. Install 18" DRC to left.	
83	Marin County/MTSP	Muir Woods Rd	SC	231	ML	1. Excavate xing TOP to BOT. 2. Replace CMP with 36" lower in fill. 3. Install 36" flared inlet. 4. Import 19 yds3 to rebuild.	
84	Marin County/MTSP	Muir Woods Rd	DRC	9	L	1. Install 10' fullround downspout to existing DRC. 2. Install I DRC to left.	
85	Marin County/MTSP	Muir Woods Rd	DRC	4	ML	1. Install 40' fullround downspout to existing DRC. 2. Install I DRC to left road. Dip trail below downspout. May need chainsaw to notch wooden retaining wall on trail (3 hours labor).	
86	Marin County/MTSP	Muir Woods Rd	SC	165	L	1. Excavate xing TOP to BOT. 2. Install 24" CMP at natural channel grade.	
87	Marin County/MTSP	Muir Woods Rd	SC	1093	ML	1. Excavate xing TOP to 25' down outboard fill. 2. Replace culvert with 42". 3. Install 50' fullround downspout. 3. Install 1 DRC to left.	
88	Marin County/MTSP	Muir Woods Rd	DRC	8	ML	1. Install 1 18" DRC to left road. 2. Install 20' fullround downspout to existing DRC. 3. Clean existing inlet.	
89	Marin County/MTSP	Muir Woods Rd	SC	840	M	1. Excavate xing TOP to 20' down outboard fill. 2. Replace CMP with 36". 3. Install 30' fullround downspout.	
90	Marin County/MTSP	Muir Woods Rd	RSDP	22	HM	1. Install 3 DRC to left road. 2. Install 1 cross road drain to abandoned road.	

Table 1. Summary table of all sediment delivery sites inventoried in PWA's original 2002 assessment[1]

Site #	Responsible Agency[2]	Road	Site Type[3]	FE[4]	TI[5]	Comment on treatment[6]	Work[7] Completed
91	Marin County/MWNM	Muir Woods Rd	SC	642	M	1. Replace with 30" CMP. 2. Install 1 DRC to right road (above through cut). 3. Stockpile spoils locally.	
92	Marin County/MWNM	Muir Woods Rd	SC	92	L	1. Clean plugged DRC to left. 2. Remove 60' of bermed road show on sketch.	PLANNED
93	Marin County/MWNM	Muir Woods Rd	DRC	4		1. No treatments recommended.	PLANNED
94	Marin County/MWNM	Muir Woods Rd	SC	677	HM	1. Excavate TOP to BOT. 2. Reestablish a channel from current inlet to retaining wall. Lay sideslopes back 2:1 with 4' bottom width. 3. Replace culvert with 42" CMP with flared inlet. 4. Install trash rack. 5. May be able to spoil on abandoned road to left or temporarily store spoils in large Muir Woods Parking lot.	
95	Marin County/MWNM	Muir Woods Rd	SC	14	M	1. Replace existing with 24" CMP.	PLANNED
96	Marin County/MWNM	Muir Woods Rd	SC	20	L	1. Install DRC ~300' to left of site 95.	PLANNED
97	Marin County/MTSP	Muir Woods Rd	DRC	2	L	1. Clean inlet.	PLANNED
98	Marin County/MTSP	Muir Woods Rd	DRC	2	L	1. Clean DRC	PLANNED
99	Marin County/MTSP	Muir Woods Rd	DRC	1	L	1. Clean inlet	PLANNED
100	MTSP	Alice Eastwood Rd	DRC	150	M	1. Replace existing DRC with 18" deeper in fill. *2. Disperse road/ ditch drainage on Fire Rd and Panoramic Drive.	
101	MTSP	Alice Eastwood Rd	LS	350	M	1. Excavate unstable fill 90x3x25=250 2. Stockpile spoils behind the site.	
102	MTSP	Alice Eastwood Rd	DRC	162	HM	1. Replace existing DRC with 18" deeper in fill. 2. Actual treatment will be on Panoramic Drive.	
103	MTSP	Alice Eastwood Rd	DRC	44	L	1. Install 18" DRC to left road. 2. Replace existing DRC with 18" deeper fill.	
104	MTSP	Alice Eastwood Rd	DRC	222	HM	1. Replace existing DRC with 18" deeper infill. *Needs to disperse runoff from Panoramic Drive. Amend Treatment.	
105	MTSP	Alice Eastwood Rd	DRC	44		No treatments recommended. until further notice	
106	MTSP	Alice Eastwood Rd	DRC	59	HM	Replace with 30' of 18" CMP lower infill *Disperse drainage on Panoramic	Y
107	MTSP	Alice Eastwood Rd	DRC	169	HM	Replace existing DRC with 18" deeper in fill. * Needs to be treated on Panoramic Dr.	
108	MTSP	Alice Eastwood Rd	SC	4873	HM	1) Excavate crossing top to bot. 2) Replace culvert with 84" at base of fill. 3) Lower crossing 5' on backfill and create critical dip towards right hinge line.	Y
109	MTSP	Alice Eastwood Rd	LS	272	M	1. Excavate unstable fill 105x2x25=194	
110	MTSP	Alice Eastwood Rd	SC	3762	M	1) Excavate crossing top to bot. 2) Replace culvert with 60" at base of fill. 3) Lower crossing 4' on backfill to create critical dip. 4) Install flared inlet. 5) Install trash rack.	Y
111	MTSP	Alice Eastwood Rd	DRC	13	ML	1. Clean inlet (hand shovels)	
112	MTSP	Alice Eastwood Rd	DRC	1		No treatments recommended.	
113	MTSP	Alice Eastwood Rd	SC	66	ML	1. Excavate top to bot. 2. Replace culvert with 24" at channel grade. 3. Install critical dip to right. Spoil locally.	
114	MTSP	Alice Eastwood Rd	DRC	2	L	1. Add 2 rolling dips to left road. 2. Add 1 rolling dip at or adjacent to DRC. Additional; hours (+2 dozer hours) to breach berm. Dips should intersect IBD.	
115	MTSP	Alice Eastwood Rd	SC	30	ML	1. Excavate crossing top to bot. 2. Replace culvert with 24" at natural channel grade. 3. Install critical dip to the left. 4. Install 4 rolling dips right. * 2 extra dozer hours added for rolling dips.	
115.2	MTSP	Alice Eastwood Rd	SC	60	M	1) Excavate channel across old road bench above sure to capture flow from both channel forming into one 35x5x20=129 yd. spoil to left. 2) Excavate channel down road to reestablish drainage for stream. 3) Install 7 rolling dips to left road.	

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Site #	Responsible Agency[2]	Road	Site Type[3]	FE[4]	TI[5]	Comment on treatment[6]	Work[7] Completed
115.3	MWNM	Alice Eastwood Rd	RSDP	15	L	Install 3 rolling dips that intersect ditch	
115.4	MTSP	Alice Eastwood Rd	DRC	14	M	1. Outslope Alice Eastwood road approach at 500'. 2. Outslope Camp Eastwood driveway 500' max.	
116	MTSP	Sierra Trail	RSDP	11	L	Install 5 cross road drains.	
117	Marin County/MMWD	Panoramic Highway	Other	5	L	1. Breach curb on parking lot.	
118	Marin County/MMWD	Panoramic Highway	DRC	34	HM	1. Install 3 rolling dips up ridge spur. 2. Install one DRC on paved fire station road.	Y
118.1	Marin County/MMWD	Panoramic Highway	DRC	0		No treatments recommended.	
119	Marin County/MMWD	Panoramic Highway	DRC	88	HM	1. Install DRC to right and left. * Additional hours added due to larger excavation needed.	Y
120	Marin County/MMWD	Panoramic Highway	DRC	15	L	1. Replace 10' of outlet. 2. Add 10' downspout with angled coupler. 3. Clean inlet (be sure to drain pond water)	
121	Marin County/MMWD	Panoramic Highway	SC	611	ML	1. Replace with 30" CMP and align with centerline. 2. Excavate top to 25' down to OBF. 3. Install 30' downslope to BOT.	
122	Marin County/MMWD	Panoramic Highway	SC	431	ML	1. Excavate top to bottom. 2. Replace culvert with 24".	
123	Marin County/MMWD	Panoramic Highway	DRC	20	ML	1. Replace crushed section of DRC outlet. 2. Install one more DRC to the right.	
124	Marin County/MMWD	Panoramic Highway	DRC	30	ML	1. Replace with 18" lower infill.	
125	Marin County/MMWD	Panoramic Highway	SC	2504	M	1. Excavate top to bottom. 2. Replace culvert with 84" at natural channel grade. 3. Install flared inlet. 4. Install trash rack.	
126	Marin County/MMWD	Panoramic Highway	SC	247	L	1. Excavate xing Top to bottom. 2. Replace culvert in natural channel. *import of 81 yd3 needed with 30 degrees fillslope (OBF to Bot) 100' culvert. **308 yd3 back fill with 35 degree fillslope 80' culvert.	
127	Marin County/MMWD	Panoramic Highway	DRC	41	HM	1. Install 2 DRCs to the right	
128	Marin County/MMWD	Panoramic Highway	SC	1024	ML	1) Excavate crossing Top to Bot. 2) Replace culvert with 60" at natural channel grade. 3) Install a DRC to the right.	
129	Marin County/MMWD	Panoramic Highway	SC	372	HM	1. Excavate xing top to bottom. 2. Replace CMP in line with natural channel and @ grade. 3. Install 2 PRC to right road.	Y
130	Marin County/MMWD	Panoramic Highway	SC	251	ML	Excavate crossing top to 15' down OBF. Replace culvert with 42". Install 20' full round downspout. Excavation will require negotiation around many redwoods.	
131	Marin County/MMWD	Panoramic Highway	SC	188	L	1. Excavate top to 15' down fillslope. 2. Replace culvert with 30". 3. Install 20' downspout to bottom. 4. Install DRC to the right.	
132	Marin County/MMWD	Panoramic Highway	SC	614	M	1. Excavate xing top to 25' down. 2. Install 24" CMP in natural channel. 3. Install downspout about 50'	
133	Marin County/MMWD	Panoramic Highway	DRC	22	M	1. Install an 18" DRC to the right.	
134	Marin County/MMWD	Panoramic Highway	DRC	13		No treatments recommended.	

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Site #	Responsible Agency[2]	Road	Site Type[3]	FE[4]	TI[5]	Comment on treatment[6]	Work[7] Completed
135	Marin County/MMWD	Panoramic Highway	SC	97	L	1. Plug ditch just to left to help prevent diversion to the left. (Build up headwall) 2. Install one DRC to the right (Don't outlet over unstable fillslope.)	
136	Marin County/MMWD	Panoramic Highway	SC	117	L	1. Excavate xing from top to bottom. 2. Install 24" CMP at natural channel grade, align with natural channel.	
137	Marin County/MMWD	Panoramic Highway	SC	1713	HM	1. Excavate crossing top to bottom. @. Replace culvert with 54" at natural channel grade/	
138	Marin County/MMWD	Panoramic Highway	DRC	33	M	Replace existing DRC	
139	Marin County/MMWD	Panoramic Highway	DRC	30	H	1. Install 4 DRC to right road deep in fill.	
140	Marin County/MMWD	Panoramic Highway	SC	376	M	1. Excavate top to bottom. 2. Replace culvert with 54" at natural channel grade. 3. Install flared inlet. 4. Install trash rack/	
141	Marin County/MMWD	Panoramic Highway	SC	394	HM	1. Replace existing CMP with 72" CMP with flared inlet. 2. Maintain right ditch to capture spring flow. **production rate lower due to large boulders	
142	Marin County/MMWD	Panoramic Highway	SC	189	ML	1. Excavate top to bottom. 2. Replace culvert with 24" at natural channel, being sure to capture flow from both channels and boulder. 3. Install one DRC to the right.	
143	Marin County/MMWD	Panoramic Highway	DRC	89	HM	1. Install 10' downspout on existing DRC. Clean DRC and install ditch plug here. 2. Install 1 new DRC to right road. Low infill. Install ditch plug here. 3. Install ditch plug on 2nd existing DRC to right.	
144	Marin County/MMWD	Panoramic Highway	SC	244	M	1. Excavate crossing top to bottom. 2. Replace culvert with 24" at natural channel. 3. Install ditch plug at DRC to the right. **Backfill volume assumes rebuild will be to existing fillslope specs	
145	Marin County/MMWD	Panoramic Highway	DRC	11	ML	1. Replace existing DRC with 24". Be sure ditch is plugged to the left.	
146	Marin County/MMWD	Panoramic Highway	SC	155	M	1. Excavate top to bottom. 2. Replace with 24"CMP. **backfill volume assumes -37 degree fillslope to bottom	
147	Marin County/MTSP	Panoramic Highway	SC	179	ML	1. Excavate crossing top to bottom. 2. Replace culvert with 24" of natural channel grade. **rebuild with existing fillslope ~35 degrees.	
148	Marin County/MTSP	Panoramic Highway	DRC	7	ML	1. Replace DRC with 24"	
149	Marin County/MTSP	Panoramic Highway	SC	97	M	1. Excavate crossing top to bottom. 2. Replace culvert with 54" at natural channel. 3. Will need to rebuild similar concrete wall structure to capture overbank flow on the left. 4. Excavate notch in IBD (or plug) to capture IBD flow from the right and place flow into the left basin.	
150	Marin County/MTSP	Panoramic Highway	SC	0		No treatments recommended.	
151	Marin County/MTSP	Panoramic Highway	SC	129	M	1. Install 20' downspout to outlet. 2. Clean inlet basin. 3. Install one DRC to the right.	
152	Marin County/MTSP	Panoramic Highway	SC	234	HM	1. Excavate top to bot. 2. Replace culvert with 24" at natural channel.	
153	Marin County/MTSP	Panoramic Highway	SC	234	M	1. Excavate top to bot. 2. Replace culvert with 24" at natural channel.	
154	Marin County/MTSP	Panoramic Highway	SC	215	HM	1. Install ditch plug to existing DRC. 2. Clean existing DRC to right. 3. Install 18" DRC to right with ditch plug. 4. Remove berm for 500' to the right.	

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Site #	Responsible Agency[2]	Road	Site Type[3]	FE[4]	TI[5]	Comment on treatment[6]	Work[7] Completed
155	Marin County/MTSP	Muir Woods Rd	SC	14	ML	1. Excavate xing 2. Replace with 30" CMP. 3. Rolling dip fire trail so that is drains to no delivery DRC to right.	PLANNED
156	Marin County/MTSP	Muir Woods Rd	DRC	7	ML	1. Clean existing DRC inlet. 2. Install one DRC to the left.	PLANNED
157	Marin County/MTSP	Muir Woods Rd	SC	238	M	1. Excavate xing. Replace with 48" CMP. Excavate old xing 40" up channel. Store spoils locally (~40 yds.) (easy access to left, move 3 large boulders).	PLANNED
158	Marin County/MTSP	Muir Woods Rd	DRC	6		No treatments recommended.	PLANNED
159	Marin County/MTSP	Muir Woods Rd	SC	104	HM	1. Excavate top to bot. 2. Replace culvert with 30" at base of fill. Spoil~700' to right. Rebuild with road width and 35 degrees fillslope to bot. Do not encroach into channel any more than existing footprint.	PLANNED
160	Marin County/MTSP	Muir Woods Rd	DRC	2		No treatments recommended.	PLANNED
161	Marin County/MTSP	Muir Woods Rd	SC	253	ML	1. Excavate TOP to BOT. 2. Replace CMP with 96" at grade and must function for fish passage	Y
162	Marin County/MTSP	Muir Woods Rd	DRC	2	L	clean inlet and outlet	PLANNED
163	Marin County/MTSP	Muir Woods Rd	SC	103	M	1. Excavate top to Bot. 2. Replace culvert with 24' at base of fill.	PLANNED
164	Marin County/MTSP	Muir Woods Rd	SC	38	ML	1. Excavate xing top to Bot. 2. Replace pipe with 24" CMP lower in fill.	PLANNED
165	Marin County/MTSP	Muir Woods Rd	SC	12		No treatments recommended.	
166	Marin County/MTSP	Muir Woods Rd	DRC	2	L	clean inlet	PLANNED
167	Marin County/MTSP	Muir Woods Rd	SC	205	M	1. Excavate crossing top to Bot. 2. Replace culvert with 60" at base of fill. *entered as 166	PLANNED
168	Marin County/MTSP	Muir Woods Rd	SC	18	L	1. Install an 18" DRC to left. This DRC should be outlet onto floodplain of Redwood CR.	
169	Marin County/MTSP	Muir Woods Rd	SC	28		No treatments recommended.	
170	MTSP	Diaz Ridge Rd	RSDP	24	ML	1. Install one rolling dip at low spot where road drainage currently exits road. 2. Install 2 rolling dips to the right. 3. Install 2 rolling dips to the left. (This will require extra time from backhoe, due to thru-cut [2 hrs.])	Y
171	MTSP	Diaz Ridge Rd	RSDP	13	L	1. Install rolling dip at current outlet location. 2. Install rolling dip to left.	Y
172	MTSP	Diaz Ridge Rd	RSDP	99	ML	1. Install 1 rolling at current outlet location. 2. Install 7 rolling dips on left approach. 3. Build road realignment left or right and use spoils to recontour thru-cut.	Y
173	GGNRA	Diaz Ridge Rd	RSDP	71		No treatments recommended. (thru-cut)	
174	GGNRA	Diaz Ridge Rd	RSDP	24	M	1. Outslope and remove ditch for 400' uphill from exit. 2. Add 2 rolling dips to right road (uphill).	Y
175	MTSP	Coastal Fire Rd	RSDP	25	ML	Add (5) rolling dips to left road	Y
176	MTSP	Deer Park Rd	DRC	4	ML	1. Install a rolling dip a current DRC location. 2. Outslope road with no IBD as shown on sketch.	PLANNED
176.1	MTSP	Pan Toll Ranger Rd	RSDP	19	M	1. Outslope left approach with no IBD 2. Install one rolling dip at site and one to the left. 3. Install 3 cross road drains on abandoned road above.	

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Site #	Responsible Agency[2]	Road	Site Type[3]	FE[4]	TI[5]	Comment on treatment[6]	Work[7] Completed
176.2	MTSP	Pan Toll Ranger Rd	RSDP	23		No treatments recommended.	
176.3	MTSP	Pan Toll Ranger Rd	DRC	37	M	1. Install a rolling dip 220' to the right that captures IBD flow and sends it out of watershed. 2. Technically left road should be dipped to disperse road runoff but it is paved.	
177	MWNM	Deer Park Rd	RSDP	29	M	1. Outslope and remove ditch for 1570' of left road. 2. Install 6 rolling dips to left hand.	
178	MTSP	Deer Park Rd	RSDP	5	L	1. Install 1 rolling dip at existing DRC. 2. Install 3 rolling dips to right road.	PLANNED
180	MTSP	Camino del Canyon	SC	55	HM	1. Excavate 15' top to smooth transition (15'x4'x2~~4 yd3) 2. Excavate top to Bot. 3. Install 24" CMP at natural channel grade. 4. Install one rolling dip to right road. 5. Outslope road from rolling dip to right road. 6. Outslope road from rolling dip to CLP. 7. Install dip on left hinge. 8. Rerock road.	
181	MTSP	Camino del Canyon	RSDP	52	HM	1. Outslope road with no IBD for 700' right. 2. Install 2 rolling dips to right.	
182	MTSP	Camino del Canyon	SC	113	HM	1) Excavate TOP to BOT. 2) Replace culvert with 36" set at base of fill. 3) Outslope right approach with no IBD. 4) Inslope 10' to right and left of CLP to drain towards inlet.	
183	MTSP	Camino del Canyon	RSDP	21	ML	1. Outslope road for 340' (no ditch).	
184	MTSP	Camino del Canyon	DRC	27	L	1. Outslope road for 225' (no ditch)	
185	MWNM	Camino del Canyon	SC	147	H	1. Excavate top to Bot. 2. Replace culvert with 60" at base of fill. 3. Install critical dip to right. 4. Build up inboard berm to capture runoff at inlet (at right). Rebuild with 35 degree fillslope. *import 75 yds3	
186	MWNM	Camino del Canyon	RSDP	15	ML	Outslope road to the right and left	
187	MWNM	Camino del Canyon	SC	211	ML	1) Excavate crossing Top to Bot. 2) Install 24" CMP with 30' downspout to inboard ditch of lower driveway. 3) Outslope and remove ditch for 155'. 4) Decommission lower crossing, re-establish lower channel, lay back slopes 2:1, store spoils locally on landing (8x5x40)= 50 yds.	
188	MWNM	Camino del Canyon	SC	76	HM	1. Excavate TOP to BOT. 2. Excavate stable transition from BOT to LES. 3. Excavate extra material (slide deposit and deposition) for 30' below BOT (10*7*30=78 yds3). 4. Endhaul material right 400' to turnout. 5. Replace pipe with 36" at base of fill. 6. Outslope road with no inboard ditch 540' to right. 7. Install 2 rolling dips to right.	
189	MWNM	Camino del Canyon	LS	111	M	1) Excavate failing perched fill adjacent to stream. 75x2x20=111 End haul to turnout to right ~400'	
190	MWNM	Camino del Canyon	SC	105	M	1) Excavate top to bot. 2) Replace culvert with 30" at base of fill. 3) Outslope road with no IBD 870' to the right. 4) Install critical dip to left. 5) Install 3 rolling dips to right.	
191	MWNM	Camino del Canyon	RSDP	3	L	Outslope left and right approach 370' total.	
192	MWNM	Camino del Canyon	RSDP	43	ML	1. Outslope without IBD driveways that contribute to site (see sketch). 2. Install 3 rolling dips up 720' driveway. 3. Install one rolling dip at 175' driveway and 270' road reach.	
193	MWNM	Old Service Rd	LS	417	M	1. Excavate unstable fill 150x3x25'=417 yd3 2. End haul to Muir Woods parking area, temporary outslope road after excavated.	Y
194	MWNM	Old Service Rd	SC	432	H	1) Excavate crossing from top to bot. 2) Reestablish channel with 2:1 sideslopes, 6' wide.	Y
195	MWNM	Old Service Rd	LS	347	ML	1. Excavate unstable fill beginning at right hinge of site #195 (125'x3'x25'=347 yd3). 2. Endhaul spoils to Muir Woods parking area…temporarily. 3. Outslope length of road.	Y
196	MWNM	Old Service Rd	DRC	10	L	Install 3 rolling dips to left road	Y
197	MWNM	Muir Woods Service Rd	SC	24	ML	1) Excavate crossing from top to bot. 2) Install 42" CMP. 3) Repave	
198	MWNM	Muir Woods Service Rd	SC	73	L	Excavate top to bot. Replace culvert with 42" at grade.	
199	MWNM	Conlon Ave	SC	189	M	1. Excavate crossing top to Bot. 2. Lay back banks 2 to 1. 3. Spoil to right (will not be able to lay back left bank without undercutting foundation of home.	
200	MWNM	Conlon Ave	SC	624	M	1) Install flared inlet to existing CMP inlet. 2) Install new trash rack. 3) Maintain dip to left that acts as overflow channel.	

