Final Report

Sediment Assessment of Roads and Trails within the Pescadero/Memorial/Sam McDonald County Park Complex, Pescadero Creek Watershed, San Mateo County, California
Contract # 39000-02-C212

prepared for

San Mateo County Parks and Recreation Department and
California Department of Fish and Game

by

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February 17, 2003

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Year 2000 CDF&G S.B. 271
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Background

The Pescadero-Butano Watershed is the largest watershed in coastal San Mateo County, encompassing over 80 square miles. It drains to the Pacific Ocean within the Monterey Bay National Marine Sanctuary. The main stem of the Pescadero Creek is approximately 26 miles in length and has an additional 44 linear miles of perennial tributaries. The watershed supports a substantial southern Steelhead trout population, as well as a small remnant Coho salmon run. It is estimated that approximately 21 miles of main stem Pescadero Creek and Peters, Slate, Oil and Butano Creeks are potentially viable coho rearing habitat (Draft Strategic Plan for Restoration of the Endangered Coho Salmon South of San Francisco Bay, CDFG, 1998). San Gregorio Creek has a Steelhead trout population, which has since disappeared.

A key attribute of this watershed is the Pescadero Marsh – the largest coastal estuary between Tomales Bay and Elkhorn Slough. The marsh provided critical steelhead rearing habitat, equal to the value of over 8 miles of instream production within the watershed (Dr. J. Smith, 1990, Steelhead Restoration and Management Plan for California, CDFG,1996). However, the marsh over the last several decades has experiencing severe aggradation due to excessive siltation and sedimentation from the upper watershed, resulting in a loss of habitat quality and quantity (Pescadero Marsh Natural Preserve Hydrologic Enhancement Plan, Phillip Williams and Associates, 1990).

Historic land uses, in particular pre-Forest Practice Act logging, upland grazing and farming, high visitor use levels and antiquated private, county and state road design, construction and maintenance practices, have combined with a highly erodible and seismically unstable geology to result in severe sedimentation of the streambed for much of the lengths of Pescadero and Butano Creeks. Many of the early logging roads were rough cut-fill construction along stream banks. The streambeds themselves, particularly along ephemeral streams in the upper watershed, were used as skid trails. Large areas of the upper watershed were clear-cut between 1856 and 1970. Most of these lands have been acquired by County or State agencies as recreational lands; however, the now maintained and abandoned logging road system still exists, and continues to be a source of sedimentation in the streams (Analysis of the Pescadero-Butano Marsh Watersheds, R. Osterling, 1987). The Pescadero/Memorial/Sam MacDonald County Park Complex (PMSM-CPC) is the largest single landowner in the Pescadero Creek watershed. Within the park complex, there are a total of 65 miles of known and abandoned roads and trails.

In 1998, Pescadero/Butano and San Gregorio Creek watersheds were listed as 'impaired' for sediment by the Regional Water Quality Control Board, and the basins are scheduled for development of Total Maximum Daily Load (TMDL) regulations in the next three years. This final report and *"Sediment Assessment for the Pescadero Creek County Park Complex"* addresses many of the requirements of the NPDES permit issued by the Regional Water Quality Control to the City/County Association of Government of San Mateo County (C/CAG) on July 29, 1999.

Introduction

In January 2002, Pacific Watershed Associates (PWA) was contracted by San Mateo County Parks and Recreation (SMCPR) to inventory 65 miles of roads and trails within the Pescadero/Memorial/Sam McDonald County Park Complex for sites of future erosion and sediment delivery to streams, and to prepare a prioritized erosion prevention plan (Figure 1). This project was funded through a CDFG S.B. 271 watershed restoration grant (Contract # P-0030412). This project was specifically aimed at identifying future erosion sources that are impacting fish bearing streams and to develop prescriptions aimed at reducing sediment input to the watershed. This project was not concerned with those erosional features that are not delivering sediment to the stream network.

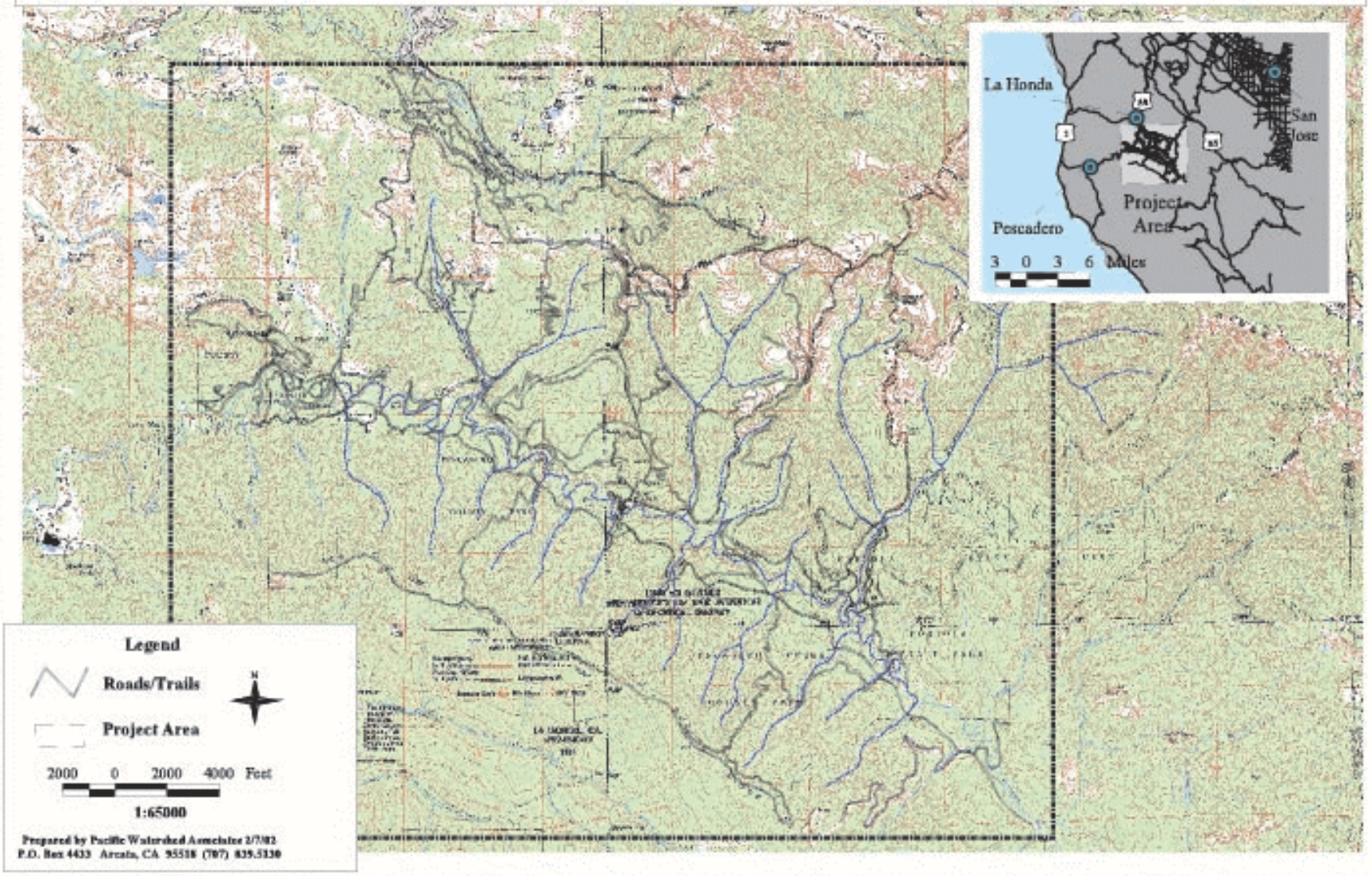
Pescadero Creek Watershed Assessment

Perhaps the two most important, watershed elements needed for long term restoration of salmon habitat, and the eventual recovery of salmonid populations in the Pescadero Creek watershed, are 1) the reduction of accelerated erosion and sediment delivery to the stream channel system and 2) improving estuarine rearing habitat. The latter is a very complex problem influenced by tectonic and seismic activity in the watershed, a long history of levee construction and channel flow course alteration, among other factors.

In relation to reducing the effects of past and current land management practices on sediment production, this summary report describes the erosion assessment and inventory process that was employed on County Park Lands in the Pescadero Creek watershed. It also serves as a prioritized plan-of-action for cost-effective erosion control and erosion prevention treatments for the watershed. When implemented and employed in combination with protective land use practices, the proposed projects are expected to significantly contribute to the long term protection and improvement of salmonid habitat in the basin.

The implementation of erosion control and erosion prevention work is an important step toward protecting and restoring watersheds and their anadromous fisheries (especially where sediment input is a limiting or potentially limiting factor to fisheries production, as is thought to be the case for Pescadero Creek). Road systems and trail systems (to a lesser extent) are perhaps the most significant and most easily controlled sources of sediment production and delivery to stream channels. Pescadero Creek is underlain by erodible and potentially unstable geologic substrate, and both field observations and aerial photo analysis suggests that roads have been a significant source of accelerated sediment production in the watershed. In Pescadero Creek, as in many other coastal watersheds, the disturbance caused by excess sediment input to stream channels during large rainfall events is perhaps one of the most significant factors affecting salmonid populations. Chronic sediment inputs to the channel system, from roads, trails and other bare soil areas, are also important contributors to impaired habitat and reduced salmonid populations.

Figure 1. Location map of the Pescadero /Memorial/Sam McDonald County Park Complex road and trail assessment, Big Basin, Franklin Point, La Honda, and Mindego Hill USGS 7.5' quadrangles, San Mateo County, California



Unlike many watershed improvement and restoration activities, erosion prevention and "storm-proofing" of road systems and trails have an immediate benefit to the streams and aquatic habitat of the basin. It helps ensure that the biological productivity of the watershed's streams is not impacted by future human-caused erosion, and that future storm runoff can cleanse the streams of accumulated coarse and fine sediment, rather than depositing additional sediment from managed areas. Sites targeted as high treatment immediacy in Pescadero Creek have been identified as high priority for implementation so that fill failures, stream crossing erosion, washouts, ditch relief gully erosion and stream diversions do not degrade the stream system.

The completed assessment identified all recognizable current and future sediment sources from roads and trails within the watershed assessment area. The field inventory identified future sediment sources from approximately 65 miles of road and trail system in the watershed. The primary objective of the road and trail upgrading and decommissioning recommendations which have been prepared, is to implement cost-effective erosion control and erosion prevention work on sites that were identified as a part of this comprehensive watershed assessment and inventory. This assessment is also intended to be used as a tool for basin-wide transportation planning in which the ecological impacts of specific roads and trails can be balanced against the needs for transportation, management, fire safety and public access.

Project Description

The project involved a complete field inventory of the road and trail systems in the three County Parks in the watershed. Technically, this assessment was neither an erosion inventory nor a road maintenance inventory. Rather, it was an inventory of sites where there is a potential for future sediment delivery to the stream system that could impact fish bearing streams in the watershed. All roads and trails, including both maintained and abandoned routes, were walked and inspected by trained personnel and all existing and potential sediment delivery sites were identified, described and a recommendation for treatment was made. Sites, as defined in this assessment, include locations where there is direct evidence that future erosion or mass wasting could be expected to deliver sediment to a stream channel. Sites of past erosion were not inventoried unless there was a potential for additional future sediment delivery. Similarly, sites of future erosion that were not expected to deliver sediment to a stream channel were not included in the inventory, but were mapped on the field maps during the assessment. A map of the road and trail system in the watershed was developed from field maps, air photos and GIS.

Inventoried sites generally consisted of stream crossings, potential and existing landslides related to the road or trail system, gullies below ditch relief culverts and long sections of uncontrolled road and ditch surface runoff which currently discharge to the stream system. For each identified existing or potential erosion source, a database form was filled out and the site was mapped on a mylar overlay on a 1:12,000 scale topography map. The database form (Figure 2) contained questions regarding the site location, nature and magnitude of existing and potential erosion problems, the likelihood of erosion or slope failure and recommended treatments to eliminate the site as a future source of sediment delivery.

The erosion potential (and potential for sediment delivery) was estimated for each problem site or potential problem site. The future volume of sediment expected to be eroded and delivered to streams was estimated for each site. The data provides quantitative estimates of how much material could be eroded and delivered in the future, if no erosion control or erosion prevention work is performed. In a number of locations, especially at stream diversion sites, actual sediment loss could easily exceed field

predictions. All sites were assigned a treatment priority, based on their potential or likelihood to deliver sediment to stream channels in the watershed and on the cost-effectiveness of the proposed treatment.

In addition to the database information, tape and clinometer surveys were completed on virtually all stream crossings. These surveys included a longitudinal profile of the stream crossing through the road prism, as well as two or more cross sections. The survey data was entered into a computer program that calculates the volume of fill in the crossing. The survey allows for an accurate and repeatable quantification of future erosion volumes (assuming the stream crossing was to wash out during a future storm), decommissioning volumes (assuming the road was to be closed) and/or excavation volumes that would be required to complete a variety of road upgrading and erosion prevention treatments (culvert installation, culvert replacement, complete excavation, etc.).

As shown by this assessment, the net benefit of treating the legacy road network and the risk associated with road sediment delivery to streams exceeds, by orders of magnitude, the sediment impacts associated with trail erosional processes (Table 1 and Table 6).

Inventory Results

Approximately 73.8 miles of roads and trails (39.4 miles of roads and 34.4 miles of trails) were inventoried for future sediment sources within the Pescadero/Memorial/Sam McDonald County Park Complex (PMSM-CPC). All County Park roads and the Sheriff Honor Camp roads have been assigned site numbers ranging from #1 to #310, and include site #609. All county park trails have been assigned site numbers in the 500's, and all county public works department roads have site numbers in the #600's (See Maps 1,2 and 3).

The sediment assessment was completed in two phases, and is reported on in two separate parts of this report. In January, 2002, at the request of County Park Senior Planner Sam Herzburg, PWA personnel completed the sediment assessment along the 5.7 mile long "Old Haul Road" located in Pescadero County Park (See Maps 1 and 2). Results of the "Old Haul Road" sediment assessment are reported in Appendix A. All the remaining roads (33.7 miles) and the 34.4 miles of trails within the County Park Complex were inventoried during the summer and fall of 2002, and the results of the sediment assessment are presented in the following Tables #1 though #6.

Inventoried future erosion sites fell into one of two treatment categories: 1) upgrade sites - defined as sites on maintained roads or trails that are to be retained for access and management and 2) decommission sites - defined as sites exhibiting the potential for future sediment delivery that have been recommended for either temporary or permanent closure. Virtually all future road and trail related erosion and sediment delivery in the PMSM-CPC is expected to come from four sources: 1) erosion at or associated with stream crossings (from several possible causes), 2) road surface and ditch erosion, 3) landslides associated with road fill slopes or cut banks, and 4) gully erosion below ditch relief culvert outlets.

Figure 2. Road erosion inventory data form used in the Pescadero Creek watershed assessment

*ASAP*_____	**PWA ROAD INVENTORY DATA FORM** (3/98 version)				*Check*_____		
GENERAL	**Site No:** _____	GPS:	Watershed:		CALWAA:		
Treat (Y,N):	Photo: _____	T/R/S:	Road #:		Mileage: _____		
	Inspectors:_____	Date: _____	Year built:_____	Sketch (Y):			
	Maintained	Abandoned	Driveable	Upgrade	Decom.	Maintenance	
PROBLEM	Stream xing	Landslide (fill, cut, hill)	Roadbed (bed, ditch, cut)	DR-CMP	Gully	Other	
	Location of problem (U, M, L, S)	Road related? (Y)	Harvest history: (1=<15 yrs old; 2=>15 yrs old) TC1, TC2, CC1, CC2, PT1, PT2, ASG, No		Geomorphic association: Streamside, I.G., Stream Channel, Swale, Headwall, B.I.S.		
LANDSLIDE	Road fill	Landing fill	Deep-seated	Cutbank	Past failure	Potential Failure	
	Slope shape: (convergent, divergent, planar, hummocky)			Slope (%) _____	Distance to stream (ft) _____		
STREAM	CMP	Bridge	Humboldt	Fill	Ford	Armored fill	
	Pulled xing: (Y)	% pulled _____	Left ditch length (ft) _____		Right ditch length (ft) _____		
	cmp dia (in) _____	inlet (O, C, P, R)	outlet (O, C, P, R)	bottom (O, C, P, R)	Separated?	Rd grade (%) _____	
	Headwall (in) ____	CMP slope (%) _____	Stream class (1, 2, 3)	Rustline (in)	% washed out ____		
	D.P.? (Y)	Currently dvted? (Y)	Past dvted? (Y)	Plug pot: (H, M, L)	Ch grade (%) _____		
	Ch width (ft) _____	Ch depth (ft) ____	Sed trans (H, M, L)	Drainage area (mi^2) _____			
EROSION	E.P. (H, M, L)	Potential for extreme erosion? (Y, N)		Volume of extreme erosion (yds^3): 100-500, 500-1000, 1K-2K, >2K			
Past erosion...	Rd&ditch vol (yds^3) (yds^3)_____	Gully fillslope/hillslope (yds^3)_____	Fill failure volume (yds^3) _____	Cutbank erosion (yds^3)_____	Hillslope slide vol. (yds _____	Stream bank erosion (yds^3) _____	xing failure vol (yds^3) _____
	Total past erosion (yds) _____	Past delivery (%) _____	Total past yield (yds) _____	Age of past erosion (decade)_____			
Future erosion...	Total future erosion (yds) _____	Future delivery (%) _____	Total future yield (yds) _____	Future width (ft) _____	Future depth (ft) _____	Future length (ft) _____	
TREATMENT	Immed (H,M,L)	Complex (H,M,L)	Mulch (ft^2)				
	Excavate soil	Critical dip	Wet crossing (ford or armored fill) (circle)	sill hgt (ft) ____	sill width (ft) _____		
	Trash Rack	Downspout	D.S. length (ft)_____	Repair CMP	Clean CMP		
	Install culvert	Replace culvert	CMP diameter (in) _____	CMP length (ft) _____			
	Reconstruct fill	Armor fill face (up, dn)	Armor area (ft^2) _____	Clean or cut ditch	Ditch length (ft) _____		
	Outslope road (Y)	*OS and Retain ditch (Y)*	*O.S. (ft)* _____	*Inslope road*	*I.S. (ft)* _____	*Rolling dip*	*R.D. (#)* __
	Remove berm	*Remove berm (ft)* _____	*Remove ditch*	*Remove ditch (ft)* _____	*Rock road- ft^2* _____		
	Install DR-CMP	*DR-CMP (#)* _____	Check CMP size? (Y)	Other tmt? (Y)	No tmt. (Y)		
COMMENT ON PROBLEM:							
EXCAVATION VOLUME		Total excavate (yds^3)____	Vol put back in (yds^3) ____		Volume removed (yds^3) ____		
		Vol stockpiled (yds^3)_____	Vol endhauled (yds^3)___	Dist endhauled (ft)____	Excav prod rate (yds^3)		
EQUIPMENT HOURS		Excavator (hrs) _____	Dozer (hrs)____	Dump truck (hrs)____	Grader (hrs) ____		
		Loader (hrs)_____	Backhoe (hrs) _____	Labor (hrs) _____	Other (hrs) _____		
COMMENT ON TREATMENT							

Part 1: Road-related sites

Site types

A total of 137 sites were identified along 33.7 miles of road (39.4 miles - 5.7 miles reported in Appendix A for the Old Haul Road) with the potential to deliver sediment to streams. Of these, 122 sites were recommended for erosion control and erosion prevention treatment. Approximately 53% (n=73) of the sites are classified as stream crossings, 30% (n=41) as ditch relief culverts and 10% (n=14) as potential landslide sites. The remaining 7% (n=9) of the inventoried sites consist of "other" sites which include road reaches, springs, gullies, etc. (Table 1 and Maps 1A and 1B).

Stream crossings - Seventy-three (73) stream crossings were inventoried in the PMSM-CPC road assessment area, including 41 culverted crossings, 18 unculverted fill crossings, 5 humboldt log crossings, 4 "ford or wet" crossings and 5 bridges. An unculverted fill crossing refers to a stream crossing with no formal drainage structure to carry the flow through the road prism. Stream flow either

Table 1. Site classification and sediment delivery from all inventoried road sites (excluding the Old Haul Road, see Appendix A) with future sediment delivery, Pescadero/Memorial/Sam McDonald County Park Complex, Pescadero Creek, San Mateo County, California.

Site Type		Number of sites or road miles	Number of sites or road miles to treat	Sites recommended for treatment			
				Future yield (yds^3)	Stream crossings w/ a diversion potential (#)	Stream crossings currently diverted (#)	Stream culverts with a high to moderate plugging potential (#)
Stream crossings		73	71	15,230	40	17	43
Landslides		14	8	1,288	--	--	--
Ditch relief culverts		41	35	483	--	--	--
Other		9	8	131	--	--	--
Total (all sites)		137	122	17,132	40	17	43
Persistent surface erosion[1]	Paved	3.3	2.9	2,269	--	--	--
	Non-paved	10.0	9.9	19,315	--	--	--
Totals		**137**	**122**	**38,716**	**40**	**17**	**43**

[1] Paved roads assume 10' cutbank and ditch contributing area, and 0.4' of cutbank surface lowering over two decades. Non-paved roads assume 25' wide road prism and cutbank contributing area, and 0.4' of road/cutbank surface lowering over two decades.

flows over the road surface, or it is diverted down the road to the inboard ditch. Most unculverted fill crossings are located at small Class III streams that exhibit flow only in the larger runoff events.

Of the 73 stream crossing sites inventoried, 71 have been recommended for some form of erosion control and erosion prevention treatment. The treatments range from simply installing a downspout at the culvert outlet (to prevent fill slope erosion) or a trash rack at the culvert inlet (to reduce the plugging potential), to removing a major bridge in order to excavate 500 yds^3 of failing fill beneath the bridge, and then putting the bridge back in place (see Site #236). Approximately 15,230 yds^3 of future road-related sediment delivery in the PMSM-CPC assessment area could originate from erosion at stream crossings, if the crossings were to wash out (Table 1). This amounts to nearly 39% of the total expected future sediment delivery from the road system. Not all these crossings can be expected to wash out, but over long periods of time many will experience repeated episodes of partial erosion, stream diversion or complete failure. The rate of failure will be higher for crossings which are located on abandoned roads or for those which are not designed to current 100-year design standards.

