

Summary Report

**WATERSHED RESTORATION UNIT 98-5
L-2-2-1**

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Redwood National Park

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INTRODUCTION

Redwood National Park is located in the lower third of the 280-square-mile Redwood Creek watershed. 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 boundaries protected a ½-mile wide corridor of forest along the lower third of Redwood Creek. Land located upslope and upstream remained in private ownership.

In 1978 Congress enacted Public Law 95-250, legislation which expanded the boundaries of Redwood National Park by approximately 48,000 to include land up to the watershed divide in the lower third of the Redwood Creek basin. At the same time, Congress authorized the establishment of a watershed rehabilitation program in Redwood National Park (RNP) for lands added to the park. The primary goal of this program are to minimize man-induced erosion and speed the natural revegetation process by restoring the hillslope hydrology to conditions that existed prior to man's influences.

Redwood Creek and its tributary streams are subject to frequent flooding from winter storms, and basin soils are naturally unstable and highly erosive. Even under natural conditions landslides and earthflows are widespread. Until purchase by RNP, the additional 48,000 acres and lands upstream of RNP were the site of intense timber harvest practices and related road construction. These activities adversely influenced erosion rates, sediment deposition and water quality within the entire basin. Studies indicate these activities caused unnatural and excessive erosion that resulted 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 skid trails created intensely disrupted hydrologic regimes and severe erosion problems.

Watershed restoration project Unit 98-5 was part of the program designed to restore disturbed lands (FIGURE 1). The purpose of the project was to remove roads in order to reduce future erosion problems and restore the natural landscape along the road corridor, as near as possible, to original topography. This was accomplished mainly by using heavy equipment to excavate road fill from stream channels and pulling back side-cast road fill to recreate original land configurations such as ridges, valleys and swales. Heavy equipment work was done under Invitation for Bid contract awarded to Lambert's Excavating of Arcata, California. The contract was split between two projects, watershed restoration Unit 98-5 (L-2-2-1) and Unit 98-6 (A-9-7-1 North) (FIGURE 2). The two units parallel each other on the slope, the L-2-2-1 road above the A-9-7-1 North. Some of the hillslope treatments for each unit actually merged with each other. In order to ease access and logistical problems, one contractor was hired to complete both projects. This report will focus solely on Unit 98-5, the L-2-2-1 road.

In January 1997, an eleven-year storm hit the Redwood Creek basin, arriving on the heels of several months of above-average precipitation in the basin. Heavy precipitation in combination with intensely disrupted hydrologic patterns caused numerous erosion problems. The most obvious and dramatic erosion events were numerous mass failures and debris flows, most of which originated from saturated sidecast fill material on major haul roads in Redwood National Park. Four mass failures originated from the L-2-2-1. The two largest failures moved an estimated 3,000-10,000 cubic yards of soil downslope. Because of the road prism failures, the L-2-2-1 road was evaluated and approved for removal under 1997 Storm Damage funding.

Location

The unit is located in Redwood National Park approximately 1.5 miles due south of the Orick bridge over Redwood Creek (FIGURE 1). It is in Township 10 North, Range 1 East, Section 10.

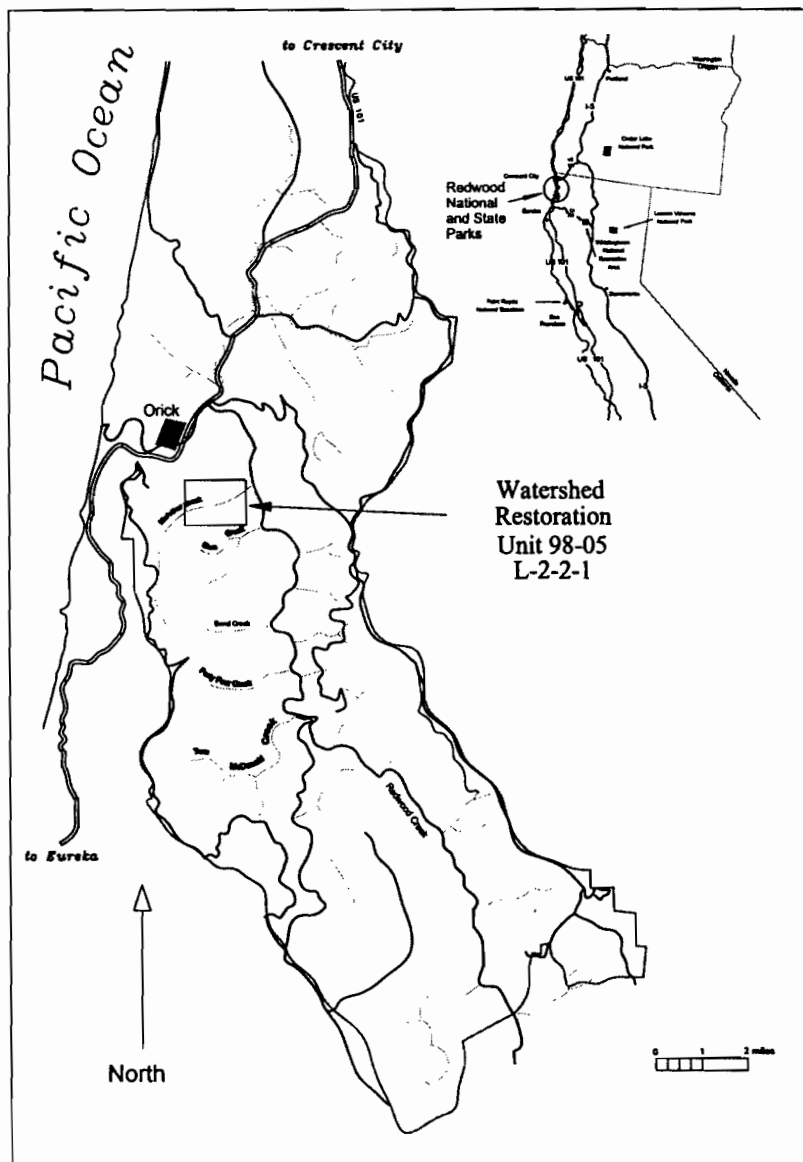


FIGURE 1. SITE LOCATION MAP.

