

Watershed Restoration Unit 02-04
Summary Report
AA1/AA2

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July 2003

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Introduction

Redwood National Park was established "in order to preserve significant examples of the primeval coastal redwood (*Sequoia sempervirens*) forests and the streams and seashores with which they are associated for purposes of public inspiration, enjoyment, and scientific study" (Public Law 90-545).

Original park boundaries (1968) protected a ½ mile wide corridor of forest along the lower ⅓ of Redwood Creek, while lands located upslope and upstream of this corridor remained in private ownership. Prior to the establishment of the park, much of these lands were forested with old growth mix conifer forests. Subsequent to the park's establishment, these lands were subject to aggressive timber harvesting. This timber harvesting and the related road construction adversely influenced erosion rates, sediment deposition and water quality within the entire basin. Studies indicate these activities cause unnatural and excessive erosion that result in adverse impacts to riparian habitat, anadromous fisheries, and amphibian species (Narver, 1971). The existence of several hundred miles of major haul roads and thousands of miles of tractor trails creates severe erosion problems. The cutting of logging roads into steep slopes often results in massive slope failures, causing sediment to be delivered directly into perennial and intermittent stream channels. Surface runoff can be intercepted and concentrated by inboard ditches along these roads, and often discharged onto slopes that have no natural drainage channels, resulting in severe gullying. During major storms, culverts and inboard ditches often become blocked by debris, and water is diverted onto road surfaces, causing new gullies and saturating road fills, which in turn lead to slope failures. The altering of drainage patterns, the resulting loss of top soil, soil compaction, and destruction of ground cover, combined with increased runoff rates are among the results of logging activities in the Redwood Creek basin. These factors lead to increased sedimentation, increased streamside slope failures, greater bank erosion, and loss of anadromous fish-spawning habitat. Further, these events lead to a general degradation of the watershed, including damage to the aquatic and riparian environments in the Redwood Creek basin.

Congress enacted the expansion legislation of 1978 (Public Law 95-250) in order "...to protect existing irreplaceable Redwood National Park resources from damaging upslope and upstream land uses, to provide a land base sufficient to insure preservation of significant examples of the coastal redwood in accordance with the original intent of Congress, and to establish a more meaningful Redwood National Park for the use and enjoyment of visitors." The boundaries of Redwood National Park were expanded by approximately 48,000 acres, and Congress directed the National Park Service to undertake a watershed restoration program. The primary goals of the restoration program are to minimize man-induced erosion and speed the natural re-vegetation process. Ultimately the efforts should result in the restoration of natural ecosystems to a condition similar to what would have existed without disturbance by man.

It is National Park Service policy to "actively seek to understand and preserve the soil resources of parks and to prevent, to the extent possible, the unnatural erosion, physical removal, or contamination of the soil, or its contamination of other resources..." The NPS

Management Policies (2001) describe actions that shall be undertaken to restore disturbed lands: “The Service will re-establish natural functions and processes in human-disturbed components of natural systems in parks unless otherwise directed by Congress. Landscapes disturbed by natural phenomena, such as landslides, earthquakes, floods, hurricanes, tornadoes, and fires, will be allowed to recover naturally unless manipulation is necessary to protect park developments or visitor safety. Impacts to natural systems resulting from human disturbances include the introduction of exotic species; the contamination of air, water, and soil; changes to hydrologic patterns and sediment transport; the acceleration of erosion and sedimentation; and the disruption of natural processes. The Service will seek to return human-disturbed areas to the natural conditions and processes characteristic of the ecological zone in which the damaged resources are situated. The Service will use the best available technology, within available resources, to restore the biological and physical components of these systems, accelerating both their recovery and the recovery of landscape and biological-community structure and function.” Management objectives of Redwood National Park are “to restore and/or maintain the natural ecosystems of the park” and “to continue with biological and physical restoration of park lands severely impacted by past land-use practices” (Redwood National Park, Statement for Management, 1992). These policies and objectives provided the guidance and direction for the removal of the AA1 and AA2 roads.

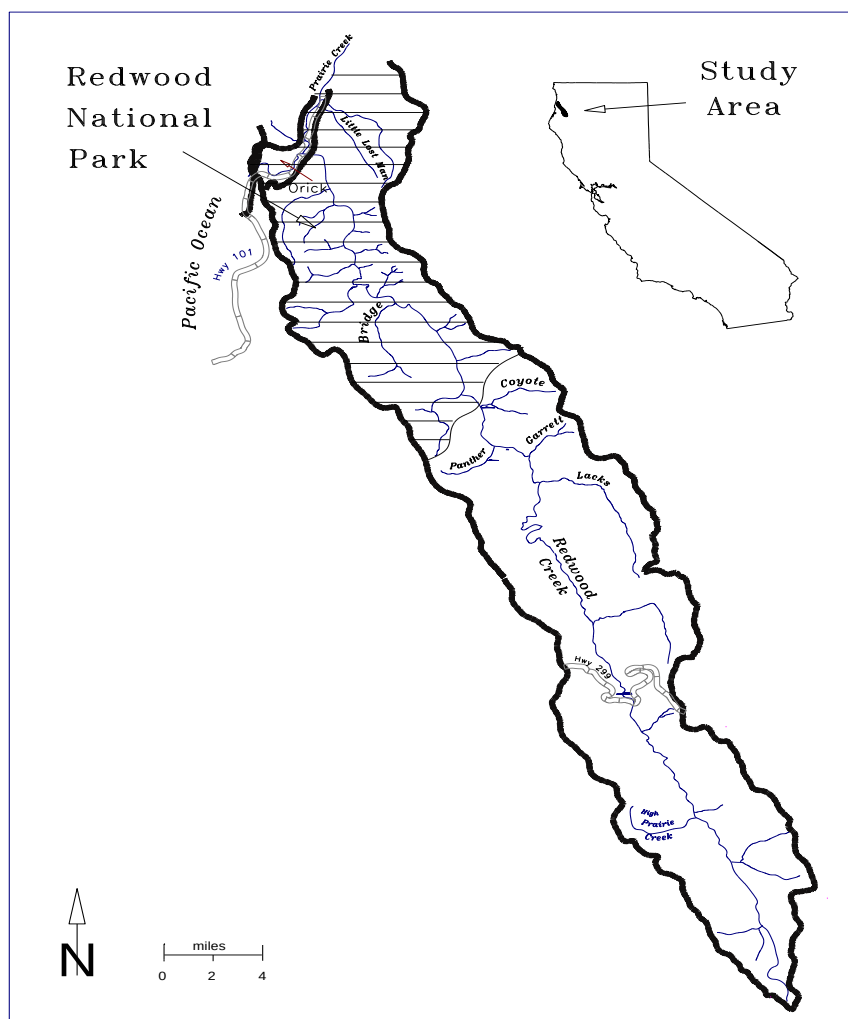


Figure 1. Map of Redwood National Park and the Redwood Creek basin.

Site Description

Redwood National and State Parks (RNSP) is located in the lower $\frac{1}{3}$ of the 280 square mile Redwood Creek watershed, in the mountainous, coastal region of northwestern California (Figure 1). The basin is characterized by high relief, steep, unstable slopes, and narrow valley bottoms. Redwood Creek and its tributary streams are subject to frequent flooding from winter storms, and basin soils are naturally unstable and highly erodible. Landslides and earthflows are widespread in the basin, and even under natural conditions, streams swelled by winter rains transport large volumes of sediment. With over 90% of the forests in the basin harvested, and $\frac{2}{3}$ of the basin in active timber management, sediment levels in Redwood Creek are twice the mean annual erosion rates for the north coast (U.S. Congress, House, Committee on Government Operations 1976).

Watershed Restoration Unit 02-04 is located approximately 4 miles northeast of Orick, California. The AA1/AA2 roads are located in the northwestern portion of the Lost Man Creek watershed. The AA1 runs along the right or northwest bank of Larry Damm Creek, a major tributary to Lost Man Creek; the AA2 is a spur road leading to a large landing. Lost Man Creek flows into Prairie Creek, which subsequently flows into Redwood Creek roughly 2 miles upstream of the estuary (Figure 2). These roads, constructed between 1962 and 1966, were minor haul roads for Arcata Redwood Company.

The project addressed accelerated erosion problems along 2,050 ft. of the AA1 road and 1,000 ft. of the AA2 road. Restoration focused primarily on the removal of the stream crossings and unstable side cast fill, and restoring natural hillslope topography and drainage patterns interrupted by the AA1/AA2 road complex. The excavation of the stream crossings uncovered the natural channel bed and banks, and excavated fill was used to re-create the natural topography. Recovered organic and nutrient rich side cast was returned to the surface in order to help speed recovery of native vegetation. Vegetation disturbed during excavation was stockpiled and dispersed along the finished surface in order to provide habitat, simulate natural forest litter, and to impede surface runoff erosion processes. This project involved the excavation of over 56,200 yds³ of fill material, including 45,200 yds³ associated with 4 stream crossings. Methodology for road removal was consistent with past restoration projects, employing heavy equipment for all excavations. Excavations were executed through IDIQ Contract number 1443-CX-8530-99-006, and work was performed by Z Logging L.L.C. of Orick, California. Project costs are summarized in Table 1.

