

SUMMARY OF EROSION CONTROL WORK

Unit 82-3

Devils Creek Basin

Redwood National Park

Orick, California

By

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and

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INTRODUCTION

Description

Unit 82-3 is located in the Devils Creek basin 35 miles southwest of Orick, California (see Map A). The Devils Creek watershed drains some 18 km² (4,450 acres) into the Redwood Creek system. It is the southernmost westside tributary located within the 1978 Redwood National Park expansion area and is characterized as one of the relatively few low relief, redwood dominated tributaries (J. Pitlick, 1982) to Redwood Creek. Topographic relief in the project area is 1,718 feet from the rock pit at 2,038 feet to the confluence of Devils Creek and Redwood Creek at 320 feet in elevation. Late development of the basin left large areas of old growth forest intact. Pristine conditions are reflected by low volumes of stored sediment found in the mainstem of Devils Creek.

Most of the project entailed removal of the Y-Line Road from its junction with the M-2 Road to its terminus near the confluence of Devils Creek and Redwood Creek. Of the 4.1 miles of this length, 3.6 miles were removed. The remaining section can be accessed from the Y-3 Road. Along this remaining section, preparation for contract work, anticipated to follow next year, was carried out.

The project also dealt with mass movement features in cutover areas near the Y-Line/M-2 road junction. Removal of short sections of the M-2 Road and drainage improvement of the rockpit were carried out in an attempt to reduce further mass wasting.

In addition, a short (.24 mile) section of secondary haul road adjacent to the Y-Line was treated.

Primary treatments administered to these areas included ripping, cross road drain installation, outsloping, and stream crossing excavation and were completed by heavy equipment following grade stake information. Secondary treatments consisted of producing and placing erosion control rock by heavy equipment and labor intensive spreading of straw mulch over disturbed ground.

Site locations in project 82-3 are described by station numbers beginning at the terminus end of the Y-Line Road. Lathes were placed above the road every 100 feet in areas where no disturbance by heavy equipment was anticipated. This established reference points along the project route. Further increments were measured along the centerline of the roadway's travel path and measured in feet. This station system covered several roads in the project area. The Y-Line became road project designation "A" while the M-2 and M-2-3 roads became road segments "B" and "C", respectively. Thus, station A56+23 refers to a point on the Y-Line 5,623 feet from the Y-Line's terminus. Locations of erosional problems and rehabilitation treatments are identified with this system.

Land Use History

Earliest timber harvests in Devils Creek basin were completed by 1937 (see Map B). The Hammond Lumber Company accessed the headwaters region of Devils Creek by railroad. Large areas of the relatively flat ridge dividing the Redwood Creek and Maple Creek drainages were harvested by steam donkey clearcutting. Splays of the railroad followed ridges, ending in pads at the slope breaks. Logs were yarded to the pads and hauled out by rail. A large rockpit (Y-Line rockpit #1) was developed in Devils Creek basin near the terminal end of one segment of railway. At the same time, earliest routes of the M-Line, the beginning of the Y-Line from its junction with the M-Line, and the M-2-2 were established.

Early in the period from 1936 to 1947, tractor yarding replaced steam donkey harvest methods on the gentle topography above the M-2-2. Earliest tractor harvests were select cut units.

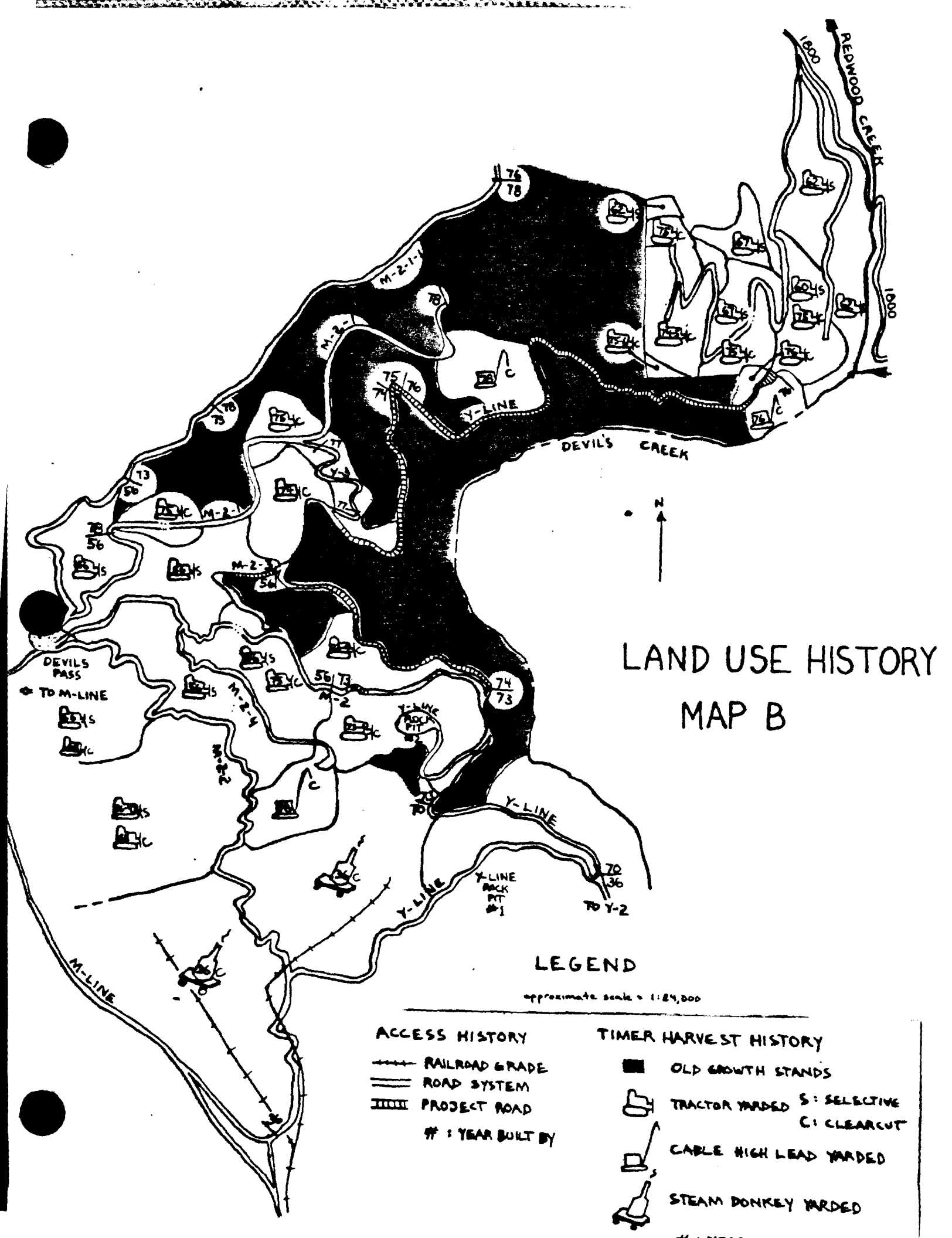
Trucks eventually replaced the railroad with the onset of diesel technology. By 1956 the M-2 was built through Devil's Pass, and several spur roads were developed. These include sections of the M-2, M-2-1, M-2-1-1, M-2-3 (road segment "C"), and M-2-4. These roads were unsurfaced, with Humboldt log stream crossings or slash/fill crossings, and a few (if any) culverts. The cutblocks were selectively logged by tractor yarding methods. Stream channels provided convenient yarding routes but were highly impacted by harvest activities. The M-2-3 Road bordered a unit that was apparently never harvested, but had been heavily burned in a previous fire, age unknown.

In 1968, early selectively cut units were re-entered and clearcut on the broad ridge above the M-2-2 Road.

Beginning in 1973, accelerated timber harvest and associated road construction were characteristic until park expansion in 1978. The M-2 Road (road segment "B") was linked to the Y-Line in 1973, and slopes above their intersection were tractor clearcut. By 1974 a second rockpit (Y-Line rockpit #2) that provided road surface material for the M-2, and later, the Y-Line and M-2-1 roads was developed. Culverts were probably added to the M-2 at this time.

In 1974, the Y-Line (road segment "A") was extended to RX A98+06. Concurrently, the M-2-3 was reopened to provide access to a 1974 cutblock on the Y-Line. The dual access to this cutblock was probably developed in an attempt to reduce conflict between timber harvesting and Y-Line construction traffic. The cutblock abutted 1956 cutover areas and harvest encompassed some of the old burned area not harvested in 1956.

In 1975, the 1956 selective cut above the M-2 Road was re-entered and clearcut. The M-2-4 was improved for access to this unit.