The most common problems which lead to erosion at stream crossings include: 1) crossings with undersized culverts, 2) crossings with culverts that are likely to plug, 3) stream crossings with a diversion potential and 4) crossings with gully erosion at the culvert outlet. The sediment delivery from stream crossing sites is always classified as 100% because any sediment eroded at the crossing site is then delivered to the channel. Even sediment which is delivered to small ephemeral streams will eventually be transported downstream to fish-bearing stream channels.

At stream crossings, the largest volumes of future erosion can occur when culverts plug or when potential storm flows exceed culvert capacity (i.e., the culvert is undersized for the100-year design storm flow or prone to plugging with sediment or organic debris), and flood runoff spills onto or across the road. When stream flow goes over the fill, part or all of the stream crossing fill may be eroded.

Approximately 97% (n=71) of the stream crossings inventoried in the PMSM-CPC assessment area will need to be upgraded for the roads to be considered "storm-proofed." For example, 59% of the existing crossings have a "moderate" to "high" plugging potential (Table 1). Because most of the roads were constructed many years ago, culverted stream crossings are typically under-designed for the 100-year storm flow, and the expected high amounts of wood and sediment which will be in transport.

Alternately, when flow is diverted down the road, either on the road bed or in the ditch (instead of spilling over the fill and back into the same stream channel), the crossing is said to have a "diversion potential" and the road bed, hillslope and/or stream channel that receives the diverted flow can become deeply gullied or destabilized. These hillslope gullies can be quite large and can deliver significant quantities of sediment to stream channels. In some instances, diverted stream flow which is discharged onto steep, potentially unstable slopes can also trigger large hillslope landslides. Of the 71 stream crossings recommended for treatment in the PMSM-CPC assessment area, 80% (n=57) have the potential to divert in the future and of these, 17 streams are currently diverted at stream crossing sites (Table 1).

At stream crossings with undersized culverts or where there is a diversion potential, corrective prescriptions have been outlined on the data sheets and in the following tables. Preventative treatments

include such measures as constructing critical dips (rolling dips) at stream crossings to prevent stream diversions, installing larger culverts wherever current pipes are under-designed for the 100-year storm flow (or where they are prone to plugging), installing culverts at the natural channel gradient to maximize the sediment transport efficiency of the pipe, to reduce plugging, and ensure that the culvert outlet will discharge on the natural channel bed below the base of the road fill, and installing debris barriers and/or downspouts to prevent culvert plugging and outlet erosion, respectively.

Landslides - Only those landslide sites with a potential for sediment delivery to a stream channel were inventoried. Potential landslides account for approximately 10% of the inventoried sites in the PMSM-CPC assessment area (Table 1). Most of the potential landslide sites were found along roads where material had been sidecast during earlier construction and now shows signs of instability. Potential landslides are expected to deliver nearly 1,288 yds^3 of sediment to Pescadero Creek and its tributaries in the future. Correcting or preventing potential landslides associated with the road is relatively straightforward, and involves the physical excavation of potentially unstable road fill and sidecast materials.

There are a number of potential landslide sites located in the Pescadero Creek assessment area that did not, or will not deliver sediment to streams. These sites were not inventoried using data sheets (Figure 2) due to the lack of expected sediment delivery to a stream channel, but they were mapped on the mylar overlays of the 1:12000 scale field maps. They are generally shallow and of small volume, or located far enough away from an active stream such that delivery is unlikely to occur.

Ditch relief culverts - Only those ditch relief culverts that currently deliver or will potentially deliver sediment to streams in the future were inventoried in this project. Forty-one (41) ditch relief culverts with potential sediment delivery were identified and these cumulatively account for approximately 30% of the inventoried sites in the PMSM-CPC assessment area. Gully erosion can occur below ditch relief culvert outlets due to excessive road and/or ditch contribution to the inlet. Gully erosion can also occur as a result of poor installation techniques such as shotgunned outlets or the culvert being placed too high in the fill without functional downspouts. Ditch relief culverts are expected to deliver approximately 483 yds^3 of sediment to Pescadero Creek and its tributaries in the future. Correcting or reducing sediment delivery associated with ditch relief culverts generally involves reducing and dispersing excessive ditch flow by installing additional ditch relief culverts, installing rolling dips and outsloping roads. Reducing outlet erosion below these sites involves installing functional downspouts as well as replacing ditch relief culverts deeper in the fill.

"Other" sites - A total of 9 "other" sites were also identified in the PMSM-CPC assessment area (Table 1 and Map 1A and 1B). Other sites include road surface, ditch, major springs, and gullies not associated with ditch relief culverts which exhibited the potential to deliver sediment to streams. The main cause of existing or future erosion at these sites is surface runoff and uncontrolled flow from long sections of undrained road surface and/or inboard ditch. Uncontrolled flow along the road or ditch may affect the road bed integrity as well as cause gully erosion on the adjacent hillslopes. Road runoff is also a major source of fine sediment input to nearby stream channels.

Of the 9 "other" sites, 8 have been recommended for erosion control and erosion prevention treatment. We estimate 131 yds^3 of sediment will be delivered to streams if they are left untreated. Sediment

delivery from these sites represents less than 1% of the total potential sediment delivery from sites recommended for erosion control and erosion prevention treatment.

Persistent surface erosion - In the PMSM-CPC assessment area, we measured approximately 13.3 miles of road surface and/or road ditch (representing over 39% of the total inventoried road mileage) which currently drain directly to streams, and delivers ditch and road runoff and sediment to stream channels. These roads are said to be "hydrologically connected" to the stream channel network. When these roads are being actively maintained and used for access, they represent a potentially important source of chronic fine sediment delivery to the stream system throughout the year.

Of the 13.3 miles of road surface and/or ditch contribution , 12.8 miles have been recommended for treatment. From the 12.8 miles of "connected" road segments, we calculated approximately 21,584 yds^3 of sediment will be delivered to stream channels in the Pescadero Creek watershed over the next 20 years if no efforts are made to change road drainage patterns (Table 1).[1] This will occur through a combination of 1) cutbank erosion delivering sediment to the ditch triggered by dry ravel, rainfall, freeze-thaw processes, cutbank landslides and brushing/grading practices, 2) inboard ditch erosion and sediment transport, 3) mechanical pulverizing and wearing down of the road surface, and 4) erosion of the road surface during wet weather periods.

Relatively straight forward erosion prevention treatments can be applied to upgrade road systems to prevent fine sediment from entering stream channels. These treatments generally involve dispersing road runoff and disconnecting road surface and ditch drainage from the natural stream channel network. Road surface treatments include the installation of rolling dips, road surface outsloping and/or installation of additional ditch relief culverts prior to rocking road surfaces.

Treatment Priority

An inventory of future or potential erosion and sediment delivery sites is intended to provide information which can guide long range transportation planning, as well as identify and prioritize erosion prevention, erosion control and road decommissioning activities in the watershed. Not all of the sites that have been recommended for treatment have the same priority, and some can be treated more cost effectively than others. Treatment priorities are evaluated on the basis of several factors and conditions associated with each potential erosion site. These include:

1) the expected volume of sediment to be delivered to streams (future delivery - yds^3),
2) the potential or "likelihood" for future erosion (erosion potential - high, moderate, low),
3) the "urgency" of treating the site (treatment immediacy - high, moderate, low),
4) the ease and cost of accessing the site for treatments, and
5) recommended treatments, logistics and costs.

[1] The applied, average rate of surface lowering on cutbanks and along road beds (i.e. 0.2 feet/decade) is based on observed retreat or erosion rates in the Pescadero Creek watershed, and on un-published data from sediment budget studies on similar geologies in the Redwood Creek watershed, Humboldt County (Redwood National Park, unpublished data).

The ***erosion potential*** of a site is a professional evaluation of the likelihood that future erosion will occur during a future storm event. Erosion potential is an estimate of the potential for additional erosion, based on field observations of a number of local site conditions. Erosion potential was evaluated for each site, and expressed as "High", "Moderate" or "Low." The evaluation of erosion potential is a subjective estimate of the probability of erosion, and not an estimate of how much erosion is likely to occur. It is based on the age and nature of direct physical indicators and evidence of pending instability or erosion. The likelihood of erosion (erosion potential) and the volume of sediment expected to enter a stream channel from future erosion (sediment delivery) play significant roles in determining the treatment priority of each inventoried site (see "treatment immediacy," below). Field indicators that are evaluated in determining the potential for sediment delivery include such factors as slope steepness, slope shape, distance to the stream channel, soil moisture and evaluation of erosion process. The larger the potential future contribution of sediment to a stream, the more important it becomes to closely evaluate its potential for cost-effective treatment.

Treatment immediacy (treatment priority) is a professional evaluation of how important it is to "quickly" perform erosion control or erosion prevention work. It is also defined as "High", "Moderate" and "Low" and represents both the severity and urgency of addressing the threat of sediment delivery to downstream areas. An evaluation of treatment immediacy considers erosion potential, future erosion and delivery volumes, the value or sensitivity of downstream resources being protected, and treatability, as well as, in some cases, whether or not there is a potential for an extremely large erosion event occurring at the site (larger than field evidence might at first suggest). If mass movement, culvert failure or sediment delivery is imminent, even in an average winter, then treatment immediacy might be judged "High". *Treatment immediacy is a summary, professional assessment of a site's need for immediate treatment.* Generally, sites that are likely to erode or fail in a normal winter, and that are expected to deliver significant quantities of sediment to a stream channel, are rated as having a high treatment immediacy or priority.

One other factor influencing a site's treatment priority is the difficulty (cost and environmental impact) of reaching the site with the necessary equipment to effectively treat the potential erosion. Many sites found on abandoned or unmaintained roads require brushing and tree removal to provide access to the site(s). Other roads require minor or major road rebuilding of washed out stream crossings and/or existing landslides in order to reach potential work sites farther out the alignment. Road reconstruction adds to the overall cost of erosion control work and reduces project cost-effectiveness. Potential work sites with lower cost-effectiveness, in turn may be of relatively lower priority. However, just because a road is abandoned and/or overgrown with vegetation is not sufficient reason to discount its need for assessment and potential treatment. Treatments on heavily overgrown, abandoned roads may still be both beneficial and cost-effective.

Evaluating Treatment Cost-Effectiveness

Treatment priorities are developed from the above factors, as well as from the estimated cost-effectiveness of the proposed erosion control or erosion prevention treatment. 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. For example, if it would cost $2000 to develop access and treat an eroding stream crossing that would have delivered 500 yds^3 (had it been left to erode), the predicted cost-effectiveness would be $4/$yds^3$ ($2000/500$yds^3$).

To be considered for priority treatment a site should typically exhibit: 1) potential for sediment delivery to a stream channel (with the potential for transport to a fish-bearing stream), 2) a high or moderate treatment immediacy and 3) a predicted cost-effectiveness value averaging in the general range of approximately \$7 to \$15/yd^3, or less.[2] Treatment cost-effectiveness analysis is often applied to a group of sites (rather than on a single site-by-site basis) so that only the most cost-effective groups of sites or projects are undertaken. During road decommissioning, groups of sites are usually considered together since there will only be one opportunity to treat potential sediment sources along the road. In this case, cost-effectiveness may be calculated for entire roads or road reaches that fall into logical treatment units.

Cost-effectiveness can be used as a tool to prioritize potential treatment sites throughout a sub-watershed (Weaver and Sonnevil, 1984; Weaver and others, 1987). It assures that the greatest benefit is received for the limited funding that is typically available for protection and restoration projects. Sites, or groups of sites, that have a predicted marginal cost-effectiveness value (>\$20/yd^3), or are judged to have a lower erosion potential or treatment immediacy, or low sediment delivery volumes, are less likely to be treated as part of the primary watershed protection and "erosion-proofing" program. However, these sites should be addressed during future road reconstruction (when access is reopened into areas for future management activities), or when heavy equipment is performing routine maintenance or restoration at nearby, higher priority sites.

Types of Prescribed Heavy Equipment Erosion Prevention Treatments

Roads can be storm-proofed by one of two methods: upgrading or decommissioning (closure) (Weaver and Hagans, 1999). Upgraded roads are kept open and are inspected and maintained. Their drainage facilities and fills are designed or treated to accommodate or withstand the 100-year storm. In contrast, properly decommissioned roads are closed and no longer require maintenance. Generic treatments for decommissioning roads and landings range from mild outsloping or simple cross-road drain construction, to full road decommissioning (closure), including the excavation of unstable and potentially unstable sidecast materials, road fills, and all stream crossing fills. The characteristics of storm-proofed roads, including those which are either upgraded or decommissioned, are depicted in Figure 3. Appendix 2 illustrates typical design and construction standards for upgrading or decommissioning roads. Only 5 sites are recommended for decommissioning in the PMSM-CPC assessment area (Table 2).

[2] The cost-effectiveness values of \$7 to \$15/yds^3, or less, was developed by the CDF&G in 1996 based on cost estimates to treat and up-grade road erosion sites along roads in the northern California counties of Humboldt, Trinity, Del Norte and Mendocino. Several factors indicate that in the San Francisco Bay Area counties, a more appropriate cost-effectiveness value should be between \$10 to \$20/yd^3 saved or prevented from entering a stream channel. The acceptability of the proposed revision in cost-effectiveness values is based on the following considerations: 1) numerous road assessments PWA has performed over the last 5 years in the greater Bay Area from Sonoma to Monterey Counties, where the cost-effectiveness values frequently exceed \$15/yd^3 saved, 2) heavy equipment rental rates in the Bay Area counties on average, exceed the north coast counties by 25% to 50%, 3) the cost-effectiveness values established by CDF&G over 6 years ago have not been adjusted for cost-of-living rate changes, whether based on inflation or the higher cost of living in the greater Bay Area, and 4) the vast majority of upland road projects in the Bay Area counties are conducted at prevailing wage rates compared to owner-operator rates charged on similar projects in the north coast counties.

FIGURE 3. CHARACTERISTICS OF STORM-PROOFED ROADS

The following abbreviated criteria identify common characteristics of "storm-proofed" roads. Roads are "storm-proofed" when sediment delivery to streams is strictly minimized. This is accomplished by dispersing road surface drainage, preventing road erosion from entering streams, protecting stream crossings from failure or diversion, and preventing failure of unstable fills which would otherwise deliver sediment to a stream. Minor exceptions to these "guidelines" can occur at specific sites within a forest or ranch road system.

STREAM CROSSINGS

- ✔ all stream crossings have a drainage structure designed for the 100-year flow
- ✔ stream crossings have no diversion potential (functional critical dips are in place)
- ✔ stream crossing inlets have low plug potential (trash barriers & graded drainage)
- ✔ stream crossing outlets are protected from erosion (extended, transported or dissipated)
- ✔ culvert inlet, outlet and bottom are open and in sound condition
- ✔ undersized culverts in deep fills (> backhoe reach) have emergency overflow culvert
- ✔ bridges have stable, non-eroding abutments & do not significantly restrict design flood
- ✔ fills are stable (unstable fills are removed or stabilized)
- ✔ road surfaces and ditches are "disconnected" from streams and stream crossing culverts
- ✔ decommissioned roads have all stream crossings completely excavated to original grade
- ✔ Class 1 (fish) streams accommodate fish passage

ROAD AND LANDING FILLS

- ✔ unstable and potentially unstable road and landing fills are excavated (removed)
- ✔ excavated spoil is placed in locations where eroded material 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 "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 road surface drainage and do not rely on ditches

Table 2. Treatment priorities for all inventoried sediment sources (excluding the Old Haul Road, see Appendix A), Pescadero/Memorial/Sam McDonald County Park Complex, Pescadero Creek, San Mateo County, California.

Treatment Priority	Upgrade sites (# and site #)	Decommission sites (# and site #)	Problem	Future sediment delivery (yds^3)
High	**7** (site #: 210, 236, 245, 264, 295, 299, 605)	**0**	7 stream crossings	6,247
High Moderate	**21** (site #: 200, 204, 205, 206, 207, 214, 217, 218, 221, 221.1, 242, 244, 253, 256, 263, 265, 274, 282, 287, 293, 298)	**0**	16 stream crossings, 2 landslides, 3 ditch relief culverts	10,224
Moderate	**31** (site #: 202, 202.1, 211, 212, 220, 222, 231, 232, 239, 243, 248, 250, 251, 255, 259, 260, 262, 264.1, 270, 271, 272, 281, 291, 297, 304, 305, 308, 606, 607, 608, 609)	**2** (site #: 215, 288)	21 stream crossings, 1 landslide, 8 ditch relief culverts, 3 other	12,018
Moderate Low	**37** (site #: 200.1, 208, 213, 216, 217.2, 219, 219.3, 221.3, 221.6, 223, 227, 235, 237, 238, 240, 249, 249.1, 252, 254, 266, 268, 269, 273, 276, 277, 278, 279, 283, 285, 286, 292, 294, 300, 301, 302, 307, 602)	**0**	16 stream crossings, 5 landslides, 13 ditch relief culverts, 3 other	7,441
Low	**21** (site #: 203, 209, 219.2, 221.4, 221.5, 221.7, 221.8, 221.9, 226, 233, 234, 241, 246, 247, 258, 261, 275, 290, 296, 303, 306)	**3** (site #: 217.1, 221.2, 267)	11 stream crossings, 11 ditch relief culverts, 2 other	2,786
Total	**117**	**5**	**71 stream crossings, 8 landslides, 35 ditch relief culverts, 8 other**	**38,716**

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 stream crossing upgrading (especially culvert up-sizing to accommodate the 100-year storm flow and debris in transport, and to eliminate stream diversion potential), removal of unstable sidecast and fill materials from steep slopes, and the application of drainage techniques to improve dispersion of road surface runoff. Road drainage techniques include

berm removal, road outsloping, rolling dip construction, and/or the installation of ditch relief culverts. The goal of all treatments is to make the road as "hydrologically invisible" as is possible.

Along some low strength road routes, re-rocking or repaving the road following stream crossing upgrading, installation of ditch relief culverts, rolling dip construction and road outsloping or insloping will often be necessary. These activities will incorporate pre-existing road rock into the new road shape design, thereby providing some road bed strength and stability. However, this often may not be enough material to provide safe passage in the winter months. Predicting the total amount of new road rock required can be difficult but, at a minimum, rock or pavement has been prescribed at all newly constructed rolling dips and culvert locations on roads which are currently rocked or paved and are proposed for upgrading and winter use.

Treatments

Basic treatment priorities and prescriptions were formulated concurrent with the identification, description and mapping of potential sources of road-related sediment delivery. Table 2 and Maps 2A and 2B outline the treatment priorities for all 122 inventoried road-related sites with future sediment delivery that have been recommended for treatment in the PMSM-CPC assessment area. Appendix C (**see attached document**) contains all the individual data sheets for each site.

Ot the 122 sites with future sediment delivery recommended for erosion control and erosion prevention treatment, 28 sites were identified as having a high or high-moderate treatment immediacy with a potential sediment delivery of approximately 16,471 yds^3 (Table 2). Seventy (70) sites were listed with a moderate or moderate-low treatment immediacy and these account for nearly 19,459 yds^3 of future sediment delivery. Finally, 24 sites were listed as having a low treatment immediacy with approximately 2,786 yds^3 of future sediment delivery.

Table 3 summarizes the proposed treatments for sites inventoried on all roads in the PMSM-CPC assessment area. These prescriptions include both upgrading and road closure measures. The database, as well as the field inventory sheets, provide details of the treatment prescriptions for each site. Most treatments require the use of heavy equipment, including an excavator, tractor, dump truck, grader and/or backhoe. Some hand labor is required at sites needing new culverts, downspouts, culvert repairs, trash racks and/or for applying seed, plants and mulch following ground disturbance activities.

It is estimated that erosion prevention work will require the excavation and permanent disposal of approximately 5,106 yds^3 of soil from 24 sites. A total of 105 yds^3 of 0.5 to 1.5 foot diameter mixed and clean rip-rap sized rock will be needed to construct 10 proposed armored fill or wet crossings and to armor 2 outboard fill faces (Table 3). At 44 stream crossing sites, we have recommended replacing or installing new culverts designed for the 100 year storm discharge.

We have recommended 237 rolling dips be constructed at selected locations along the road network, at spacing dictated by the steepness of the road. A minimum of 59 new ditch relief culverts are recommended to be installed and/or replaced along the inventoried road routes to disconnect ditches from streams. Some of the proposed rolling dips can be replaced with additional ditch relief culverts at the discretion of the landowner, but there will be increased costs due to the need to purchase the culvert.

Table 3. Recommended treatments along all inventoried roads (excluding the Old Haul Road, see Appendix A), Pescadero/Memorial/Sam McDonald County Park Complex, Pescadero Creek, San Mateo County, California.

Treatment	No.	Comment	Treatment	No.	Comment
Critical dip	24	To prevent stream diversions	Install flared inlet	3	Install flared inlet to increase culvert capacity
Install CMP	13	Install a CMP at an unculverted fill	Outslope road and remove ditch	1	Outslope 268 feet of road to improve road surface drainage
Replace CMP	30	Upgrade an undersized CMP	Inslope road	1	Inslope 100 feet of road to improve road surface drainage
Excavate soil	40	Typically fillslope & crossing excavations; excavate a total of 5,672 yds^3	Remove berm	3	Remove 450 feet of berm to improve road surface drainage
Down spouts	5	Installed to protect the outlet fillslope from erosion	Install ditch relief CMP	52	Install ditch relief culverts to improve road surface drainage
Wet crossing	10	Install 1 rocked ford and 9 armored fill crossings using 90 yds^3 of rip-rap	Install rolling dips	246	Install rolling dips to improve road drainage
Clean CMP	2	Remove debris and/or sediment from CMP inlet	Cross road drains	5	Install cross road drains to improve road drainage
Install bridge	1	Install bridge	Rock road surface	125	Rock or re-rock road surface using 1,390yds^3 road rock at 8 ditch relief culvert installations, 103 rolling dip installations and 14 stream crossing upgrades
Add trash rack	13	Install trash rack	Other	11	Miscellaneous treatments
Armor fill face	3	Rock armor to protect fillslope from erosion using 17 yds^3 of rock	No treatment recommended	15	

A total of 1,450 yds^3 of 1.5 inch minus road rock is recommended to re-rock disturbed areas along roads which are currently rocked.