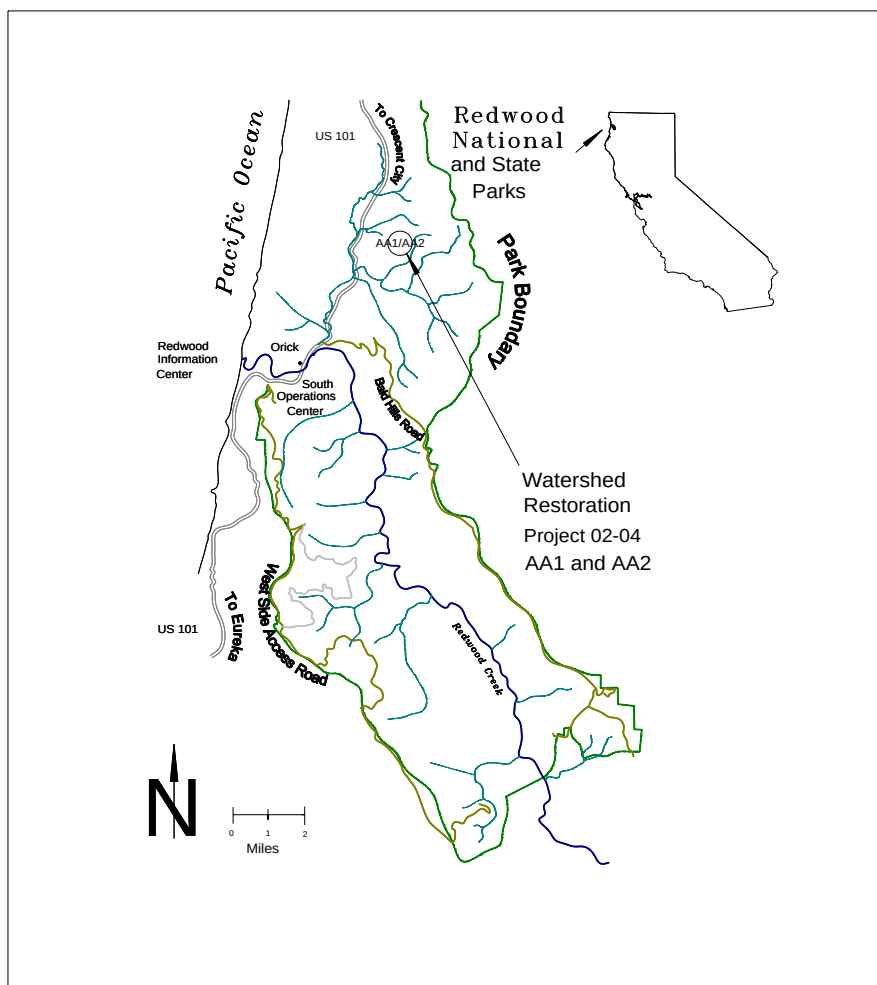


Figure 2. Map of Watershed Restoration Project 02-04, AA1/AA2 road complex location.

Table 1. Restoration Work Cost Summary for Unit 02-04, AA1/AA2					
Treatment	Quantity (cubic yards)	Number of Sites	Total Costs (\$)	Percent of Grand Total	Average Unit Costs (\$)
Heavy Equipment					
Road Crossings	45218	4	\$288,325.60	77.1%	\$6.38
Export Outslope	6693	3	\$32,793.70	8.8%	\$4.90
Outslope	4323	7	\$10,507.50	2.8%	\$2.43
Move In	--	--	\$4,400.00	1.2%	--
Move Out	--	--	\$4,400.00	1.2%	--
Miscellaneous	--	--	\$370.79	0.1%	--
Hog Fuel	40	--		0.0%	
Brushing and Rebuilding	--	--	\$7,995.51	2.1%	--
Winterization	--	4	\$540.00	0.1%	--
Subtotal	56234		\$349,333.10		\$6.21
Activity	COTR Hours *	Personnel Hours **	Total Costs (\$)	Percent of Grand Total	
Project Implementation					
Mapping	91		\$1,631.63	0.4%	
Brushing/Road Rebuilding	50	252	\$5,936.50	1.6%	
Prescriptions and Layout	16	6	\$406.88	0.1%	
Aerial Photo Interpretation	30		\$537.90	0.1%	
Surveying	90	90	\$3,413.70	0.9%	
Contract Preparation	5		\$89.65	0.0%	
Contract Administration/					
Heavy Equipment Supervision	572		\$10,255.96	2.7%	
Photo Documentation	5		\$89.65	0.0%	
Report Writing	90		\$1,613.70	0.4%	
Subtotal	949	348	\$23,975.57		
Grand Total \$373,975.67					
* COTR hourly wage \$17.93 per hour					
** Personnel hourly wage estimated at \$20.00 per hour					

Geology

The AA1/AA2 project area primarily underlain by the Prairie Creek Formation. The eastern portion of the project area is close to the Lost Man fault contact with the Franciscan Formation.

The Prairie Creek Formation represents the onshore and nearshore portion of an extensive sedimentary sequence deposited near the mouth of the Klamath River. It is dominantly

composed of fluvial sediments but also includes nearshore marine, beach, and estuarine deposits. Macro faunal fossils constrain the maximum age of the Prairie Creek Formation to 2-4 Ma. (Kelsey and Trexlor, 1989).

Kelsey and Trexlor (1989) described three sections through the Prairie Creek Formation, one of which is in Larry Damm Creek, near the 560 and 540 roads, and south west of the AA1/AA2 road complex. Here, the first 60 meters of sediments deposited on the Franciscan graywacke are medium to fine-grained sands. Above this, the section is dominated by sandstone and mudstone, with some intervals rich in clay and others consisting of massive conglomerate. Above 175 meters, the section becomes more conglomeratic and generally coarser.

Prairie Creek sediments were deposited with angular unconformity on the Jurassic-Cretaceous Franciscan Assemblage. In the Lost Man Creek area, the Franciscan is designated as the coherent unit of Lack's Creek (Harden et al., 1982). Harden et al (1982) describes the predominant rock types of the unit as coherent sandstone and interbedded sandstone and mudstone with rhythmic bedding and internal sedimentary structures typical of turbidites. Sandstone occurs as massive beds up to 10 meters thick, but most beds are between 0.1 and 3 meters thick with thinner mudstone interbeds; individual beds cannot be traced laterally for more than 100 meters due to complex folding and faulting (Harden et al., 1982).

The Prairie Creek Formation and the coherent unit of Lack's Creek are juxtaposed along the Lost Man Fault, a high angle fault trending north-northwest to south-southeast near the eastern portion of the project area (Kelsey and Trexlor, 1989). According to Kelsey and Trexlor (1989), the Lost Man Fault displaces the Franciscan basement upward along its east side, exposing it near the headwaters of Larry Damm Creek. Activity of the Lost Man Fault during the late Pleistocene to Holocene is not known (Kelsey and Trexlor, 1989).

Geomorphology

The geomorphic processes acting within the project area are a direct result of the physical characteristics of the bedrock units, high rainfall, and recent disturbance by intensive logging and road building activities. The unconsolidated sediments of the Prairie Creek Formation are readily mobilized by surface runoff, especially where the sediments have been cut and sidecast to construct roads and lay-outs, and where natural drainage patterns have been obliterated by logging disturbances. These sediments are also susceptible to natural and disturbance-induced mass wasting processes.

The eastern contact between the Prairie Creek Formation and the Franciscan (east and upslope of the project area) is a probable hydrologic boundary and a potential zone of instability; groundwater that accumulates in the porous Prairie Creek "cap-rock" is likely to accumulate and move along the buried valleys of the ancient surface of the Franciscan Assemblage, and come to the surface where the fault exposes the contact. The steep slopes of the fault scarp below tend to facilitate the formation of debris flows along this contact, with the debris flow deposits influencing the stream morphology in the easternmost part of the project area.

The tributaries in the remainder of the AA1 and AA2 project area exhibit steep slopes, narrow, confined canyons, and high-energy stream flow. As the tributary streams near their confluences with Larry Damm Creek, the terrain is gentler and streams are less confined; sediment tends to accumulate in these areas.

Timber Harvest History

Timber harvesting in Unit 02-04 occurred between 1962 and 1966, prior to the establishment of the California Forest Practice Rules. The area was clear-cut logged and heavily tractor-yarded by Arcata Redwood Company. The Arcata Redwood Company lands suffered extreme ground disturbance due to a combination of factors including the recently increased power developments in large bulldozers; old growth logging and tractor-yarding methods of the period; construction of large haul roads and landings with little regard for preserving natural drainage networks; and highly remoldable unconsolidated substrate of the Prairie Creek Formation. Imminent park expansion also influenced the logging activities in the Larry Damm watershed (Franke and others, personal communications, 2002).

Erosional Features

The timber harvest practices described above, in combination with major storm events in 1964, 1972, and 1975, caused major disruptions to the natural hydrologic conditions including the formation of large gullies in stream crossing, landing and sidecast fills, slope failures due to diversions of surface and stream flows, and chronic road slumping of sections of the AA1 road along Larry Damm Creek. These conditions have led to increased sedimentation in Larry Damm Creek and its associated tributaries. While much erosion had occurred by 2002, there was still the potential for tremendous quantities of future erosion if the remaining road and landing fills were not untreated. This area was prioritized for watershed restoration work due to the threat it posed to the downstream anadromous fish habitat and federally listed threatened species.

The greatest erosion potential identified in Unit 02-04 was associated with the three landings built in the tributaries to Larry Damm Creek (RX1, RX3 and RX16). These landings buried the stream courses with as much as 25 ft. of fill and organic debris. The tributary streams flowed subsurface through the landings much of the time. Numerous sinkholes had developed in the landings as woody debris rotted and collapsed. Surface flow that did occur, occurred during high flow periods, cutting large gullies through the landings, and triggering failures along the outboard edges. Even though only a small proportion of each landing had failed at the time of mapping, the sediment had aggraded the tributary channels downstream, and delivered large amounts of sediment to Larry Damm Creek. There was potential for far greater damage to still occur if the landings were not removed.

ADD DISCUSSION OF ROAD FILL FAILURES ALONG LDC

Slopes above the AA1/AA2 were characterized by intense skid trail networks that essentially

became the new hillslope drainage pattern. Many of the prominent stream courses were utilized as skidding corridors, destroying the natural stream course form and function. These skid trail networks were in an advanced stage of erosion and consequently, the benefits of treating these upslope features were not recognized as warranting the degree of re-disturbance that would result from equipment operations. **ADD EROSION POTENTIAL DISCUSSION.**

Threatened and Endangered Species Concerns and Project Work Schedule

Redwood National and State Parks are home to five species listed as threatened under the Endangered Species Act and that are potentially effected by watershed restoration projects; marbled murrelet (*Brachyramphus marmoratus*), northern spotted owl (*Strix occidentalis caurina*), Southern Oregon/Northern California Coasts coho salmon (*Oncorhynchus kisutch*), California Coastal chinook salmon (*Oncorhynchus tshawytscha*), and Northern California steelhead trout (*Oncorhynchus mykiss*).