By 1976, the Y-Line was extended to the Simpson Timber Company boundary near the confluence of Devils and Redwood Creeks. A high lead cable yarded unit was extended from the Y-Line to Devils Creek and was tractor clearcut above the road to the Simpson boundary. Adjacent units were accessed from the 1800 Road and experienced multiple entries from 1967 to 1976.

In 1978, the M-2-4 and M-2-2 road provided access to a high lead cable yarded unit located between those roads. The M-2-2 was rock surfaced for winter access to the unit. Surface material was probably provided by the adjacent rockpit #1. The M-2-1 was extended along the slope above the Y-Line, and provided access to another 1978 high lead cable yarded unit where the road ends in a pioneered segment beyond the cutblock.

EROSIONAL FEATURES

Y-Line

Road project designation "A" (the Y-Line) was built between 1974 and 1976 as a major haul road, although few cutblocks were entered by the time of Redwood National Park expansion in 1978. Cutblocks entered from the Y-Line had few erosional problems, with the exception of those cutblocks above the end of the project reach near the Y-Line/M-2 junction. These are discussed in the M-2 road erosional features report section. Because of the minimal cutting history, young age of the road, and relatively mild winter storms since its construction, many erosional problems were incipient. Potential erosional problems consisted of fill failures along the road bench where it traversed steep slopes, and stream crossing fills. Deep seated mass movement features predate road building, but it is likely that the road's construction contributed to recent movement (See Erosional Features Map C in pocket).

The Y-Line was built along the break-in-slope directly above the inner gorge area of the mainstem of Devils Creek and V's upstream as it crosses several deeply incised tributary streams in an effort to maintain an even road grade. Slopes range from 10 to 80 percent above and range from 15 to 95 percent below the road. The road lies within an unstable zone, susceptible to mass movement and associated with excessive soil moisture and slope adjustments during major storm events (Coleman, 1973). A soil survey was completed in June 1982, and is included in Appendix 1.

Much of the road crosses steep slopes and was constructed by cut and fill. Tensional cracks and scarps associated with fill failure occurred along many of these sections and physically extended during winter storms of 1981-82.

Compound (multiple scarp) slumps occurred in two locations on the Y-Line. The largest involves some 30 acres of old growth forest. The feature crosses the Y-Line at stations A89+00 to A96+20. The headscarps are located about 500 feet upslope near the M-2-1 Road. Mudflows from the toe of the feature have delivered sediment to a large tributary about 300 feet downslope from the Y-Line. The 15-foot scarps indicate a deep seated feature, although movement is predominantly translational.

Competent schist lying within a zone of highly sheared bedrock outcrops in cutbanks along the Y-Line in the slide area. Mottled soils are evidence for highly saturated conditions in the zone. Locally, old growth trees frequently display broken or repaired tops or show signs of rotation due to soil creep and slope instability. Large diameter trees are few in number, and may also indicate that slope movement pre-dates road construction.

Proximity of the Bridge Creek linament may account for local instability. Recent geologic mapping locates the lineament to the west of the feature (H.M. Kelsey, S.D. Morrison, T.A. Stephens, 1982) (Appendix 3).

Y-Line construction across the slide area in 1976 destabilized the slope by undercutting. Cutbank failures and downed trees appear on air photos by 1978. By 1981, the raw scarps were vegetated. The first large storm event since road construction occurred in winter of 1981-82 and caused further slope adjustments. Many old growth trees were toppled and 10-15 foot scarps developed on the midslope section. Headscarps developed near the M-2-1 Road while side scarps could be traced about halfway down the slope, gradually becoming inconspicuous in the duff.

Another large compound slump occurs on the Y-Line between station A167 and A172 (see map, Appendix 2). In 1973, prior to the Y-Line's construction, the slope failed, leaving a large scarp and toppling old growth trees. Apparently movement was triggered through undercutting by the stream at its base. In 1974, the Y-Line was built across the area. A very large fill prism was constructed, overloading the slope. One-foot scarps developed by 1980 at the road bench. During the winter storms of 1981-82 the road segment failed. Multiple scarps developed, with four to six foot headscarps at the road prism, and sediment delivery to the stream occurred by mudflow. Recent headscarps can be traced downslope to the stream, reactivating older scarps. Movement seems to be dominantly translational, with rotational slump blocks present within the slide mass.

Eight major stream crossings, with hydrologic areas between 25 to 503 acres, were crossed by the "A" road. Six of these were removed this year, leaving the largest and one other intact. All were well constructed stream crossings with adequately sized (30 to 48 inches) corrugated aluminum culverts set near channel grade during initial road construction. RX 51+55, however, is comprised of two drainages. The smaller drainage, at 36 acres, was diverted 80 feet down the inboard ditch and combined with the larger (45 acre) flow. Combined, they crossed the road through a culvert set in the larger channel.

All crossings were intact and functional, with one exception. In the storm of January 1982, a debris torrent triggered by landing failure on the M-2 road, reamed the channel between the M-2 and Y-Line, depositing mud and debris on the road bench and burying the culvert at station A191+42.

Smaller drainages were periodically culverted across the road, along with inboard ditch flow. The culvert pipes were, with one exception, 24-inch diameter corrugated aluminum pipes, with debris racks and commonly with

long half rounds or culvert bags. One pipe apparently was installed during timber harvest before Y-Line construction. It was a 18-inch non-corregated pipe draining springs away from a landing. Old growth forest separates the road from stream channels downslope along the length of the project reach, and acted to disperse concentrated inboard ditch flow.

Tractor yarding units accessed from the Y-Line have numerous skid trail crossings across minor drainages and swales. These were small (40-80 yards) slash/fill crossings that allow percolation during low flow. High flow caused ponding and minor flow diversions. Rilling and minor gullies were created by diverted flow before they recombined with main flow courses downslope. As sediment sources, the skid trail crossings were relatively minor and released sediment slowly. One skid trail in an old growth stand bordering a 1975 cutblock concentrated flow into an old growth stand, re-activating a headscarp and causing a large old growth Douglas-fir to fall.

M-2-3 Road

Erosional problems on road segment C, which is a section of the M-2-3 Road were: continued erosion at a major stream crossing, rilling, and potential fill failure. The proximity of this road reach to a large stream channel guaranteed delivery of sediment directly to the stream (See Erosional Features Map C).

The adjacent hillslopes are well vegetated since logging occurred in 1956. Although channels were impacted, stream diversions were not created. However, in 1974, one skid trail system was re-opened and a swale was crossed causing flow to be diverted down a parallel skid trail and onto road segment C. Rilling of the unsurfaced road bench was effected by the absence of culverted water crossings.

The M-2-3 Road was first constructed to access the 1956 cutblocks. Spurring from the M-2 Road, the M-2-3 crossed steeply downslope towards the stream crossing. After crossing the channel it followed along the contour above the stream, constituting the lower border of the 1956 cut. Slopes average 35 percent above the road segment. This second section is road segment "C" and was constructed by cut and fill, while the first section was almost entirely full bench, the fill being used to construct the stream crossing.

The stream crossing acted as a landing during the 1956 logging activities. Channels made convenient tractor yarding routes in the steep terrain, and logs were skidded down the channel towards the crossing.

The crossing was eroded in the 1964 storm but was rebuilt in 1974 when the road was used to access timber adjacent to that harvested in 1956. Progressive erosion since 1974 has cut through the fill, carving a new channel for the stream.

M-2 Road/Rockpit

In 1973, the M-2 or "B" Road was extended into the project area. The road crosses slopes averaging 50 percent in a bowl shaped basin with a poorly defined drainage network. Hummocky topography was produced by mass wasting processes with geomorphic expression tied to the varied bedrock composition found in this location. Erosional problems reflected these conditions and were compounded by rockpit development and oversteepened fill as a consequence of road building (See Erosional Features Map C).

Fill failures occurred during the heavy winter storms of 1974/1975, and tensional scarps and cracks developed in successive winter storms. By 1978, a 12-inch culvert at station B47+50 had failed and was replaced by a new 12-inch culvert and the road was repaired. Field crews in the winter of 1980-81 re-opened the then sediment-choked culvert, but early in the winter of 1981-82 tensional scarps developed across the road bench. Later that winter the road failed, although the culvert was still functioning. Compound slumping offset the road by about 12 feet and the headscarp migrated upslope from the center of the road past the inboard ditch.

Also in the winter of 1981-82, the failure of a landing at station B42+00 triggered a debris torrent. The water saturated fill collapsed 150 feet into a channel below, scouring about 200 feet of its length and finally depositing a mudflow across the Y-Line road bench at station A191+42. A similar landing failure occurred at station B52+00. Fifteen to thirty foot headscarps developed across the fill bench, while mud and debris traveled down 70 percent slopes and was deposited on the Y-Line road bench 200 feet below at station A197+50.

