

COPPER CREEK REHABILITATION SITE 79-4

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The purpose of rehabilitation of Copper Creek was to reduce on-going and future erosion and encourage the return of a natural pattern of vegetation. Diverted streams were re-routed into their natural channels and fill was removed from haul road and skid trail stream crossings. Unstable fill on landings was removed wherever a high potential for failure into nearby streams was present. Mulches were spread and grass was seeded for surficial erosion control. Shrubs, Madrone and alders were planted as colonizing and intermediate stages of succession and conifers were planted to speed forest re-establishment. Except for grass seeding and conifer planting, vegetation treatments were restricted to excavated stream crossings. Heavy equipment and labor intensive techniques were employed.

Site Description

- The Copper Creek rehabilitation unit (site 79-4) includes approximately 607 acres of cutover land and 6.7 miles of logging roads on the south side of the Copper Creek basin (Figure 1). Boundaries for the site include the main channel of Copper Creek to the north, oak woodlands and grasslands to the east and south, and the 1920-1900 road system to the west. The area is underlain by sedimentary rocks of the Franciscan assemblage which include graywacke sandstone, fractured and sheared mudstone and isolated outcrops of pebble conglomerate.

Soils of the unit are youthful, mostly colluvial Inceptisols in fine-loamy and loamy-skeletal families. Depth to the C horizon is usually one to two meters

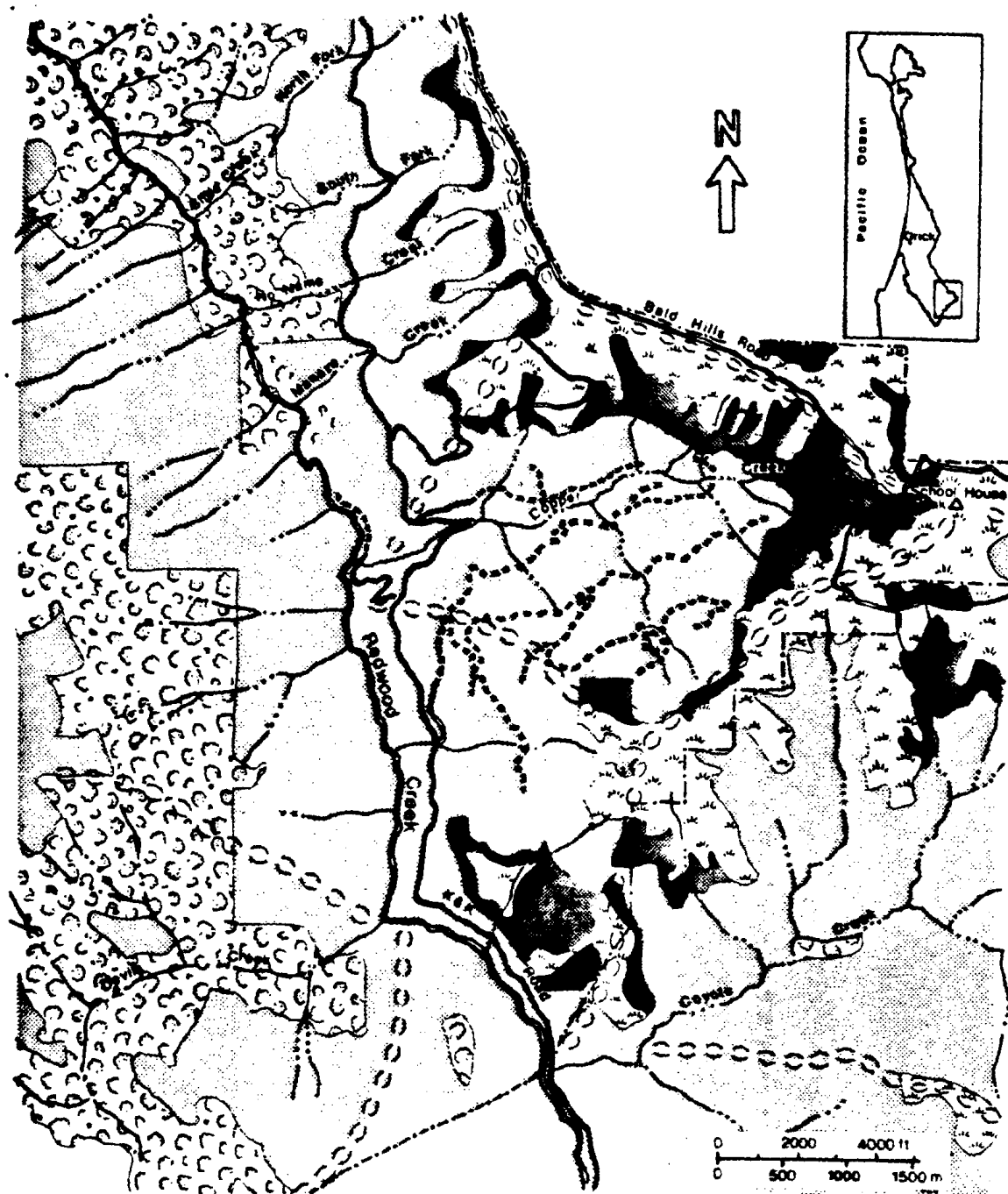


Figure . Vegetation patterns of the Copper Creek drainage basin and surrounding areas. Redwood National Park

- LEGEND
- | | | | |
|---------|------------------------------------|---|--------------|
| ----- | intermittent and perennial streams |  | logged areas |
| ———— | primary roads |  | prairie |
| ———— | secondary roads |  | oak woodland |
| ----- | abandoned roads |  | old growth |
| - - - - | major ridges | | |
| - . - . | park boundary | | |

and depth to bedrock usually exceeds two meters. Roadbed material is loam or light clay loam with 20 to 75 percent rock fragments and pH 5 to 6. Nutrient elements in the road bed are equivalent to those in the upper B horizon of soils adjacent to the road (Popenoe, 1982). The Inceptisol has a high infiltration capacity and is susceptible to surface erosion (Iwatsubo, 1976). Severe surface erosion can occur when the soil is subjected to concentrated runoff. Lower streamside slopes have a clayey Alfisol which is more prone to mass-movement than surface erosion (Popenoe, personal communication).

Elevation within the rehabilitation unit ranges from 1,500 feet (~~457m~~) to 2,400 feet (~~732m~~). Slopes average between 30 and 50 percent but can locally exceed 80 percent near Copper Creek and Camp Creek (Figure 2). Three perennial streams (including Copper Creek) and eight intermittent streams are included within the rehabilitated area. Only Camp Creek and Copper Creek are deeply incised which attests to the role of mass-movement as a dominant landscape-shaping process on the site.

The site is bisected by a prominent northwest-trending ridge system. West of the ridge the topography is concave or bowl shaped, suggestive of ancient landslide or earthflow activity, and east of the ridge overall topography becomes more convex in profile. The unit faces generally north-northwest toward Copper Creek.

The climate is mild ~~year-around~~ with strong marine influence. ~~Mean annual precipitation is about 200 cm and~~ mean annual temperature is about ~~12°C.~~
54°F

Annual precipitation near Copper Creek, between 1938 and 1980, averaged approximately 80 inches (Janda et al., 1975). The Redwood Creek watershed

experienced three 20 yr. return interval storms (Harden et al. 1978) between the end of logging and the beginning of rehabilitation. Rainfall in the winter of 1979 and 1980, the first winter following rehabilitation in Copper Creek, was just over 64 inches. Two storms occurred during the winter: 10.46 inches in five days, October 18 - 23,; and 8.32 inches in three days, January 13 - 15, neither of which accounted for more than a one year return interval storm discharge at the USGS gaging station in Orick.

In water year 1980-1981, Copper Creek received roughly 55 inches of rainfall (RNP unpublished rainfall data). Again, the maximum storms, ^{accounted for} less than one year return interval intensities.

Prior to logging, the principle overstory species included redwood Douglas-fir, tan oak, big leaf maple and madrone with an understory of huckleberry, and rhododendron and salal. Following logging, the pioneer shrub, coyote brush, and the subshrub, whipplea have become prominent in the area. These two species dominate and are associated with lesser numbers of herbaceous pioneers, including wild pea, star flower and iris where surface soil is present. On abandoned skid trails, roads and landings without surface soil the vegetation is dominated by ruderal herbs and coyote brush. Sprouts and seedlings of former forest species are gradually becoming established throughout the area under all but the worst soil conditions (Popence, 1981).

Land Use History

AMERICAN INDIAN BURNING & VEG PRACTICES
 ARE WILDLIFE MANAGEMENT STRATEGIES & PRACTICES
 WHY IS THIS NEVER ACKNOWLEDGED?
 The Copper Creek basin has experienced a complex logging history highlighted by three major episodes of harvesting and tractor yarding of redwood and

Douglas-fir. The majority of the area was selectively cut between 1958 and 1961. In 1963 and 1964 much of the area was selectively re-cut and, finally, in 1970 and 1971 virtually all of the basin was clearcut_x (Figure 2). Each harvest involved re-use and expansion of existing roads and skid trails. Reforestation was attempted by planting and aerial seeding between 1970 and 1973.

Three major storms (one in 1964 and two in 1972) occurred immediately following major periods of logging in the Copper Creek basin. The area was also affected by a large storm in 1975. A combination of large storms, disruptive landuse activities and poor road maintenance resulted in unnaturally high erosion rates (Weaver, et al. 1981). Widespread tractor disturbance in and adjacent to poorly incised stream channels combined with poor road drainage and numerous plugged culverts caused streams to be diverted down roads and skid trails. Water from these diverted streams either ran across the road prism and formed gully systems, or entered adjacent stream channels and caused extensive stream bank erosion and channel enlargement.

Waterbars or cross-road drains were lacking on most roads and skid trails. Many of these bare areas became severely gullied by concentrated runoff. By 1979, many sections of unstable roads and landings had failed into adjacent stream channels. Approximately 163,000 yd³ of sediment were lost from the area prior to rehabilitation (Weaver et al., 1981).

SCA JEFFC Work Experience

Detailed geomorphic mapping of the area took place between February and April 1979 (1,100 person hours). Heavy equipment and labor intensive treatments

were then prescribed for each work location. Heavy equipment operations began on July 5 and completed by October 25, 1979. Labor intensive contracts were written by November 1979 and the work was performed between December 1979 and February 1980. Follow-up maintenance took place in December 1980. Some additional planting was done during April and May 1980 and February 1981. The following sections describe heavy equipment and labor intensive erosion control treatments in detail.

HEAVY EQUIPMENT PHASE

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There were sixteen erosional situations that required heavy equipment treatment. Eight pieces of equipment were contracted (Table 2). Of the \$200,750 ~~60~~ spent on heavy equipment treatments, \$148,1⁴⁰~~38~~ ~~25~~ (71 percent) was spent on work that would resolve active erosion and sediment yield problems. These work tasks include: (1) excavation of haul road and tractor stream crossings, (4) log jam removal, (6) construction of cross-road drains, (5) ripping roads and landings, (3) outslöping roads and landings, (7) rocking channels (Table 1).

ROAD RECONSTRUCTION

Many of the stream crossings at Copper Creek washed out or failed prior to rehabilitation, leaving many of the potential work sites inaccessible. Crawler tractors were used to temporarily reconstruct portions of roads by placing logs in the channel covered with brush and a thin layer of soil. Since the amount of flow in stream channels increased downslope, stream crossings lower on the slope were more frequently and completely washed out than those higher on the slope.

To avoid reconstructing the large, completely washed out crossing a flatcar bridge loaned by Simpson Timber Co. was installed on the 1910 Road at ~~crossing~~ R43 (Figure 4 and Photo).

STREAM CROSSING EXCAVATIONS

- Thirty-five percent of the heavy equipment expenses consisted of the
- excavation of 49 ^{logging} ~~haul~~ road and 43 skid trail stream crossings. Type of equipment used to remove haul road crossings primarily depended upon the amount of material to be excavated; most were treated with an excavator or backhoe. Backhoes were generally used on small crossings requiring excavations of less than 150 yd³ in size. A crawler tractor towed the backhoes to steep sites and assisted the excavation by distributing excavated material along the adjacent road or winching logs uncovered by the excavation. On some larger crossings (R9, 12, 34, 38, 39, 41, 43, and 47) a dragline crane prepared the crossing by removing material which was beyond reach of an excavator or backhoe. The backhoe or excavator was then used to remove the remainder of the fill from each prepared crossing. Three road crossings (R1, 2, and 32) were completely excavated by the crane with assistance from a crawler tractor.
- The total cost to excavate all haul road crossings was \$55,744.⁵₈₅. Average
- sized stream crossings contained between 200-~~yd³~~ and 300 yd³ of material; ranging from 40 yd³ to 1,250 yd³. Costs varied from \$4.40 to \$8.50 (Table 3).
- Thirty-five skid trail stream crossings were excavated with backhoes. The remaining eight skid trail crossings (S13, 25, 33, 36, 38, 40, 41, and 43) were treated with an excavator because they were either too close to ^{logging} ~~haul~~

road stream crossings where the excavator was working or were too large for the backhoes to effectively remove all fill.