With respect to terrestrial species, the U.S. Fish & Wildlife Service (FWS), as administrator of the Endangered Species Act, set noise restriction guidelines for management projects that do not remove or degrade suitable habitat for both the northern spotted owl and the marbled murrelet. These noise restrictions are designed to reduce human impact to nesting sites during the breeding season and apply to management projects that are located within a ¼ mile radius of suitable habitat. Additionally, FWS may impose restrictions due to impacts to foraging habitat. Project 02-04 was located entirely outside of the ¼ mile radius for suitable habitat and therefore was excluded from the noise restrictions. The second growth trees in the area are too young (< 40 yrs.) to provide suitable foraging habitat.

With respect to aquatic species, the National Marine Fisheries service (NMFS), as administrator of the Endangered Species Act, set restrictions and guidelines for management projects requirements to minimize short-term adverse effects to aquatic habitat and listed species of Pacific salmonids (coho, chinook, and steelhead). These restrictions and guidelines include the implementation of erosion control methods such as the distribution of woody debris along and in stream channels, and minimizing the disturbance to existing riparian cover along non-fish bearing and fish bearing streams. They also define the work season as June 15 to October 15 of each year. For a complete list of the required measures to be taken to minimize impacts to aquatic threatened species, see Appendix 1.

Heavy equipment typically operated 10 hours per day, 50 hours per week. Heavy equipment operations on Unit 02-04 began August 20 and were completed October 24, 2002. The NMFS extended the work season past October 15 due to favorable weather in the later part of October.

Project Implementation

Restoration work focused on reducing accelerated erosion and restoring the land to a condition similar to what would have existed without human disturbance by restoring natural hydrologic and geomorphic conditions. The work included complete excavation of road fill

from stream and swale crossings, complete excavation of perched fill along the road, and reconstruction of ridges using fill excavated from stream and swale crossings. A summary of restoration tasks and associated costs is shown in Table 1.

Two roads, the AA1 and the AA2, were treated. The majority of the work on the AA1 involved three stream crossings, two of which were used as landings, and one of which was flowing during the time of excavation. Between these crossings, a total of 701 ft. of outslowing and 898 ft. of export outslowing along Larry Damm Creek was completed. Work on the AA2 work involved excavating an approximately 1,000 ft. long section of a tributary to Larry Damm Creek that was buried by a landing. All treatments are described in narrative format below. Volumes, production rates and costs associated with the actual heavy equipment phase of the restoration are detailed in Tables 2, 3, 4, and 5. Variations in production rates were the result of site specific conditions.

The 02-04 project (AA1/AA2) was awarded to Z Logging of Orick, California, (contract number 1443-CX-8530-99-006; delivery order number T8530-02-0029) and heavy equipment work began on August 20 and was completed on October 24, 2002. Equipment used for this contract was owned by the contractor and included a Caterpillar® D8K bulldozer with a winch, a Caterpillar® D8L bulldozer, a Caterpillar® 330 excavator with a 3.5 cubic yard bucket and a thumb, a Caterpillar® D6H with a winch, and a Caterpillar® D6H with a grapple hook. Equipment operators were Jim Ponts primarily on the D8K, Albert Zuber primarily on the D8L, Chris Mills primarily on the 330, and Paul Johnson primarily on the D6H winch. Larry Zuber also operated equipment as needed, and operators occasionally switched equipment when the job required.

The project geologist, Ingrid Corson, mapped geomorphic and hydrologic features, prescribed restoration treatments, surveyed cut and fill volumes before and after excavation, oversaw heavy equipment operations as the contracting officer's technical representative (COTR), photo documented work, compiled costs and data, and wrote the final report.

TABLES 2, 3, 4

Table 5

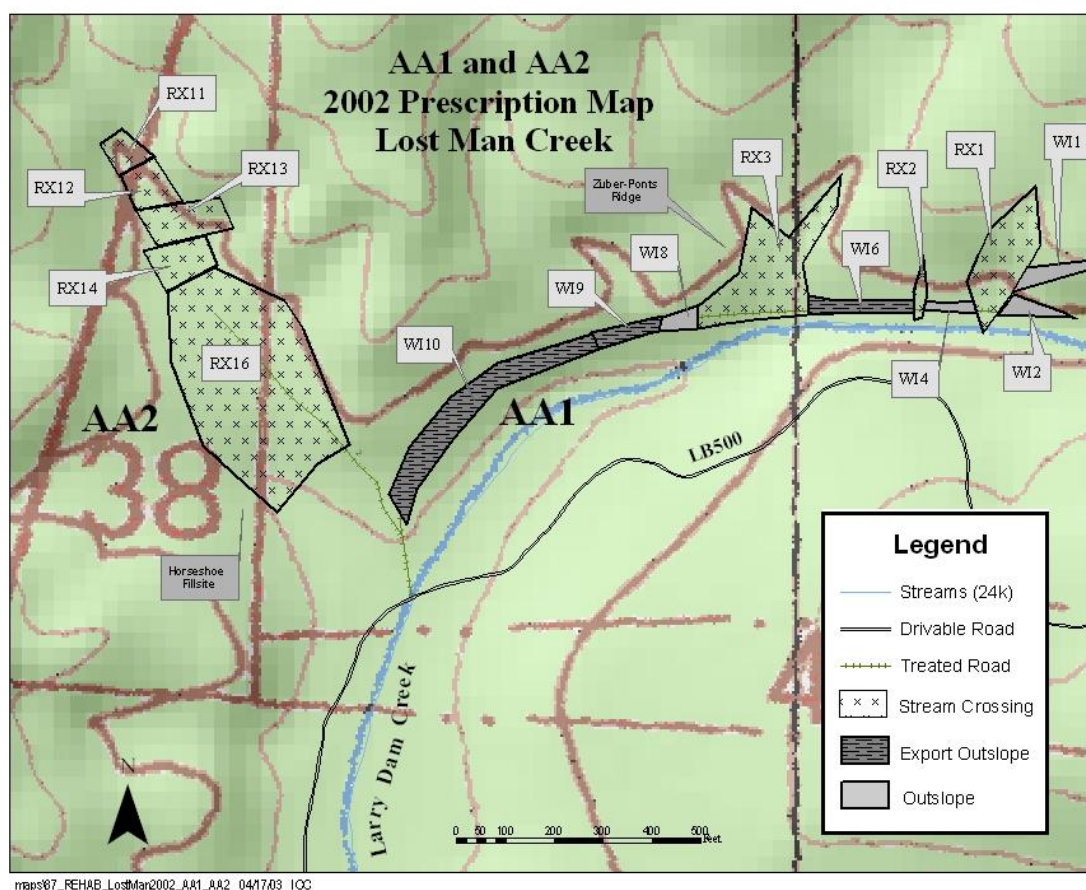


Figure 3. Larry Damm Creek AA1/AA2 2002 prescription map. Map shows stream crossing, export outslope, and outslope areas.

Stream Crossings

AA1

RX1

RX-1 was created by filling the lower reaches of a steep stream that enters Larry Damm Creek at almost a right angle. Prior to excavation there was an approximately 150 ft. long, 20 ft. tall wall of fill perched alongside Larry Damm Creek. Numerous active gullies riddled this fill, some as deep as 12 ft. There were also tension cracks and buried large woody debris (LWD) evident in the wall of fill.

In 1997, an upslope and upstream landslide buried Larry Damm Creek to a point approximately 400 ft. downstream of the confluence of RX-1's creek with Larry Damm; the downstream end of this deposit consists of a large logjam. The surface of the deposit in Larry Damm Creek is wide and flat and composed of angular rocks. At the time of excavation,

Larry Damm Creek flowed on the surface in a naturally levied channel to a point approximately 20 ft. above the confluence with RX-1's creek. At this point Larry Damm ran subsurface, not emerging until just downstream of the logjam.



Figure 4. Pre-excavation view of RX1, Work Item 3, looking downstream from the middle of the Larry Damm Creek debris deposit just upstream its the confluence with Rx-1's creek. The right side of the image is a 20 foot high wall of fill covered in vegetation.

RX-1 was a 7,864 yd³ crossing and the first crossing of the contract. It took 95.5 equipment hours to complete using the D8K, D8L, and 330 excavator, and yielded an average production rate of 82 yds³/hr. From top to bottom, RX-1 was approximately 300 ft. long, widening from top towards the bottom, and the excavation was approximately 180 ft. wide and 20 ft. deep at the confluence with Larry Damm. Most of the fill from RX-1 was returned to the hillside just west of the crossing. RX-1 was mostly dry during excavation; the only wet areas coincided with trapped subsurface water associated with buried stumps and buried LWD. During the early December rain storm event, RX-1 had surface flow in the channel.

There was a fair amount of brush in the form of large alder trees that needed to be located out of the immediate work area before excavation began and initially some extra time was spent moving piles of brush around. Eventually, the contractors developed a system for getting brush out of the way during excavation while having it readily accessible for spreading over finished surfaces per the erosion control guidelines (Klein, 2002). The production rate that was attained, 82 yds³/hr, is higher than the project average due to dry soils, short pushes to fillsites, and easy topography encountered. This was the first major bid item undertaken for this equipment season and it took a while for the contractors to develop the communication and coordination required to work at an efficient rate.

The excavation of RX-1 was fairly straightforward and began with bulldozer work at the downstream end of the excavation. The fill was dry and easily pushed uphill to local fillsites. There were many buried wood chunks in the lower third of the crossing and most of these were placed along the banks of RX-1 and along its channel to help trap any excess sediment that might be carried down the channel after excavation. As this tributary is a headwater stream and not a fish bearing stream there were no concerns that the LWD placed in the channel would create barriers to anadromous fish passage.



Figure 5. The finished slope of RX1, Work Item 3, looking downstream from the middle of the Larry Damm Creek debris deposit just upstream its the confluence with RX-1's creek. The wall of fill has been removed and the finished surface covered with vegetation.

The original ground exposed during excavation varied. We found darkly colored in-place top soil, old redwood needle layers, clay layers, and hard blue beach gravel layers with orange beach gravels below. There were a few large rocks uncovered at the confluence with Larry Damm Creek. A handful of large in-place stumps were exposed during the excavation and these, along with soil type and structure, helped to define the original topography of the site.

On December 14, 2002, during the first site visit (during the first big storm of the winter) I noticed that the RX-1 excavation (monitoring site 3) tributary was carrying fines and in a few places was quite cloudy. This cloudiness was most likely due to a few small (1-3 cubic foot blocks) settling in to tributary channel as the channel banks adjusted in the heavy rains. On

March 27, 2003 I noticed that the tributary creek was running clear while Larry Damm Creek was visibly cloudy. By April 24, 2003 there seemed to be no new adjustments at this site. The two shallow adjustments on the right bank of the crossing occurred in steep uncompacted soil placed by the excavator as it was working away from the site.