Unit 98-5 encompassed approximately 20 acres in the McArthur Creek watershed. These acres included 0.6 miles of the L-2-2-1 road, hillslopes above (up to the L-2-2 road), and hillslopes immediately below the L-2-2-1 road (FIGURE 2). The unit is located mid-slope, approximately 800 feet elevation, on the south ridge of McArthur Creek drainage. The L-2-2-1 road is on a northwest and northeast facing slope. Only 0.2 miles of the originally planned 0.6 miles of the L-2-2-1 road was actually removed. The 2½-week project took place in October, and time restrictions, difficult equipment access, and inclement weather restricted progress. However, in addition to the 0.2 miles of haul road removed, another 0.15 miles of associated skid trails was also removed as planned.

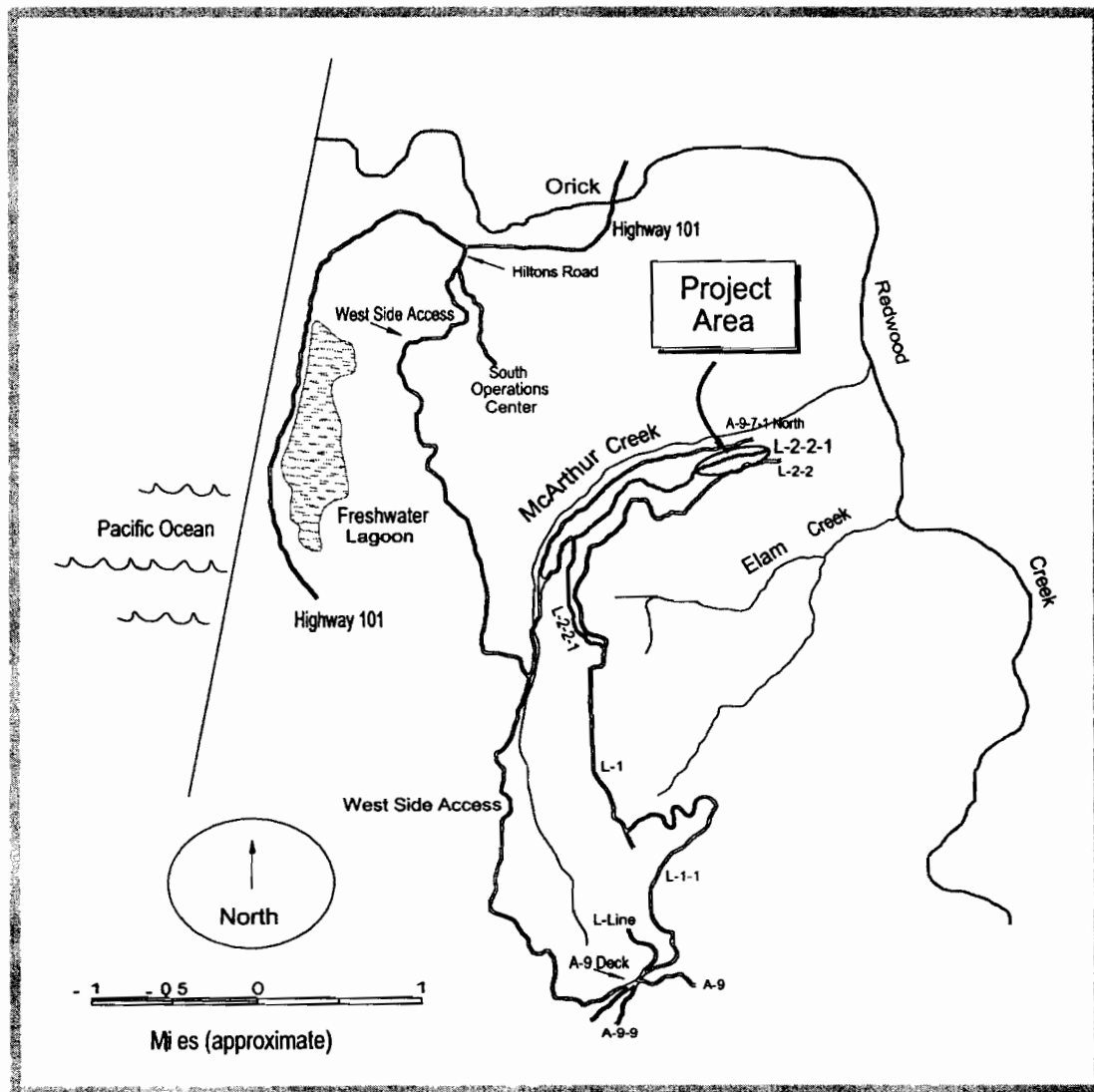


FIGURE 2. PROJECT AREA AND ACCESS.

Road and Logging History

Watershed restoration Unit 98-5 had been quickly and intensely harvested for timber beginning in 1971 and ending in 1976 just prior to RNP expansion (FIGURE 3). Clearcut tractor yarding was the primary method of timber harvest. The goal of the clearcut was most likely to extract as many healthy conifer trees as possible, as quickly as possible, with the knowledge that the land would soon be converted to National Park land. Although timber operators followed what were the best practices at that time, they left very few trees standing on this unit.

