Summary Report
1998 S. B. 271 Watershed Assessment
within Mill Creek, Tributary to the Navarro River

prepared by
Pacific Watershed Associates

for
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Mendocino County Resource Conservation District, and the
California Department of Fish and Game

Background

Mill Creek is an important anadromous fish bearing third order tributary to the Navarro River basin in Mendocino County. The basin is approximately 12 mi^2 with the confluence of Mill Creek and the Navarro River located approximately 4 miles downstream from the town of Philo (Figure 1). Three tributaries, Hungry Hollow Creek, Little Mill Creek, and Meyer Gulch within the Mill Creek watershed are known to have or be capable of sustaining populations of anadromous salmonids including coho salmon and steelhead trout. There is a high abundance of steelhead trout in Mill Creek, but lack of pool habitat and large amounts of fine sediment have limited the presence of and rearing habitat for coho salmon (NWRP, 1998).

Initial timber harvesting in the lowland areas of the Mill Creek watershed occurred early in this century with the construction of a rail line along the mainstem of Hungry Hollow Creek. Timber harvesting and livestock grazing (first by sheep and then by cattle) were the predominant land uses during the recent historical period from the 1940's to the 1970's. There are approximately 130 landowners in the Mill Creek watershed. Currently, the dominant land uses in the watershed are rural residential, small orchards or vineyards, and limited grazing (primarily sheep). A few landowners have continued some timber harvesting activities that involve selective thinning.

In the summer of 1998, funding was secured through the California Department of Fish and Game Senate Bill 271 Proposal process for the Mendocino County Resource Conservation District and Daniel T. Sicular to develop an erosion control and prevention plan of action for a portion of the Mill Creek watershed. The grant is administered by the Mendocino County Resource Conservation District (MCRCD), with Daniel Sicular serving as the Contractor's Representative. Pacific Watershed Associates (PWA) was retained as a sub-contractor by Daniel Sicular to conduct the upland sediment source assessment and develop an implementation plan for controlling erosion and sediment yield to Mill Creek and its tributaries. The assessment area included all the primary routes maintained by 4 separate landowner/road association groups. These are the 1) Bates ownership, 2) Hungry Hollow Road Association, 3) Holmes Ranch Road Association, and 4) Nash-Mill Road Association). The goal of the assessment is to lessen road related impacts on Mill Creek and ultimately improve the habitat for coho populations.

This summary report describes the watershed assessment and inventory process, as well as serves as a plan-of-action for erosion control and erosion prevention treatments for the entire assessment area

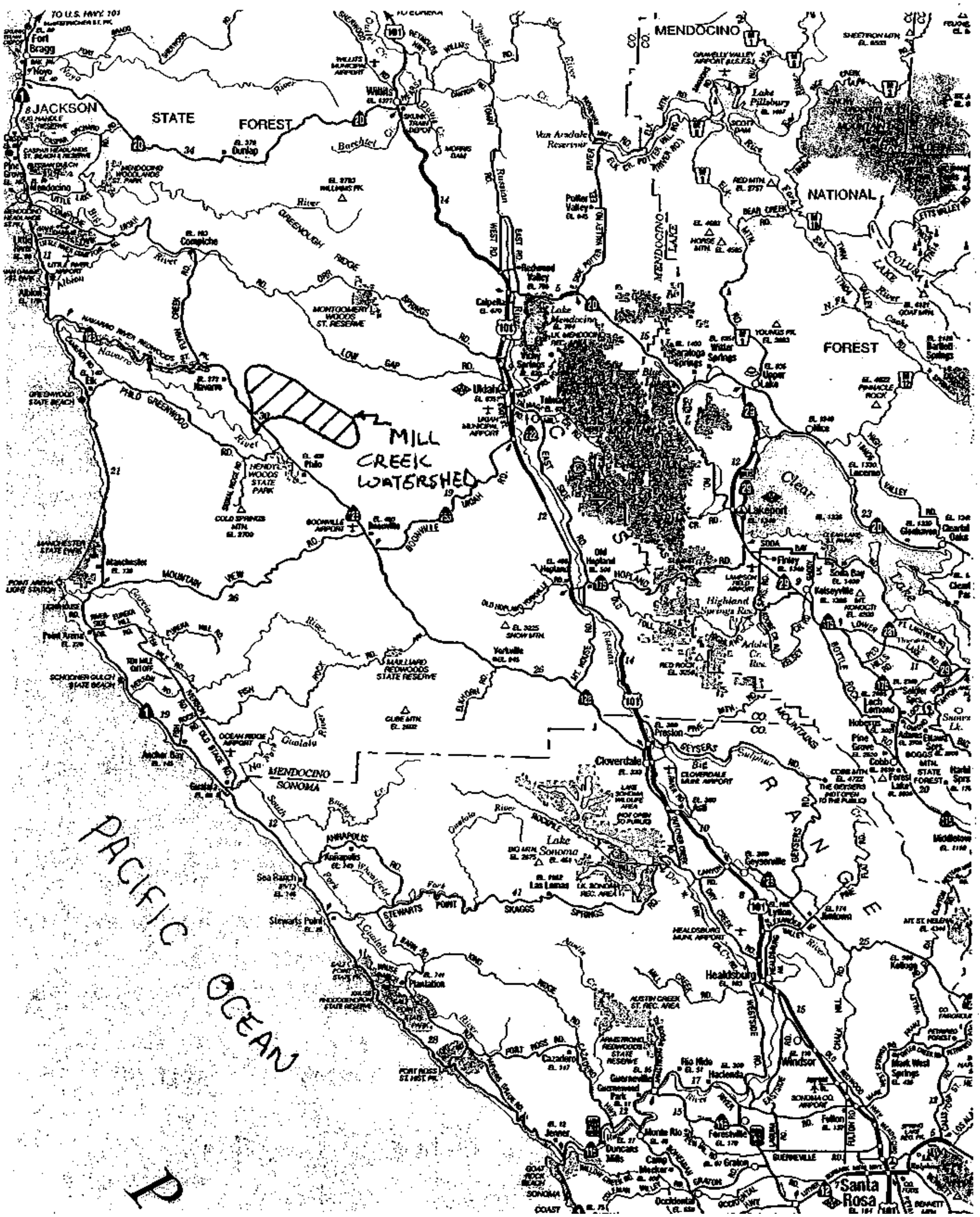

Figure 1. Location map of Mill Creek watershed, Navarro River basin identifying portions of the watershed inventoried for future sediment sources in 1998.

in the Mill Creek watershed. Separate assessments and implementation plans are also provided in Appendix A through D for each of the 4 landowners/road associations. Based on the leadership provided by the three road associations and Mr. Bates to permit this first phase of assessment, additions areas of the Mill Creek have now also received watershed assessment funding from the California Department of Fish and Game and will be inventoried this fall and winter.

Project Description

In the first phase of the Mill Creek inventory project all roads within the study area were identified and age dated from historic aerial photography. Aerial photographs were analyzed to identify the location and approximate date of road construction. Each road identified was mapped on mylar overlays on the most recent aerial photos. A composite map of the road system in Mill Creek was drafted and served as the base map for locating sites. The base map, used in combination with the aerial photos, shows the primary road network managed by the 4 landowners/road associations in the watershed and shows the location of sites with future erosion and sediment delivery to the stream system.

The second phase of the project involved a complete inventory of the road systems, as well as selected hillslope areas. Each road was walked by experienced PWA staff and all existing and potential erosion sites were classified as either sediment delivery sites or as maintenance sites (where there is no future sediment yield to streams but if left untreated the sites could affect the road integrity). 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. For each identified existing or potential erosion source, a database form was filled out and the site was mapped on a mylar overlay over a 1:12,000 scale aerial photograph. 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 sediment yield site. All sites were assigned a treatment priority, based on either their potential to deliver sediment to stream channels in the watershed or their potential to affect the road integrity.

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 one or more cross sections. The survey data was entered into a computer program that computed the volume of fill contained in each stream crossing and allowed for accurate and repeatable volume estimates to be made for a variety of possible erosion prevention treatments (culvert installation, culvert replacement, complete excavation, etc.).

Inventory Results

Approximately 29 miles of road were inventoried within the 12 mi^2 assessment area in the Mill Creek watershed. Only roads managed and maintained by the Holmes Ranch Road Association, Nash-Mill Road Association, Hungry Hollow Road Association and the Bates land ownership were inventoried in this 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	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.I.S.		
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:							

Most of the roads in this assessment were built between the 1930's and 1960's for timber and grazing activities. Most of the road routes inventoried have been constructed on weak and low strength marine sandstones and shales of the Coastal Belt of the Franciscan Complex bedrock. The road beds are very prone to mechanical breakdown, rutting, rilling and gullying in the presence of the very high year around use levels. At the time of the inventory, the majority of roads assessed were open and maintained routes with few abandoned sections. Virtually all the routes have the same road drainage approach (i.e., crowned, flat or mostly insloped road bed with inboard ditches and grader berms). In the majority of these cases, the prescribed treatments have focused on road upgrading to provide low maintenance and long term life of the road network. There are a few short routes managed by the Nash-Mill Road Association that have been recommended for temporary or permanent closure.

Inventoried sites fell into one of three types: 1) ***upgrade -*** defined as sites on maintained open roads with future sediment delivery to a stream channel, 2) ***decomission -*** defined as sites with future sediment delivery that are recommended for permanent hydrological closure and 3) ***maintenance -*** defined as sites that do not have future sediment delivery but if left untreated will affect the road integrity. Past and potential erosion sites that did not deliver, or would not deliver eroded sediment to a stream channel or seriously affect the condition of the road were not inventoried as sites for this assessment. They may represent potential sources of erosion, but they do not represent a threat to water quality, fisheries resources or the road integrity.

Virtually all future erosion and road-related sediment yield in the Mill Creek watershed is expected to come from five sources: 1) the failure of road and landing fills (landsliding), 2) large deep seated landslides, 3) erosion at (or associated with) stream crossings (from several possible causes), 4) gully erosion on hillslopes below ditch relief culverts and 5) road surface and ditch erosion. The latter source of sediment (road and ditch erosion and subsequent sediment delivery) is defined by the length of road and ditch currently contributing runoff and fine sediment to stream channels.

The erosion potential (and potential for sediment delivery) was estimated for each major problem site or potential problem site. Estimates of future expected volume of sediment to be eroded and the volume 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.

A total of 124 sites were identified with potential to deliver sediment to streams. Of these, 121 sites were recommended for erosion control and erosion prevention treatment. Approximately 61% (n=75) of the sites are classified as stream crossings, 7% (n=9) as road surface problems and 7% (n=8) as potential landslides (Table 1 and Map 1). The remaining 25% of the inventoried sites consist of ditch relief culverts and gullies. An additional 39 sites were identified as maintenance sites where there was no sediment delivery but chronic road surface drainage problems will affect the long term condition of the road.

Landslides - Only those landslide sites with a potential for sediment delivery to a stream channel were inventoried. Potential landslides account for approximately 7% of the inventoried sites in the Mill Creek assessment area (Table 1). The majority of the potential landslide sites (75%) were found along roads and landings where material has been sidecast during earlier construction and now shows signs of instability. Potential landslides currently do not appear to be a large sediment contributor to the Mill Creek watershed. This may be due to the generally old age of most of the roads in the watershed, where past large storms have triggered failures at most of the locations where the road was poorly located or where spoil had been placed in inappropriate places. 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.

Table 1. Site classification and sediment yield from all inventoried sites with future sediment delivery in the Mill Creek watershed assessment area, Mendocino County, California .

Site Type	Number of sites or road miles	Number of sites or road miles to treat	Future yield (yds^3)	Stream crossings w/ a diversion potential (#)	Streams currently diverted (#)	Stream culverts likely to plug (plug potential rating = high or moderate)
Landslides	8	7	3,908	NA	NA	NA
Stream crossings	75	75	28,255	49	14	28
Road surface	9	9	292	NA	NA	NA
Other	32	30	729	NA	NA	NA
Total (all sites)	124	121	33,184	49	14	28
Persistent surface erosion[1]	18.04	18.04	20,691	NA	NA	NA
Totals	**124**	**121**	**53,875**	**49**	**14**	28

[1] Assumes 25' wide road prism on Bates property and 30' wide road prism and cutbank contributing area on the other three Road Associations, and 0.2' of road/cutbank surface lowering per decade.

There are a number of potential landslide sites located in the Mill Creek assessment area that did not, or will not deliver sediment to streams. These sites were not inventoried using data sheets due to the lack of delivery to a stream channel. They are generally shallow failures, or located far enough away from an active stream such that delivery is unlikely to occur. For reference, the sites determined to have no sediment delivery potential were mapped on the mylar overlays of the aerial photographs.

Stream crossings - Seventy-five stream crossings were inventoried in the Mill Creek assessment area including 52 culverted crossings, 19 unculverted fill crossings, 3 fords and 1 Humboldt log crossing. An unculverted fill crossing refers to a stream crossing with no drainage structure to carry the flow through the road prism . Flow is either carried beneath or through the fill, or it flows over the fillslope, 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. If logs were intentionally placed in the axis of the channel at or near the base of the fill to convey flow beneath the road, then these crossings are commonly known as “Humboldt” or log crossings.