Treatment Conclusions

All the treatment recommendations listed in this report have the specific aim of reducing sediment delivery to the watershed's stream network. These treatments will be effective at minimizing sediment delivery, and are generally the minimum, most cost effective prescriptions necessary to achieve this goal.

Additional treatment activities might be considered at the time of implementation to meet broader land management goals. Broader land management goals may include, but are not limited to, full ecological restoration, restoration of native plant communities, successional processes, natural drainage patterns that provide diversity, wildlife habitat improvements, natural creek function and maintaining visually intact landscapes. Some additional treatment activities that are not necessary for sediment delivery reduction but may complement land management goals to reduce impacts on natural resources are listed below:

- Rerouting or abandoning problematic sections of roads or trails when the original alignment is so poor that it cannot be sustainable.
- The use of more extensive outsloping, with dips at small topographic drainage features, and elimination of as much inboard ditch as possible, rather than extensive use of rolling dips.
- Removal of ditch relief culverts that are no longer functional after outsloping.
- Addition of drain lenses and armored drains that may be used to drain springs and seeps which are bisected by a road or trail.
- The use of culvert headwalls constructed of quick-crete sacks either independently or in addition to flared inlets.
- Complete topographic obliteration on decommission roads where no threat of sediment delivery exists.

These treatments listed above were considered as options if sediment delivery to a stream channel was a possibility, however our recommended treatments are the most effective and cost effective prescription. There are an infinite number of treatment possibilities that may be applied to attain management goals, however, they generally cost more than those prescribed for this project.

Equipment Needs and Costs

Treatments for the 122 sites identified with future sediment delivery in the Pescadero Creek road assessment area will require approximately 573 hours of excavator time and 635 hours of D-5 tractor time to complete all prescribed upgrading, road closure, erosion control and erosion prevention work

Table 4 Estimated heavy equipment and labor requirements for treatment of all inventoried sites (excluding the Old Haul Road, see Appendix A), with future sediment delivery, Pescadero/Memorial/ Sam McDonald County Park Complex, Pescadero Creek, San Mateo County, California.

Treatment Immediacy	Site (#)	Total Excavated Volume (yds^3)	Excavator (hrs)	Tractor (hrs)	Dump Trucks (hrs)	Backhoe (hrs)	Labor (hrs)
High, High/Moderate	28	6,164	225	268	5	51	241
Moderate, Moderate/Low	70	5,725	260	303	0	92	340
Low	24	644	88	64	0	10	79
Total	**122**	**12,533**	**573**	**635**	**5**	**153**	**660**

[1] Total excavated volume includes permanently excavated material and temporarily excavated materials used in backfilling upgraded stream crossings.

(Table 4). Excavator and tractor work is not needed at all the sites that have been recommended for treatment and, likewise, not all the sites will require both a tractor and an excavator. Approximately 5 hours of dump truck time has been listed for work in the basin for end-hauling excavated spoil from stream crossings. Approximately 153 hours of backhoe time is needed primarily for installing additional or replacing existing undersized and rotten ditch relief culverts. Approximately 660 hours of labor time is needed for a variety of tasks such as installation or replacement of culverts, installation of debris barriers and downspouts (Table 4), and an additional 80 hours are for laborers to seed and mulch disturbed areas (Table 5). Roughly 500 hours of water truck time, 100 hours of grader time and 200 hours of roller time has been prescribed in order to apply road surface treatments such as rolling dips, additional ditch relief culverts, road outsloping, berm removal, etc., and to achieve good compaction at all new stream crossing work sites (Table 5).

Estimated costs for erosion prevention treatments - Prescribed treatments are divided into two components: a) site specific erosion prevention work identified during the watershed inventories, and b) control of persistent sources of road surface, ditch and cutbank erosion and associated sediment delivery to streams. The total costs for road-related erosion control at sites with future sediment delivery is estimated at approximately $596,267 for an average cost-effectiveness value of approximately $15.40 per cubic yard of sediment prevented from entering Pescadero Creek and its tributaries (Table 5). This estimate includes costs to re-pave or re-rock all currently paved or rocked work sites. However, it should be noted that costs to re-rock or re-pave the entire upgraded road system following implementation of the proposed storm-proofing activities are not included in this table.

Overall site specific erosion prevention work: Equipment needs for site specific erosion prevention work at sites with future sediment delivery are expressed in the database, and summarized in Tables 5, as direct excavation times, in hours, to treat all sites having a high, moderate, or low treatment immediacy. These hourly estimates include only the time needed to treat each of the sites and their associated length of road bed and ditch, and do not include travel time between work sites, times for basic road surface treatments that are not associated with a specific “site,”or the time needed for work conferences at each site. These additional times are accumulated as "logistics" and must be added to the work times to determine total equipment costs as shown in Table 5.

The costs in Table 5 are based on a number of assumptions and estimates, and many of these are included as footnotes to the table. The costs provided are assumed reasonable if work is performed by outside contractors, with no added overhead for contract administration and pre- and post-project surveying. Movement of equipment to and from the site will require the use of low-boy trucks. The majority of treatments listed in this plan are not complex or difficult for equipment operators experienced in road upgrading and road decommissioning operations. The use of inexperienced operators would require additional technical oversight and supervision in the field.

All recommended treatments conform to guidelines described in “The Handbook for Forest and Ranch Roads” prepared by PWA (1994) for the California Department of Forestry, Natural Resources Conservation Service and the Mendocino County Resource Conservation District. It should also be noted that approximately 7.1 miles of the road length inventoried was on paved county roads (5.5 miles) or county jail roads (1.6 miles) where engineers may need to be involved in the design of upgrade work Extra costs could include safety flagging, concrete slurry around new culverts, painting, guard rails, etc. This could add a significant cost to completing the proposed work. .

Table 5 lists a total of 595 hours for "supervision" time for detailed pre-work layout, project planning (coordinating and securing equipment and contractors), on-site equipment operator instruction and supervision, establishing short and long term, effectiveness monitoring measures, and post-project cost effectiveness analysis and reporting. It is expected that the project coordinator will be on-site full time at the beginning of the project and intermittently after equipment operations have begun.

As mentioned previously, it is often advantageous to lump a number of sites together based on a sub-watershed area, in order to develop a logical project and improve cost-effectiveness. Table 6 and Map

Table 5. Estimated logistic requirements and costs for road-related erosion control and erosion prevention work on all inventoried sites (excluding the Old Haul Road, see Appendix A), with future sediment delivery, Pescadero/Memorial/Sam McDonald County Park Complex, Pescadero Creek, San Mateo County, California.

Cost Category[1]		Cost Rate[2] ($/hr)	Estimated Project Times			Total Estimated Costs[5] ($)
			Treatment[3] (hours)	Logistics[4] (hours)	Total (hours)	
Move-in; move-out[6] (Low Boy expenses)	Excavator	100	30	--	30	3,000
	D-5 tractor	85	30	--	30	2,550
Heavy Equipment requirements for site specific treatments	Excavator	135	432	130	562	75,870
	D-5 tractor	125	386	116	502	62,750
	Dump Truck	65	5	2	7	455
	Backhoe	95	40	12	52	4,940
	Water truck	90	200	60	260	23,400
	Roller	100	100	30	130	13,000
Heavy Equipment requirements for road drainage treatments	Excavator	135	141	42	183	25,705
	D-5 tractor	125	249	72	312	39,000
	Backhoe	95	113	34	147	13,965
	Grader	120	100	30	130	15,600
	Water truck	90	300	90	390	35,100
	Roller	100	100	30	130	13,000
Laborers[7]		40	900	270	1,170	46,800
Traffic control[8]		30	200	60	260	7,800
Rock Costs: (includes trucking for 1,390 yds^3 of road rock and 97 yds^3 of rip-rap sized rock)						52,395
Culvert materials costs (20' of 12", 2,130 of 18', 1,590' of 24", 480' of 30", 610' of 36", 150' of 48", 70' of 60", 90' of 72", and 60' of 84". Costs included for couplers, elbows and flared inlets)						79,742
Paving Costs (for 18,880 ft^2 (@ $1.50/ ft^2)						28,320
Mulch, seed and planting materials for 15acres of disturbed ground[9]						8,250
Layout, Coordination, Supervision, and Reporting[10]		75	--	--	595	44,625
Total Estimated Costs						**$596,267**

Potential sediment savings: 38,716 yds[3]
Overall project cost-effectiveness: $15.40 spent per cubic yard saved [3]

[1]Costs for tools and miscellaneous materials have not been included in this table. Costs for administration and contracting are variable and have not been included.

[2] Costs listed for heavy equipment include operator and fuel. Costs listed are estimates for favorable local private sector equipment rental and labor rates.

[3] Treatment times include all equipment hours expended on excavations and work directly associated with erosion prevention and erosion control at all the sites.

[4] Logistic times for heavy equipment (30%) include all equipment hours expended for opening access to sites, travel time for equipment to move from site-to-site, conference times with equipment operators at each site to convey treatment prescriptions and strategies, and for difficulties in excavating complicated sites. Logistic times for laborers (30%) includes estimated daily travel time to project area.

[5] Total estimated project costs listed are averages based on private sector equipment rental and labor rates.

[6] Lowboy hauling for tractor and excavator, 3 hours round trip for 5 work seasons to areas within the Pescadero/Memorial/Sam McDonald County Park Complex. Costs assume 2 hauls each for two pieces of equipment (one to move in and one to move out).

[7] An additional 240 hours of labor time is added for straw mulch and seeding activities.

[8] An additional 200 hours of labor time is added for traffic control on County Public Works roads. Includes time for 2 laborers.

[9] Seed costs equal $6/pound for erosion control seed. Seed costs based on 50# of erosion control seed per acre. Straw costs include 50 bales required per acre at $5 per bale. Sixteen hours of labor are required per acre of straw mulching.

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

3A and 3B illustrates a variety of erosion control and prevention projects by selected roads or maintenance responsibility within the PMSM-CPC watershed assessment area. Table 6 lists the number of sites or road miles to treat, by treatment immediacy, the general proposed types of treatments, the estimated sediment savings, the estimated costs for erosion control and erosion prevention treatments, and the cost-effectiveness of implementing the project. The Pomponio Trail Road example includes all road sites in a subwatershed, whereas the Towne Fire Road example is a long segment of road and associated spur roads which weaves through several sub-watersheds, and the Public Works Department and Sheriff Honor Camp Roads are examples of different management responsibilities. We have included the same data on the "Old Haul Road" portion of the sediment assessment (Appendix A), for comparison purposes in Table 6.

Part 2: Trail-related sites

Site types

Erosional problems along foot, horse and bike trails are the same as on roads, however, the scale and magnitude or volume of the erosion is generally an order of magnitude lower than along roads. The frequency of erosional problems or risk is often similar, but the costs to mobilize people and get materials to the individual sites results in enormously high costs and very poor cost-effectiveness.

Approximately 34.4 miles of single treed, horse, foot and bike trails are present in the PMSM-CPC assessment area. Along these, a total of 68 sites were identified with the potential to deliver sediment to streams. Of these, 56 sites were recommended for erosion control and erosion prevention treatment. Approximately 88% (n=60) of the sites are classified as stream crossings, 3% (n=2) as potential or

[3] See footnote #2 on Page 15 for explanation concerning appropriate cost-effectiveness values.

Table 6. Future delivery and treatment costs for inventoried sites in the Pescadero/Memorial/Sam McDonald County Park Complex by sub-watershed, management responsibility, road or group of roads, San Mateo County, California .

Road name	Total no. of sites (#)	Site recommended for treatment by problem type				No. of sites to treat (#)	No. of road miles to treat[1] (mi)	Treatment immediacy[2]			Treatment type			Total future delivery (yds^3)[1]	Cost ($)	Cost effectiveness ($/yds^3)
		No. of stream crossings (#)	No. of landslides (#)	No. of ditch relief culverts (#)	No. of other sites (#)			H/ HM	M/ M L	L	Upgrade stream crossing[3] (#)	Install RD[4] (#)	Install/ Replace ditch relief culverts (#)			
County Public Works Roads	9	2	0	1	2	5	0.62	1	4	0	2	0	7	4,358	72,687	16.68
Tarwater Creek/ Bridge Trail Road	15	10	0	4	0	14	1.40	2	10	2	5	34	1	4,184	65,643	15.69
Towne Fire Roads	18	10	0	8	0	18	2.99	7	9	2	6	76	3	8,090	95,924	11.86
Pomponio Trail (Memorial Park)	17	9	3	1	0	13	1.07	3	9	1	8	27	0	3,369	50,129	14.88
Ridge Trail Rd (Sam McDonald)	18	10	1	6	1	18	1.04	4	10	4	9	49	2	6,739	65,594	9.73
Sheriff Honor Camp Roads	36	12	3	15	1	31	1.53	6	13	12	9	5	34	10,089	125,433	12.43
SUBTOTAL	**113**	**53**	**7**	**35**	**4**	**99**	**8.65**	**23**	**55**	**21**	**39**	**191**	**47**	**36,829**	**475,410**	**12.91**
Old Haul Road	45	20	10	10	4	44	3.79	5	32	7	17	59	16	67,326	1,147,182	17.03
TOTAL	158	73	17	45	8	143	12.44	28	87	28	56	250	63	104,155	1,622,592	15.58

[1] Number of road miles "hydrologically connected" to streams that are recommended for treatment.
[2] Treatment immediacy: H/HM - High/High-moderate, M/ML - Moderate/Moderate-low, L- Low
[3] Upgrade stream crossings include culvert installations and replacements and the installation of armored fill crossings and fords.
[4] RD - Rolling dips

Stream crossings -Sixty (60) stream crossings were inventoried in the PMSM-CPC trail assessment area including 29 culverted crossings, 11 unculverted fill crossings, 16 bridges, 3 humboldt log crossings and 1 wet or ford crossing. Approximately 1,204 yds^3 (50%) of future trail-related sediment delivery in the PMSM-CPC trail assessment area could originate from erosion at stream crossings, if the crossings are not treated and they fail during future storms (Table 7). This amounts to nearly 49% of the total expected future sediment delivery from the trail system. Not all identified trail crossings can be expected to wash out, but over long periods of time many will experience repeated episodes of partial erosion and/or stream diversion, or complete failure.

The most common problems which lead to erosion at trail stream crossings include: 1) crossings with insufficient cross sectional area to allow peak flows to pass across armored fills or under bridges, 2) stream crossings with a diversion potential and 3) crossings with culverts which are likely to plug. The sediment delivery from stream crossing sites on trails, as with roads, is always classified as 100% because any sediment eroded at the crossing site is usually delivered to a stream channel. Even sediment which is delivered to small ephemeral streams will eventually be delivered to downstream fish-bearing stream channels.

Approximately 82% (n=56) of the trail stream crossings inventoried in the PMSM-CPC trail assessment area will need to be upgraded for the trails to be considered "storm-proofed." For example, 32% of the

Table 7. Site classification and sediment delivery from all inventoried trail-related sites with future sediment delivery, Pescadero/Memorial/Sam McDonald County Park Complex, Pescadero Creek, San Mateo County, California.

Site Type	Number of sites or road miles	Number of sites or road miles to treat	Sites recommended for treatment			
			Future yield (yds^3)	Stream crossings w/ a diversion potential (#)	Stream crossings currently diverted (#)	Stream culverts likely to plug (plug potential rating = high or moderate) (#)
Stream crossings	60	50	1,204	14	1	19
Landslides	2	1	3	--	--	--
Other	6	5	19	--	--	--
Total (all sites)	68	56	1,226	14	1	19
Persistent surface erosion[1]	2.6	2.5	1,173	--	--	--
Totals	**68**	**56**	**2,399**	**14**	**1**	**19**

[1] Assumes 6' wide road prism and cutbank contributing area, and 0.4' of road/cutbank surface lowering over two decades.

existing stream crossings have a "moderate" to "high" culvert plugging potential, and approximately 25% of the stream crossings exhibit a diversion potential (Table 7). Because some of the trails were constructed years ago, stream crossings are typically under-designed for the 100-year storm flow. At stream crossings with insufficient cross sectional area, undersized culverts or where there is a diversion potential, corrective prescriptions have been outlined on the data sheets and in the following tables.

Preventative treatments include such measures as excavating sufficient area and placing armor at armored fills, fords and bridges, constructing critical dips (rolling dips) at stream crossings to prevent stream diversions, installing larger culverts wherever current pipes are under-designed for the 100-year storm flow (or where they are prone to plugging), installing culverts at the natural channel gradient to maximize the sediment transport efficiency of the pipe and ensure that the culvert outlet will discharge on the natural channel bed below the base of the road fill, and installing bridges at specified stream crossing locations.

Landslides- Only 2 potentially controllable landslides were identified along the trail system in the PMSM-CPC assessment area. The total future sediment delivery is minimal at 3 yds^3, however we have recommended treating one of the sites.

"Other"sites - A total of 6 "other" sites were identified in PMSM-CPC trail assessment area. Of the 6 "other" sites, 5 have been recommended for erosion control and erosion prevention treatment. We estimate 19 yds^3 of sediment will be delivered to streams from the 5 "other" specific trail sites if left untreated (Table 7 and Maps 1A and 1B). The main cause of existing or future erosion at these sites is surface runoff and uncontrolled flow from long sections of undrained trail surface. Uncontrolled flow along the trail may affect the trail bed integrity as well as cause gully erosion on the hillslopes below the outlet of ditch relief culverts. Concentrated trail runoff can also be a major source of fine sediment input to nearby stream channels.

Persistent surface erosion - In the PMSM-CPC trail assessment area, we measured approximately 2.6 miles of trail surface (representing approximately 8% of the total inventoried trail mileage) which currently drain directly to streams and deliver surface runoff and sediment to stream channels. These trails are said to be "hydrologically connected" to the stream channel network. When these trails are being actively maintained and used for access, they represent a potentially important source of chronic fine sediment delivery to the stream system.

Of the 2.6 miles of "connected" trail segments, 2.5 miles have been recommended for treatment. We estimate approximately 1,173 yds^3 (i.e. 49% of the total trail derived sediment delivery) of sediment will be delivered to stream channels in the assessment area over the next 20 years if no efforts are made to change trail drainage patterns. This will occur through a combination of 1) mechanical pulverizing and wearing down of the trail surface by foot, bike, and horse traffic, and 2) erosion of the trail surface during wet weather periods.

Relatively straight-forward erosion prevention treatments can be applied to upgrade trail systems to prevent fine sediment from entering stream channels. These treatments generally involve dispersing trail runoff and disconnecting the trail surface from the natural stream channel network. Trail surface treatments include the installation of trail dips, outsloping and the occasional installation of ditch relief

culverts. Treatment of trail drainage is very similar to road surface drainage treatment techniques. These trails are treated as if they are small roads.

Prescribed Erosion Prevention Treatments

All the trails inventoried within the PMSM-CPC have been recommended for upgrading in order to storm-proof the trail system (Table 8).

Trail upgrading involves a variety of treatments used to make a trail more resilient to large storms and flood flows. The most important of these include stream crossing upgrading (especially armored fills, fords or bridges to accommodate the 100-year storm flow and debris in transport, and to eliminate stream diversion potential), and the application of drainage techniques to improve dispersion of trail surface runoff. Trail drainage techniques include berm removal, outsloping, trail dip construction, and/or the installation of ditch relief culverts. The goal of all treatments is to make the trail as "hydrologically invisible" as is possible.

Table 8. Treatment priorities for all inventoried trail-related sediment sources, Pescadero/Memorial/ Sam McDonald County Park Complex, Pescadero Creek, San Mateo County, CA.

Treatment Priority	Upgrade sites (# and site #)	Problem	Future sediment delivery (yds^3)
High	**1** (site #: 534)	1 stream crossings	67
High Moderate	**9** (site #: 503, 504, 506, 509, 517, 535.1, 536, 559, 560)	8 stream crossings, 1 landslide,	790
Moderate	**17** (site #: 500, 502, 519, 520, 523, 532, 537, 545, 545.1, 549, 550, 551, 552, 553, 558, 562, 564)	16 stream crossings, 1 other	842
Moderate Low	**14** (site #: 501, 510, 511, 515, 516, 522, 524, 529, 535, 540, 541, 544, 554, 556)	13 stream crossings, 1 other	304
Low	**15** (site #: 505, 508, 513, 518, 525, 526, 527, 528, 531, 533, 538, 539, 545.2, 555, 563)	12 stream crossings, 3 other	193
Total	**56**	**50 stream crossings, 1 landslides, 5 other**	**2,193**

Treatments

Basic treatment priorities and prescriptions were formulated concurrent with the identification, description and mapping of potential sources of trail-related sediment delivery. Table 8 and Maps 2A and 2B outline the treatment priorities for all 56 inventoried sites with future sediment delivery that have been recommended for treatment in the PMSM-CPC assessment area. Of the 56 sites with future sediment delivery, 10 sites were identified as having a high or high-moderate treatment immediacy with a potential sediment delivery of approximately 857 yds^3. Thirty-one (31) sites were listed with a moderate or moderate-low treatment immediacy and account for 1,146 yds^3 of future sediment delivery. Finally, 15 sites were listed as having a low treatment immediacy with approximately 193 yds^3 of future sediment delivery.

Table 9 summarizes the proposed treatments for sites inventoried on all trails in the PMSM-CPC assessment area. The database, as well as the field inventory sheets, provide details of the treatment prescriptions for each site. Some treatments require the use of heavy equipment, including an excavator, tractor or bobcat. Hand labor is required at sites needing ford, bridge, and armored fill construction, and for applying seed and mulch following ground disturbance activities.

It is estimated that erosion prevention work will require the excavation and permanent disposal of approximately 437 yds^3 at 12 sites. A total of 31 yds^3 of 0.5 to 1 foot diameter mixed and clean rip-rap sized rock will be needed to construct 5 proposed armored wet crossings and armor fill slope (Table 9).