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Site #	Responsible Agency[2]	Road	Site Type[3]	FE[4]	TI[5]	Comment on treatment[6]	Work[7] Completed
201	MWNM	Conlon Ave	SC	31	ML	1. Excavate crossing top to Bot. 2. Replace culvert with 54" at base of fill. 3. Construct critical dip to right. 4. Install cross road drain to right. (be sure to catch spring flow)	
202	MWNM	Conlon Ave	DRC	30	M	1. Outslope road and remove IBD for 400' 2. Install 3 rolling dips along road reach. 3. Remove DRC midway along road reach. (There is a wooden remaining wall that will have to be worked around [maintain IBD along length of retaining wall]). 4. Install new DRC at end of reach aligned perpendicular to driveway.	
203	MWNM	Conlon Ave	SC	45	H	Excavate crossing top to bot. Install 60"x40' CMP at natural channel grade (culvert needs to realigned in direction of natural flow). Install trash rack. Outslope and remove IBD 150' driveway to the right. Install cross road drain at top of driveway to capture spring flow. Install critical dip at crossing.	
204	MWNM	Conlon Ave	SC	91	H	1. Excavate fill in crossing top to Bot. Replace culvert with 60" CMP and add trash rack. Armor downstream fill face with 30yd, 0.75--1.25' diameter rip-rap	Y
205	MWNM	Conlon Ave	SC	172	H	1. Excavate crossing top to Bot, laying back banks 2 to 1. 2. Stockpile spoils locally (two large bay tress need to be removed for excavation (1 hr labor, 1 person)	
206	MTSP	Deer Park Fire Rd	DRC	32	ML	1. Maintain ditch for first 350' to right. 2. Outslope and remove ditch for 1360' to right road. 3. Replace existing DRC with 18". 4. Install 3 rolling dips to right.	PLANNED
207	MTSP	Deer Park Fire Rd	RSDP	17	L	1. Outslope and remove ditch for 500' to right road. 2. Install rolling dip to right road. 3. Start outslope treatment 150' right road.	PLANNED
208	MTSP	Deer Park Fire Rd	DRC	29	ML	1) Replace DRC with 18" 2) Install rolling dips to 1480' left road. 3) Dips across Dipsea Tr.	PLANNED
209	MTSP	Deer Park Fire Rd	SC	7	M	1) Excavate top to Bot. 3) Replace culvert with 24" at base of fill. 3) Install critical dip to left. 4) Install 3 rolling dips to right. 5) Excavate 20' above top to create stable transition, remove berm on rebuild. Raise road 1' on rebuild. Stockpile locally.	PLANNED
210	MTSP	Deer Park Fire Rd	DRC	5	ML	1) Replace existing DRC with 18". 2) Outslope road and retain IBD for 100' to right retain ditch for another 50' to capture spring into IBD. **This ousloping will involve significant berm removal. Some of this material can be side casted but special care should be taken to not sidecast near stream.	PLANNED
211	MTSP	Deer Park Fire Rd	DRC	12	ML	1) Install rolling dip instead of DRC. 2) Install 2 dips to left road.	PLANNED
212	MTSP	Deer Park Fire Rd	DRC	28	M	1) Outslope road and remove IBD on left approach. (This will involve removal of 4 DRCs) (4 backhoe hours). 2) Install 4 rolling dips to the left.	PLANNED
213	MTSP	Deer Park Fire Rd	DRC	44	M	1) Replace 18" DRC with 18" lower in fill. 2) Install 2- 18" DRCs low in fill to left of road. 3) Outslope and retain ditch for 400' of left road.	PLANNED
214	MTSP	Deer Park Fire Rd	DRC	10	ML	1) Outslope and remove IBD for 280' left. 2) Install a rolling dip at DRC.	PLANNED
215	MTSP	Deer Park Fire Rd	SC	52	HM	1) Excavate crossing top to Bot. 2) Replace culvert with 36" at base of fill. 3) Install critical dip to right. 4) Outslope road with no IBD to left. 5) Install 2 rolling dips left. (import 9 yds. for 30 degree fillslopes)	PLANNED
216	Marin County/MTSP	Muir Woods Rd	DRC	13	HM	1) Install 18" CMP low in fill. 2) Install 10" downspout	PLANNED
217	Marin County/MTSP	Muir Woods Rd	SC	40	L	1) Excavate top to Bot. 2) Replace culvert with 24" at base of fill.	PLANNED
218	Marin County/MTSP	Muir Woods Rd	SC	36	ML	1) Excavate top to Bot. 2) Replace culvert with 24" at base of fill. 3) Install an 18" DRC to the right. (rebuild with existing fillslopes	PLANNED
219	Marin County/MTSP	Muir Woods Rd	DRC	9		No treatments recommended.	
220	Marin County/MTSP	Muir Woods Rd	DRC	4		No treatments recommended.	

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221	Marin County/MTSP	Muir Woods Rd	SC	23		No treatments recommended.	
222	Cal Trans/GGNRA	HWY 1	DRC	9	ML	1) Replace existing DRC with 18". 2) Install one DRC to the left.	
223	Cal Trans/GGNRA	HWY 1	DRC	3	L	Install 18" DRC to left road	`
224	Cal Trans/GGNRA	HWY 1	DRC	33	L	1) Replace existing DRC with 18" 2) Install DRC to the left.	
225	Cal Trans/GGNRA	HWY 1	DRC	7	ML	Install 1 DRC to left road	
226	Cal Trans/GGNRA	HWY 1	DRC	6	M	Install 18" DRC with 30' downspout at current DRC location	
227	Cal Trans/GGNRA	HWY 1	DRC	27	ML	Install an 18" DRC to the left	
228	Cal Trans/GGNRA	HWY 1	DRC	11		No treatments recommended.	
229	Cal Trans/GGNRA	HWY 1	DRC	13		No treatments recommended.	
230	Cal Trans/GGNRA	HWY 1	DRC	10		No treatments recommended.	
231	Cal Trans/GGNRA	HWY 1	SC	183	HM	1) Excavate top to Bot. 2) Replace culvert with a 30" at base of fill. 3) Install a flared inlet. 4) Install a DRC to the right. (remove berm on rebuild, rebuild to existing fillslopes)	
232	Cal Trans/GGNRA	HWY 1	DRC	3	M	1) Replace existing DRC with 24" CMP. 2) Replace existing CMP drop inlet. 3) Remove berm for 750' of right road.	
233	Cal Trans/GGNRA	HWY 1	SC	0		No treatments recommended.	
234	Cal Trans/MTSP	HWY 1	SC	150		No treatments recommended.	
235	Marin County/MTSP	Muir Woods Rd	DRC	100		No treatments recommended.	
236	GGNRA	Banducci Rd	SC	10	M	1) Excavate crossing from top to bot. 2) Replace existing with 30" CMP at natural channel grade. 3) Reestablish channel below outlet to edge of terrace, lay side slopes back 2:1 with 3.5' bottom. 4) Install rolling dip to right. Install critical dip.	
237	GGNRA	Banducci Rd	SC	8	ML	1) Excavate top to bot. 2) Replace culvert with 30" deeper infill. 3) Construct two broad rolling dips to the right to capture any flow out of Broad Valley. 4) Install 2 more rolling dips left.	Y
238	GGNRA	Banducci Rd	SC	26	M	1) Excavate top to Bot. 2) Replace culvert with a 36" at the base of fill. 3) Outslope right approach with no IBD.	Y
239	GGNRA	Banducci Rd	DRC	4	L	replace existing DRC with 18"	Y
240	GGNRA	Banducci Rd	SC	17	M	1) Excavate top to Bot. 2) Lay back banks 2 to 1.	
241	MTSP	Coastal Fire Rd	RSDP	0	L	1) Install 20 rolling dips at strategic locations to disperse runoff along the coastal fire road. This is for maintenance purposes.	Y
242	MMWD	Hogback Ridge Rd	RSDP	34	M	1) Outslope right approach up to Old RR grade. 2) Install 6 rolling dips along reach.	
245	MTSP	Kent Canyon Rd	SC	12	HM	1) Excavate crossing top to Bot. 2) Reestablish channel 4' Bot width, lay back slopes 2:1 3) Install cross roads drains to right road. 4) Spoil locally.	

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Site #	Responsible Agency[2]	Road	Site Type[3]	FE[4]	TI[5]	Comment on treatment[6]	Work[7] Completed
246	MTSP	Kent Canyon Rd	SC	91	M	1) Excavate top to Bot. 2) Lay back banks 2:1 3) Minimum channel width 4". 4) Excavate 20' above top to provide stable transition and to be sure to capture all flow from above. [6'x3'x20'=13 yd3] 5) Install 2 crossroad drains to right. Spoil locally. End haul some material to right.	
247	MTSP	Kent Canyon Rd	SC	32	L	1) Excavate top to Bot. 2) Lay back banks 2:1 3) Minimum 4' channel width. 4) Spoil locally to the left. 5) Install 2 cross road drains right.	
248	MTSP	Kent Canyon Rd	RSDP	52	M	1) Option 1: Outslope road with no IBD along 350' reach, heavy equipment would have to access road from above. 2) Option 2: Use hand labor to install at least 5 cross road drains.	
249	MTSP	Kent Canyon Rd	RSDP	150	HM	1) Outslope entire 670' road reach. This should be a severe decommission outslope. Will need to full gullied road with fill from out edge.	
250	MTSP	Kent Canyon Rd	SC	9	L	1) Install wet crossing [ford]. 2) Rock thru crossing with 6" rock. 3) Spoil locally. (EW - 50x18' = 900ft2)	
250.1	MTSP	Kent Canyon Rd	SC	241	ML	Excavate crossing top to bot. Lay back banks 2 to 1 and spoil locally. Lay back vertical bank of Kent Creek near confluence with this channel. 80x7x5=104yds.	
250.2	MTSP	Kent Canyon Rd	SC	129	ML	Excavate crossing top to bot laying back banks 2 to 1. Outslope skid approach to right after excavation is complete. Store spoils locally.	
250.3	MTSP	Kent Canyon Rd	SC	188	ML	Excavate crossing top to bot laying back backs 2 to 1. Outslope left approach skid after finished with access to sites 250.1 and 250.2. Store spoils locally	
251	GGNRA	Coastal South Rd	RSDP	24	M	1) Outslope road with no IBD (IPOS) 2) Install 3 rolling dips along reach.	
252	GGNRA	Coastal South Rd	SC	114	ML	1. Excavate TOP to BOT. 2. Replace both pipes with one 24". 3. Install critical dip to let road below crossing. 4. Outslope 350' of left road above crossing. 5. Install 2 rolling dips to left road above crossing.	Y
253	GGNRA	Coastal South Rd	RSDP	111	M	1) Install 30 functional rolling dips and these will be placed at short regular intervals on steep stretches. Also need trench OBF in certain locations to be sure that flow leaves road. (backhoe 15 hours)	Y
254	GGNRA	Coastal South Rd	RSDP	0	M	Install rolling concentrate in steeper areas. Smaller thru-cut areas will need berm removal	Y
255	GGNRA	Coyote Ridge Rd	RSDP	0	L	1) Install 10 rolling dips along road reach. May need to breach berm to allow water to outlet properly.	
256	GGNRA	Middle Green Gulch Rd	SC	40	M	1. Excavate xing TOP to BOT. 2. Replace culvert with 24" deeper in fill. Be sure to reestablish ditch to catch all flow. 3. Install critical dip to left hinge. 4. Install 15 rolling dips to right trail. 5. Rebuild with 40 degree fillslope.	Y
257	GGNRA	Middle Green Gulch Rd Middle Green Gulch	SP	18	M	1) Install 4 functional rolling dips. One of these should be a large broad dip at axis of swale.	Y
258	GGNRA	Middle Green Gulch Rd	SC	78	HM	1. Excavate xing TOP to BOT. 2. Replace with 30" CMP. 3. Rebuild road to 5' width to allow for foot, horse and bike traffic. 4. Install critical dip to right. 5. Install 6 rolling dips to left. 6. Endhaul extra spoils 2000' to right.	Y
259	GGNRA	Middle Green Gulch Rd Middle Green Gulch	LS	185	ML	1) Excavate unstable perched fill. 2) Place some spoils against cutbank to create 125'x2'x20'=185 yd3 outslope. 3) Endhaul remaining material to right. **Hours based on excavator.	Y
260	GGNRA	Middle Green Gulch Rd	SC	26	ML	1. Excavate xing TOP to BOT. 2. Install 24" culvert at base of fill. 3. Outslope 250' of left road with no inboard ditch.	Y
261	GGNRA	Middle Green Gulch Rd	SC	217	ML	1) Excavate crossing top to bot. 2) Replace with 24" pipe at natural channel. 3) Critical dip to right	Y
262	GGNRA	Green Gulch Rd	SC	33	M	1) Excavate top to Bot. 2) Replace culvert with 24" at base of fill. 3) Install critical dip to right. 4) Clean ditch to 50' to left. 5) Install 5 rolling dips to the left. ** Any extra spoil can be stored just above to the left.	

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Site #	Responsible Agency[2]	Road	Site Type[3]	FE[4]	TI[5]	Comment on treatment[6]	Work[7] Completed
263	GGNRA	Green Gulch Rd	SC	32	M	1) Excavate top to Bot. 2)	
264	GGNRA	Green Gulch Rd	DRC	15	ML	1) Outslope 25' to right. Reattach existing downspout. 2) Install 1 DRC to right road (capture all spring flow). 3) Cut ditch 25' to right of new DRC. 4) Outslope and remove ditch about 400' of right road (IPOS). 5) Install 3 dips to right road.	
265	GGNRA	Green Gulch Rd	DRC	67	HM	1) Outslope road with no IBD for 900' to right. 2) Install 4 rolling dips to right.	
266	GGNRA	Green Gulch Rd	LS	400	HM	1) Pull back unstable fill (135'x2'x25'=250yd3). 2) End haul to Green Gulch Farm below (2000')	
267	GGF	Green Gulch Parking Lot	SC	90	M	1) Excavate crossing TOP to BOT. 2) Reestablish channel with 8' bottom. 3) Lay back side slopes from TOP to BOT. Spoil to left.	
268	GGF	Green Gulch Driveway	SC	258	M	1) Install 36" CMP to right of concrete flume (near current 24" overflows). 2) Add 20' downspout to bot. Culvert base should be set lower than base of concrete flume so that flume functions as emergency overflow only. 3) Install 3 cross-road drains on abandoned road.	Y
269	GGF	Green Gulch Driveway	DRC	27	L	1) Replace existing DRC with 18". 2) Outslope and remove ditch for 1000' of dirt road (Green Gulch Rd). 3) Install 4 rolling dips to Green Gulch Rd to right. 4) Install 1 DRC to paved road to right (Green Gulch Driveway).	
270	GGNRA	Green Gulch Abandoned #1	SC	3	ML	1. Decommission site. 2. Excavate slide deposit. 3. Pull back sideslopes 2:1. 4. Spoil locally.	
270.1	GGNRA	Middle Green Gulch Rd	SC	23	L	1) Clean outlet and bottom of culvert.	Y
271	GGNRA	Green Gulch Abandoned #1	SC	3	L	1) Excavate crossing from TOP to BOT. 2) Lay back slopes 2:1 3) Spoil locally. 4) Install 3 crossroad drains to right approach.	
271.1	GGF	Green Gulch Driveway	SC	893		No treatments recommended.	
272	GGNRA	Green Gulch Abandoned #1	LS	133	M	1) Excavate unstable fill (40'x3'x25'=111 yd3). Endhaul 400' to left. 2) Inslope road for 240' to the right. 3) Install 240' right a DRC that captures spring flow. 4) Outslope left approach. 5) Install rolling dip left.	
273	GGF	Green Gulch Abandoned #2	DRC	10	ML	1) Outslope and remove ditch for 300' to right road. 2) Install 3 cross road drains to right road. **watch for domestic water supply lines.	
274	GGF	Green Gulch Driveway	DRC	6	L	Replace existing CMP, reattach it to existing functioning downspout.	
274.1	GGF	Green Gulch Spur Driveway #1	DRC	17	ML	1) Maintain ditch and outslope road for 150'. 2) Install 3 rolling dips to left road 450'. 3) Spoil locally.	
275	GGF	Green Gulch Driveway #1	RSDP	9	L	1) Install 3 DRCs to the right (this will need acceptance from Green Gulch Farm)	
300	MMWD	Rock Spring Tr.	RSDP	4	ML	1) Install 1 dip to right trail. Regular equipment access.	
301	MMWD	Rock Spring Tr.	SC	2	L	1. Install 2 dips right. 2. Armor outboard fill face (30ft2)	
302	MMWD	Rock Spring Tr.	SC	6	M	1) Excavate channel 1:1 below bridge.	
303	MMWD	Rock Spring Tr.	SC	1	L	1) remove boulder under bridge	
304	MMWD	Rock Spring Tr.	SC	1		No treatments recommended.	
305	MMWD	Rock Spring Tr.	SC	1	L	1) Install 1 rolling dip to right. 2) Rock 7' of right approach (5x7=35 sq.ft.) for foot traffic.	
306	MMWD	Rock Spring Tr.	SC	4	ML	1) Re-establish channel through crossing. 2) Be sue to build up right bank sufficiently to prevent diversion down trail. 3) Install 1 dip to left approach. Labor hours will include dam removal and step removal.	
307	MMWD	Rock Spring Tr.	SC	1	L	1) Install 1 dip to right and one to left. 2) Pull back fill on left channel. 3) Strategic rock placement to prevent flow to left	
308	MMWD	Rock Spring Tr.	SC	1	L	1) Excavate soil (4x3x5) = 2 yds.	
309	MMWD	Rock Spring Tr.	RSDP	18	M	1) Install 19 cross road drains to left road. 2) Install permanent trail drains.	

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Site #	Responsible Agency[2]	Road	Site Type[3]	FE[4]	TI[5]	Comment on treatment[6]	Work[7] Completed
310	MMWD	Rock Spring Tr.	SC	2	ML	1) Repair armored fill crossing on OBF. 2) Install 7 rolling dips to right trail. 3) Outslope 360' of right trail.	
311	MMWD	Rock Spring Tr	SC	2	M	1) Remove existing bridge and armored footings. Install 15' bridge 5' downstream.	
312	MMWD	Nora Tr	SC	1	L	1) Install 15 dips to right trail.	
313	MMWD	Nora Tr	SC	1	L	1) one rolling dip to left	
314	MMWD	Nora Tr	SC	1	L	1) Install 10 rolling dips to right at 30' intervals.	
315	MMWD	Matt Davis Tr	SC	0		No treatments recommended.	
316	MMWD	Matt Davis Tr	SC	0		No treatments recommended.	
317	MMWD	Matt Davis Tr	SC	1	ML	1) Excavate crossing Top to Bot. 2) Install ford. 3) Lay back sides 2:1.	
318	MMWD	Matt Davis Tr	SC	1	L	1) Excavate soil Top to Bot. 2) Install ford. 3) Install 6 rolling dips left. 4) Install 5 rolling dips right.	
319	MMWD	Matt Davis Tr	SC	0		No treatments recommended.	
320	MMWD	Matt Davis Tr	SC	1	M	1) Outslope trail. 2) Install 7 dips to right trail.	
321	MMWD	Matt Davis Tr	SC	0		No treatments recommended.	
322	MMWD	Matt Davis Tr	SC	1		No treatments recommended.	
323	MMWD	Matt Davis Tr	SP	1	M	rock trail (30x4=120 ft2)	
324	MMWD	Matt Davis Tr	SC	2	ML	1) Install 2 cross trail drains to the right	
325	MTSP	Troop 80 Trail	Ditch	5	L	Install 17 rolling dips to right trail.	
326	MTSP	Troop 80 Trail	SC	0		No treatments recommended.	
327	MTSP	Troop 80 Trail	SC	0		No treatments recommended.	
328	MTSP	Troop 80 Trail	DRC	3	L	Install 9 rolling dips to right trail	
329	MTSP	Troop 80 Trail	SC	1	L	Install 5 dips to left 150'	
330	MTSP	Troop 80 Trail	SP	4	L	outslope right trail 25'	
331	MTSP	Troop 80 Trail	SP	4	L	Excavate pipe. Rock trail thru crossing	
332	MTSP	Troop 80 Trail	SC	1	L	Install 3 dips to right trail and 2 dips to left trail	
333	MTSP	Troop 80 Trail	Gully	0		No treatments recommended.	
334	MTSP	Troop 80 Trail	SC	1	L	1) Lower outboard road. 2) Install 1 dip to right. 3) Install 2 dip to left.	
335	MTSP	Troop 80 Trail	SC	1	L	Install 2 dips left trail.	
336	MTSP	Troop 80 Trail	SC	0		No treatments recommended.	
337	MTSP	Troop 80 Trail	RSDP	75	L	Add 10 rolling dips to right 300'.	
338	MTSP	Troop 80 Trail	SC	1	L	Install 4 dips to left trail	
339	MTSP	Troop 80 Trail	SC	1	ML	Raise existing bridge (1-2'). Install 3 dips right trail.	
340	MTSP	Troop 80 Trail	SC	1	ML	1) Raise bridge (1-2') 2) clean out 1.5' boulder. 3) Install 3 dips right trail 6.	
341	MTSP	Troop 80 Trail	SC	0		No treatments recommended.	
342	MTSP	Troop 80 Trail	SC	0		No treatments recommended.	
343	MTSP	Boot Jack Trail	SC	3	L	replace with 24" at channel grade	Y
344	MTSP	Boot Jack Trail	SC	1	ML	lower outboard fill	Y
345	MTSP	TCC Trail	SC	0		No treatments recommended.	
346	MTSP	TCC Trail	SC	3	L	Install 6 dips right trail and 6 dips left trail	
347	MTSP	TCC Trail	SC	0		No treatments recommended.	
348	MTSP	TCC Trail	SC	1	L	pull pipe with ford	
349	MTSP	TCC Trail	SC	1	L	ford crossing	