Approximately 28,255 yds^3 of future road-related sediment yield in the Mill Creek assessment area is expected to originate from stream crossings (Table 1). This amounts to nearly 52% of the total sediment yield from the road system. The most common mechanisms of erosion at stream crossings include crossings with undersized culverts, culverts that are likely to plug frequently, stream crossings with a diversion potential and collapsing Humboldt crossings. The sediment delivery from stream crossing sites is always classified as 100% because any sediment introduced to even small ephemeral streams will eventually be delivered 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 too small for the drainage area) 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. 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. These hillslope gullies can be quite large and can deliver significant quantities of sediment to stream channels. Of the 75 stream crossings inventoried, 49 have the potential to divert in the future and 14 stream crossings are currently diverted (Table 1).

Three road design conditions indicate a high potential for future erosion at stream crossings. These include 1) undersized culverts (the culvert is too small for the 50 year design storm flow), 2) culverts that are prone to plugging with sediment or organic debris and 3) stream crossings with a diversion potential. The worst scenario is for the culvert to plug and the stream crossing to wash out or the stream to divert down the road in a major storm.

The majority of the stream crossings on the roads inventoried in the Mill Creek assessment area will need to be upgraded. For example, 53% of the existing culverts had a moderate to high plugging potential and nearly 65% of the stream crossings exhibit a diversion potential (Table 1). Because the roads were constructed many years ago, many culverted stream crossings are under designed for the 50 year storm flow. At stream crossings with undersized culverts or where there was 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 50 year storm flow, 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 debris barriers and/or downspouts to prevent culvert plugging and outlet erosion, respectively.

Road Surface and "Other"sites - A total of 9 road surface and 32 "other" sites were identified in the Mill Creek assessment area. The main cause of existing or future erosion at these sites is long sections of uncontrolled flow along the road surface and ditch . Uncontrolled flow along the road or ditch may affect the road bed integrity as well as cause gully erosion on the hillslopes below ditch relief culverts. It is also a major source of fine sediment input to nearby stream channels. In general, 18 miles of roads in the assessment area (62% of the total mileage of roads inventoried) deliver ditch and road sediment and runoff to stream channels in Mill Creek. Although at first glance fine sediment contributions from the roads may seem an unimportant sediment source relative to stream crossings and landslides, it can affect the recovery of fish-bearing streams.

We estimate 1,021 yds^3 of sediment will be delivered to streams from the 41 "road surface" and "other" specific sites inventoried (Table 1). From the 18 miles of road, we calculated an additional 20,691 yds^3 of sediment will be delivered to stream channels in the Mill Creek watershed over the next 10 years if no efforts are made to change road drainage practices. Current road drainage practices in the assessment area are responsible for nearly 40% of the expected future erosion and sediment delivery (Table 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 slides and brushing practices, 2) inboard ditch erosion and sediment transport, 3) mechanically pulverizing and wearing down the road surface during dry periods due to high amounts of vehicular use, and 4) erosion of the road surface during wet weather periods where every vehicle pass entrains sediment which is transported to nearby streams.

Relatively easy treatments can be applied to upgrade road systems to prevent fine sediment from entering stream channels. These include installing a series or combination of road surface treatments such as rolling dips, outsloping, and/or additional ditch relief culverts to disperse runoff and hydrologically disconnect the roads from the stream network.

Treatment Priority

An erosion inventory is intended to provide information which can guide long range transportation planning, as well as identify and prioritize erosion prevention, erosion control and road decomissioning activities in the watershed. As a result, not all of the sites that have been recommended for treatment have the same priority, and some are more cost effective than others to treat. 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,
2) the potential for future erosion (high, moderate, low),
3) the "urgency" of treating the site (treatment immediacy),
4) the ease and cost of accessing the site for treatments, and
5) recommended treatments, logistics and costs.

The likelihood of erosion (erosion potential) and the volume of sediment expected to enter stream channels from future erosion (sediment delivery) at each site play a significant roles in determining its treatment priority. 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. The ***erosion potential*** of a site is a professional evaluation of the likelihood that future erosion will occur during a storm with a greater than 25 year peak flow return interval. Erosion potential was evaluated for each site, and expressed as "High", "Moderate" or "Low". Erosion potential is an estimate of the potential for additional erosion, based on local site conditions and field observations. Thus, it is employed as a subjective probability estimate, and not an estimate of how much erosion is likely to occur.

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 the severity or urgency of the threat 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 $\$4/yds^3$ ($\$2000/500yds^3$).

To be considered for a priority treatment a site should typically exhibit: 1) potential for significant (>25-50 yds^3) 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 \$5 to \$15/yds^3, or less. 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 or projects are undertaken. During road decomissioning, groups of sites are usually considered together since there will only be one opportunity to treat potential sediment sources along the road.

Cost-effectiveness can be used as a tool to prioritize potential treatment sites throughout a sub-watershed (Weaver and Sonnevil, 1984; Weaver and Hagans, 1999). It assures that the greatest benefit is receive 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 (>\$15/yds^3), or are judged to have a lower erosion potential or treatment immediacy, or low sediment delivery rates, 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
Forest roads can be erosion-proofed by one of two methods: upgrading or decommissioning. Upgraded roads are kept open and are inspected and maintained. Their drainage facilities and fills are designed or treated to accommodate or withstand the 50-year storm. In contrast, properly decommissioned roads are closed and no longer require maintenance. Generic treatments for decommissioning roads and landings range from 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. All proposed treatments conform to accepted guidelines spelled out in the "Handbook for Forest and Ranch Roads" (PWA, 1994).

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 50-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. The 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. The majority of roads in the Mill Creek assessment area are recommended for upgrading.

Along some low strength road routes, such as those in the Mill Creek watershed, re-rocking the road following rolling dip construction and road outsloping or insloping efforts 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 should be applied at all newly constructed rolling dips.

General heavy equipment treatments for ***road decommissioning*** or closure are newer and less well published, but the basic techniques have been tested, described and evaluated. Decommissioning essentially involves "reverse road construction," except that full topographic obliteration of the road bed is not normally required to accomplish sediment prevention goals. In order to protect the aquatic ecosystem, the goal is to "hydrologically" close the road; that is, to minimize the adverse effect of the road on natural hillslope processes and watershed hydrology.

Treatments

Basic treatments priorities and prescriptions were formulated concurrent with the identification, description and mapping of potential sources of road-related sediment yield and road maintenance sites with no potential sediment delivery. Table 2 and Map 2 outline the treatment priorities for all 121 inventoried sites with future sediment delivery that are recommended for treatment and the 39 maintenance sites with no future sediment delivery in the Mill Creek assessment area. Of the 121 sites with future sediment delivery, 39 sites were identified as having a high or high-moderate treatment immediacy with a potential sediment delivery of approximately 20,200 yds^3. Sixty sites were listed with a moderate or moderate-low treatment immediacy and account for nearly 8,660 yds^3. Finally, 22 sites were listed as having a low treatment immediacy and approximately 3,530 yds^3 of future sediment delivery. The 39 inventoried maintenance sites with no future sediment delivery were assigned the following treatment immediacies: 1 high-moderate, 9 moderate or moderate- low and 29 low.

Table 3 summarizes the proposed treatments for sites inventoried on all roads in the Mill Creek assessment area. These prescriptions include both upgrading, road closure and maintenance 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, flaired inlets or culvert repairs, trash racks or for applying seed, plants and mulch following ground disturbance activities. It is estimated that erosion prevention work will require the excavation of approximately 11,545 yds^3 at 45 sites. Approximately 70% of the proposed volume to excavate is associated with upgrading stream crossings and nearly 25% of the volume is proposed for excavating potentially unstable road fills (landslides).

Finally, long lengths of road are proposed to be converted from insloped, flat or crowned shapes to outsloped road routes, along some of which we will retain the ditch (Table 3). We have recommended 357 rolling dips be constructed at selected locations along the road, at different spacing, depending on the steepness of the road. Re-rocking of the rolling dips post construction will require 3,643 yd^3 of rock. A minimum of 110 new ditch relief culverts are recommended to be installed along the road routes inventoried. Some proposed rolling dips can be replaced with additional ditch relief culverts, but this will increase costs at each dip by 125%.

Table 2. Treatment priorities for all inventoried sediment sources in the Mill Creek watershed assessment area, Mendocino County,California						
Treatment Priority	Upgrade sites (#)	Decommission sites (#)	Upgrade/ Decom. Problem	Future sediment delivery (yds^3)	Maintenance sites (#)	Maintenance problems
High	**16** (site #: 2, 4, 28, 33, 37, 44, 46, 49, 62, 65, 76, 80.1, 87, 103, 121, 134)	**0**	2 landslides, 2 ditch relief culverts, 12 stream crossings	14,989	**0**	
Moderate High	**23** (site #:10, 16, 17, 25, 26, 35, 39, 42, 47, 48, 58, 59, 60, 80, 81, 85, 99, 100, 102, 117, 142, 145, 151)	**1** (site #:100)	2 landslides, 1 gully, 2 road surface, 2 ditch relief culverts, 16 stream crossings	5,208	**1** (site #: 114)	1 other misc. site
Moderate	**40** (site #:1, 3, 6, 9, 11, 15, 27, 36, 38, 43, 45, 53, 54, 56, 61, 64, 67, 68, 72, 73, 74, 75, 77, 78, 90, 101, 119, 126, 128, 134.1, 135, 136, 138, 139, 140, 149, 150, 152, 153, 162)	**0**	1 landslide, 6 gullies, 5 ditch relief culverts, 3 road surface, 25 stream crossings	7,060	**4** (site #: 8, 18, 20, 122)	2 ditch relief culvert, 1 gully, 1 road surface
Moderate Low	**20** (site #: 29, 30, 34, 38.1, 50, 51, 57, 70, 81.1, 84, 86, 89, 97, 118, 123, 127, 132, 137, 148, 161)	**0**	3 road surface, 7 ditch relief culverts, 10 stream crossings	1,598	**5** (site#: 23, 32, 66, 104, 141)	3 ditch relief culvert, 2 road surface
Low	**22** (site #:29.1, 40, 41, 82, 96, 106, 107, 108, 109, 110, 111, 112, 113, 116, 120, 125, 129, 143, 144, 146, 156, 157)	**0**	2 landslides, 1 gully, 2 road surface, 5 ditch relief culverts, 12 stream crossings	3,527	**29** (site #: 7, 12, 13, 14, 19, 21, 22, 24, 31, 52, 55, 71, 88, 91, 92, 93, 94, 95, 98, 105, 124, 130, 131, 133, 146.1, 147, 155, 158, 160)	10 ditch relief culvert, 19 road surface
Total	**121**	**1**		**32,382**	**39**	

Table 3. Recommended treatments along all inventoried roads in the Mill Creek watershed assessment area, Mendocino County, California.

Treatment	No.	Comment	Treatment	No.	Comment
Critical dip	38	To prevent stream diversions	Outslope road & fill ditch	103	Outslope 76,653 feet of road to improve road surface drainage (19 maintenance sites for 18, 087')
Install CMP[1]	17	Install a CMP at an unculverted fill	Outslope road & retain ditch	10	Outslope 6,419 feet of road & retain ditch to improve road surface drainage (6 maintenance sites for 3, 234')
Replace CMP[1]	32	Upgrade an undersized CMP	Inslope road	7	Inslope 1,855 feet of road to improve road surface drainage (1 maintenance site for 100')
Excavate soil	45	Typically fillslope & xing excavations; excavate a total of 11,545 yds^3	Install rolling dips	357	Install rolling dips to improve road drainage (131 rolling dips for maintenance sites)
Down spouts	13	Installed to protect the outlet fillslope from erosion (1 maintenance site)	Remove ditch	2	Remove 550 feet of inboard ditch (1 maintenance site for 300')
Wet crossing	13	Install 1 rocked ford and 12 armored fill crossings (127 yd^3 rip-rap sized rock)	Clean ditch	5	Clean 930 feet of ditch (1 maintenance site for 100')
Install bridge	1	Install bridge where stream is large and culvert or wet crossing is not feasible	Remove berm	26	Remove 20,514 feet of berm to improve road surface drainage (9 maintenance sites for 10,117')
Install trash rack	3	Installed to prevent culvert from plugging	Install ditch relief CMP[1]	110	Install ditch relief culverts to improve road surface drainage[2] (27 maintenance sites)
Clean CMP	8	Remove debris and/or sediment from CMP inlet (3 maintenance sites)	Rock road surface	414	Rock road surface using 3,643 yd^3 using road rock (1,310 yd^3 for maintenance sites)
Armor fill face	3	Rock armor to protect outboard fillslope from erosion using 40 yds^3 of rock	Other	1	Miscellaneous treatments
Install flared inlet	8	Installed to increase CMP capacity	No recom-mendation	7	No treat sites

[1] Culvert replacement and ditch relief installation requires placement of the following culvert sizes and lengths including couplers and flared inlets, where prescribed: 1) 4040' of 18" diameter pipe, 2) 1440' of 24" diameter pipe, 3) 600' of 30" diameter pipe, 4) 160' of 36" diameter pipe, 5) 140' of 42" diameter pipe, 5) 260' of 48" diameter pipe, 6) 220' of 60" diameter pipe and 7) 160' of 72" diameter pipe.