Table 9. Recommended treatments for all inventoried trail-related sediment sources, Pescadero/ Memorial/Sam McDonald County Park Complex, Pescadero Creek, San Mateo County, Ca. .

Treatment	No.	Comment	Treatment	No.	Comment
Critical dip	12	To prevent stream diversions	Clean CMP	4	Remove debris and/or sediment from CMP inlet
Excavate soil	12	Typically fillslope & crossing excavations; excavate a total of 437 yds^3	Install trail bridge	6	Install 3 horse trail bridges and 3 foot bridges
Wet crossing	3	Install 2 ford crossings and 1 armored fill crossing using 16 yds^3 rip-rap	Install ditch relief culvert	1	Install ditch relief culvert to improve surface drainage
Armor fill face	2	Rock armor to protect fillslope from erosion using 15 yds^3 rip-rap	Install trail dips	288	Install trail dips to improve surface drainage
Replace CMP	9	Upgrade an undersized CMP	Remove berm	1	Remove berm along 216' of trail to improve surface drainage
Trash rack	4	Install trash rack to protect culvert from plugging	Rock trail surface	5	Rock trail surface using 14 yd^3 road rock at 4 trail dips and 1 “other” site specific location
Down spouts	3	Installed to protect the outlet fillslope from erosion	No treatment recommended	12	

Culverts at 9 stream crossings have been recommended to be replaced with culverts sized for the 100 year storm, and at 6 stream crossings, we have recommended wooden foot bridges be constructed to replace failing culverts. We have recommended 288 trail dips be constructed at selected locations along the trail, and at spacings dictated by the steepness of the trail.

Equipment Needs, Labor Times and Costs

Treatments for the 56 trail sites identified with future sediment delivery in the assessment area will require approximately 18 hours of excavator time, 50 hours of D-4 dozer time, 151 hours of bobcat time and 1,134 hours of labor time to complete all prescribed upgrading, erosion control and erosion prevention work (Table 10). Excavator and dozer work has been prescribed for trail sites along overgrown, former logging roads.

Estimated costs for erosion prevention treatments - Prescribed treatments are divided into two components: a) site specific erosion prevention work identified during the watershed inventories, and b) control of persistent sources of trail surface erosion and associated sediment delivery to streams. The total costs for trail-related erosion control at sites with future sediment delivery is estimated at approximately $117,310 for an average cost-effectiveness value of approximately $48.90 per cubic yard of sediment prevented from entering Pescadero Creek and its tributaries (Table 10).

Table 10. Estimated heavy equipment and labor requirements for treatment of all inventoried trail-related sediment sources, Pescadero/Memorial/Sam McDonald County Park Complex, Pescadero Creek, San Mateo County, California.

Treatment Immediacy	Site (#)	Total Excavated Volume (yds^3)	Excavator (hrs)	Tractor (hrs)	Bobcat (hrs)	Labor (hrs)
High, High/Moderate	10	343	7	9	57	397
Moderate, Moderate/Low	31	383	11	41	89	623
Low	15	5	0	0	5	114
Total	**56**	**731**	**18**	**50**	**151**	**1,134**

[1] Total excavated volume includes permanently excavated material and temporarily excavated materials used in backfilling upgraded stream crossings.

Overall site specific erosion prevention work: Equipment and labor needs for site specific erosion prevention work at sites with future sediment delivery are expressed in the database, and summarized in Table 11, as direct excavation and labor times, in hours, to treat all sites having a high, moderate, or low treatment immediacy. These hourly estimates include only the time needed to treat each of the sites, and do not include travel time between work sites, times for basic road surface treatments that are not associated with a specific "site," or the time needed for work conferences at each site. These additional times are accumulated as "logistics" and must be added to the work times to determine total equipment costs as shown in Table 11. The costs in Table 11 are based on a number of assumptions and estimates, and many of these are included as footnotes to the table.

All recommended trail treatments are basic construction techniques currently utilized by various state and federal parks trail construction crews. Some treatment prescriptions conform to techniques described in the "Trails Handbook" prepared by The California Department of Parks and Recreation.

Table 11. Estimated logistic requirements and costs for road-related erosion control and erosion prevention work for all inventoried trail-related sediment sources, Pescadero/Memorial/Sam McDonald County Park Complex, Pescadero Creek, San Mateo County, California.

Cost Category[1]		Cost Rate[2] ($/hr)	Estimated Project Times			Total Estimated Costs[5] ($)
			Treatment[3] (hours)	Logistics[4] (hours)	Total (hours)	
Move-in; move-out[6] (Low Boy expenses)	Excavator	110	3	--	3	330
	Dozer	85	3	--	3	255
Heavy Equipment requirements for site specific treatments	Excavator	135	18	5	23	3,105
	Dozer	95	47	14	61	5,795
	Bobcat	95	124	37	161	15,295
Heavy Equipment requirements for road drainage treatments	Dozer	95	3	1	4	380
	Bobcat	95	27	8	35	3,325
Laborers[8]		35	1,142	343	1,485	51,975
Foot bridge costs (6 horse/foot trail bridges)						$6,000
Culvert materials costs (20' of 18")						155
Rock Costs: (includes trucking for 13 yd^3 of road rock and 31 yds^3 of rip-rap sized rock)						1,320
Mulch, seed and planting materials for 0.5 acre of disturbed ground[9]						275
Layout, Coordination, Supervision, and Reporting[10]		75	--	--	388	29,100
Total Estimated Costs						**$117,310**

Potential sediment savings: 2,399 yds^3

Overall project cost-effectiveness: $ 48.90 spent per cubic yard saved

[1] Costs for tools and miscellaneous materials have not been included in this table. Costs for administration and contracting are variable and have not been included.

[2] Costs listed for heavy equipment include operator and fuel. Costs listed are estimates for favorable local private sector equipment rental and labor rates.

[3] Treatment times include all equipment hours expended on excavations and work directly associated with erosion prevention and erosion control at all the sites.

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

[5] Total estimated project costs listed are averages based on private sector equipment rental and labor rates.

[6] Lowboy hauling for tractor and excavator, 3 hours round trip for one (1) crew to areas within the Pescadero/Memorial/Sam McDonald County Park Complex. Costs assume 2 hauls each for two pieces of equipment (one to move in and one to move out).

[8] An additional 8 hours of labor time is added for straw mulch and seeding activities.

[9] Seed costs equal $6/pound for erosion control seed. Seed costs based on 50# of erosion control seed per acre. Straw costs include 50 bales required per acre at $5 per bale. Sixteen hours of labor are required per acre of straw mulching. Does not include additional seed and mulch required on decommissioned road surfaces within the Water/Lake Protection Zones.

[10] Supervision time includes detailed layout (flagging, etc) prior to equipment arrival, training of equipment operators, supervision during equipment operations, supervision of labor work and post-project documentation and reporting). Supervision times based on 30% of the total bobcat time, 30% of the labor time plus 1 week prior and 1 week post project implementation

Other treatment prescriptions conform to techniques described in "The Handbook for Forest and Ranch Roads" prepared by PWA.

Table 11 lists a total of 388 hours for "Layout" time for detailed pre-work layout, project planning (coordinating and securing equipment), on-site equipment operator instruction and supervision, establishing effectiveness monitoring measures, and post-project cost effectiveness analysis and reporting. It is expected that the project coordinator will be on-site full time at the beginning of the project and intermittently after equipment operations and labor work have begun.

Conclusion

The expected benefit of completing the erosion control and prevention planning work lies in the reduction of long term sediment delivery to Pescadero Creek, an important salmonid stream. A critical first-step in the overall risk-reduction process is the development of a watershed analysis and transportation plan. In developing this plan, all roads and trails in an ownership or sub-watershed are considered for either decommissioning or upgrading, which should first depend upon the risk of erosion and sediment delivery to streams, among other park concerns / values. Not all roads and trails are high risk and those that pose a low risk of degrading aquatic habitat in the watershed may not need immediate attention. It is therefore important to rank and prioritize roads and trails in each sub-watershed, and within each ownership, based on their potential to impact downstream resources, as well as their importance to the overall transportation system and to management needs.

Trail systems are treated and assessed in much the same manner as road systems. In the PMSM-CPC assessment area, it has been shown that the trail networks have significantly less potential for erosional impacts on aquatic resources compared to road networks. Nearly 34.4 miles of trails could contribute approximately 2,399 yds^3 of sediment to the stream network (an average of 70 yds^3 per mile), compared to 33.7 miles of roads which could contribute nearly 38,716 yds^3 of sediment (an average of 1,150 yds^3 per mile of road), if left untreated. With this information, the focus of erosion prevention planning projects, for the benefit of anadromous fisheries, should be on road based, treatment implementation.

Good land stewardship requires that roads and trails either be upgraded and maintained, or intentionally closed ("put-to-bed"). The old practice of abandoning roads and trails, by either installing barriers to traffic (logs, "tank traps" or gates) or simply letting them naturally revegetate, is no longer considered acceptable. These roads and trails typically continue to fail and erode for decades following abandonment. The proper word for proactive road and trail closure is "decommissioning."

Road and trail upgrading consists of a variety of techniques employed to "erosion-proof" and to "storm-proof" a road or trail and prevent unnecessary future erosion and sediment delivery. Erosion-proofing and storm-proofing typically consists of stabilizing slopes and upgrading drainage structures so that the road or trail is capable of withstanding both annual winter rainfall and runoff, as well as a large storm event without failing or delivering excessive sediment to the stream system. Most all the roads and trails in the Pescadero/Memorial/Sam McDonald County Park Complex have been prescribed for upgrading. The goal of upgrading is to strictly minimize the contributions of fine sediment from roads, trails and ditches to stream channels, as well as to minimize the risk of serious erosion and sediment delivery when large magnitude, infrequent storms and floods occur.

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Appendix A.

Inventory results, erosion control and erosion prevention plan for 5.7 miles of the Old Haul Road, Pescadero/Memorial/Sam McDonald County Park Complex, San Mateo County, California.

Inventory results, erosion control and erosion prevention plan for the 5.7 miles of the Old Haul Road, Pescadero/Memorial/Sam McDonald County Park Complex, San Mateo County, California.

Background

In January 2002, Pacific Watershed Associates (PWA) was contracted by San Mateo County Parks and Recreation (SMCPR) to inventory 65 miles of roads and trails within the Pescadero/Memorial/ Sam McDonald County Park Complex. In the agreement, PWA was to immediately assess 5.7 miles of the Old Haul Road located in Pescadero Creek County Park, with the remaining mileage to be inventories in the Spring and Summer months. The inventoried section of the Old Haul Road begins at the intersection with Wurr Road, extending southeasterly for 5.7 miles where it terminates at the gate before Trestle Creek (Figure 1).

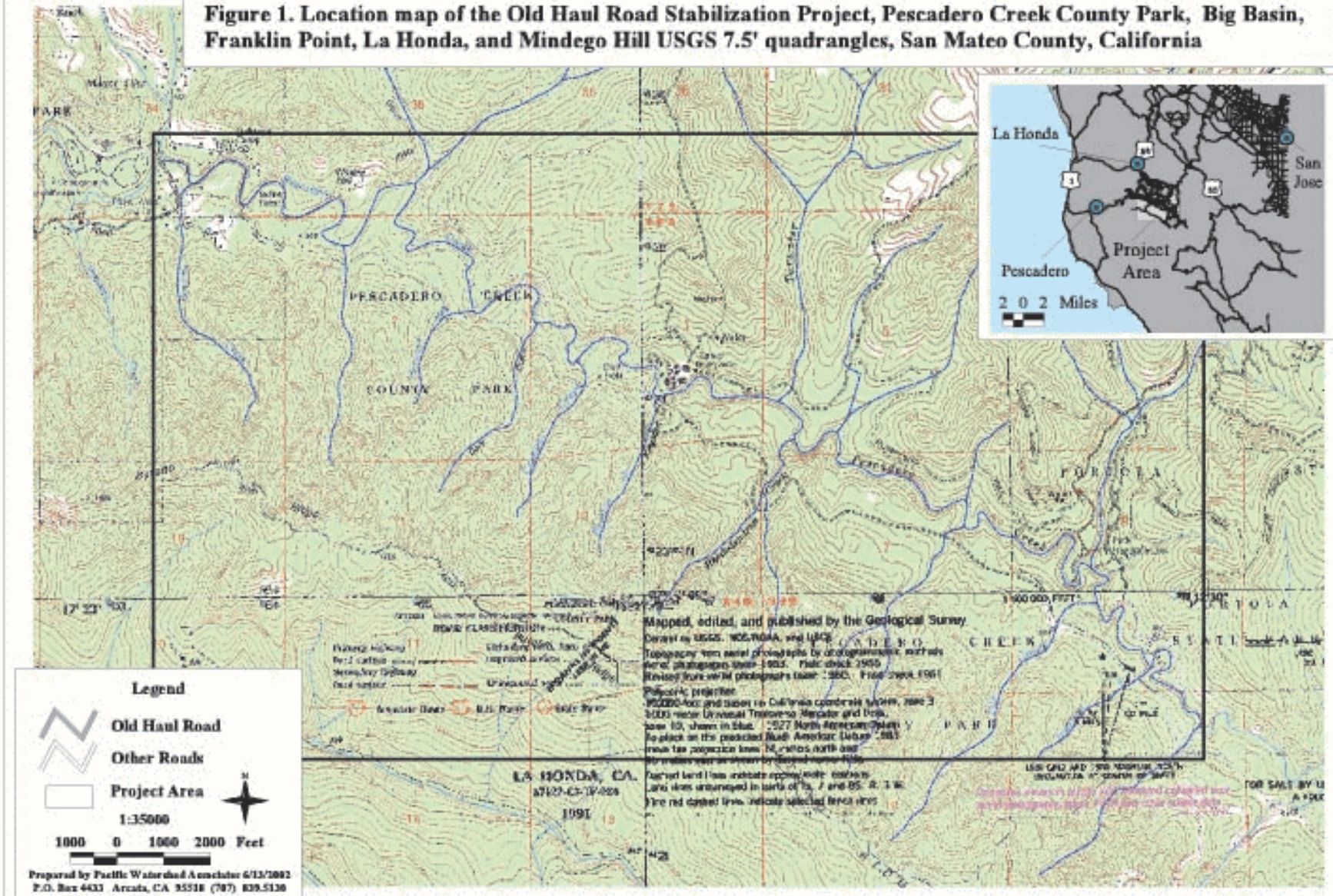
The initial PWA assessment of the Old Haul Road segment was requested to be used as a check to the County Park's 2001 S.B. 271 funded road drainage treatment plan (Old Haul Road Trail Drainage Improvement Project #2). The County Park's road drainage treatment plan was developed by park staff to reduce sedimentation to Pescadero Creek and its tributaries through the treatment of road drainage problems along the Old Haul Road. The S.B. 271 approved treatment plan is to be implemented in conjunction with four FEMA/County projects located along the 5.7 miles of the Old Haul Road. The implementation schedule has yet to be determined.

The Old Haul Road is located along lower hillslopes of the mainstem of Pescadero Creek. Slopes south of Pescadero Creek below Butano Ridge were clear-cut between 1940 and 1953 by the Santa Cruz Lumber Company and as a result tributaries and slopes above the Old Haul Road have been heavily disturbed by tractor activity. The Old Haul Road was originally built in the 1940's as a major railroad alignment used to transport saw logs to a Santa Cruz Lumber Company mill located at Waterman Gap in Santa Cruz County. In order to keep the Old Haul Road railroad alignment on contour and at a relatively even grade, huge log and fill structures were constructed to span major tributaries to Pescadero Creek which cross the alignment.

SMCPR intends to keep the Old Haul Road open and accessible for the following reasons: 1) it is the main access into Pescadero Creek County Park and to its network of multi-use recreational trails, 2) it serves as a secondary emergency route to the San Mateo County Sheriff's Men's Correctional Center and to Portola Redwood Creek State Park and 3) it serves as the only maintenance and fire road access to the northern Butano Ridge area.

The following report summarizes the results of the road erosion assessment inventory conducted by Pacific Watershed Associates (PWA) during the week of January 14, 2002 and provides a prioritized erosion control and erosion prevention treatment plan for the 5.7 miles of the Old Haul Road. In addition, we have reviewed and discussed the differences between the PWA erosion prevention plan and the prescriptions contained in the SMCPR "Old Haul Road Trail Drainage Improvement Project #2".

Figure 1. Location map of the Old Haul Road Stabilization Project, Pescadero Creek County Park, Big Basin, Franklin Point, La Honda, and Mindego Hill USGS 7.5' quadrangles, San Mateo County, California



Old Haul Road Assessment Inventory Results

Sites, as defined in this assessment, include locations where there is direct evidence that future erosion or mass wasting could be expected to deliver sediment to Pescadero Creek and its tributaries. Sites of past erosion were not inventoried unless there was a potential for additional future sediment delivery. Similarly, sites of future erosion that were not expected to deliver sediment to a stream channel were not included in the inventory, but their approximate locations were recorded on the field base map.

Inventoried sites generally consisted of stream crossings, potential and existing landslides related to the road system, gullies below ditch relief culverts and long sections of uncontrolled road and ditch surface runoff which currently discharge to the stream system. For each identified existing or potential source of sediment delivery, a database form was filled out and the site was mapped on a 1:12,000 scale topographic base map. The database form (Figure 2) contained questions regarding the site location, the nature and magnitude of existing and potential erosion problems, the likelihood of erosion or slope failure and recommended treatments to eliminate the site as a future source of sediment delivery. Road surface drainage problems were also identified where long stretches of road or ditch deliver fine sediment to stream channels. The "other" category of sites includes miscellaneous erosional features such as ditch relief culverts, gullies, swales or springs that have or demonstrated the potential to deliver sediment to a stream channel.

A total of 45 sites with sediment delivery were identified in this assessment. These sites were identified as having a high, high-moderate, moderate, moderate-low or low risk of future sediment delivery to Pescadero Creek and its tributaries (Table 1). Sites include 21 stream crossings, 10 landslides and 14 miscellaneous "other" sites (Map 1). Of the 45 inventoried sites, 44 have been recommended for erosion prevention treatment. In addition, 3.8 miles (67%) of the 5.7 miles of inventoried road currently deliver sediment and runoff to streams. Treatments have been prescribed to "disconnect" this surface drainage. Most future erosion is expected to originate from erosion at stream crossings (Table 1).

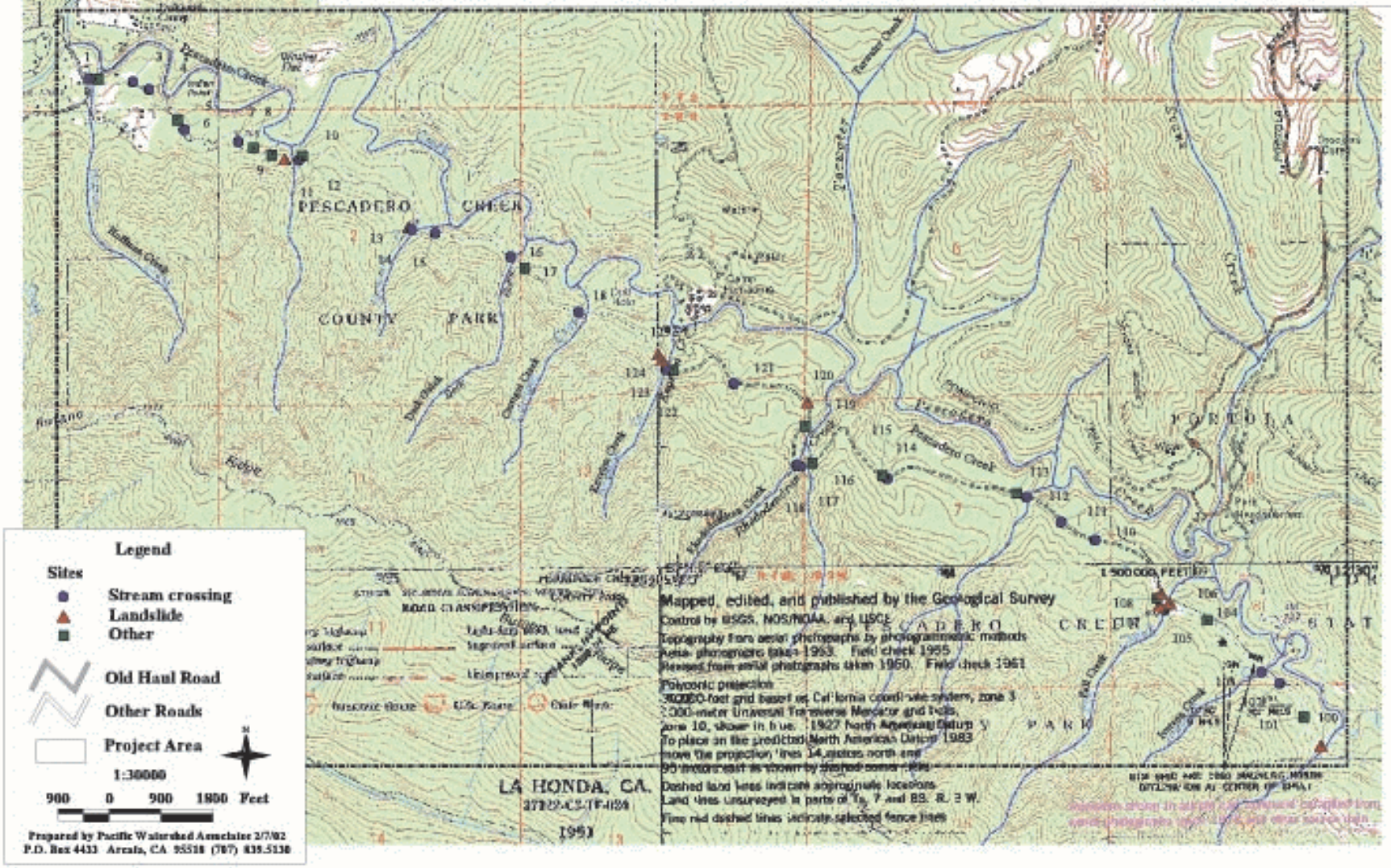
Stream crossings - Of the twenty-one stream crossings identified in the field, twenty are recommended for erosion control and erosion prevention treatment. The twenty crossings recommended for treatment include 15 culverted fill crossings, 3 Humboldt (log and fill) crossings, 1 bridge and 1 unculverted fill crossing. Total potential future erosion and sediment delivery from failure of the stream crossing sites inventoried on the Old Haul Road is approximately 54,660 yds^3 if erosion prevention measures are not undertaken. Of this, 39,508 yds^3 is estimated to deliver from two large log and fill crossings at site # 16 (Dark Gulch - 22,857 yds^3) and site # 18 (Carriger Creek - 16,651 yds^3). These large log and fill crossings are currently exhibiting erosion in the form of collapse structures (sink holes), fill failures and gullies. Over time if left untreated, erosion at these sites will involve accelerated fill collapse and the chronic release of sediment into the stream system if left untreated and ultimately, over the next two or more decades, the entire fill could fail delivering large volumes of sediment to Pescadero Creek and its respective tributaries.