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Site #	Responsible Agency[2]	Road	Site Type[3]	FE[4]	TI[5]	Comment on treatment[6]	Work[7] Completed
351	MMWD	Thock Morton Fire Trail	Gully	370	ML	Use hand labor to create 15 cross road drains at specific locations.	
352	MMWD	Fern Creek Trail	SC	0		No treatments recommended.	
353	MMWD	Fern Creek Trail	Other	14	M	1) Install shut off valve on to water tank. 2) Replace input pipe so that water does not flow down the trail. 3) Hand dig 3 cross road drains to the left.	
354	MMWD	Tavera Pump Trail	SC	0		No treatments recommended.	
355	MMWD	Tavera Pump Trail	SC	3		No treatments recommended.	
356	MMWD	Miller Trail	SC	14	ML	1) Hand dig 10+ cross road drains up trial from road drains.	
357	MMWD	Miller Trail	SC	0		No treatments recommended.	
358	MMWD	Miller Trail	SC	0		No treatments recommended.	
359	MMWD	Miller Trail	SC	123	M	Excavate a more defined channel using hand labor. Will need chain saw and largest hand equipment available.	
360	MMWD	Hoo-Koo-E Trail	SC	5	L	Hand labor (install 8 cross drains to the left)	
361	MMWD	Matt Davis Trail	SC	0		No treatments recommended.	
361.1	MMWD	Nora Trail	SC	0		No treatments recommended.	
362	MMWD	Matt Davis Trail	SC	3	L	Install 3 trail drains to the right	
363	MMWD	Matt Davis Trail	SC	1		No treatments recommended.	
364	MMWD	Matt Davis Trail	SC	0		No treatments recommended.	
365	MMWD	Matt Davis Trail	SC	16		No treatments recommended.	
366	MMWD	Matt Davis Trail	SC	133	H	1) Excavate remaining fill top to bot. 2) Use extra spoils for enhanced outslope on approach.	
367	MTSP	Matt Davis Trail	SC	0		No treatments recommended.	
368	MTSP	Matt Davis Trail	SC	1	L	Install 1 trail drains to the left	
369	MTSP	Bootjack Trail	SC	17		No treatments recommended.	Y
370	MTSP	Bootjack Trail	SC	1	ML	1) Use hand labor to remove existing fill and create ford crossing.	Y
371	MTSP	Bootjack Trail	SC	2	ML	Use hand labor to excavate fill and create ford crossing.	Y
372	MTSP	Bootjack Trail	SC	1	ML	Excavate fill at both channels to allow drainage (install ford)	Y
373	MTSP	Easy Grade Trail	SC	1	M	1) Install 2 broad rolling dips to the right of crossing to capture seepage and place into channel. 2(8x2x10) to excavate. Use hand labor	
374	MTSP	Old Mine Trail	SC	1		No treatments recommended.	
375	MTSP	Easy Grade Trail	SC	0		No treatments recommended.	
376	MTSP	Matt Davis Trail	SC	1	L	Use hand labor to excavate and establish more permanent dip.	
377	MTSP	Matt Davis Trail	SC	1		No treatments recommended.	
378	MTSP	Matt Davis Trail	SC	1		No treatments recommended.	
379	MTSP	Fern Creek Trail	SC	4		No treatments recommended.	
380	MTSP	Fern Creek Trail	SC	1		No treatments recommended.	
381	MTSP	Fern Creek Trail	SC	3		No treatments recommended.	
382	MTSP	Fern Creek Trail	SC	0		No treatments recommended.	
383	MTSP	Dipsea Trail	RSDP	44	M	1) Install up to 12 trail drains or dips to the right of outlet gully. 2) Install 3 more dips to the left to disperse trail drainage before reaching swale.	PLANNED
384	MTSP	Dipsea Trail	RSDP	27	M	1) Install up to 10 trail dips to the right of delivery location. 2) Install one to the left. (Bobcat work)	PLANNED
385	MTSP	Dipsea Trail	RSDP	10	ML	1) Install 7 trail drains or dips to the right and one at site.	PLANNED

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Site #	Responsible Agency[2]	Road	Site Type[3]	FE[4]	TI[5]	Comment on treatment[6]	Work[7] Completed
386	MWNM	Dipsea Trail	RSDP	46	M	1) Install up to 30' trail drains (dips). **The upper segment may be accessible with Bobcat with heavy ground disturbance. The lower portion of trail will be hard labor only.	
387	MTSP	Fern Creek Trail	SC	2	ML	1) Use hand labor to excavate larger critical dip just beyond armored fill to prevent any high flow diversion. 2) Use hand labor to redistribute alluvial sediments in channel below bot. Currently flow is forced to the left and right causing bank erosion. Redistribute sediments to create more 'V' shaped channel. 3) Install 3 rolling dips right.	PLANNED
388	MTSP	Fern Creek Trail	SC	0		No treatments recommended.	
389	MTSP	Fern Creek Trail	SC	0		No treatments recommended.	
390	MWNM	Fern Creek Trail	SC	2	L	Use hand labor to better define channel thru fan and across trail to help prevent diversion down trail.	
391	MWNM	Fern Creek Trail	SC	0		No treatments recommended.	
392	MWNM	Hillside Trail	SC	0		No treatments recommended.	
393	MWNM	Hillside Trail	SC	1		No treatments recommended.	
394	MWNM	Hillside Trail	SC	2		No treatments recommended.	
395	MWNM	Hillside Trail	SC	2		No treatments recommended.	
396	MWNM	Muir Woods Trail	SC	0		No treatments recommended.	
397	MWNM	Muir Woods Trail	SC	7		No treatments recommended.	
398	MWNM	Muir Woods Trail	SC	0		No treatments recommended.	
399	MWNM	Muir Woods Trail	SC	0		No treatments recommended.	
400	MTSP	TCC Trail	SC	1	L	2 dips left trail	
401	MTSP	TCC Trail	SC	1		No treatments recommended.	
402	MTSP	TCC Trail	SC	0		No treatments recommended.	
403	MTSP	TCC Trail	SC	0		No treatments recommended.	
404	MTSP	TCC Trail	SC	1	L	1 dip left trail	
405	MTSP	Alpine Trail	SC	3	L	Install up to 40 dips to right	
406	MTSP	Alpine Trail	SC	0		No treatments recommended.	
407	MTSP	Alpine Trail	SP	1	ML	1) Rock 20' on right approach. 2) Rock 20' on left approach. 3) Install 1 dip 20' to left (into old stream channel). 4) Install 3 or more large rocks to capture spring flow from right (from local source). (Extend rocks towards Panoramic)	
408	MTSP	Bootjack Trail	SC	0		No treatments recommended.	Y
409	MTSP	Bootjack Trail	SC	2	L	1) Install 5 dips to right (where possible). 2) Armor class 2 to right. (1 hour labor, rocks readily available)	Y
410	MTSP	Bootjack Trail	SC	0		No treatments recommended.	Y
411	MTSP	Bootjack Trail	SC	1	L	1 dip to left	Y
412	MTSP	Troop 80 Trail	DRC	1	M	1. Excavate TOP to BOT. 2. Pull pipe. 3. Remove trail where currently ditched (~55 ft.). 4. Spoil locally.	
413	MTSP	Troop 80 Trail	RSDP	5	L	1. Decommission 400' of trail segment. 2. Outslope and remove ditch for approximately 500'. Install 25 cross trail drains every 10 or 15'.	
414	MTSP	Bootjack Trail	RSDP	12	M	Inplace outslope 1250' abandoned trail. Hand labor.	Y
415	MTSP	Bootjack Trail	SC	1	ML	1. Install ford. 2) Lay sides back 1:1	Y
416	MTSP	Bootjack Trail	SC	1	L	1 dip to left (mid stairs)	Y
417	MTSP	Bootjack Trail	SC	1	L	Excavate to establish channel through crossing removing wooden culvert.	Y
418	MTSP	Bootjack Trail	SC	0		No treatments recommended.	Y
419	MTSP	Bootjack Trail	SC	0		No treatments recommended.	Y
420	MTSP	Bootjack Trail	SC	0		No treatments recommended.	Y
421	MTSP	Bootjack Trail	SC	2	L	*raise bridge 1-2' if possible.	Y

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Site #	Responsible Agency[2]	Road	Site Type[3]	FE[4]	TI[5]	Comment on treatment[6]	Work[7] Completed
422	MTSP	Bootjack Trail	SC	0		No treatments recommended.	Y
423	MTSP	Bootjack Trail	SC	0		No treatments recommended.	Y
424	MWNM	Bootjack Trail	SC	2	L	7 dips to right trail	
425	MWNM	Ben Johnson Trail	SC	0		No treatments recommended.	
426	MWNM	Ben Johnson Trail	SC	0		No treatments recommended.	
427	MWNM	Ben Johnson Trail	SC	0		No treatments recommended.	Y
428	MWNM	Ben Johnson Trail	SC	1	ML	1) Lower OBF 2". 2) Install 3 road drains to the left.	
429	MWNM	Ben Johnson Trail	SC	0		No treatments recommended.	
430	MWNM	Ben Johnson trail	SC	1	M	Above the site, where the flow splits, trench to direct as much flow as possible to the bridge. Plug, pull or put an elbow on the metal pipe to stop or direct flow into channel. Excavate 6" clay pipe and replace with 12" CMP at base of fill. Direct all flow into original channel below.	PLANNED
431	MTSP	Stapelveldt Trail	SC	0		No treatments recommended.	
432	MTSP	Stapelveldt Trail	SC	0		No treatments recommended.	
433	MTSP	Stapelveldt Trail	SC	1	L	10dips to left trail (or water bars)	
434	MTSP	Stapelveldt Trail	SC	0		No treatments recommended.	
435	MTSP	Stapelveldt Trail	SC	0		No treatments recommended.	
436	MTSP	Stapelveldt Trail	SC	0		No treatments recommended.	
437	MTSP	Stapelveldt Trail	SC	1	M	1) Install wet ford (3x5). 2) Rock thru crossing. 3) Install 10 dips to right 250'.	
438	MTSP	Stapelveldt Trail	SC	0		No treatments recommended.	
451	MWNM	Muir Woods Left Trail	SC	15	L	1) Excavate to establish wide enough channel with 2:1 banks 2(4x4x12) =14 yds3. Spoil locally. 2) Replace bridge with wider planked crossing. **There is small equipment access.	
452	MWNM	Muir Woods Left Trail	SC	0		No treatments recommended.	
453	MWNM	Muir Woods Left Trail	SC	0		No treatments recommended.	
454	MWNM	Muir Woods Left Trail	SC	0		No treatments recommended.	
455	MWNM	Muir Woods Left Trail	SC	7	HM	1) Excavate top to bot. Creating a channel with 2:1 banks. 2) Build wooden foot bridge across excavated channel.	
456	MWNM	Muir Woods Left Trail	DRC	10		No treatments recommended.	
457	MWNM	Muir Woods Left Trail	DRC	12	M	1) Excavate crossing top to bot. Establishing channel with 2:1 banks. 2) Install wooden bridge for trail.	
458	MTSP	Miwok trail	RSDP	6	L	Use hand labor to install up to 11 trail dips especially one at swale crossing.	PLANNED
459	MTSP	Miwok trail	SC	1	L	1) Use hand labor to excavate broader, deeper dip, removing fill along OBF and being sure flow is captured from above. Use spoils locally to build up left inboard trail to help prevent diversion. * use gavel size rock to rock trail surface thru crossing and use hand labor to rebuild permanent dips to the right.	PLANNED
460	MTSP	Miwok trail	RSDP	15	M	1) Enhance dips across 3 swale crossings by excavating fill using hand labor (4 hrs. each). 2) Install up to 8 trail dips at approaches to these swales (2 hrs. each).	PLANNED
461	MTSP	Miwok trail	SC	1	L	1) Install gravel size rock thru crossing (4x12=48ft2). 2) Install 3 rolling trail dips right.	PLANNED
462	MTSP	Miwok trail	SC	1	L	Rebuild or enhance dips to the right.	PLANNED

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Site #	Responsible Agency[2]	Road	Site Type[3]	FE[4]	TI[5]	Comment on treatment[6]	Work[7] Completed
463	MTSP	Miwok trail	SC	2	ML	1) Use hand labor to remove top row of rock at OBF and create broad, stable, more pronounced dip thru crossing. 8x1x10 removal. 2) Install 3 trail dips to the right.	PLANNED
464	MTSP	Miwok trail	SC	2		No treatments recommended.	
465	MTSP	Redwood Creek Trail	SC	0		No treatments recommended.	
466	MTSP	Redwood Creek Trail	SC	3	L	1) Install 6 trail dips to the right.	PLANNED
467	MTSP	Redwood Creek Trail	SC	0		No treatments recommended.	
468	MTSP	Diaz Ridge Right Spur Trail	RSDP	13	L	1) Install frequent cross-road drains on upper road reach (10). There is equipment access from above up until the lowest 600'. 2) Use hand labor to create cross trail drains on lower 600'. * These will not work if horses and bikes are allowed on trail.	
469	MTSP	Redwood Creek Trail	SC	4	M	Install armored fill crossing. Currently only foot access but could build short access for bobcat.	PLANNED
470	MTSP	Old Mine Trail	SC	1	L	1) Excavate fill to create ford thru trail. 2) Rock trail with 6" diameter rock. 3) Install 3 trail dips to the right.	Y
471	MTSP	Old Mine Trail	SC	1	L	Excavate fill thru crossing to create ford. Rock trail thru crossing	Y
471.1	MTSP	Redwood Sun Trail	SC	3	ML	1) Install up to 6 trail dips to the right. Use hand labor to better establish channel through crossing and prevent diversion to left.	
472	MTSP	Old Mine Trail	SC	1	ML	1) Install 1 DRC to left paved road (near trail head). 2) Excavate fill crossing. 3) Install ford. 4) Install 1 road drain to left trail (in addition to existing 2).	Y
472.1	MTSP	Redwood Sun Trail	SC	2	M	1) Install 4 trail dips to the right, especially one at spring 50' left of site #471	
473	MTSP	Redwood Sun Trail	SC	0		No treatments recommended.	
474	MTSP	Redwood Sun Trail	SC	0		No treatments recommended.	
475	MTSP	Redwood Sun Trail	SC	4	M	1) Install armored fill crossing, 20 hours hand labor. Perched fill on left OBF should be pulled back. 2) Install 2 rolling dips left.	
476	MTSP	Redwood Sun Tr.	SC	1		No treatments recommended.	
477	MTSP	Redwood Sun Tr.	SC	1		No treatments recommended.	
478	MTSP	Redwood Sun Tr.	SC	1		No treatments recommended.	
479	MTSP	Redwood Sun Trail	SC	1		No treatments recommended.	
480	MTSP	Redwood Sun Trail	SC	0		No treatments recommended.	
481	MTSP	Lost Trail	SC	1		No treatments recommended.	
482	MTSP	Lost Trail	SC	1	ML	1) Use hand labor to remove boulder at CLP and create dip for channel, 5x2x7 dirt removal. Use local rock to rearmor fillslope and channel.	PLANNED
483	MTSP	Lost Trail	SC	0		No treatments recommended.	
484	MTSP	Lost Trail	SC	1		No treatments recommended.	
485	MTSP	Lost Trail	SC	1		No treatments recommended.	
486	MTSP	Canopy View Trail	SC	1	L	1) Use hand labor to excavate a better defined dip. 5x2x7 approximate removal.	PLANNED
487	MTSP	Canopy View Trail	SC	3	M	1) Excavate fill removing old CMP and replace with armored fill crossing. This will be done with hand labor. 2) Install 3 trail dips right.	PLANNED
488	MTSP	Panoramic Trail	SC	1	L	1) Install 2 trail dips right.	
489	MTSP	Panoramic Trail	SC	0		No treatments recommended.	
490	MTSP	Panoramic Trail	RSDP	37	M	1. Outslope with no inboard ditch (IBD) 450' on left approach. Equipment access via Panoramic Hwy. 2. Install 3 rolling dips to left. 3. Install 5 trail dips to right.	

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Site #	Responsible Agency[2]	Road	Site Type[3]	FE[4]	TI[5]	Comment on treatment[6]	Work[7] Completed
500	MTSP	Redwood Creek Tr.	SC	52	ML	1) Excavate Top to Bot. 2) Replace existing with a 72" CMP.	PLANNED
501	MTSP	Redwood Creek Tr.	SC	0		No treatments recommended.	
502	MTSP	Redwood Creek Tr.	SC	1	M	1) Install 8' footbridge sturdy enough to support horse traffic. 2) Rock 9' to the left. 3) Rock 7' to the right.	PLANNED
503	MTSP	Redwood Creek Tr.	SC	1	L	Armor 4' right and 4' left approach. Average bedload 6"	PLANNED
504	MTSP	Redwood Creek Tr.	SC	0		No treatments recommended.	
505	MTSP	Redwood Creek Tr.	RSDP	6	M	1) Install 10 cross road drains to 300' left trail where possible.	PLANNED
506	MTSP	Redwood Creek Tr.	SC	0		No treatments recommended.	
507	MTSP	Redwood Creek Tr.	SC	0		No treatments recommended.	
508	MTSP	Redwood Creek Tr.	SC	1	M	1) Notch top tie to allow drainage. 2. Rock road (4x4) with large rock.	PLANNED
509	MTSP	Redwood Creek Tr.	SC	1	ML	1) Notch top of railroad tie to allow drainage. 2) Excavate channel from Top to OBF.	PLANNED
510	MTSP	Heather Cutoff Trail	SC	6	L	1) Install 50 cross road drains 1500' to right. From fire road down to crossing.	PLANNED
511	MTSP	Heather Cutoff Trail	SC	1	L	1) Excavate crossing Top to OBF. 2) Install ford.	PLANNED
512	MTSP	Heather Cutoff Trail	SC	1	M	1) Rock ford 4x2. 2) Install ford at spring 75' to right. 3) Install cross road drains to 120' right trail.	PLANNED
513	MTSP	Heather Cutoff Trail	SC	42	L	1) Notch wood to allow drainage. 2) Rock through crossing. 3) Install 10 drains to left trail.	PLANNED
514	MTSP	Heather Cutoff Trail	SC	1	ML	1) Install rock ford (3x15). 2) Install 10 cross road drains to 450' right trail.	PLANNED
515	MTSP	Dipsea Trail	SC	0		No treatments recommended.	
516	MTSP	Dipsea Trail	SC	0		No treatments recommended.	
517	MTSP	Dipsea Trail	SC	2	M	1) Install 6 cross road drains	
518	MTSP	Dipsea Trail	SC	2	L	1) Install 2 cross road drains to left 90'	
519	MTSP	Dipsea Trail	SC	1	L	1) Install 2 cross road drains to right trail. Will need chainsaw to notch wooden retaining wall.	
520	MTSP	Dipsea Trail	SC	4	ML	1) Install 12 trail drains left 700'. 2) Install 4 trail drains right 165'. Will need chainsaw for right approach. Site is 165' from road, easy access for hand labor.	
521	MTSP	Dipsea Trail	SC	1	L	1) Use hand labor to better define dip through crossing (6hrs). 2) Install 2 trail dips left.	
521.1	MTSP	Dipsea Trail	SC	56	M	1) Excavate crossing Top to Bot. Re-establish channel width to 4', layback slopes to 2:1. 2) Use spoil to outslope abandoned road to left (up to 2000'). 3) Decommission abandoned trail to left 1000', cross road drains where possible, revegetate other sections (seed 4000ft2).	
522	MTSP	Dipsea Trail	SC	1	L	1) Install 2 trail dips left.	
522.1	MTSP	Dipsea Trail	SC	99	M	1) Excavate crossing Top to Bot. 2) Re-establish channel 4' bottom width. 3) Lay back slopes 2:1. 4) Spoil on abandoned road to left, outslope abandoned road.	
523	MWNM	Dipsea Trail	DRC	8	L	1) Install 3 rolling dips left	
524	MTSP	Canopy View Trail	SC	1	L	1. Install 1 trail drain to right trail.	PLANNED
525	MTSP	Canopy View Trail	SC	1	M	Excavate TOP to BOT. Install ford with hand labor.	PLANNED
526	MTSP	Canopy View Trail	SC	1		No treatments recommended.	
527	MTSP	Canopy View Trail	SC	1	ML	Excavate channel 10' above and 10' below crossing at bridge. Spoil locally. Move bridge downstream and replace with 9' with new footings.	PLANNED
528	MTSP	Canopy View Trail	SC	1		No treatments recommended.	

Table 1. Summary table of all sediment delivery sites inventoried in PWA's original 2002 assessment[1]

Site #	Responsible Agency[2]	Road	Site Type[3]	FE[4]	TI[5]	Comment on treatment[6]	Work[7] Completed
529	MTSP	Canopy View Trail	SC	1	ML	Excavate xing TOP to BOT. Install ford with 3' channel width. Rock (2*4) 1-2" bedload. Spoil locally	PLANNED
530	MWNM	Canopy View Trail	SC	2	L	Remove culvert. Install wet ford crossing.	
531	MWNM	Canopy View Trail	SC	1		No treatments recommended.	

[1] All information included in this table was provided by responsible agency.
[2] Responsible Agencies are abbreviated as follows: MMWD = Marin Municipal Water District; MTSP = Mt. Tamalpais State Park; GGNRA = Golden Gate National Recreation Area; MWNM=
[3] Site Types are abbreviated as follows: SC = stream crossing, DRC = ditch relief culvert, RSDP = road surface discharge point, and LS = landslide.
[4] TI - Treatment Immediacy. Ratings are abbreviated as follows: L= low, ML= moderate low, M= moderate, HM=high-moderate, H=high, and NA – not applicable.
[5] Future erosion includes only the estimated "episodic" future sediment delivery for site specific volumes based on a 30 year interval with no rounding.
[6] Details regarding comment on treatment was taken directly from the 2002 report unless modified by client. Refer to Table 5 in the report for treatment dates and details as well as revised treatment recommendations based on 2016-2017 re-evaluation. Also refer to Appendix C (Typical Drawings) and Appendix D (Supplementary Information) for definitions and more details regarding treatment types. "Left" and "Right" are defined looking downstream from a site.
[7] Details regarding work completed and planned was provided by the responsible agency. PWA did not review any completed work or construction plans for any proposed ("planned") work. Refer to Table 5 in the report for treatment dates and details as well as revised treatment recommendations based on 2016-2017 re-evaluation.