- The total cost to excavate all 43 skid trail crossings was \$16,164.²⁰; an average of \$376 for each crossing (Table 3). Costs to excavate these four crossings varied from \$4.76/yd³ to \$8.16/yd³. The estimated average fill removed from skid trail crossings was 70 yd³.
- Thirty-five percent of the total skid trail crossings within the unit were excavated. Twenty percent warranted treatment but were left untreated because of the difficulty of access or the complexity of erosional processes. The remaining crossings were totally washed out, no longer representing a significant current or potential source of erosion.

OUTSLOPING LANDINGS AND ROADS

- Thirty-nine landings were surveyed. One landing required no treatment since it was stable and re~~x~~vegetating adequately. Eighteen landings were ripped to increase infiltration and aid revegetation. An excavator or a crane was used to remove perched material around landing edges while crawler tractors shaped the material into gently sloped surfaces on the remaining 13 landings. Landing treatment totaled \$39,247.⁵⁰₇₅ and averaged \$1,961.⁰₃₉ for each landing.

Road Sloping

Eight sections of road, totaling one-third mile, were outsloped (Figure 3) to improve drainage and stabilize oversteepened road fill in areas which showed indications of potential failure into watercourses. At seven locations

outsloping was performed by retrieving sidecast material and placing it along the cutbank. Material was excavated by the backhoes or excavator and shaped by a crawler tractor. The section of road between crossings R22 and R23 was outsloped entirely by a crawler tractor with the fill removed from R22. Road outsloping cost \$3,0¹⁰⁰~~97~~ (\$9,02⁰~~1~~ per mile).

LOG JAM REMOVAL

Five percent of the heavy equipment expense involved the removal of three log jams in Copper Creek. The log jams were composed of partially sawed logs (predominantly Douglas-fir) which had a high potential to release the sediment stored behind them. Unstable sideslopes caused by flow deflection were also excavated and the toe of the unstable right bank between the upper and middle log jams was protected with riprap.

This process required the crane, excavator, both crawler tractors, and the dump truck. Approximately 600 yd³ of sediment was excavated during log jam removal at a cost of \$7,760.~~45~~. The excavator and tractors removed 850 yd³ of unstable material along the channel sideslopes at a cost of \$805.~~75~~. Riprapping the toe of the unstable right bank with boulders cost \$1,680.~~50~~ includes¹⁰⁰ quarry and transportation costs. All material excavated from the log jams and side banks was placed in a stable location on the 1910 road between the log jams and crossing R47 (Figure 3). The total heavy equipment cost associated with log jam excavation was \$10,246.⁵⁰~~75~~.

Ripping of Roads and Landing

Approximately 6.7 miles of road and 38 landings, totaling 28.2 acres, were

ripped (disaggregated) to a depth of 24 inches. Ripping was performed by the TD-25 crawler tractor with a pair of hydraulically operated ripper or chisel teeth. Roads and landings were ripped to increase infiltration of water into the road surface and promote revegetation of formerly compacted areas. Ripping was done throughout the heavy equipment phase of rehabilitation and, to avoid recompaction, shortly preceeded final road removal efforts. The total cost of ripping roads and landings was \$8,280.00.

Cross-Road Drains

Backhoes, crawler tractors and ~~the~~ excavator constructed 291 cross-road drains and slope ditches to route surface flow into less erosive areas and to disperse water which collected along the road surface. Table 4 identifies road reaches and the number of cross-road drains contained within each reach of road. Twenty-four ditches, not shown on Figure 4 were constructed near skid trail crossings to route surface flow into stream channels. Total cost of drains was \$13,330.

Rocking Channels

Twelve ^{log} ~~had~~ road stream crossings were protected with rock placed by heavy equipment to minimize downcutting and sidecutting in the freshly excavated channels (Figure 3). Conditions necessary to warrant protecting excavations by this method included: 1) the availability of dump truck access, 2) the amount of anticipated winter flow in the channel and 3) whether or not there was sufficient rock in the natural channel to provide adequate protection.

Rock was transported by dump truck to storage areas near the prescribed work

sites. After the crossing was excavated, a backhoe or excavator took rock from the nearest storage area and placed it in the freshly excavated channel. Total cost was \$6,874.~~00~~ and includes quarrying, transportation and placement of rock, as well as reshaping the rock pit following use. Approximately 410 yd³ of rock were placed in channels at an average cost of \$16.⁸⁰~~00~~/yd³.

Skid trail stream crossings were not accessible to the dump truck.

Miscellaneous

Miscellaneous heavy equipment work included salvage, equipment transportation, road winterizing, standby time and other costs. Approximately 69,880 board feet of timber (92 percent redwood and 8 percent Douglas-fir) were salvaged from landings and along roads. Salvage costs total \$16,574.~~00~~, of which approximately 25 percent was spent for hauling culverts and yarding cable from the site.

The cost of transporting equipment to and from the rehabilitation ^{unit} site amounted to \$4,863.~~00~~ with an average round trip cost of \$810.~~00~~ for each piece of leased equipment.

EVALUATION OF HEAVY EQUIPMENT TREATMENTS

Watershed rehabilitation at Copper Creek treated nearly 1 square mile of hillslope, 6.7 miles of log^{ging} ~~hauling~~ roads, 50 plus miles of skid trails, 93 individual road or slope stream crossings and many unstable areas. Many erosional problems were beyond the scope of cost-effective treatment. Stream crossing excavations resulted in the removal of 13,24⁰~~2~~ yd³ of fill which would

have entered the stream system. This does not include the sediment saved from active gullies which were dewatered by re-establishing natural drainage patterns. Post rehabilitation erosion and expected erosion from excavated stream crossings totals 3,130 yd³. This, at worst, approximates one-quarter of the volume of fill saved from entering the stream system.

Physical conditions encountered during heavy equipment work were the greatest single factor influencing the quality of excavations, the effectiveness of treating erosion problems and the expected volume of post-rehabilitation erosion. These factors 1) stream topography (including sideslope and channel gradients necessary to construct stable crossings) 2) locations of subtle variations in soils and bedrock, and 3) buried stream channel indicators (root mats, boulder beds, and pre-logging concentrations of organic debris).

According to Weaver et al. (1981) erosion control work, primarily heavy equipment work, corrected roughly 80 percent, by volumetric contribution, of the remaining, currently active sediment sources on the 1979 Copper Creek rehabilitation unit. The dewatering of management-induced gullies, the greatest single cause of erosion, by excavating stream crossings was primarily responsible for the noted reduction of erosion rates.

The success and total cost of various aspects of watershed rehabilitation is strongly influenced by the appropriateness of the prescription, the types of heavy equipment chosen to perform individual tasks and, by the skill and ability of the equipment operator.

Transit time required to move equipment between various work locations was an unavoidable expense. Accounts include any travel time greater than 15 minutes

and some standby time for equipment working with another machine which had broken down. Where work locations were adjacent to each other (less than 10 or 15 minutes travel distance), the time was included as part of the treatment. Transit time amounted to approximately \$6,406.~~00~~.

A standby cost of \$9,580~~00~~ was incurred because the TD-25 crawler tractor was guaranteed 40 hours per week of work but was used for less than that amount. This guarantee was necessary to keep the TD-25 tractor on site throughout the heavy equipment phase so that road ripping and large earth moving tasks could be accomplished as needed. No similar equipment was found that could be leased on the basis of actual engine-hours.

Costs to re-winterize access roads after rehabilitation amounted to \$2,027.⁵~~00~~. This includes installation or renovation of cross-road ditches, road grading, breaching outboard road berms and cleaning out culvert inlets along 6.7 miles of access roads, which were not removed as a part of this project.

Other miscellaneous costs for heavy equipment operations totalled \$7,065.~~00~~ for culvert installation on the D-Line Road, preparation^{of} pads for mulch storage, use of a spike roller to punch in mulch, spreading of mulches, changing of forks to bucket on the loader, freeing stuck equipment, show-up time paid to operators when a work day was rained-out, and the move-in costs for a dump truck and one backhoe, not included in equipment transportation cost section.

LABOR INTENSIVE PHASE

Labor intensive work was designed to reduce short term surface and stream channel erosion and to restore vegetation to disturbed sites. ✓

Both physical erosion control and revegetation treatments are components of this phase. Contract specifications for labor intensive work are given in Appendix A.

Physical erosion control consisted of both in-channel (stream) and hillslope (road) rehabilitation treatments. Stream work included channel clearance, gully headcut removal, gully diversions, rocking newly excavated stream channels, check dam construction, water ladders and knickpoint removal. Hillslope treatments were ravel catchers, water bars and bank stabilization.

Revegetation treatments included transplants, mulching, seeding, wattling and fertilizing and were applied to ripped roads and landings.

The Copper Creek rehabilitation site was divided into three labor intensive work units (Figure 8). Redwood National Park employees spread mulch, grass seed and fertilizer, and planted conifers throughout the site. On the upper and middle portions of the drainage. All other intensive separate invitation for Bid (IFB) contracts. On the lower portion of the rehabilitation unit, RNP crews implemented all labor intensive work tasks (Table X).

TABLE

X

VEGETATION TREATMENTS

PHYSICAL EROSION CONTROL

				IN-CHANNEL		HILLSLOPE
	CREW	TASK	COST	CREW		
UPPER						
COPPER		Mulch, Grass, Wattles,		North		Install Ravel Catchers
CREEK	RNP	Transplants, Fert	\$3,287.75	Coast	Rocking	and
				Re-	Channels	Contour Trenches
	North Coast	Grass seeding		Inh.		
	Rehabilitation	and fertilizing	14.94	GP.	\$5,026.37	\$1,883.80
MIDDLE				Forrest		Install Ravel Catchers
COPPER	RNP	Transplants,		D.	Rocking	and
CREEK		Mulch	464.00	Lane	Channels	Gully Erosion
					\$6,258.35	\$1,258.20
LOWER	Redwoods	Planted Trees, and			Rocking	Waterbar
COPPER	United	Shrubs, Wattling	1,364.35	RNP	Channels	Construction
CREEK						
	RNP	Mulch, Seed,				
		Transplants	5,383.35		\$2,848.00	\$ 444.00

UPPER COPPER CREEK

The upper Copper Creek labor intensive contract area consisted of approximately 220 acres of hillslope above and below the 2.0 mile long 1930 Road (Figure 8). Although some contract work was scattered throughout the unit, most of the work was concentrated along the 1930 road within an area of approximately 20 acres.

Northcoast Rehabilitation Group, Incorporated of Blue Lake, California, was awarded the contract for \$10,166.82 on December 7, 1979. All work was accomplished between January 4, 1980, and January 28, 1980. Three change orders, totalling \$1,155.71, were necessary to modify treatments to accommodate the effects of winter rains on the geomorphic character of stream channels and hillslopes. The total Upper Copper Creek contract costs were \$11,322.51.

Physical Erosion Control

In-Channel

Most of the physical labor intensive work was secondary in-channel treatments, mainly armoring excavated crossings. Fifteen of 28 stream crossing excavations were protected with hand-gathered and placed 4-, 6-, or 8-inch mean diameter rock. Discharges were expected to be relatively low because the area was high on the slope and included stream crossing worksites with small drainage areas. Streams with deeper incisions, larger drainage areas and higher estimated discharges received the largest size of rock.

Other in-channel, secondary treatments designed to minimize channel erosion included one rock and wood knickpoint plug, a channel clearance and bank stabilization task, notching of a log across a channel to act as a spillway and a manual excavation of a small channel. A waterladder was also constructed at Site 9 (Figure 5) to prevent a cutbank headcut from developing and migrating upstream. The waterladder is of the Type 4 design (Madej, 1980), made from milled redwood planks.

Hillslope

Nine waterbars were the only primary labor intensive treatment. All other hillslope work consisted of secondary treatments including ravel catchers, wooded terraces, contour trenches, and manual excavation (for descriptions, see Madej *et al.*, 1980; and Weaver and Madej, 1981). Construction of ravel catchers along the sideslopes of excavated stream crossings accounted for the majority of hillslope treatment costs (Table 6).

Revegetation

Transplants, stem cuttings, grass seed and fertilizer were installed January 11, 25, 26, and 27, 1980. Seven native species were transplanted: 'Alta' fescue, cattail, coyote brush, madrone, rush, salal and whipplea. Five species of stem cuttings were planted: black-berried huckleberry, coyote brush, salmonberry, sitka willow and whipplea. Sources for transplants and stem cuttings was on site.

The contractors spread a small amount of grass seed and fertilizer on one site following the installation of ravel catchers and contour trenches. The seed

mixture was the same "RNP" mixture applied at 50 lbs. per acre. Fertilizer (16-20-0-) application rate was 250 lbs pre acre.

Costs

Vegetal treatments tallied 29% (\$3302.69) and physical treatments were 61% (\$6,910.17) of the total contract cost. Contractor administration costs amounted to \$1,110.00 (10 percent). Of the physical treatments, \$5,026.37 was for in channel work, \$1,883.80 was for hillslope and stream sideslope work.

Middle Copper Creek

The middle Copper Creek hand-labor contract area is located immediately downslope of the upper contract area. It consists of approximately 90 acres of hillslope bisected a 0.8 mile-long portion of the 1900 Road (Figure 5). Most erosion control and revegetation work locations were concentrated along the road on approximately 4 acres.

Both vegetal and physical erosion control treatments were prescribed over 6 person-days in September, 1979. Forrest D. Lane of Orick, California, was awarded the contract for \$4,888.00 on January 23, 1980. All work was completed between January 24, 1980, and February 22, 1980. One major change order (\$3,316.55) was issued to compensate for changes at work sites due to winter rains. The majority of work on the change order was for channel armoring at locations where up to 5 feet of downcutting had occurred. The total middle Copper Creek contract costs, including change order, was \$8,204.55.