A significant additional problem identified from stream crossings inventoried along the Old Haul Road arises from stream crossings with a diversion potential. Stream diversions, which can occur

Figure 2. Road erosion inventory data form used in the Old Haul Road assessment, Pescadero Creek County Park, San Mateo County, California

*ASAP*___	PWA ROAD INVENTORY DATA FORM (3/98 version)						*Check*_____
GENERAL	Site No: _____	County Site No:	Watershed:		Subwatershed:		
Treat (Y,N):	Photo: _____	T/R/S:	Road #:		Mileage: _____		
	Inspectors:_____	Date: _____	Year built:_____	Sketch (Y):			
	Maintained	Abandoned	Driveable	Upgrade	Decommission	Maintenance	
PROBLEM	Stream xing	Landslide (fill, cut, hill)	Roadbed (bed, ditch, cut)	DR-CMP	Gully	Other	
	Location of problem (U, M, L, S)	Road related? (Y)	Harvest history: (1=<15 yrs old; 2=>15 yrs old) TC1, TC2, CC1, CC2, PT1, PT2, ASG, No		Geomorphic association: Streamside, I.G., Stream Channel, Swale, Headwall, B.LS.		
LANDSLIDE	Road fill	Landing fill	Deep-seated	Cutbank	Already failed	Pot. failure	
	Slope shape: (convergent, divergent, planar, hummocky)			Slope (%) _____	Distance to stream (ft) _____		
STREAM	CMP	Bridge	Humboldt	Fill	Ford	Armored fill	
	Pulled xing: (Y)	% pulled _____	Left ditch length (ft) _____		Right ditch length (ft) _____		
	cmp dia (in) _____	inlet (O, C, P, R)	outlet (O, C, P, R)	bottom (O, C,P, R)	Separated?		
	Headwall (in) ____	CMP slope (%) _____	Stream class (1, 2, 3)	Rustline (in)			
	% washed out ____	D.P.? (Y)	Currently dvted? (Y)	Past dvted? (Y)	Rd grade (%)_____		
	Plug pot: (H, M, L)	Ch grade (%) _____	Ch width (ft) _____	Ch depth (ft) ____			
	Sed trans (H, M, L)	Drainage area (mi^2) _____					
EROSION	E.P. (H, M, L)	Potential for extreme erosion? (Y, N)		Volume of extreme erosion (yds^3): 100-500, 500-1000, 1K-2K, >2K			
Past erosion...	Rd&ditch vol (yds^3) (yds^3)_____	Gully fillslope/hillslope (yds^3)_____	Fill failure volume (yds^3) _____	Cutbank erosion (yds^3)_____	Hillslope slide vol. (yds^3)	Stream bank erosion (yds^3)	xing failure vol (yds^3)
	Total past erosion (yds) _____	Past delivery (%) _____	Total past yield (yds) _____	Age of past erosion (decade)_____	_____	_____	_____
Future erosion...	Total future erosion (yds) _____	Future delivery (%) _____	Total future yield (yds) _____	Future width (ft) _____	Future depth (ft) _____	Future length (ft) _____	
TREATMENT	Immed (H,M,L)	Complex (H,M,L)	Mulch (ft^2)				
	Excavate soil	Critical dip	Wet crossing (ford or armored fill) (circle)		sill hgt (ft) ___	sill width (ft) _____	
	Trash Rack	Downspout	D.S. length (ft) _____	Repair CMP	Clean CMP		
	Install culvert	Replace culvert	CMP diameter (in) _____	CMP length (ft) _____			
	Reconstruct fill	Armor fill face (up, dn)	Armor area (ft^2) _____	*Clean or cut ditch*	*Ditch length (ft)* _____		
	Outslope road (Y)	*OS and Retain ditch (Y)*	*O.S. (ft)* _____	*Inslope road*	*I.S. (ft)* _____	*Rolling dip*	*R.D. (#)* __
	Remove berm	*Remove berm (ft)* _____	*Remove ditch*	*Remove ditch (ft)* _____		*Rock road*	*- ft^2* _____
	Install DR-CMP	*DR-CMP (#)* _____	Check CMP size? (Y)	Other tmt? (Y)	No tmt. (Y)		
COMMENT ON PROBLEM:							
EXCAVATION VOLUME Total excavated (yds^3) _____			Vol put back in (yds^3) _____		Volume removed (yds^3) _____		
	Vol stockpiled (yds^3) _____	Vol endhauled (yds^3) _____	Dist endhauled (ft) _____	Excav prod rate (yds^3/hr) _____			
EQUIPMENT HOURS	Excavator (hrs)	Dozer (hrs)	Dump truck (hrs)	Grader (hrs)	Loader (hrs)	Backhoe (hrs)	Labor (hrs)	Other (hrs)
COMMENT ON TREATMENT:							

Map 1. Road-related sites with future sediment delvivery, Old Haul Road Stabilization Project, Pescadero Creek County Park, Big Basin, Franklin Point, La Honda, and Mindego Hill USGS 7.5' quadrangles, San Mateo County, California



when culverts are plugged, can cause substantial erosion and sediment delivery from newly developed gullies. Of the 20 crossings recommended for treatment, 9 have a diversion potential and three are currently diverted. Treatment for stream diversions is straight-forward and requires installing a "critical dip" at the down-road hinge line of the stream crossing to direct flow back into its natural drainage.

Table 1. Site classification and potential sediment delivery from all inventoried sites along 5.7 miles of the Old Haul Road, Memorial County Park, Pescadero Creek, San Mateo County, California.

Site Type	Number of sites or road miles	Number of sites or road miles to treat	Sites recommended for treatment			
			Future yield (yds^3)	Stream crossings w/ a diversion potential (#)	Streams currently diverted (#)	Stream culverts likely to plug (plug potential rating = high or moderate) (#)
Stream crossings	21	20	54,660[1]	9	3	5
Landslides	10	10	2,099	--	--	--
Other	14	14	199	--	--	--
Total (all sites)	??	44	56,958	9	3	5
Persistent surface erosion[2]	3.80	3.79	10,368	--	--	--
Totals	**45**	**44**	**67,326**	**9**	**3**	**5**

[1] Two large log and fill crossings are expected to yield 39,508 yds^3 (72%) of the future yield from stream crossings recommended for treatment.
[2] Assumes average 35' wide road prism and cutbank contributing area, and 0.4' of road/cutbank surface lowering over 2 decades.

Significant erosion can also occur from undersized culverts and poor culvert installation. Undersized culverts are too small for the 100-year design storm flow, are often prone to plugging and this can cause flow to overtop the road and erode of the stream crossing fill. Alternatively, flow can be diverted down the road to create hillslope gullies. Of the 15 culverted stream crossings, 11 were undersized for the 100-year design storm flow based on drainage calulations and 5 were classified as having a moderate to high plug potential. Erosion can also occur as a result of poorly installed culverts which cause serious gully erosion below the outlet.

Landslides - Only those road-related landslide sites with a potential for future sediment delivery to a stream channel were inventoried. The term "road-related" implies that the road appears to have played (or is playing) a role in causing or accelerating landslide movement and sediment delivery to stream channels. There are a few past and potential deep seated rotational or translational landslides

along the 5.7 miles of the Old Haul Road that may have been initiated by the Old Haul Road or old abandoned roads located above or below the Old Haul Road alignment. Although the road may have been a "causative" factor in their initiation or continued movement, there is often very little that can be done to treat this deep seated process. For this reason, some of the larger features were not inventoried and prescribed for treatment. Monitoring and maintaining areas where deep seated landslides affect roads and de-watering the road system is often the most cost-effective treatment for these sites. At one site (site #15.5), road surface drainage treatments have been prescribed to de-water a landslide and the gullies that traverse it. Locations of deep seated landslides and other road-related landslides that did not or will not deliver sediment to a stream were mapped in the field on the 1:12,000 topographic base map.

In total, ten (10) potential debris landslides with potential sediment delivery were identified along the Old Haul Road (Map 1). These fillslope failures are expected to deliver approximately 2,099 yd^3 of sediment to Pescadero Creek and its tributaries in the future (Table 1). Potential landslide sites were found along roads where material had been sidecast during earlier construction and now show signs of instability. Correcting or preventing potential landslides associated with the road is relatively straightforward, and involves the physical excavation of potentially unstable road fill and sidecast materials.

"Other"sites - A total of 14 "other" sites were also identified along the inventoried section of the Old Haul Road (Table 1 and Map 1). "Other" sites include ditch relief culverts and road surface drainage problems which exhibited the potential to deliver sediment to Pescadero Creek and/or its tributaries. The main cause of existing or future erosion at these sites is surface runoff and uncontrolled flow from long sections of undrained road surface and/or inboard ditch. Uncontrolled flow along the road or ditch may affect the road bed integrity as well as cause gully erosion on the hillslopes below the outlet of ditch relief culverts. We estimate 199 yds^3 of sediment will be delivered to streams from the 14 "other" specific sites inventoried if they are left untreated (Table 1). Sediment delivery from these sites represents less than 1% of the total potential sediment yield from sites recommended for erosion control and erosion prevention treatment.

Chronic erosion - Road runoff is also a major source of fine sediment input to nearby stream channels. We measured approximately 3.80 miles of road surface and/or road ditch (representing 67% of the total inventoried road mileage) which currently drain directly to stream channels and deliver ditch flow, road runoff and fine sediment to stream channels along the Old Haul Road (Table 1). These roads are said to be "hydrologically connected" to the stream channel network. Of the 3.80 miles of "hydrologically connected" roads, 3.79 miles of road have been recommended for erosion control and erosion prevention treatment.

From the 3.79 miles of "connected" road segments recommended for treatment, we calculated over 10,368 yds^3 of sediment could be delivered to stream channels in the Pescadero Creek watershed over the next two decades, depending on road use, if no efforts are made to change road drainage patterns. [1] This will occur through a combination of 1) cutbank erosion (dry ravel, rainfall, freeze-

[1] The applied, average rate of surface lowering on cutbanks and along road beds (i.e. 0.2 feet/decade) is based on observed retreat or erosion rates in the Pescadero Creek watershed, and on un-published data from

thaw processes, cutbank failures and brushing/grading practices) delivering sediment to the ditch, 2) inboard ditch erosion and sediment transport, 3) mechanical pulverizing and wearing down of the road surface, and 4) erosion of the road surface during wet weather periods.

Relatively straight-forward erosion prevention treatments can be applied to upgrade road systems to prevent fine sediment from entering stream channels. These treatments generally involve dispersing road runoff and disconnecting road surface and ditch drainage from the natural stream channel network.

Treatment Priority

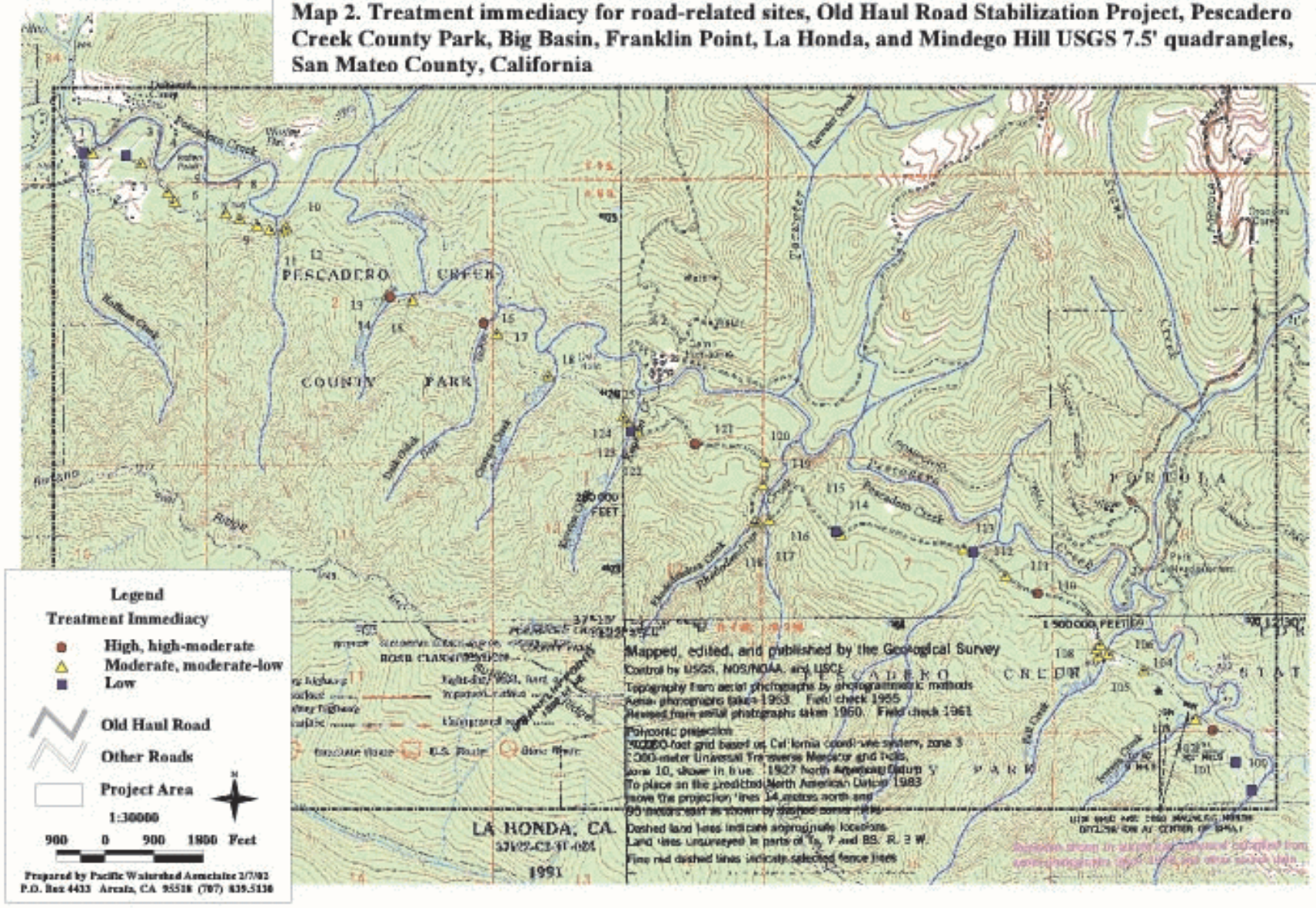
Table 2 and Map 2 outline the treatment immediacy (priority) assigned to each of the 44 inventoried sites with potential for future sediment delivery along the Old Haul Road. Altogether, 5 sites were identified as having a high or high-moderate treatment immediacy with a potential sediment delivery of approximately 31,000 yds^3. Thirty-two sites were listed with a moderate or moderate - low treatment immediacy with the potential for delivering approximately 32,600 yds^3. Finally, seven sites were listed with a low treatment immediacy and these account for over 3,700 yds^3 of future sediment delivery.

Table 2. Treatment priorities for inventoried future sediment sources along 5.7 miles of the Old Haul Road, Memorial County Park, Pescadero Creek, San Mateo County, California.

Treatment Priority	Upgrade sites (# and site #)	Problem	Future sediment delivery (yds^3)
High	**1** (site #: 110)	1 stream crossing	1,931
Moderate High	**4** (site #: 14, 16, 102, 121)	4 stream crossings	29,070
Moderate	**18** (site #: 4, 7, 9, 10, 13, 15, 15.5, 17, 18, 103, 107, 109, 114, 117, 118, 120, 122, 124)	8 stream crossings, 7 landslides, 3 ditch relief culverts	27,925
Moderate Low	**14** (site #: 2, 5, 6, 8, 11, 12, 104, 106, 108, 111, 113, 116, 119, 125)	3 stream crossings, 2 landslides, 7 ditch relief culverts, 2 other	4,668
Low	**7** (site #: 1, 3, 100, 101, 112, 115, 123)	4 stream crossings, 1 landslide, 2 other	3,732
Total	**44**	**20 stream crossings, 10 landslides, 14 other**	**67,326**

sediment budget studies on similar geologies in the Redwood Creek watershed, Humboldt County (Redwood National Park, unpublished data).

Map 2. Treatment immediacy for road-related sites, Old Haul Road Stabilization Project, Pescadero Creek County Park, Big Basin, Franklin Point, La Honda, and Mindego Hill USGS 7.5' quadrangles, San Mateo County, California



Treatments

Table 3 lists the site specific treatments for all inventoried sites recommended for erosion prevention work along 5.7 miles of the Old Haul Road. Each site has an individual data form which outlines the problem and describes in detail the recommended treatment and the estimated heavy equipment and labor requirements that has been prescribed. Recommended erosion prevention work involves upgrading at site locations that have future sediment delivery and/or need for road surface drainage improvements. Upgrading typically consists of properly installing new culverts designed to accommodate the 100-year return interval peak storm flow and debris which will be in transport. Upgrading also includes improving the road drainage by utilizing different road surface treatments such as installing frequent rolling dips, additional ditch relief culverts and/or reshaping the road surface.

It is estimated that erosion prevention work will require the excavation of just over 14,830 yds^3 at 25 stream crossing sites. Approximately 80% of the volume excavated is associated with upgrading

Table 3. Recommended treatments along 5.7 miles of the Old Haul Road, Memorial County Park, Pescadero Creek, San Mateo County, California.

Treatment	No.	Comment	Treatment	No.	Comment
Critical dip	5	To prevent stream diversions	Flared inlet	3	Install flared inlet to increase culvert capacity
Install CMP	3	Install a CMP at an unculverted fill	Inslope road	3	Inslope 740 feet of road to improve road surface drainage
Replace CMP	14	Upgrade an undersized CMP	Install rolling dips	59	Install rolling dips to improve road drainage
Excavate soil	25	Typically fillslope & crossing excavations; permanent excavation of 14,832 yds^3	Remove berm	4	Remove 1,325 feet of berm to improve road surface drainage
Down spouts	3	Installed to protect the outlet fillslope from erosion	Install ditch relief CMP	16	Install ditch relief culverts to improve road surface drainage
Clean CMP	1	Remove debris and/or sediment from CMP inlet	Clean/cut ditch	1	Clean/cut 140 feet of ditch
Armor fill face	4	Rock armor to protect outboard fillslope from erosion using 116 yds^3 of rock	Rock road surface	93	Rock road surface using 1,109 yds^3 road rock at 59 rolling dips, 17 stream crossing culvert installations, 16 ditch relief culvert installations and 1 site specific location
Trash rack	5	Install trash rack at culvert inlet to prevent plugging	No treatment recommended	1	

stream crossings and nearly 20% of the volume is proposed for excavating potentially unstable road fills (landslides). Other miscellaneous treatments for inventoried sites on the Old Haul Road will include installation of downspouts to prevent culvert outlet erosion, installation of flared inlets to increase the culvert capacity to carry water and debris, installation of trash racks upstream of culvert inlets to prevent plugging by woody debris, a variety of road surface drainage treatments (such as rolling dips and berm removal) and the installation of additional ditch relief culverts to disperse runoff and lessen fine sediment delivery from the road surface during wet winter months. Road surface rock will be applied at the specific locations including proposed rolling dips, ditch relief culvert installations, stream crossing culvert installations and other site specific locations. Re-rocking the entire road surface after treatment implementation is not included in this plan.

Equipment needs

Table 4 lists the expected heavy equipment and labor requirements according to treatment immediacy, to treat all the inventoried sites, as well as providing for improved road drainage along the 3.79 miles of contributing road bed and ditch of the Old Haul Road. Treatments for the 44 sites with potential sediment delivery will require approximately 1,830 hours of excavator and 1,840 hours of tractor time to complete all prescribed upgrading, erosion control and erosion prevention work (Table 4). Approximately 2,573 dump truck hours are needed for endhauling excess spoil. Dump truck times for road rocking following construction of rolling dips, installation of ditch relief culverts and stream crossing culvert installations are included with rock costs. Approximately 260 hours of labor is necessary for installing new culverts and other miscellaneous tasks. The remaining equipment hours apply to implementing the prescribed road surface drainage and resurfacing treatments.

Table 4. Estimated heavy equipment and labor requirements for treatment of all inventoried sites along 5.7 miles of the Old Haul Road, Memorial County Park, Pescadero Creek, San Mateo County, California.

Treatment Immediacy	Site (#)	Total Excavated Volume (yds^3)	Excavator (hrs)	Tractor (hrs)	Dump Trucks (hrs)	Compactor (hrs)	Labor (hrs)
High, High/Moderate	5	37,082	866	879	1,321	149	85
Moderate, Low/Moderate	32	34,666	856	857	1,480	144	116
Low	7	2,934	108	104	24	10	58
Total	**44**	**74,682**	**1,830**	**1,840**	**2,573**	**303**	**259**

[1] Total excavated volume includes permanently excavated material and temporarily excavated materials used in backfilling upgraded stream crossings.

Labor intensive needs

Many potential work sites will need mulching, seeding and/or tree planting following re-construction activities. These include fillslopes at stream crossings where new culverts are to be installed, at

fillslope excavation sites, as well as at all spoil disposal areas. Costs have been included for 80 hours of labor to seed and mulch approximately 5 acres of ground following heavy equipment work along the 5.7 miles of the Old Haul Road. Weed-free straw mulch will be applied at 4,000 pounds/acre.