RX2

The tributary of RX-2 is a small steep creek entering a remnant channel of Larry Damm Creek approximately 100 ft. below the 1997 landslide logjam. Larry Damm Creek is very complex in this area and it appears to have been diverted due to the 1997 landslide. The current active channel is roughly 30 ft. from the downstream end of RX-2, on the other side of a tall island. Prior to excavation, the bottom $\frac{1}{4}$ of RX-2 was buried under the AA1 haul road, while the upper $\frac{3}{4}$ was buried by skid roads and a small mid-channel landing. Prior to excavation, there were 2-4 ft. deep gullies, evidence of down-cutting and subsurface flow, and sizable tension cracks in the fill along Larry Damm Creek. The banks along RX-2 are considerably steeper than those of RX-1, especially the right bank of RX-2, which contained some pockets of perched fill.

RX2, Work Item 5, was a 2,335 yd³ crossing, took 33.25 hours to complete using the D8K, D8L, and 330 excavator, and yielded a production rate of 70 yds³/hr (Table 2). From top to bottom, RX-2 crossing was approximately 300 ft. long, widening from approximately 15 ft. at the top to 30 ft. at the bottom. The deepest excavation depth (roughly 9 ft.) was at the top where the upper section of the small landing was removed. Most of the fill from the excavation was used to re-form the ridge between RX-1 and Rx-2. RX-2 was dry during excavation except for some wetness along the channel bottom. During the early December rain storm event RX-2 had surface flow in the channel.

The excavation of RX-2 was relatively slow due to the steep side slopes and tight work area. Because RX-2 was so narrow it restricted the swing movements of the excavator and it was not always possible to have more than one piece of equipment working at the same time in the area. Aside from the tight and steep working environment the excavation went smoothly. The fill was mostly dry and easy to push. There was plenty of brush to cover the steep finished slopes and 20 yards of hog fuel were delivered to the lower $\frac{1}{3}$ of RX-2 and subsequently spread by the excavator. There was some buried wood in the upper channel and some in the lower channel but not much in the middle. The original ground exposed during excavation varied and included some areas of in-place top soil, pockets of angular rock, and areas of clay. There were two large in-place stumps and some live redwood stump sprout clusters that helped to define the topography. We also exposed one large buried stump that helped to define the lower right bank.

RX3

RX-3 was a landing that filled in a naturally wide flat spot near the confluence of two creeks that subsequently flow into Larry Damm Creek. It seems that this confluence area might actually be an ancient landslide deposit, with the tributary entering Larry Damm at the

upstream end of the ancient log jam as evidenced by some alluvial deposits that are uniform in size and color (blue unconsolidated pea-sized gravels) that do not match the other gravels found in the surrounding ridges. Also, the current elevation of Larry Damm Creek is actually higher than the pre-logging elevation of the tributary creek. The current Larry Damm Creek level may be higher due to channel sedimentation initiated by logging activities.

Prior to excavation, there was a large swampy area coinciding with the confluence of the two smaller tributaries and that extended to the banks above Larry Damm Creek. The swampy area had standing water, surface and subsurface flow, sink holes and a 3 ft. deep gully that down-cut to a large buried log running parallel to Larry Damm Creek. In the upper reach of the excavation on the left fork, where the channel sides steepen, there were large sinkholes, and large buried stumps and logs. The upper reach of the right fork contained a pond flowing into a short but well-defined meandering channel incising through a large layout. The channel sides were steep on both creeks (60%) but especially steep on the right fork.



Figure 6. RX3, Work Item 7, prior to excavation viewed from across Larry Damm Creek. The view is up towards the confluence of the two tributaries.

RX3 was an 8,694 yd³ crossing and took 211.5 equipment hours to complete using the D8K, D8L, and 330 excavator. The average production rate was 41 yds³/hr. This is a low production rate and reflects the difficulty of this excavation. Production was slow for a few reasons, including long push distances, steep pushes, and a tight and steep working environment. While the lower portion of the excavation was wide and flat from downstream of the confluence of the two forks to the confluence with Larry Damm Creek, the upper reaches of both forks were very steep (>60%) and quite narrow. The 330 excavator was unable to swing in the upper sections of the right fork and had to constantly drag excavated

fill backwards out of the confines of the tight slopes, climb over the fill pile and walk back into the steep channel so the D8K bulldozer could push the spoils pile away. The right fork was too narrow and steep for the D8's so they were excluded from this portion of the excavation until just above the confluence with the left fork.



Figure 7. RX3, Work Item 7, after excavation viewed from across Larry Damm Creek. The view is up towards the confluence of the two tributaries. Notice the twin second growth redwoods in Figures 6 and 7.

Due to the proximity of RX-3 to Larry Damm Creek and the surrounding steep topography, fill sites were limited. Most of the fill from this excavation went into the rebuilding of a ridge to the west. This fillsite was accessed by a steep push road with a turn at the top and while the site took lots of fill, it was a hard and slow push to the top.

The lower section of RX-3 was the most interesting and difficult to design due to its proximity to the confluence with Larry Damm Creek and to the active geomorphology of the area. There were two unusual issues that needed to be dealt with in this confluence area; 1) Larry Damm Creek being higher in elevation than the newly excavated, pre-logging elevation of the tributary and; 2) the spring at the base of a cutbank. While these issues were not the only challenges to this excavation, they were site specific enough to mention here.

The first difficulty we encountered in RX-3 was how to join the tributary to Larry Damm Creek. The lower left bank of the tributary at the confluence is marked by a very large and very old burned out and partially buried snag. As excavation proceeded it became apparent

that the contemporary Larry Damm Creek elevation was actually higher than the pre-logging tributary elevation. There was a unique layer of blue unconsolidated gravel that may be an old alluvial or landslide deposit in the confluence area. This blue layer comprised some of the material burying the large snag and didn't hold together well when disturbed or wet. Instead of completely excavating this blue layer near the confluence, we created a large settling pond in the middle of the tributary. This pond acts to trap sediment before it enters Larry Damm Creek and also allowed us to blend the two actively flowing channels without rerouting either one. Because of this elevation difference we also left some fill and buried LWD on the right bank of the tributary just downstream of the confluence with Larry Damm Creek. This area seems to be part of an old logjam and to excavate it would have required disturbing the flowing Larry Damm Creek and completely eliminating the existing riparian buffer. Farther up the channel we exposed a similar dry blue gravel layer, and excavated it to reveal old top soil and root mats below. As there was evidence of pre-logging top soil, we fully excavated the blue layer in this area. One thing we learned here was that if you are following a wet channel and hit a dry gravel layer, that dry layer is most likely fill in the channel and should be excavated.

A shallow adjustment originating mid-slope on the left bank of RX-3 (monitoring site 2) occurred during the first big December storm. The upper slope is a fillsite and the slide is in the same location as a steep push road used to access the fillsite. The push road was removed and the hillslope shaped by the excavator. The finishing fill was not compacted by the bulldozer. The scarp was 1.5 feet tall on March 27, 2003, and there was no delivery to Larry Damm Creek as of April 24, 2003.



Figure 8. RX3, Work Item 7, during excavation viewed from the lower left bank. The bluish unconsolidated gravel can be seen above water level and

around the partially buried stump just left of center.

The second site-specific challenge was how to treat a spring at the base of a 12 ft. tall cutbank on the lower right bank of RX-3. It is current operating procedure to leave all springs in the Prairie Creek Formation uncovered, so we left this cutbank unfilled.



Figure 9. RX3, Work Item 7, finished slopes viewed from the lower left bank up to the top of RX3. The springy cutbank is on the center left edge of the photo and the settling pond is just out of view in the bottom right corner.

AA2

Volumes of fill moved on the AA2 were not surveyed due to time constraints, but were estimated by applying production rates for similar work. Production rates were also verified by periodically keeping track of the number of buckets or blades of fill moved during a given time period. Production rates were low on the AA2 due to long pushes, steep terrain, and wet fill.

The primary tributary impacted by the AA2 Road is a relatively steep stream entering Larry Damm Creek through a culvert on the Lower B500. Upstream of the culvert the creek is extremely aggraded for roughly 300 ft and then completely buried by a large landing. There is a small haul road that leads upstream from the top of the landing that also buried the upper reaches of the creek. At some time between 1966 and 1972 the downstream edge of the landing failed ($\sim 1,500 \text{ yd}^3$), leaving a horseshoe shaped scar. Prior to excavation, there were

gullies, large tension cracks and sink holes along the downstream edges of this landing, as well as along the entire length of the landing and upstream haul road. Stream crossing excavation work was broken into five different work items to facilitate contractor communication and contract invoicing. The first four stream crossings, RX11-14, are relatively small ($\leq 2,000 \text{ yd}^3$) and involved moderate push distances, and the fifth, RX16, was very large ($\sim 19,500 \text{ yd}^3$), and involved long steep pushes.

RX11, RX12, RX13, RX14

RX11 (WI11) was the upper most excavation. It was a straight forward excavation that took 35.75 equipment hours using the D8K, D8L, and 330 excavator and during which time approximately $2,000 \text{ yd}^3$ of fill were removed from the buried stream channel ($56 \text{ yd}^3/\text{hr}$ production rate, Table 2). The upper extent of RX11 was just below an old log jam and small landslide scar on the left slope. The valley slopes were relatively steep (30-60%) and most of the fill was pushed to a fillsite on the left bank of RX16.

RX12 (WI12), adjacent to RX11 on the downstream side, was a straight forward excavation that took 20.5 equipment hours using the D8K, D8L, and 330 excavator and during which time approximately $1,100 \text{ yd}^3$ of fill were excavated ($54 \text{ yd}^3/\text{hr}$ production rate). The fill from this stream channel excavation was pushed approximately 300 ft. to the same fillsite as was used for RX11. In a few spots throughout this reach there was evidence of periodic high stream flow on the surface, but no water flow was encountered until the old stream channel was exposed.