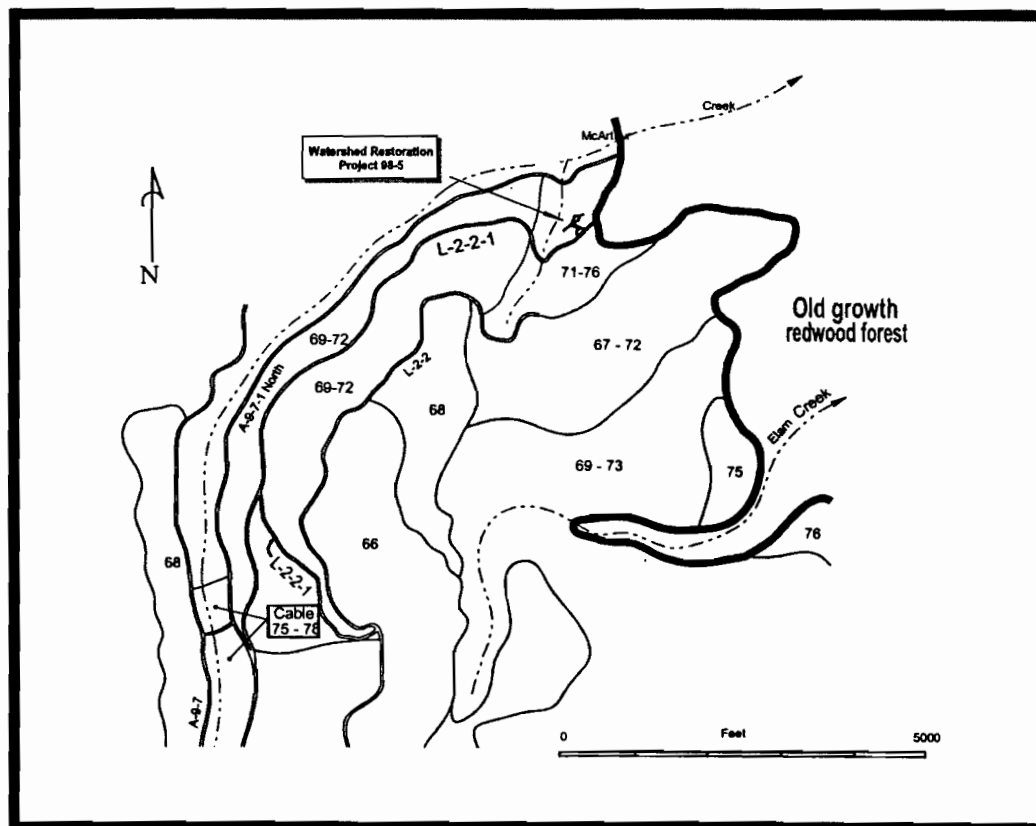


FIGURE 3. LOGGING HISTORY. THE EASTERNMOST END OF THE L-2-2-1 ROAD BEGINS CLOSE TO THE ORIGINAL 1968 PARK BOUNDARY, WHERE UNCUT OLD GROWTH CONIFEROUS FOREST CONTINUES FOR A MILE AND A QUARTER BEFORE REACHING THE REDWOOD CREEK FLOODPLAIN.

Tractor yarding employed large bulldozers to build roads directly to trees. This type of access created a dense network of skid roads that crisscrossed the entire hillslope. As a result, there was very little hillslope surface area above and below the L-2-2-1 that was not disturbed (FIGURE 4). Tractor yarding also resulted in major disruption of natural hydrologic conditions. Hydrologic disruption along the L-2-2-1 road corridor is evidenced by large debris flows, gullies and slope failures due to interception of ground water and diversions of surface and stream flow.

Timber operators built bridges called "Humboldt crossings" which enabled them to cross small stream channels with their equipment. These Humboldt crossings were constructed by placing logs lengthwise in the stream channel and packing soil around them to build a road surface. There are numerous Humboldt crossings of varying size in Unit 98-5. The packed soil in virtually all of the crossings have completely or partially eroded downstream. This soil, and the soil from debris flows, gullies and slope failures, travels down McArthur Creek and eventually reaches the Redwood Creek floodplain. Increased sedimentation in Redwood Creek and its tributaries jeopardizes the habitat and therefore the continued existence of the threatened Southern Oregon/Northern California Coast coho salmon, and the Southern Oregon and California Coastal chinook salmon.



FIGURE 4. AERIAL PHOTOGRAPH SHOWING EXTENT OF LOGGING AND RELATED ROAD CONSTRUCTION BY 1974 NEAR THE L-2-2-1. ALL WHITE LINES ARE EITHER HAUL ROADS OR SKID TRAILS. THE L-2-2-1 ROAD IS HIGHLIGHTED IN ITS ENTIRETY. OLD GROWTH REDWOOD FOREST OCCUPIES THE UPPER THIRD OF THE PHOTOGRAPH, WHERE INDIVIDUAL TREES AND THEIR SHADOWS ARE VISIBLE.

Geology and Physiography

The Redwood Creek basin is almost entirely underlain by the Jurassic-Cretaceous Franciscan formation. Exposures of these rocks typically show closely spaced fractures and/or shearing. Fractures seem to have resulted from deformation from tectonic activity, likely by subduction, and from brecciation along high angle faults.

Unit 98-5 is underlain by quartz-mica Redwood Creek schist unit of Franciscan assemblage (Harden, et al., 1982). The schist in this unit is sheared, with complex folding and faulting, and is prone to mass wasting and fluvial erosion. However, in local areas, more competent schist forms resistant ridges between sub-basins and maintains more stable slopes up to 70% or steeper.

This unit drains into McArthur Creek, a tributary on the west side of Redwood Creek. McArthur Creek is separated from the ocean only by its western ridge, which parallels the north-south coastline in the upper watershed (Figure 2). In the lower watershed, however, McArthur Creek swings east to join Redwood Creek. This drainage morphology is unusual for tributaries of Redwood Creek.

The flat-topped ridges east and west of McArthur Creek are the only ones of their kind in the Redwood Creek basin (Popenoe and Bevis, 1990) (FIGURE 5). They are topped by uplifted marine terraces containing sediments largely from the Klamath province (Harden et al, 1982). The marine sediments contain a high proportion of granitics, cherts, and other silicious metamorphic rocks. Slopes drop off steeply below the flat-topped ridges. It is not uncommon to find stable slopes approaching angles greater than 70% in the project unit.