The unique bedrock geology in the Devils Creek basin led to the development of the rockpit 400 feet upslope from the M-2 Road. Development began soon after the area was clearcut in 1973. Meta-volcanic rock was quarried, being harder and therefore more useful in road building than the predominant shale bedrock found on most of the west side of Redwood Creek. The area disturbed by quarrying soon grew to over 15 acres. The rockpit was reshaped by the National Park Service in 1981 in an effort to allow drainage and remove the visual scar.

Due to the expanse of bared ground, rilling and gullying became another erosional problem. Runoff from the rockpit concentrated on skid trails and eventually was intercepted by the inboard ditch of the M-2 Road. Concentrated flow from M-2 culvert pipes caused small mudflows and still larger gullies downslope.

Skid trail stream crossings were generally not identified as erosional problems. Small catch basin areas and poorly developed drainages combine to allow percolation through the fills and the slow release of sediment from these slope crossings.

EROSION CONTROL WORK

Introduction

Procedures

Rehabilitation efforts on the site 82-3 may be divided into three phases. These are evaluation, layout, and heavy equipment and labor intensive treatment work.

Evaluation consists of site identification based on preliminary reconnaissance mapping of erosional and geomorphic features. Erosional problems are identified and detailed mapping of problem areas ensues. Prescription work usually followed mapping, but in some cases directly followed identification of the major erosional problems and mapped in detail after layout work was done.

Layout consists of field surveys, drafting of plan sheets, slope staking, and finally establishing photo documentation locations. A photo point location map is included in Appendix 3.

Familiarity with certain phrases and techniques is essential to understanding the tables included in this report. A deep dish (D.D.) is a type of stream crossing excavation where the cross-section profile consists of 2:1 sideslopes tangential to a 30-foot radius vertical curve. Slope stakes are placed at the top of the thalweg, at the bottom of the thalweg, and at the outboard edge of the road fill where each of the sideslopes at the widest point of the crossing intersect the road surface. Design flow capacity for a unarmored deep dish (with thalweg not exceeding 30 percent grade and flowing at one-foot depth in a 25 year storm event) may not exceed 20 acres of catch basin area. Therefore the standard RX excavation is normally employed at the larger stream crossings. Variation of the deep dish format include splitting the 30 foot radius curve by 10 feet (deep dish type II) creating a wider channel while increasing flow capacity, and armoring the dish with rock, again, increasing capacity.

RX type excavations used this year were much like those employed on unit 81-5 (Y-2 contract) but had slightly rounded channel bottoms in an effort to centralize flow and avoid undercutting of channel banks.

Total outslope (TOS) refers to road sections where an outslope was desired, but fill could not be placed at the inboard edge due to springs and seeps. Therefore the fill has been moved to a more stable location.

Slope stakes (grade stakes) are used for directing all heavy equipment work. Stakes delineate prescription reaches and cut or fill boundaries of excavations. Placement of the stakes is a product of initial surveys and drafting plan sheets.

Traditional use of slope stakes and plan sheets are in contract work where the contractor is required to meet certain specifications. Because the project was completed with rental equipment, combined data generated from the plan sheets and equipment completion times will help in writing future contracts and in analyzing heavy equipment performance.

Surveying was done exclusively with tape, compass, and clinometer for all types of treatment work. A detailed explanation citing methods is titled "Surveying Procedures for Positive Grade Control During Excavation" by E.P. Wosika (1981) and can be found in Appendix 4. Table 1 summarizes layout costs and gives a breakdown of the site hydrologist and technician hours during the phase.

Heavy equipment work is the first phase of actual watershed restoration. Erosional problems are addressed with physical treatments in an attempt to stabilize hillslopes and restore drainage networks in a cost effective manner. Fill sites are prepared, stream crossing fills removed, roads and landings outsloped or ripped and cross road drains installed, and water is directed away from problem areas. These are the primary treatments while secondary treatments, such as channel armoring and mulch application, follow where appropriate. Labor intensive work was restricted to mulch application in areas disturbed by the heavy equipment phase.

Objectives

Map D locates physical treatment locations on site 82-3 (in pocket).

Y-Line (A Road) - Outsloping of 2.22 miles of the Y-Line Road was prescribed where road prism failure had potential to deliver sediment to stream channels below the road. The potential impact of fill failures on stands of old growth timber below the road was also considered.

Except for the special areas noted below, all outsloping was done at a 3:1 finished grade or about 1.7 cubic yards removed per linear foot of road. Total outsloping at a finished grade of 5:1, applied where the inboard ditch was too wet for fill placement, yielded an average of 4.1 cubic yards per linear foot. Across the slide area between station A89+00 to 97+40, a slight (approximately 6:1) outslope was prescribed in hopes of transferring water and slurry flow across the road bench. No attempt was made to immobilize the failure. The slide area at station A167+00 to 171+89 was deeply outsloped at the headscarp area. This treatment may be considered to be a total outslope averaging 2:1 finished grade with 15.9 cubic yards removed per linear foot of road. Removal of a large volume of fill was desired to lessen movement on the overloaded slope and minimize sediment delivery to the creek below.

Rock surfacing of roads, 1 to 2.5 feet thick, was disaggregated by ripping in an effort to encourage productivity of compacted areas and to prevent concentration of water. Fill areas were disaggregated to allow infiltration and normal groundwater circulation.

In the reach of road segment A not removed this year, the objective was to eliminate non-standard or off road prescriptions that tend to be difficult to administer in contract work. With a contract in mind for next year, a french drain was installed and a ditch excavated. The latter collected flow from gully-rill systems that had developed from closely spaced skid trail crossings on a minor drainage. The flow was ditched into the channel above RX A148+70 (an excavation to be completed next year). Combining this flow into the stream crossing was considered cost effective over restoring the minor drainage and providing a larger excavation across the Y-Line for the natural flow course.

Table 1.
PROJECT PREPARATION
SITE 82-3

	Hours		Wages		Percentage of Total Spent on This Year's Project
	Hydrologist ¹	Technician ²	Hydrologist	Technician	
Map	100	225	999.00	1,482.75	18%
Prescribe	135	166	1,348.65	1,143.74	16%
Draft	195	185	1,948.05	1,274.65	22%
Field Layout	285	554	2,847.15	3,814.06	45%
Next Year's Project	115	275	1,148.85	1,894.75	N/A
TOTALS	1,845		\$17,872.25		

¹Hydrologist = GS-09 at \$9.99/hour.

²Technician = GS-06 at \$6.89/hour.

M-2-3 (C Road) - The main objectives of the C Road treatment were to improve drainage across the road and to discourage fill failure that may directly contribute sediment into the stream that the road parallels. This was accomplished by disaggregation of the surface to a depth of two feet, installation of cross-road drains, deep dish excavation, and extensive outsliping at a 3:1 grade.

M-2 (B Road)/Y-Line Rockpit #2 - The main objectives included the total outslope of short sections on the M-2 Road to reduce the overburden of fill on two of three failures located there, and placing the fill in locations that were stable. Also, drainage was restored by the installation of a partial deep dish (i.e. not to final grade) to eliminate substantial inboard ditch flow towards the failure area. Breaching of the berm that held ponded water upslope from the failure and directing the flow into the deep dish should lessen saturated conditions in the area. De-watering of the gully and rill systems on the slope above the M-2 Road failures by contour ripping of the rockpit area should improve percolation and deconcentrate flows.

Summary Costs

Table 2 summarizes costs involved in the various phases of erosion control work in project 82-3. The evaluation phase accounted for 11 percent of the project's total cost. Log salvage and access improvement also formed 11 percent. Heavy equipment treatments combined to total 67 percent with the remaining 11 percent of total costs incurred in labor intensive mulch application.

Table 2. SUMMARY COSTS OF EROSION CONTROL WORK SITE 82-3

	Task	Hydrologist & Technician		Laborers R.N.P.	Laborers R.U.I. CETA ¹	Heavy Equip. Rental	Materials	% of Total	Total Cost
		Hours	Cost						
EVALUATION	Map Prescribe Draft Field Layout	1560	\$14,928.55					9	\$14,928.55 ✓
	Next Year's Layout	390	2,943.70					2	2,943.70 ✓
ACCESS	Log Salvage			6,792.90 ✓		9,038.26 ✓		9	15,831.16
	Brushing Opening Up			2,082.60 ✓		1,352.66 ✓		2	3,435.26
HEAVY EQUIPMENT	Primary Treatments	920	7,330.80	P 8, 31814.85 → ~~35,889.85~~ ~~44,109.00~~ ✓ 44809. 1,114.65 <u>1,110.45</u> 613.80				52	90,168.55 ³
	Rock					14,265.77 ² 891.36 ✓		9	15,157.13
	Next year 1983					2,469.81 891.36 ²		2	3,361.17
	Misc.					7,523.77 ✓		4	7,523.77
	Travel Time, Move In/Out Cost, FD etc.								
LABOR INTEN- SIVE	Straw (Mulch) Application			8,059.00	5,861.00		5,046.25	11	18,966.25 ✓
TOTALS			\$25,203.05	\$16,934.50	\$5,861.00	~~\$119,270.74~~ 115,935.74	\$5,046.25		\$172,315.54

¹ CETA provided at no charge.² Does not include cost of RNP backhoe for installation.³ Includes total hours of RNP hydrologist and technician.