RX13 (WI13), adjacent to RX12 on the downstream side, incorporated an excavation of a portion of the main stem of RX16's creek and a shallow tributary that entered from the left bank. This excavation was more difficult than the upstream ones as the side banks become steeper through this reach, and because there were a few large buried stumps that made heavy equipment maneuvering difficult. It took 26.5 equipment hours to excavate approximately $1,200 \text{ yd}^3$ from RX13 using the D8K, D8L, and 330 excavator ($45 \text{ yd}^3/\text{hr}$ production rate).

Adjacent to RX13 on the downstream side was RX14 (WI14). This excavation included an area associated with the confluence of a flowing tributary entering RX16's creek from the right bank. While this tributary was larger than RX13's, the excavations were similar and large stumps and steep valley slopes continued to impede heavy equipment maneuvers. RX14 took 56 equipment hours using the D8K, D8L, and 330 excavator, and approximately $2,500 \text{ yd}^3$ of fill were excavated ($45 \text{ yd}^3/\text{hr}$ production rate). Fill was pushed a distance of over 500 ft. to a fillsite on the ridge on the southwest side of RX16.

RX16

RX16 (Work Item (WI) 16) was the largest work item and largest crossing undertaken in the AA1/AA2 road complex. A large landing had been constructed at the confluence of two small streams, several hundred feet upstream of their confluence with the mainstem of Larry Damm Creek. The excavation of RX 16 in 2002 was limited to the left or northwesterly-trending

fork. The right fork will be excavated in 2003. There were also several small tributaries that joined the left fork, upstream of the actual landing, that were crossed by skid roads. These crossings (RX 11-14) all coalesced into what now appears to be one very large excavation.

RX16 was an approximately 19,500 yd³ crossing; this volume was estimated based on equipment excavation hours and estimated production rates (timing of the work precluded surveying). It took 513.75 hours to complete using the D8K, D8L, D6H winch, D6H grapple, and 330 excavator. Production rates were estimated to be low, at 38 yd³/hr, due to the steep, long (800 ft. average) push to the fillsite on the ridge to the south. The steep, long push required the fill to be passed from the excavator, to three bulldozers before arriving at its end destination. No other local fillsites were available, the alternative being trucking fill, which would have been more expensive.

The scarcity of fillsites in the area is due mostly to the steep topography. The fillsite was on a long and steeply sloping ridge. All that remained of the ridge after logging were numerous one-blade-wide through-cuts into the gravely bedrock. Some of these through-cuts were over 10 ft. deep and separated by less than 15 ft. of less disturbed ground. Many of these through-cuts were created as layouts or as source sites for material needed to build layouts, and, according to Paul Johnson and Jim Anderson, contractors who logged in the area in their youth, it was easier to bring fill down the hill with every skidded log rather than pick up the skidder blade and leave the material in place. The blade was also used as a brake on steep slopes. The near complete disturbance of the fillsite area, caused by logging practices and combined with the unconsolidated nature of the underlying bedrock, is similar to the disturbance level elsewhere in the AA1/AA2 road complex area.



Figure 10. Fillsite to southwest of RX16. Finished slopes viewed from the lower left bank looking downstream. Settling pond is in the lower center and the unexcavated right fork is in the middle right of the photo.

The excavation of RX-16 went relatively smoothly despite being slow. Prior to excavation the stream ran completely subsurface from the upstream end of the landing to the culvert on the Lower B500 but there were wet areas evident. Excavation began at the downstream end of the landing where we dug a settling pond to trap sediment from the excavated area. The pond did not fill despite the inflow of water, indicating a subsurface conduit. Once the settling pond was complete and most of the lower reach of RX16 was dished down to damp fill, excavation resumed at the upstream end of the landing. The contractors chose to proceed with excavation at the top of the crossing out of necessity. Due to the narrow and steep nature of the valley walls there was no other practical solution. Proceeding from the top of a flowing crossing does have its drawbacks and in this case the contractors did have to push wet fill up to the fillsite. This was usually only an issue in the morning, and by mid-day the excavator was able to catch-up with the water and able to provide the bulldozers with drier fill.

A few unexpected developments made RX-16 interesting. The first development was uncovering an enormous in-place stump in the stream channel. We also uncovered numerous very large redwood root-wads that appeared to have been pushed down the left slope and into the channel, as evidenced in part by the unusual lack of stumps on the adjacent left slope. Along with the root-wads there were a number of huge (wide and long) fir logs in the

channel. While all this wood, whether in-place or not, required time and equipment and contributed to the low production rate, it also helped to define the original topography. A second development involved the treeless left slope. This slope turned out to be more of a wall than a gently sloping valley side. We found intact and in-place layers of original topsoil on the left bank and the underlying ground was very hard. The final development worthy of discussion pertains to mulching finished slopes. The steep valley slopes provided an extra challenge to the heavy equipment operators as it was very difficult to maneuver on the steep slopes, much less push mulch material around. We also encountered a few situations where the slopes were too steep to hold mulch, such as the extremely steep left slope of RX16. This finished slope is mostly without mulch because, despite the consistency of the mulch or the placement of the mulch, nothing would remain. Elsewhere, the contractors did an excellent job of meeting the mulching guidelines outlined in the aquatic habitat Biological Assessment and should be commended for their commitment to the goals described therein. They took the extra time necessary to spread mulch evenly and completely on all slopes where it would stay.

There were two notable adjustments in RX-16 (monitoring site 1), both occurring during the December 14, 2002 storm. The shallow adjustment in the push road below the fillsite occurred in fill placed by the excavator as it was working out of a site. This steep fill was not compacted by a bulldozer. There is also a small depression at the top of the slope where the excavator placed fill blindly. This depression collects and holds water and may contribute to the saturation of uncompacted soils. The other notable adjustment also occurred in excavator-placed fill at the bottom of a through-cut. There was also a small depression left by the excavator working blindly out and off this steep slope that may have contributed to the shallow failure by ponding water and causing the fill to saturate. During the December 14, 2002 storm while walking to the upstream grab sample site in saturated soils I actually caused a small (< 1 cubic yard) slide off the steep left bank with some delivery to tributary channel above the settling pond. There were no noticeable changes to the adjustments as of April 24, 2002.



Figure 11. RX16 (Work item 16) finished slopes viewed from the lower left bank looking upstream to the top of excavation. The enormous in-place stump is in the left center of the photo.

Export Outsloping

Export outsloping work items included WI6, WI9, and WI10 on the AA1, and there were no export outsloping work items on the AA2. All three export outsloping work items became considerably larger than designed in part due to topographic indicators uncovered during excavation, and in part due to an early attempt to leave as much of the existing riparian buffer intact. During a pre-excavation peer review field trip, concerns were raised regarding the potential elimination of the riparian buffer along Larry Damm Creek. It was suggested that we should avoid disrupting this barrier during the project implementation. In some areas, however, once excavation began, it became apparent that it was more important and practical to remove the large amounts of fill perched above Larry Damm Creek than leave the fill in order to preserve the thick alder band standing on the bank of the creek. The topography resulting from complete recontouring in these areas was more stable than what was initially designed and, in most cases, still contained at least a narrow riparian buffer.

Work item six was a section of the AA1 between RX2 and RX3 that ran along Larry Damm Creek. Most of WI6 fill was pushed to the ridge on the opposite side of RX3, to the west. There were approximately 2,000 yds³ moved in 38.75 equipment hours using the D8K, D8L, and the 330 excavator (Table 3). The production rate was 52 yds³/hr and reflects the long push distance and the care taken to not disturb the riparian buffer along Larry Damm Creek. During excavation, we uncovered a buried stump and a buried wind-throw, indicating that the

pre-logging surface to be much deeper than originally estimated. In fact, in this area the pre-logging ground surface was lower than the contemporary Larry Damm Creek; similar to the area at the bottom of RX3. The extra fill was perched on a steep slope along the Larry Damm Creek and needed to be removed. However, we could not excavate to original all the way to Larry Damm Creek as this would have re-routed Larry Damm Creek. Instead, we shaped a stable low berm between Larry Damm Creek and the completely excavated WI6 section and created an outlet at the downstream end. The resulting topography included an area that will be wet during the rainy season. This change in design allowed the existing Larry Damm Creek riparian buffer to remain intact. Also, the final shape of the bank along Larry Damm Creek is natural in appearance and is geomorphologically stable.

Work Item nine involved outslowing a narrow section of the AA1 perched above Larry Damm Creek on a steep slope and exporting the fill down the road through WI10. Approximately 1,750 yds³ were moved in 24.25 equipment hours using the D8K, D8L, and the 330 excavator (Table 3). The production rate for this work item was 72 yds³/hr; slightly higher than the other export outslows because the contractors had an efficient system in place and the excavation was fairly straight forward (Figure 12). This excavation became larger than designed when a stump with a large alder growing out the top that was thought to be in-place turned out to be a cut wind-throw buried in the perched fill along Larry Damm Creek. What was thought to be a 5 ft. tall stump became a 20 ft. cut section and what was thought to be the root swell was actually part of the upper section of the tree. I learned that any stump with a flat cut is not an in-place stump and instead, must be a buried log or the stump of a cut wind-throw that is no longer in place.



Figure 12. Export outslope work items 9 and 10 from work item 8. Larry Damm Creek flows from the bottom left towards the upper center left.

Work item ten was similar to WI9: it was narrow, along Larry Damm Creek, and became larger than design for similar reasons as those mentioned above. Approximately 2,950 yds³ were moved in 52.25 equipment hours using the D8K, D8L, and the 330 excavator (Table 3).

The production rate of 56 yds³/hr for this work item was low due to the narrowness of the road (requiring the excavator to pass fill and then wait for the bulldozers to push the fill away), and the long push distance to the fillsite. The discovery of two buried stumps along Larry Damm Creek near the end of the AA1 caused the excavation to become deeper than designed and resulted in larger final volumes and to achieve a stable topography along the creek.

Outsloping

Table 4 summarizes the volumes, equipment hours, and production rates of the seven outslope work items on the AA1. In general, production rates for outslope sections of the AA1 were higher than other prescriptions. The higher production rates were due to dry fill, short pushes, and the relatively gentle slopes associated with the AA1 outslopes. Most outslope prescriptions were adjacent to wide areas in the road where the D8L could easily access the fill. Work item one, a short outslope above WI2, became larger with the discovery of a swale in the middle of the road section. Work item two, a short outslope along a steep section of Larry Damm Creek, became larger with the discovery of a buried stump along the outboard edge of the road. Outslopes in WI5, WI9, and WI10 were all up slope work items that were not previously defined, arose during the developing excavation of adjacent prescriptions, and were executed to correct slope hydrology.