Soils and Vegetation

The L-2-2-1 road is located predominantly in soils with brown clay loam B horizons (Coppercreek, Ahpah, Tectah, and Lacks creek). Wet soils with gray, mottled Cg horizons (Devils creek) are found in some streams and hollows (Popenoe and Bevin, 1990). Soils on slopes below the uplifted marine terraces, including the L-2-2-1, contain mostly schist fragments (metamorphosed mudstone) mixed with a small percentage of terrace material (Popenoe and Bevis, 1990). These soils "held up" well during the first precipitation events following road removal; that is, no significant soil movement or channel adjustment was evident even though precipitation was intense, approximately 6-7 inches in a 24-hour period.

Soils of this unit support vegetation that thrives in the cool shade of north-facing slopes. Old-growth redwood, douglas-fir, western hemlock and western red cedar historically grew in these soils, and remnants of old-growth forest remain on the unit. Red alder now grows in dense stands wherever soil was disturbed by logging, especially along road corridors, and the twenty-year old trees are approximately 50-70 feet tall. Understory vegetation includes salal, rhododendron, huckleberry, salmonberry, and oregon grape. Swordfern reach head height in some of the shadiest areas, and water cress is found in some of the wettest.

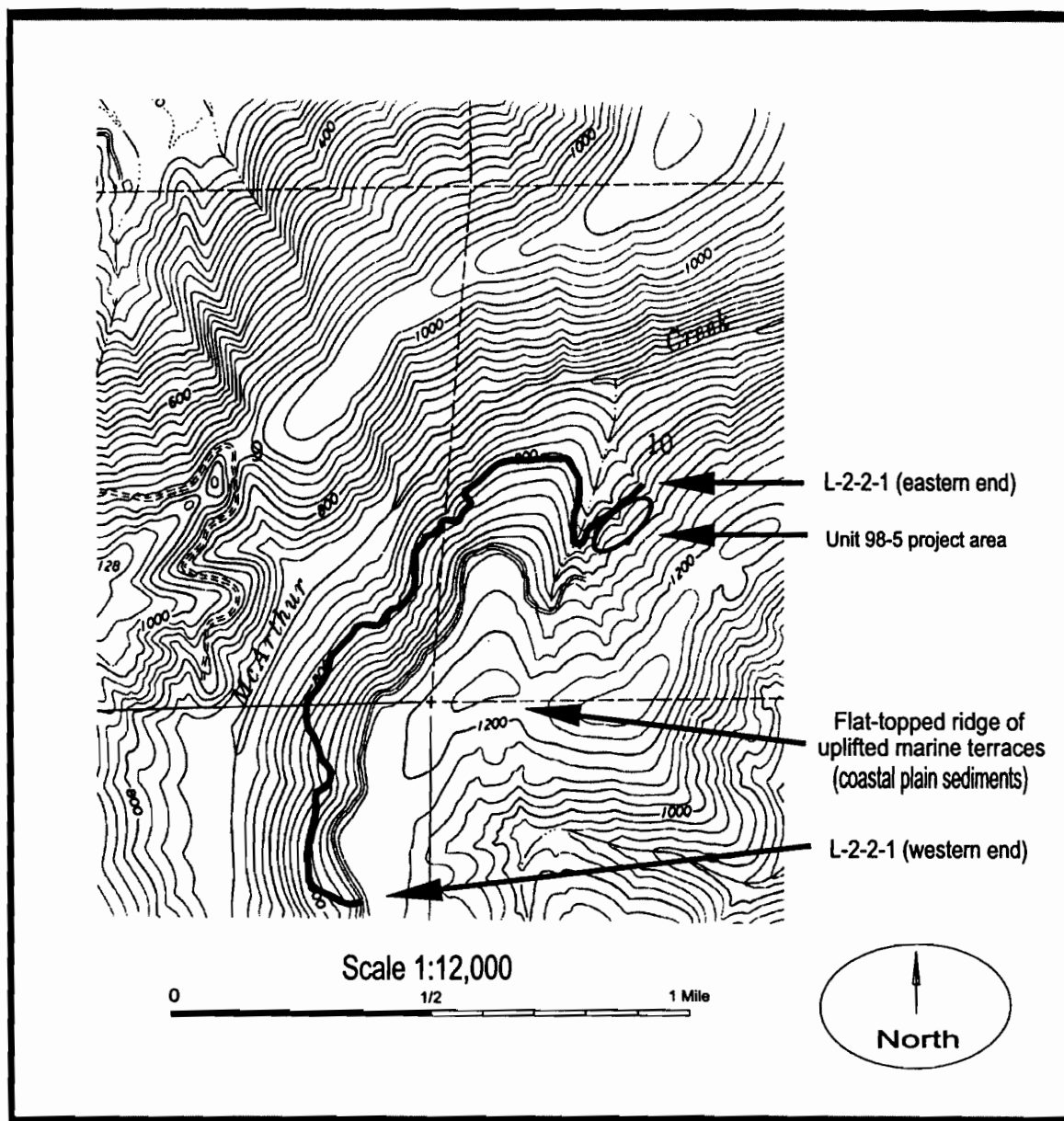


FIGURE 5. TOPOGRAPHIC MAP OF MCARTHUR CREEK ALONG L-2-2-1 ROAD.

Erosion Processes and Hydrology

The combination of sheared schist bedrock and uplifted marine terrace geology allows water to readily infiltrate and percolate through cracks and fissures in the ground. Often this flow emerges in places contrary to normal expectations (for example, at the base of a cutbank on a ridge). The criss-crossing logging road network in this unit has intercepted groundwater flow in many locations, causing it to emerge on the ground surface sooner than it normally would under undisturbed conditions.

Roads in this unit commonly divert, pond, and channel water away from natural drainages, discharging concentrated flow onto naturally dry hillslopes, or force ponded water to seep through road fill. I stated in the preceeding section that these soils "hold up" to precipitation well following complete road removal, and so far, this appears to be true. Conversely, where water is unnaturally ponded or perched road fill is saturated (i.e. prior to road removal) these soils have moved under gravity, creating massive debris flows continuing hundreds or thousands of feet downslope, evidenced by the mass soil movements of 1997.