[2] Additional ditch relief culverts (DRC) can be substituted for rolling dips. Each additional DRC will increase costs by 125% (i.e. more than double the costs).

Equipment needs and costs

Treatments for the 121 sites identified with future sediment delivery in the Mill Creek assessment area will require approximately 658 hours of excavator time and 802 hours of tractor time to complete all prescribed upgrading, road closure, erosion control and erosion prevention work (Table 4 and Map 2). 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 16 hours of dump truck time has been listed for work in the basin for endhauling excavated spoil from stream crossings and unstable road and landing fill where local disposal sites are not available. Nearly 147 hours of grader time is necessary to apply road surface treatments including outsloping and insloping. Finally, approximately 387 hours of labor time is needed for a variety of tasks such as installation or replacement of culverts, installation of debris barriers and downspouts, and 227 hours are for seeding, mulching and planting activities..

Table 4. Estimated heavy equipment and labor requirements for treatment of all inventoried sites with future sediment delivery, Mill Creek watershed assessment area, Mendocino County, California.

Treatment Immediacy	Site (#)	Excavated Volume (yds^3)	Excavator (hrs)	Tractor (hrs)	Dump Trucks (hrs)	Grader (hrs)	Backhoe (hrs)	Labor (hrs)
High, High/Moderate	39	10,116	330	388	6	48	4	141
Moderate, Low/Moderate	60	1,074	272	383	8	82	6	194
Low	22	355	56	31	2	17	3	52
Total	**121**	**11,545**	**658**	**802**	**16**	**147**	**13**	**387**

Table 5 summarizes the equipment hours necessary to treat the 39 maintenance sites with no future sediment delivery in the Mill Creek assessment area. It is expected that approximately 81 hours of excavator will be required for installation of ditch relief culverts and 131 hours of tractor time to install rolling dips (tractor time can be switched to backhoe/excavator time if additional ditch relief culverts are preferable to rolling dips). Approximately 65 hours of grader time is necessary to apply various road surface treatments such as outsloping, insloping, removing the berm, cleaning the ditch, etc. Approximately 5 hours of backhoe time is necessary to clean ditch relief culvert inlets. In addition, 83 hours of labor time is necessary to aid with installation of ditch relief culverts.

<u>Estimated costs for erosion prevention treatments</u> - Prescribed treatments were divided into two categories: a) site specific erosion prevention work identified during the watershed inventories at sites with future sediment delivery, and b) site specific erosion prevention maintenance work at sites with no future sediment delivery to control road surface, ditch and cutbank erosion and its impact on

Table 5. Estimated heavy equipment and labor requirements for treatment of all inventoried maintenance sites, Mill Creek watershed, Mendocino County, California.						
Treatment Immediacy	Site (#)	Excavator (hrs)	Tractor (hrs)	Grader (hrs)	Backhoe (hrs)	Labor (hrs)
High, High/Moderate	1	3	2	3	0	3
Moderate, Low/Moderate	9	18	18	15	0	20
Low	29	60	111	47	5	60
Total	**39**	**81**	**131**	**65**	**5**	**83**

the road network. The total costs for road related erosion control at sites with sediment delivery is estimated at approximately $ 419,346. for an average cost-effectiveness value of approximately $7.78 per cubic yard of sediment prevented from entering Mill Creek and its tributaries (Table 6). **(Note: costs to re-rock the whole road system following implementing the proposed storm proofing activities are not included in this table. Costs are not included for purchasing/constructing the 1 proposed bridge)**. The total costs for treating maintenance sites with no future delivery is figured at nearly $70,552. (Table 7).

<u>*Overall site specific erosion prevention work:*</u> Equipment needs for site specific erosion prevention work at both sites with future sediment delivery and maintenance sites are expressed in the database, and summarized in Tables 4 and 5, as direct excavation times, in hours, to treat all sites in the basin which have a high, moderate, or low treatment immediacy. These hourly estimates include <u>only</u> the time needed to treat each of the sites, and do not include travel time between work sites, the time needed to reconstruct or clear roads which have been abandoned, 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 Tables 6 and 7. Costs in Tables 6 and 7 assume that the work in this watershed is accomplished during two summer work period, employing two equipment teams. This minimizes moving and transport costs for equipment and personnel.

The costs in Tables 6 and 7 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 majority of treatments listed in this plan are not complex or difficult for equipment operators experienced in road maintenance and road building operations on forest lands.

Table 6 and 7 list a total of 760 and 100 hours, respectively for "supervision" time for detailed pre-work layout, project planning (coordinating and securing equipment and obtaining plant and mulch materials), on-site equipment operator instruction and supervision, 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.

Conclusion

The expected benefit of completing the erosion control and prevention planning work lies in the reduction of long term sediment delivery to Mill Creek, an important salmonid stream in the Navarro River watershed. An important first phase of inventory work has been completed in the lower Mill Creek watershed. While the extent of potential future sediment yield is moderately high within the subdivisions which have been inventoried, we have no idea of what potential risks exist in the remainder of the Mill Creek watershed.

With this prioritized plan of action, the various road associations and landowners can work with the Mendocino County RCD to obtain potential funding to implement the proposed projects. However, watershed assessment inventories should be conducted on upland roads, both driveable and abandoned, in the remainder of the Mill Creek watershed. This will permit us to continue to refine the prioritization of which sites throughout the watershed pose the most critical threats to salmonid recovery, as well as allow us to know we are spending the limited available funds on the highest priority work sites in the watershed.

Table 6. Estimated logistic requirements and costs for road-related erosion control and erosion prevention work on all inventoried sites with future sediment delivery in the Mill Creek watershed, Mendocino County, California

Cost Category[1]		Cost Rate[2] ($/hr)	Estimated Project Times			Total Estim. Costs[5] ($)
			Treatment[3] (hours)	Logistics[4] (hours)	Total (hours)	
Move-in; move-out[6] (Low Boy expenses)		70	40	--	40	2,800
Heavy Equipment	Excavator	115	658	197	855	98,325
	D-5 size tractor	85	802	241	1043	88,655
	Dump Truck	60	16	5	21	1,260
	Grader	85	147	44	191	16,235
	Backhoe	65	13	4	17	1,105
Laborers		20	614	184	798	15,960
Rock costs: (includes trucking for 2,333 yds^3 of road rock and 170 yds^3 rip-rap sized rock)						42,500
Culvert materials costs: (see Table 3 for list of culvert sizes, includes bands)						90,006
Mulch, seed and planting materials						24,500
Layout, Coordination, Supervision, and Reporting[7]		50	--	--	760	38,000
Total Estimated Costs						**$ 419,346.**
Cost-effectiveness: $ 7.78 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, five hours round trip for each ownership or road association area. Costs assume 2 hauls for two pieces of equipment to the Mill Creek watershed (one to move in and one to move out).

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

Table 7. Estimated logistic requirements and costs for road-related erosion control and erosion prevention work on all inventoried maintenance sites in the Mill Creek watershed, Mendocino County, California.

Cost Category[1]		Cost Rate[2] ($/hr)	Estimated Project Times			Total Estim. Costs[5] ($)
			Treatment[3] (hours)	Logistics[4] (hours)	Total (hours)	
Move-in; move-out[6] (Low Boy expenses)		70	--	--	--	--
Heavy Equipment	Excavator	115	81	24	105	12,075
	D-5 size tractor	85	131	39	170	14,450
	Grader	85	65	20	85	7,225
	Backhoe	65	5	2	7	455
Laborers		20	83	25	108	2,160
Rock Costs (includes trucking for 1310 yds³ of road rock)						21,670
Culvert materials costs: (see Table 3 for list of culvert sizes, includes bands)						7,517
Layout, Coordination, Supervision, and Reporting[7]		50	--	--	100	5,000
Total Estimated Costs						**$ 70,552.**

[1]Costs for tools, for mulching and related materials (grass seed, fertilizer and straw), and for plant 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 is accounted for in cost estimate table for upgrade sites with future sediment delivery.

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

APPENDIX A

Inventory results, erosion control and erosion prevention plan for roads managed by the Bates ownership

The Bates ownership manages approximately 3.1 miles of road within the Mill Creek watershed. The Bates roads are mostly located along the middle section of Little Mill Creek. PWA personnel inventoried all of these roads for potential sediment delivery to the main stem and its tributaries, and to determine maintenance reaches of road and sites that would adversely affect the condition of the road, but not deliver sediment to streams.

Sites with either future sediment delivery or which are maintenance sites were inventoried using a PWA data form (Figure 2 and Map 1). Table 8 displays the distribution of site types mapped during the sediment source investigation. Two potential landslides which pose a risk of delivering sediment to streams were identified along the Bates roads. Every stream crossing was inventoried and described in detail for all Class I, II or III watercourses. Stream crossings are sensitive areas since they represent the greatest opportunity for sediment to be introduced into stream channels. Regardless of the size of the stream, once sediment is introduced to a stream it will eventually be transported downstream to a fish bearing stream and ultimately impact fish habitat.

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 gullies, ditch relief culverts, swales or springs that have the potential to deliver sediment to a stream channel. Finally, maintenance sites were inventoried where there is no sediment delivery but where chronic road surface drainage problems could affect the long term condition of the road. These sites include long stretches of road surface or ditch that do not deliver sediment to streams or ditch relief culverts that drain long segments of road onto gently sloping to flat hillslopes. All sites were mapped on 1 : 12,000 aerial photo mylar overlays.

A total of 23 sites were identified with a risk of future sediment delivery along roads within the Bates ownership (Table 8). Sites include 15 stream crossings, 2 potential landslides, 4 specific road surface sites and 2 miscellaneous "other" sites. Of the 23 inventoried sites, all have been recommended for erosion prevention treatment. In addition, 2.44 miles (79%) of the 3.1 miles of road managed by the Bates ownership currently deliver sediment and runoff to streams. Finally, 5 sites were identified as maintenance reaches of road (non-sediment delivery sites).

Landslides - Potential road-related landslides identified during the road inventory were divided into cutbank failures, landing fill failures, road fill failures, deep seated failures and others. Of the 2 identified sites of future road-related mass wasting, both are potential road fill failures. Left untreated, road-related landslides are expected to deliver approximately 85 yds^3 to the stream system.

Stream crossings - Fifteen stream crossings were identified in the field with 5 culverted fill crossings, 9 unculverted fill crossings and 1 ford crossing. Total future erosion and sediment yield from stream crossing sites is approximately 1,274 yds^3 if erosion prevention measures are not undertaken.

Table 8. Site classification and sediment yield from inventoried sites with future sediment delivery in the Bates ownership, Mill Creek watershed, Mendocino County, California .						
Site Type	Number of sites or road miles	Number of sites or road miles to treat	Future yield (yds^3)	Stream crossings w/ a diversion potential (#)	Streams currently diverted (#)	Stream culverts likely to plug (plug potential rating = high or moderate)
Landslides	2	2	85	NA	NA	NA
Stream crossings	15	15	1,274	9	2	4
Road surface	4	4	28	NA	NA	NA
Other	2	2	11	NA	NA	NA
Total (all sites)	23	23	1,398	9	2	4
Persistent surface erosion	2.44	2.44	2,386	NA	NA	NA
Totals	**23**	**23**	**3,784**	**9**	**2**	**4**

[1] Assumes a 25' wide road prism and cutbank contributing area, and 0.2' of road/cutbank surface lowering per decade

The most significant problem from stream crossings inventoried on roads in the Bates ownership arise from stream crossings with a diversion potential. Of the 15 crossings inventoried, 9 have a diversion potential and 2 are currently diverted. Treatment for stream diversions is easy and requires installation of a “critical” dip placed at the down-road hinge line of the stream crossing to direct flow back into its natural drainage.

Significant erosion can also occur from undersized culverts and poor culvert installation. Undersized culverts can plug causing flow to overtop the road and cause erosion of the stream crossing fill, or flow can be diverted down the road to create hillslope gullies. Of the 15 culverted stream crossings, 4 have a moderate to high plug potential. Erosion can also occur as a result of poorly installed culverts causing major gully erosion below the outlet. Approximately 34% of the total future sediment yield would result from erosion associated with stream crossing failures.

Road Surface sites and "Other" - Four road surface erosion sites and 2 "other" sites were identified for future sediment yield to stream channels. Road surface sites refer to locations where long sections of road surface runoff have caused gully erosion to the stream system. "Other" sites are mainly ditch relief culverts with gullies below their outlets. Combined, approximately 39 yds^3 of future sediment yield is expected to occur associated with these miscellaneous sites. The road surface and "other" sites represent approximately 1% of the total predicted sediment yield from road-related erosion.