Physical Erosion Control

In-Channel

Manual placement of rock armor in newly excavated stream channels accounted for 94 percent (\$5,900.85) of in-channel work on the middle Copper Creek contract area (Table 6). Nine out of eleven stream channel excavations were protected with 4-, 6-, 8-, or 12-inches mean diameter rock. Because the contract area was in the midslope region, drainage areas were generally larger and stream crossings were observed to have significantly higher discharges than the upper creek area. Therefore, the average diameter of rock armor was 8 inches as opposed to 6 inches on the upper contract area. Four work horses were used to transport rock aggregate from the ripped road and slopes to stream channel work sites.

At worksite 1 (Figure 5), about 25 yd³ was stockpiled by dump trucks during the heavy equipment operations. The contractor had only to distribute the rock, most of which averaged about 12 to 15 inches in diameter, the upper limit easily handled by people.

Checkdams were installed by the contractor at Site 8, to prevent head cut development and migration where a small stream crossed the steep sideslopes of a larger channel. Channel clearance work at Site 3 (Figure 5) was the only primary in-channel treatment performed.

Hillslopes

Treatments designed to control sheet and rill erosion from bare soil areas

involved the installation of ravel catchers on the steep sideslopes of four excavated stream crossings. Treatments designed to route concentrated runoff included construction of waterbars, extra deep waterbars and ditch extensions at five locations, and minor gully diversion treatments at three locations (Table 8 and Appendix A).

Revegetation

The rehabilitated road was a narrow corridor through dense vegetation, requiring little treatment. Treatments were restricted to five excavated stream crossings and one skid trail (Figure 6). Whippen^a stem cuttings and transplants and willow stem cuttings were the only techniques used.

Costs

Labor intensive physical treatment costs totalled \$7,516.55 or 92 percent of the total contract cost (Table 9). Of the total physical treatment, 83 percent was spent on in-channel treatment 17 percent for hillslope and stream sideslope treatment.

Contractor administrative costs (primarily the preparation of daily worksheets) were \$200.00 or 2 percent of the total contract.

Lower Copper Creek

Redwood National Park crews performed the labor intensive work on the the lower Copper Creek rehabilitation unit. The majority of in-house labor was concentrated along the 1.8 mile 1910 Road. Of the total 300 acres of

hillslope within the lower Copper Creek area most work occurred on a total of 20 acres along the 1910 road (Figure 5).

Prescriptions were written and erosion control work commenced on December 17, 1979, lasting until January 10, 1980.

Physical Erosion Control

In-Channel

Channel rocking at 16 stream crossing locations represented the main work task. A total of 9,540 ft² of rock, averaging 8 to 12 inches in diameter, was placed in stream crossing excavations (Table 10). Half of the rock was supplied to the work sites by heavy equipment and laborers were only required to distribute rock in the stream channel. The remainder of the rock was hand gathered from the adjacent road or slopes. Every stream channel which crossed the 1910 road was protected from downcutting with rock armor placed by hand and/or heavy equipment.

Hillslopes

Waterbars and straw mulching constituted the other major work tasks. Twenty-five waterbars were constructed by hand at scattered locations above and below the 1910 Road (Figure 8).

Revegetation

Alder seedling and alder/grass seed mixture test plots were installed by NPS

vegetation personnel in March, 1980. Whipplea and coyote brush rooted cuttings and coyote brush seedlings from an experimental propagation contract were planted by Redwood Uniteds crews between April 28 and May 8, 1980. In February 1981 redwood and additional Whipplea seedlings were planted. Portions of the Copper Creek unit were mulched, grass seeded and fertilized by RNP crews prior to October 15, 1979 and the onset of winter rains (Figure ____). Straw mulch was applied at a rate 2,000 pounds per acre. Experimental mulches included a manure/sawdust mixture, hardwood bark, monterey pine, Douglas-fir chips and redwood chips. The redwood chips and hardwood bark were purchased from local mills and the manure purchased from a local dairy. A park roadside thinning project provided monterey pine and Douglas-fir "chips". Barley and a mixture of perennial grasses (33% 'Highland' colonial bentgrass, 33% 'Alcaroa' orchardgrass, 17% 'Linn' perennial ryegrass and 17% creeping red fescue by weight) were applied at rates of 30 and 50 pounds per acre (34 and 56 kilograms/hectare). Ammonium phosphate fertilizer (16-20-0) was applied 250 and 500 pounds per acres (280 and 560 kilograms per hectare).

Experimental combinations of grass seed, fertilizer and mulch were installed to evaluate application rates, seed mixtures and the effects on natural revegetation (Popenoe, 1981).

Evaluation of Labor Intensive

Fifty seven percent of the total cost rock lining newly excavated stream channels (Table 13).

A qualitative evaluation of the effectiveness of rock armoring by heavy equipment and by hand is shown in Table 14. Evaluations were based on whether

rock armor was necessary if applied, needed if not applied, and effective in preventing erosion.

Seventy-four crossings showed little post-treatment erosion. These were either excavated to the original channel or a stable base level or were properly rocked. The remaining 18 crossings showed substantial preventable erosion (eroded more than 5% of the excavated volume of 20 yd³ or more). Seven crossings did not receive any secondary in-channel protection.

Channel widening and downcutting were the dominant form of erosion on the 11 rocked crossings experiencing significant erosion. Problems included (1) rock too small (8-12 inch diameter) to stay in place, (2) rock deflected flow into sideslopes causing bank erosion and flow channelization around rock armor, and (3) stream channel gradients too steep to anchor or prevent transport of even large (12" mean diameter) rock. Rock armoring by hand was generally effective where streams drained less than 25 acres, but was not cost-effective on larger drainages.

Larger rock supplied and placed by heavy equipment was found to be better for protecting channel beds. Most heavy equipment-placed rock required some adjustment by hand after the first few major storms.

Other In-Channel Treatments

Primary and secondary in-channel treatments other than rock armor totalled 5 percent of the labor intensive costs (Table 13). Notching or removing logs in channels, and the construction of knickpoint plugs and waterladders are extremely site specific applications.

The five checkdams and the single waterladder are still functioning properly after four winters but will deteriorate and eventually fail. Checkdams and waterladders are comparatively cost-ineffective (Weaver et al., 1982) for correcting erosional problems but are used as temporary measures while vegetation establishment occurs.

Hillslope Treatments

Waterbars constitute the majority of primary hillslope treatments. All 38 hand-constructed waterbars appear necessary and are working effectively to route concentrated hillslope flow toward nearby stream channels away from mass movement features or slopes prone to gullying.

The majority of secondary hillslope treatments were installed on less than 60% of sideslopes freshly excavated stream crossings. These included techniques to control surface erosion such as ravel catchers, wooded terraces, contour trenches, and mulches. With the exception of mulches, none of the treatments were judged cost-effective or necessary. The structures appear to concentrate more runoff than they disperse. Little sediment was impounded behind the structures, and rills usually developed where boards were joined or structures ended.

Weaver and Seltenrich, (1981) and Weaver et al., (1982) found that hillslope treatments such as ravel catchers, wooded terraces and contour trenches are most effective on slopes greater than 60 percent. In most cases, straw mulches applied at a heavy rate, 6,000 to 8,000 pounds/acre have been found to be more and cost-effective than hillslope structures in reducing surface erosion (Weaver and Seltenrich, 1980; Kveton, et al., 1982)

A detailed breakdown is not available for the hauling and distributing straw mulch. It appears straw applied at 2,000 pounds per acre on all bare areas was very effective in controlling surface erosion. While the rate appears adequate (nearly a complete covering of the ground), straw application along flat or gently sloping segments of cross-road-drained roads and landings was not necessary to control the little erosion that occurred. Such factors as steepness of slope, erodability of the soil and the proximity to stream channels influence whether and at what rate straw should be applied. Straw mulch can effectively aid in revegetation efforts. Gentle, recently decompacted surfaces throughout Copper Creek now exhibit a denser groundcover of naturally seeded coyote brush and Douglas-fir seedlings compared to bare surfaces and where other types of mulches were used (Popenoe, 1982).

Revegetation

Revegetation treatments were designed to speed the natural revegetation on rehabilitated sites and to test several techniques. The grass, fertilizer and mulch treatments in the 1930 road allowed for documentation of grass species success, fertilizer rate comparisons, and observations of natural revegetation with different treatments.

Initially, the grass cover produced by the 50 pounds per acre rate of the RNP grass mix was higher than the 30 pound per acre rate, but after three years the grass cover was similar for both rates. Ryegrass was the early dominant but by the second year the bentgrass gained cover. By the third year the bentgrass was dominant with the ryegrass a much smaller component. The fescue and orchardgrass did not achieve significant cover at any time but were present as scattered individuals.

There was little difference in response to the 250 pounds per acre and 500 pounds per acre rates of fertilizer the first year and none persisting to the third. Where the RNP grass mix was seeded and left unfertilized, the total cover was low and remained lower than fertilized areas after three years. Successful grass establishment on these sites required fertilization. Ryegrass seemed to require fertilizer more than the bentgrass. This may be one reason the ryegrass was strong the first year but less successful the succeeding years.

Where the RNP mix was seeded and fertilizer applied, grass persisted with high enough cover (greater than 60 percent) to exclude significant natural invasion (photo). Coyote brush is the main woody plant colonizing the site. Coyote brush was relatively sparse in areas seeded with the RNP mix but abundant in unseeded areas and areas seeded with barley. Areas seeded with barley were indistinguishable from untreated areas. The barley was noted to be sprouting uniformly with some shoots 2-8 inches tall in September, 1979 but by the next summer little remained.

The most widely used mulch was straw. Average cover the first year was 90 percent, but declined to less than 5 percent the third year. The only straw mulched site was seeded with the RNP grass mix and fertilized had a lower average vegetative cover than comparable unmulched areas the first year. By the third year grass cover was equal to the unmulched areas. Heavy coyote brush invasion was seen on many unseeded, strawed areas along with many other herbaceous species. Several areas mulched with manure, chips and straw were similar to seeded areas. The heavy grass cover excluded most invading species.

Natural revegetation was greatest with straw mulch. The straw may initially reduce the size of the coyote brush seedlings but not the density. Rapid nitrogen uptake by micro-organisms decomposing the straw reduces plant-available nitrogen. According to Popenoe (1982), this early nitrogen reduction may actually encourage spring germinating species such as coyote brush. After the straw has partially decomposed, many of the micro-organisms die, making the nitrogen grasses have germinated in the fall and have had difficulty becoming established in the low nitrogen conditions.

The Douglas-fir mulched areas had some natural Douglas-fir seedlings invading as well as coyote brush and other ruderals. A large amount of the Douglas-fir mulch remained on the ground after three years. The Monterey pine mulched areas had greater and more uniform coyote brush invasion. Most of the pine needles had disintegrated by the third year mainly leaving stems. The redwood chip mulch was more persistent than either Douglas-fir or Monterey pine mulch. The redwood chip mulch was highly inhibitory to coyote brush establishment. Adjacent, identically prepared areas without chips are now heavily revegetated with coyote brush.

Upper Copper Creek Contract. Transplants and stem cuttings were the two main treatments used. Transplants were more successful than stem cuttings (Table 15). Rush and grass transplant plugs were the most successful of the transplants. There was a leaf blight on the madrone, not restricted to the transplants but common in the area. The surviving madrone, 30 and 50 percent on the two sites, are now well established. Salal was difficult to transplant due to its rhizomes and not entirely successful. Good survival was seen in well-trimmed, medium-sized whipplea. Some whipplea transplants were shaded with rocks and sticks, a successful technique. Coyote brush transplants were

successful but possibly not necessary. By the third year, naturally seeded coyote brush covered many sites making an inventory of transplanted coyote brush impossible.

Overlapping contract sites with in-house grass seeding treatments created problems in assessing survival of transplants and stem cuttings. Survival of planted species and invasion of natural species was reduced where grass cover was high. The survival of salal, madrone, whipplea and coyote brush transplants and willow stem cuttings was probably lower than necessary due to grass competition. Browsing by deer and elk may also have reduced survival. Greater survival of the whipplea the second year was due to not being able to pull all plants the first year. The actual survival of willow stem cuttings may be higher but they were difficult to locate in the dense streamside vegetation.

Stem cuttings may have been more successful under different weather conditions. Many stem cuttings were planted under extremely wet conditions, but post-planting weather soon changed to freezing. The ground became frozen and frost heaving occurred. Willow stem cuttings grew well near a water source. Coyote brush and whipplea stem cuttings were less successful than transplants. Based on survival per unit cost, the more costly transplants were more cost-effective than the stem cuttings. Neither huckleberry nor salmonberry stem cuttings were successful.

One site seeded by the contractor was an area of ravel catchers and contour trenches. By June 1983, grass cover behind ravel catchers was 80 percent but only 10 percent near contour trenches. The dominant species was orchard grass which was found only occasionally in areas which were seeded four months before contract seeding.