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Erosion Sites from the PWA Watershed Assesment and Erosion Prevention Planning Summary Report (March, 2002):

Erosion Site Status

Work Status

- Work completed
- Work planned
- No work planned

PWA Treatment Immediacy Level

- High
- Medium - high
- Medium

Site has been reassessed

Paved Road
Caltrans Road
County of Marin Road
Fire Road
Trail
Stream
Marin Municipal Water District Boundary
Mount Tamalpais State Park
Golden Gate National Recreation Area
Redwood Creek Watershed Boundary

MARIN MUNICIPAL WATER DISTRICT

0 0.5 1 Miles

Erosion Sites from the PWA Watershed Assesment and Erosion Prevention Planning Summary Report (March, 2002):

Erosion Site Status

DRAFT 3/13/17

Work Status

- Work completed
- Work planned
- No work planned

PWA Treatment Immediacy Level

- No immediacy level
- High
- Medium - high
- Medium
- Medium - low
- Low

Site has been reassessed

- Paved Road
- County of Marin
- Fire Road
- Trail
- Stream
- Marin Municipal Water District
- Mount Tamalpais State Park
- Redwood Creek Watershed Boundary

NORTH

0 500 1,000 Feet

Marin Municipal Water District

Ridgecrest Blvd

Old Railroad Grade Fire Rd

Tavern Pump Trail

Fern Creek Trail

Miller Trail

Mountain Top Trail

Rock Spring Trail

Old Stage Fire Rd

Nora Trail

Matt Davis Trail

Bootjack Trail

Easy Grade Trail

Panoramic Hwy

TCC Trail

Sierra Trail

Alice Eastwood Fire Rd

Erosion Sites from the PWA Watershed Assesment and Erosion Prevention Planning Summary Report (March, 2002):

Erosion Site Status

Work Status

- Work completed
- Work planned
- No work planned

PWA Treatment Immediacy Level

No Immediacy Level · High · Medium - high · Medium · Medium - low · Low

Site has been reassessed

CENTER

Mount Tamalpais State Park

Muir Woods National Monument (GGNRA)

Alice Eastwood Campground

Old Mine Trail · Alpine Trail · Bootjack Trail · Redwood Creek · Ben Johnson Trail · Fern Creek · Fern Creek Trail · Lost Trail · Panoramic Trail · Canopy View Trail · Redwood Trail · Hillside Trail · Redwood Creek Trail · Stapleveldt Trail · CC Trail · Deer Park Fire Rd · Dipsea Trail · Bohemian Grove Trail · Canopy View Trail · Tourist Club · Sun Trail · Muir Woods Rd · Dipsea Trail · Panoramic Hwy · Conlon Ave · Camino del Canon · Conlon Creek

Paved Road · County of Marin Road · Fire Road · Trails · Stream · State Park Boundary · National Park Boundary · Redwood Creek Watershed Boundary

0 · 1,000 · 2,000 Feet

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Erosion Sites from the PWA Watershed Assesment and Erosion Prevention Planning Summary Report (March, 2002):

Erosion Site Status

- Paved Road
- Caltrans Road
- County of Marin Road
- Fire Road
- Trail
- Stream
- Mount Tamalpais State Park
- Golden Gate National Recreation Area
- Redwood Creek Watershed Boundary

Work completed
Work planned
No work planned

PWA Treatment Immediacy Level

No immediacy level | High | Medium - high | Medium | Medium - low | Low

Site has been reassessed

Mount Tamalpais State Park
Golden Gate National Recreation Area
Muir Woods Rd
Redwood Creek
Redwood Creek Trail
Heather Cutoff Trail
Dias Ridge Trail
Miwok Trail
Banducci Ranch Rd
Muir Beach Trail
Kaashi Way
Green Gulch Trail
Middle Green Gulch Trail
Green Gulch Farm
Muir Beach
Coastal Fire Rd

0 1,000 2,000 Feet

DRAFT 3/13/17

Appendix C

Typical drawings (schematic diagrams) showing components of erosion control and erosion prevention treatments, and techniques for construction.

Redwood Creek Watershed, Muir Woods Road/Trail Re-Assessment
Marin County, California

No.	Drawing title
1	Typical problems and applied treatments for a non-fish bearing upgraded stream crossing
2	Typical design of a non-fish bearing culverted stream crossing
3	Typical design of a single-post culvert inlet trash rack
4	Typical design for armoring fillslopes
5	General armored fill dimensions
6	Typical armored fill crossing installation
7	Ten steps for constructing a typical armored fill crossing
8	Typical ditch relief culvert installation
9	Typical designs for using road shape to control road runoff (using insloping, outsloping, and crowning)
10	Typical methods for dispersing road surface runoff with waterbars, cross-road drains, and rolling dips
11	Typical road surface drainage by rolling dips
12	Typical sidecast or excavation methods for removing outboard berms on a maintained road
13	Typical excavation of unstable fillslope on an upgraded road
14	Typical problems and applied treatments for a decommissioned stream crossing
15	Typical design for road decommissioning treatments employing export and in-place outsloping techniques
16	Typical excavation of unstable fillslope on a decommissioned road
17	Typical construction of road decompaction and cross road drain installation
18	Typical rock grade control structure installation
19a	Standard (Type 1) rolling dip construction
19b	Type 2 rolling dip construction for through-cut or thick berm road reaches
19c	Type 3 rolling dip construction for steep slope road reaches
20	Typical ford crossing installation
21	Typical design for de-watering streams

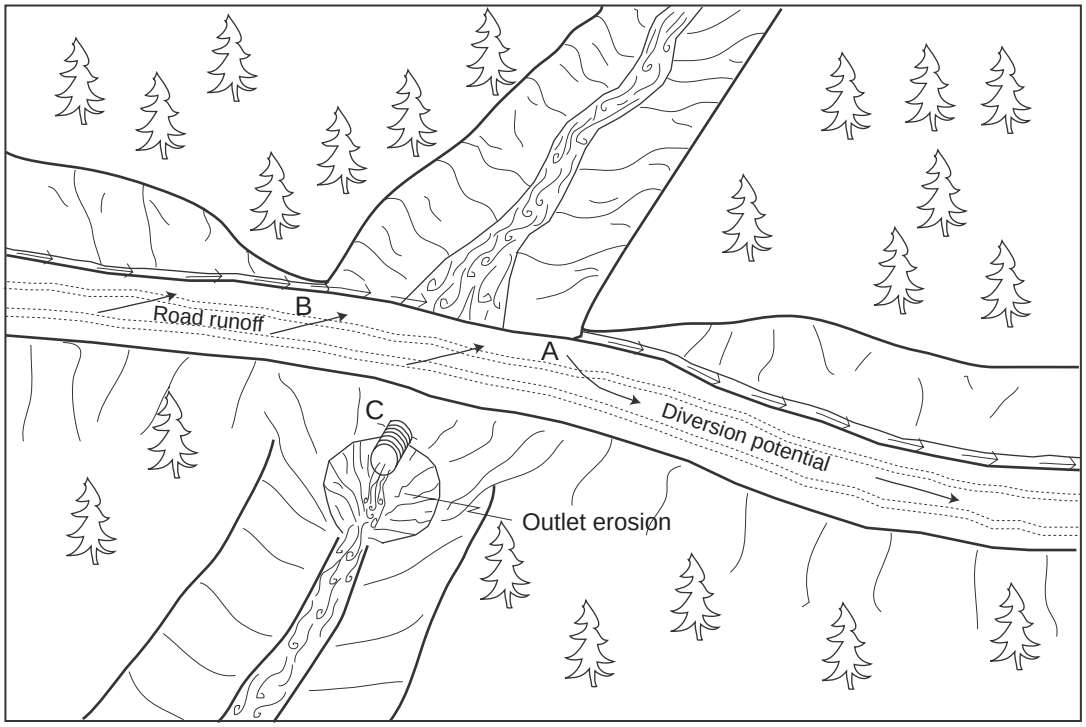
Typical Problems and Applied Treatments for a Non-fish Bearing Upgraded Stream Crossing

Problem condition (before)

A - Diversion potential

B - Road surface and ditch drain to stream

C - Undersized culvert high in fill with outlet erosion

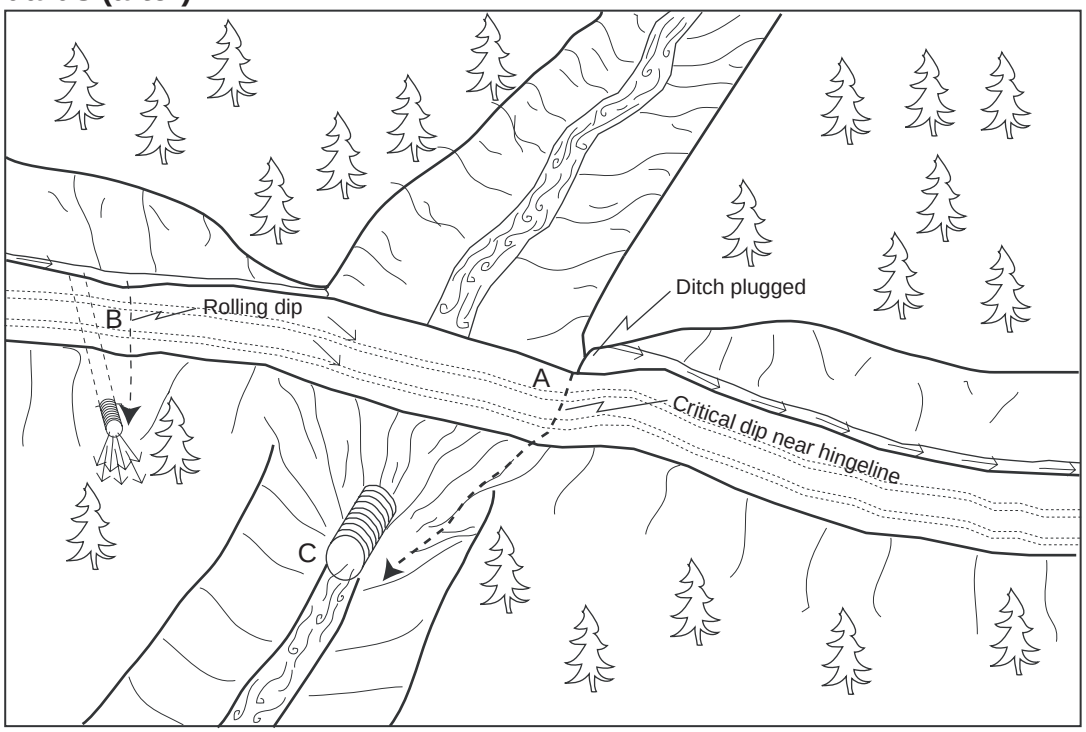


Treatment standards (after)

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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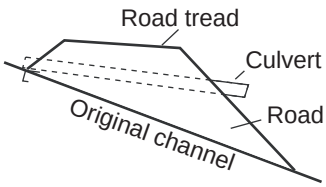
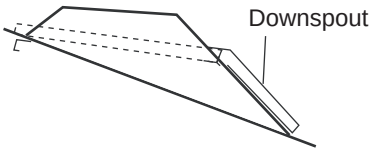
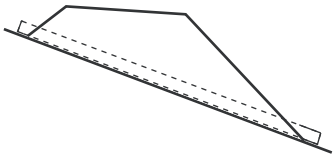
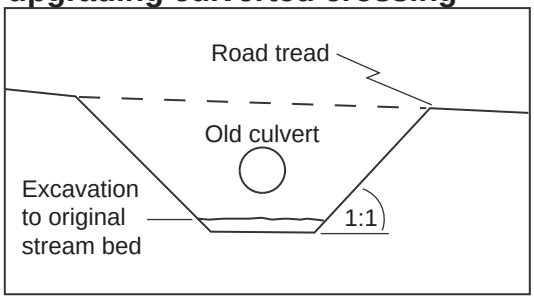
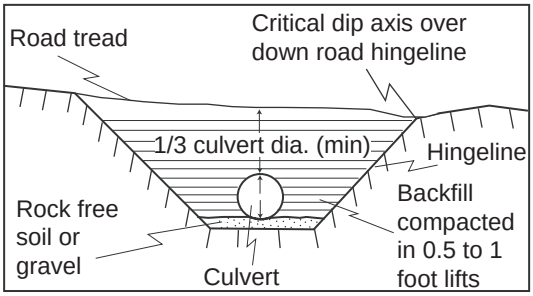
Typical Design of a Non-fish Bearing Culverted Stream Crossing

Existing	Upgraded	Upgraded (preferred)
		
1. Culvert not placed at channel grade. 2. culvert does not extend past base of fill.	1. Culvert not placed at channel grade. 2. Downspout added to extend outlet past road fill.	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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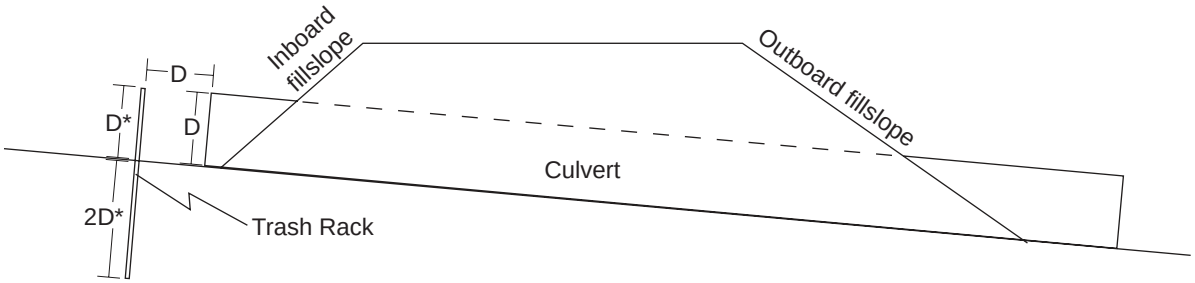
Typical Design of a Single-post Culvert Inlet Trash Rack

Cross section view



D - Culvert diameter

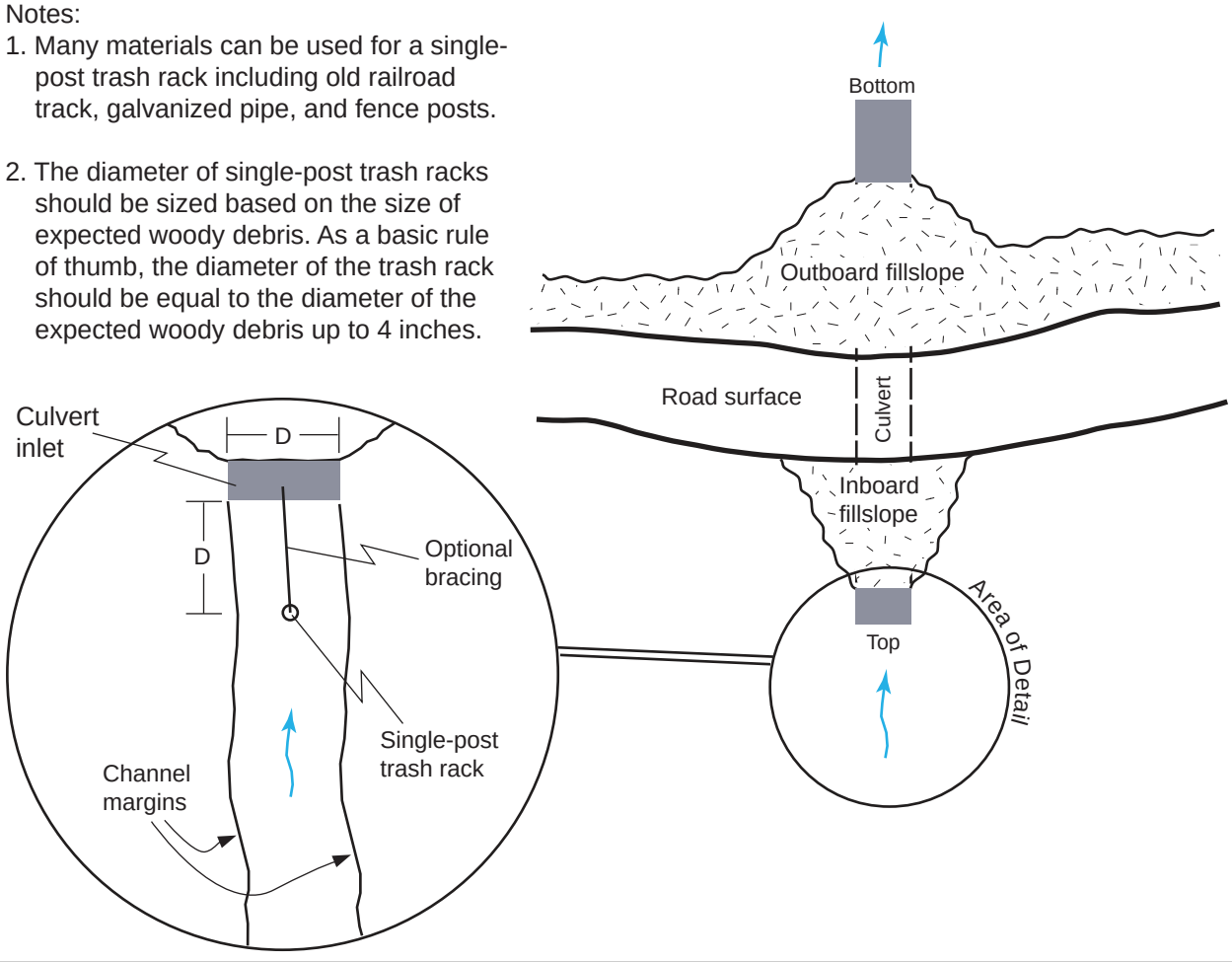
D* - If the culvert is designed for the 100-year peak storm flow, the trash rack height above the streambed should equal D.
If the culvert is undersized, then the trash rack needs to be extended vertically above the streambed to match or exceed the expected headwall height.

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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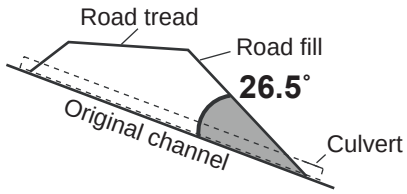
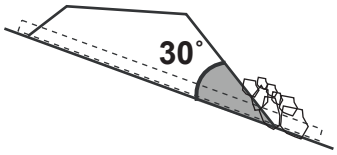
Typical Design of Stream Crossing Fill Armor

Fill angles ≤26.5˚ (2:1)



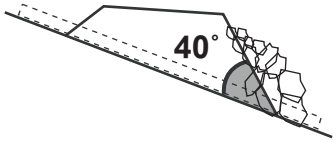
No rock armor needed

Fill angles 26.5˚ - 35˚ (1.5:1)



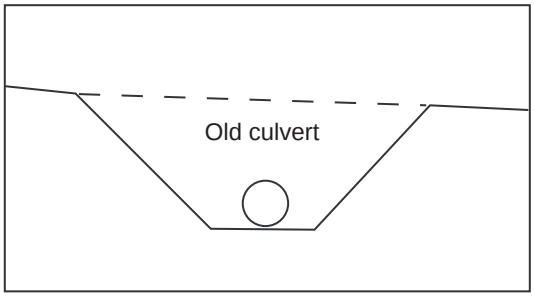
Armor 1/4 up fill face

Fill angles 35˚ - 45˚ (1:1)

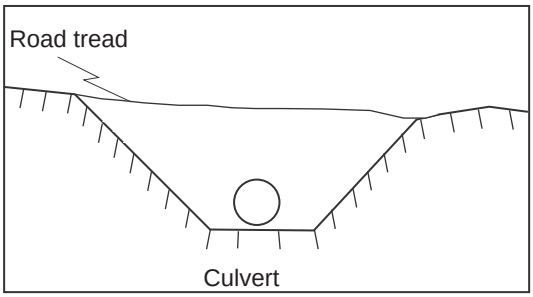


Armor 3/4 way up fill face

Fill angles 26.5˚ - 35˚ (1.5:1)



Fill angles 35˚ - 45˚ (1:1)



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.

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.

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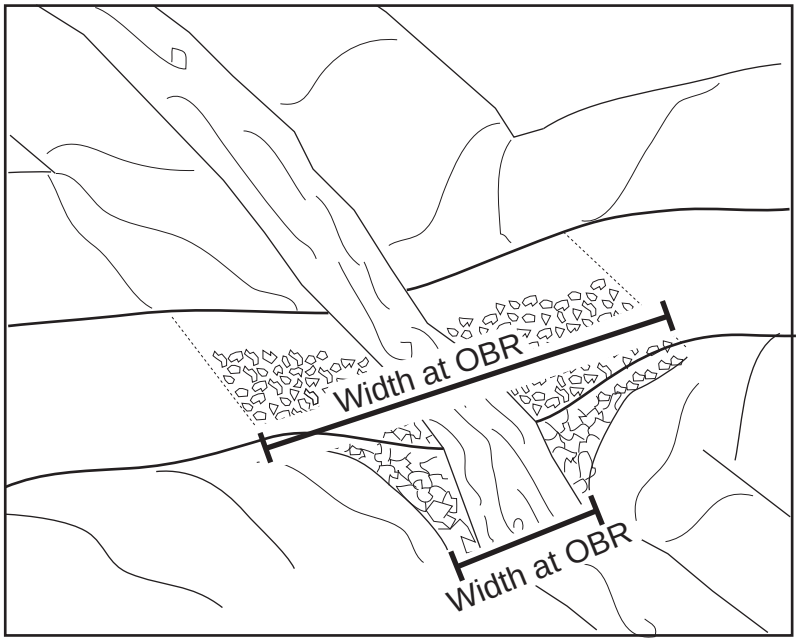
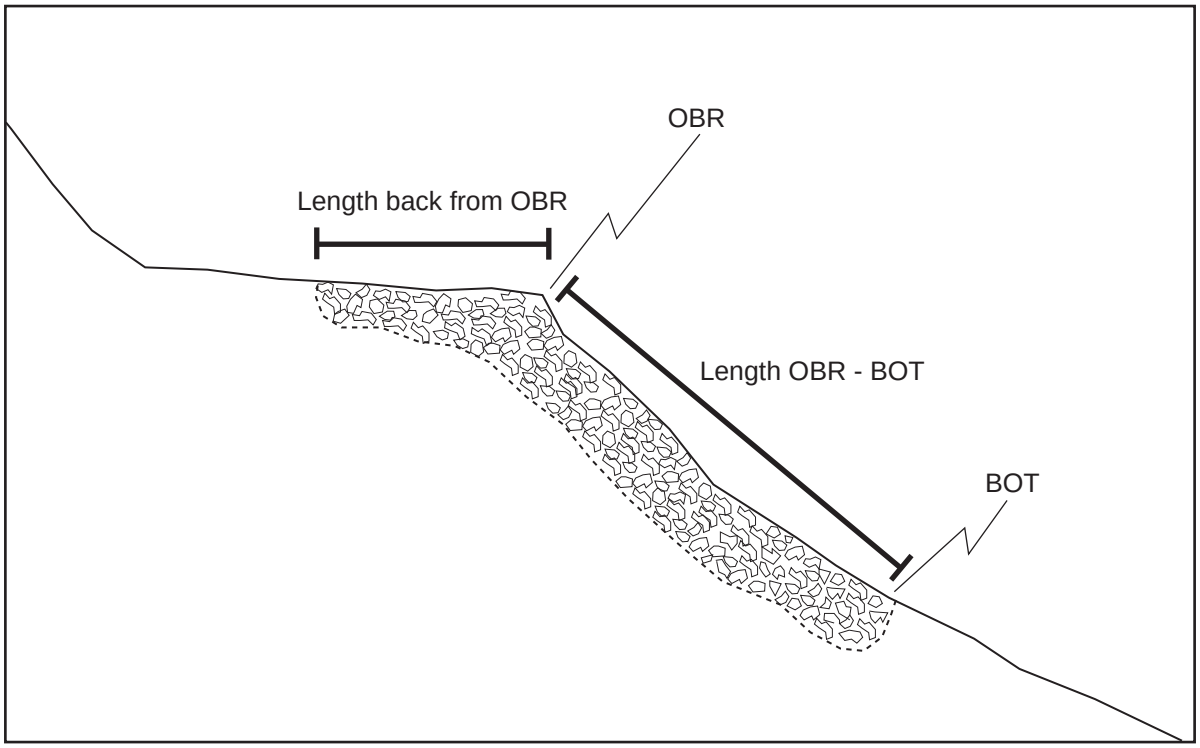
Typical Dimensions Refered to for Armored Fill Crossings