Concentrated road surface runoff can generate fine sediment which can negatively impact general stream health and fish habitat. A total of 2.44 miles of the roadbed, ditch and cutbank currently persistently deliver fine sediment and runoff to stream channels. Cutbank, road bed and ditch erosional processes are predicted to yield nearly 2,386yds^3 (63%) of sediment to nearby streams over the next decade, if road drainage practices remain the same. Relatively easy treatments can be applied to upgrade road systems to prevent material from entering stream channels. These include installing a series or combination of road surface treatments such as rolling dips, outsloping, and/or additional ditch relief culverts to disperse runoff.

Treatment Priority

Table 9 and Map 2 outline the treatment immediacy for all 23 inventoried sites with future sediment delivery as well as the 5 maintenance sites recommended for treatment along roads in the Bates ownership. Altogether, 5 sites were identified as having a high or high-moderate treatment immediacy with a potential sediment delivery of approximately 567 yds^3.

Table 9. Treatment priorities for all inventoried sediment sources in the Bates ownership, Mill Creek watershed, Mendocino County, California

Treatment Immediacy	Upgrade sites (#)	Upgrade Problem	Future sediment delivery (yds^3)	Maintenance sites (#)	Maintenance Problem
High	**2** (site#: 44, 134)	2 stream crossings	158	**0**	
Moderate/ High	**3** (site #: 42, 145, 151)	3 stream crossings	409	**0**	
Moderate	**10** (site #: 43, 134.1, 135, 136, 138, 139, 140, 150, 152, 153)	1 gully, 1 landslide, 2 road surface, 6 stream crossings	566	**0**	
Moderate/ Low	**2** (site #: 137, 161)	1 road surface, 1 stream crossing	56	**0**	
Low	**6** (site #: 40, 41, 144, 146, 156, 157)	1 gully, 1 landslide, 1 road surface, 3 stream crossings	209	**5** (site #: 146.1, 147, 155, 158, 160)	1 ditch relief culvert, 4 road surface
Total	**23**		**1,398**	**5**	

Twelve sites were listed with a moderate or moderate-low treatment immediacy and account for nearly 622 yds^3. Finally, 6 sites were listed as having a low treatment immediacy which could yield approximately 209 yds^3 of future sediment delivery. Five maintenance sites with no future sediment delivery were identified and recommended for erosion control treatment to improve road surface drainage.

Treatments

Table 10 lists the site specific treatments for all inventoried sites recommended for erosion prevention work in the Bates ownership. Recommended erosion prevention work includes

Table 10. Recommended treatments along inventoried roads in the Bates ownership, Mill Creek watershed, Navarro River, Mendocino County, California.

Treatment	No.	Comment	Treatment	No.	Comment
Critical dip	8	To prevent stream diversions	Install flared inlet	3	Installed to increase CMP capacity
Install CMP[1]	7	Install a CMP at an unculverted fill	Install ditch relief culverts[1]	16	Install ditch relief culverts to improve road drainage (3 maintenance related ditch relief culverts)
Replace CMP[1]	4	Upgrade an undersized CMP	Outslope road & fill ditch	15	Outslope 9,616 feet of road to improve road surface drainage (2 maintenance sites for 1000')
Excavate soil	11	Typically fillslope & crossing excavations; excavate a total of 856 yds^3	Install rolling dips[2]	36	Install rolling dips to improve road drainage (6 maintenance rolling dips)
Wet crossing	5	Install armored fill crossings using 55 yds^3 rip-rap sized rock	Remove berm	4	Remove 2,462 feet of berm to improve road surface drainage (1 maintenance site for 760')
Rock road surface	41	Rock road surface using 380 yds^3 rock (includes rocking at all rolling dips)	Other	1	Miscellaneous treatments
Install trash rack	3	Installed to prevent culvert from plugging	No treatment recommended	2	
Armor fill face	1	Rock armor to protect outboard fillslope from erosion using 20 yds^3 of rip-rap sized rock			

[1] Culvert replacement and ditch relief installation requires placement of the following culvert sizes and lengths including couplers and flared inlets, where prescribed: 1) 640' of 18" diameter pipe, 2) 340' of 24" diameter pipe, 3) 120' of 30" diameter pipe and 4) 50' of 42" diameter pipe.

[2] Additional ditch relief culverts (DRC) can be substituted for rolling dips. Each additional DRC will increase costs by 125% (i.e. more than double the costs).

upgrading existing roads located in stable locations and maintaining sections of roads that do not have future sediment delivery but need road surface drainage improvements. Upgrading typically consists of properly installing new culverts designed to accommodate the 50 - 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 or additional ditch relief culverts and/or outsloping the road bed. When rolling dips are constructed, itemized costs include 10 yd^3 of road rock per rolling dip. It is estimated that erosion prevention work will require the excavation of just over 850 yds^3. Approximately 83% of the volume excavated is associated with upgrading stream crossings and nearly 13% of the volume is a result of excavating potentially unstable road fills (landslides).

Other miscellaneous treatments for inventoried sites on roads in the Bates ownership will include culvert replacements and installations, installation of flared inlets and trash racks to protect culvert inlets from plugging, a variety of road surface treatments (such as rolling dips, berm removal and outsloping) and additional ditch relief culverts to lessen erosion and fine sediment delivery from the road surface during wet winter months. Re-rocking the road prism for approximately 100 feet has been prescribed at every rolling dip location. 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 necessary at each site.

Equipment needs

Tables 11 and 12 list the expected heavy equipment and labor requirements by treatment immediacy to treat inventoried sites with future sediment delivery and maintenance sites (i.e., sites with no future sediment delivery to a stream). Costs and heavy equipment requirements for sites with sediment delivery and maintenance sites have been separated since it is assumed that 1) maintenance sites on inventoried roads do not have impacts on water quality and/or fish bearing streams, 2) the work is the responsibility of the individual landowner to fund and 3) the work is not fundable through California Department of Fish and Game S. B. 271 grants.

Table 11. Estimated heavy equipment and labor requirements for treatment of inventoried sites with future sediment delivery in the Bates ownership, Mill Creek watershed, Mendocino County, California.

Treatment Immediacy	Number (#)	Excavated Volume (yds^3)	Excavator (hrs)	Tractor (hrs)	Dump Trucks (hrs)	Grader (hrs)	Labor (hrs)
High, High/Moderate	5	555	38	34	1	8	30
Moderate, Moderate/Low	12	110	42	36	2	10	37
Low	6	191	21	10	2	1	18
Totals	**23**	**856**	**101**	**80**	**5**	**19**	**85**

Treatments for the 23 sites with potential sediment delivery along 3.1 miles of the roads in the Bates ownership will require approximately 101 hours of excavator and 80 hours of tractor time to complete all prescribed upgrading, erosion control and erosion prevention work (Table 11) . Approximately 5 dump truck hours are needed for endhauling excess spoil and importing rock for rocking wet crossings and the road surface in selected locations. Dump truck times for road rocking following construction of rolling dips are included with rock costs. Eighty-five hours of labor is necessary for installing new culverts and other miscellaneous tasks, and 16 hours are for seeding, mulching and planting activities. The remaining equipment hours apply to prescribed road surfacing treatments.

Table 12 lists the expected heavy equipment required to treat maintenance sites with no sediment delivery. Prescribed treatments emphasize various road surface drainage mostly utilizing an excavator, tractor and a grader.

Table 12. Estimated heavy equipment and labor requirements for treatment of inventoried maintenance sites in the Bates ownership, Mill Creek watershed, Mendocino County, California.

Treatment Immediacy	Number (#)	Excavator (hrs)	Tractor (hrs)	Grader (hrs)	Labor (hrs)
High, High/Moderate	0	0	0	0	0
Moderate, Moderate/Low	0	0	0	0	0
Low	5	9	6	3	9
Total	**5**	**9**	**6**	**3**	**9**

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 excavations to prevent future landsliding, as well as at all areas where excess spoil material derived from excavations is disposed of. Where roads are proposed for outsloping or where rolling dips will be constructed, all disturbed areas outside the road prism/bed will also be seeded and mulched. Costs have been included for laborers to seed and mulch approximately 1 acre of ground following heavy equipment work along the **Bates** road system. Weed free straw mulch will be applied at 4000 pounds/acre. Native seeds should be applied at 20 pounds/acre and follow the Circuit Riders Inc. guidelines in the Navarro Watershed Restoration Plan (Entrix, 1998).

Cost estimate for inventoried sites along 3.1 miles of road in the Bates ownership

Tables 13 and 14 summarize the necessary costs by equipment types for the 23 sites with future sediment delivery and 5 maintenance sites with no future delivery, respectively. The estimate includes costs for seed and mulch, new culverts, downspouts, flared inlets, as well as rock necessary for rip rap and road surfacing at rolling dip 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 13 and 14).

Total costs for the project are estimated at approximately $ 53,669. to treat the 23 sites inventoried with future sediment delivery and to significantly reduce sediment yield from the 3.1 miles of road feeding sediment annual to streams. Total costs to improve road drainage at maintenance sites with no future sediment delivery is $ 4,188. The average cost effectiveness value of the project is $ 14.18 per cubic yard of sediment prevented from entering Mill Creek and its tributaries. Costs in Tables 13 and 14 assume that the work in the watershed will be accomplished during a single summer work period using a single equipment teams. **(Note: Costs to re-rock the whole road system following implementing the proposed storm-proofing activities are not included in this table**.)

The cost estimate includes a minimal amount of 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 Tables 13 and 14 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 majority of treatments listed in this plan are not complex or difficult for equipment operators experienced in road maintenance and road building operations on forest lands.

Table 13. Estimated logistic requirements and costs for road-related erosion control and erosion prevention work on inventoried sites with future sediment delivery in the Bates ownership, Mill Creek watershed, Mendocino County, California						
Cost Category[1]		**Cost Rate[2] ($/hr)**	**Estimated Project Times**			**Total Estim. Costs[5] ($)**
			Treatment[3] (hours)	**Logistics[4] (hours)**	**Total (hours)**	
Move-in; move-out[6] (Low Boy expenses)		70	5	--	5	350
Heavy Equipment	Excavator	115	101	30	131	15,065
	D-5 size tractor	85	80	24	104	8,840
	Dump Truck	60	5	2	7	420
	Grader	85	19	6	25	2,125
Laborers		20	101	30	131	2,620
Rock Costs (includes trucking for 320 yds³ of road rock and 75 yds³ of 0.5-1 ft. diameter coarse rock)						6,715
Culvert materials costs (see Table 10 for list of culvert sizes, includes bands)						12,034
Mulch, seed and plant materials for 1 acre of disturbed ground						1,500
Layout, Coordination, Supervision, and Reporting[7]		50	--	--	80	4,000
Total Estimated Costs						**$ 53,669.**
Cost-effectiveness: $ 14.18 spent per cubic yard saved						

[1]Costs for tools, for mulching and related materials (grass seed, fertilizer and straw), and for plant materials have not been included in this table. Costs for administration and contracting are variable and have not been included. Excluding new rolling dips, costs and dump truck time (if needed) for re-rocking the road surface have not been estimated.

[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, five hours round trip. Costs assume 2 hauls for two pieces of equipment to the Mill Creek watershed (one to move in and one to move out).

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

Table 14. Estimated logistic requirements and costs for road-related erosion control and erosion prevention work on inventoried maintenance sites in the Bates ownership, Mill Creek watershed, Mendocino County, California						
Cost Category[1]		**Cost Rate[2] ($/hr)**	**Estimated Project Times**			**Total Estim. Costs[5] ($)**
			Treatment[3] (hours)	**Logistics[4] (hours)**	**Total (hours)**	
Move-in; move-out[6] (Low Boy expenses)		70	--	--	--	--
Heavy Equipment	Excavator	115	9	3	12	1,380
	D-5 size tractor	85	6	2	8	680
	Grader	85	3	1	4	340
Labor		20	9	3	12	240
Rock Costs: (includes trucking for 60 yds[3] of road rock)						420
Culvert costs: (see Table 10 for list of culvert sizes, includes bands)						978
Layout, Coordination, Supervision, and Reporting[7]		50	--	--	3	150
Total Estimated Costs						**$ 4,188.**

[1]Costs for tools, for mulching and related materials (grass seed, fertilizer and straw), and for plant materials have not been included in this table. Costs for administration and contracting are variable and have not been included. Excluding new rolling dips, costs and dump truck time (if needed) for re-rocking the road surface have not been estimated.

[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 is accounted for in cost estimate table for upgrade sites with future sediment delivery.

[7] 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).

APPENDIX B

Draft inventory results, erosion control and erosion prevention plan for roads managed by the Hungry Hollow Road Association

The Hungry Hollow Road Association manages approximately 2.3 miles of road within the Mill Creek watershed. The Hungry Hollow roads are mostly located either to the north and south of the mainstem of Mill Creek. PWA personnel inventoried all of these roads for potential sediment delivery to the main stem and its tributaries, and to determine maintenance reaches of road and sites that would adversely affect the condition of the road, but not deliver sediment to streams.