Non-Bid Items

Non-bid items are categorized as jobs that result in non-recoverable costs on the part of the contractor. These items are defined as time that is not directly attributable to any specific bid item. Table 6 provides a cost breakdown for Non-bid items.

Idle time represents the time a piece of equipment is inactive while work proceeds. Idle time differs from downtime in that the equipment is able to be used but the contractor or operator chooses not to use it. For this project, idle time was only recorded for times when a given piece of equipment was idle on a day when it was otherwise operating. For this contract, there were times when the contractor had more pieces of equipment on site than operators. The extra equipment allowed the contractor greater flexibility in day to day planning, and in approaching specific worksites.

Fueling equipment and routine servicing are also included as a non-bid item. These times are a given necessity for the operations of equipment but could not be attributed to a specific job item. Consequently, these are also looked upon as an inherent cost to the contractor.

Downtime occurs when equipment is unable to perform in its expected capacity. For this

contract, downtime was most often the result of mechanical failure, predominately the rupturing of a hydraulic line. Downtime also included time equipment was either stuck or assisting in the rescuing of stuck equipment.

Discussion time is defined as periods of time where equipment operations are interrupted by discussions pertaining to the job. Typically, operators would stop to discuss the progress of a particular phase of a bid item or develop a strategy for the work. Other discussion times included the contractor discussing the operations of the equipment. On occasion, the C.O.T.R. interrupted the operators to make sure that the specifications of the contract were understood and being met.

Table 6

Discussion

The removal of the AA1/AA2 road complex met the goals of National Park Service Management Policies (2001), the Redwood National and State Parks' General Management Plan/General Plan (2000), Statement for Management (1992), and Watershed Rehabilitation Plan (1981).

This project excavated approximately 56,230 yd³ of fill material from stream crossings and failing road benches. The project's total heavy equipment cost was \$349,333.10 with an average cost per cubic yard of \$6.21.

The implementation of this project effectively eliminated unnatural sediment sources associated with the roads and associated hillslopes. Diversion potentials along the treated road corridors were eliminated, and the potential for hillslope and sidecast failures reduced through the restoration of natural hillslope topography and drainage patterns. The recovery of nutrient and organic-rich soil should greatly speed the recovery of native vegetation. The restoration work will reduce the delivery of unnaturally large quantities of sediment to Larry Damm Creek, and in the long term, will help preserve the prime aquatic and forest resources in the lower Lost Man Creek watershed. It has also eliminated the costly drain on the parks' road maintenance resources.

There have been short-term impacts to local stream turbidity levels from project implementation, as the excavations went through minor adjustments during the first winter. Much effort was expended to reduce post-excavation erosion by covering the finished slopes with mulch per the guidelines developed by Randy Klein and others in the aquatic Biological Assessment covering the Lost Man watershed restoration projects (Holden et al. 2002). The finished surfaces were covered with the brush removed prior to excavation. To help achieve surface erosion mitigation requirements on some of the more sparsely mulched areas of RX1 and RX2, trees on the periphery of the excavations were felled by park trail crews. Erosion control mitigation requirements were also achieved by hand spreading hog fuel (redwood bark) on steep slopes and/or in areas adjacent to streams. Hand spreading hog fuel was a slow, somewhat dangerous, and quite labor intensive method of meeting surface erosion guidelines. Some of the difficulty arose from the available methods of transporting the hog fuel to target sites. In most cases the 330 excavator brought a bucket load to the work area in the morning. The hog fuel was typically deposited in a pile as close as possible to target sites and then carried in a five gallon bucket by the COTR and hand spread where needed. It usually took over 30 minutes to hand spread 3 yd³ of this type of mulch if the hog fuel pile was close to target areas. Hog fuel piles were rarely close to the target areas. We did try to spread hog fuel with the 330 excavator on RX2, but with little success. The biggest problem with this method of mulching was that the excavator operator lacked accuracy, resulting in piles of hog fuel being dumped into the stream course that had to be subsequently spread by hand. If we could develop a cost effective method to supply hog fuel to the excavation area then hog fuel would be a good mulching substance as it is a natural native and effective mulch on gentle to moderate slopes. However, the results of post excavation discussions and peer reviews regarding the use of hog fuel deem hog fuel use as generally not a time and cost effective method of achieving mulching guidelines.

Acknowledgements

The restoration work accomplished by the completion of Unit 02-04 is the result of the dedication and hard work of numerous individuals. This report is a compilation of those efforts.

Thanks to Neal Youngblood, Mike Sanders, Greg Gibbs and Gilbert Craven, geologists at Redwood National Park, for assisting in contractual preparation, site investigation, and idea development. Thank you to Van Hare for his patience and map making skills. Many thanks to Dick Mayle and his crews for site preparation, surveying and enthusiasm. Finally, thanks to those who have come before us: for their words of wisdom, written words, and expertise.

References

Harden, D.R., H.M. Kelsey, S.D. Morrison, and T.A Stephens, 1982. Geologic map of the Redwood Creek drainage basin, Humboldt County, California. U.S. Geological Survey Water Resources Investigations, Open-file Report 81-496. 1 sheet.

Holden, Baker, Terry Spreiter, Mike Sanders, Neal Youngblood, Randy Klein and Gilbert Graven, eds., 2002. A Biological Assessment of Impacts to Aquatic Threatened Species from the Watershed Restoration Program in the Northern Portion of Lost Man Creek Watershed, Redwood National and State Parks, 2002.

Kelsey, H.M., and J.H. Trexlor, 1989. Pleistocene Deformation of a Portion of the Southern Cascadia Forearc: Prairie Creek Formation, Northern California. American Geophysical Union, Vol. 94, No. B10.

Narver, D.W., 1971. Effects of logging debris on fish production. In: Krygier, J.T. and J.D. Hall, eds. Forest land uses and stream environment; Proceedings of the symposium. Corvallis, Oregon. Oregon State University, Continuing Education Publications. p. 100-111.

Spreiter, T.A., 1979. Factors Affecting Gully Formation in Coastal San Mateo County, California. Stanford University Master's Thesis.

United States Congress, House, Committee on Government Operations, Forest Management and Redwood National Park. Hearings Before the Conservation, Energy, and Natural Resources Subcommittee, September 18, 1976. 94th Congress, 2nd Session.

Appendix 1: Measures Taken to Minimize Impacts to Threatened Species

From: A Biological Assessment of Impacts to Aquatic Threatened Species from the Watershed Restoration Program in the Northern Portion of Lost Man Creek Watershed, Redwood National and State Parks, 2002.

Post Excavation Monitoring

All completed projects are visited a number of times during the first winter, and photo-points established prior to excavation are re-photographed. The distribution of woody debris and rock in the excavated channel may be rearranged using hand tools, to minimize post-excavation erosion. Additional on- and off-site monitoring is described in the Post-excavation Erosion Control Plan in the appendix.

Measures Taken to Minimize Impacts to Threatened Species

- 1) RNSP geologists will continue to plan and design all excavation work. The geologist that planned and designed the work will continue to directly oversee all excavation work on the ground as it proceeds and follows the POST-EXCAVATION EROSION CONTROL GUIDELINES as written in Appendix 2.
- 2) A detailed, final project summary report, similar to those normally prepared by the parks, will be submitted to NMFS by the end of the July following project completion.
- 3) RNSP will ensure that erosion control measures are used to minimize short-term adverse effects to aquatic habitat and listed, proposed, or candidate species of Pacific salmonids.
- 4) Woody debris will be concentrated on finished slopes adjacent to stream crossings to reduce surface erosion, contribute to amounts of organic debris in the soil, encourage fungi, provide immediate cover for small terrestrial species and to speed recovery of native forest vegetation.
- 5) Large woody debris will be placed in the streams when completing crossing excavations. This will provide storage locations for trapping sediment that moves through the channel from natural upstream and post-excavation erosion, and provide immediate cover for aquatic/riparian species.
- 6) Riparian cover on fish-bearing streams and non fish-bearing (where non-fish bearing streams lead immediately into fish-bearing waters) will be protected wherever reasonably feasible, balancing quality and benefits of the riparian cover against risks of sediment delivery. Proposed treatments in

riparian areas will be reviewed by an interdisciplinary team prior to implementation; the team will include a park restoration geologist and a park fishery biologist.

7) All non-emergency project work will be completed during the normal operating season (NOS), that is, between June 15 and October 15 of each year. If more than 0.5 inches of rain is forecast during the dry season, project operations will temporarily cease and sites will be winterized. If periods of dry weather are predicted outside of the NOS, additional small work items may be done, if they can be completed within the window of predicted dry weather. Only those repairs needed to reduce risks from active erosion will be undertaken outside of the NOS, in coordination with NMFS.

8) Work sites will be winterized at the end of each day when significant rains are forecast that may cause unfinished excavations to erode. Winterization procedures are supervised at all times by RNSP geologists and involve taking measures necessary to minimize erosion on unfinished work surfaces. Winterization includes the following: smoothing unfinished surfaces to allow water to freely drain across them without concentrating or ponding; compacting unfinished surfaces where concentrated runoff may flow with an excavator bucket or similar to minimize surface erosion and the formation of rills; and installation of culverts, silt fences and other erosion control devices where necessary to convey concentrated water across unfinished surfaces, and trap eroded sediment before it leaves the work site.

9) Equipment, both hand tools and heavy equipment, will be inspected daily to check for leaks. Equipment that may leak lubricants or fuels into drainage will not be used until leaks are repaired. All equipment will be stored, serviced and fueled outside of riparian areas and away from stream crossings. Heavy equipment will be cleaned (e.g., power washed, steam cleaned) prior to use below the ordinary high water mark.

10) A spill plan and materials for spill containment will be available to onsite personnel and all personnel shall know how to use them. In the event of a spill, work shall be stopped immediately, clean up shall begin and the appropriate authorities will be notified.

11) Petroleum products, chemicals, fresh cement, deleterious materials, or water contaminated by the aforementioned shall not be allowed to enter flowing waters.