Widths in oblique view



OBR - Outboard edge of road

Lengths in profile view



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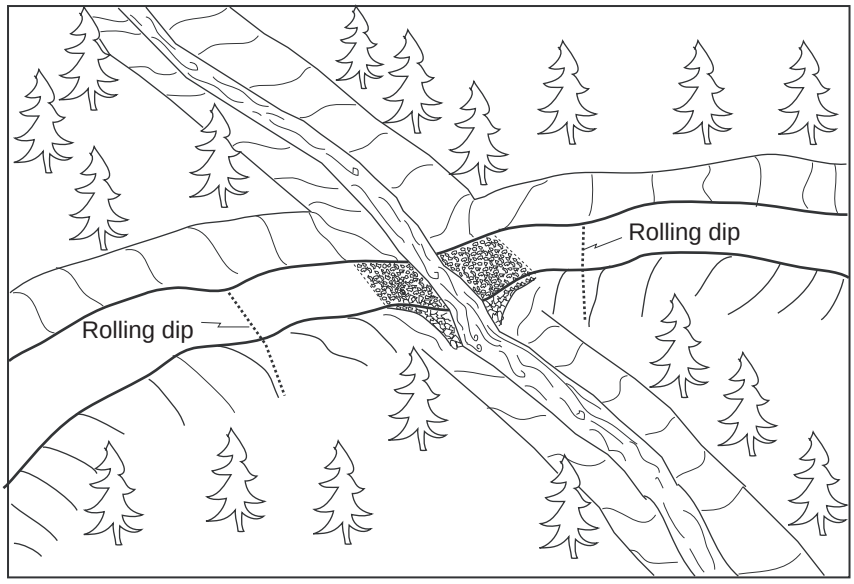
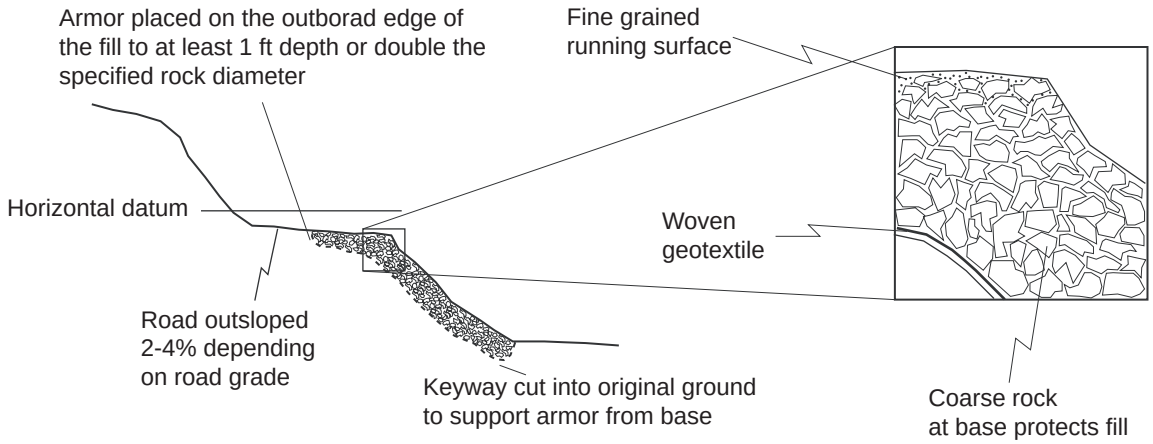
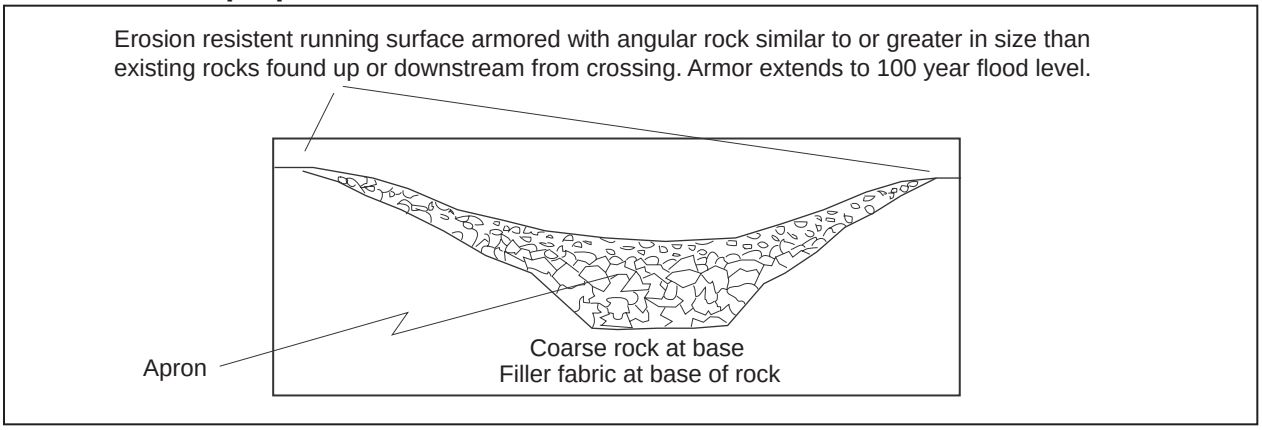
Typical Armored Fill Crossing Installation



Cross section parallel to watercourse



Cross section perpendicular to watercourse



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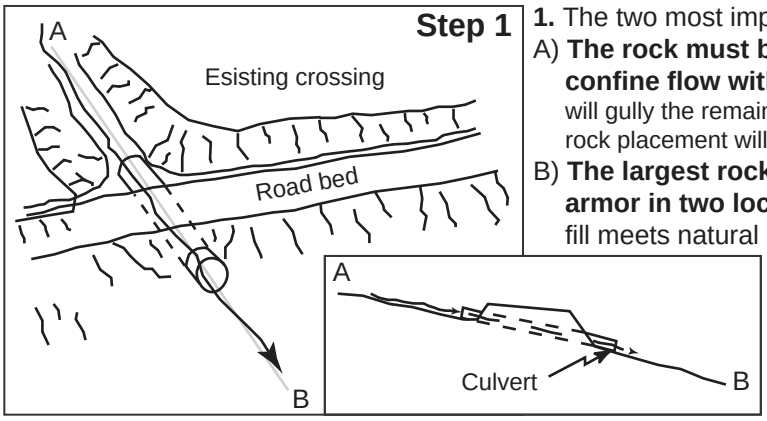
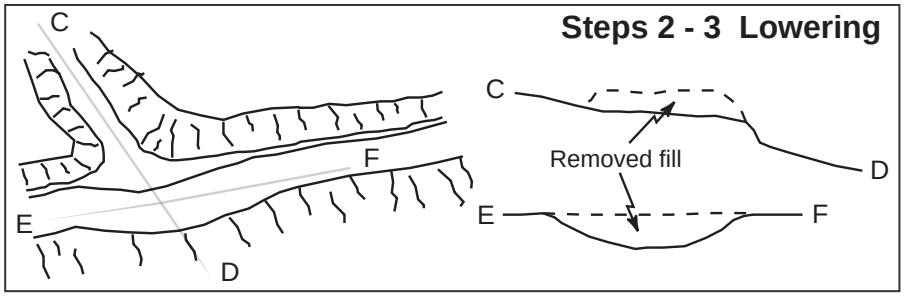
Ten Steps for Constructing a Typical Armored Fill Stream Crossing



1. The two most important points are:

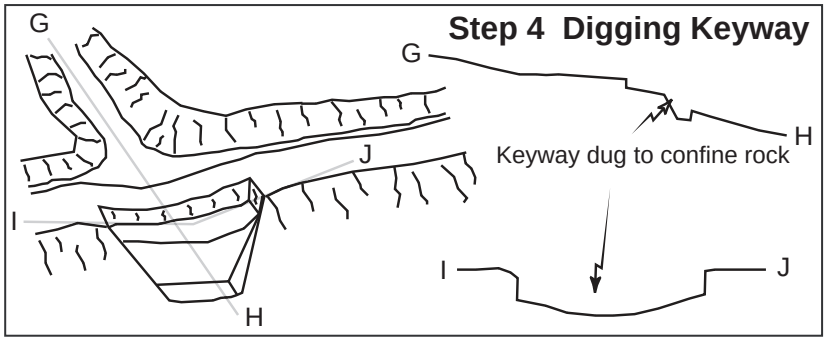
A) **The rock must be placed in a "U" shape across the channel to confine flow within the armored area.** (Flow around the rock armor will gully the remaining fill. Proper shape of surrounding road fill and good rock placement will reduce the likelihood of crossing failure).

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).



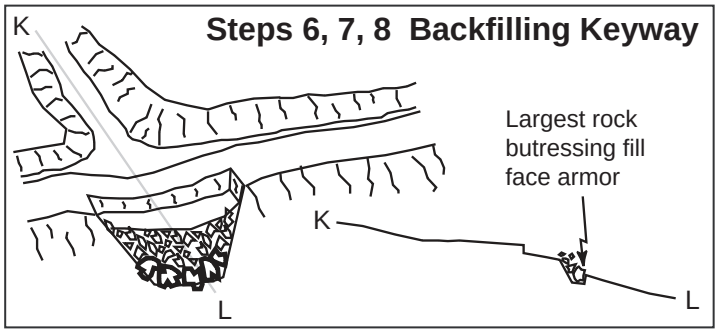
2. Remove any existing drainage structures including culverts and Humboldt logs.

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).

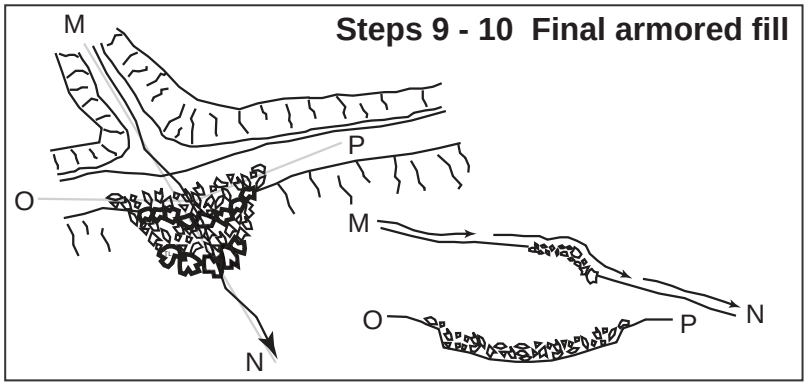
5. Install geofabric (optional) within keyway to support rock in wet areas and to prevent winnowing of the crossing at low flows.



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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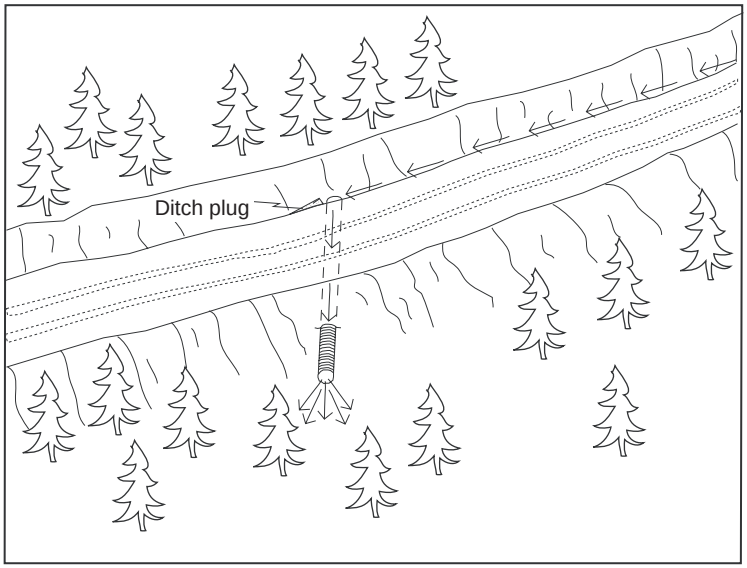
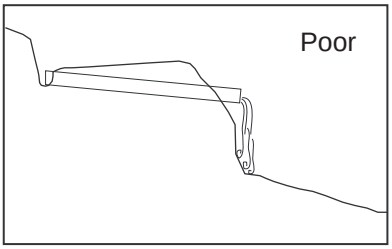
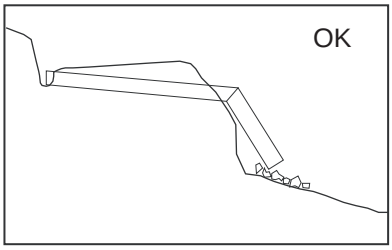
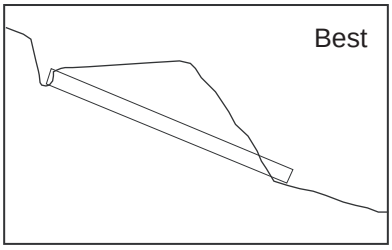
Typical Ditch Relief Culvert Installation









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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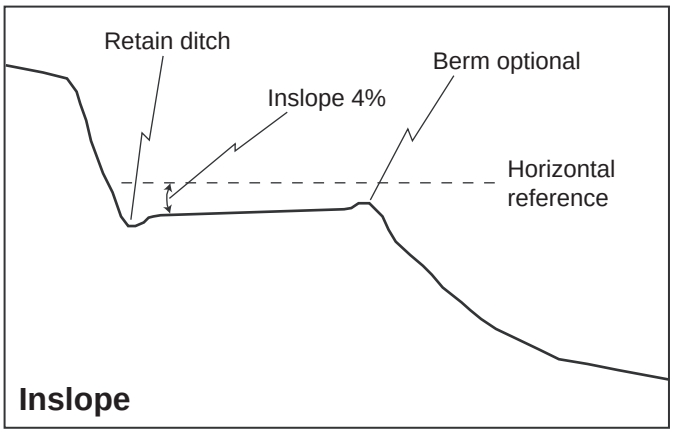
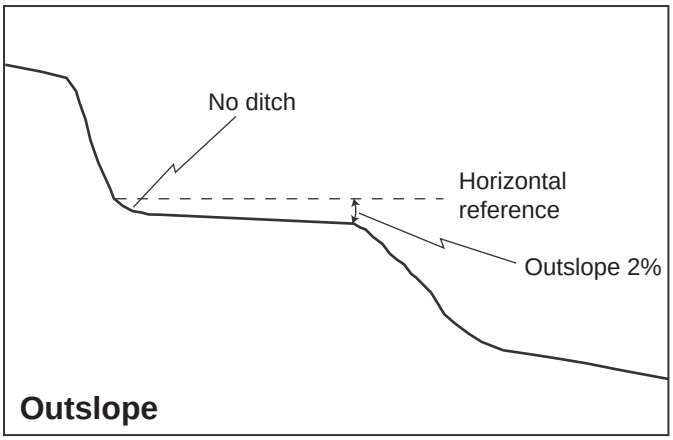
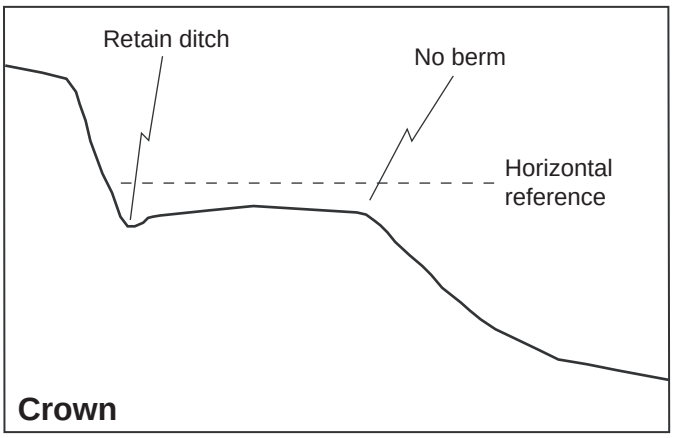
Typical Designs for Using Road Shape to Control Road Runoff







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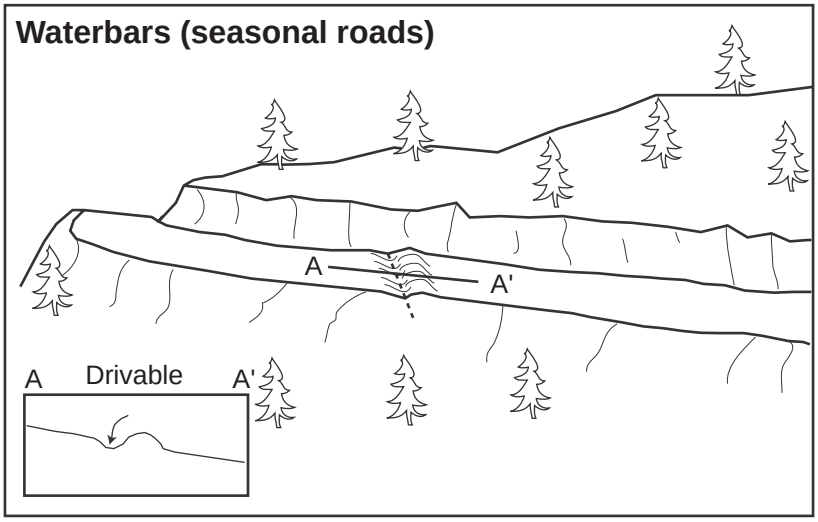
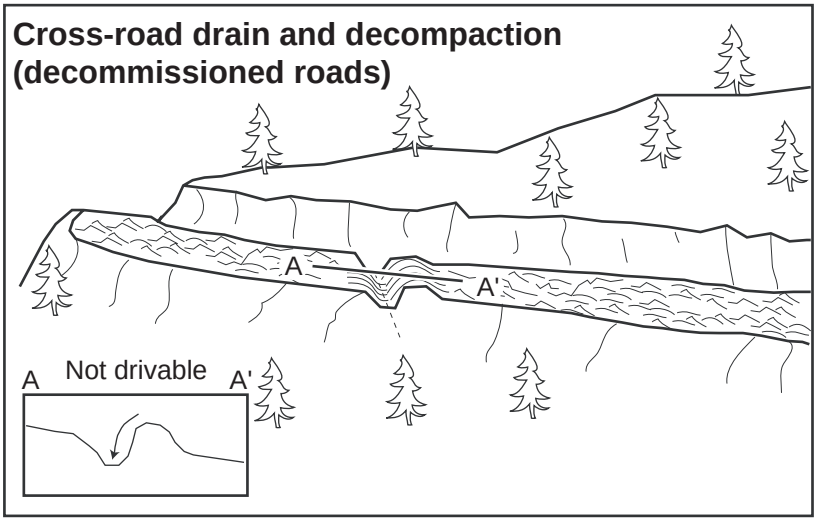
Typical Methods for Dispersing Road Surface Runoff with Waterbars, Cross-road Drains, and Rolling Dips

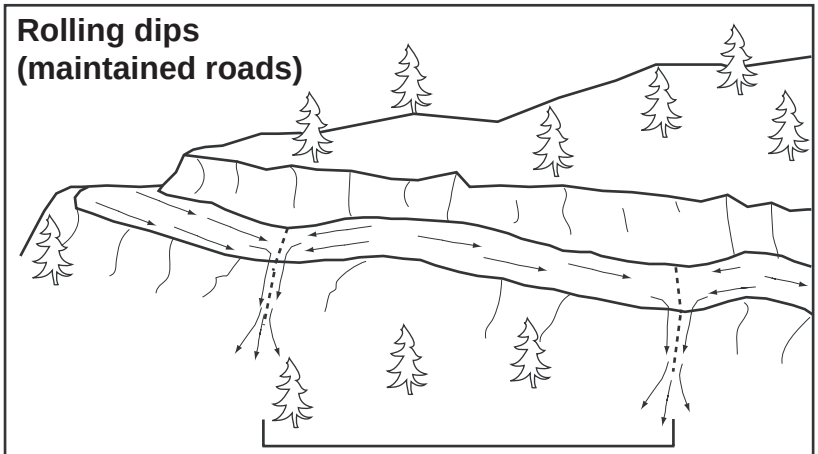
Waterbars (seasonal roads)



Cross-road drain and decompaction (decommissioned roads)



Rolling dips (maintained roads)



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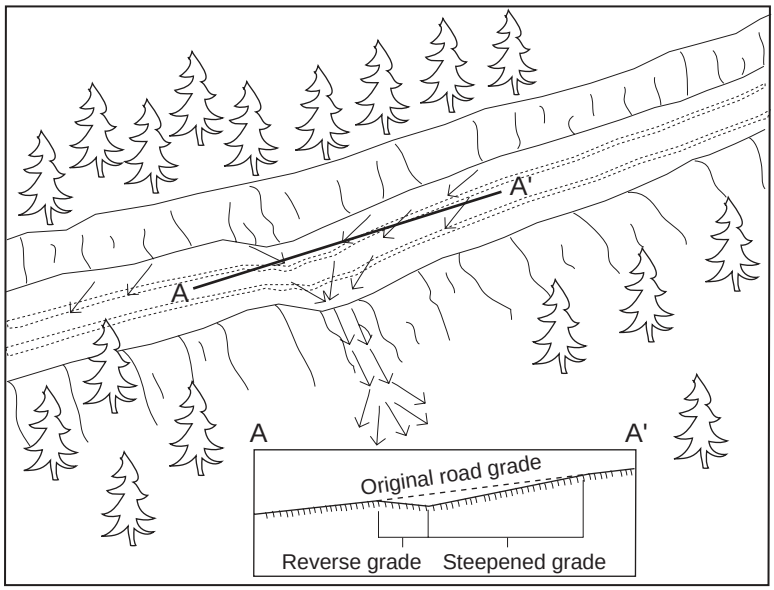
Typical Road Surface Drainage by Rolling Dips