Emergent groundwater is common on the slope, and it is not surprising to find water at any elevation. Valley incision develops immediately downslope of the springs, and there is no trace of valley geomorphology above the springs. Seeps are especially common along the L-2-2-1 road, where roadbuilding intersected groundwater flow and caused it to emerge higher on the slope than it would naturally. Large pools of water have established along the L-2-2-1 road in the twenty-two years since the road was last used. During that time bog ecosystems have developed along the road corridor, complete with soft, spongy ground, hydrophytic vegetation, and methane production. Springs are evident even during the driest months of the year.

Figure 6 is a treatment map for Unit 98-5. Near station 04+00, (four hundred feet west from station 0+00), water ponds on the upslope haul road (L-2-2 road), infiltrates, and travels as subsurface flow until it emerges below the L-2-2-1. Where it emerges, it flows perpendicularly eastward to the slope along one skid trail, then perpendicularly westward along another, where it disappears again. Flow reappears 100 feet downslope and ponds on yet another skid trail within Unit 98-6, the A-9-7-1 North road removal project. The preceeding is an example of how the two projects are hydrologically related and why they were combined under one contract. Ideally, the L-2-2 road will soon be removed as well, since it creates upslope hydrologic diversions and imbalances which directly affect both the L-2-2-1 and the A-9-7-1 North roads (Figure 2). However, there was only one major debris flow originating from the L-2-2 in the January 1997 storm, and other roads are listed as higher priority for removal.

The L-2-2 road fill became saturated and slumped in a historically wet area above the L-2-2-1 between stations 09+00 and 11+00. The slumped material split the surface flow into two distinct channels which now flow side-by-side across the L-2-2-1 approximately 50 feet apart with a narrow ridge between them. One of the channels caused a debris slide on the L-2-2-1 that completely removed the road. Geologists decided not to attempt to traverse the slide with heavy equipment; therefore, work on Unit 98-5 began at the eastern edge of the slide and work was performed "backwards" along station numbers towards zero. The continuing work, Unit 99-5, will begin on the westernmost edge of the slide and proceed in a normal direction towards larger station numbers.

Near station 07+50, a spring emerges where roadbuilding intercepted groundwater. Road fill saturated by this spring caused a debris slide approximately 350 feet long to the tributary stream below. This tributary received material from five recent debris slides in one concentrated area. The other four sources are described in the summary report for Unit 99-5, the continuation of the L-2-2-1 road removal project.

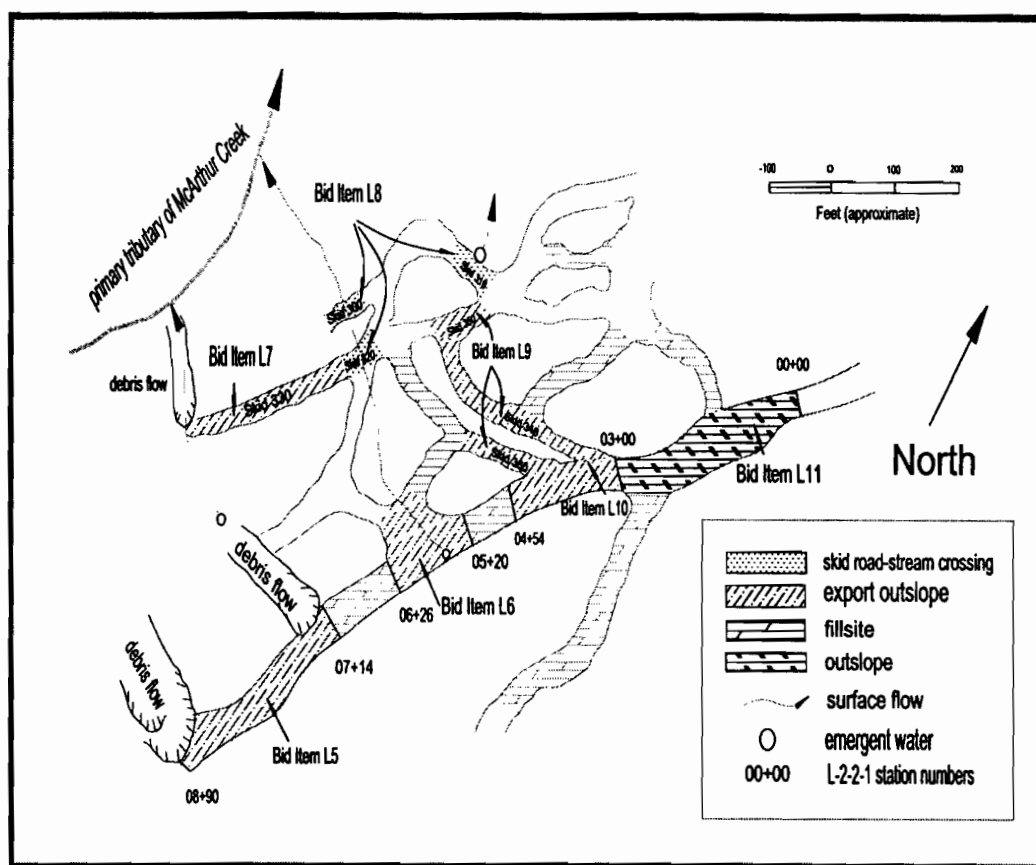


FIGURE 6. TREATMENT MAP FOR UNIT 98-5, L-2-2-1 ROAD.

Wildlife Concerns and Work Schedule

The U.S. Fish and Wildlife Service (FWS), as administrator of the Endangered Species Act, has 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 on nesting sites during the breeding season. Restrictions apply to management projects that are located within ¼-mile radius of nesting habitat. These projects require consultation with FWS prior to project implementation. In joint cooperation, RNP, FWS, and the National Marine Fisheries Service (NMFS) created a Biological Assessment followed by biological and conference opinions, adopted July 1998. This document outlines specific guidelines such that RNP may continue watershed restoration work without adversely affecting critical habitat of the wildlife in question.

Watershed restoration Unit 98-5 was entirely within the ¼-mile radius for suitable habitat; therefore, a time restriction was imposed on the project. We could not use mechanized tools within the restricted zone between February 1 through September 15, so heavy equipment could not mobilize until September 16. Because ours was a shared contract, equipment began on Unit 98-6 before it arrived on Unit 98-5. We did not actually begin to move dirt on the L-2-2-1 until September 29. Road removal work on the L-2-2-1 was complete in two and a half weeks (on October 16).