Sites with either future sediment delivery or which are maintenance sites were inventoried using a PWA data form (Figure 2 and Map 1). Table 15 displays the distribution of site types mapped during the sediment source investigation. No potential landslides which pose a risk of delivering sediment to streams were identified along any of the Hungry Hollow roads. Every stream crossing was inventoried and described in detail for all Class I, II or III watercourses. Stream crossings are sensitive areas since they represent the greatest opportunity for sediment to be introduced into stream channels. Regardless of the size of the stream, once sediment is introduced to a stream it will eventually be transported downstream to a fish bearing stream and ultimately impact fish habitat.

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 gullies, ditch relief culverts, swales or springs that have the potential to deliver sediment to a stream channel. Finally, maintenance sites were inventoried where there is no sediment delivery but where chronic road surface drainage problems could affect the long term condition of the road. These sites include long stretches of road surface or ditch that do not deliver sediment to streams or ditch relief culverts that drain long segments of road onto gently sloping to flat hillslopes. All sites were mapped on 1 : 12,000 aerial photo mylar overlays.

A total of 18 sites were identified with a risk of future sediment delivery along roads within the Hungry Hollow Road Association (Table 15). Sites include 11 stream crossings, 2 specific road surface sites and 5 miscellaneous “other” sites. Of the 18 inventoried sites, 17 have been recommended for erosion prevention treatment. In addition, all 2.3 miles of road managed by the Hungry Hollow Road Association currently deliver sediment and runoff to streams. Finally, 1 site was identified as a maintenance reach of road (non-sediment delivery site).

Stream crossings - Eleven stream crossings were identified in the field with 6 being culverted fill crossings, 2 being unculverted fill crossings, 2 ford crossings and 1 “Humboldt” log crossing. Total future erosion and sediment yield from stream crossing sites is approximately 1,142 yds^3 if erosion prevention measures are not undertaken.

The most significant problem from stream crossings inventoried on roads in the Hungry Hollow Road Association arise from stream crossings with a diversion potential. Of the 11 crossings inventoried, 7 have a diversion potential and 1 is currently diverted. Treatments for stream diversions are easy and require the installation of a “critical” dip placed at the down-road hinge line of the stream crossing to direct flow back into its natural drainage.

Significant erosion can also occur from undersized culverts and poor culvert installation. Undersized culverts can plug causing flow to overtop the road and cause erosion of the stream crossing fill, or flow can be diverted down the road to create hillslope gullies. Of the 6 culverted stream crossings, 5 have a moderate to high plug potential.

Table 15. Site classification and sediment yield from inventoried sites with future sediment delivery on the Hungry Hollow road, Emal ownership, Mill Creek watershed, Mendocino County, California .						
Site Type	Number of sites or road miles	Number of sites or road miles to treat	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	11	11	1,142	7	1	5
Road surface	2	2	138	NA	NA	NA
Other	5	4	115	NA	NA	NA
Total (all sites)	18	17	1,395	7	1	5
Persistent surface erosion	2.3	2.3	2,700	NA	NA	NA
Totals	**18**	**17**	**4,095**	**7**	**1**	**5**
[1] Assumes a 30' wide road prism and cutbank contributing area, and 0.2' of road/cutbank surface lowering per decade						

Erosion can also occur as a result of poorly installed culverts causing major gully erosion below the outlet. Approximately 31% of the total future sediment yield would result from erosion associated with stream crossing failures.

"Other" and Road Surface sites - Two specifc road surface sites and 5 "other" sites were identified for future sediment yield to stream channels. Road surface sites refer to locations where long sections of road surface runoff have caused gully erosion to the stream system."Other" sites are mainly ditch relief culverts with gullies below their outlets. Combined, approximately 39 yds^3 of future sediment yield is expected to occur associated with these miscellaneous sites. The "other" and road surface sites represent approximately 7% of the total predicted sediment yield from road-related erosion.

Concentrated road surface runoff can generate fine sediment which can negatively impact general stream health and fish habitat. A total of 2.3 miles of the roadbed, ditch and cutbank currently persistently deliver fine sediment and runoff to stream channels. Cutbank, road bed and ditch erosional processes are predicted to yield nearly 2,700 yds^3 (66%) of sediment to nearby streams over the next decade, if road drainage practices remain the same. Relatively easy treatments can be applied to upgrade road systems to prevent material from entering stream channels. These include installing a series or combination of road surface treatments such as rolling dips, outsloping, and/or additional ditch relief culverts to disperse runoff.

Treatment Priority
Table 16 and Map 2 outline the treatment immediacy for all 17 inventoried sites with future sediment delivery recommended for erosion prevention treatment as well as the 1 maintenance site along roads in the Hungry Hollow Road Association. Altogether, 6 sites were identified as having a high or high-moderate treatment immediacy with a potential sediment delivery of approximately 782 yds^3. Ten sites were listed with a moderate or moderate-low treatment immediacy and account for nearly 596 yds^3. Finally, 1 site were listed as having a low treatment immediacy which could yield approximately 10 yds^3 of future sediment delivery. One maintenance site with no future sediment delivery was identified and recommended for erosion control treatment to improve road surface drainage.

Treatments
Table 17 lists the site specific treatments for all inventoried sites recommended for erosion prevention work in the Hungry Hollow Road Association. Recommended erosion prevention work includes upgrading existing roads located in stable locations and maintaining sections of roads that do not have future sediment delivery but need road surface drainage improvements. Upgrading typically consists of properly installing new culverts designed to accommodate the 50-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 or additional ditch relief culverts and/or outsloping the road bed. When rolling dips are constructed, itemized costs include 10 yd^3 of road rock per rolling dip. It is estimated that erosion prevention work will require the excavation of nearly 550 yds^3. Approximately 53% of the volume excavated is associated with upgrading stream crossings.

Other miscellaneous treatments for inventoried sites on roads in the Hungry Hollow Road Association will include culvert replacements and installations, installation of downspouts to prevent culvert outlet erosion, a variety of

Table 16. Treatment priorities for all inventoried sediment sources on the Hungry Hollow Road Association, Mill Creek watershed, Mendocino County, California

Treatment Immediacy	Upgrade sites (#)	Upgrade Problem	Future sediment delivery (yds^3)	Maintenance sites (#)	Maintenance problem
High	**3** (site #: 76, 80.1, 87)	3 stream crossings	527	**0**	
Moderate/High	**3** (site #: 81, 80, 85)	2 stream crossings, 1 road surface	255	**0**	
Moderate	**6** (site: 72, 73, 74, 75, 77, 78)	1 ditch relief culvert, 5 stream crossings	538	**0**	
Moderate/Low	**4** (site #: 70, 81.1, 84, 86)	1 stream crossing, 3 ditch relief culverts	58	**0**	
Low	**1** (site #: 71)	1 road surface	10	**1** (site #: 82)	1 ditch relief culvert
Total	**17**		**1,388**	**1**	

Table 17. Recommended treatments along inventoried roads on the Hungry Hollow Road Association, Mill Creek watershed, Navarro River, Mendocino County, California.

Treatment	No.	Comment	Treatment	No.	Comment
Critical dip	5	To prevent stream diversions	Armor fill face	1	Rock armor to protect outboard fillslope from erosion using 10 yds^3 of rock
Install CMP[1]	2	Install a CMP at an unculverted fill	Outslope road & fill ditch	15	Outslope 9,680 feet of road to improve road surface drainage (1 maintenance site for 720')
Replace CMP[1]	5	Upgrade an undersized CMP	Inslope road	1	Inslope 100 feet of road to improve road surface drainage
Excavate soil	6	Typically fillslope & crossing excavations; excavate a total of 549 yds^3	Install rolling dips[2]	31	Install rolling dips to improve road drainage (2 maintenance related rolling dips)
Down spouts	1	Installed to protect the outlet fillslope from erosion	Clean ditch	1	Clean 100 feet of ditch
Wet crossing	2	Install armored fill crossings using 20 yds^3 of rip-rap sized rock	Install ditch relief CMP[1]	17	Install ditch relief culverts to improve road surface drainage (1 maintenance ditch relief culvert)
Rock road surface	3	Rock road surface using 326 yds^3 of road rock	No treatment recommended	1	

[1] Culvert replacement and ditch relief installation requires placement of the following culvert sizes and lengths including couplers and flared inlets, where prescribed: 1) 570' of 18" diameter pipe, 2) 70' of 24" diameter pipe, 3) 170' of 30" diameter pipe, 4) 40' of 36" diameter pipe, 5) 40' of 48" diameter pipe and 6) 60' of 60" diameter pipe.

[2] Additional ditch relief culverts (DRC) can be substituted for rolling dips. Each additional DRC will increase costs by 125% (i.e. more than double the costs).

road surface treatments (such as rolling dips, berm removal and outsloping) and additional ditch relief culverts to lessen erosion and fine sediment delivery from the road surface during wet winter months. Re-rocking the road prism for approximately 100 feet has been prescribed at every rolling dip location. 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 necessary at each site.

Equipment needs

Tables 18 and 19 list the expected heavy equipment and labor requirements by treatment immediacy to treat inventoried sites with future sediment delivery and maintenance sites (i.e., sites with no future sediment delivery to a stream). Costs and heavy equipment requirements for sites with sediment delivery and maintenance sites have been separated since it is assumed that 1) maintenance sites on inventoried roads do not have impacts on water quality and/or fish bearing streams, 2) the work is the responsibility of the individual landowner to fund and 3) the work is not fundable through California Department of Fish and Game S. B. 271 grants.

Treatments for the 17 sites with potential sediment delivery along 2.3 miles of the roads in the Hungry Hollow Road Association will require approximately 100 hours of excavator and 69 hours of tractor time to complete all prescribed upgrading, erosion control and erosion prevention work (Table 18) .

Table 18. Estimated heavy equipment and labor requirements for treatment of inventoried sites with sediment delivery on the Hungry Hollow Road Association, Mill Creek watershed, Mendocino County, California.

Treatment Immediacy	Site (#)	Excavated Volume (yds^3)	Excavator (hrs)	Tractor (hrs)	Dump Truck (hrs)	Grader (hrs)	Backhoe (hrs)	Labor (hrs)
High, High/Moderate	6	519	33	32	3	4	4	21
Moderate/ Moderate Low	10	30	61	36	0	14	3	55
Low	1	0	6	1	0	2	0	6
Total	**17**	**549**	**100**	**69**	**3**	**20**	**7**	**82**

Approximately 3 dump truck hours are needed for endhauling excess spoil and importing rock for rocking wet crossings and the road surface in selected locations. Dump truck times for road rocking following construction of rolling dips are included with rock costs. Eighty-two hours of labor is necessary for installing new culverts and other miscellaneous tasks, and 16 hours are for seeding, mulching and planting activities. The remaining equipment hours apply to prescribed road surfacing treatments.

Table 19 lists the expected heavy equipment required to treat one maintenance site with no sediment delivery. Prescribed treatments emphasize various road surface drainage mostly utilizing an excavator, tractor and a grader.

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 excavations to prevent future landsliding, as well as at all areas where excess spoil material derived from excavations is disposed of. Where roads are proposed for outsloping or where rolling dips will be constructed, all disturbed areas outside the road prism/bed will also be seeded and mulched. Costs have been included for laborers to seed and mulch approximately 1 acre of ground following heavy equipment work along the Hungry Hollow road system. Weed free straw mulch will be applied at 4000 pounds/acre. Native seeds should be applied at 20 pounds/acre and follow the Circuit Riders Inc. guidelines in the Navarro Watershed Restoration Plan (Entrix, 1998).

Table 19. Estimated heavy equipment and labor requirements for treatment of inventoried maintenance sites on the Hungry Hollow Road Association, Mill Creek watershed, Mendocino County, California.					
Treatment Immediacy	Site (#)	Excavator (hrs)	Tractor (hrs)	Grader (hrs)	Labor (hrs)
High, High/Moderate	0	0	0	0	0
Moderate, Low/Moderate	0	0	0	0	0
Low	1	3	2	2	3
Total	**1**	**3**	**2**	**2**	**3**

Cost estimate for inventoried sites along 2.3 miles of road in the Hungry Hollow Road Association
Tables 20 and 21 summarize the necessary costs by equipment types for the 17 sites with future sediment delivery and 1 maintenance site with no future delivery, respectively. The estimate includes costs for seed and mulch, new culverts, downspouts, flared inlets, as well as rock necessary for rip rap and road surfacing at rolling dip 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 20 and 21).

Total costs for the project are estimated at approximately $ 52,232. to treat the 17 sites inventoried with future sediment delivery and to significantly reduce sediment yield from the 2.3 miles of road feeding sediment annual to streams. Total costs to improve road drainage at maintenance sites with no future sediment delivery is $ 1,689. The average cost effectiveness value of the project is $ 12.76 per cubic yard of sediment prevented from entering Mill Creek and its tributaries. Costs in Tables 20 and 21 assume that the work in the watershed will be accomplished during a single summer work period using one equipment team. **(Note: Costs to re-rock the whole road system following implementing the proposed storm-proofing activities are not included in this table**.)

The cost estimate includes a minimal amount of 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 Tables 20 and 21 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 majority of treatments listed in this plan are not complex or difficult for equipment operators experienced in road maintenance and road building operations on forest lands.