Cost estimate for inventoried sites along 5.7 miles of the Old Haul Road in the Pescadero/Memorial/Sam McDonald County Park Complex

Table 5 summarizes the necessary costs by equipment types, for treating the 44 sites with future sediment delivery. The estimate includes costs for seed and mulch, new culverts, downspouts, flared inlets, trash racks as well as rock necessary for rip rap and road surfacing at proposed rolling dips, ditch relief culverts, stream crossing culvert installations and other specific locations. Hours represent direct equipment times and do not include travel time between work sites, additional costs for unseen complications or the time needed for conferences with equipment operators. These additional times are accounted for as "logistics" and are added to the total equipment hours to determine the total project cost (Tables 5).

Total costs for the project are estimated at approximately $1,147,000 to treat the 44 sites inventoried. Of the $1,147,182 necessary to treat the 44 sites on the Old Haul Road, approximately 63% of the costs are associated with treating the 2 large log and fill stream crossing sites (site #16 = $360,983, site #18=- $361,403).

The average cost effectiveness value of the project is $ 17.03 per cubic yard of sediment prevented from entering Pescadero Creek and its tributaries. According to current CFG&G guidelines for funding upland erosion control and prevention projects, the generally accepted standard is that projects cost between $7 to $15/yd^3 saved from entering a stream. We believe this standard should be increased to $10 to $20/yd^3 saved for the San Francisco Bay Area counties for several reasons.

The cost-effectiveness values of $7 to $15/yds^3, or less, was developed by the CDF&G in 1996 based on cost estimates to treat and up-grade road erosion sites along roads in the northern California counties of Humboldt, Trinity, Del Norte and Mendocino. Several factors indicate that in the San Francisco Bay Area counties, a more appropriate cost-effectiveness value should be between $10 to $20/yd^3 saved or prevented from entering a stream channel. The acceptability of the proposed revision in cost-effectiveness values is based on the following considerations: 1) numerous road assessments PWA has performed over the last 5 years in the greater Bay Area from Sonoma to Monterey Counties, where the cost-effectiveness values frequently exceed $15/yd^3 saved, 2) heavy equipment rental rates in the Bay Area counties on average, exceed the north coast counties by 25% to 50%, 3) the cost-effectiveness values established by CDF&G over 6 years ago have not been adjusted for cost-of-living rate changes, whether based on inflation or the higher cost of living in the greater Bay Area, and 4) the vast majority of upland road projects in the Bay Area counties are conducted at prevailing wage rates compared to owner-operator rates charged on similar projects in the north coast counties.

Costs in Table 5 assume that the work in the watershed will be accomplished during two summer work periods using two equipment teams. The cost estimate includes layout, coordination, monitoring and reporting hours for a PWA professional to work with equipment operators to insure

the plan is cost effectively implemented, as proposed, and treatments are installed or constructed properly and according to specifications.

Finally, the costs in Table 5 are based on a number of assumptions and estimates. The costs provided are reasonable if work is performed by outside contractors, with no added overhead for contract administration, and pre- and post-project surveying. Movement of equipment to and from the site will require the use of low-boy trucks. The treatments listed in this plan range from relatively simple to very complex, as in the case of the 2 log and fill stream crossing sites (site # 16 and site # 18) . Therefore, it would be advisable to contract equipment operators experienced in road upgrading operations on steep forest lands. The use of inexperienced operators would require additional technical oversight and supervision in the field and result in a decrease in equipment production rates and increased overall costs. We would be happy to provide you a list of qualified contractors. All recommended treatments conform to guidelines described in "The Handbook for Forest and Ranch Roads" prepared by PWA (1994) for the California Department of Forestry and Fire Protection, the Natural Resources Conservation Service and the Mendocino County Resource Conservation District.

Recommendations

According to SMCPR, the 1998 winter storms caused approximately 17,370 yds^3 of erosion and sediment delivery to Pescadero Creek and its tributaries from four sites located along the Old Haul Road. The four sites include two landslides and two large log and fill stream crossings. All four of these sites have been recommended for treatment using FEMA/County funds. Since the four FEMA/County sites are separately funded projects, the SMCPR prepared the "Old Haul Road Trail Drainage Improvement Plan # 2". The drainage improvement plan does not include the four FEMA/County sites and instead addresses the remainder of the Old Haul Road. Our erosion control and erosion prevention plan involves assessment of the entire road and includes treatments for the four FEMA/County sites.

SMCPR recommended treatments for the two FEMA/County log-and-fill stream crossings involves excavating down to logs and woody debris (approximately two-thirds of stream crossing fills would be excavated), emplacement of geo-fabrics and installation of larger culverts. It was planned to leave the underlying logs, woody debris and fill in the stream crossings. The same processes that are causing failure of the two log and fill crossings today will, over time occur again. The logs and woody debris will continue to decay. This will ultimately result in the failure of the stream crossing fills. For example, PWA site #121 is a stream crossing that had recently been partially excavated down to logs and woody debris with a culvert placed on top. A channel was cut through crib logs located below the outboard edge of the road. Currently, the crossing is beginning to fail by stream flow gullying through logs deep in the fill and stream bank failures located just downstream of the culvert outlet. As an alternative, we have recommended fully excavating the stream crossings, removing all logs, fill and debris, and installing culverts sized for the 100-year storm event at the base of the fill and in the natural channel.

Both the PWA erosion prevention plan and the SMCPR road drainage improvement project aim to reduce future sedimentation to Pescadero Creek and its tributaries. The main difference between the assessments is that the PWA assessment and treatment plan identified and prioritized all sources of

erosion that have the potential to deliver sediment to Pescadero Creek and its tributaries. This includes all potential landslides, stream crossings, road drainage problems and other miscellaneous sites that have the potential for sediment delivery, as well as chronic road surface erosion and delivery. To ensure a long term erosion control and erosion prevention plan it is important to identify problems and prioritize treatments for all sites with future sediment delivery. The SMCPR road drainage plan identified locations of all stream crossings, but only recommended larger culverts at 4 small stream crossings. Excluding the FEMA/County sites, the PWA assessment recommends upgrading 15 stream crossings with culverts sized for the 100-year design storm flow. We suggest that first treating all the stream crossing sites and the associated length of road draining to each stream crossing, will result in significantly higher "sediment savings" and protection of water quality (Table 1).

Table 5. Estimated logistic requirements and costs for road-related erosion control and erosion prevention work on all inventoried sites with future sediment delivery along 5.7 miles of the Old Haul Road, Memorial County Park, Pescadero Creek, San Mateo County, California.

Cost Category[1]		Cost Rate[2] ($/hr)	Estimated Project Times			Total Estimated Costs[5] ($)
			Treatment[3] (hours)	Logistics[4] (hours)	Total (hours)	
Move-in; move-out[6] (Low Boy expenses)	Excavator	100	6	--	6	600
	D-8 tractor	100	6	--	6	600
	D-6 tractor	85	6	--	6	510
	Compactor	85	6	--	6	510
Heavy Equipment requirements for site specific treatments	Excavator	135	1,830	535	2,317	312,795
	D-8 tractor	125	1,144	343	1,487	185,875
	D-6 tractor	95	635	191	826	78,470
	Dump Truck	65	2,573	772	3,345	217,425
	Compactor	100	303	91	394	39,400
	Water truck[7]	90	1,000	300	1,300	117,000
Heavy Equipment requirements for road drainage treatments	Excavator	135	48	14	62	8,370
	D-6 tractor	95	61	18	79	7,505
	Grader[8]	90	46	14	60	5,400
	Roller[9]	75	10	3	13	975
Laborers[10]		35	339	102	441	15,435
Rock Costs: (includes trucking for 1,109 yds^3 of road rock and 116 yds^3 of rip-rap sized rock)						24,500
Culvert materials costs (600' of 18', 300' of 24", 180' of 36", 150' of 48", 60' of 54", 500' of 60" and 620' of 72". Costs included for couplers)						77,452
Mulch, seed and planting materials for 5 acres of disturbed ground[11]						2,750
Layout, Coordination, Supervision, and Reporting[12]		65	--	--	794	51,610
Total Estimated Costs						**$1,147,182**

Potential sediment savings: 67,326 yds^3
Overall project cost-effectiveness: $17.03 spent per cubic yard saved

[1]Costs for tools and miscellaneous materials have not been included in this table. Costs for administration and contracting are variable and have not been included.

[2] Costs listed for heavy equipment include operator and fuel. Costs listed are estimates for favorable local private sector equipment rental and labor rates.

[3] Treatment times include all equipment hours expended on excavations and work directly associated with erosion prevention and erosion control at all the sites.

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

[5] Total estimated project costs listed are averages based on private sector equipment rental and labor rates.

[6] Lowboy hauling for tractor and excavator, 3 hours round trip for two (2) crews to the Old Haul Road within the Pescadero Creek watershed. Costs assume 2 hauls each for two pieces of equipment (one to move in and one to move out).

[7] 1,000 hours of water truck time added for compaction of stream crossing fills.

[8] 46 hours of grader times added to grade the 5.7 miles of the Old Haul Road after treatment implementation.

[9] 10 roller hours added to surface road rock at stream crossing culvert installations, ditch relief culvert installations and rolling dips.

[10] An additional 80 hours of labor time is added for straw mulch and seeding activities.

[11] Seed costs equal $6/pound for erosion control seed. Seed costs based on 50# of erosion control seed per acre. Straw costs include 50 bales required per acre at $5 per bale. Sixteen hours of labor are required per acre of straw mulching. Does not include additional seed and mulch required on decommissioned road surfaces within the Water/Lake Protection Zones.

[12] Supervision time includes detailed layout (flagging, etc) prior to equipment arrival, training of equipment operators, supervision during equipment operations, supervision of labor work and post-project documentation and reporting). Supervision times based on 30% of the total excavator time plus 1 week prior and 1 week post project implementation.

The SMCPR road drainage plan proposes to reduce road surface erosion and fine sediment delivery by the installation and replacement of ditch relief culverts and grading and rocking along the entire Old Haul Road alignment. SMCPR plans on installing 23 new ditch relief culverts and replacing 20 existing ditch relief culverts to treat road drainage along the entire 5.7 miles of the Old Haul Road. Currently, only two-thirds of the Old Haul Road persistently delivers fine sediment to streams, so treatments along the remaining one-third of the road provide no water quality benefits. The PWA erosion prevention plan also suggests installing more frequent road drainage treatments but only along reaches of the road that persistently deliver fine sediment to streams. PWA recommended road drainage treatments include frequent rolling dips (n=59), installation of new ditch relief culverts where rolling dips are inappropriate (n=12) and replacement of existing ditch relief culverts (n=4). De-watering the road system at frequent locations along the road alignment will help prevent fine sediment from delivering to Pescadero Creek and its tributaries and preserve the integrity of the road bed surface.

The PWA erosion prevention plan does not propose rocking the entire road surface after treatment implementation. Road rock is recommended site specific locations including stream crossing culvert installations and replacements, ditch relief culvert installations and replacements, proposed rolling dips and other site specific locations. It is our belief that the entire road surface does not need to be rocked if the road has been sufficiently de-watered through road surface treatments such as outsloping, insloping, ditch relief culverts and/or rolling dips.

Potential “sediment savings” and treatment “cost effectiveness” are considered in creating a sound erosion control and erosion prevention plan. Sediment savings refers to the amount of sediment that

could be prevented from entering the stream system if erosion control and erosion prevention measures are implemented. Cost-effectiveness is defined as the average amount of money spent to prevent one cubic yard of sediment from entering or being delivered to the stream system and ideally should be less than $15 per cubic yard. According to our assessment of the Old Haul Road, the total sediment savings is estimated to be approximately 67,326 yds^3 (includes both site specific and chronic road surface erosion, Table 1) for a cost-effectiveness of about $17 per cubic yard "saved" (Table 5) to treat all sites with potential future sediment delivery. The cost-effectiveness value is slightly high for this plan due to the recommended treatments at the 2 large log and fill crossings (PWA site #16 and site#18). However, as stated earlier, based on the substantially higher cost-of-living for the Bay Area counties, we believe the acceptable range for funding cost-effective upland projects should be between $10 to $20/$yd^3$ saved from entering stream channels.

The SMCPR drainage plan estimates that up to 1,873 yds^3 of sediment could be delivered to Pescadero Creek and its tributaries in the future if not treated. The estimate of future erosion and sediment delivery is based on a 10-12% loss of the road surface caused by "undersized or collapsed culverts, insufficient ditch volume, rutting and washouts, water sheeting over unstable edge fill, and lack of compaction and rock on the travel surface". According to the SMCPR road drainage plan, recommended treatments would cost $578,713 for an average "cost effectiveness" of approximately $310 per cubic yard "saved". High costs associated with the SMCPR drainage plan result from the proposed application of costly treatments.

For example, all proposed ditch relief culverts are designed with concrete aprons at inlets and gabion baskets at outlets for energy dissipation. Inlet protection and outlet energy dissipation should not be necessary if the road is 1) de-watered frequently by applying road surface treatments such as road-shaping and/or rolling dips and ditch relief culverts along reaches that persistently deliver sediment to streams, and 2) installing ditch relief culverts at steeper angles so they discharge at the base of the fill. Furthermore, costs could be further reduced if road rock was applied at site specific locations (such as proposed rolling dips, ditch relief culverts and stream crossing culvert upgrades) instead of along the entire length of the Old Haul Road since only two-thirds of the road contributes fine sediment to streams.

We recommend discussing the PWA proposed prioritization and treatment plan with the California Department of Fish and Game in order to revise the emphasis of the SMCPR road drainage plan towards achievement of maximum sediment savings and reduction of erosion along the Old Haul Road. We would be happy to assist you with these discussions. It is likely that if FEMA funds are applied to the four FEMA work sites, the existing California Department of Fish and Game restoration grant monies, together with county matching funds would be sufficient to complete the proposed erosion control and erosion prevention work on all but the lowest priority sites that we have identified.

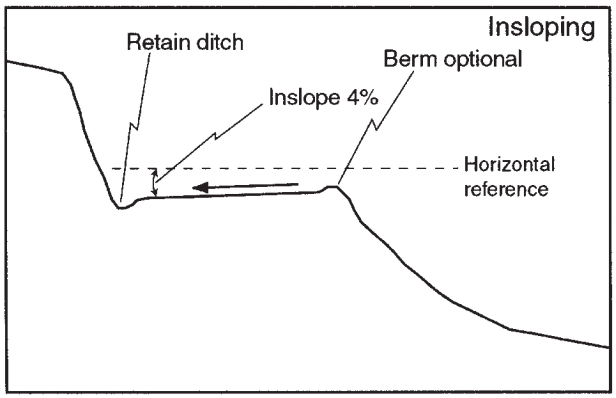
It is imperative that experienced contractors familiar with excavating large, complex log and debris filled stream crossings be used to complete the projects. As can be seen with the recent repair of site #121, successfully reconstructing a stable stream crossing will require the complete removal of all organic material which has been incorporated in the crossing.

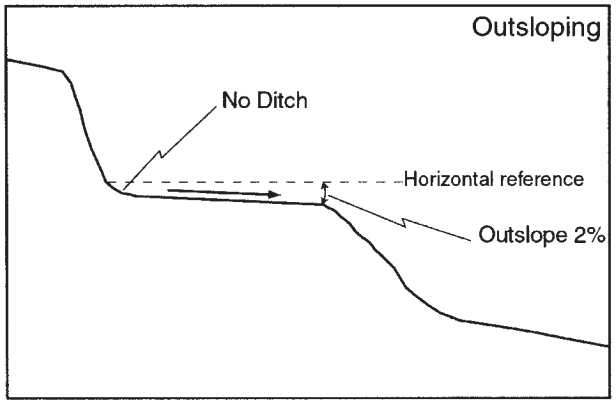
Thank you for the opportunity to assist you in prioritizing erosion control and erosion prevention efforts that will provide for the maximum protection of water quality and fish habitat in the Pescadero Creek watershed. We look forward to completing the assessment of the remaining roads throughout parklands in the watershed. We believe shifting the emphasis of the Old Haul Road erosion control and erosion prevention effort can be easily accomplished. Monies that were formerly ear-marked for extensive use of labor and materials to construct secondary erosion control measures can be used to repair additional stream crossings, excavate potential landslides and provide for significant reduction of fine sediment originating from the road bed.

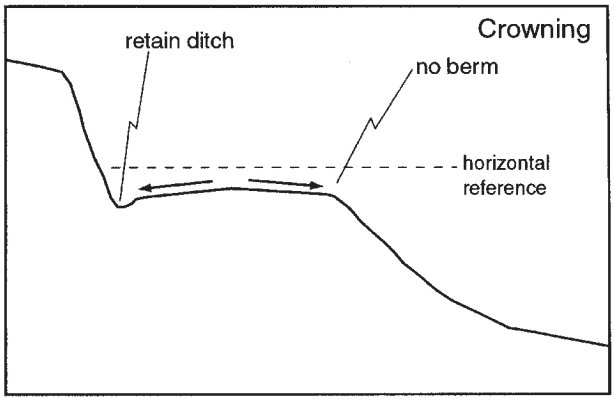
Appendix B

Typical Construction Drawings for Road Up-Grading and Road Decommissioning Projects

Using road shape to control road runoff

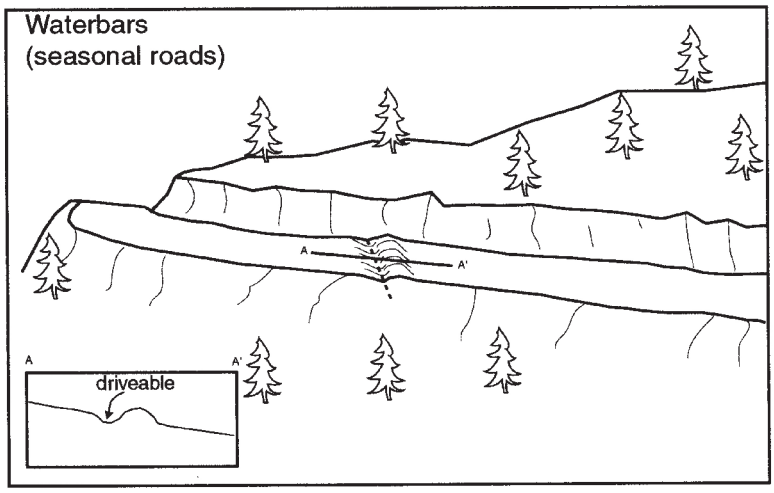


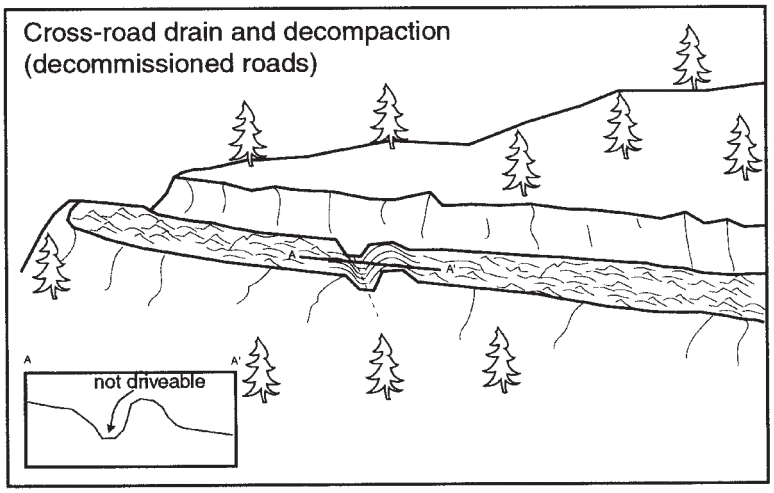


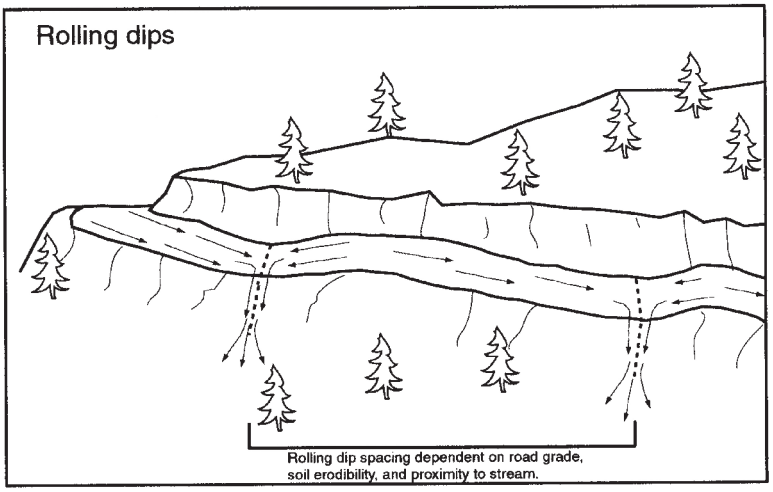


Outsloping pitch for roads up to 8% grade		
Road grade	Outslope pitch for unsurfaced roads	Outslope pitch for surfaced roads
4%, or less	3/8" per foot	1/2" per foot
5%	1/2" per foot	5/8" per foot
6%	5/8" per foot	3/4" per foot
7%	3/4" per foot	7/8" per foot
8%, or more	1" per foot	1 1/4 per foot