Middle Copper Creek Contract. Revegetation treatments on this narrow road were minimal (Table 16). Planted a month later than treatments on the upper road, the extremes of weather plaguing the upper contract were avoided. Whipplea transplants on this site were larger and unpruned. While survival was equal to that on the upper road, the vigor noted in the initial survey was much lower. Heavy grass on several sites also made the treatments difficult to locate. No grass was seeded on the middle road, however. Some of the whipplea stem cuttings were more like transplants since several rooted portions were used. Resprouting of plants thought dead in the first survey increased the number of surviving whipplea stem cuttings the second time.

Lower Copper Creek In-House Revegetation. A small number of willow stem cuttings were planted in a wet section of the rehabilitated road shortly after heavy equipment work; some of the cutting were lost when the site eroded. The remaining cuttings were successfully established by April 1983, attaining a browsed height of four feet.

The lower Copper Creek site has a good alder seed source along portions of the 1910 road but large bare areas and slopes presented problems for rapid natural colonization. In the spring of 1980, alders were planted or seeded on moderate to harsh sites or those lacking an abundant seed source to assure rapid colonization.

Five sites of grass/alder seed were sown to test the effectiveness of seeding alder in the spring. The grass was added to facilitate spreading the small alder seed. The mixes were composed of 25:1 and 50:1 grass and alder seeds by weight. The grass mix was the standard RNP mix. The five sites had average grass cover varying from 25 to 80-90 percent. Seed wash was a problem. The

lower portion of slopes often had heavier grass than upper areas and across some slopes the grass was patchy. Where grass cover was high, few alders grew. More alders were found in the lightly grassed areas.

The dominant grass was orchardgrass but bentgrass was also heavily represented. Little ryegrass or fescue was noted the third year. None of these sites was fertilized. It was concluded that alder seeded alone in the spring would have been more successful than the grass/alder mix for rapidly establishing alder on this site.

Alder seedlings were planted at four sites on the 1910 road. All sites had heavy alder cover by April 1983. This technique was successful for alder establishment.

Native shrubs were also planted in the spring of 1980. Even by the next year, the planted coyote brush seedlings were difficult to distinguish from naturally invading coyote brush. High survival of tagged seedlings indicated that overall survival was high. Whipplea does not colonize as rapidly or aggressively as coyote brush so was easier to assess survival. Whipplea survival varied by site from 0 to 93 percent, with an overall average of 33 percent. The highest survival was found on moist, shaded, north-facing slopes where grass competition was low. Whipplea did not do well on sites that were heavily grassed. The shrub survival was high considering that they were planted in May, after having been left in flats exposed to wind, rain and sun for several months.

Surplus one-year old, containerized redwood seedlings were planted in February 1981. Survival by April 1983 was low, approximately 20 percent. Many of

those surviving are stressed but may become better established as alders shade more of the road. The small number of whipplea also planted could not be evaluated because heavy older growth obscured the site.

There was high survival of the two-year old bareroot Douglas-fir seedlings planted on the upper and middle roads in February 1980 by in-house labor. Growth of the seedlings is variable. In strawed areas, growth is very good with most trees a healthy green color. Some trees are very bushy from browsing, especially on the upper road. Survival is lower on very rocky sections and trees are chlorotic. Trees planted in grassed areas had lower survival. Greater survival and up to twice the stem diameter was found in areas with less than 50 percent grass cover. Where barley was sown, the Douglas-fir survival and growth was high because of little competition. Of the chipped mulch areas, trees in the Douglas-fir mulch had the highest survival. Trees in the Monterey pine mulch had lower survival with lowest survival in the redwood chip mulch.

There has been little natural conifer regeneration on the Copper Creek site since clearcutting occurred in the early 1970's. As timber company reforestation by seedling planting and aerial seeding becomes well established, the seed source for disturbed areas will increase. Stump sprouting redwoods and dense stands of Douglas-fir already surround the road. The greatest number of naturally seeded conifers was on the middle road. The lower road had very few naturally seeded Douglas-fir.

At the time of rehabilitation, much of the site was still very bare with skid trails very much in evidence. Natural revegetation is slowly changing the appearance of the Copper Creek site. Many madrone and blueblossom seedlings

are rapidly colonizing some of the rockier, drier stretches of road. Some tanoak and madrone are becoming established on skid trails but the dominant colonizer is coyote brush. On much of the area, coyote brush and aerial seeded Douglas-fir have become so dense that passage is difficult. Alder is becoming established on the lower road and should alter the microhabitat to be more conducive to conifer establishment.

Evaluation of Manual Labor Contracts Versus In-House Labor Crews

The 1979 rehabilitation sites were greatly expanded in the size and number of treatment sites. This was only the second year of an evolving watershed rehabilitation program at. Several shortcomings were identified in the pilot labor intensive contracts completed in 1978 (Madej, et al., 1980). In order to improve labor intensive work, extensive modifications were made to the design and performance specifications of the 1979 contracts. In-house labor crews were utilized for cost comparisons.

In 1978, an average of 81 percent of the total rehabilitation costs were spent on labor intensive work (Sonnevil and Weaver 1982). On the 1979 Copper Creek Rehabilitation Unit, only 10 percent of the total costs were spent on labor intensive work. The difference in total costs reflects three points. One, a major shift in Redwood National Park policy toward utilizing heavy equipment to correct man induced erosion by the excavation of fill material as opposed to the use of labor intensive work to stabilize in-place, potentially erodible fill. Two, a realization by Redwood National Park staff that treatments designed to prevent surface erosion (such as wattles) are not generally cost-effective when viewed in terms of the total amount of sediment generated by erosional processes. Far more erosion is produced by concentrated runoff

(channel adjustments and hillslope failures). Finally, strong competition between prospective bidders and contract groups resulted in significantly lower unit costs for bid items and lower overall contract costs in 1979.

When sufficient lead time was available, Invitation For Bids (IFB), firm, fixed price contracts were found to be very suited for labor intensive rehabilitation work. However, heavy equipment work was completed at the onset of winter rains and labor intensive work was not begun until 2 months later. This delay resulted in erosion which could have been prevented had labor crews been trailing immediately behind heavy equipment work. As a section of road was rehabilitated, labor intensive treatments could have been prescribed and implemented during the dry summer period.

According to Tables 5, 6, and 7, a comparison of unit costs for individual work items indicates in-house labor crews performed the same task as contract crews for less than one-half the cost. However, heavy equipment supplied nearly one half of the rock distributed by in-house crews. The significant difference in these unit costs may reflect the higher rate of pay contract groups pay themselves as opposed to in-house park crews hourly wage. Administrative and overhead costs are significantly higher for the park when contracts are written. This results from the extensive amount of personnel time needed to prepare a contract, as well as, variable charges by the contractor to prepare requested worksheets and other administrative costs. These costs are above base line Park Service costs, whether contract or in-house work, which are incurred while actually prescribing treatments, overseeing implementation and during the final checkoff of completed work tasks.

POST-REHABILITATION

Winter Maintenance

Forty inches of rainfall, two thirds of the annual precipitation had fallen by the completion of rehabilitation work in mid February 1980. High surface runoff and stream discharges immediately after the completion of the heavy equipment phase resulted in erosion and channel adjustment in some of the excavated stream crossings. Maintenance and erosion control work were often undertaken together during the first winter following heavy equipment operations.

A total of 170 person hours, at a cost of \$1,124.00, were spent conducting winter maintenance work primarily on the lower 1910 Road. Virtually all the work was conducted in early December 1980. Most work consisted of gathering and adding additional rock or redistributing existing rock in excavated stream crossing. This was to fill small headcuts that had developed and to provide stream bank protection at points where flow had moved into the sideslope.

Other maintenance work included construction of six waterbars, breaking apart recently exposed organic debris which was deflecting stream flow into the right bank at the log jam worksite, and manually excavating two deep trenches to channelize errant streamflow below excavated stream crossing R-28 on the middle 1900 Road (Figure 3). A total of 44.75 person hours (\$303.00) were spent digging 70 feet of trench (averaging 3 feet wide and 2 feet deep) to ensure that the streamflow reentered the natural channel below the worksite. The short-lived, rehabilitation-caused gully resulted in approximately 30 yd³

to 50 yd³ of hillslope erosion of which approximately 20 yd³ to 35 yd³ entered a stream channel.

Monitoring

The only location where detailed ground surveys were conducted both before and after rehabilitation was at the log jam removal and bank stabilization site (Figure 4). Cross-sections and a channel profile were surveyed with tape, compass and surveying rod both before and after heavy equipment work. A planimetric map was constructed and the volume of material excavated from the stream channel and sideslope was computed. Subsequent surveys in the summer of 1980, 1981 and 1983 have documented erosion, sediment production and channel changes following rehabilitation.

Permanent photo points were established at nearly every work location to visually monitor changes. Photographs were taken before and after heavy equipment work as well as after labor intensive work. Specific areas have been rephotographed in 1981 and 1982.

Determination of fill volumes excavated from stream crossings were calculated by using a double-end-area-method following the completion of heavy equipment work.

Haul Road Stream Crossings

Stream channels can be excavated with a crane (above the channel), a backhoe or an excavator. The excavator has the advantage over a crane of greater mobility in reconstructing the natural configuration of the channel. It has a

360 degree turning radius allowing excavated material to be deposited well behind the machine and out of the stream channel. The 25 foot reach and the power of the hydraulic system to remove most large organic debris makes the machine more versatile. On medium to large crossings (200 yd³ to 500 yd³) an excavator, and a crawler tractor was the best equipment combination. The crawler tractor may experience some periods of slow work depending on the channel gradient, and amount and size of organics. The tractor can initially doze out the upstream portions of the fill, working material out along the road, winching logs as needed and distributing fill removed by the excavator. In excavating large fills (1,000 yd³ and greater) in steep gradient streams (greater than 35 percent), the use of an excavator and tractor will generally result in gentler than natural sideslopes because the dozer needs gentler slopes to doze out fill supplied from the downstream edges of the crossing by the excavator (see sketch, photo, etc.).

Crossings having large drainage areas and high discharges have the potential for significant amounts of erosion. However, in Copper Creek, a qualitative survey of drainage areas above excavated crossings does not totally predict erosion. Crossings not excavated to stable base generate the largest volumes of sediment. On all drainages greater than 10 acres where crossings were excavated to a stable base some post-rehabilitation erosion has occurred but does not appear that it will cause high sediment yields in the future. Many of the future high erosion sites are on perennial streams along or adjacent to the 1910 Road. Erosion on these sites is related to the steeper convex hillslope position near the inner gorge of Copper Creek, unstable mixes of Hugo and Atwell soils, well incised stream channels with steep sideslopes, and large fill crossings.

Skid Trail Stream Crossings

Backhoes have a difficult time getting to and excavating hillslope skid trail crossings.

Many of the skid trail stream crossings treated were left incompletely excavated due to logs or stumps which could not be removed by the backhoes. On some crossings, backhoes could not remove all of the fill because of wet conditions, large or steep crossings or insufficient working space. Complete excavations reaching original grade on sideslope configurations was especially important, since secondary protection (checkdams, etc.) couldn't always be installed. The tractor driven excavator capable of climbing 50-60% slopes was able to approximate the original channel configuration and distribute the excavated fill without the assistance of a tractor on many small crossings of less than 100 yd³.

Outsloping Roads and Landings

Cranes were most useful where considerable volumes of fill and debris was perched or failing on steep slopes and where it was necessary to retrieve the material from the hillslope. The 40 to 50 foot reach of a crane allowed excavation of material which was inaccessible to other equipment. Much of the work done by cranes can be accomplished more efficiently by hydraulic excavators and tractors. When necessary to reach far downslope from roads or landing surfaces benches can be constructed to permit an excavator or tractor to retrieve the material.

Thirteen out of 20 landings excavated in Copper Creek exhibited tension cracks as well as other indications of pending failures. One-third of these had some portion of the landing fail before the summer of 1979. While many of these failures involved fill material only, a few resulted in the release of several thousand cubic yards of hillslope.

Although it is difficult to assess the effectiveness of excavations, examination after three winters indicates no failures have occurred on any landings. More importantly, on treated landings which displayed signs of instability before rehabilitation, no new scarps, tension cracks or indications of a pending failure are present.

Log Jam Removal

The mechanisms of large organic debris (LOD) accumulation and the effects of LOD on channel morphology have been extensively documented (Pitlick, 1981; Keller and Talley, 1979; Swanson and Lienkaemper, 1978). Organic debris and log jams commonly alter the hydraulics of a stream reach and causes changes in channel morphology. For example, an abrupt step in the longitudinal profile may form at the jam with an associated decrease in gradient and frequently an increase in channel width upstream of the jam. These effects were seen at the Copper Creek log jam worksite. As shown in Figure 4, the log jam also caused hillslope failure by diverting flow into the banks and undercutting the toe of the slope.

Six channel cross sections (Figure 9) and the stream's longitudinal profile (Figure 10) at the log jam site were surveyed on five separate occasions: prior to rehabilitation, immediately after heavy equipment work, and after the

next three winters. A tape and compass map of the area was also made in 1979 prior to rehabilitation and following the third winter (Figure 4). These data were then used to document subsequent channel changes and evaluate the work. Approximately 1,450 yd³ of sediment were excavated by heavy equipment preventing re-introduction and/mobilization by the stream. Of this total, 600 yd³ of alluvium was removed from the channel behind the log jams and 850 yd³ from the oversteepened hillslope adjacent to the channel.

As a result of the 1980 winter storms, 560 yd³ was eroded from the site. Most of the bedload loss was associated with channel scour from increased flow velocities on the unprotected loose sediment in the unobstructed reach of the stream.