12) Disruption of natural hydrologic flow paths, including diversion of streamflow and interception of surface and subsurface flows, shall be minimized during excavation.

13) Adequate erosion control supplies (gravel, straw bales, shovels, etc.) shall be kept at all restoration sites to ensure materials are kept out of water bodies.

14) Water drafting from fish-bearing streams will be conducted only at sites approved by a park fishery biologist, and shall be done in accordance with NMFS's "Water Drafting Specifications" (attached in Appendix 4)

15) Any disturbed ground must receive appropriate erosion control treatment prior to the beginning of the wet season. (See Appendix 2)

16) Streams with significant surface flow capable of sediment transport off-site must be diverted around excavation areas. The diverted flows shall be returned to their natural streamcourse as soon as restoration is complete and prior to the rainy season. Any turbid wastewater from project activities and de-watering is disposed of off-site in a location that will not drain directly into a stream channel or carry sediment laden water into a stream channel.

17) Listed salmonids that would be in the area shall be removed prior to and during stream flow diversion and de-watering. Listed salmonids will be relocated to a suitable instream location immediately up or down stream of the work area. This will be done by qualified fishery biologists using nets to capture and relocate listed salmonids when practical. When it is necessary to use eletroshockers, the Park will follow and be consistent with NMFS guidelines. The Parks' section 10 permit does not cover the capture and relocation of listed salmonids during culvert replacement and installations activities, therefore take coverage is necessary. All efforts shall be taken to neither exhaust nor kill listed salmonids during the capture and relocation process.

18) Effective erosion control measures shall be in place at all times during restoration activities. Activities within the 5-year floodplain will not begin until all temporary erosion controls (e.g., straw bales, silt fences that are effectively keyed in) are in place, downslope of project activities within the riparian area. Erosion control structures shall be maintained throughout, and possibly after, activities. Erosion control devices such as check dams, silt fences, and other acceptable techniques, shall be used when the potential exists to have sediment or other materials entering water bodies. Note: The maintenance of all roads used to access work sites for the North Fork of Lost Man and Larry Damm Creeks are listed and covered in the current Routine/Non-Routine Road Maintenance BA.

Appendix 2: Post-Excavation Erosion Control Guidelines

INTRODUCTION

Studies have shown that erosion from roads is a primary cause of the decline in salmonids throughout the Pacific Northwest. In Redwood National and State Parks (RNSP), the erosion and resultant sedimentation downstream is also threatening streamside ancient redwoods by increased bank erosion and flooding. The parks are actively involved in watershed restoration work, with the goals of reducing unnaturally accelerated erosion, restoring natural geomorphic and hydrologic processes, and speeding the recovery of native forest vegetation in areas disturbed by the logging and road building that occurred before park acquisition.

These goals are achieved by:

- completely excavating stream crossing fills,
- excavating potentially unstable sidecast road fills,
- uncovering buried topsoil where reasonably feasible,
- placing native vegetative debris and large woody debris on the finished surfaces, and
- transplanting native plant species on finished slopes where a boost to re-establishment of vegetation is needed.

During the restoration process, large volumes of road fill are excavated using heavy equipment, and re-distributed to stable locations. The potential exists for post-excavation erosional adjustments to occur, particularly if the excavations do not uncover the original channel beds and banks, or where roads are located on unstable slopes. Generally the total volume of post-excavation erosion is small in comparison to the volumes being prevented from eroding by moving road fill from removed stream systems. However, new information on the effects of turbidity and suspended sediment on the survival of young salmonids has raised concerns about the surface erosion that may occur during the first winter post-excavation. This document describes measures that will be taken to control this erosion, and minimize management-related contributions to downstream turbidity and suspended sediment.

BACKGROUND

The watershed restoration program goals of erosion control and restoring geomorphic/hydrologic processes focus on removing road fill from stream crossings, minimizing failure of sidecast road fill into streams, and reducing driving forces on management-related mass movements. Initial adjustments and potential for continued post-treatment erosion were generally most pronounced in the early years of the watershed restoration program before more effective excavation techniques were developed. Myriad combinations of ground cover and vegetation were used to reduce surface erosion from treated areas. Various methods were tried to reduce fluvial erosion following the stream channel treatments, including building check dams and placing rock armor in the flow courses. As heavy equipment techniques were improved, more complete excavations became cost-effective, and the need for secondary erosion control treatments declined. Extensive monitoring and cost-effectiveness analyses were undertaken during this period, providing feedback to the restoration project leaders.

This information is described in RNSP's technical report series and numerous other papers.

SURFACE EROSION CONTROL

In the early years of the restoration program, the park relied on imported mulch and other surface erosion control blankets reduce post-excavation surface erosion. At that time, there was little vegetation that had to be removed in order to do the work, or to spread on finished surfaces, and there was little choice but to import mulch or other blanket materials. In the late 1980's, approximately \$50,000, or 10% of the erosion control and watershed restoration implementation budget, was being invested in straw mulch (includes purchase, delivery and spreading costs).

In 1989, the cost-effectiveness of controlling surface erosion was reviewed, particularly in light of the improving efficiency of heavy equipment excavation techniques. The \$50,000 spent on straw would also move 25,000 cubic yards of sediment from the stream system, or completely recontour 5 miles of road. Minimizing the small volume of sediment generated from surface erosion post-excavation was not viewed as cost-effective in addressing the large-scale problems associated with abandoned logging roads. The decision was made to greatly reduce straw mulching, and concentrate on more complete excavations of stream channels and sidecast road fills (Spreiter, personal communications).

Aside from the benefit of removing more sediment from the stream system, other restoration goals were addressed by the additional earthmoving. Natural hillslope drainage patterns were restored, potentially unstable sidecast fills were stabilized, and buried topsoil was uncovered beneath the fill. Native forest species quickly re-established on the organic and nutrient rich soil. Meanwhile, the heavy applications of straw most effective at controlling surface erosion were found to slow the re-establishment of native forest species, and straw, although certified weed-free, generally introduced exotic species. The additional earthmoving also eliminated long term maintenance and potential future failures associated with inboard ditch and cross-road ditch systems that had been constructed along many of the treated roads in the early years.

At the same time, the density and size of vegetation along the road corridors was increasing. On a few projects, large amounts of vegetative debris were buried in fillsites. This practice was quickly discontinued, with the realization that large voids would develop as the debris decayed, potentially affecting slope drainage and stability. Vegetative debris began to be stockpiled and scattered on the finished slopes. Benefits to re-establishment of vegetation were quickly noted, as many of the first successful plants were those protected by the cover of the debris. It was also noted that where shallow slumping occurred on finished slopes, the vegetative debris acted as a "binder", trapping much of the mobilized material. This has been the standard practice for the last 10 years.

New Developments

Recently, concerns have been raised about post-excavation surface erosion potentially contributing to turbidity and suspended sediment in the fish-bearing streams, impacting young salmonids. These concerns have caused RNSP to re-evaluate the importance of surface erosion control measures.

In order to address these new concerns, the parks propose to alter the distribution of the vegetative debris. Rather than random scattering of debris, vegetative material will be collected and concentrated on slopes adjacent to live streams and other locations where fine sediment may be mobilized and enter the stream system. If there is not enough on-site vegetative debris to achieve the desired level of ground cover, additional materials may be imported to the site. Materials will be selected to comply with NPS guidelines to minimize introduction of exotics and interference with re-establishment of native forest species. Shredded redwood bark is the current preferred material.

Guidelines have been established to help determine where surface erosion control materials will be most useful, and in what quantities, based on the factors that affect erosion and transport of fine sediment, described below.

Interactions between these factors are often complex and somewhat unpredictable. Best professional judgement will be used in analysis of these factors in the field.

The potential for surface erosion from a completed watershed restoration project is largely a function of:

Material properties (e.g., texture, cohesion, coarse fragment content, etc.) of the soil subject to erosive forces.

Slope length of the finished area (in a downslope direction).

Slope steepness of the of the finished area (in a downslope direction)

Slope form or convergence of the finished slopes.

Surface treatments applied to control erosion following earthmoving activities (ground cover type and degree of cover or rate of application).

The potential for sediment delivery to a stream channel is largely a function of buffer characteristics:

Slope steepness of the hillslope between the treated area and the stream.

Slope length from the treated road segment down to a stream channel

Surface conditions of the intervening slope (e.g., slope form, ground cover) that control the ability of the intervening slope to trap sediment delivered from upslope prior to reaching the channel.

A chart (Figure 1) has been developed to help plan the surface erosion control efforts. The rationale for the chart is that the potential for sediment delivery from finished slopes to streams is largely a function of the ability of the intervening ground to trap eroded sediment as it moves downslope. In general, excavated stream crossing side slopes have the highest risk of sediment delivery if not treated with preventative measures. Adjacent recontoured road segments that approach a stream crossing will have a relatively moderate to high sediment delivery risk, depending on the buffering factors. Road segments that are not near a stream crossing will have relatively low risk of sediment delivery, except: 1) where such segments are crossed by fluvial transport features (rills, gullies, swales), and 2) where such segments are located low on the hillslope, in close proximity to stream channels. Low risk areas may be left bare in order to insure adequate cover at the higher risk locations.

Controlling post-earthmoving erosion and sediment delivery from watershed restoration projects in a cost-effective manner requires balancing erosion and sedimentation risks with treatment costs and site logistics. While the chart provides guidance, site-specific conditions both on the finished slope and within the buffer will affect the amount of ground cover actually needed to achieve the goals of reducing downstream turbidity and suspended sediment. For example, the greater the levels of duff, live vegetation, downed woody debris and micro-topography within the buffer, the greater the natural trapping efficiency, and the less ground cover needed on the finished slope directly above. Where particularly vulnerable species or habitat are located immediately downstream, or where highly erodible soils are found, the guidelines shall be adjusted to favor more complete surface erosion control. Conversely, some areas may allow relaxing of guidelines, for example where buffer zones have atypically high sediment trapping efficiency due to topographic benches or particularly dense understory and litter accumulations or where excavated materials contain large coarse fragment content that would readily form an erosion pavement.

These guidelines will be used and adapted as needed to actual field conditions to insure that fine sediment is prevented from entering the stream systems as much as is reasonably possible. Best professional judgement of an interdisciplinary team including a park geologists and park biologist will be used in analysis of these factors in the field.