HEAVY EQUIPMENT PHASE

Heavy Equipment Use

Four pieces of heavy equipment were used throughout the rehabilitation season. They were two bulldozers, a hydraulic excavator, and a loader. Several other pieces of heavy equipment were also used briefly on the site. Table 3 is a summary of all the equipment used, their specifications, rates and total hours.

Employing two D-8 Caterpillar bulldozers was necessary due to the large volume of material planned to be excavated. One D-8 could have accomplished the job, but due to rigid time limitations, two D-8s were utilized. The D-8 Caterpillar bulldozers were planned to excavate 80 percent of the rehabilitation work. Both came equipped with a four-way hydraulic tilt blade. This attachment allows for vertical (up and down) motion of the blade, as well as being able to rotate the blade a few degrees clockwise or counter-clockwise in a plane perpendicular to the axis of the chassis body.

One bulldozer was equipped with a set of 24-inch rippers. The rippers were used to break up compacted road fill and to loosen earth at excavation sites. The other D-8 came equipped with a winch that was employed for salvaging cut logs left behind by logging companies.

The D-8s did virtually all the outsloping on the site. Outsloping was initiated by ripping the width of the road. Excavation began at the outboard edge of the road with the D-8 positioned approximately parallel with the road. The excavated fill was pushed in arcs so as to pile the fill up against the cutbanks with an ending position of the D-8 approximately at a 45 degree angle to the road. A small fill berm on the outboard edge of the road occasionally resulted from this technique. When this occurred, the D-8 removed it by back-blading it into the outsloped fill. This procedure still allowed for some sidecast material to be lost downslope. This lost material was minimal in comparison to the amount of fill removed and the technique proved to be very quick and effective.

The major problem during outsloping that was encountered (and of great dismay to the operators) were buried stumps of trees. These trees were cut during road construction on or in the proximity of the "outboard edge" of the road and were consequently covered by the road fill prism. When these buried stumps were encountered, the outsloping was resumed on the far side of the stump, then the fill inboard of the stump was removed. Maneuverability became the greatest problem when stumps were encountered and outsloping the fill was occasionally tedious and time consuming, even though the mean production rate of this method was still very high.

The deep dishes were specifically designed to be excavated by the D-8s. The planned morphology of the deep dish crossing was a merger of how an excavation by a D-8 would appear and the hydrologic and geomorphic restraints to guarantee a stable stream crossing. The D-8 would first rip the planned fillsite area and, working parallel to the road, would begin "scooping" out the fill, utilizing the "edge" stakes as reference points. The deep dish technique proved to be very fast and effective and was utilized wherever possible.

Table 3: SUMMARY OF EQUIPMENT TYPES AND RATES

Equipment Type	Make/Model	Year	Rate/Hour	Total Hours
Hydraulic Excavator	Case 980B w/1 1/4 yd ³ toothed bucket and triple grouser tracks	1980	\$77.00	201
Bulldozer	Catepillar DBH 46A w/13' wide 4-way hydraulic tilt blade and 24" rippers	1968	\$99.00	250
Bulldozer	Catepillar DBH 46A w/13' wide 4-way hydraulic tilt blade and winch	1969	\$76.35	302
Bulldozer	Catepillar D8 46A w/10' wide 4-way hydraulic tilt blade and 24" rippers	1967	\$100.00	30
Loader	Catepillar 977K track loader w/2 3/4 yd ³ 4-in-1 bucket and 18" rippers	1972	\$79.50	245
Backhoe	Case 580C extendahoe w/3/4 yd ³ loader bucket and 1/3 yd ³ excavator bucket	1980		30
Loader	Catepillar 988 w/log forks tire-mounted	1965	\$100.00	35
7 - Dump Trucks	10 yd dump truck	1966-1979	\$34.00*	642
Short Logging Truck	No trailer - self loading		\$38.00	18.5

*Average Rate.

The D-8s were utilized to do as much of the haul road crossing excavations as possible. This 60-80 percent of the total volume. Initially, the excavation proceeded extremely fast because the D-8s were able to push large amounts of fill (having a lot to work with). Excavation slowed after approximately two-thirds of the total volume was removed and again slowed when the last 10 percent of the crossing was being completed. This was primarily a result of "sculpturing" the excavation rather than moving shear volume as in the beginning.

The D-8s generally were unable to complete most stream crossings unassisted, unless there was room to back down below the lower end and push the lost armor up the channel. A piece of support equipment was usually needed to clean up the upper and lower ends of the excavation.

The excavation of the cross-road drains was implemented by the D-8s. This approach proved extremely fast and effective. A D-8 would position itself parallel to the road and slightly tilt its blade towards the outboard edge of the road. After a few "delicate scoops" the cross road drain was completed, averaging only a few minutes apiece. This technique is much faster than using a backhoe or an excavator.

Another valuable technique was used for transporting fill for relatively short distances. A form of "endhauling" was accomplished using the D-8s. As a D-8 pushes a large pile of earth, a small amount of fill is shed constantly from the two ends of the blade, forming a small continuous berm of sidecast fill. By remaining between the two berms in each successive pass, the berm becomes large enough (blade height) to act as a "trough". This trough contains the excavated fill in front of the D-8's blade so as to enable the D-8 to push a maximum load without losing material. When the excavation is completed the two berms are then outsloped and/or pushed to the fill site. The longest distance that fill was transported by this technique on the rehabilitation site 350 feet, but 600 feet is the practical limit.

The D-8 techniques briefly outlined above are best suited for major haul roads. Smaller haul roads (less than 20 feet of road bench) are generally too restricted to allow favorable maneuverability with these large bulldozers. The techniques are still applicable but will warrant deviations to fit site-specific conditions. If a D-8 can physically be fit into the completed lateral and grade limits of the excavation, the cost/cubic yard figure will be cheaper than with other equipment. Tight work sites will have a higher unit cost, but will still be cheaper than with slower equipment. Adjusting the desired grade (or profile) to suit a D-8 will give both lower unit and overall costs. In conclusion, D-8s need a lot of room to work and are most valuable in terms of the shear volume they are able to move.

The excavator was utilized to cover areas not suitable for D-8 work, such as "cleaning-up" the lower reaches of stream crossing excavations and placing rock. It has the ability to rotate its cab (and arm) 360 degrees about its tracks. This ability allows for the placement of excavated fill in a wide variety of temporary fill locations. In restricted areas this ability becomes most important in transferring excavated fill to the support equipment for final removal to the fill site.

The excavator has an effective bucket reach of approximately 25 feet, which allows for excavation to be performed where other heavy equipment cannot venture. For example, this could be due to extremely steep bank slopes or marshy and unstable ground. This long reach also proved excellent at sites that required removal of slash. The excavator would balance debris and logs between it's arm and bucket, enabling it to transfer the material up to the road for removal. Work time was greatly reduced since at these sites time consuming winching of debris and logs was not necessary.

The excavator has the ability to dig out objects hindering the excavation, such as large boulders and stumps. It was essential in digging out culverts intact. Some culverts were saved and transported to the Y-Line rock pit #1.

In space-restricted stream crossings where endhauling of excavated fill was necessary, the excavator was again very valuable. Due to the limited space, such as at the triple stream crossing (sta. 50+55 - 53+00), the loader could not maneuver around the excavator to facilitate the loading of the dump trucks. This prompted using the excavator to load the trucks directly. This technique was slower than using the combination of excavator and loader but under the limited conditions was very effective.

The excavator proved ideal for the placement of rock used to protect freshly excavated stream crossings. It's long reach and variable-position bucket allowed for the placement of rock wherever necessary.

Generally, the excavator needs a piece of support equipment. It's most prominent values are the ability to work in space-restricted locations, and its peerless rocking capability.

The Caterpillar 977K loader came equipped with a 2 3/4 cubic yard, 4-in-1 bucket, which prove invaluable in terms of the large variety of tasks it could perform. This bucket permitted the loader to back-blade fill, pick up logs, load the dump trucks, and transport fill and rock to appropriate sites. The teeth on the bucket enabled the loader to do some primary excavations where conditions allowed. The large capacity of the bucket (2 3/4 yd³) was well matched in excavation with the 1 1/4 cubic yard bucket of the excavator. Thus at excavations sites, the loader was able to keep up with the excavator by removing fill to the fill site and returning before the excavator "buried" itself in excavated material.