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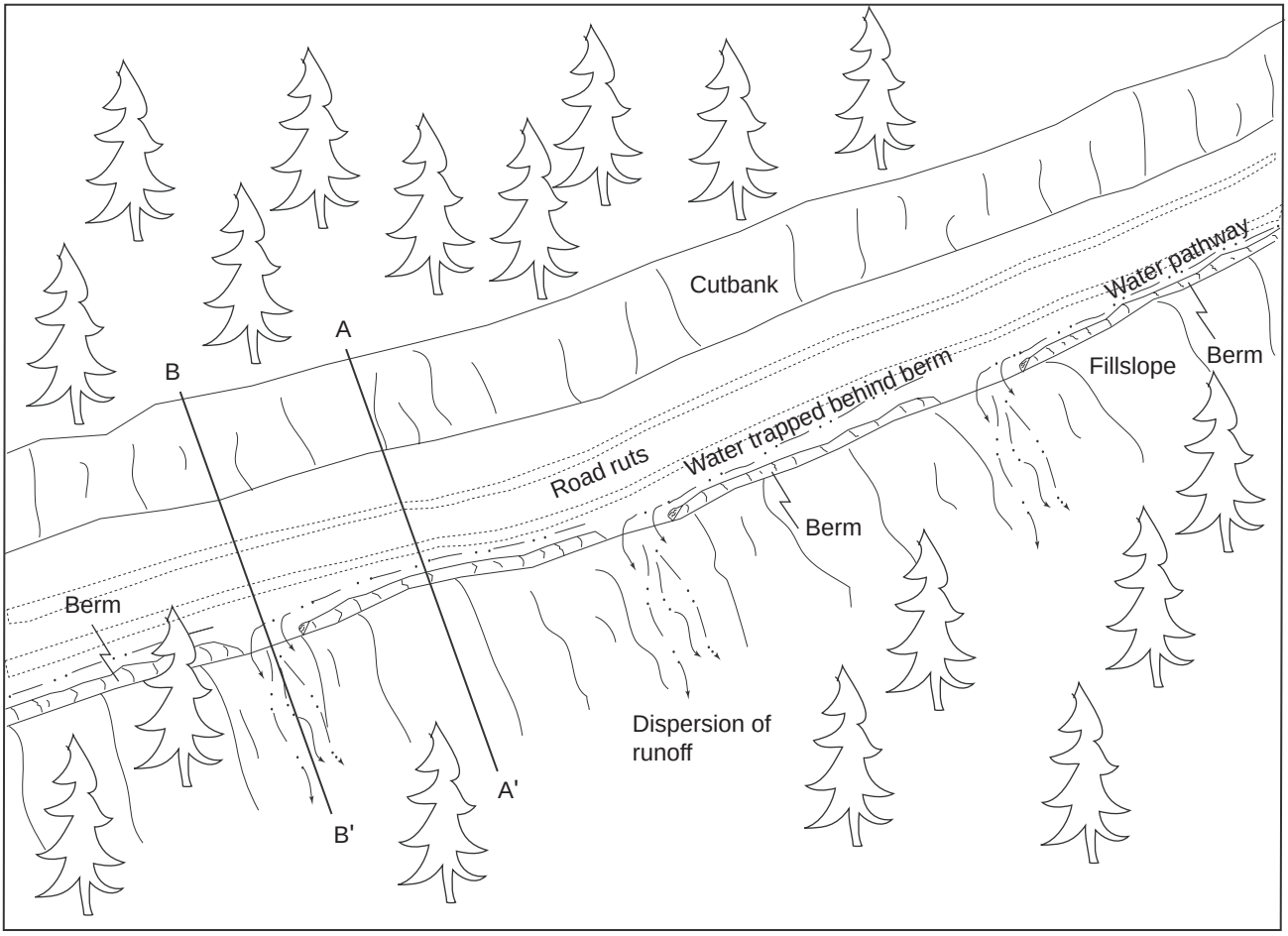
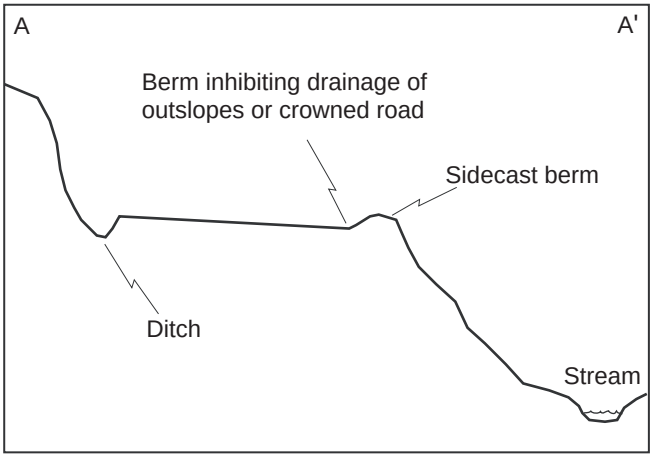
Typical Sidecast or Excavation Methods for Removing Outboard Berms on a Maintained Road

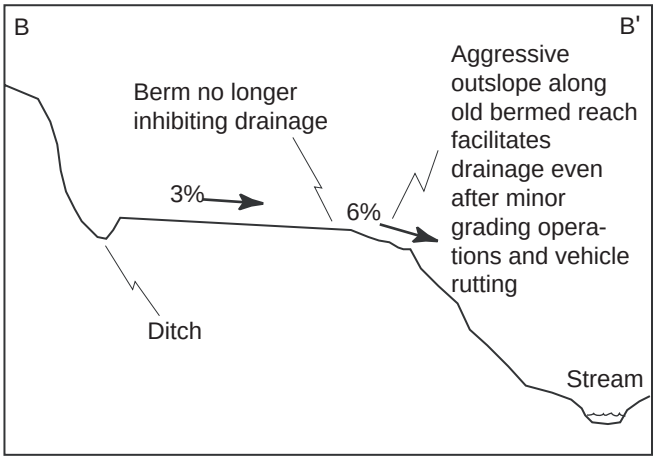
1. On gentle road segments berms can be removed continuously (see B-B').
2. On steep road segments, where safety is a concern, the berm can be frequently breached (see A-A' & B-B') Berm breaches should be spaced every 30 to 100 feet to provide adequate drainage of the road system while maintaining a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



Road cross section between berm breaches



Road cross section at berm breaches



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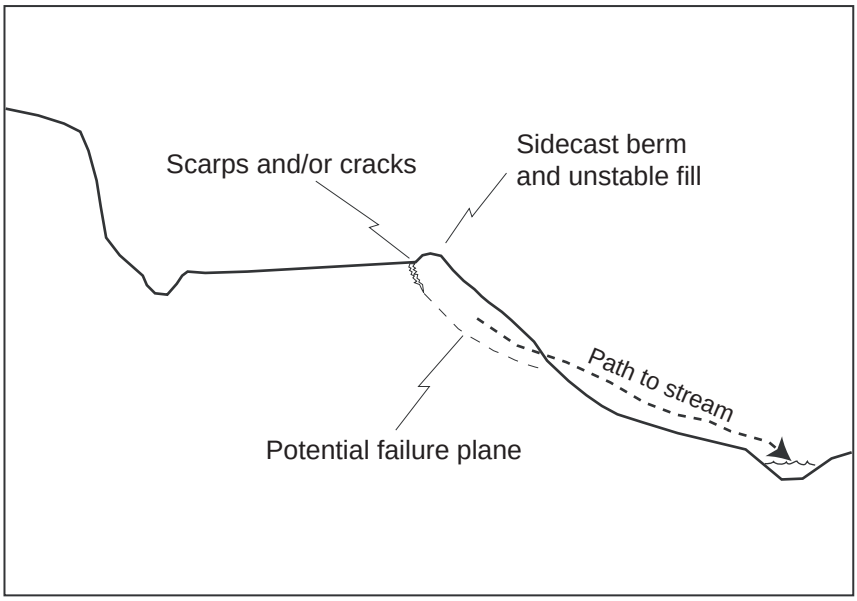
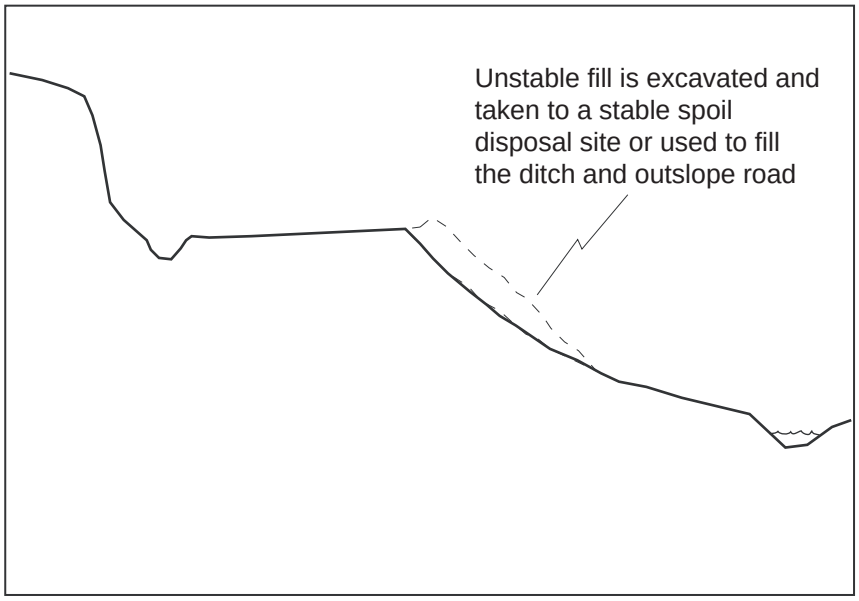
Typical Excavation of Unstable Fillslope on an Upgraded Road

Before



After



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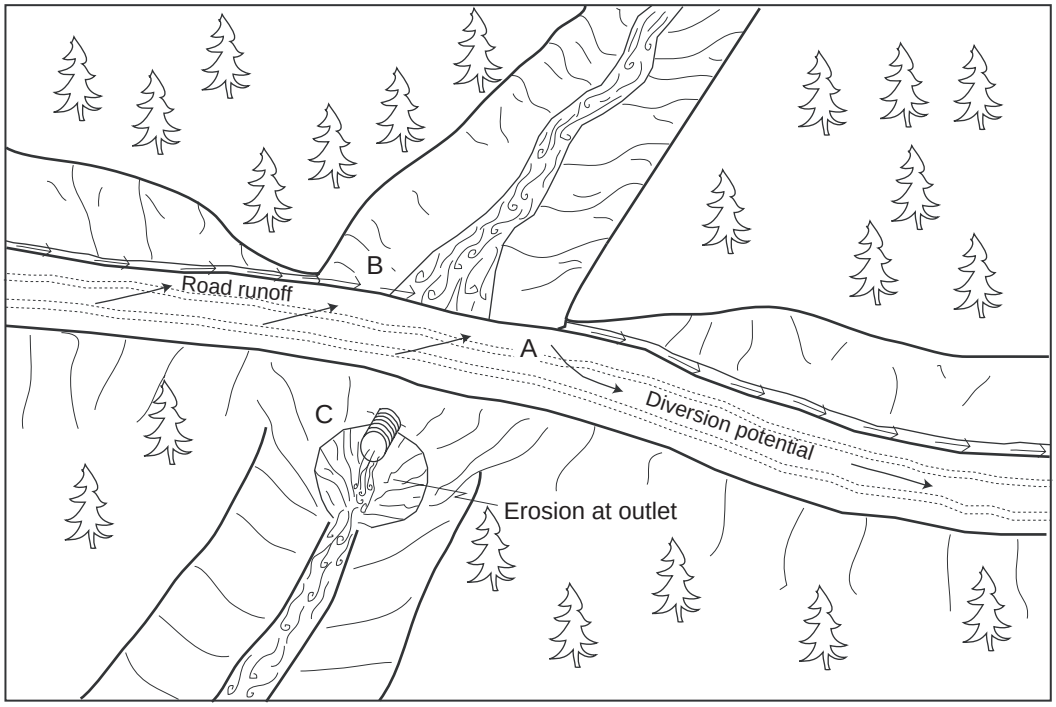
Typical Problems and Applied Treatments for a Decommissioned Stream Crossing

Problem condition (before)

A - Diversion potential

B - Road surface and ditch drain to stream

C - Undersized culvert high in fill with outlet erosion

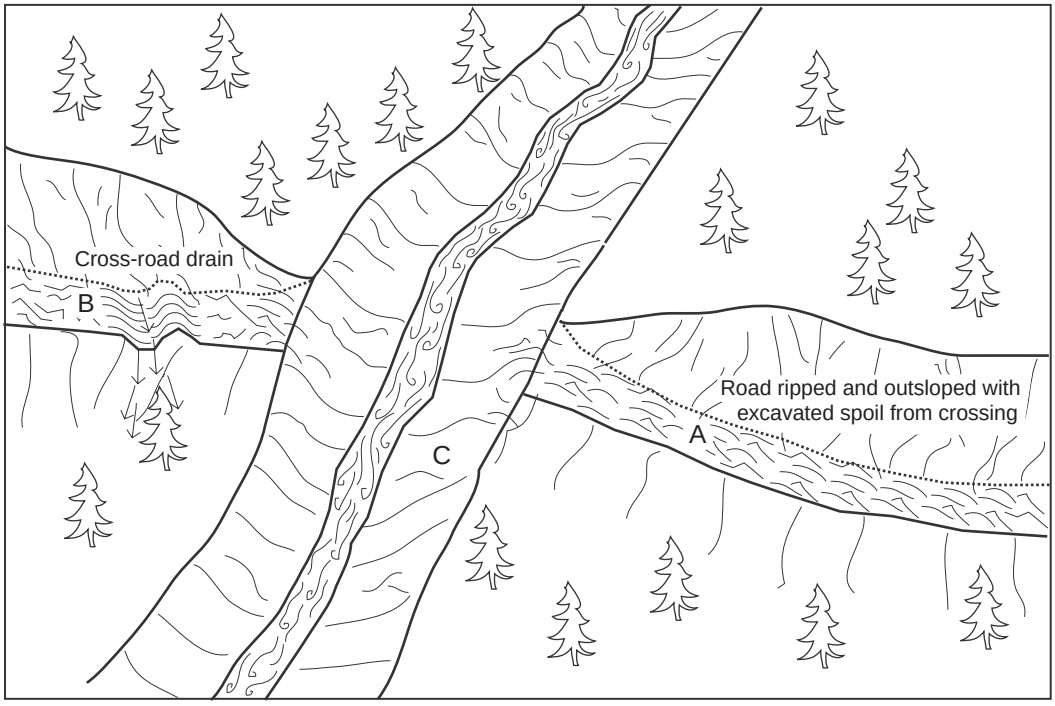


Treatment standards (after)

A - Diversion prevented by road surface ripping and outsloping using excavated spoils

B - Road surface and ditch disconnected from stream by road surface decompaction and cross-road drains

C - Stream crossing fill completely excavated



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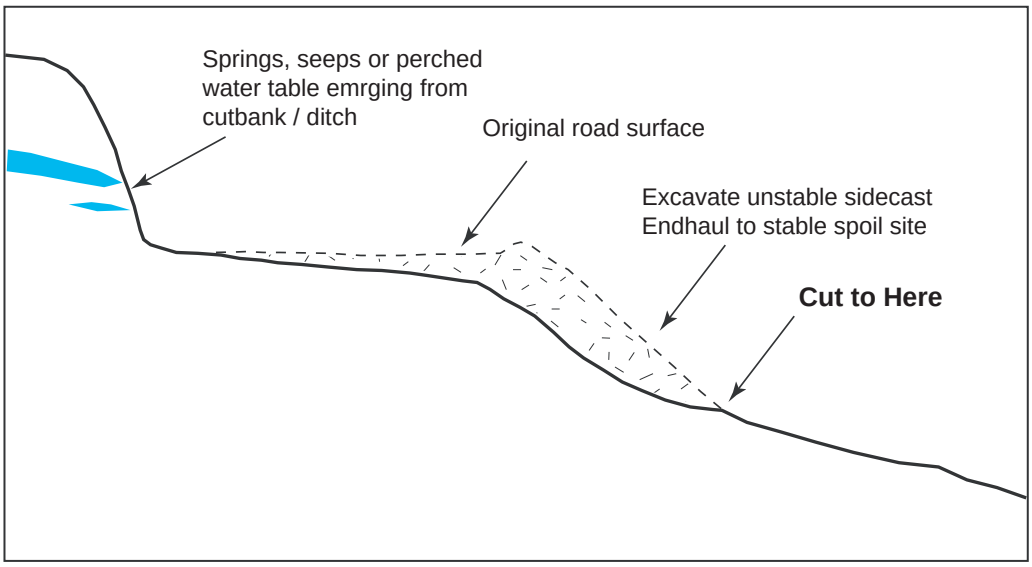
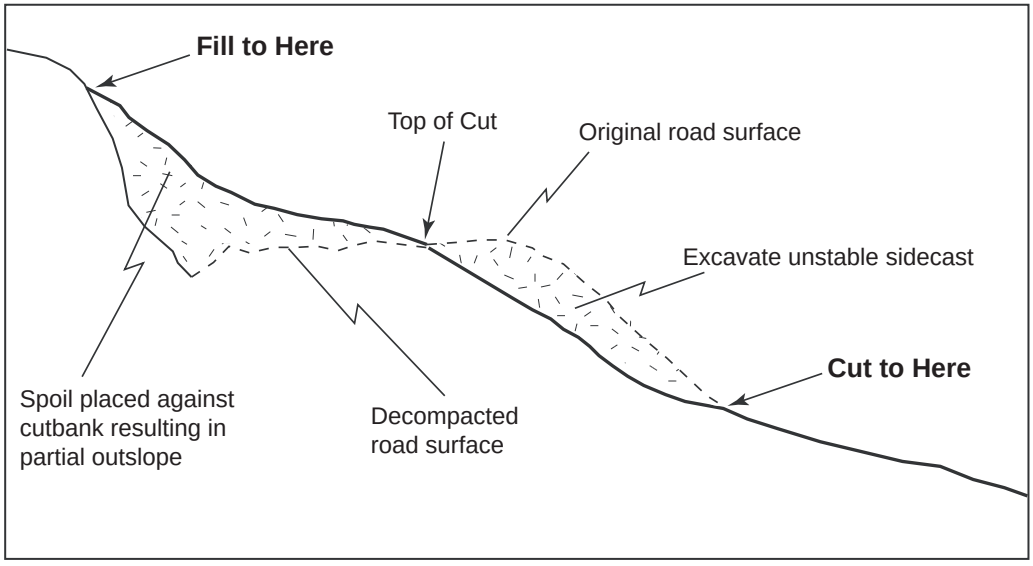
Typical Design for Road Decommisioning Treatments Employing Export and In-Place Outsloping Techniques

Export outslope (EPOS)



In-place outslope (IPOS)



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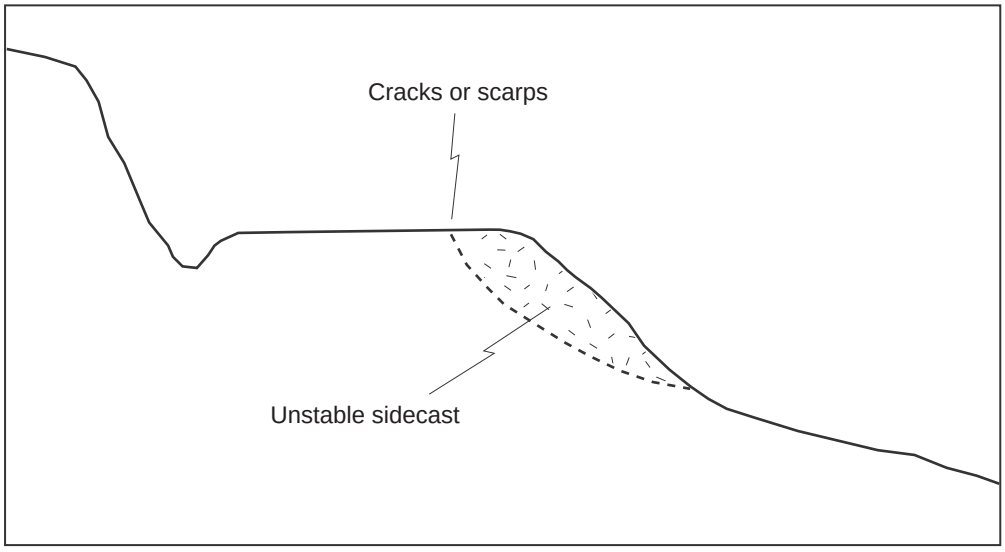
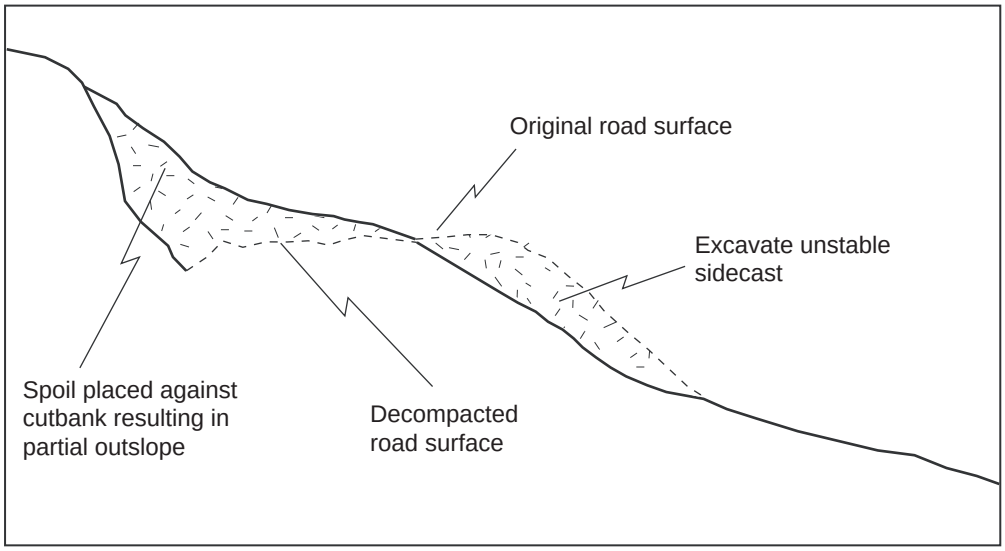
Typical Excavation of Unstable Fillslope on a Decommissioned Road

Before



After



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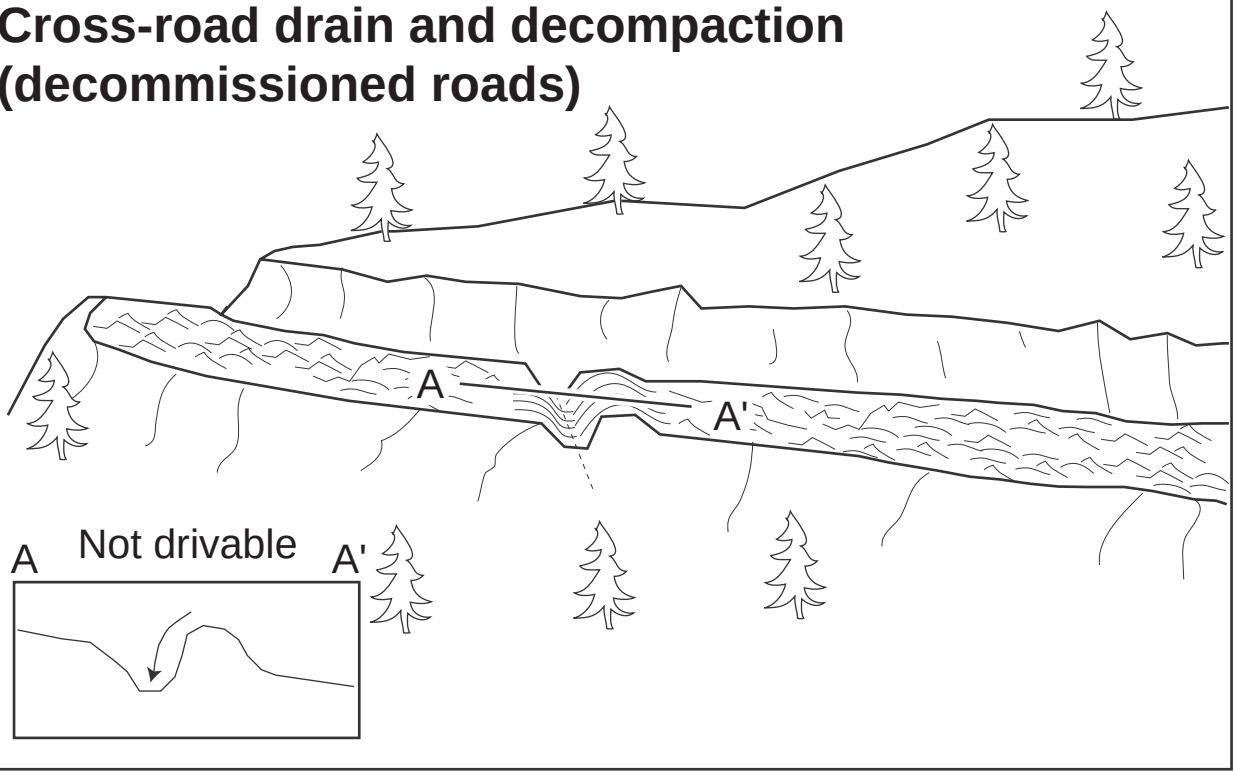
Cross-road drain and decompaction (decommissioned roads)



Cross road drain construction will ensure gullies, springs, road runoff and other concentrated flow will no longer collect over long lengths of road causing gully erosion and sediment delivery to streams. Cross road drains will be constructed at approximately 75 ft spacing intervals and these cross road drains will direct road surface runoff off the road onto stable hillslope locations.