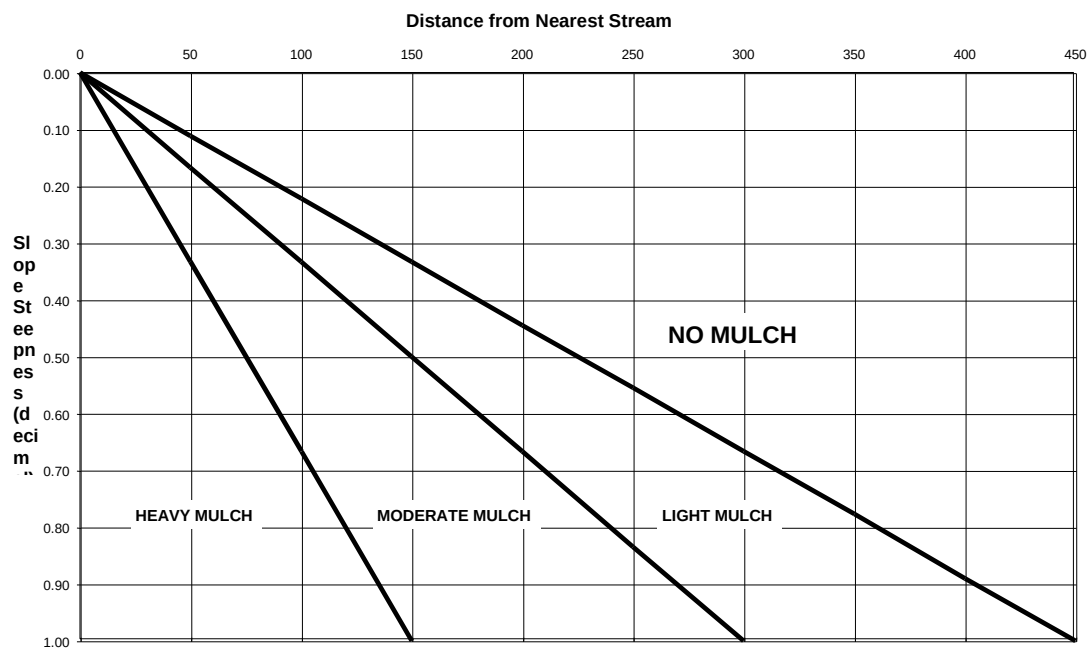


Figure 1. Mulching Guidelines

In planning ground cover needs, the site geologist will estimate the finished slope steepness and length along road segments with potential to contribute surface erosion to streams, and use the guidelines to determine appropriate ground cover rates. Where flow is expected to cross the finished slopes, ground cover will be increased to reduce erosion and trap sediment. Small swales that may not exhibit signs of surface runoff will also be covered with vegetative debris to reduce erosion and sediment delivery. Ground cover in both cases will be done to “moderate” specifications. As excavations proceed, and slopes are finished, final adjustments to ground cover rates will be made to insure the intent of reducing downstream turbidity and suspended sediment is achieved.

There is abundant vegetation that must be disturbed in order to get to the fill that needs to be excavated, and this material provides a good source of on-site, native material that can be used as ground cover. Recently, this material has been spread relatively evenly over all finished slopes, but observations show that this often results in insufficient ground cover to control surface erosion adjacent to streams. Practices are being changed to collect this material and concentrate the vegetative debris on finished slopes leading directly to streams, and on recontoured slopes where the downslope buffer is inadequate to catch mobilized fine sediments.

Where surface erosion control is critical equipment operators will be asked to “mash” the woody debris to increase ground contact. If needed, hand crews will cut and lop debris that is suspended to further increase ground contact, following placement of the debris with the heavy equipment. Woody debris scattering may have to be supplemented with imported mulching material (shredded bark, wood chips, etc.) to achieve the needed ground coverage. This would consist of applying the imported mulch over small bare areas that compose gaps in woody debris application.

From previous monitoring studies, surface erosion from bare areas is greatest the first winter following earthmoving, then declines exponentially in subsequent years as erosion pavements and leaf litter accumulate and revegetation proceeds. To speed re-establishment of vegetation, and provide long-term surface erosion control, seed bearing vegetation may be collected and scattered on the slopes to spread native seed. Similarly, duff, laden with seed, nutrients and fungi may be collected and scattered. Care will be taken not to impact source areas.

Figure 2 represents a hypothetical application of the surface erosion control guidelines to a watershed restoration project to be implemented in 2002 (note that this was a map exercise as would be used in project planning; actual ground-based prescriptions will vary somewhat).

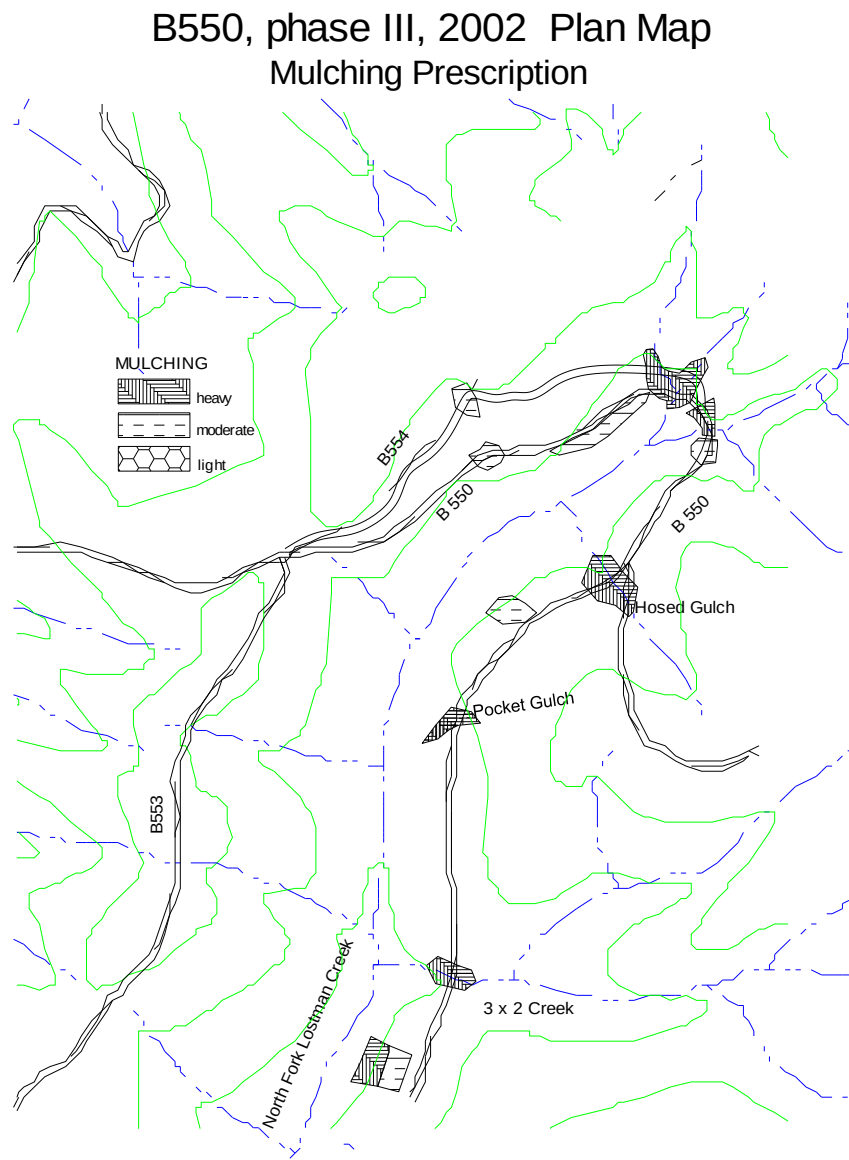


Figure 2. Hypothetical application of surface erosion control guideline to a planned 2002 rehabilitation site. Roads, streams, and contour lines are shown.



Figure 3. Vegetative debris mulching on excavation sideslopes provides for control of surface and fluvial erosion (this depicts a heavy rate of mulch application). Note the excavated stream channel with large woody debris placement in the foreground.

CHANNEL EROSION CONTROL

With the parks' goal of re-exposing the natural channel bed and banks, stream channel adjustments following excavation are generally small in volume (less than 5%), relative to the amount of material removed from the stream system during excavation. Adjustments are most pronounced during the first winter, but the erosional response is also affected by the sequence of high flow events following excavation.

The potential for channel erosion from a completed stream crossing excavation is largely a function of:

Stream power during storm runoff events (proportional to drainage area and channel gradient).

Material properties (e.g., texture, cohesion, coarse fragment content, etc.) of the soil subject to erosive forces.

Length of the excavated channel.

Steepness of the excavated channel.

The degree to which intact **original channel structure** (woody debris, boulders, bedrock) was exhumed upon completion of the excavation.

The type and degree of **treatments** applied to control channel scour following earthmoving activities.

Sediment delivery resulting from scour processes in stream channels is immediate and total. While many types of channel erosion control measures might be considered (and have been used in the past at RNSP), the park relies on finding original channel structure, supplemented by large woody debris placement. Check dams or import rock riprap to armor channels were tried and abandoned primarily due to the high cost, high maintenance

and questionable ecological consequences of using non-native materials and structures. The best case scenario for avoiding significant channel adjustment (scour) is successful excavation of original channel beds and banks. Fortunately this is usually possible. In addition, large woody debris encountered during excavation is placed in arrangements that mimic natural accumulations observed in stream channels. In most cases, abundant woody debris is available for placement in stream crossing excavations. Figure 4 shows a completed stream crossing excavation with extensive woody debris placement as it appeared in spring, 2001, following a relatively mild winter. While channel scour will occur even with woody debris placement, the extent of scour will be minimized, much of the sediment is trapped within the excavated reach, and the channel will have the structural elements needed to re-establish a natural morphology relatively quickly with this approach.



Figure 4. A stream crossing excavation with extensive woody debris placement. This photo was taken after the first winter following excavation.
Adaptive Management

It is anticipated that the guidelines for preventing surface and fluvial erosion included herein will be sufficient for achieving the desired level of protection for downstream resources. However, the monitoring program included in this biological assessment will provide feedback on the performance of these guidelines through time. Insights gained through monitoring will be used to adapt these criteria as may be required to achieve the desired level of protection in a cost-efficient manner.