Road removal work on both units was targeted for completion by November 1. This date was chosen in order to minimize impacts to threatened fish species by protecting the aquatic habitat from sediment pollution following the onset of winter rains. The National Marine Fisheries Service allowed for additional small work items to be implemented during November only if periods of dry weather were expected, and the work items could be completed within the window of predicted dry weather. It was for this reason that both COTRs sharing this project, the contractor, and the contracting officer decided to delete (in their entirety) Base Bid Items 12 through 15 for Unit 98-5. Therefore, on October 26, a contract modification was completed by the Contracting Officer relieving the contractor of all responsibility to perform further road removal work on Unit 98-5.

We were apprehensive about continuing work on the L-2-2-1 because to do so would have meant opening separate access on the far side of the slide near station 10+00 (previously mentioned). Therefore, we unanimously decided to focus attention instead on the A-9-7-1 North, which was farther downslope and closer to the equipment access road. The A-9-7-1 North provided a quicker escape route and posed less threat to the fisheries resource if the winter rains caused a project shut-down.

RESTORATION WORK

Heavy equipment work was done under Invitation for Bid contract awarded to Larry Lambert of Lambert's Excavating of Arcata, California, for \$45,427.50 (TABLE 1). Because there were two road removal projects (units) which shared the same contract, certain miscellaneous bid items were only assigned to one unit. In this case, the Move In/Move Out costs and the cost to open the access road were assigned to Unit 98-6, the A-9-7-1 North, in their entirety. The access road will be used again in 1999 to access the A-9-7-1 North, but the continuing project on the L-2-2-1 will be completed using a different access route from the A-9 deck (FIGURE 2). The access logistics of the 1998 restoration work were convoluted because of the presence of a landslide mentioned earlier, which prohibited normal access to Unit 98-5.

Two pieces of equipment were used to complete the contract: a rented John Deere 892D-LC hydraulic excavator, and a Caterpillar D8H bulldozer, owned by the contractor. The contractor, Larry Lambert, operated the excavator, and the bulldozer was operated by Paul Curtright, also of Arcata. This project marked the first time Curtright had done road removal work in steep, forested areas, but he grasped the concepts immediately and the good results of his work show his talent. Larry has been doing road removal in the Park for nearly two decades, and is conscientious about details such as recovering original topsoil to determine original grade.

Heavy equipment typically operated 10-11 hours daily, six days a week. The bulldozer had many breakdowns which slowed progress tremendously. Excavation rates in Tables 2, 3, and 4 reflect earth moving hours only, and do not reflect time that the equipment was broken down.

Project Implementation

The geologist responsible for this project was Meredith Manning. It was my responsibility to perform the following tasks: evaluate and formulate rehabilitation prescriptions, survey and photo-document the project, generate plansheets and technical specifications for contracting, oversee heavy equipment operations as the contracting officer's technical representative (COTR), and complete the final documentation. I will plan, develop, and oversee the continuation of the L-2-2-1 road removal project (however, the report will list "Meredith Howard" as author of subsequent reports due to a name change). Additional geologists at RNP were designated as site inspectors, but were never called upon to oversee the heavy equipment work. Work was overseen by Terry Spreiter, supervisory geologist. The Storm Damage Coordinator was Darci Short, Sherri Romanini managed the budget, and Kris Swofford from Point Reyes National Seashore was the Contracting Officer for the project.

Primary restoration treatments included:

- three skid road-stream crossings
- 475 feet of haul-road exported outslowing
- 450 feet of skid-road exported outslowing
- 300 feet of outslowing

No haul road-stream crossings were excavated. The only one included in the original contract was one of the bid items deleted from the contract during contract modifications. See Figure 5 for a treatment map of the unit.

Prices for road removal work on Unit 98-5 were higher than other projects the same year. The sole contractor who bid on the unit, and who was eventually awarded the contract, bid within \$6,000 of my original estimate for the work. We both knew that the cost of performing the road removal work would be expensive due to the nature of the access (a long, steep, muddy climb from the A-9-7-1 North every day); the difficulty of working in wet, and sometimes saturated soil; working remotely from the service truck; working in confined spaces between dense stands of 22-25 year old alder trees, etc.

Of all factors involved, perhaps the most frustrating factor was working within dense stands of 22-25 year old alder trees (50-60 feet tall). Their presence slowed down production considerably. The dozer was required to "clear" them from the area and stockpile them in an "out of the way" location, so that the excavator could place them on the finished slope. Much of the Unit 98-5 work was performed on narrow skid roads; the L-2-2-1 itself was not very wide; and the piles of alder trees were constantly in the way. They also were responsible for ripping numerous hydraulic lines and getting caught in the dozer tracks. A few unruly alders caused major dents in the excavator and shattered the glass of the cab more than once. The remaining alder stands outside the area of excavation confined the excavator swing, which also slowed production considerably.

Although the alder trees are becoming prolific and difficult to manage due to their density and height, they are still required to be spread over the finished slope with other large organic material rather than buried. There is a good reason for this. Buried trees may "pipe" or funnel water through fill material, and will eventually break down, causing fill material to settle and pond water. Unnaturally ponded water or any concentrated flow outside of the normal channel creates a potentially unstable hillslope situation and is contrary to RNP's watershed restoration goals.

Skid Road-Stream Crossings

The timber harvest method used in this unit, tractor logging, created a series of densely-spaced skid roads above and below the L-2-2-1 haul road. Many of these skid roads crossed stream channels, and during the mapping phase I determined which skid crossings should be removed with heavy equipment. My criteria were based primarily on potential for failure and secondarily on cost-effectiveness of removing the crossing based on access to the site.

Studies on previously harvested forest lands in the Redwood Creek basin have shown that sediment production from fluvial erosion is greater than or equal to that produced from mass movement (Hagans and Weaver, 1987; Janda et al., 1975). Man-induced fluvial erosion can best be addressed at road/stream intersections where excavation of fill from buried stream channels removes immediate sediment sources and eliminates the potential for diverted flows to gully natural slopes.