The loader was track-mounted, which enabled it to turn around easily and gave it greater stability on rough terrain than the tire mounted version. Being track-mounted also allowed for minimal compaction and provided improved "flotation" in wet areas.

The loader also came equipped with a set of 1 1/2 foot rippers. These were utilized where it joined in on the primary excavation, being used for loosening earth.

The loader was mainly used to load the dump trucks, support the excavator, and transport stream crossing rock from its storage site to the channel. Occasionally, it helped out with the primary excavation of stream crossings. However, conditions rarely favored such an approach. The crossing would have to be large enough so the excavator and loader could maneuver around one another. In addition, the fill site had to be close enough so that the loader could assist the excavator in removing it's generated fill.

The loader was also used in producing, sorting and loading rock at the Y-Line Rock Pit #1. It was effective in the rock pit and was able to achieve a gross sorting of the rock.

The loader is restricted from being able to maneuver on rough or steep terrain due to suspension and grouser limitations. In many applications, loaders are valuable but their limitations should be realized and adhered to. Often a bulldozer can do the same job better.

The backhoe (owned by RNP) came equipped with a 3/4 cubic yard loader bucket and a 1/4 cubic yard excavator bucket. The extendahoe provides variable reach for excavating and has a greater total reach than a standard backhoe. The backhoe was able to move about the rehabilitation site very quickly because it was tire mounted. Its greatest limitation is that it is a slow earth mover. However, it is very useful in extremely space-restricted work sites with small excavations and is excellent for digging ditches and drains. The backhoe was used exclusively for the construction of the french drains.

The Caterpillar 988 loader is a extremely large and specialized piece of equipment. Its only use was to load large logs during the log salvage operation.

Heavy Equipment Sequencing

Table 4 summarizes the heavy equipment sequencing and gives dates for each major phase of work.

The heavy equipment sequencing began with the log salvage operation. A large active landslide located at A86+00 to A96+00 on the rehabilitation site blocked off the lower reach of the Y-Line (A-Road). Numerous trees fell across the road and many precariously overhung the road. A Caterpillar 988K loader, Caterpillar D-8 bulldozer, and a "short" log truck were the equipment brought in to open up access and to transport all salvagable logs to the Y-Line Rock Pit #1. The salvaged timber came to 70,390 board feet of prime redwood. This work was managed by Earl Roberts. The heavy equipment was released upon completion of the salvage operation.

The formal opening of the Y-Line came in late June. Access on the Y-Line had been closed off by a landslide at A197+00 to A198+00, a debris flow at A191+00 to A192+00, and a large landslide at A167+00 to A172+00 in which part of the road prism slipped out and moved downslope. All features, including the landslide blockage at the log salvage operation occurred the previous winter. In conjunction with gaining access, the D-8 widened portions of the road to achieve adequate width to allow dump trucks to pass one another. The D-8 also made temporary rock storage sites at stream crossings.

Table 4.
HEAVY EQUIPMENT SEQUENCING

Heavy Equipment Phase	Dates
Log salvage operation	June 21 - June 28
Opening access to Y-Line	June 28 - June 30
Producing and sorting rock at Y-Line Rock Pit #1 and rock distribution	July 6 - July 14
Begin rehabilitation work on Y-Line (A-Road)	July 15
Rehabilitation work on landslide at A167+00 - A172+00	August 4 - August 11
Finish lower reach (A0+00 - A145+00) of the Y-Line	August 17
Finish upper reach (A167+00 - A214+00) of the Y-Line	August 20
Rehabilitation work on C-Road	August 23 - August 25
Rehabilitation work on Y-Line Rock Pit #2	August 26 - August 27
Rehabilitation work on section of M-2 (B-Road)	August 30 - September 3
Completion of rehabilitation heavy equipment work for 1982	September 3

At the beginning of July the making and sorting of the stream channel rock at Y-Line Rock Pit #1 was accomplished. The equipment used was a D-8 (ripper and the 977K loader). The D-8 broke up the bedrock for sorting by the loader into appropriate sizes. The D-8 also built the access road for the dump trucks in the rock pit to the loading pad. The loader mainly worked at sorting and stockpiling the rock.

After the rock pit was prepped, seven dump trucks were brought in to distribute the rock. The trucks were loaded by the 977K loader. During the rock delivery, in-house labor delivered straw (used for mulching) to the site and distributed the straw to its appropriate localities. Upon completion of the rock deliveries, five dump trucks and the D-8 were dismissed.

The next phase of heavy equipment was the actual beginning of the rehabilitation work. On July 15, work began on the lower reach of the Y-Line at the triple stream crossing A51+00 through A53+00. The Case 980B excavator was brought in to work along with the two dump trucks and the 977K loader.

Before completion of the triple stream crossing, two D-8s were brought in to start work on the lower Y-Line reach beginning at station A0+00 and working their way upstation, outsloping and installing deep dishes and cross road drains. During work on this lower road reach, one D-8 had a terminal breakdown and a replacement had to be brought on site. By the time the triple stream crossing was completed both D-8s had caught up with the other equipment at station A53+00.

With the triple crossing completed, the excavator, loader, both dump trucks, and one D-8 were moved to the upper road reach of the Y-Line to begin work on the landslide at A167+00 to A172+00. Three additional dump trucks were brought in to help with the endhauling of excavated fill. The other D-8 continued work from station A53+00 upstation on the lower reach of the Y-Line.

The landslide excavation began at two locations, with the dump trucks being loaded at each site. The first location was at A167+00 and started with the D-8 occasionally pushing fill up to the excavator on the road. The excavator was loading the fill into the dump trucks as well as excavating the landslide. Primarily, the D-8 was at the second location at station A172+00 pushing fill to the loader. The loader had excavated a loading pad below the road here, and was loading the dump trucks. The road from A172+00 back to A167+00 had to remain open so dump trucks could be loaded at A167+00 by the excavator. Thus all the excavation was initially being done below the road on the landslide.

The dump trucks endhauling 1,540 feet to a stable landing used as the fill site. Turn-around time was short and the fill pile accumulated quickly. This necessitated having to "walk" the D-8 from the excavation site to the fill site in order to push fill upslope so the dump trucks could have ample space to dump their load.

It soon became apparent that one D-8 could not keep up with the other equipment working between the excavation site and the fill site. Consequently the other D-8, working on the lower reach of the Y-Line, was brought over to help out on the landslide, allowing one D-8 to work at the excavation site and the other work the fill site. This approach proved very effective until most of the excavation of the landslide was completed below the road. The D-8 was having great difficulty in working around the excavator and the dump trucks, and the excavation slowed tremendously. At this point the excavator was put on standby until the slide excavation was completed. After the excavator was removed the excavation proceeded very efficiently with the loader loading all the trucks at station A172+00. The work proceeded this way until the completion of the excavation of the landslide.

Upon completion of the landslide at stations A167+00 to A172+00 on August 11, the dump trucks were all released. Both D-8s were sent back to finish the lower reach of the Y-Line. The excavator and loader continued work on the upper reach of the Y-Line. On August 17, the lower reach of the Y-Line was completed and all the equipment was utilized to complete work on the upper reach.

The excavator and loader finished their assignment work on August 18, and were released from the site. The two D-8s continued the remaining work and the Y-Line was completed on August 20. At this point one of the D-8s was released.

The remaining D-8 started work on a minor haul road (the C-Road) at station C0+00 and worked upstation. This work entailed placing one deep dish, out-sloping, ripping, and cross-road draining the reach of road.

When the C-Road was completed, the D-8 was taken upslope to the Y-Line Rock Pit #2. Here it contour-ripped the entire quarried area of the rock pit and most of its access road (total of 15 acres).

After completion of the work at the Y-Line Rock Pit #2 the D-8 started work on a small section of the M-2 (B-Road) addressed this year. This work mainly entailed excavating two large landslides at station B41+00 to B43+00 and B52+00 to B53+00.

Rehabilitation work for this 1982 season ended on September 3, 1982.

HEAVY EQUIPMENT CONTROL

The out-sloping was controlled by grade-staking as explained in Appendix 4. Two techniques were developed and both were applied in the field to best determine which was most effective.

The first technique employed a cut/fill slope stake, which located the top of the fill, how deep to cut, and a balance point that delineated the boundary between cut and fill. This technique was extremely time consuming in placing the stakes, but was valuable in providing volume figures on out-sloping that in previous years could only be grossly estimated.

The second technique was developed to save time and used only a "cut to here" stake placed on the fillslope of the road. This technique was much faster but sacrificed the volume data of the first technique.