Ripping the road surface 16 to 24 inches deep will increase road surface infiltration rates, decompact the road surface, and prevent concentrated runoff. Road ripping will also pulverize the compacted road surface or hardpan and allow for vegetation to establish and recover naturally.

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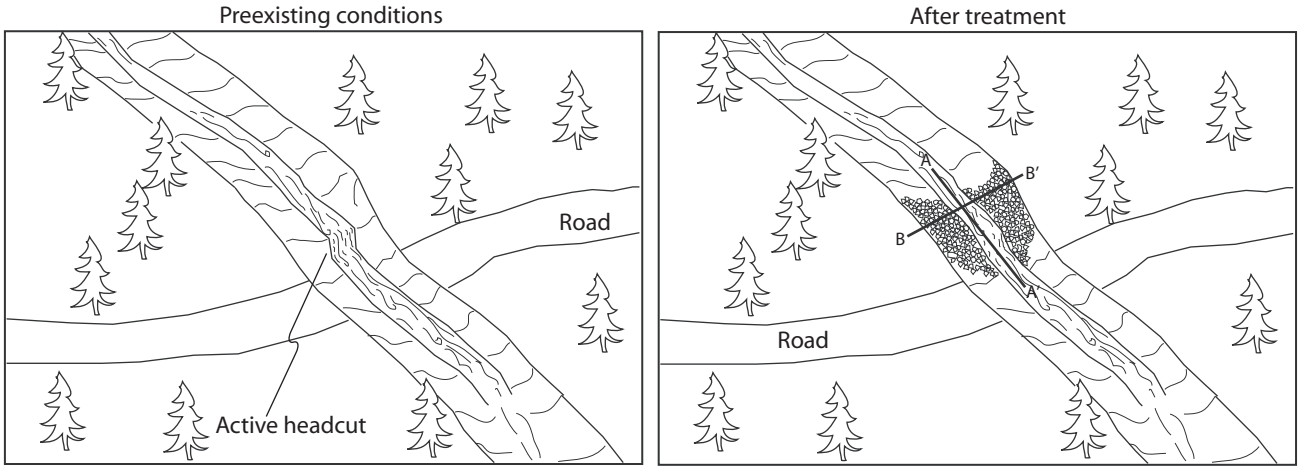
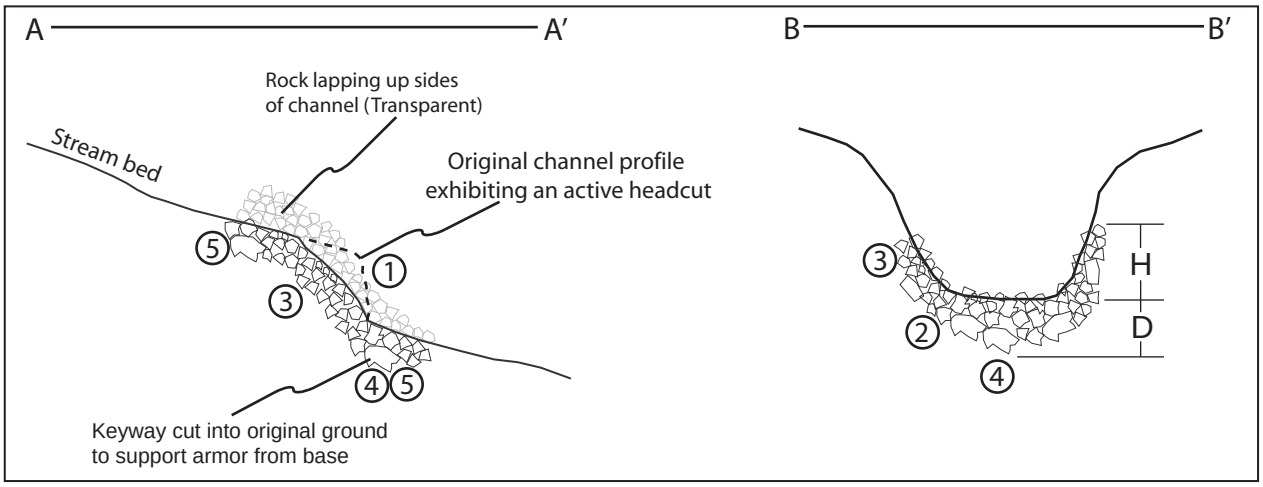
Typical Rock Grade Control Structure Installation at man-made headcuts/knickpoints in a non-fish bearing stream channel



Cross section parallel and perpendicular to watercourse



Notes

The main objective is to create a structure that will not be flanked, undercut, or eroded by the stream.

The critical elements of a successful grade control structure are:

1) Excavating the headcut to a gentler channel gradient over a distance of stream (See road log for details)
2) rock selection- rock should be selected that is resistant to transport during design flows, and has a bell shaped distribution of sizes with the median diameter equivalent to the D50 particle size of the stream at the site of installation (See road log for range of rock diameters).
3) The rock must be placed in a “U” shape that will contain the 100 yr. return interval stream flow, won’t constrict the channel cross sectional area, and be flush with the streambed and not deflect flow.
4) The rock must be imbedded into the channel at least two rock diameters in thickness.
5) The largest rock should be used at the base and top of the grade control structure to buttress the other rock

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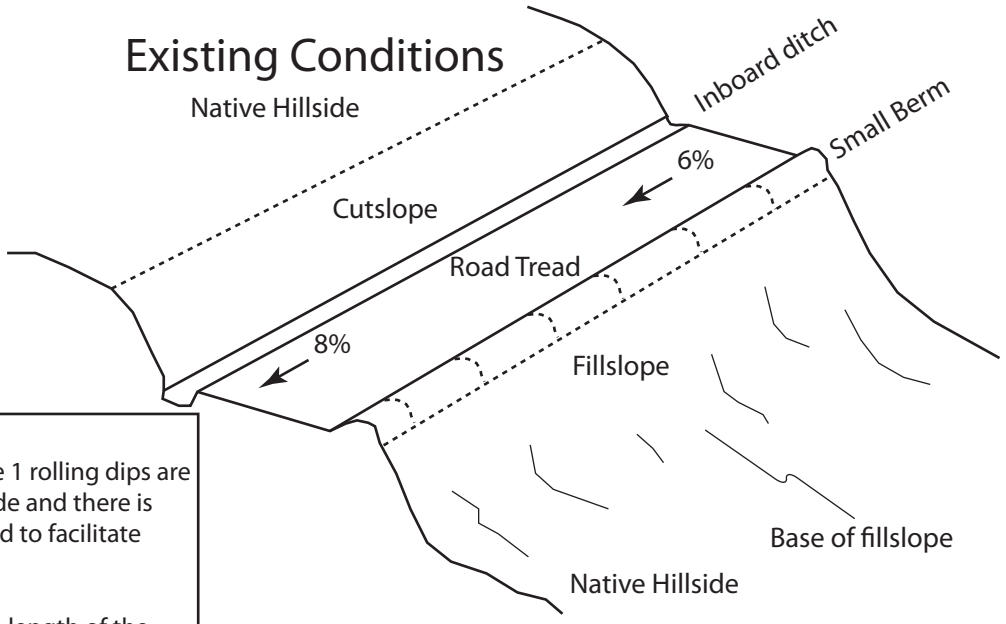
PWA Typical Drawing #18

Standard (Type 1) Rolling Dip Construction



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:

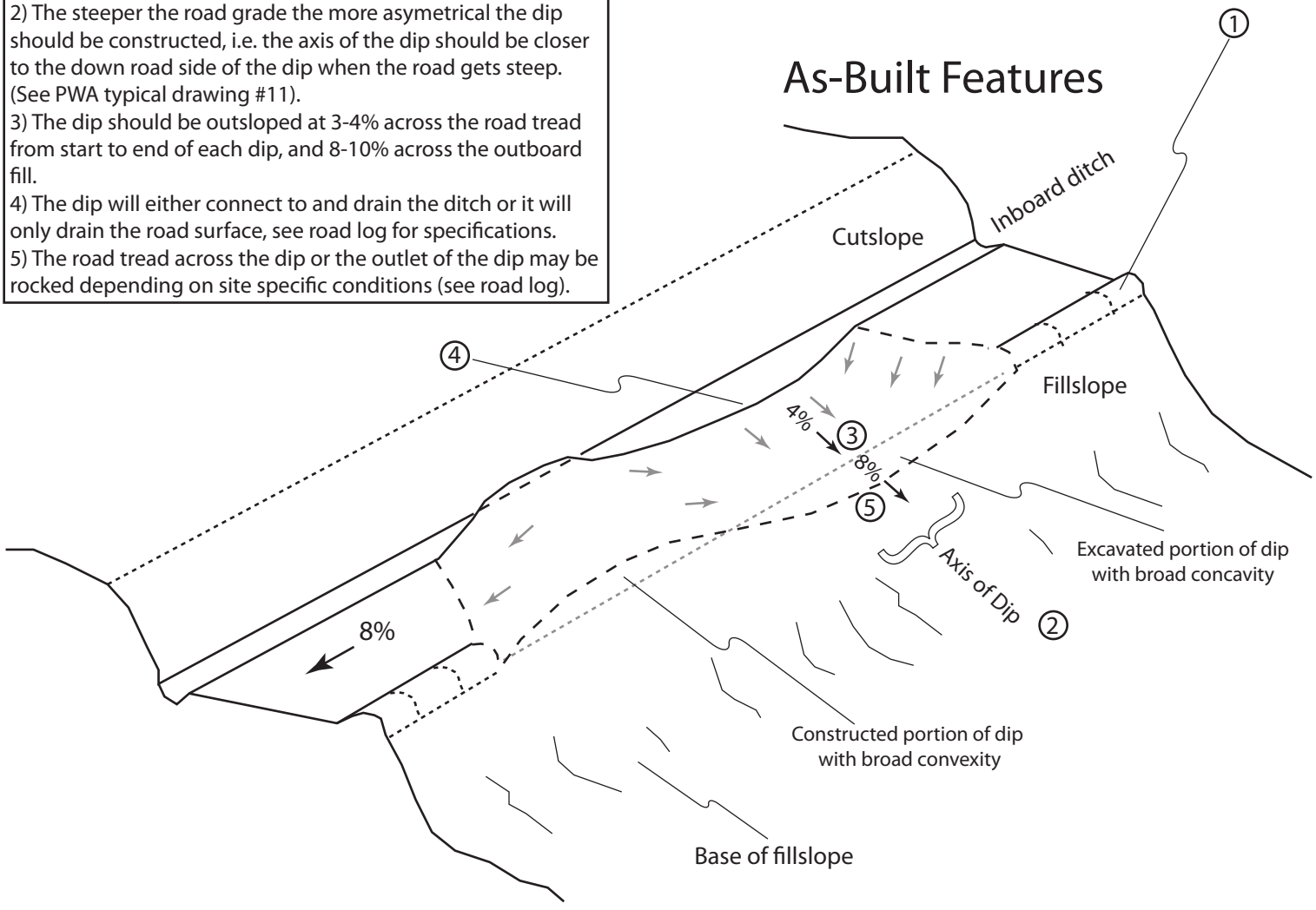
1) The berm should be removed for the entire length of the dip.

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).



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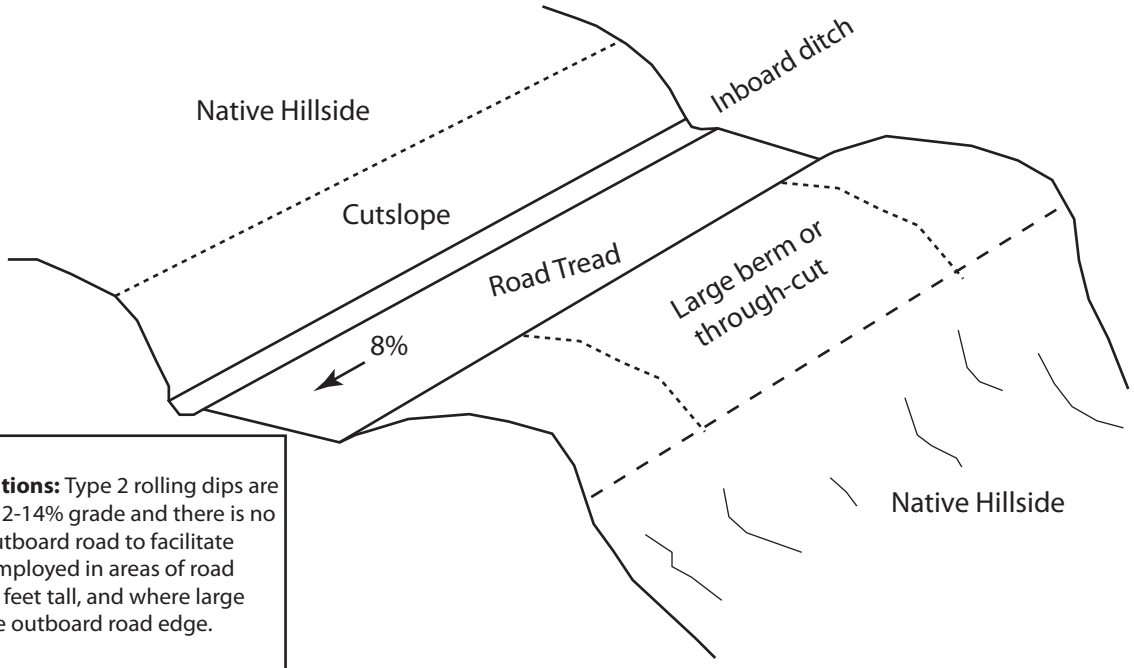
PWA Typical Drawing #19a

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.

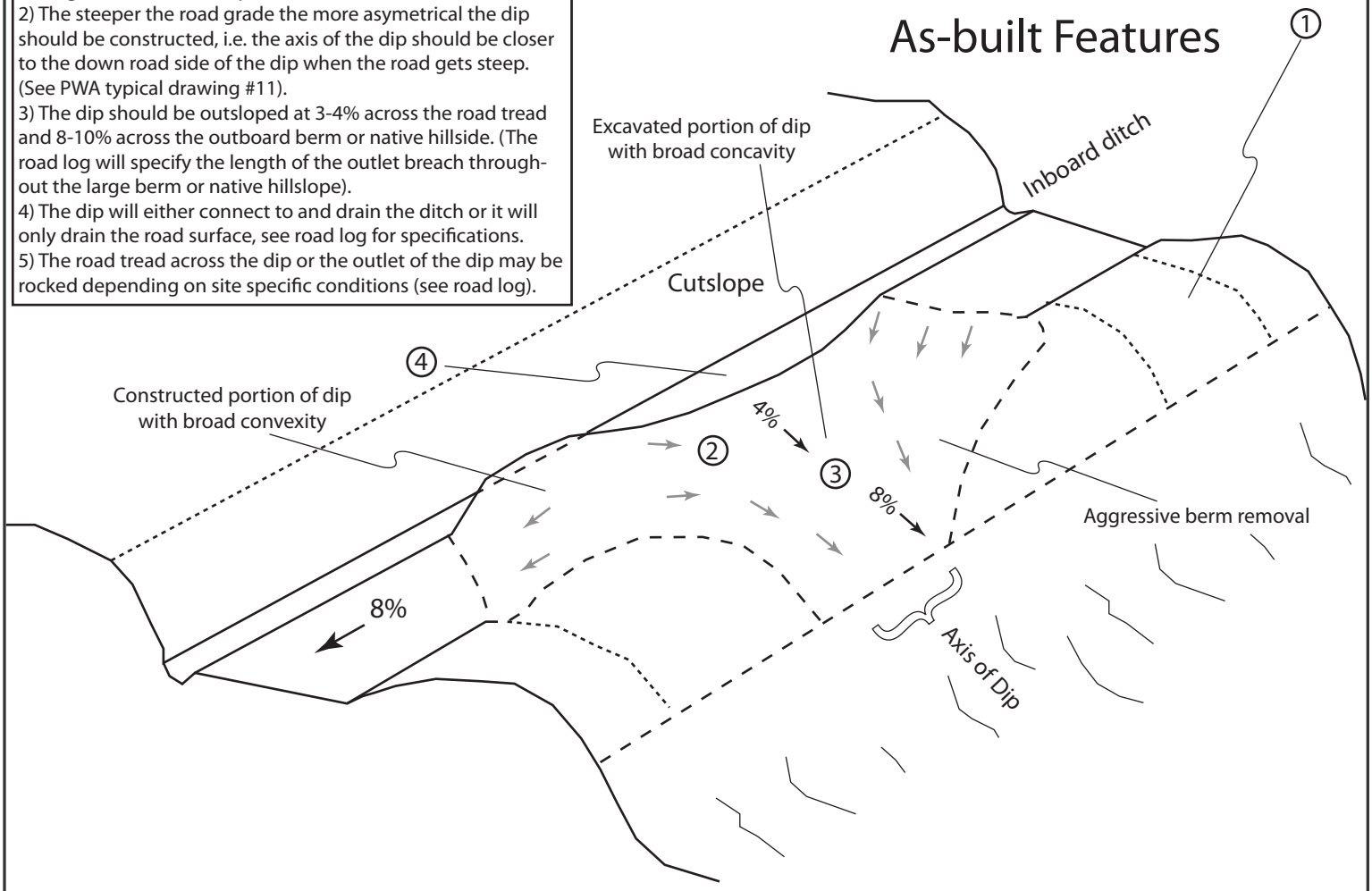
2) The steeper the road grade the more asymetrical the dip should be constructed, i.e. the axis of the dip should be closer to the down road side of the dip when the road gets steep. (See PWA typical drawing #11).

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 through-out 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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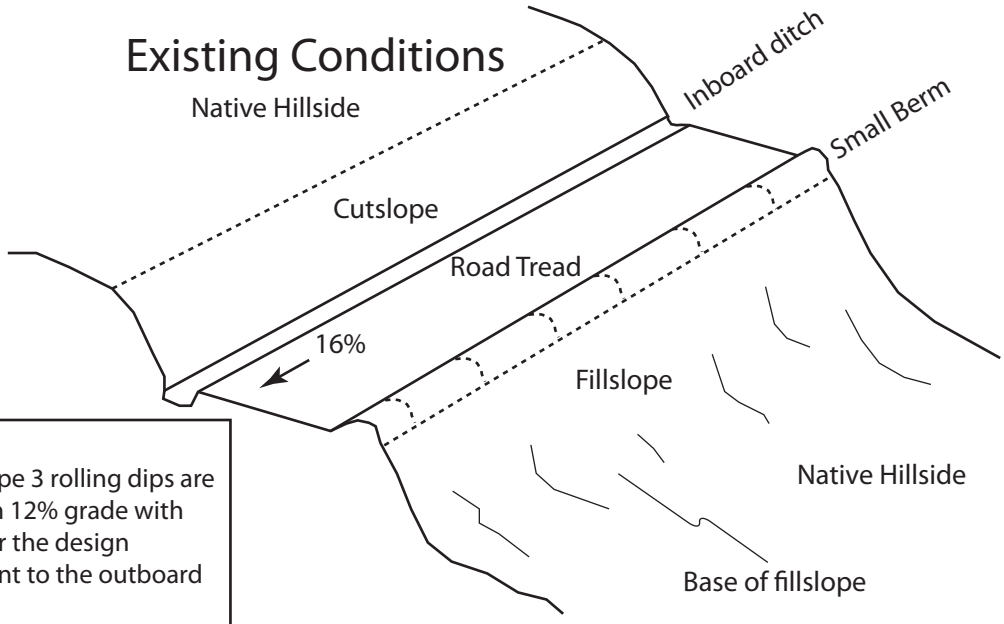
PWA Typical Drawing #19b

Type 3 Rolling Dip Construction
(steep slope outslope)



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.