During the following winter (1981) an additional 60 yd³ was eroded. Most of this occurred near cross sections 2 and 3 where an average of 2 - 4 feet of scour or bank erosion was detected (Figures 9 and 10). An additional 130 yd³ was eroded from the log jam work site during the next winter (1982). Channel widening (bank erosion) occurred at all six cross sections (Figure 9) and accounted for 85 percent of the measured erosion.

The change in erosional mechanisms from channel downcutting to channel widening, was predictable. By 1982, natural boulders were being exposed throughout much of the log jam reach. The increase in particle size (roughness) coincided with the exposure of stumps whose basal flair indicated the stream channel was near its natural grade. With the exception of the upstream migration of a few log-controlled steps in the channel profile (Figure 10), the dominant response to increased discharge was channel widening (Figure 9).

The excavated, unstable hillslopes along the right bank (Figure 4) remained intact through Nov. 1982. The primary objective of stabilizing the adjacent, unstable hillslopes, through removal of the log jam, has been attained.

Total cost for removal of the log jams was _____, averaging \$6.00 per cubic yard of material excavated.

Management recommendations for evaluating general log jams are in App._____.

Ripping Roads

Roads were ripped before any operations, such as stream crossing excavations or construction of crossroad drain. Road ripping was delayed as long as possible to reduce recompaction during rehabilitation. It was necessary to guarantee a 40 hour work week throughout the project period for the TD-25 tractor with the ripper teeth so it would remain on-site. The tractor was often idle and these additional non-productive hours greatly inflated the itemized costs (Table 1). Approximately \$25,000.00 or one-eighth of the total rehabilitation costs were associated with standby or other non-productive hours by the TD-25 tractor.

Ripping roads as the last step during rehabilitation appears to have improved natural seeding and revegetation efforts in Copper Creek. It appears more effective than similar disaggregation practices done at the beginning of heavy equipment operations.

Cross-Road Drains

In constructing typical cross-road drains (averaging 2 - 3 feet deep, 3 feet wide, and approximately 35 feet long) the combined use of a tractor and backhoe was found to be the most efficient. Including transit time between cross-road drains, the following average costs were obtained:

	# of Drains	Hrs	Hrs/Drain	Unit Cost
Backhoe	19	11	.50	\$20.26
Excavator	15	3	.20	14.00
Tractor/backhoe	23	5.5	.23	10.00

Pitlick (1981) suggests one approach to determining the feasibility of removing a log jam for the purpose of reducing streambank instability. The approach centers around producing a quantitative statement of the erosion potential of the site. We encourage rehabilitators to follow this or a similar procedure to define what positive benefits or negative effects will result from removing a log jam. The procedure (Pitlick, 1981) for evaluating a site involves the simple field measurements outlined below:

1. Assess the stability and composition of the jam keeping in mind that jams comprised of redwood logs are, in general, more stable and decay-resistant than Douglas-fir jams.
2. Survey a longitudinal profile of the channel, extending downstream and upstream of the site using a tape, rod, and hand level. The survey

provides an estimate of the depth and channel length of stored sediment associated with a jam.

3. Establish monumented cross sections across the channel and onto the adjacent hillslopes beyond the possible limits of excavation or failure.
4. Construct a morphologic map of the area showing channel perimeter, distribution of organic debris and other pertinent hillslope and channel features.
5. Estimate the depth and length of channel fill from the longitudinal profile. In cases where excavation of material off hillslopes is necessary to insure stability, the amount of material to be removed from the hillslopes can be estimated from the cross sections and from field observations.
6. Measure planimetric areas of channel and hillslope features from the morphologic map. The total volume of sediment in storage within the channel and on the slope can be computed by taking the product of the surface area of the feature and the estimated depth of sediment as determined by the profile or cross-section.
7. The amount of work necessary to remove the jam is evaluated at this point. The costs of excavating material off hillslopes and from the channel can be determined knowing the volumes of sediment. The feasibility of treating this site over others is then weighed in terms of the projected amount of sediment saved from introduction into the channel. The potential

impact on aquatic habitat is an additional factor that although not as easily assessed should be taken into account.

In the event that the jam is pulled, it is useful to make some simple measurements while work is in progress to determine if the excavation is adequate or beyond what was prescribed.

Erosion Caused by Rehabilitation Activities

Watershed rehabilitation work of this scale and complexity results in some rehabilitation generated erosion.

A total of 1,359 yd³ of soil was eroded from haul road and skid trail stream crossings (866 yd³ and 493 yd³, respectively) in the three years since rehabilitation. Of the 92, haul road and skid trail stream crossings 26 were excavated to or very near the original channel gradient and sideslope configuration. Of these, 26 experienced subsequent channel adjustments yielding volumes of sediment 5 percent or less of the originally excavated volume.

Erosion on the remainder of the crossings which had been excavated to or near original grade was mainly from channel widening. This bank erosion resulted from under designing channel width or capacity to accommodate high flows. Of the crossings not excavated to the natural channel, 17 haul road and 7 skid trail crossings, experienced less than 5 percent erosion original excavated volume. The stability of these excavations was influenced by the ability to key the excavation into large, stable organic debris already in the channel near the downstream end of the excavated area.

Five haul road crossings and 7 skid trail crossings experienced subsequent erosion equal to or greater than 25 percent of the originally excavated volume. At these locations, either: 1) active unstable slopes adjacent to the stream crossings failed, or 2) the equipment could not completely excavate the fill material, or 3) it was believed the crossing had been excavated to a stable base. The relatively high amount of erosion when compared to the amount of fill excavated, was caused by a combination of channel widening ranging from 3 to 10 feet, channel downcutting ranging from 2 to 4 feet, and individual bank failures ranging up to 50 yd³. At skid trail crossing 38 and road crossing 28, gullying related to bank failure and an unexcavated stream channel resulted in an additional 60 yd³ and 350 yd³ of post rehabilitation erosion.

Annual field reviews in Copper Creek indicate most undersized crossings experienced the majority of the erosion the first winter following rehabilitation. However, when greater magnitude storms occur, additional channel erosion can be anticipated. It is estimated that one-half of the crossings which are now experiencing high rates of erosion would not have shown significant erosion had more appropriate and versatile types of heavy equipment been used, and/or had the excavations been completed to the original channel gradient instead of to "presumed" stable base levels. On the remaining half of the crossings, excavation to a stable and non-eroding configuration wasn't possible because of unstable sideslopes, stream gradients in excess of 40 percent or the destruction of a large advanced second-growth vegetation.

Future Sediment Sources in Copper Creek

It is now possible to estimate the volume of future erosion. Table 12 lists those crossings where most future erosion is expected to occur.

Only one of these crossings was excavated to near original gradient (R44) and only two were excavated to a stable base level (R13 and R39). The mechanisms for potential erosion can be subdivided into four types: 1) large scale mass movements (greater than 100 yd³), 2) shallow and relatively small failures along steep sideslopes, 3) headcut migration (channel deepening) and 4) bank erosion (channel widening). All of these processes may initiate influence the others. Of a total of 1,770 yd³ of expected eroded material, 1,000 yd³ are associated with large scale mass movement near two stream crossings (R36 and S38). The volume of erodible material from shallow streamside failures and channel deepening is smaller than large mass movement features, but the frequency is greater. Five crossings are expected to experience shallow failures along streambanks and virtually all the crossings listed in Table 12 will experience channel downcutting through headcut migration.

The time in which erosion will occur is highly dependent on climatic, hydrologic and hillslope characteristics. Incompletely excavated stream channels or crossing with large amounts of fill still present are strongly influenced by the magnitude of peak discharges and the role of organics in arresting or encouraging erosion. In most cases, small amounts of material will be eroded episodically over many years. Most streambank slides will occur as one event, triggered by high antecedent soil moisture conditions and high discharges during a storm. The modes of delivery on large scale mass movements are much more complex. Failures can occur either catastrophically

or occur annually over many decades. With either mechanism, subsequent enlargement of the crown scarps, streambank erosion of the landslide toe or gullying will result in long-term erosion.

Arcuate rotational slump scarps extending 100 feet upslope of crossing R36 developed during the winter of 1981-1982. The drainage area is very small at the stream crossing and the slopes showed no evidence of an instability prior to rehabilitation. While it is difficult to show that the developing slump feature was not caused by rehabilitation activities, it cannot be ruled out. Depending on the rate of continued slump development, the release of sediment is expected to be slow, influenced by the capability of the small ephemeral stream to remove the introduced material.

The slope instability at skid trail Crossing 38, is much more active and resulted from the stream downcutting below the original grade of the channel to expose unstable Atwell soils. An extensive system of scarps extending upslope before rehabilitation have enlarged since 1979. The stream channel from below R44 to above S37 (Figure 3) was severely modified by stumps and sawlogs. Several thousand cubic yards of sediment and debris from a fill failure and debris torrent (landing 14) were introduced and passed through the channel. This created a situation that could not be cost-effectively rehabilitated. Erosion rates will remain high (100 yd³ per year) for many years until equilibrium is re-established.

Mass movement features are developing at two other locations (Figure 3). Both were identified as unstable before rehabilitation. Segments of roads across these unstable areas were outsloped or cross road drained improve drainage.

At both locations, material involved in a slope failure be stored on the hillslope.

Table 5.

Itemized Upper Copper Creek Contract Labor Intensive Work

A. IN-CHANNEL:

Rock Channel: 4" rock	3	1128 ft ²	.96 ¢/ft ²	\$1,080.00
Rock Channel: 6" rock	10	3269 ft ²	.73 ¢/ft ²	2389.00
Rock Channel: 8" rock	2	918 ft ²	.84 ¢/ft ²	772.00
Waterladder	1	1 Job	-	389.00
Rock & Wood knickpoint Plug	1	1 Job	-	111.00
Channel Clearance & Bank stabilization	1	1	Job	-

167.00

Log Across Channel	1	1 Job	-
Excavation of Channel	1	1 Job	-

B. HILLSLOPES AND STREAM SIDESLOPES:

Ravel Catchers	4	310 lin.ft.	\$2.46 lin.ft.
Contour Trenches	1	60 lin.ft.	1.11 lin.ft.
Wooded Terraces	1	46 lin.ft.	2.47 lin.ft.
Waterbars	9	217 lin.ft.	3.69 lin.ft.
Manual Excavation	1	5.0 lin.ft.	18.51 lin.ft.
Material Transport	1	1 Job	-

C. CONTRACTOR ADMINISTRATION COSTS: INCLUDES

Preparation and Transport of Materials

Transportation of People and Tools To &

From Worksites

Organization Time

Discussion Time With the C.O.R.

Tool Maintenance

Documentation of Person-Hours/Task

D. VEGETATION: (needs breakdown)

Total Contract Costs \$ 11,323,00

Table ____

<u>Crossing #</u>	<u>Estimated Volume (yd³)</u>	<u>Principle Cause of Expected Erosion</u>
R5	50	Head cut migration
R13	50	Head cut migration
R28	175	Gullied channel enlargement and head cut migration.
R32	150	Head cut migration
R36	500	Large scale mass movement and head cut migration.
R38	60	Channel adjustment and shallow sideslope bank failures.
R39	50	Channel adjustment and shallow sideslope bank failures.
R44	70	Channel adjustment and shallow sideslope bank failures.
S4	20	Head cut migration
S30	30	Channel downcutting and shallow sideslope bank failures.
S36	40	Head cut migration and shallow sideslope bank failures.
S38	500	Large scale mass movement and channel adjustments.
S42	50	Head cut migration
S43	25	Head cut migration

Table 4 BREAKDOWN OF TOTAL LABOR INTENSIVE COSTS

	ADMIN COSTS	IN CHANNEL		HILLSLOPE		VEGETATION
		Rock	Other ₁	Primary ₂	Secondary ₃	
Upper						
Contract	\$1,110.00	\$4,241.00	\$ 785.00	\$801.00	\$1,083.00	\$3,303.00
Middle						
Contract	200.00	5,901.00	357.00	507.00	751.00	464.00
Lower						
In-House *cost incl.						
	admin.	2,820.00	28.00	444.00	-----	Hektner, et al.
TOTALS	\$1,310.00	\$12,962.00	\$1,170.00	\$1,752.00	\$1,834.00	\$3,767.00
	6%	57%	5%	8%	8%	* lower road work

TOTALS: \$22,795.00

¹ Incl. checkdams, channel clearance, waterladder, knickpoint plug and notching and removing logs in channels.

² Incl. waterbars and gully diversion work at site 14 (Middle Contract).

³ Incl. ravel catchers, contour trenches, wooded terraces, gully diversions and manual excavations.

Table 5 EVALUATION OF EFFECTIVENESS OF ROCKED AND UNROCKED ROAD
AND SLOPE CHANNEL CROSSING

	ROCKED			NOT ROCKED	
	EFFECTIVE	NOT EFFECTIVE	NOT NECESSARY	EFFECTIVE	NEEDED ROCK
Heavy Equipment:	4½	3½	1	19	3
Labor Intensive:	5½	4½	8		
Labor Intensive:	2	3	3	30	4
Heavy Equipment:	1				
TOTALS:	13	11	12	49	7

TABLE 2.