Unfortunately, neither technique proved very effective in controlling the heavy equipment during outsloping. The "cut to here" stakes and balance point usually would be destroyed by heavy equipment movement before they could be utilized. The only stake that survived in most cases was the cut/fill slope stake. This prompted creating a new technique to be used next year that employs a nomogram in conjunction with a single slope stake. The nomogram will generate the estimated fill volume (without surveying) and will speed up the prescription of rehabilitation work. The single slope stake will be a "fill to here" stake placed above the road on the cutbank, instead of a "cut to here" stake placed on the downhill side of the road. The new "fill to here" stake remains out of the way of heavy equipment during excavation and should be left undisturbed. Heavy equipment control will be achieved by having the equipment push fill up against the cutbank until the outsloped fill (having a uniformly straight slope) reaches the fill-to-here stake. When the outsloped fill reaches the fill-to-here stakes (taking into account the expansion ratio for excavated fill) the heavy equipment will have taken the prescribed amount of material off the fill prism. This technique should prove very effective in controlling heavy equipment on outsloped reaches, in saving time during the initial layout, and in providing volume data.

Heavy equipment control on stream crossing and deep dishes is explained in Appendix 4. The stream crossing limits of excavation were very well defined and this helped the heavy equipment operators visualize the morphology of the completed stream crossing. Control was quite good and rarely did any heavy equipment excavate outside the limits of excavation.

The deep dishes only had the upper and lower ends of the excavation and the limit of excavation on the outboard edge of the road prism delineated. Due to the quickness of this form of grade staking it will be used for most stream crossings next year. Close supervisory control combined with this type of grade staking should prove adequate in control of heavy equipment, even with the largest stream crossings.

In viewing Appendix 5, it becomes evident that some deep dishes and stream crossing were unintentionally overexcavated. This was predominately due to laxness in control of the equipment. Edge stakes were destroyed by equipment movement and not relocated. Once stakes were displaced, determining when the excavation was completed was left to the supervisor's discretion. A technique to eliminate this problem has been developed.

Some over-excavation was intentional, as with R/X 98+06. The left bank, at the lower reach of the channel, was pulled farther back than planned to guarantee a more stable sideslope.

When computing cost (\$/yd) and volume (yd³/hour) on over-excavated sites, the computed volume was the volume actually excavated within the staked (planned) limits of excavation and does not include volumes of fill material incorporated in abutting reaches. Thus cost/yard figures are slightly inflated in terms of prescribed excavated volumes which were designed for minimal sidebank erosion with minimal fill excavation.

Heavy equipment control on cross-road drains is explained in Appendix 4. The heavy equipment operators had no problems placing the cross road drains in their appropriate locations and the control technique proved very effective.

HEAVY EQUIPMENT COSTS

Tables 5 through 11 summarize various costs and types of treatments that occurred on the rehabilitation site. Access costs include opening up the roads, the log salvage operation, and brushing (the later being performed by in-house labor).

Primary treatment costs are those that entail removing potentially erodible material from stream channels, road prisms, and the edge of landings in locations where this material could be easily transported into the drainage network and lost. This work entails stream crossing excavations; outslowing; cross road drains; ripping compacted areas; contour ripping the Y-Line Rock Pit #2; and restoring drainage patterns disrupted by past land use practices.

Secondary treatment costs are those that entail protecting freshly excavated areas from extensive erosion. Secondary costs include rocking of stream channel excavations and placing a straw mulch on areas disturbed by heavy equipment.

The rocking of stream channels is an extremely expensive treatment. The cost for rocking can easily be equal to or exceed that of excavation. Leaving a stream channel unprotected propagates downcutting on an average of 3-6 feet before the channel obtains a relatively stable base level. An alternative to be considered would be to partially rock a channel reach rather than it's entire length. By rocking only the lower and/or upper end(s) of a channel reach, the cost would be greatly reduced while at the same time insuring a greater stability than an unrocked channel bottom.

Traditionally, work efficiency was assessed in terms of cost per volume or cost per linear foot of road. New parameters included in the tables this year attempt to eliminate: 1) cost variations in rental equipment (i.e. D-8 yd³/hour, D-8 feet/hour); 2) road reach width variation (i.e. yd³/linear foot) (feet of drain vs. linear feet of road/hour); and 3) various degrees of outslowing cut depths (i.e. yd³/linear foot). Also included in the tables are distances for both bulldozer and truck endhaul. By standardizing an average value for each prescription variant, an assessment can be made regarding bulldozer efficiency or operator competency while work is in progress. The data generated this year may also be used to coordinate site activities or to yield a cost estimate range for a given project where several prescription types must be applied.

Table 9. SECONDARY TREATMENT AND FRENCH DRAIN FILLSITE ROCK

Site Use Location	Amount Used (YDS ³)	Site Rock Cost	% of Total Rock Produc- tion Cost	Heavy Equipment Placement				Total Cost	Total Cost Yd ³	Additional Cost to Site
				977K Loader		980B Excavator				
				Hours	Cost	Hours	Cost			
Actually Used in 82-3:										
RX51+55	210	\$3,899.70	26	15.0	\$1,192.50	17.0	\$1,309.00	\$2,501.50	\$30.48	\$6,401.20
RX53+00	224	4,159.68	28	4.8	381.60	1.8	138.60	520.20	20.89	4,679.80
DD183+40	93	1,727.01	12	1.5	119.25	1.5	115.50	234.75	21.09	1,961.36
FD185+00	48	891.36	6	*--	--	--	--	--	18.57	891.30
DD191+42	49	909.93	6	2.0	159.00	2.0	154.00	313.00	24.96	1,222.93

Not Used in 82-3:										
RX163+00	133	2,469.81	16						18.57	2,469.81
FD150+00	48	891.36	6	*--	--	--	--	--	18.57	891.36

TOTALS	805	14,948.85	100					\$3,569.45	\$24.76 Avg.	\$18,517.82

*French drains installed with R.N.P. backhoe at no cost to individual site.

Table 10. ROCK PRODUCTION AND DISTRIBUTION

Task	D-8 Ripper		Heavy Equipment 977K Loader		10-12 yd Dumptrucks		Total H.E. Cost	YDS ³ of Rock	Cost YD ³
	Hours	Cost	Hours	Cost	Hours	Cost			
Rock pit development & rock production	21	\$2,079.00	30	\$2,385.00	--	--	\$4,464.00	805*	\$5.54
Loading & hauling	--	--	30	2,385.00	237	\$8,098.38	10,483.38	805	13.02
TOTALS							\$14,947.38	805	\$18.57

*Approximately 1800 yd³ produced.

TABLE 11

PRIMARY HEAVY EQUIPMENT TREATMENTS CROSS ROAD DRAINS AND DISAGGREGATION

Road Reach (Stations)	Feet of Road	Feet of XRD	Total Cost	Time Dozer Hours	Ripping		XRD		Combined		Comments
					Hour/ 100'	Cost/ 100'	Hour/ 100'	Cost/ 100'	Hour/ 100' RD	Cost/ 100' RD	
A0-12+00	1200	548	\$140.61	1.6	.065	\$6.50	.1496	\$11.42	.1333	\$11.71	Landing
A16+40-19+80	340	68	100.00	1.0	.2451	24.51	.2451	24.51	.2941	29.41	
A32+10-36+90	480	46	80.00	0.8	.0835	8.33	.8696	86.96	.1667	16.67	
A43+45-48+80	535	157	80.54	0.9	.09346	9.35	.2548	19.45	.1682	15.05	
A76+70-82+70	600	120	93.05	1.1	.06667	6.60	.5833	44.54	.1833	15.51	
A108+20-110+30	210	136	49.50	0.5	.0952	9.43	.1428	14.14	.238	23.57	
A116+80-133+00	1562	384	357.75	4.3	.08323	8.24	.1921	14.66	.2753	22.90	
A138+35-140+00	165	127	49.12	0.6	.0833	8.25	.3622	27.65	.3636	29.77	
A208+50-210+00	520	174	88.18	1.0	.09615	9.52	.2874	21.94	.1923	16.96	
C2+00-6+46	446	174	75.90	0.7	.067264	6.66	.2299	22.76	.1570	17.02	Unrocked reach
Total/ Average	6058	1934	\$114.65	12.5	.08834	\$8.76	.2471	\$20.25	.2063	\$18.40	

The two most expensive heavy equipment treatments on the site were excavating haul road stream crossings and outsloping road reaches. These two treatments accounted for over 96 percent of the total cost of heavy equipment in primary treatments. Of this 96 percent, haul road stream crossings and outsloping were approximately evenly distributed. This cost entailed excavating 32,156 cubic yards for outsloped road reaches (72 percent of the total volume moved) and 12,236 cubic yards for stream crossing excavations (see Table 5).