All three skid road-stream crossings were close together below the L-2-2-1, and all were included in one bid item. Therefore, unit cost is uniform because the contractor bid on the whole bid item (TABLE 2; APPENDIX). One of the skid crossings was immediately upstream of another; the third was downstream of an export outslope; these skid crossings were characterized by being two continuous channel excavations. All were running water at the time of excavation. This situation created logistical challenges for the operators. In addition, the area immediately surrounding the skid crossings was planned for removal, such that a large area had to be disturbed at one time, and fill capacity was limited (FIGURE 5). The combination of wet excavation work, uncertain fill capacity, and confined work space on the narrow skid roads drove up the cost of the three skid crossings (Bid Item L-8).

Exported Outsloping

Export outslope (EOS) treatments are performed where the road fill needs to be enhailed to a stable fillsite. All enhauling on this project was performed by dozer (all material was pushed to the fillsite instead of transported by dump truck or loader).

Of approximately 1,000 feet of haul road removed in Unit 98-5, nearly half (485 feet) was treated as export outslope. This was necessary because of the quantity of emergent water along the L-2-2-1 road corridor. It was impossible to use much of the road corridor as fillsite because I was reluctant to "bury" emergent water underneath fill material. Therefore, fill material had to be pushed longer distances, and in some cases, up very steep slopes (40%). Steep, uphill pushes increased the cost of exported outsloping bid items (TABLE 3; APPENDIX). In addition to the main haul road, 450 feet of skid roads were treated as export outslope.

Outsloping

Outsloping (OS) treatments are used to reconstruct the original contours along a road corridor. This involves the removal of fill from the outboard edge of a road and placing it along a stable section of cutbank. Recontouring in this manner restores natural drainage patterns and results in the recovery of original sidecast soil. Original topsoil is the first soil layer to be sidecast downslope during road building. Long buried under fill material, the topsoil is the last to be retrieved during outsloping. This material rich in organic matter gets distributed over the finished slope, and enhances the revegetation process dramatically (Popenoe and Martin, 1990).

Excavation rates for outslope treatments are summarized in Table 4 (Appendix). There was only one bid item which required outsloping. Normally, a road removal project might require a greater percentage of outsloping treatments. In this case, it was a challenge to find dry, stable fillsite locations along the L-2-2-1 road corridor, so most treatments were export outslope.

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 distinguished by requiring time that is not directly attributable to any specific bid item. Non-bid item times are recorded to compare the cost of contract with that of hourly rentals. Table 5 provides a cost breakdown for non-bid items.

Discussion time is defined as periods of time where equipment operations were interrupted by discussions lasting more than 15 minutes. Typically the contractors stop work to discuss progress of a particular phase of a bid item or develop strategy for the work. The COTR also interrupts the operators to discuss the current work and develop understanding of the contract specifications while the bid item is in-progress.

Down time occurs when equipment is unable to perform in its expected capacity. On Unit 98-5, down time was most often the result of mechanical failure, predominantly the rupturing of a hydraulic line. Down time also included time equipment was either stuck or assisting in the rescuing of other stuck equipment. However, down time was only recorded if the other piece of equipment was still working, as when the dozer was getting a new hydraulic line installed while the excavator continued to work on bid items.

Idle time for equipment was recorded as a non-bid item but is markedly different than the previous items. Idle time represents the time a piece of equipment was inactive while work proceeded. Idle time differs from down time in that the equipment is able to be used, but the contractor or operator chooses not to use it. There was no idle time in this contract.

DISCUSSION

Project 9805 met the goals of Redwood National Park's watershed restoration program by removing a portion of the L-2-2-1 road. The work restored natural hydrologic patterns along the road corridor and associated hillslopes. Restoration work also restored natural landforms as practically as possible given the extent of damage caused by timber harvest. Both goals of restoring hydrology and landforms help minimize human-caused erosion in McArthur Creek.

A total of 12,400 cubic yards of fill material was excavated from potentially unstable locations and moved to stable fillsites. The 2½-week project heavy equipment cost was \$39,014, with an overall average cost of \$3.15 per cubic yard.

The original goal of the project was to move nearly 47,000 cubic yards of potentially unstable fill material. We only succeeded in moving 13,000 cubic yards due to a shortage of contractors willing to bid on the projects. Lambert's Excavating bid on my project, but there were no bidders for the A-9-7-1 North project, immediately downslope of the L-2-2-1. It was generally agreed between both COTR's (myself and Phil Freiberg), the Supervisory Geologist (Terry Spreiter) and our Contracting Officer (Kris Swofford) that we should "share" one contractor between two projects. This decision was made for several reasons: access into the sites, close proximity of projects, and integrity of the completed restoration work.

Larry Lambert is a longtime advocate of road removal and has worked with RNP's watershed restoration program for decades. He has honed his ability to recognize when he is nearing original topsoil during excavation work, which is always a blessing for the COTR, who is ultimately responsible when excavation goes below original grade. His newcomer assistant Paul Curtwright had the right energy and drive to learn the new skills involved in road removal. Based on his questions I think he caught on to the overall goals right away, and was genuinely excited at the results. Although it seems we suffered every hydraulic breakdown possible during those 2½ weeks, the site looks wonderful after the first season, and there were no significant adjustments to the finished restoration work. I hope they will work in the Park for a long time to come.

ACKNOWLEDGMENTS

Thanks to the other watershed restoration geologists for technical support from start to finish: Terry Spreiter, Becca Smith, Neal Youngblood, Phil Freiberg, Jim Howard, and Mike Sanders, from whom I borrowed prose for sections of this report.

Also thanks to Darci Short and Sheri Romanini for tackling—with patience and grace—the intricacies of funding the project; Kris Swofford for her sense of contracting humor, and Terry Hofstra for his unconditional support for doing it right the first time. Dick Mayle graciously sent his NCIDC crew to my site for a few weeks loaded with chainsaws. Tim Tanno, Darlene Buckskin, Keith Richey ("Harry"), and Doug Smith put a lot of energy into my project site, helping me brush and survey for months at a time. Not enough thanks can be said for Rodney Poole for dropping everything else and helping me whenever I needed it.