HEAVY EQUIPMENT: COPPER CREEK

<u>CONTRACTOR (operator)</u>	<u>EQUIPMENT</u>	<u>COST/HOURS</u>
Carl Kjer (Ernie Kjer)	22B Bucyrus Erie Crane (with operator and oiler), having 40' boom and 3/4 yd ³ bucket.	\$76.56 (weighted average of several rates)
Larry Lambert	JD 690B John Deere Hydraulic Excavator (with operator), having a 25' effective reach and a 5/8 yd ³ bucket.	\$67.40 (weighted average of several rates.)
Ted's Construction Company (Ted Mulder)	TD-25 International crawler tractor (with operator), having 300 HP, a 13' wide by 5' high blade, and a pair of 2' depth rippers.	\$80.00
Ted's Construction Company (Ted Mulder)	125B Michigan Loader (with operator) with 4 yds ³ bucket and log forks.	\$56.00*

Ted's Construction Company (Ted Mulder)	Peterbilt Dump Truck (with operator) having a 10-12 capacity.	\$30.00*
Ted's Constructions Company (Ted Mulder)	580B Case Extendahoe (with operator) having a 24" trenching bucket ($\frac{1}{2}$ yd ³) and a 64" loading bucket.	\$30.00
Ted's Construction Company (Ted Mulder)	580B Case Extendahoe same as a bove)	\$30.00
Bud Stockton	HD-16 Allis-Chalmers crawler tractor (with operator), having a winch (1 $\frac{1}{2}$ " Bull Line.)	\$50.00

* paid engine time only

Table 1. HEAVY EQUIPMENT COST SUMMARY: COPPER CREEK

Includes all costs incurred in the heavy equipment phase of rehabilitation on the Copper Creek Rehabilitation Test Unit: Site 79-4. Standby costs are included.

Road Reconstruction	\$2840.00
Flator Bridge Installation and Removal	3273.00
Haul Road Stream Crossings	55,744.53
Skid Trail Stream Crossings	16,164.20
Excavating and Outsloping Landings	39,247.75
Outsloping Roads	3,097.30
Log Jam Excavation and Slope Stabilization	10,246.75
Ripping Roads and Landing	8,280.00
Constructing Cross-Road Drains	13,330.00
Roading Channels	6,874.10
Salvage	16,574.00
Transit Time on Rehabilitation Site	6,406.20
Standby Costs TD-25 Tractor	9,580.00
Miscellaneous Costs	7,056.05
Equipment Lowboy Transportation Costs	4,863.00
Winterizing Park Roads	<u>2,027.40</u>
Totals	\$200,750

TABLE 3

SELECTED COST ANALYSES TO TREAT INDIVIDUAL HAUL ROAD FTREAM CROSSINGS ON SITE79-4

Costs for selected individual crossings includes costs excavate and distribute fill and shape channel sideslopes, costs to haul and place rock in excavated stream crossings. Where standby costs are excessive, costs are computed minus standby hours.

ROAD CROSSING 6

<u>EQUIPMENT</u>	<u>HOURS</u>	<u>COST/HOUR</u>	<u>COST</u>
Extendahoe	21.0	\$30.00	\$630.00
HD - 16	11.5 (7 standby)	50.00	<u>575.00</u>
Total			\$1,205.00

Excavated fill - 155 yd³

Average cost per yd³ : \$7.77

If subtract standby time - average cost per yd³ : \$5.52

ROAD CROSSING 12 (R12)

EQUIPNEMT	HOUR	COST/HOURS	COST
Crane	21 (3 standby)	\$76.56	\$1607.76
Excavator	12	67.40	808.80
TD-25	11.5 (3 standby)	80.00	920.00
HD-16	32.5 (11 standby)	50.00	1,625.00
Extendahoe	19	30.00	<u>570.00</u>
Total			\$5,531.56

Excavated fill - 1250 yd³

Average cost per yd³ : \$4.43

If subtract standby time average cost per yd³ : \$3.61

Table 4.

Frequency of constructed cross-road drains based on related slope position,
Copper Creek Unit.

ROAD	SLOPE POSITION	NO. OF DRAINS	FREQUENCY
1930	Upslope Road	46	4.2
1900	Midslope Road	65	7.2
1920	Midslope Road	48	8.2
1910	Lowest Road	108	12.0

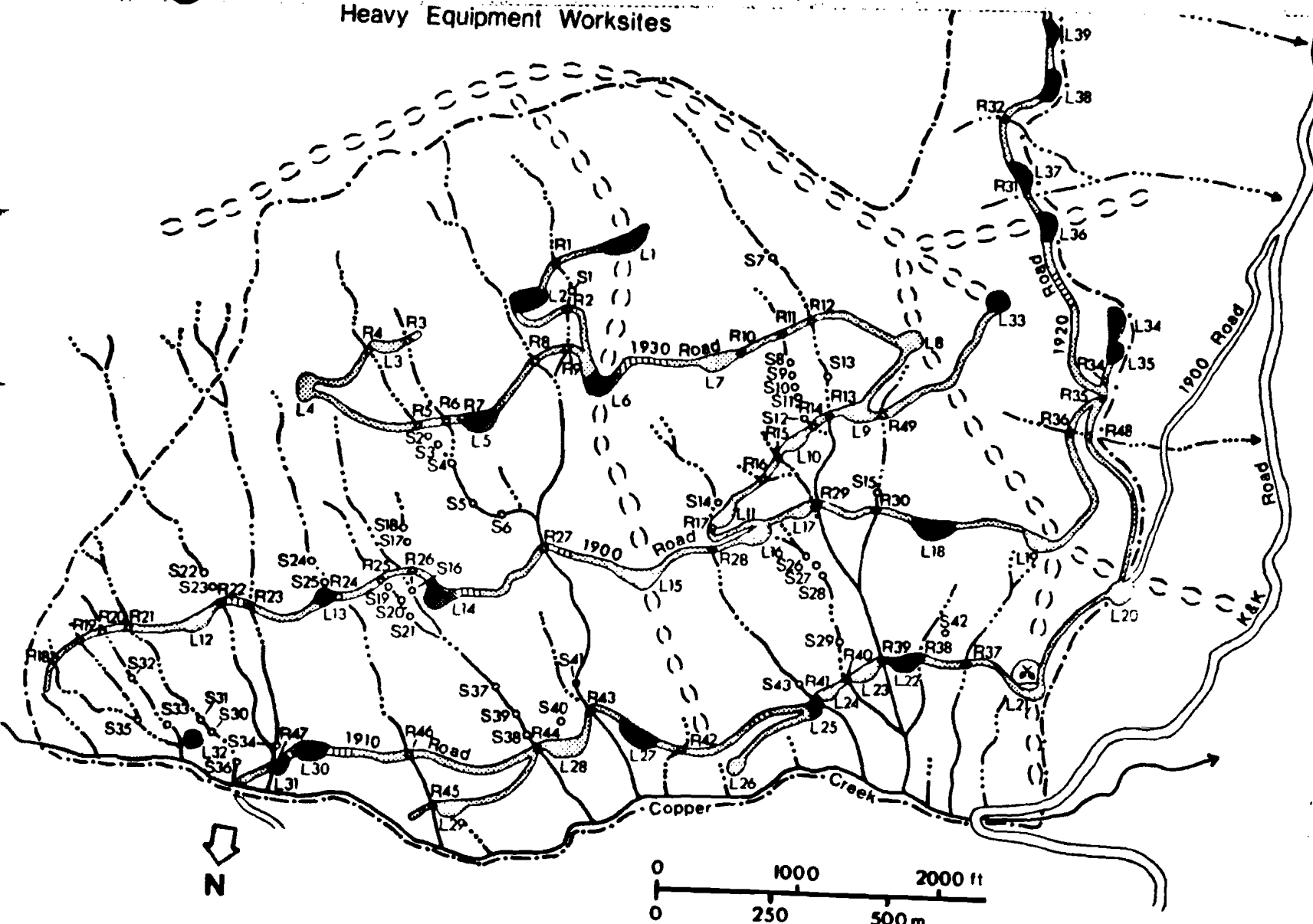
Total: 267*

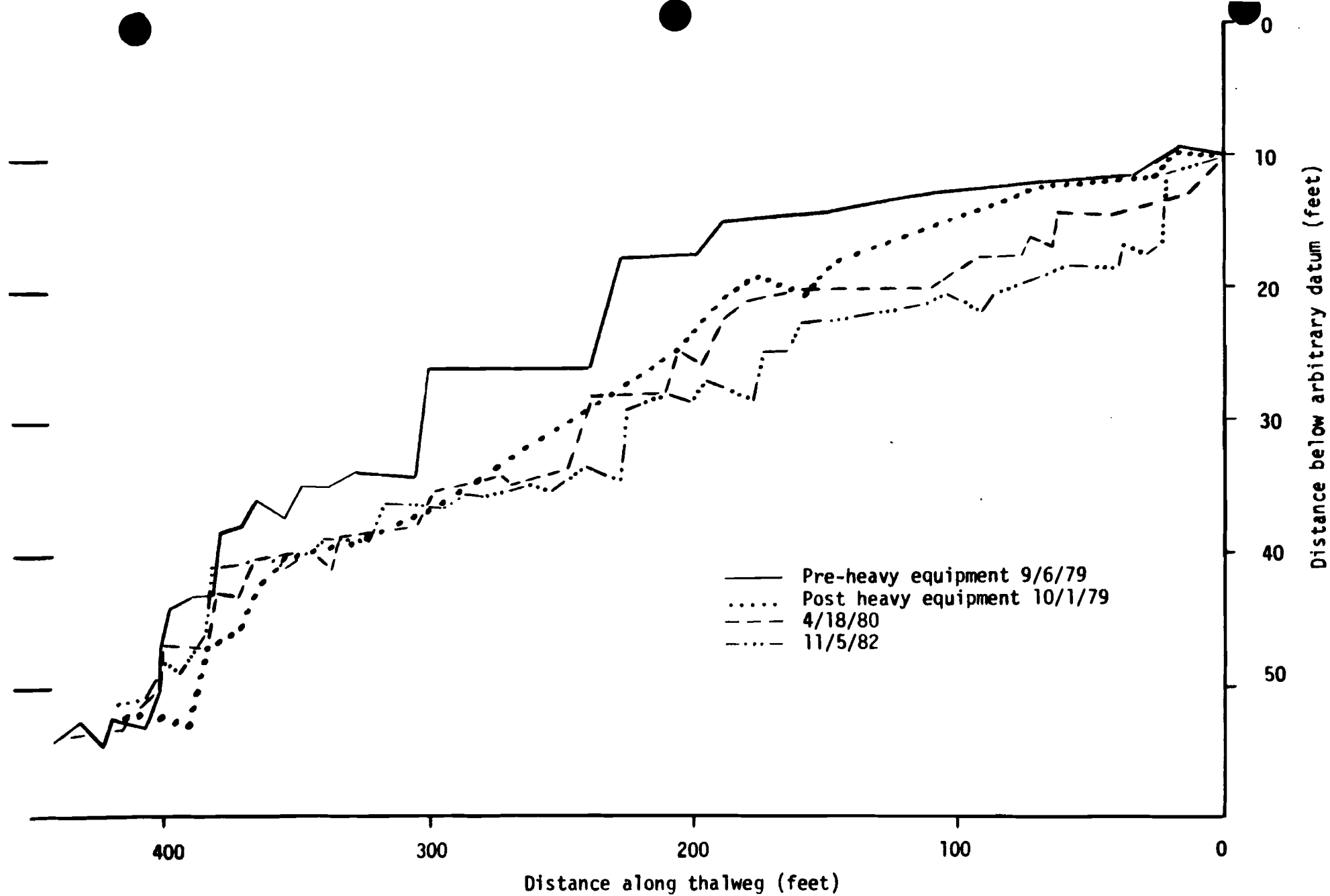
* Does not include 24 ditches or drains constructed on hill slope segments
between the roads.