Haul road crossings were broken up into four categories: small, medium, large, and extra-large (see Table 6). Generally, the average cost was around \$1 to \$3 dollars/cubic yard of excavated material for all stream crossings. Stream crossings that cost less than \$1 dollar/cubic yard were small or medium in size and were excavated by the D-8s. These crossings were free of slash and debris and maneuverability was excellent. The larger crossings had a somewhat higher cost than the average cost of the smaller crossings (see Table 7).

The only extra-large crossing (R/X A191+42) that was excavated, cost an average \$2.77/cubic yard. This price includes having to push the excavated fill approximately 350 feet to its fill site and rocking the lower end of the channel. This low unit cost, for such a large crossing, can be attributed to using the "trough endhaul" method instead of using dump trucks to remove the fill.

Of the large stream crossings, R/X A51+55 had the highest cost at \$12.15/cubic yard. This high unit cost was a result of many unfavorable conditions. The crossing was a bifurcated channel that lead to poor maneuverability for the heavy equipment. The D-8s could not work in the space-restricted area and the excavation was done solely by the excavator. The area of excavation was extremely wet (muddy) which also slowed work considerably. All the fill had to be endhauled 850 feet by truck, greatly adding to the overall cost of the excavation. By contrast another large crossing, R/X A98+06, had a low unit cost. This excavation went extremely fast due to good conditions and excellent maneuverability. The excavator, loader, and D-8 were all engaged with the primary excavation and the stream channel was not rocked. All these factors contributed to the low cost of \$1.16/cubic yard for this large crossing. An even lower cost could have been achieved if the D-8s had done all the work.

Deep dish A203+80 had a high cost/cubic yard for a small to medium sized crossing. The high cost was incurred by using the excavator and loader for the primary excavation. The excavation was partially refilled for transportation of dump trucks through the excavation site. Better planning on this excavation would have lowered the cost/cubic yard to an acceptable level.

The low unit cost for outsloping and total outsloping was achieved by exclusively using the D-8s to do the work (see Table 8). Excavation was extremely fast. The higher costs on several road reaches are a result of buried stumps and debris on the outboard edge of the road. The D-8s had some difficulty in maneuvering when buried objects were encountered, yet the mean cost/cubic yard figure was still comparable to that of stream crossing excavations.

Total outsloping proved less expensive in terms of cost/cubic yard than the outsloping (see Table 8). This can be attributed to the differing techniques used on the two treatments. Total outsloping lacks the approach of excavating the fill in arcs and the need to push the fill up steep inclines to the cutbank. Instead, fill is excavated and pushed parallel to the road. In addition, the "trough endhaul" technique, as previously described, can be utilized in transporting the excavated fill. When comparing the cost/linear foot of the two treatments, it proved to be approximately the same. This parameter can be very misleading because it only deals with the reach of road treated, not the volume of fill removed. The total outsloping volume of fill removed per foot of road is much greater than that for normal outsloping. Thus, a cost/cubic yard of fill removed in conjunction with cost/linear foot parameter leads to a fairer assessment of the cost effectiveness of the total outsloping.

The heavy equipment used on the site proved excellent. The machinery was relatively new and well maintained and we had very few mechanical breakdowns.

The equipment operators on this site (with the exception of one) were of immense help with their experience, suggestions, and attitudes, which greatly added to the success of the project.

LABOR INTENSIVE PHASE

Labor intensive work on site 82-3 was carried out by three groups. These were Redwood National Park, Redwoods United, Inc., and CETA crews. See Table 12 and 13.

Redwood National Park crews did preliminary brushing on the site, clearing within stream crossing excavation limits and widening brushy road sections in anticipation of truck traffic.

Log salvage operations were completed by RNP crews utilizing rental heavy equipment.

The bulk of labor intensive work centered around mulch (straw) application to areas disturbed by heavy equipment. CETA crews were provided at no cost, but were transported to and from McKinleyville (approximately 30 miles south of Orick) by park employees. This cost, and that of park vehicles used in distribution is not included in the tables.

Except for the rockpit mulching, which was applied at about 1500 pounds per acre, generally 6,000 pounds were applied per acre at an average of \$10.34 per bale or about \$886 per acre. Unit costs are especially high due to travel time from the Orick Operations Center to the site and for the Redwoods United crew from Manila (about 40 miles south of Orick) to the site. Further costs were incurred because of the need for a laborer to work along with the Redwoods United crew and supervisor. Similarly, a RNP labor leader was required in working with the CETA crew.

TABLE 12.
STRAW (MULCH) COSTS AND LABOR HOURS PER BALE

	<u>Per Bale Deliv. to Site</u>	<u>Average Per Bale Dist. on Site</u>	<u>Average Per Bale Spread</u>	<u>Average Per Bale Total</u>
Total Cost	\$2.75	\$3.77	\$3.82	\$10.34
On Site Hours*	N/A	.33	.38	.71

*.1 hours = 6 minutes.

Table 13. SECONDARY TREATMENT LABOR INTENSIVE STRAW (MULCH) APPLICATION COSTS¹

Group		Average Daily Wage	Misc. Cost	Working Hours		Travel Hours	Total Paid	Percentages of Total Cost		
				Material Distribution	Spreading			Working	Travel	Non- Productive
R.N.P. Crew	Material Dist.	\$8.93	\$643	348	--	165	\$5,227	60	28	12
	Spreading	8.63	432	--	188	90	2,832	57	28	15
R.U.I. Crew	Material Dist.	5.43	546	102	--	108	1,686	33	35	32
	Spreading	5.43	1351	--	260	260	4,175	34	34	32
CETA ² Crew	Material Dist.			159	--					
	Spreading	N/A	N/A	--	246	N/A	N/A	N/A	N/A	N/A
TOTALS			\$3,282	609	694	623	13,920			

¹Costs based on R.N.P. labor records and R.U.I. billing records.

²CETA provided at no cost to R.N.P. except cost of pickup and delivery of crew persons at McKinleyville (30 miles south of Orick) by R.N.P. employee (not included in costs).

Additional problems adding to the cost of placement occurred in finding suitable locations for bale storage during heavy equipment work. Since much of the road was prescribed to be outsloped, bales had to be placed above the prescribed fill level on the cutbanks. Where cutbank steepness prohibited placement, bales were stockpiled at intermittent locations and had to be re-distributed (for even cover) after road removal was accomplished. Also, bales left unused at the D-Line project were transported to rockpit #2, increasing distribution time. Table 12 examines fractions of time spent in traveling, distributing, and spreading mulch.

APPENDIX 1.