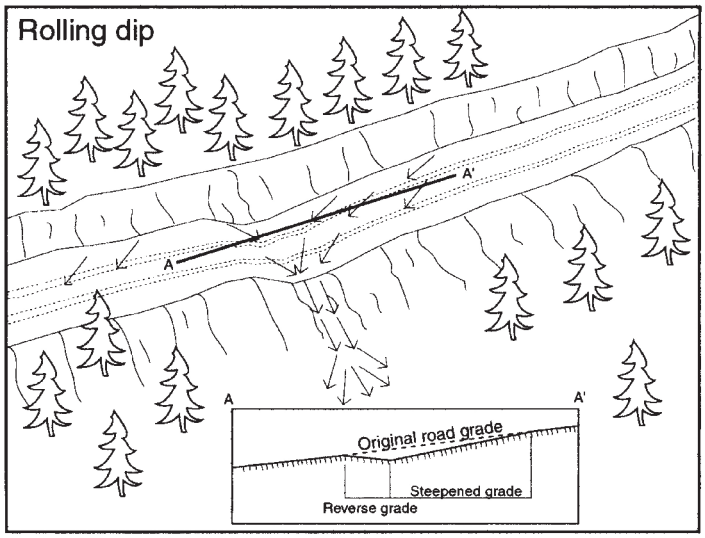
Dispersing road surface runoff







Road surface drainage by rolling dips



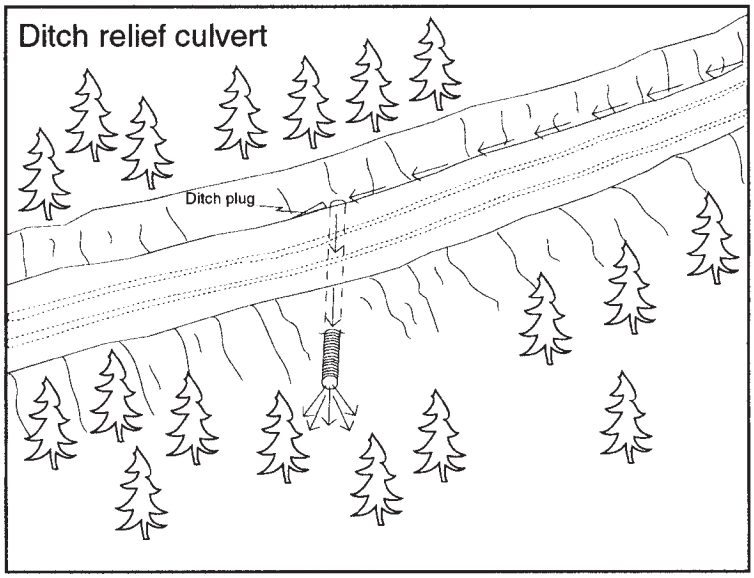
Rolling dip installation:

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

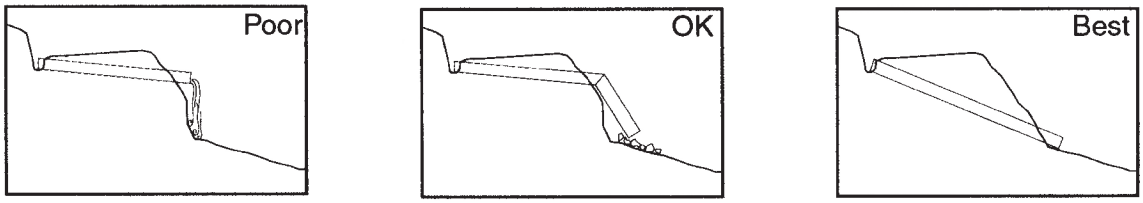
Table of rolling dip dimensions

Road grade	Upslope approach (distance from up-road start of rolling dip to trough) (ft)	Reverse grade (Distance from trough to crest)	Depth below average road grade at discharge end of trough. (ft)	Depth below average road grade at upslope end of trough. (ft)
<6	55	15-20	0.9	0.3
8	65	15-20	1.0	0.2
10	75	15-20	1.1	.01
12	85	20-25	1.2	.01
>12	100	20-25	1.3	.01

Typical ditch relief culvert installation



Cross sections of typical installations

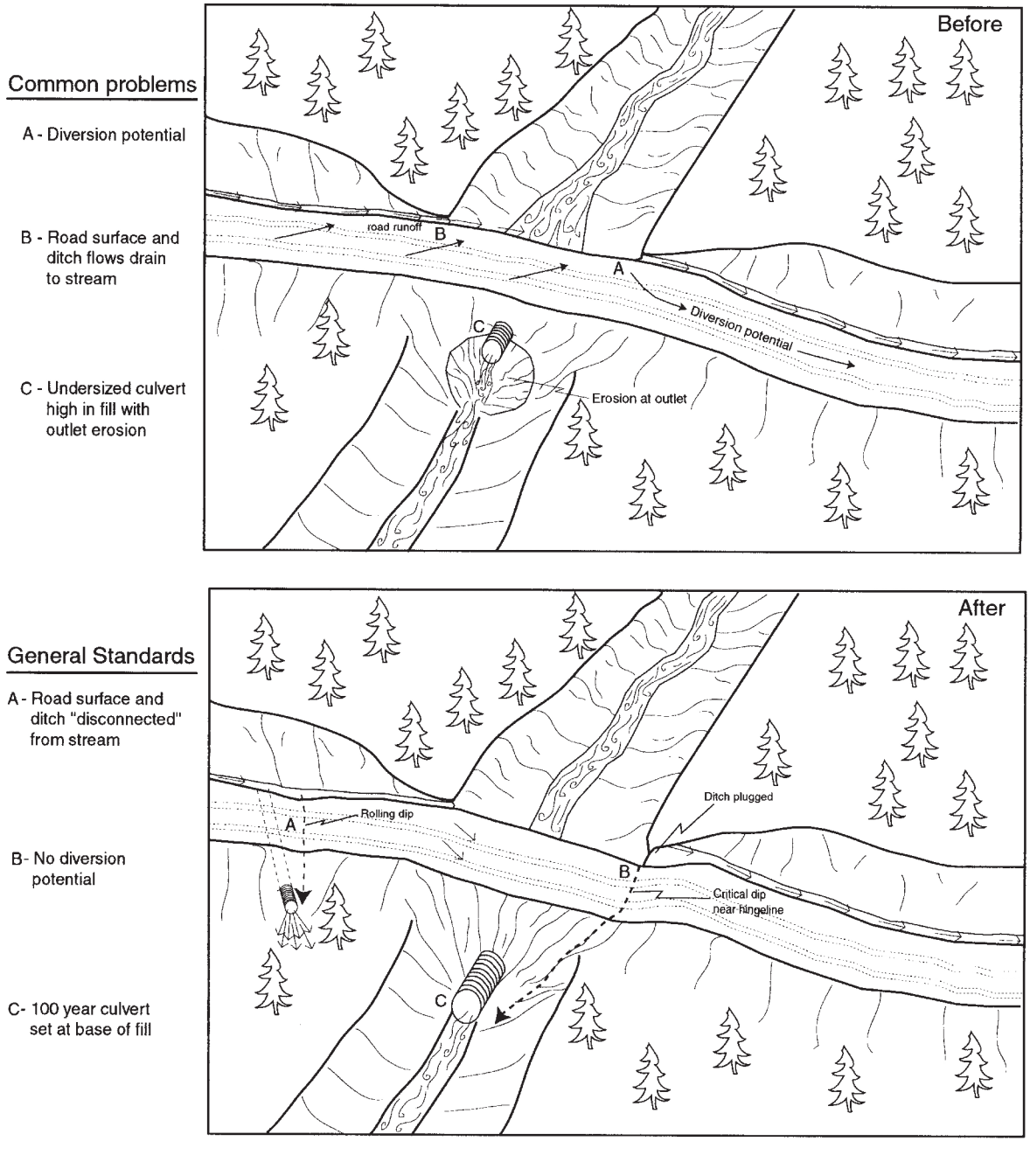


Ditch relief culvert installation

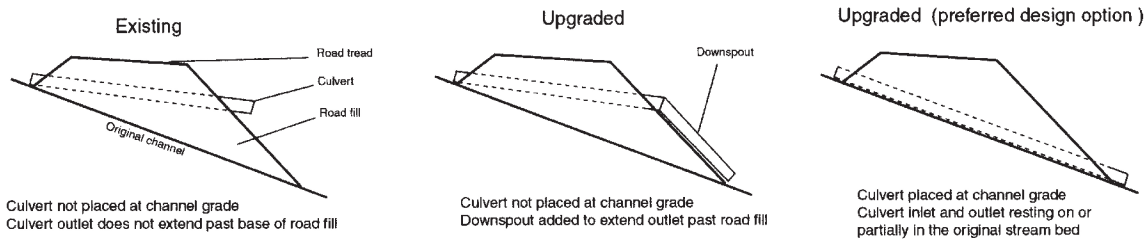
1) The same basic steps followed for stream crossing intallation should be employed.
2) Culverts should be installed at a 30 degree angle to the ditch to lessen the chance of inlet erosion and plugging.
3) Culverts should be seated on the natural slope or at a minimum depth of 5 feet at the outside edge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

Typical Schematic

Components of an upgraded stream crossing



Typical design of non-fish bearing culverted stream crossings

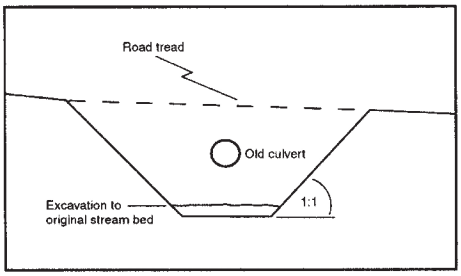


Culvert not placed at channel grade
Culvert outlet does not extend past base of road fill

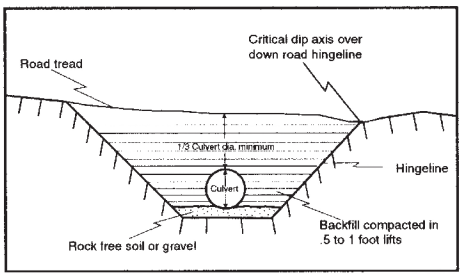
Culvert not placed at channel grade
Downspout added to extend outlet past road fill

Culvert placed at channel grade
Culvert inlet and outlet resting on or partially in the original stream bed

Excavation in preparation for upgrading culverted stream crossing



Upgraded stream crossing culvert installation



Typical installation of non-fish bearing culverted stream crossings

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 flood flow should be determined by both field observation and calculations using a procedure such as the Rational Formula.

Stream crossing culvert installation:

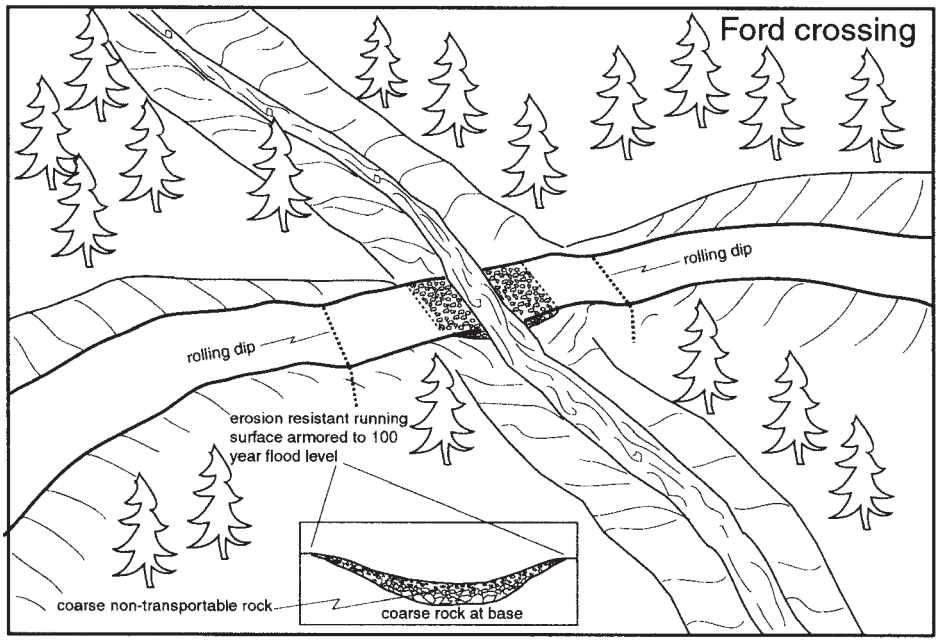
1) Culverts should be aligned with natural stream channels to ensure proper function, prevent bank erosion and debris plugging problems.
2) Culverts should be placed at the base of the fill and at the grade of the original streambed or downspouted past the base of the fill where ever possible.
3) Culverts should be set slightly below the original stream grade so that the water drops several inches as it enters the pipe.
4) Culvert beds should be composed of rock free soil or gravel, evenly distributed under the length of the pipe.
5) To allow for sagging after burial, an upward camber should be between 1.5 to 3 inches per 10 feet culvert pipe length.
6) Backfill material should be free of rocks, limbs or other debris that could dent or puncture the pipe or allow water to seep around pipe.
7) One end of the culvert pipe should be covered then the other end. Once the ends have been secured, the center will be covered.
8) Backfill material should 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 ft lifts untill 1/3 of the diameter of the culvert has been covered. A gas powered tamper should be used for this work.
9) Inlets and outlets should be armored with rock or mulched and seeded with grass as needed. Routine armoring is generally not needed.
10) Trash protectors should be installed just upstream from the culvert inlet where there is a hazard of floating debris plugging the culvert.
11) Layers of fill will be pushed over the crossing until the final, design road grade is achieved, at a minimum of 1/3 to 1/2 the culvert diameter.

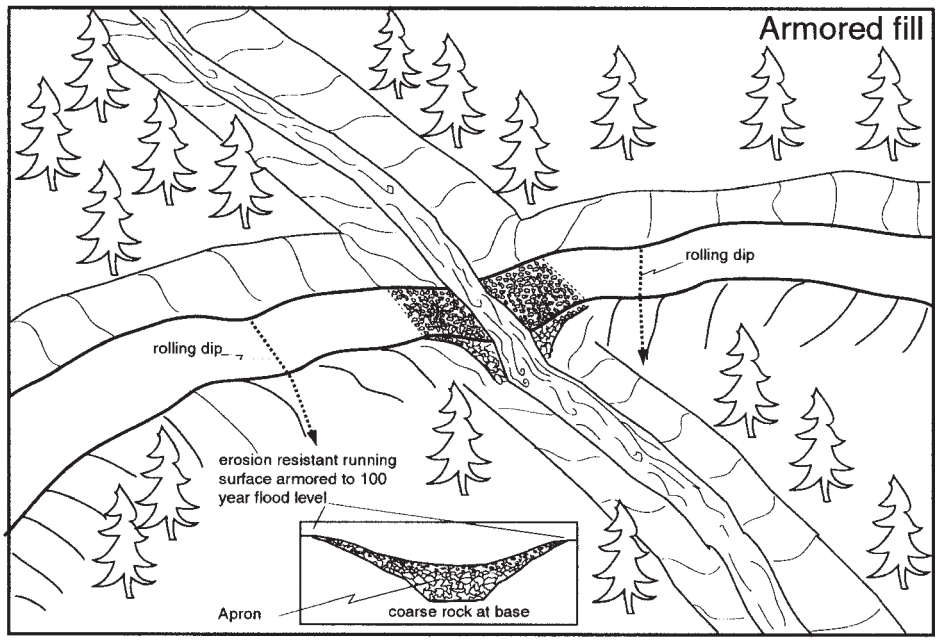
Erosion control measures for culvert replacement:

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

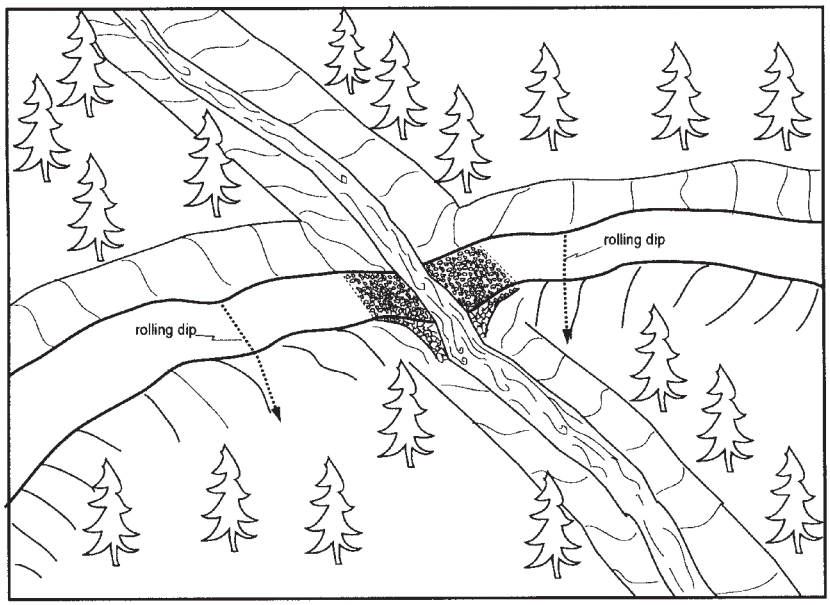
1) Minimizing soil exposure by limiting excavation areas and heavy equipment disturbance.
2) Installing filter windrows of slash at the base of the road fill to minimize the movement of eroded soil to downslope areas and stream channels.
3) Inslope the road prism to minimize fill slope erosion by road runoff.
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 fall rains.
5) Extra or unusable soil will be stored in long term spoils disposal locations that are not limited by factors such as excessive moisture, steep slopes, archeology potential, listed species or proximity to a watercoarse.
6) On running streams, water will be pumped or diverted past the crossing and into the down stream channel during the construction process.
7) Straw bales and/or silt fencing will be employed where neccessary to control runoff and sediment delivery within the construction zone.

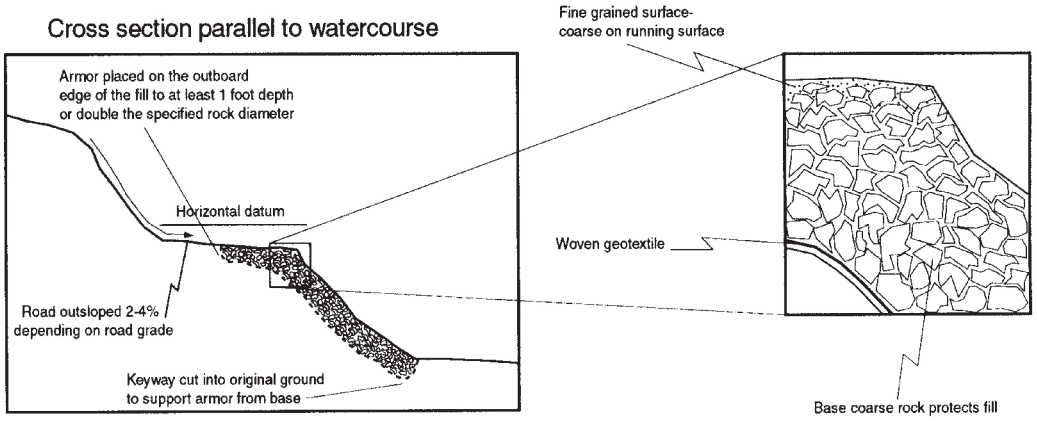
Ford and armored fill stream crossings

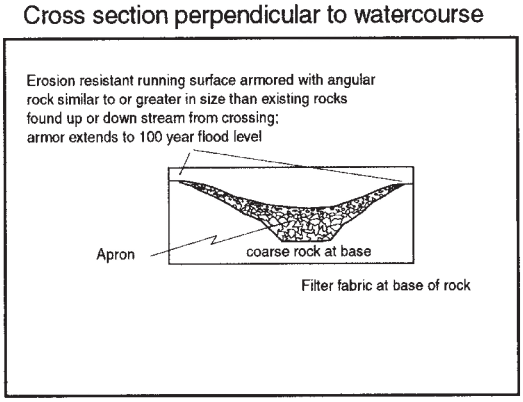




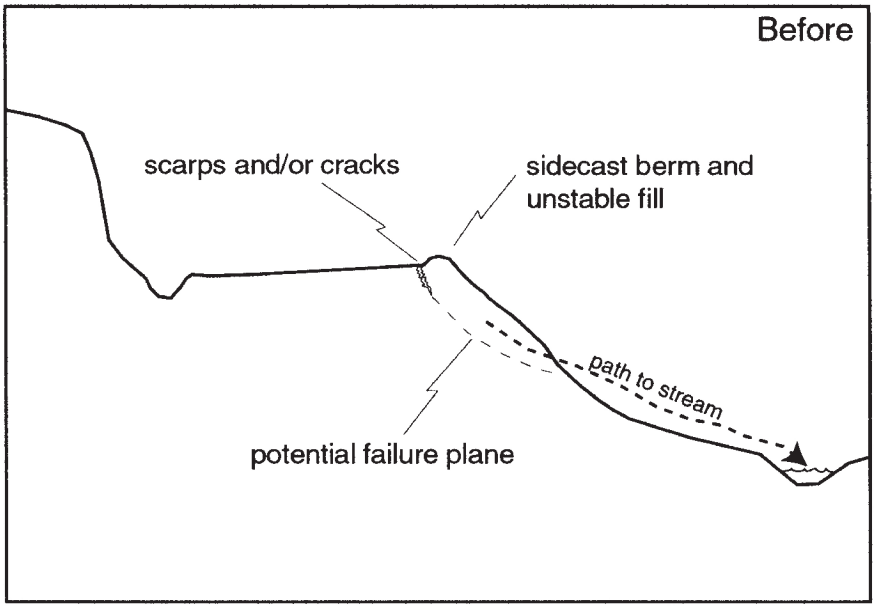
Typical armored fill crossing installation