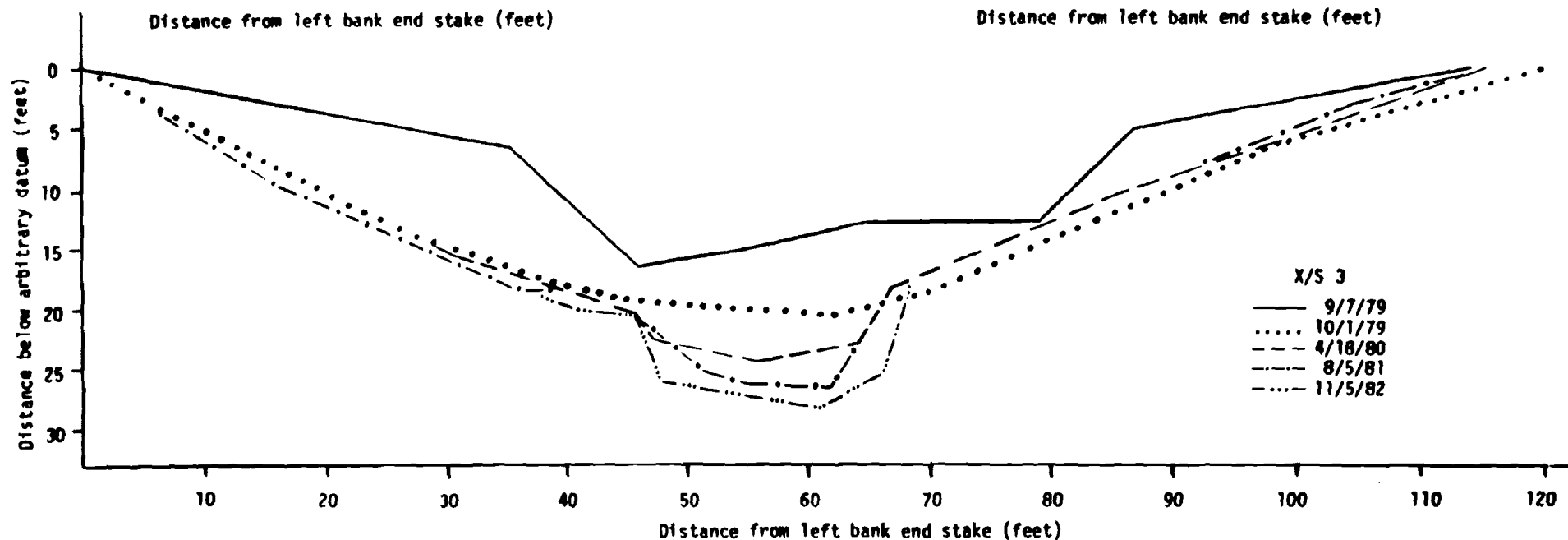
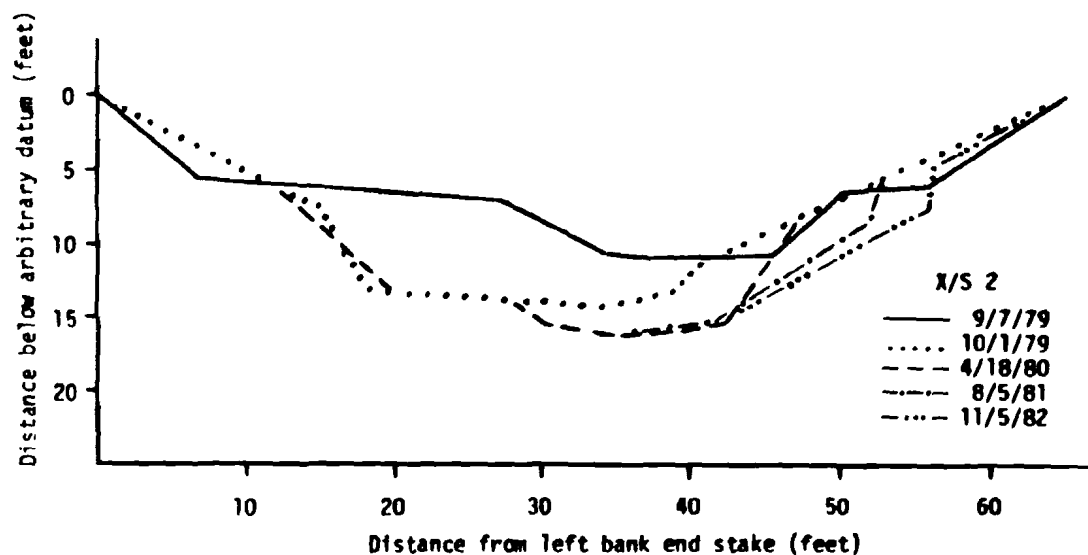
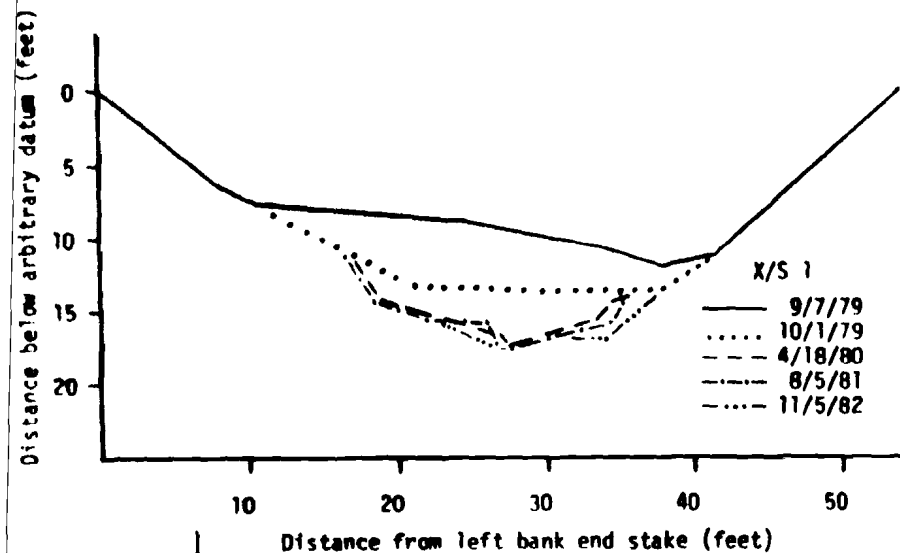
Heavy Equipment Worksites

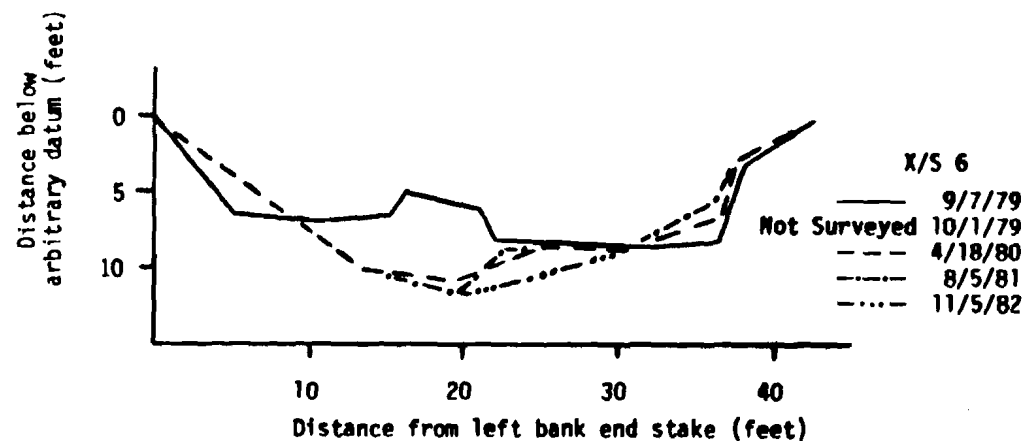
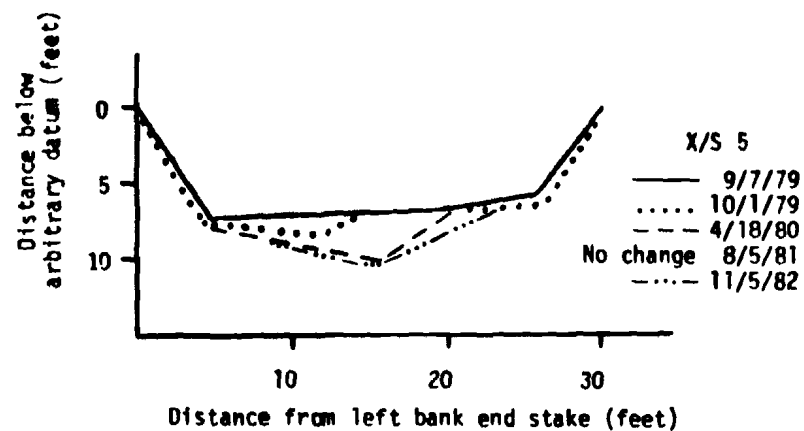
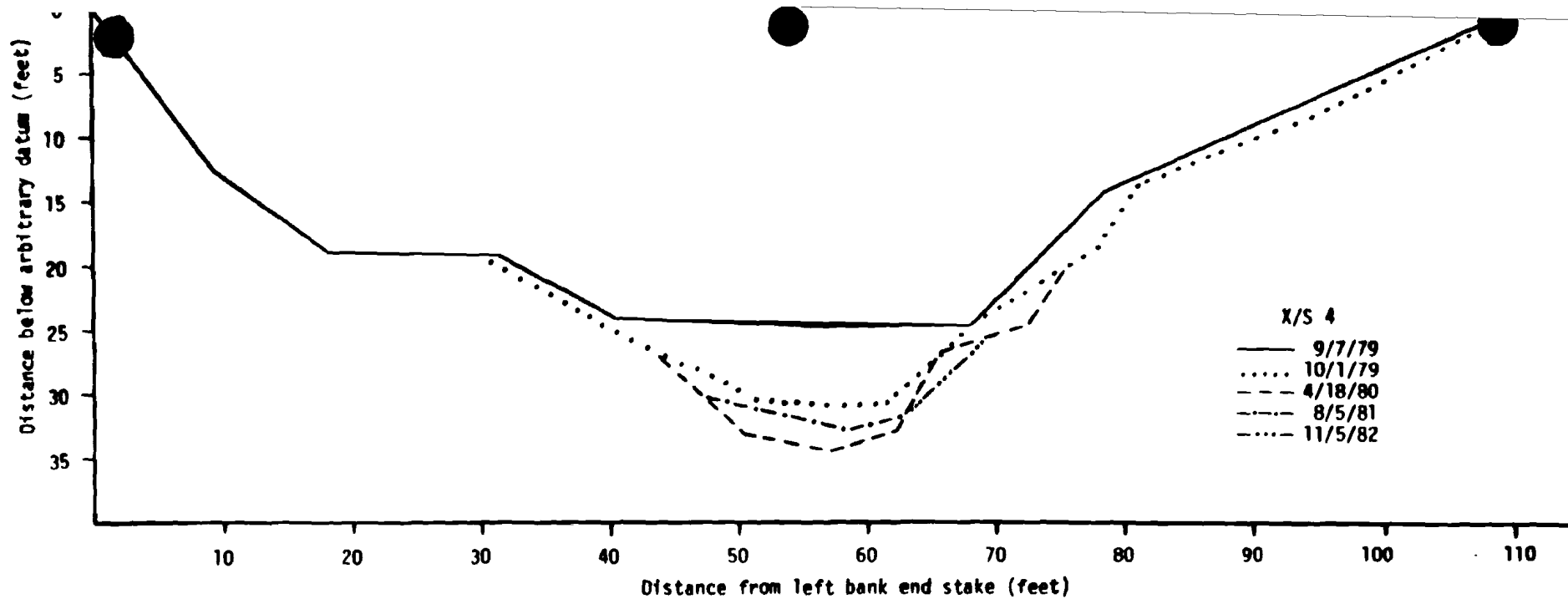
LEGEND

- boundary of reho
- ridges
- ephemeral and in streams
- perennial streams
- untreated roads
- treated roads and (ripped and c (eg L3)
- outsloped landing
- outsloped road se
- o excavated skid tra S1-S43
- o excavated road c R1-R49
- o crossings armored hauled rock
- x source of rock arm