Table 20. Estimated logistic requirements and costs for road-related erosion control and erosion prevention work on inventoried sites with future sediment delivery on the Hungry Hollow Road Association, Mill Creek watershed, Mendocino County, California

Cost Category[1]		Cost Rate[2] ($/hr)	Estimated Project Times			Total Estim. Costs[5] ($)
			Treatment[3] (hours)	Logistics[4] (hours)	Total (hours)	
Move-in; move-out[6] (Low Boy expenses)		70	5	--	5	350
Heavy Equipment	Excavator	115	100	30	130	14,950
	D-5 size tractor	85	69	21	90	7,650
	Dump Truck	60	3	1	4	240
	Grader	85	20	6	26	2,210
	Backhoe	65	7	2	9	585
Laborers		20	98	29	127	2,540
Rock costs: (includes trucking for 306 yds³ of road rock and 30 yds³ of 0.5 - 1' diam rock)						5,712
Culvert materials costs: (see Table 17 for list of culvert sizes, includes bands)						12,495
Mulch, seed and plant materials for 1 acre of disturbed ground						1,500
Layout, Coordination, Supervision, and Reporting[7]		50	--	--	80	4,000
Total Estimated Costs						**$ 52,232.**
Cost-effectiveness: $ 12.76 spent per cubic yard saved						

[1]Costs for miscellaneous tools and materials have not been included in this table. Costs for administration and contracting are variable and have not been included. Excluding new rolling dips, costs and dump truck time (if needed) for re-rocking the whole road surface have not been estimated.

[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, five hours round trip. Costs assume 2 hauls for two pieces of equipment to the Mill Creek watershed (one to move in and one to move out).

[7] Supervision time includes detailed layout (flagging, etc) prior to equipment arrival, establishing permanent photo point and other effectiveness monitoring, training of equipment operators, supervision during equipment operations, supervision of labor work, and pre and post-project monitoring, documentation and reporting).

Table 21. Estimated logistic requirements and costs for road-related erosion control and erosion prevention work on inventoried maintenance sites on the Hungry Hollow Road Association, Mill Creek watershed, Mendocino County, California						
Cost Category[1]		**Cost Rate[2] ($/hr)**	**Estimated Project Times**			**Total Estim. Costs[5] ($)**
			Treatment[3] (hours)	**Logistics[4] (hours)**	**Total (hours)**	
Move-in; move-out[6] (Low Boy expenses)		70	--	--	--	--
Heavy Equipment	Excavator	115	3	1	4	460
	D-5 size tractor	85	2	1	3	255
	Grader	85	2	1	3	255
Laborers		20	3	1	4	80
Rock Costs (includes trucking for 20 yds[3] of road rock)						340
Culvert materials costs: (see Table 10 for list of culvert sizes, includes bands)						249
Layout, Coordination, Supervision, and Reporting[7]		50	--	--	1	50
Total Estimated Costs						**$ 1,689**

[1]Costs for tools, for mulching and related materials (grass seed, fertilizer and straw), and for plant materials have not been included in this table. Costs for administration and contracting are variable and have not been included. Costs and dump truck time (if needed) for re-rocking the road surface have not been estimated.

[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 is accounted for in cost estimate table for upgrade sites with future sediment delivery.

[7] 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).

APPENDIX C

Inventory results, erosion control and erosion prevention plan for roads managed by the Holmes Ranch Road Association

The Holmes Ranch Road Association manages approximately 9.2 miles of road within the Mill Creek watershed. The Holmes Ranch roads are mostly located either to the north and west of the mainstem of Mill Creek and in the Meyer Gulch tributary. PWA personnel inventoried all of these roads for potential sediment delivery to the main stem and its tributaries, and to determine maintenance reaches of road and sites that would adversely affect the condition of the road, but not deliver sediment to streams.

Sites with either future sediment delivery or which are maintenance sites were inventoried using a PWA data form (Figure 2 and Map 1). Table 22 displays the distribution of site types mapped during the sediment source investigation. No potential landslides which pose a risk of delivering sediment to streams were identified along any of the Holmes Ranch roads. Every stream crossing was inventoried and described in detail for all Class I, II or III watercourses. Stream crossings are sensitive areas since they represent the greatest opportunity for sediment to be introduced into stream channels. Regardless of the size of the stream, once sediment is introduced to a stream it will eventually be transported downstream to a fish bearing stream and ultimately impact fish habitat.

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 gullies, ditch relief culverts, swales or springs that have the potential to deliver sediment to a stream channel. Finally, maintenance sites were inventoried where there is no sediment delivery but where chronic road surface drainage problems could affect the long term condition of the road. These sites include long stretches of road surface or ditch that do not deliver sediment to streams or ditch relief culverts that drain long segments of road onto gently sloping to flat hillslopes. All sites were mapped on 1 : 12,000 aerial photo mylar overlays.

A total of 25 sites were identified with a risk of future sediment delivery along roads within the Holmes Ranch Road Association (Table 22). Sites include 15 stream crossings and 9 miscellaneous “other” sites. Of the 24 inventoried sites, all have been recommended for erosion prevention treatment. In addition, 3.9 miles (42%) of the 9.2 miles of road managed by the Holmes Ranch Road Association currently deliver sediment and runoff to streams. Finally, 13 sites were identified as maintenance reaches of road (non-sediment delivery sites).

Stream crossings - Fifteen stream crossings were identified in the field with all being culverted fill crossings. Total future erosion and sediment yield from stream crossing sites is approximately 6,189 yds^3 if erosion prevention measures are not undertaken. The most significant problem from stream crossings inventoried on roads in the Holmes Ranch Road Association arise from stream crossings with a diversion potential. Of the 15 crossings inventoried, 9 have a diversion potential. Treatment for stream diversions is easy and requires installation of a “critical” dip placed at the down-road hinge line of the stream crossing to direct flow back into its natural drainage.

Significant erosion can also occur from undersized culverts and poor culvert installation. Undersized culverts can plug causing flow to overtop the road and cause erosion of the stream crossing fill, or flow can be diverted down the road to create hillslope gullies. Of the 15 culverted stream crossings, 8 have a moderate to high plug potential. Erosion can also occur as a result of poorly installed culverts causing major gully erosion below the outlet. Approximately 61% of the total future sediment yield would result from erosion associated with stream crossing failures.

Table 22. Site classification and sediment yield from inventoried sites in the Holmes Ranch Road Association, Mill Creek watershed, Mendocino County, California .

Site Type	Number of sites or road miles	Number of sites or road miles to treat	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	15	15	6,189	9	0	8
Other	10	10	179	NA	NA	NA
Total (all sites)	25	25	6,368	9	0	8
Persistent surface erosion	3.9	3.9	4,576	**NA**	**NA**	**NA**
Totals	**25**	**25**	**10,944**	**9**	**0**	**8**

[1] Assumes 30' wide road prism and cutbank contributing area, and 0.2' of road/cutbank surface lowering per decade.

"Other" sites - Ten "other" sites were identified for future sediment yield to stream channels. "Other" sites are mainly ditch relief culverts with gullies below their outlets. Approximately 179 yds^3 of future sediment yield is expected to occur associated with these miscellaneous sites. The "other" sites represent approximately 2% of the total predicted sediment yield from road-related erosion.

Concentrated road surface runoff can generate fine sediment which can negatively impact general stream health and fish habitat. A total of 3.9 miles of the roadbed, ditch and cutbank currently persistently deliver fine sediment and runoff to stream channels. Cutbank, road bed and ditch erosional processes are predicted to yield nearly 4,576 yds^3 (42%) of sediment to nearby streams over the next decade, if road drainage practices remain the same. Relatively easy treatments can be applied to upgrade road systems to prevent material from entering stream channels. These include installing a series or combination of road surface treatments such as rolling dips, outsloping, and/or additional ditch relief culverts to disperse runoff.

Treatment Priority
Table 23 and Map 2 outline the treatment immediacy for all 25 inventoried sites with future sediment delivery as well as the 13 maintenance sites along roads in the Holmes Ranch Road Association. Altogether, 3 sites were identified as having a high or high-moderate treatment immediacy with a potential sediment delivery of approximately 1,759 yds^3. Ten sites were listed with a moderate or moderate-low treatment immediacy and account for nearly 1,420 yds^3. Finally, 12 sites were listed as having a low treatment immediacy which could yield approximately 3,190 yds^3 of future sediment delivery. Thirteen maintenance sites with no future sediment delivery were identified and recommended for erosion control treatment to improve road surface drainage.

Treatments
Table 24 lists the site specific treatments for all inventoried sites recommended for erosion prevention work in the Holmes Ranch Road Association. Recommended erosion prevention work includes upgrading existing roads located in stable locations and maintaining sections of roads that do not have future sediment delivery but need road surface drainage improvements. Upgrading typically consists of properly installing new culverts designed to accommodate the 50 - year return interval peak storm flow and debris which will be in transport. Upgrading also includes improving the road drainage by utilizing

Table 23. Treatment priorities for all inventoried sediment sources in the Holmes Ranch Road Association, Mill Creek watershed, Mendocino County, California

Treatment Immediacy or Priority	Upgrade sites (#)	Upgrade Problem	Future sediment delivery (yds^3)	Maintenance sites (#)	Maintenance Problem
High	**2** (site #: 103, 121)	1 stream crossing, 1 ditch relief culvert	138	**0**	
Moderate/High	**1** (site #: 117)	1 stream crossing	1,621	**1** (site #: 114)	1 other misc.
Moderate	**5** (site #: 90, 119, 126, 128, 162)	1 road surface, 1 ditch relief culvert, 3 stream crossings	816	**1** (site #: 122)	1 ditch relief culvert
Moderate/Low	**5** (site #: 89, 118, 123, 127, 132)	3 stream crossings, 2 ditch relief culverts	601	**1** (site#: 104)	1 ditch relief culverts
Low	**12** (site #: 106, 107, 108, 109, 110, 111, 112, 113, 116, 120, 125, 129)	7 stream crossings, 5 ditch relief culverts	3,192	**10** (site #: 88, 91, 92, 93, 94, 105, 124, 130, 131, 133)	2 ditch relief culverts, 8 road surface
Total	**25**		**6,368**	**13**	

Table 24. Recommended treatments along inventoried roads in the Holmes Ranch Road Association, Mill Creek watershed, Navarro River, Mendocino County, California.

Treatment	No.	Comment	Treatment	No.	Comment
Critical dip	8	To prevent stream diversions	Outslope road & retain ditch	4	Outslope 2,229 feet of road & retain ditch to improve road surface drainage (3 maintenance sites for 1,904')
Replace CMP[1]	5	Upgrade an undersized CMP	Inslope road	1	Inslope 150 feet of road to improve road surface drainage
Excavate soil	1	Typically fillslope & crossing excavations; excavate a total of 1,239 yds^3	Install rolling dips[2]	75	Install rolling dips to improve road drainage (48 maintenance related rolling dips)
Down spouts	4	Installed to protect the outlet fillslope from erosion	Clean ditch	1	Clean 500 feet of ditch
Rock road surface	76	Rock road surface using 755 yds^3 of road rock	Remove berm	9	Remove 7,707 feet of berm to improve road surface drainage (3 maintenance sites for 4,837')
Clean CMP	8	Remove debris and/or sediment from CMP inlet (3 maintenance sites)	Install ditch relief CMP[1]	36	Install ditch relief culverts to improve road surface drainage (22 maintenance site)
Install flared inlet	1	Installed to increase CMP capacity	No treatment recommended	1	
Outslope road & fill ditch	26	Outslope 18,623 feet of road to improve road surface drainage (6 maintenance sites for 6,827')			

[1] Culvert replacement and ditch relief installation requires placement of the following culvert sizes and lengths including couplers and flared inlets, where prescribed: 1) 1130' of 18" diameter pipe, 2) 70' of 24" diameter pipe, 3) 110' of 30" diameter pipe, 4) 80' of 42" diameter pipe and 5) 130' of 48" diameter pipe.

[2] Additional ditch relief culverts (DRC) can be substituted for rolling dips. Each additional DRC will increase costs by 125% (i.e. more than double the costs).

different road surface treatments such as installing frequent rolling dips or additional ditch relief culverts and/or outsloping the road bed. When rolling dips are constructed, itemized costs include 10 yd^3 of road rock per rolling dip. It is estimated that erosion prevention work will require the excavation of nearly 1,240yds^3 at 1 stream crossing site.

Other miscellaneous treatments for inventoried sites on roads in the Holmes Ranch Road Association will include culvert replacements and installations, installation of downspouts to prevent culvert outlet erosion, a variety of road surface treatments (such as rolling dips, berm removal and outsloping) and additional ditch relief culverts to lessen erosion and fine sediment delivery from the road surface during wet winter months. Re-rocking the road prism for approximately 100 feet has been prescribed at every rolling dip location. 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 necessary at each site.

Equipment needs

Tables 25 and 26 list the expected heavy equipment and labor requirements by treatment immediacy to treat inventoried sites with future sediment delivery and maintenance sites (i.e., sites with no future sediment delivery to a stream). Costs and heavy equipment requirements for sites with sediment delivery and maintenance sites have been separated since it is assumed that 1) maintenance sites on inventoried roads do not have impacts on water quality and/or fish bearing streams, 2) the work is the responsibility of the individual landowner to fund and 3) the work is not fundable through California Department of Fish and Game S. B. 271 grants.