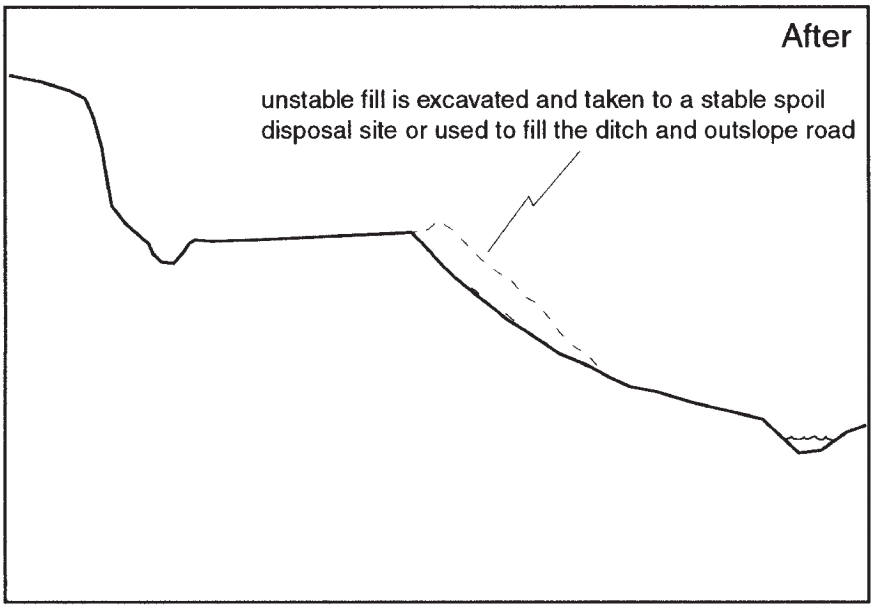






Excavating unstable fill slope on maintained road

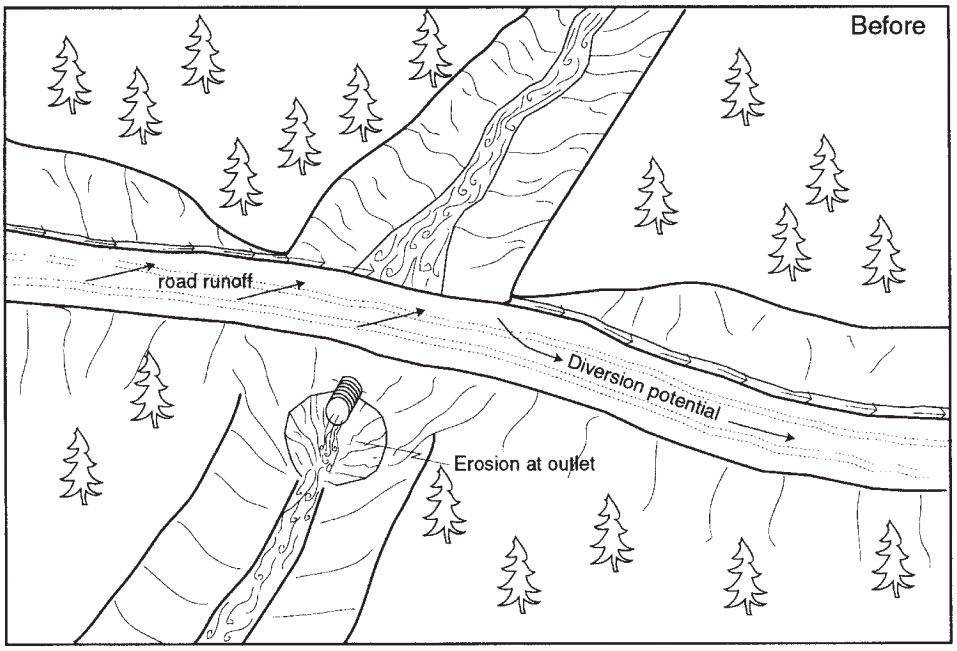




Typical stream crossing decommissioning

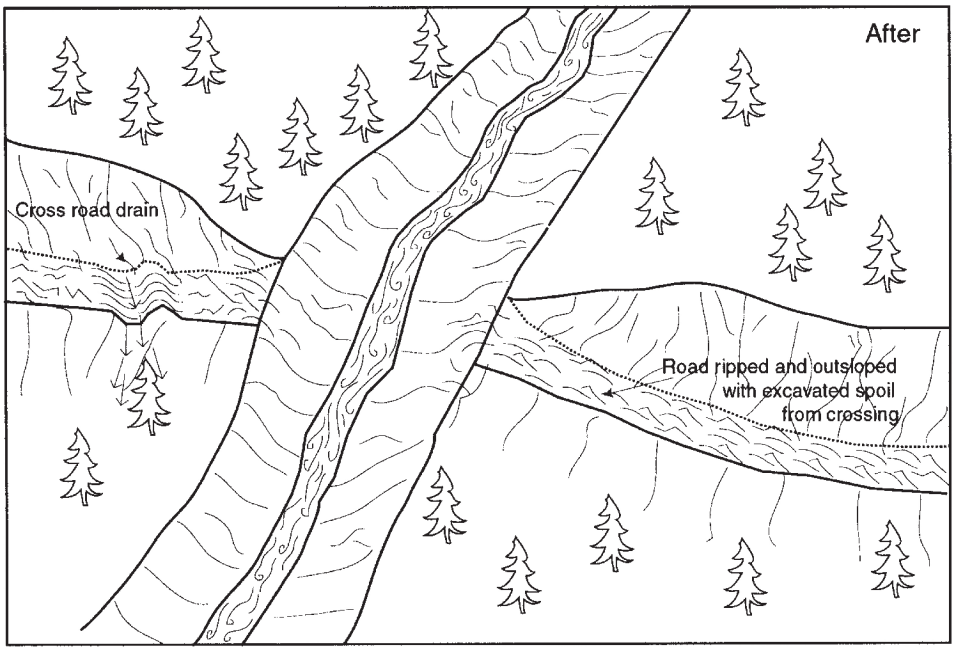
Condition

- Diversion potential
- Road surface and ditch flows drain to stream
- Undersized culvert high in fill with outlet erosion and elevated plugging potential

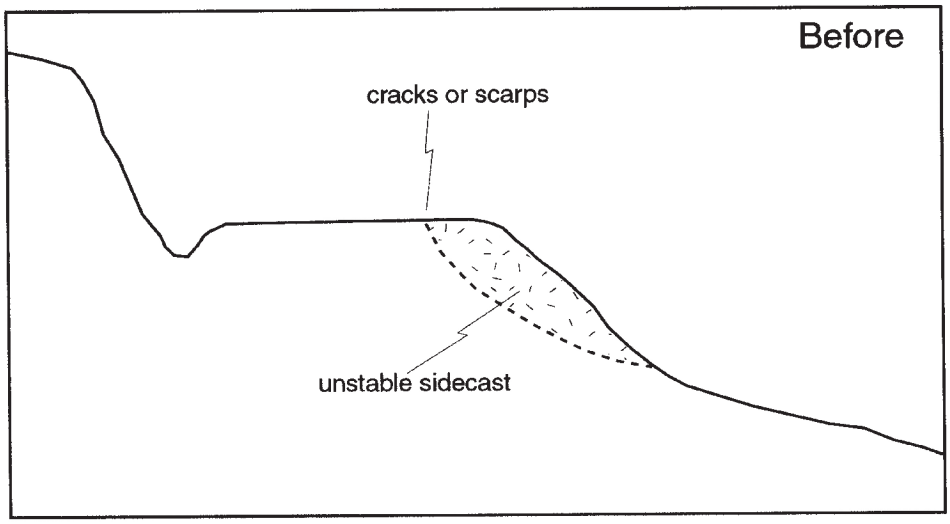


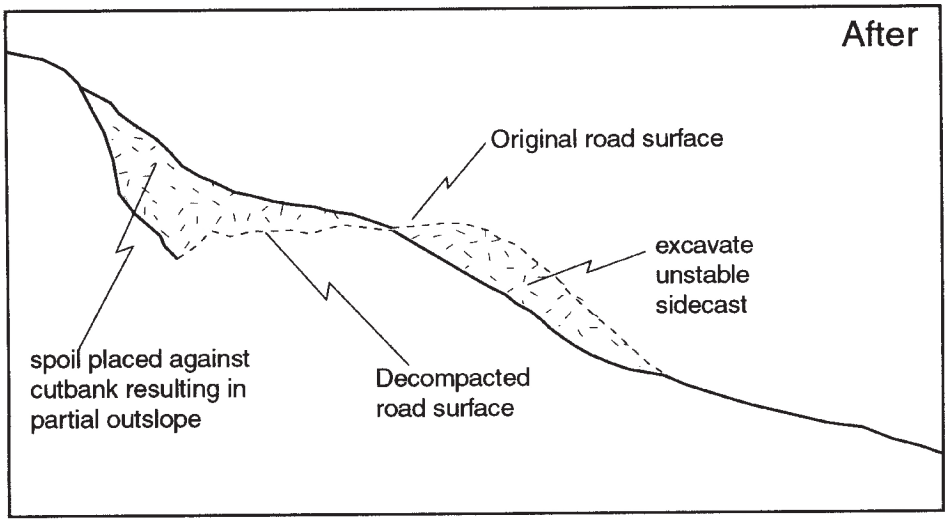
Treatment

- Road surface decompacted
- Cross road drains on old road
- Stream crossing fill completely excavated
- Excavated spoil used to outslope adjacent road



Excavation of unstable fill slope on decommissioned road





Map 1a. Road-related and trail-related sites with future sediment delivery by problem type, Pescadero /Memorial/Sam McDonald County Park Complex, San Mateo County, California

Legend

Road-related sites Problem type

- S — Stream crossing
- T — Landslide
- U — Ditch relief culvert
- U — Other
- S — Phase I Old Haul Road sites

Trail-related sites Problem type

- S — Stream crossing
- T — Landslide
- U — Other

- Roads
- County roads
- Trails
- Non-inventoried roads
- Streams
- Park Boundary

1000 0 1000 2000 Feet

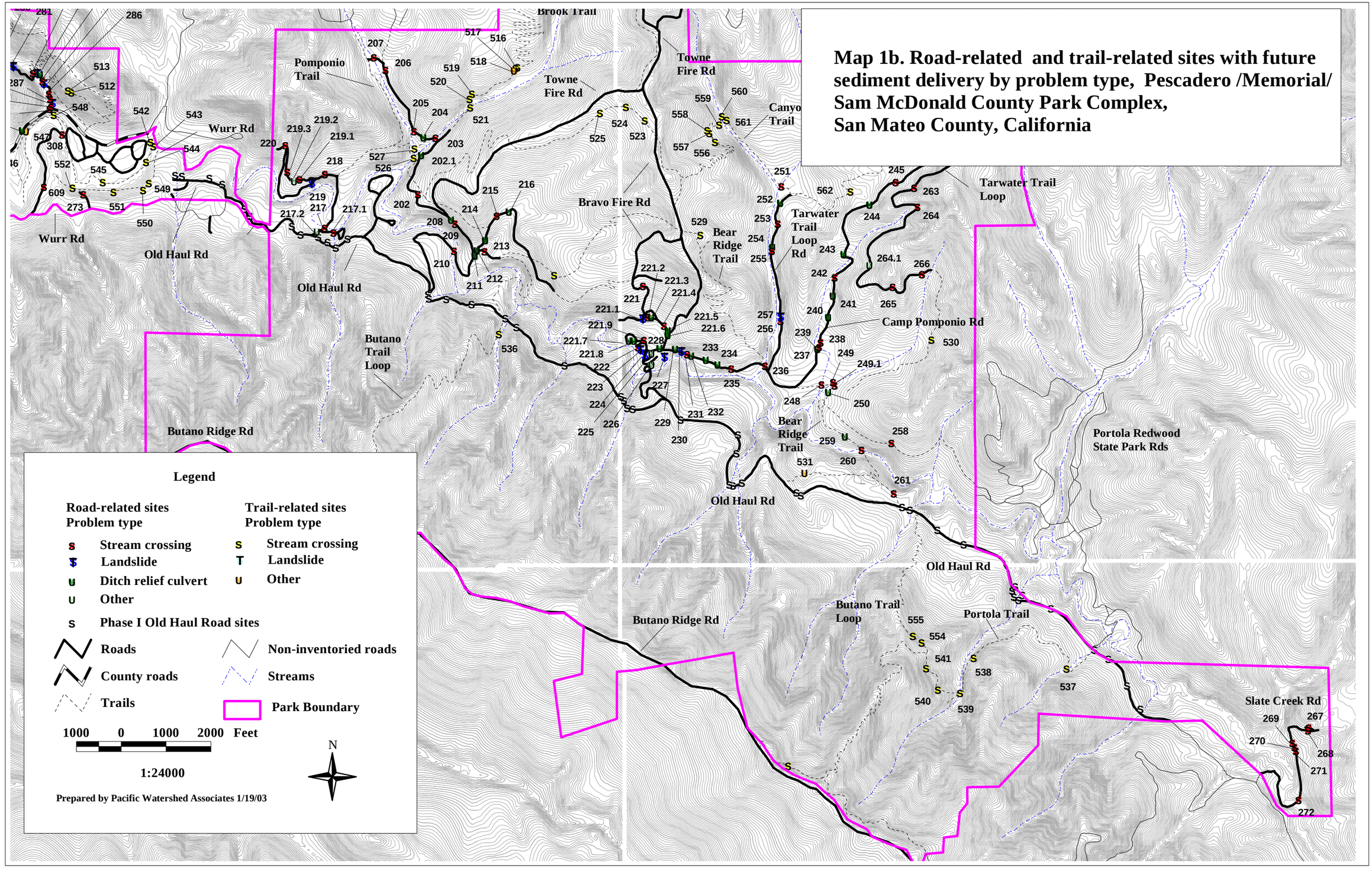
1:24000

N

Prepared by Pacific Watershed Associates 1/19/03

Ridge Trail Rd
Pescadero Rd
Ridge Trail Rd
Pescadero Rd
Ridge Fire Rd
Pescadero Rd
Pescadero Rd
Alpine Rd
Big Tree Trail
Alpine Rd
Towne Fire Rd
Pescadero Rd
Brook Trail
Towne Fire Rd
Pomponio Trail Rd
Pomponio Trail
Towne Fire Rd
Canyon Trail
Camp Pomponio Rd
Tarwater Trail Loop
Tarwater Trail Loop
Pescadero Rd
Wurr Rd
Bravo Fire Rd
Tarwater Trail Loop Rd
Wurr Rd
Old Haul Rd
Old Haul Rd
Bear Ridge Trail

Map 1b. Road-related and trail-related sites with future sediment delivery by problem type, Pescadero /Memorial/ Sam McDonald County Park Complex, San Mateo County, California



Map 2a. Road-related and trail-related sites with future sediment delivery by treatment immediacy, Pescadero/Memorial/Sam McDonald County Park Complex, San Mateo County, California

Legend

Road-related sites
Treatment immediacy

- S — High/ High Moderate
- U — Moderate/ Moderate-low
- T — Low
- 0 — No treatment

Trail-related sites
Problem type

- S — High/ High Moderate
- U — Moderate/ Moderate-low
- T — Low
- 0 — No treatment

- Roads
- County roads
- Trails
- Non-inventoried roads
- Streams
- Park Boundary

1000 0 1000 2000 Feet

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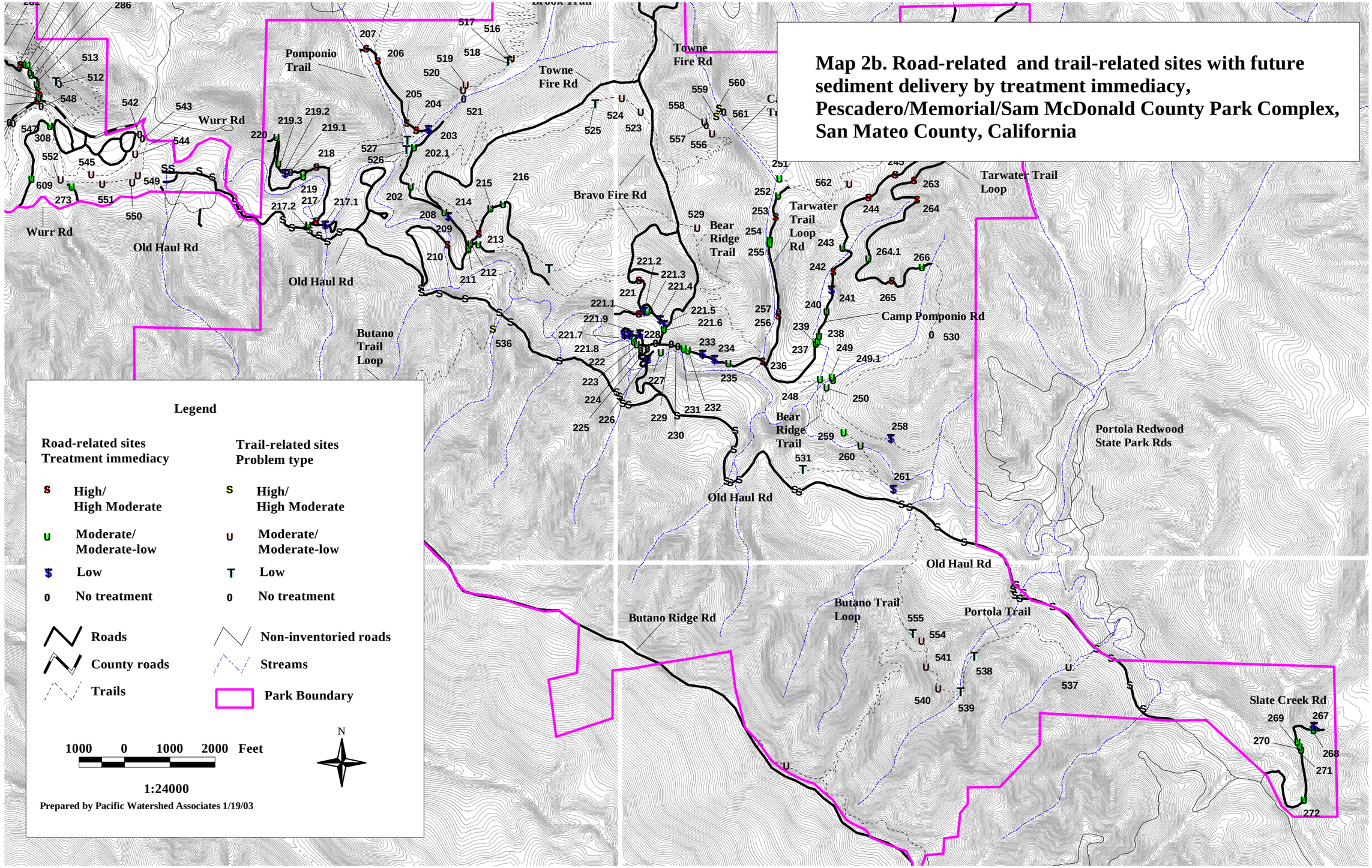
Prepared by Pacific Watershed Associates 1/19/03

Ridge Trail Rd
Pescadero Rd
Ridge Trail Rd
Pescadero Rd
Ridge Fire Rd
Pescadero Rd
Pescadero Rd
Alpine Rd
Big Tree Trail
Towne Fire Rd
Alpine Rd
Pescadero Rd
Brook Trail
Towne Fire Rd
Towne Fire Rd
Pomponio Trail Rd
Pomponio Trail
Wurr Rd
Pescadero Rd
Canyon Trail
Camp Pomponio Rd
Tarwater Trail Loop
Tarwater Trail Loop
Bravo Fire Rd
Tarwater Trail Loop Rd
Bear Ridge Trail
Wurr Rd
Old Haul Rd
Old Haul Rd

Map 2b. Road-related and trail-related sites with future sediment delivery by treatment immediacy, Pescadero/Memorial/Sam McDonald County Park Complex, San Mateo County, California



Legend

Road-related sites Treatment immediacy		Trail-related sites Problem type	
S	High/ High Moderate	S	High/ High Moderate
U	Moderate/ Moderate-low	U	Moderate/ Moderate-low
T	Low	T	Low
0	No treatment	0	No treatment

Roads
County roads
Trails
Non-inventoried roads
Streams
Park Boundary

1000 0 1000 2000 Feet

1:24000

N

Prepared by Pacific Watershed Associates 1/19/03

Map 3a. Potential road-related sediment reduction projects by road, groups of roads or management responsibilities, Pescadero /Memorial/Sam McDonald County Park Complex, San Mateo County, California

Legend

Road-related sites
Problem type

- S — Stream crossing
- S — Landslide
- U — Ditch relief culvert
- U — Other
- S — Phase I Old Haul Road sites

Trail-related sites
Problem type

- S — Stream crossing
- T — Landslide
- U — Other

- Roads
- County roads
- Trails
- Non-inventoried roads
- Streams
- Park Boundary

1000 0 1000 2000 Feet

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N

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Ridge Trail Road in Sam McDonald Park (see Table 6)

Towne Fire Roads in Pescadero Park (see Table 6)

Pomponio Trail Road in Memorial Park (see Table 6)

Ridge Trail Rd
Pescadero Rd
Ridge Fire Rd
Pescadero Rd
Pescadero Rd
Alpine Rd
Big Tree Trail
Towne Fire Rd
Alpine Rd
Pescadero Rd
Brook Trail
Towne Fire Rd
Pomponio Trail
Towne Fire Rd
Canyon Trail
Camp Pomponio Rd
Tarwater Trail Loop
Pomponio Trail Rd
Wurr Rd
Pescadero Rd
Bravo Fire Rd
Tarwater Trail Loop
Bear Ridge Trail
Tarwater Trail Loop Rd
Wurr Rd
Old Haul Rd
Old Haul Rd

Map 3b. Potential road-related sediment reduction projects by road, groups of roads or management responsibilities, Pescadero /Memorial/ Sam McDonald County Park Complex, San Mateo County, California

Pomponio Trail
Towne Fire Rd
Towne Fire Rd
Camp Pomponio Rd
Wurr Rd
Canyon Trail
Tarwater Trail Loop
Tarwater Trail Loop
Bravo Fire Rd
Bear Ridge Trail
Tarwater Trail Loop Rd
Old Haul Rd
Old Haul Rd
Butano Trail Loop
Camp Pomponio Rd
Tarwater Creek/ Bridge Trail Road in Pescadero Park (see Table 6)
Portola Redwood State Park Rds
Butano Ridge Rd
Sheriff Honor Camp Roads in Pescadero Park (see Table 6)
Bear Ridge Trail
Old Haul Rd
Old Haul Rd
Butano Trail Loop
Portola Trail
Butano Ridge Rd
Slate Creek Rd

Legend

Road-related sites Problem type		Trail-related sites Problem type	
S	Stream crossing	S	Stream crossing
T	Landslide	T	Landslide
U	Ditch relief culvert	U	Other
U	Other		
S	Phase I Old Haul Road sites		

Roads
County roads
Trails
Non-inventoried roads
Streams
Park Boundary

1000 0 1000 2000 Feet

1:24000

N

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