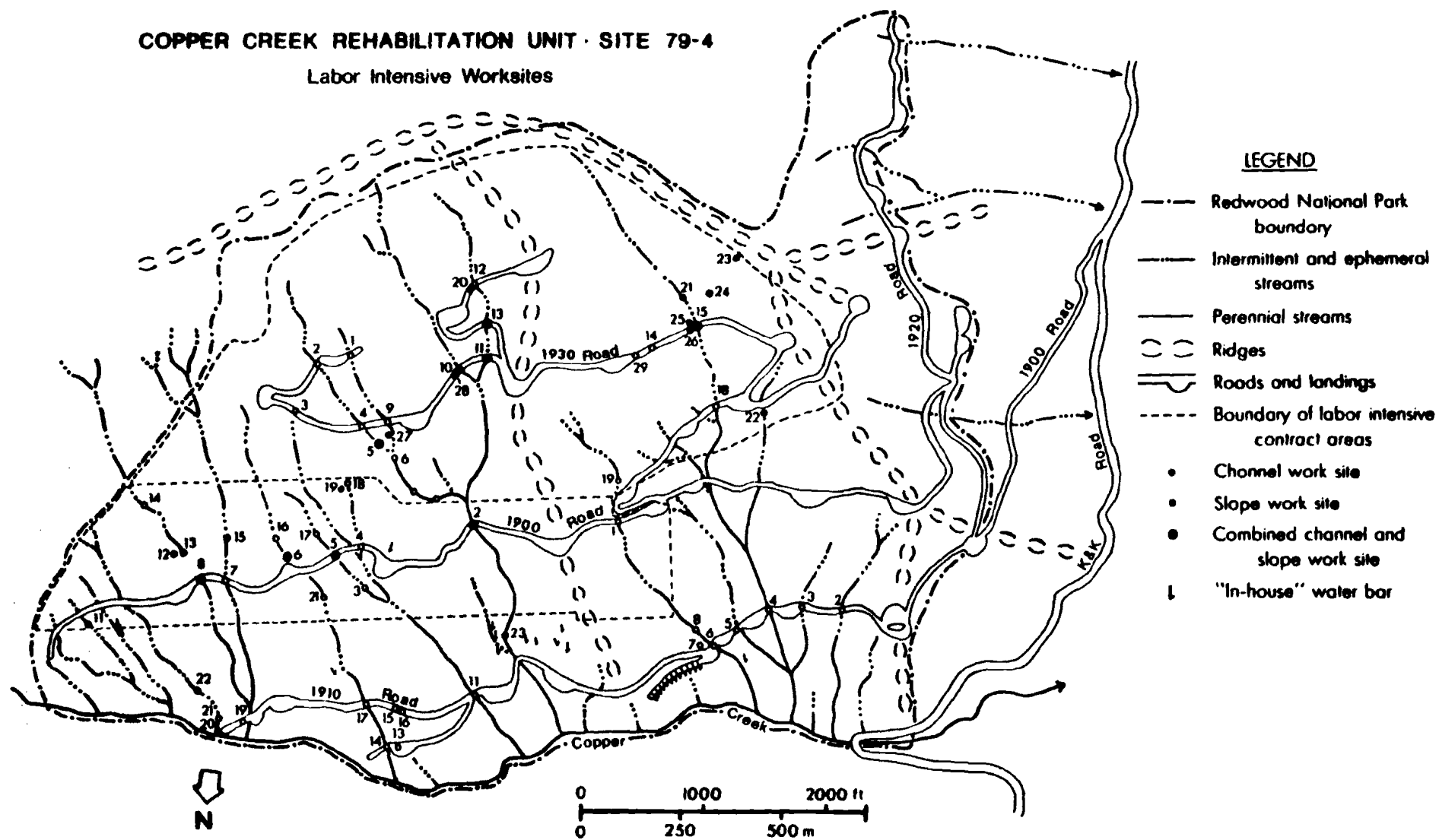






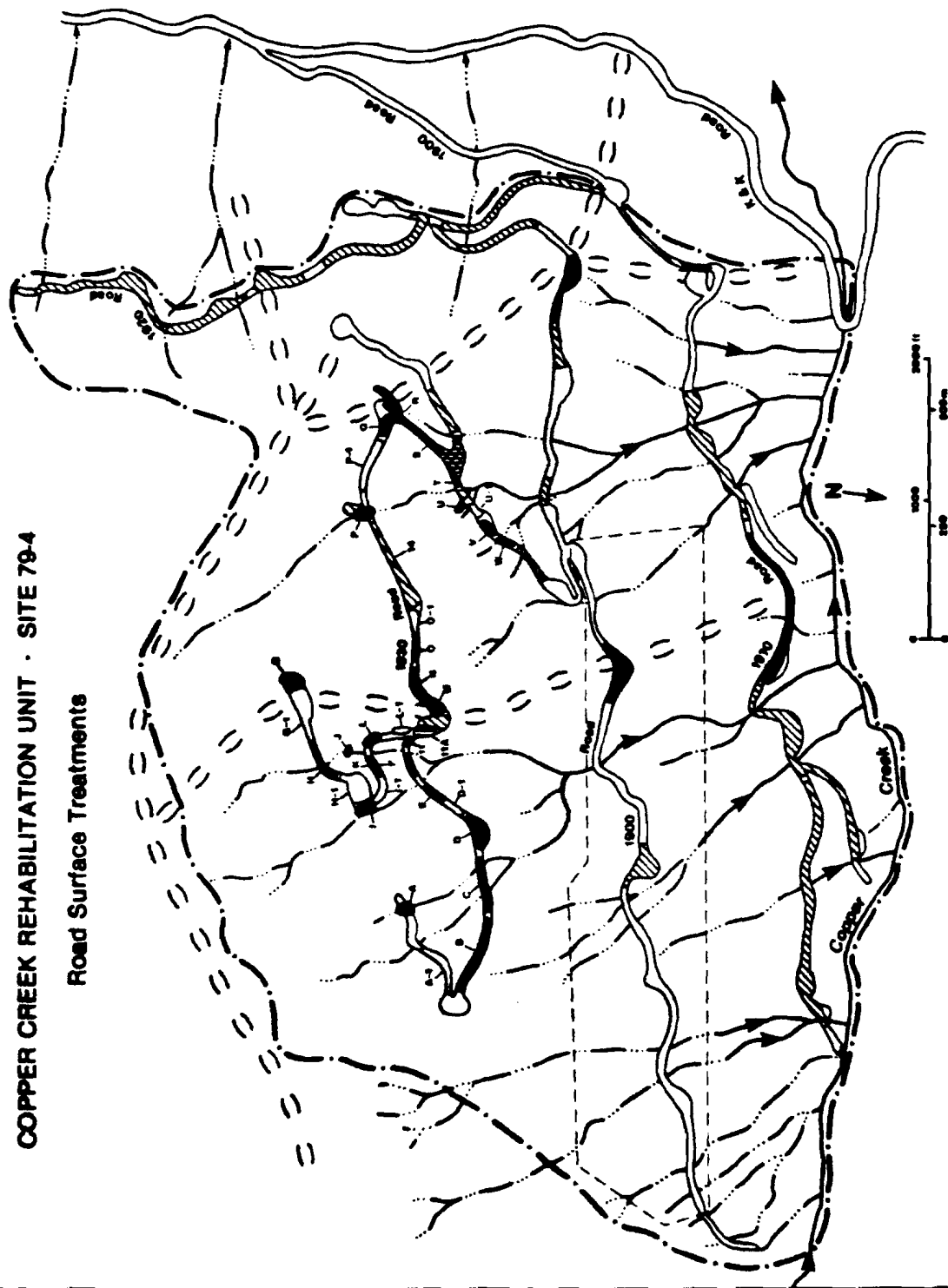
COPPER CREEK REHABILITATION UNIT · SITE 79-4

Labor Intensive Worksites



COPPER CREEK REHABILITATION UNIT · SITE 79-4

Road Surface Treatments

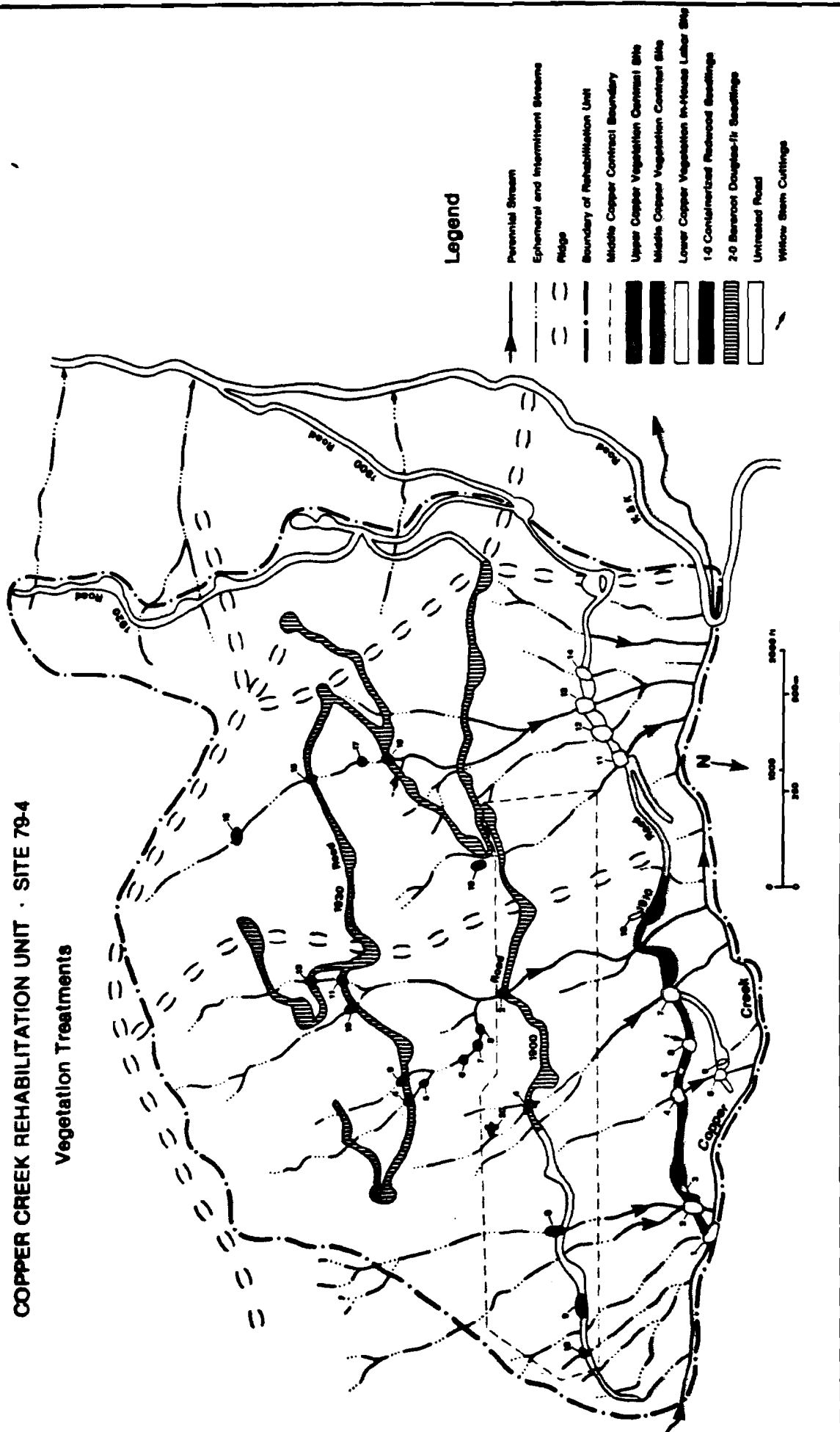


Legend

	Perennial Stream
	Epithermal and Intermittent Streams
	Ridge
	Boundary of Rehabilitation Unit
	Middle Copper Contact Boundary
Treatments	
	Straw Mulch
	Grass
	Redwood Chips
	Douglas-fir Chips
	Manure, Chips, and Straw
	Monterey Pine Chips
	Hardwood Bark
	Control
	Untreated Road

COPPER CREEK REHABILITATION UNIT · SITE 79-4

Vegetation Treatments



Legend

- Perennial Stream
- Ephemeral and Intermittent Stream
- Ridge
- Boundary of Rehabilitation Unit
- Middle Copper Contrast Boundary
- Upper Copper Vegetation Contrast Site
- Middle Copper Vegetation Contrast Site
- Lower Copper Vegetation In-House Labor Site
- 1-6 Containerized Redwood Seedlings
- 2-0 Bareroot Douglas-Fir Seedlings
- Unreated Road
- Willow Stem Cuttings



Unit:79-4 Date:6-26-1979, PP308, (EW)



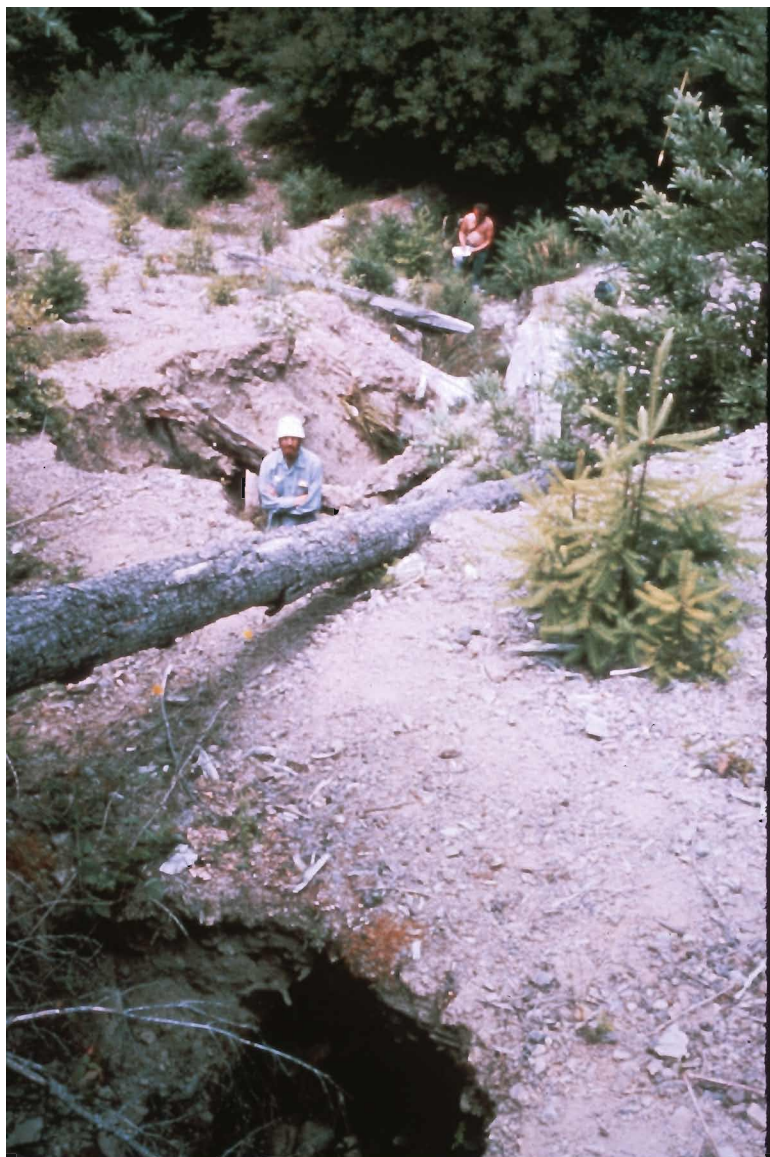
Unit: 79-4 Date: 2-3-1980, PP308, (EW)



Unit:79-4 Date:8-5-1979, PP174,Copper Ck. (EW)



Unit:79-4 Date:1-22-1980, PP174, Copper Ck. (EW)



Unit:79-4 Date:8-5-1979, PP191A



Unit: 79-4 Date: 1-22-1980, PP191A, (EW)