Treatments for the 25 sites with potential sediment delivery along 9.2 miles of the roads in the Holmes Ranch Road Association will require approximately 93 hours of excavator and 87 hours of tractor time to complete all prescribed upgrading, erosion control and erosion prevention work (Table 25). Dump truck times for road rocking following construction of rolling dips are included with rock costs. Seventy-seven hours of labor is necessary for installing new culverts and other miscellaneous tasks, and 16 hours are for seeding, mulching and planting activities. The remaining equipment hours apply to prescribed road surfacing treatments.

Table 26 lists the expected heavy equipment required to treat maintenance sites with no sediment delivery. Prescribed treatments emphasize various road surface drainage mostly utilizing an excavator, tractor and a grader.

Table 25. Estimated heavy equipment and labor requirements for treatment of inventoried sites with sediment delivery in the Holmes Ranch Road Association, Mill Creek watershed, Mendocino County, California.

Treatment Immediacy	Site (#)	Excavated Volume (yds^3)	Excavator (hrs)	Tractor (hrs)	Grader (hrs)	Backhoe (hrs)	Labor (hrs)
High, High/Moderate	3	1,239	37	34	3	0	17
Moderate, Low/Moderate	10	0	32	41	15	3	35
Low	12	0	24	12	14	3	25
Total	**25**	**1,239**	**93**	**87**	**32**	**6**	**77**

Table 26. Estimated heavy equipment and labor requirements for treatment of inventoried maintenance sites in the Holmes Ranch Road Association, Mill Creek watershed, Mendocino County, California.							
Treatment Immediacy	Site (#)	Excavated Volume (yds^3)	Excavator (hrs)	Tractor (hrs)	Grader (hrs)	Backhoe (hrs)	Labor (hrs)
High, High/Moderate	1	0	3	2	3	0	3
Moderate, Low/Moderate	2	0	15	0	6	0	15
Low	10	0	48	46	19	5	48
Total	**13**	**0**	**66**	**48**	**28**	**5**	**66**

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 excavations to prevent future landsliding, as well as at all areas where excess spoil material derived from excavations is disposed of. Where roads are proposed for outsloping or where rolling dips will be constructed, all disturbed areas outside the road prism/bed will also be seeded and mulched. Costs have been included for laborers to seed and mulch approximately 1 acre of ground following heavy equipment work along the Holmes Ranch road system. Weed free straw mulch will be applied at 4000 pounds/acre. Native seeds should be applied at 20 pounds/acre and follow the Circuit Rider Inc. guidelines in the Navarro Watershed Restoration Plan (Entrix, 1998).

Cost estimate for inventoried sites along 9.2 miles of road in the Holmes Ranch Road Association

Tables 27 and 28 summarize the necessary costs by equipment types for the 25 sites with future sediment delivery and 13 maintenance sites with no future delivery, respectively. The estimate includes costs for seed and mulch, new culverts, downspouts, flaired inlets, as well as rock necessary for rip rap and road surfacing at rolling dip 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 27 and 28).

Total costs for the project are estimated at approximately $ 57,597 to treat the 25 sites inventoried with future sediment delivery and to significantly reduce sediment yield from the 3.9 miles of road feeding sediment annual to streams. Total costs to improve road drainage at maintenance sites with no future sediment delivery is $36,194. The average cost effectiveness value of the project is $ 5.27 per cubic yard of sediment prevented from entering Mill Creek and its tributaries. Costs in Tables 27 and 28 assume that the work in the watershed will be accomplished during a single summer work period using two equipment teams. **(Note: Costs to re-rock the whole road system following implementing the proposed storm-proofing activities are not included in this table**.)

The cost estimate includes a minimal amount of 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 Tables 27 and 28 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 majority of treatments listed in this plan are not complex or difficult for equipment operators experienced in road maintenance and road building operations on forest lands.

Table 27. Estimated logistic requirements and costs for road-related erosion control and erosion prevention work on inventoried sites with future sediment delivery in the Holmes Ranch Road Association, Mill Creek watershed, Mendocino County, California

Cost Category[1]		Cost Rate[2] ($/hr)	Estimated Project Times			Total Estim. Costs[5] ($)
			Treatment[3] (hours)	Logistics[4] (hours)	Total (hours)	
Move-in; move-out[6] (Low Boy expenses)		70	10	--	10	700
Heavy Equipment	Excavator	115	93	28	121	13,915
	D-5 size tractor	85	87	26	113	9,605
	Grader	85	32	10	42	3,570
	Backhoe	65	6	2	8	520
Laborers		20	93	28	121	2,420
Rock costs: (includes trucking for 275yds^3 of road rock)						4,675
Mulch, seed and plant materials for 1 acre of disturbed ground						1,500
Culvert materials costs: (see Table 24 for list of culvert sizes, including bands)						14,213
Layout, Coordination, Supervision, and Reporting[7]		50	--	--	100	5,000
Total Estimated Costs						**$ 57,597.**
Cost-effectiveness: $ 5.27 spent per cubic yard saved						

[1]Costs for miscellaneous tools and materials have not been included in this table. Costs for administration and contracting are variable and have not been included. Excluding new rolling dip locations, costs and dump truck time (if needed) for re-rocking the whole road surface have not been estimated.

[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, five hours round trip. Costs assume 2 hauls for two pieces of equipment to the Mill Creek watershed (one to move in and one to move out).

[7] Supervision time includes detailed layout (flagging, etc) prior to equipment arrival, establishing permanent photo point and other effectiveness monitoring, training of equipment operators, supervision during equipment operations, supervision of labor work and post-project documentation and reporting).

Table 28. Estimated logistic requirements and costs for road-related erosion control and erosion prevention work on inventoried maintenance sites in the Holmes Ranch Road Association, Mill Creek watershed, Mendocino County, California

Cost Category[1]		Cost Rate[2] ($/hr)	Estimated Project Times			Total Estim. Costs[5] ($)
			Treatment[3] (hours)	Logistics[4] (hours)	Total (hours)	
Move-in; move-out[6] (Low Boy expenses)		70	--	--	--	—
Heavy Equipment	Excavator	115	66	20	86	9,890
	D-5 size tractor	85	48	14	62	5,270
	Grader	85	28	8	36	3,060
	Backhoe	65	5	2	7	455
Laborers		20	66	20	86	1,720
Rock costs: (includes trucking for 480 yds^3 of road rock)						8,160
Culvert materials costs: (see Table 10 for list of culvert sizes, includes bands)						5,639
Layout, Coordination, Supervision, and Reporting[7]		50	--	--	40	2,000
Total Estimated Costs						**$ 36,194**

[1]Costs for tools, for mulching and related materials (grass seed, fertilizer and straw), and for plant materials have not been included in this table. Costs for administration and contracting are variable and have not been included. Costs and dump truck time (if needed) for re-rocking the road surface have not been estimated.

[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 is accounted for in cost estimate table for upgrade sites with future sediment delivery.

[7] 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).

APPENDIX D

Draft inventory results, erosion control and erosion prevention plan for roads managed by the Nash-Mill Road Association

The Nash-Mill Road Association manages approximately 14 miles of road within the Mill Creek watershed. The Nash-Mill roads are mostly located either along east and north portions of the lower mainstem of Mill Creek and adjacent to the Little Mill Creek and Stump Hollow tributaries. PWA personnel inventoried all of these roads for potential sediment delivery to the main stem and its tributaries, and to determine maintenance reaches of road and sites that would adversely affect the condition of the road, but not deliver sediment to streams.

Sites with either future sediment delivery or which are maintenance sites were inventoried using a PWA data form (Figure 2 and Map 1). Table 29 displays the distribution of site types mapped during the sediment source investigation. Six potential landslides which pose a risk of delivering sediment to streams were identified along all the Nash-Mill roads. Every stream crossing was inventoried and described in detail for all Class I, II or III watercourses. Stream crossings are sensitive areas since they represent the greatest opportunity for sediment to be introduced into stream channels. Regardless of the size of the stream, once sediment is introduced to a stream it will eventually be transported downstream to a fish bearing stream and ultimately impact fish habitat.

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 gullies, ditch relief culverts, swales or springs that have the potential to deliver sediment to a stream channel. Finally, maintenance sites were inventoried where there is no sediment delivery but where chronic road surface drainage problems could affect the long term condition of the road. These sites include long stretches of road surface or ditch that do not deliver sediment to streams or ditch relief culverts that drain long segments of road onto gently sloping to flat hillslopes. All sites were mapped on 1 : 12,000 aerial photo mylar overlays.

A total of 58 sites were identified with a risk of future sediment delivery along roads within the Nash-Mill Road Association (Table 29). Sites include 34 stream crossings, 6 potential landslides, 3 specific road surface sites and 15 miscellaneous “other” sites. Of the 58 inventoried sites, 56 have been recommended for erosion prevention treatment. In addition, 9.4 miles (67%) of the 14 miles of road managed by the Nash-Mill Road Association currently deliver sediment and runoff to streams. Finally, 20 sites were identified as maintenance reaches of road (non-sediment delivery sites).

Landslides - Potential road-related landslides identified during the road inventory were divided into cutbank failures, landing fill failures, road fill failures, deep seated failures and others. Of the 6 identified sites of future road-related mass wasting, 4 are road fills, 1 is a cutbank failure and 1 is a potential deep seated failure. Left untreated, road-related landslides are expected to deliver over 3,800 yds^3 to the stream system.

Stream crossings - Thirty-four stream crossings were identified in the field with 26 being culverted fill crossings and 8 being unculverted fill crossings. Total future erosion and sediment yield from stream crossing sites is approximately 19,650 yds^3 if erosion prevention measures are not undertaken.

The most significant problem from stream crossings inventoried on roads in the Nash-Mill Road Association arise from stream crossings with a diversion potential. Of the 34 crossings inventoried, 24 have a diversion potential and 11 are currently diverted. Treatment for stream diversions is easy and requires installation of a "critical" dip placed at the down-road hinge line of the stream crossing to direct flow back into its natural drainage.

Significant erosion can also occur from undersized culverts and poor culvert installation. Undersized culverts can plug causing flow to overtop the road and cause erosion of the stream crossing fill, or flow can be diverted down the road to create hillslope gullies. Of the 26 culverted stream crossings, 11 have a moderate to high plug potential. Erosion can also occur as a result of poorly installed culverts causing major gully erosion below the outlet. Approximately 59% of the total future sediment yield would result from erosion associated with stream crossing failures.

"Other" and Road Surface sites - Fifteen "other" sites were identified for future sediment yield to stream channels. "Other" sites are mainly ditch relief culverts with gullies below their outlets. Approximately 420 yds^3 of future sediment yield is expected to occur associated with these

Table 29. Site classification and sediment yield from inventoried sites in the Nash-Mill Road Association, Mill Creek watershed, Mendocino County, California .

Site Type	Number of sites or road miles	Number of sites or road miles to treat	Future yield (yds^3)	Stream crossings w/ a diversion potential (#)	Streams currently diverted (#)	Stream culverts likely to plug (plug potential rating = high or moderate)
Landslides	6	5	3,823	NA	NA	NA
Stream crossings	34	34	19,650	24	11	11
Road surface	3	3	126	NA	NA	NA
Other	15	14	424	NA	NA	NA
Total (all sites)	58	56	24,023	24	11	11
Persistent surface erosion	9.40	9.40	11,029	**NA**	**NA**	**NA**
Totals	**58**	**56**	**35,052**	**24**	**11**	**11**

[1]Assumes 30' wide road prism and cutbank contributing area, and 0.2' road/cutbank surface lowering over the next decade.

miscellaneous sites. The "other" sites represent approximately 1% of the total predicted sediment yield from road-related erosion.

Concentrated road surface runoff can generate fine sediment which can negatively impact general stream health and fish habitat. A total of 9.4 miles of the roadbed, ditch and cutbank currently persistently deliver fine sediment and runoff to stream channels. Cutbank, road bed and ditch erosional processes are predicted to yield nearly 11,029 yds^3 (31%) of sediment to nearby streams over the next decade, if road drainage practices remain the same. Relatively easy treatments can be applied to upgrade road systems to prevent material from entering stream channels. These include installing a series or combination of road surface treatments such as rolling dips, outsloping, and/or additional ditch relief culverts to disperse runoff.

Treatment Priority
Table 30 and Map 2 outline the treatment immediacy for all 56 inventoried sites with future sediment delivery as well as the 20 maintenance sites along roads in the Nash-Mill Road Association. Altogether, 24 sites were identified as having a high or high-moderate treatment immediacy with a potential sediment delivery of approximately 17,100 yds^3. Twenty-eight sites were listed with a moderate or moderate-low treatment immediacy and account for nearly 6,000 yds^3. Finally, 3 sites were listed as having a low treatment immediacy which could yield approximately 120 yds^3 of future sediment delivery. Twenty maintenance sites with no future sediment delivery were identified and recommended for erosion control treatment to improve road surface drainage.