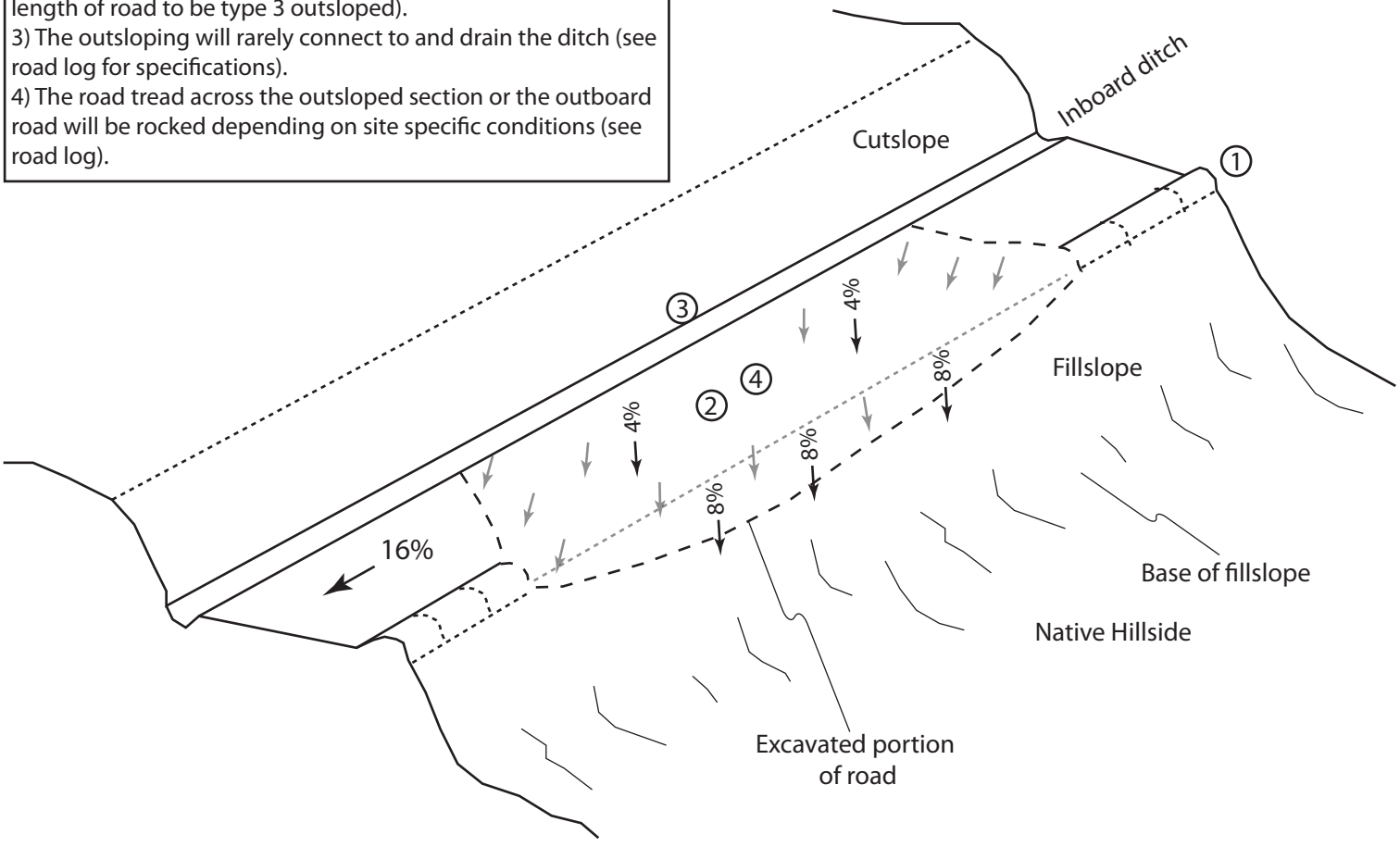
Design Notes:

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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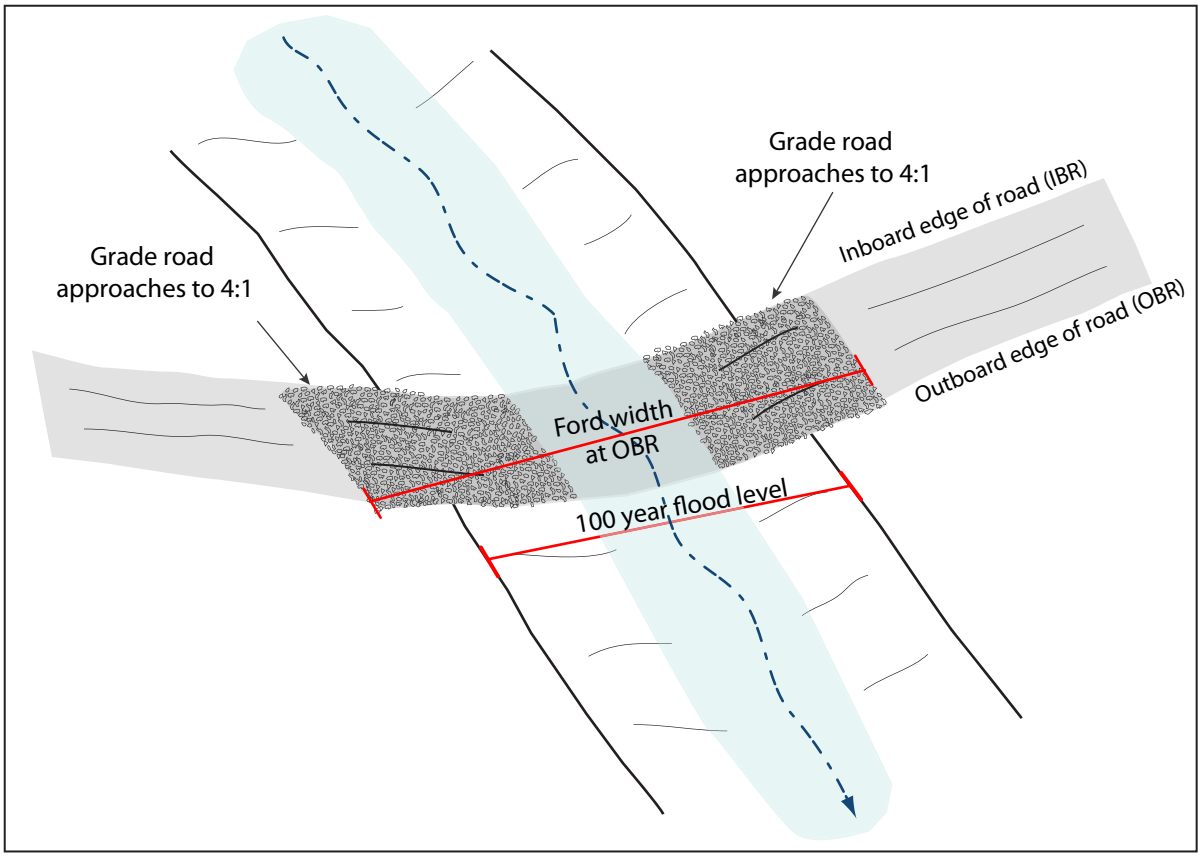
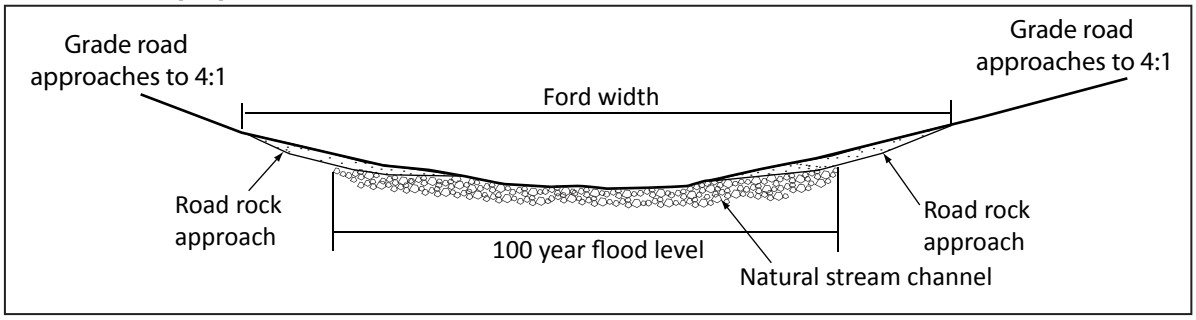
PWA Typical Drawing #19c

Typical Ford Crossing Installation

Oblique view



Cross-section perpendicular to watercourse



Steps for ford crossing construction:

1. Remove any existing structures (culverts, logs, large boulders, etc.)
2. Remove all road fill as you dip through the crossing to reach natural stream channel.
3. Establish a "U" shape across the channel at the width specified in the road logs.
4. Grade road approaches to specified slope angle (e.g., 4:1). Approaches may or may not be rocked; follow specifications in the road logs.

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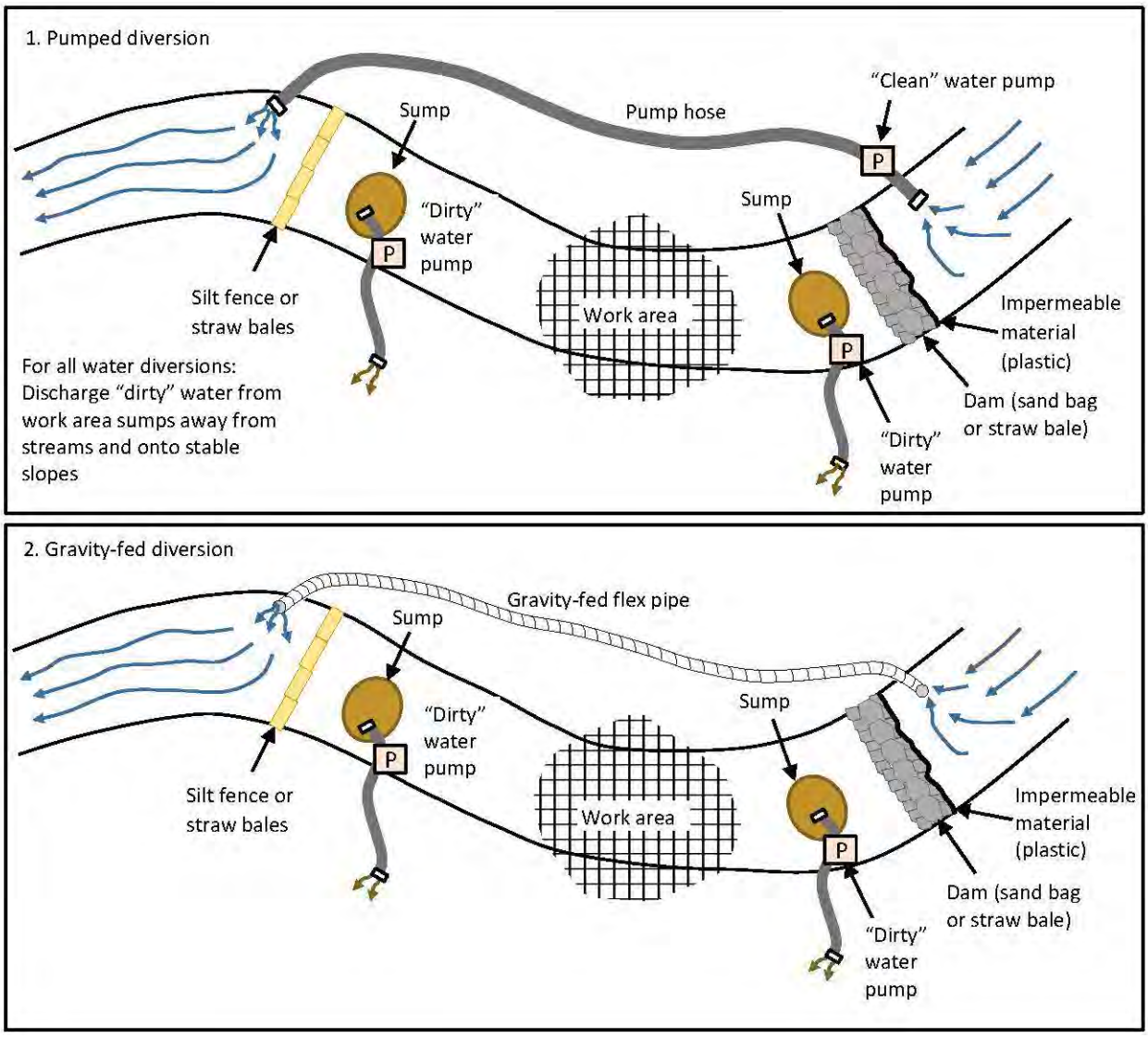
Typical Design for De-watering Streams



Stream crossing de-watering

Prior to working in and around the active stream channel, proper stream dewatering and avoidance of increasing downstream turbidity should be employed. Stream flows will be isolated upstream of the work area using cofferdams and transported downstream / around the work site through either a pumped diversion (Type 1) or by gravity diversion (Type 2) to keep the stream "live" (flowing) below the work area. An additional dam will be installed downstream of the work areas to capture any subsurface flow that might travel through the construction area. Any "dirty" water will be collected at this location and pumped away from the site where it can infiltrate into the ground without the potential to delivery to the stream and/or be used to wet fill being deposited in the spoil disposal areas.

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PWA Typical Drawing #21

Appendix D

Supplementary Information for road/trail related erosion assessments

Redwood Creek Watershed, Muir Woods Road/Trail Re-Assessment Marin County, California

1 SUPPLEMENTARY INFORMATION: TERMINOLOGY AND TECHNIQUES USED IN ROAD/TRAIL RELATED EROSION ASSESSMENTS

1.1 Sources of Road/Trail 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 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.

1.1.1 Site-specific erosion sources

Stream crossings

A stream crossing is the location where a road crosses a stream channel (Weaver et al., 2015). 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.

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[1] 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 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, which promotes plugging and decreases the culvert's capacity to carry streamflow. The outdated practice of

[1] 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.

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.

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.

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.

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 rain splash 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.

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.

Fillslope gullies.
These are sites of focused runoff (not related to stream or spring flow) that form on fillslopes, and may exacerbate erosion at the roadway or contribute sediment to the system during high discharge.

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.

1.1.2 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/TRAILS (UPGRADING, DECOMMISSIONING, AND MAINTENANCE)

Forest and rural roads may be storm-proofed by one of two methods: upgrading or decommissioning (Weaver and Hagans, 1999; Weaver et al., 2006, 2015). 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 reduce or prevent future sediment delivery to the local stream system. A well-designed storm-proofed road includes specific characteristics (see table, next page), all proven to contribute to long-term improvement and preservation of watershed hydrology and aquatic habitat.

2.1 Road/trail 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).

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.

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.

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.

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.

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.

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 exceedance of the primary culvert is anticipated.

2.2 Road/trail 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, 2015; Harr and Nichols, 1993).

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.

Installing cross-road drain

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.

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.

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.

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.

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.

Road to trail conversion (R2T)

R2T is a technique comparable to IPOS, except that a portion of the outboard road and fill material is excavated to narrow the existing roadbed from its current width to approximately a 6 ft wide, mutli-use recreational trail that will be outsloped at 6% with no inboard drainage ditch or berm. This treatment will prohibit the use of vehicular traffic.

2.3 Road maintenance and inspection schedule

Unless all the roads are paved in some manner, any Erosion Control and Erosion Prevention Plan accepts the fact that land managers cannot stop all erosion. However, the implemented Plan measures are designed to significantly reduce the risk of catastrophic erosion and sediment delivery from occurring, as well as significantly reduce the contributions of fine sediment from roadbeds associated with surface erosion and gully erosion processes. Once implemented, the longevity of the erosion control and erosion prevention treatments installed for the project will be primarily dependent on good maintenance practices for the years to come. As land managers, you are responsible for the upkeep of all treatments to ensure the continued effectiveness of the treatments.

In order to maintain the effectiveness at culvert installations, future road maintenance activities should:

a. Carefully clean and clear culvert inlets when woody debris and sediment has accumulated and plugs more than 10% of the culvert capacity. Be careful not to damage or crush the culvert inlet. If the culvert is crushed, use whatever means are available to re-define a functional, 100% open culvert inlet.

b. Inspect downspouts and/or rock armor for signs of erosion and, if observed, repair and prevent the erosion from occurring, usually by applying additional rock armor. If hillslope gullies are forming below the outlets of ditch relief culverts with connectivity to a downslope

stream channel, then reduce the contributing drainage area by going up road and installing additional ditch relief culvert(s).

c. If a particular stream crossing culvert inlet exhibits a frequent need to be cleaned of woody debris and sediment, install a single-post trash rack upstream and centered on the culvert inlet. This will substantially reduce the culvert plugging potential and lower the risk of the crossing washing out in future storms. Single-post trash racks should be sturdy enough to retain wood without bending over, and be positioned and pounded securely into the stream bed at a distance dictated by the culvert diameter. For example, if a trash rack is being installed above a 36" culvert, it should be installed 36" above the culvert inlet and centered on the culvert inlet.

In order to maintain the current road shapes and roadbed drainage patterns, future road grading activities should address or consider the following guidelines:

Road shaping

a. Maintain proper road outsloping when road grading. Grading work should retrieve material from the outer half of the road and use the material to elevate the inner half of the roadbed, and maintain or re-establish a 3% to 6% outslope across the road along straight road reaches; re-establish a flat to 2% outslope across the road at the apex of sharp outside bends in the road (for safety concerns); and re-establish a 4% to 8% outslope across the road at the apex of inside bends in the road (i.e. super-outslope to ensure all road runoff and roadbed derived sediment leaves the road at the bend).

b. Make sure outboard road shoulder is properly outsloped. When re-grading roads, always ensure that the outer 2' to 4' (or greater) shoulder area along the outside edge of the road (i.e., non-normal driving surface) is outsloped with a 2% to 5% steeper angle than the adjacent roadbed (i.e., if the roadbed is outsloped with a 4% grade, then the shoulder area should be outsloped with a 6% to 9% grade). The shoulder area will either accumulate dense litter or grass and shrub cover with time, yet the steeper shoulder slope angle will allow sediment and water to flow to and beyond the very outside edge of the road for many years before grading is required.

c. Avoid annual grading of inboard ditches unless the capacity is greatly reduced due to sedimentation. Only re-grade the ditch where cutbank slides have reduced capacity. A grass covered inboard ditch with adequate runoff and flow capacity (i.e., cross sectional area) can provide years of excellent filtration from any road-bed derived sediment that is delivered to the ditch.

d. Avoid creating new earthen berms along the outside edge of outsloped or crowned road sections (no matter how small). Where berms have been periodically breached at 20' to 50' intervals along a reach of road, always maintain the existing berm breaches with a steeper slope angle than the adjacent reach of road draining to each berm breach. For example, if the road grade is 10% in steepness, then the berm breach should be constructed or maintained with a 12% to 15% slope angle, and extend far enough beyond the road shoulder to provide positive drainage and minimize future grading. Observing minor scour or down-cutting

through the length of the berm breach, as opposed to deposition, indicates a properly constructed berm breach that will require minimal future maintenance.

Rolling dips and critical rolling dips

Physically, there is no difference between a rolling dip and a critical rolling dip, but each serve a different purpose. Rolling dips are a roadbed drainage structure, similar to ditch relief culverts, intended to provide permanent drainage breaks along a length of road in order to disperse and not collect runoff. The spacing between a series of rolling dips, as well as using rolling dips in conjunction with road outsloping, is fundamental to dispersing road runoff effectively and minimizing sediment delivery from the roadbed.

Critical rolling dips are constructed at the down road hinge line of stream crossing fills, and are intended to prevent stream diversions during severe winter storms. In the event the culvert inlet plugs with debris and sediment, and stream flow overtops the culvert and enters the roadbed, the critical rolling dip directs the stream flow back into the natural channel below the road as quickly as possible.

Both rolling dips and critical rolling dips are most effective when properly constructed to provide both a permanent drainage point along the road, as well as maintain a safe, easily driveable road at the posted speed limit. Either type of dip can drain just the roadbed, or both the roadbed and the adjacent inboard ditch.

a. Maintain the overall form of the dip both down the road and across the road.

b. When redefining (deepening) the axis or low point of the dip, use the excavated material to enhance (raise) the down road high point, or reverse grade, of the dip to ensure the dip functions as a permanent road drainage point.

c. When grading dips, always ensure that each dip has a 3% to 6% outslope along the length of the dip on the primary driving surface, as well as across the road for the length of each dip, and ensure that the shoulder area along the outside edge of the road has a 2% to 5% steeper grade than the driving surface portion of the road.

d. Re-rock the dips when necessary.

e. Some minor erosion on the fillslope at the dip outlet beyond the outside edge of the road is common, but if the rolling dip spacing is designed properly, there will be no erosion and sediment delivery on the native hillslopes beyond the base of the fill. If the fillslope erosion in the form of minor gullying is of concern, import a mix of 0.3' to 0.75' diameter rip-rap to armor the gully between the outside edge of the road and the base of the fillslope, where necessary.

Annual Maintenance Schedule: always prepare for the winter rainy season

All road drainage structures should be inspected and cleaned annually by October 1st, prior to the onset of the rainy season. This includes all culvert inlets, trash racks and culvert downspouts attached to the outlets of culverts, inboard ditches along the road, rolling dips and critical rolling dips, berm breaches and sediment basins. If any of the structures are clogged with debris and sediment, they should be cleaned either by hand, with a backhoe or with a grader (in the case of

the rolling dips) to start the winter period with full capacity so as to carry runoff as intended. During large severe winter storms, a two person work crew should be available to inspect the roads and culverts to ensure no problems are developing, particularly at stream crossing culverts.

3 DETERMINING TREATMENT IMMEDIACY AND COST-EFFECTIVENESS

Identifying *treatment immediacy* is an integral part of an assessment used to prioritize sites prior to implementation. Treatment immediacy is a professional evaluation of how important it is to quickly perform erosion control or erosion prevention work. It is defined as "high," "moderate," or "low," and represents the urgency of treating the site before it erodes or fails. An evaluation of treatment immediacy is based on the following criteria: (1) *erosion potential*, or whether there is a low, moderate, or high likelihood for future erosion at a site; (2) *sediment delivery*, which is an estimate of the sediment volume projected to be eroded from a site and delivered to a nearby stream; and (3) the value or sensitivity of downstream resources being protected. Generally, sites that are likely to erode or fail in a normal winter, and are expected to deliver significant quantities of sediment to a stream channel, are rated as having high treatment immediacy.

The *erosion potential* of a site is a professional evaluation of the likelihood that erosion will occur during a future storm, based on local site conditions and field observations. It is a subjective probability estimate, expressed as "low," "moderate," or "high," and not an estimate of how much erosion is likely to occur. The volume of sediment projected to erode and reach stream channels is described by *sediment delivery*, which plays a significant role in determining the treatment immediacy for a site. The larger the volume of potential future sediment delivery to a stream, the more important it becomes too closely evaluate the need for treatment.

From this assessment, treatment immediacy and *cost-effectiveness* may be analyzed, along with the client's transportation needs, to prioritize treatment sites or locations for implementation. *Cost-effectiveness* is not only a necessary consideration for environmental protection and restoration projects for which funding may be limited, but is also an accepted and well-documented tool for prioritizing potential treatment sites in an area (Weaver and Sonnevil, 1984; Weaver and Hagans, 1999). A quantitative estimate for cost-effectiveness is determined by dividing the cost of accessing and treating a site by the volume of sediment prevented from being delivered to local stream channels. The resulting value, or *sediment savings*, provides a comparison of cost-effectiveness among sites, and an average for the entire project area. For example, if the cost to develop access and treat an eroding stream crossing is projected to be $5000, and the treatment will potentially prevent 500 yd^3 of sediment from reaching the stream channel, the predicted cost-effectiveness for that site would be $5000/500$yd^3$, or $10/$yd^3$.

PWA further evaluates cost-effectiveness for an entire assessment area by organizing sites into logistical groups based on similar requirements for heavy equipment and materials, and addressing these as a unit to minimize expenses. Furthermore, although sites and road segments with the lowest immediacy ratings are placed last on the list for treatment, it is sometimes possible to treat these sites once the project is underway, as opportunities to cost-effectively treat low-immediacy sites often arise when heavy equipment is already located nearby to perform maintenance or restoration at higher-immediacy sites.

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