And for the contractor, Larry Lambert, and his able assistant Paul Curtwright, for conscientious and thoughtful work. You made my job easy.

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APPENDIX

Cost Tables for Unit 98-5:

Skid Road-Stream Crossing Excavation
Export Outslope Excavation
Outslope Excavation
Non-Bid Item Costs

Table 2. Skid Road-Stream Crossing Excavation Cost and Production Rates for Unit 98-5, L-2-2-1 Road

Bid Item	Worksite (station numbers)	Surveyed Volume (cubic yards)	Heavy Equipment Hours (earth moving only)		Total Cost		Unit Cost		Original Bid (price per cubic yard)	Average Fillsite Distance (feet) (b)	Excavation Rate Both Equip (cubic yards per hour) (c)		
			John Deere 892D-LC	Caterpillar D8H	Actual	H.E.R.E.	Actual					H.E.R.E.	
SKID ROADS													
L8	Skids 300-320	830	17.25	1.50	\$ 3,735.00	\$ 3,150.69	\$ 4.50	\$ 3.80	\$ 4.50	15	44		

- (a) Heavy Equipment Rental Equivalent (H.E.R.E.) is the cost to complete each job based on actual hours worked. Costs are calculated from Caterpillar 1998 Rental Rates, plus 40% profit and overhead, and include the cost of the operator for: Caterpillar D8H dozer @ 158.34/hr and John Deere 892D-LC @ \$168.88/hr.
- (b) Fill material was pushed to the fillsite by bulldozer.
- (c) Excavation rate is based on the ratio of the total yardage excavated and the total of all equipment time used to complete the individual bid item.

Table 3. Export Outslope Excavation Cost and Production Rates for Unit 98-5, L-2-2-1 Road

Bid Item	Worksite (station numbers)	Surveyed Volume (cubic yards)	Heavy Equipment Hours (earth moving only)		Total Cost		Unit Cost		Original Bid (price per cubic yard)	Average Fillsite Distance (feet) (b)	Excavation Rate Both Equip (cubic yards per hour) (c)
			John Deere 892D-LC	Caterpillar D8H	Actual	H.E.R.E. (a)	Actual (price per cubic yard)	H.E.R.E. (a)			
HAUL ROAD											
L5	07+14 - 08+90	3,073	24.25	17.00	\$ 11,523.75	\$ 6,787.12	\$ 3.75	\$2.21	\$ 3.75	200	74
L6	05+20 - 06+26	725	8.50	6.50	\$ 2,175.00	\$ 2,464.69	\$ 3.00	\$3.40	\$ 3.00	50	48
L10	03+00 - 04+54	1,838	21.75	8.50	\$ 5,514.00	\$ 5,019.03	\$ 3.00	\$2.73	\$ 3.00	150	61
Total or Weighted Avg		5,636	54.50	32.00	\$ 19,212.75	\$ 14,270.84	\$ 3.41	\$2.53	---	---	65
SKID ROADS											
L7	Skid 300	(LS)1150	7.00	3.00	\$ 4,600.00	\$1,343.50	\$ 4.00	\$ 1.17	\$ 4.00	25	115
L9	Skids 340-360	966	7.50	7.75	\$ 3,864.00	\$1,432.69	\$ 4.00	\$ 1.48	\$ 4.00	200	63
Total or Weighted Avg		2,116	14.50	10.75	\$ 8,464.00	\$2,776.19	\$ 4.00	\$ 1.31	---	---	84

- (a) Heavy Equipment Rental Equivalent (H.E.R.E.) is the cost to complete each job based on actual hours worked. Costs are calculated from Caterpillar 1998 Rental Rates plus 40% profit and overhead, and include the cost of the operator for: Caterpillar D8H dozer @ 158.34/hr and John Deere 892D-LC @ \$168.88/hr.
- (b) Fill material was pushed to the fillsite by bulldozer.
- (c) Excavation rate is based on the ratio of the total yardage excavated and the total of all equipment time used to complete the individual bid item.

Table 4. Outslope Excavation Cost and Production Rates for Unit 98-5, L-2-2-1 Road

Bid Item	Worksite (station numbers)	Surveyed Volume (cubic yards)	Heavy Equipment Hours (earth moving only)		Total Cost		Unit Cost		Original Bid (price per cubic yard)	Average Fillsite Distance (feet) (b)	Excavation Rate Both Equip (cubic yards per hour) (c)
			John Deere 892D-LC	Caterpillar D8H	Actual	H.E.R.E.	Actual (price per cubic yard)	H.E.R.E. (a)			
L11	00-20 - 03+00	3800	17.75	17.25	\$ 7,600.00	\$ 5,728.99	\$ 2.00	\$ 1.51	\$ 2.00	200	109

Table 5. Non-Bid Item Costs for Unit 98-5

Item	Heavy Equipment Hours		H.E.R.E. Costs (a)
	John Deere 892D-LC	Caterpillar D8H	
Discussion (b)	4.50	2.75	\$ 1,195.40
Down (c)	0.75	30.25	\$ 4,916.45
Fuel & Service (d)	4.00	3.25	\$ 1,190.13
Subtotal	9.25	36.25	\$ 7,301.97
Idle (e)	0.00	0.00	\$ -
Total	9.25	36.25	\$ 7,301.97

- (a) Heavy Equipment Rental Equivalent (H.E.R.E.) is the cost to complete each job based on actual hours worked. Costs are calculated from Caterpillar 1998 Rental Rates plus 40% profit and overhead, and include the cost of the operator for: Caterpillar D8H dozer @ 158.34/hr and John Deere 892D-LC @ \$168.84
- (b) Fill material was pushed to the fillsite by bulldozer.
- (c) Excavation rate is based on the ratio of the total yardage excavated and the total of all equipment time used to complete the individual bid item.