Treatments
Table 31 lists the site specific treatments for all inventoried sites recommended for erosion prevention work in the Nash-Mill Road Association. Recommended erosion prevention work includes upgrading existing roads located in stable locations and maintaining sections of roads that do not have future sediment delivery but need road surface drainage improvements. Upgrading typically consists of properly installing new culverts designed to accommodate the 50 - 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 or additional ditch relief culverts and/or outsloping the road bed. When rolling dips are constructed, itemized costs include 10 yd^3 of road rock per rolling dip.

It is estimated that erosion prevention work will require the excavation of just over 8,900yds^3 at 27 stream crossing sites. Approximately 66% of the volume excavated is associated with upgrading stream crossings and nearly 32% of the volume is a result of excavating potentially unstable road fills (landslides).

Other miscellaneous treatments for inventoried sites on roads in the Nash-Mill Road Association will include culvert replacements and installations, installation of downspouts to prevent culvert outlet erosion, a variety of road surface treatments (such as rolling dips, berm removal and outsloping) and additional ditch relief culverts to lessen erosion and fine sediment delivery from the road surface during wet winter months. Re-rocking the road prism for approximately 100 feet has been prescribed at every rolling dip location. 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 necessary at each site.

Table 30. Treatment priorities for all inventoried sediment sources in the Nash-Mill Road Association, Mendocino County, California						
Treatment Immediacy or Priority	Upgrade sites (#)	Decommission sites (#)	Upgrade/ Decom. Problem	Future sediment delivery (yds^3)	Maintenance sites (#)	Maintenance Problem
High	**9** (site #: 2, 4, 28, 33, 37, 46, 49, 62, 65)	**0**	1 ditch relief culvert, 2 landslides, 6 stream crossings	14, 166	**0**	
Moderate/ High	**15** (site #: 10, 16, 17, 25, 26, 35, 39, 47, 48, 58, 59, 60, 99, 102, 142)	**1** (site #: 100)	1 road surface, 1 gully, 2 landslides, 2 ditch relief culverts, 10 stream crossings	2, 923	**0**	
Moderate	**19** (site #: 1, 3, 6, 9, 11, 15, 27, 36, 38, 45, 53, 54, 56, 61, 64, 67, 68, 101, 149)	**0**	3 ditch relief culverts, 5 gullies, 11 stream crossings	5,140	**3** (site #: 8, 18, 20)	1 ditch relief culverts, 1 gully, 1 road surface
Moderate/ Low	**9** (site #: 29, 30, 34, 38.1, 50, 51, 57, 97, 148)	**0**	2 road surface, 2 ditch relief culverts, 5 stream crossings	883	**4** (site #: 23, 32, 66, 141)	2 ditch relief culverts, 2 road surface
Low	**3** (site #: 29.1, 96, 143)	**0**	1 landslide, 2 stream crossings	116	**13** (site #: 7, 12, 13, 14, 19, 21, 22, 24, 31, 52, 55, 95, 98)	6 ditch relief culverts, 7 road surface
Total	**55**	**1**		**23,228**	**20**	

Equipment needs

Tables 32 and 33 list the expected heavy equipment and labor requirements by treatment immediacy to treat inventoried sites with future sediment delivery and maintenance sites (i.e., sites with no future sediment delivery to a stream). Costs and heavy equipment requirements for sites with sediment delivery and maintenance sites have been separated since it is assumed that 1) maintenance sites on inventoried roads do not have impacts on water quality and/or fish bearing streams, 2) the work is the responsibility of the individual landowner to fund and 3) the work is not fundable through California Department of Fish and Game S. B. 271 grants.

Table 31. Recommended treatments along inventoried roads in the Nash-Mill Road Association, Mill Creek watershed, Navarro River, Mendocino County, California.

Treatment	No.	Comment	Treatment	No.	Comment
Critical dip	17	To prevent stream diversions	Outslope road & retain ditch	6	Outslope 4,190 feet of road & retain ditch to improve road surface drainage (3 maintenance sites for 1,330')
Install cmp	8	Install a cmp at an unculverted fill	Inslope road	5	Inslope 1,605 feet of road to improve road surface drainage (1 maintenance site for 100')
Replace cmp	18	Upgrade an undersized cmp	Install rolling dips [1]	215 [1]	Install rolling dips to improve road drainage (75 maintenance related rolling dips)
Excavate soil	27	Typically fillslope & crossing excavations; excavate a total of 8,901 yds^3	Remove ditch	2	Remove 550 feet of inboard ditch
Down spouts	8	Installed to protect the outlet fillslope from erosion (1 maintenance site)	Clean ditch	3	Clean 330 feet of ditch
Wet crossing	6	Install 1 rocked ford and 5 armored fill crossings using 52 yds^3 coarse rock	Remove berm	13	Remove 10,345 feet of berm to improve road surface drainage (5 maintenance sites for 4,520')
Rock road surface	263	Rock road surface using 2182 yd^3 of road rock	Install ditch relief cmp	41	Install ditch relief culverts to improve road surface drainage (1 maintenance site)
Armor fill face	1	Rock armor to protect outboard fillslope from erosion using 10 yds^3 of coarse rock	Install bridge	1	Install bridge where stream is large and culvert or wet crossing is not feasible
Install flared inlet	4	Installed to increase Cmp capacity	No treatment recommended	3	
Outslope road & fill ditch	47	Outslope 38,734 feet of road to improve road surface drainage (10 maintenance sites for 9, 540')			

[1] Culvert replacement and ditch relief installation requires placement of the following culvert sizes and lengths including couplers and flared inlets, where prescribed: 1) 1700' of 18" diameter pipe, 2) 955' of 24" diameter pipe, 3) 190' of 30" diameter pipe, 4) 110' of 36" diameter pipe, 5) 90' of 48" diameter pipe, 6) 150' of 48" diameter pipe and 7) 160' of 72" diameter pipe

[2] Additional ditch relief culverts (DRC) can be substituted for rolling dips. Each additional DRC will increase costs by 125% (i.e. more than double the costs).

Treatments for the 56 sites with potential sediment delivery along 14 miles of the roads in the Nash-Mill Road Association will require approximately 364 hours of excavator and 566 hours of tractor time to complete all prescribed upgrading, erosion control and erosion prevention work (Table 32) . Approximately 8 dump truck hours are needed for endhauling excess spoil. Dump truck times for road rocking following construction of rolling dips are included with rock costs. One hundred and forty-three hours of labor is necessary for installing new culverts and other miscellaneous tasks, and 181 hours are for seeding, mulching and planting activities. The remaining equipment hours apply to prescribed road surfacing treatments.

Table 33 lists the expected heavy equipment required to treat maintenance sites with no sediment delivery. Prescribed treatments emphasize various road surface drainage mostly utilizing a tractor and a grader.

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 excavations to prevent future landsliding, as well as at all areas where excess spoil material derived from excavations is disposed of. Where roads are proposed for outsloping or where rolling dips will be constructed, all disturbed areas outside the road prism/bed will also be seeded and mulched. Costs have been included for laborers to seed and mulch approximately 12.5 acres of ground following heavy equipment work along the Nash-Mill road system. Weed free straw mulch will be applied at 4000 pounds/acre. Native seeds should be applied at 20 pounds/acre and follow the guidelines in the Navarro Watershed Restoration Plan (Entrix, 1998).

Table 32. Estimated heavy equipment and labor requirements for treatment of inventoried sites with sediment delivery in the Nash-Mill Road Association, Mill Creek watershed, Mendocino County, California.

Treatment Immediacy	Site (#)	Excavated Volume (yds^3)	Excavator (hrs)	Tractor (hrs)	Dump Truck (hrs)	Grader (hrs)	Labor (hrs)
High, High/Moderate	25	7,803	222	288	2	33	73
Moderate, Low/Moderate	28	934	137	270	6	43	67
Low	3	164	5	8	0	0	3
Total	**56**	**8,901**	**364**	**566**	**8**	**76**	**143**

Table 33. Estimated heavy equipment and labor requirements for treatment of inventoried maintenance sites in the Nash-Mill Road Association, Mill Creek watershed, Mendocino County, California.						
Treatment Immediacy	Number (#)	Excavated Volume (yds^3)	Excavator (hrs)	Tractor (hrs)	Grader (hrs)	Laborers (hrs)
High, High/Moderate	0	0	0	0	0	0
Moderate, Low/Moderate	7	0	3	18	9	5
Low	13	0	0	57	23	0
Total	**20**	**0**	**3**	**75**	**32**	**5**

Cost estimate for inventoried sites along 14 miles of road in the Nash-Mill Road Association
Tables 34 and 35 summarize the necessary costs by equipment types for the 56 sites with future sediment delivery and 20 maintenance sites with no future delivery, respectively. The estimate includes costs for seed and mulch, new culverts, downspouts, flaired inlets, as well as rock necessary for rip rap and road surfacing at rolling dip and other specific locations. Proposed costs include heavy equipment and labor times to remove the existing crossing at site 58 and refit the site with a flatcar bridge (Note: the costs to purchase the bridge are not included). 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 34 and 35).

Total costs for the project are estimated at approximately $ 257,507. to treat the 56 sites inventoried with future sediment delivery and to significantly reduce sediment yield from the 9.4 miles of road feeding sediment annual to streams. The average cost effectiveness value of the project is $ 7.35 per cubic yard of sediment prevented from entering Mill Creek and its tributaries. Total costs to improve road drainage at maintenance sites with no future sediment delivery is $27,906. Costs in Tables 34 and 35 assume that the work in the watershed will be accomplished during a single summer work period using two equipment teams, or over two years using a single equipment team. **(Note: Costs to re-rock the whole road system following implementing the proposed storm-proofing activities are not included in this table**.) The cost estimate includes a minimal amount of 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 Tables 34 and 35 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 majority of treatments listed in this plan are not complex or difficult for equipment operators experienced in road maintenance and road building operations on forest lands.

Table 34. Estimated logistic requirements and costs for road-related erosion control and erosion prevention work on inventoried sites with future sediment delivery in the Nash-Mill Road Association, Mill Creek watershed, Mendocino County, California

Cost Category[1]		Cost Rate[2] ($/hr)	Estimated Project Times			Total Estim. Costs[5] ($)
			Treatment[3] (hours)	Logistics[4] (hours)	Total (hours)	
Move-in; move-out[6] (Low Boy expenses)		70	20	--	20	1,400
Heavy Equipment	Excavator	115	364	110	474	54,510
	D-5 size tractor	85	566	170	736	62,560
	Dump Truck	60	8	2	10	600
	Grader	85	75.5	23	99	8,415
Laborers		20	322	96	418	8,360
Rock costs: (includes trucking for 1,432 yd^3 of road rock and 62 yds^3 of rip-rap sized rock)						25,398
Culvert materials costs: (see Table 31 for list of culvert sizes, including bands)						51,264
Mulch, seed and plant materials for 12.5 acres of disturbed ground						20,000
Layout, Coordination, Supervision, and Reporting[7]		50	--	--	500	25,000
Total Estimated Costs						**$ 257,507.**
Cost-effectiveness: $7.35 spent per cubic yard saved						

[1]Costs for miscellaneous tools and materials have not been included in this table. Costs for administration and contracting are variable and have not been included. Excluding new rolling dip construction, costs and dump truck time (if needed) for re-rocking the whole road surface have not been estimated.

[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, five hours round trip. Costs assume 2 hauls for two pieces of equipment to the Mill Creek watershed (one to move in and one to move out).

[7] Supervision time includes detailed layout (flagging, etc) prior to equipment arrival, establishing permanent photo point and other effectiveness monitoring, training of equipment operators, supervision during equipment operations, supervision of labor work and post-project documentation and reporting).

Table 35. Estimated logistic requirements and costs for road-related erosion control and erosion prevention work on inventoried maintenance sites in the Nash-Mill Road Association, Mill Creek watershed, Mendocino County, California						
Cost Category[1]		**Cost Rate**[2] **($/hr)**	**Estimated Project Times**			**Total Estim. Costs**[5] **($)**
			Treatment[3] **(hours)**	**Logistics**[4] **(hours)**	**Total (hours)**	
Move-in; move-out[6] (Low Boy expenses)		70	--	--	--	—
Heavy Equipment	Excavator	115	3	1	4	460
	D-5 size tractor	85	75	23	98	8,330
	Grader	85	32	10	42	3,575
Laborers		20	5	1.5	7	140
Rock costs: (includes trucking for 750 yd^3 of road rock)						12,750
Culvert materials costs: (see Table 31 for list of culvert sizes, includes bands)						651
Layout, Coordination, Supervision, and Reporting[7]		50	--	--	40	2,000
Total Estimated Costs						**$ 27,906.**

[1]Costs for tools, for mulching and related materials (grass seed, fertilizer and straw), and for plant materials have not been included in this table. Costs for administration and contracting are variable and have not been included. Costs and dump truck time (if needed) for re-rocking the road surface have not been estimated.

[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 is accounted for in cost estimate table for upgrade sites with future sediment delivery.

[7] 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).