SOIL SURVEY OF Y-LINE ROAD
FOR WATERSHED REHABILITATION

Redwood National Park

Jack Lewis

June 1982

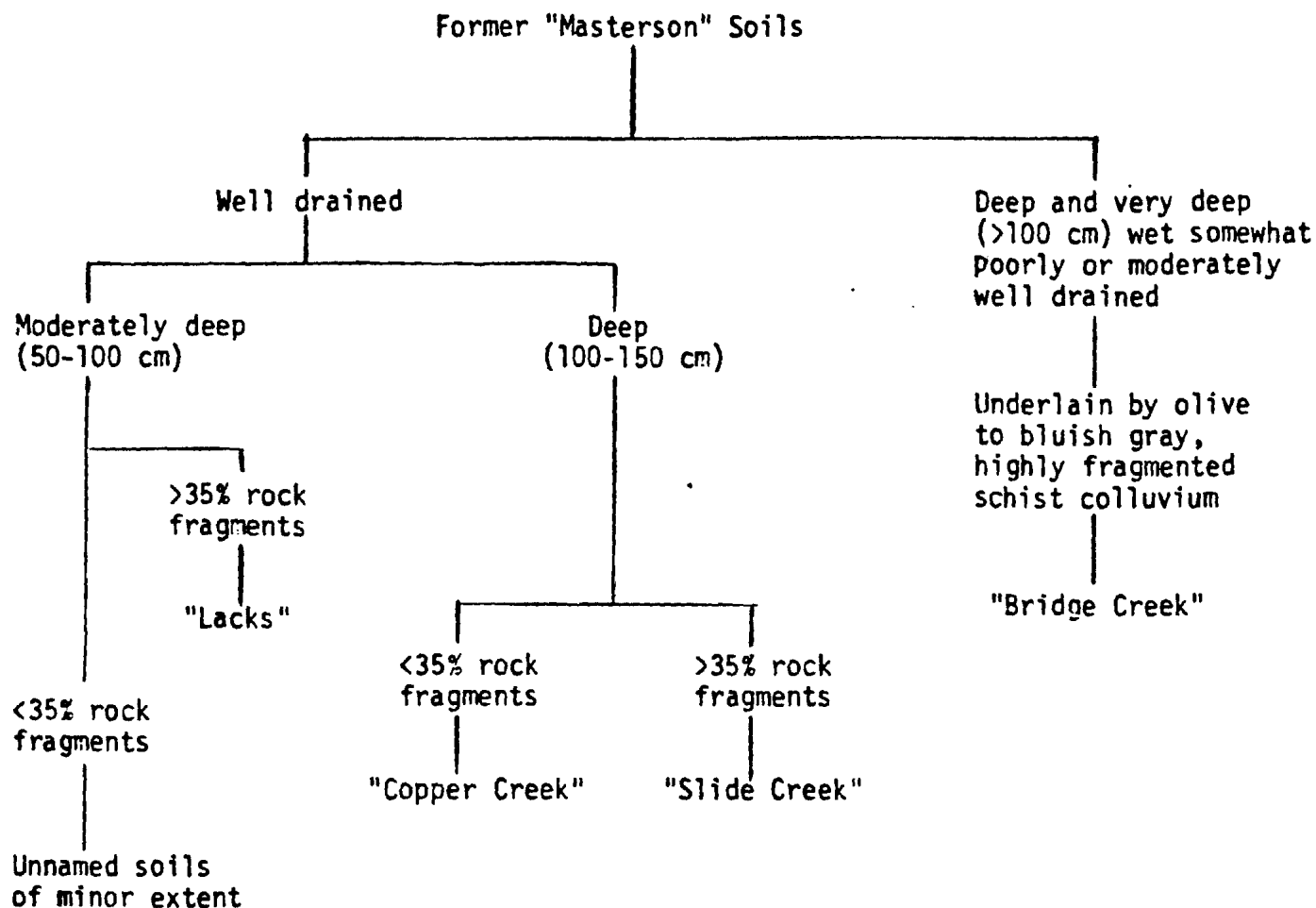
PREFACE

Jim Popenoe

The purpose of this survey was to look at management of soils on mountain side-slopes in need of rehabilitative treatment.

Soils described here are mostly in the Inceptisol order. Some of these are in wet places subject to mass movement. Others are in well-drained places. They were all mapped "Masterson" by the Soil-Vegetation Survey in 1961. Since they vary in location and management, we have subdivided the Inceptisols (see following page).

There are also some Ultisols in the general area of this survey. These are present only as minor inclusions where rehabilitation is to take place. They are more important on upper, relatively gentle slopes where erosion is not much of a problem. These soils were mapped "Orick" or "Sites" by the Soil-Vegetation Survey. Ultisols receive little mention in this survey, but there will be need to look at them soon to update the soils quad maps for areas in Redwood National Park.



NOTE: These new soil names are only tentative proposals. They have not been recognized, approved or reserved by the National Cooperative Soil Survey. Another name could be established for soils of these types at any time. Please exercise caution in use of these unapproved names.

Jim Popenoe, 6/9/82

Y-Line Road Soil Transect
Jack Lewis
May-June 1982

BC-1 Bridge Creek soils - very deep (modal) (Owg-f1-Cr4)

Very deep (>1.5 m), somewhat poorly drained Inceptisols formed in colluvial fault gouge material derived from schist.

A horizon is brown or yellowish-brown, gravelly heavy loam or light clay loam.

B horizon is yellowish brown or brownish yellow, gravelly light clay loam.

C horizon is mottled, olive or olive brown, very gravelly light or medium clay loam.

Management. Numerous large debris flows have occurred in these soils along the Y-Line. The A horizon is held together tightly by a dense mat of roots and may remain intact, overhanging a scarp as the subsoil slides out from beneath it. Islands of vegetated topsoil may often be seen floating nearly intact within a debris flow. The instability of the subsoil is related to 1) incompetency of the highly sheared fault gouge material from which it is derived and 2) high pore pressures. Pore pressures build up because 1) water tends to flow into the low landscape positions where these soils are found and 2) there are no continuous joints in the bedrock to allow subsurface drainage.

These soils also have a high gully erosion hazard when disturbed due to their lack of cohesion, moderate coarse fragment content, and small, transportable, coarse-fragment size.

Revegetation should not be a problem with these soils as long as they remain in place. Alders appear to grow readily in the cutbanks and sidecast material. Decompaction, however, will greatly accelerate natural revegetation of road surfaces.

These soils occur in and adjacent to drainages. The vegetation consists of redwood, hemlock, Douglas-fir, tanoak, alder, Rhododendron macrophyllum, Vaccinium ovatum, V. parv., Polystichum munitum, and commonly various water-loving species such as Blechnum spicant, Woodwardia fimbriata, Adiantum pedatum, Equisetum, Petasites palmatus, Rubus spectabilis, and Sambucus callicarpa.

A representative of this soil type is profile #1, photo 11-33. (Profile is found on scarp above 90+00 ft. on Y-Line):

O	3-0 cm	Fresh and decomposing leaves and twigs from RHDT, Rhc and Va			
A	0-26	10YR3/4M	gcl	25% _c	22% _g
B	26-50	10YR5/6M	gcl	28	25% _g 5% _{cob}
CB	50-87	2.5Y3/3M	vgcl	38	44% _g
2C1	87-180	5Y5/3 & 5Y6/1M	vgcl	29	27% _g 10% _{cob}
		mottles c3p 10YR5/8			
2C2	180-200+	5Y4/1M	vgcl	27	35% _g

BC-2 Bridge Creek soils - deep and moderately deep variant (Ow, Owg-fl-Cr2,Cr3)

Moderately deep to deep (0.5-1.5 m), somewhat poorly and moderately well-drained Inceptisols formed in highly fractured schist colluvium and residuum. Similar to BC-1 in colors and textures.

Management. These soils differ from the modal Bridge Creek soils in being on landscape positions where somewhat less water is concentrated, including intermittent and ephemeral streams, higher slopes above perennial streams, and some sideslopes. In addition, the soils are not as deep. There is often seepage of water from the rock in a substratum that perches groundwater.

Since less water tends to concentrate in these soils, mass erosion is less severe. However small debris flows and slumps are still commonplace. The gully erosion hazard is high when the vegetation is removed or soils compacted.

Revegetation should be managed as with modal Bridge Creek soils.

LA Lacks soils (Ow-lsk-R2)

Moderately deep (mostly 0.5-1.0 m), well-drained Inceptisols, high in rock content, formed in colluvium and residuum from schist.

A horizon is brown, gravelly loam or light clay loam.

B horizon is brown to yellowish, gravelly, very gravelly, or very cobbly clay loam.

C horizon is olive or olive brown, very gravelly or very cobbly clay loam.

Management. These soils are on steep and moderately steep sideslopes and ridges. They are the most commonly occurring soils along the Y-Line road. Vegetation consists of redwood, tanoak, Douglas-fir, madrone, hemlock, Rhododendron macrophyllum, Vaccinium ovatum, and Whipplea modesta. In logged areas, Baccharis pilularis and Ceanothus thyrsiflorus are common.

These soils do not normally experience very high pore pressures. The bedrock tends to be fairly well-jointed and coherent. However, if material is piled on too steep a slope, as on the outboard edge of roads and landings, it will fail. An example of a debris avalanche of this type occurred on the M-2-1 where photo 11-33 is marked with the numeral "3". This landslide is "resting" at a slope of 97 percent.

The gully erosion hazard on this soil is slight when undisturbed. If water is concentrated on a bare compacted surface, gullies can be expected to form. An erosion pavement is likely to form, however, since the soil is high in rock content.

Some areas along the roads are quickly invaded with red alder. In other areas, Douglas-fir seedlings grow on the road cutbanks and appear fairly healthy. Road surfaces should be decompacted to optimize the chances for revegetation, and areas that appear to be recolonizing slowly or not at all should be planted with drought-tolerant species, particularly on south-facing slopes.

A representative of this type of soil is shown as profile 2 on photo 11-33 (near 142+00 ft. on Y-Line):

0-5 cm	10YR3/4M	gcl	27%	25%	
5-34	10YR5/4M	gcl	28%	30%	
34-88	2.5Y5/4M	vgcl	28%	30%	10%cob
88-100	Fractured schist bedrock				

SC-3 Slide Creek soils - deep phase (Ow-lsk-R3)

Deep (1.0-1.5 m) well-drained Inceptisols (high in rock content) formed from colluvium and residuum from schist.

Similar to Lacks in colors and textures.

Management. These soils are similar to the Lacks soils in most management requirements. They are perhaps somewhat less droughty; however, since they are on a southwest-facing slope along the Y-Line, revegetation should be with drought tolerant species where the road is not shaded. Presently most of this section is lined with alders and would be best left with as little disturbance as possible.

CC-3 Copper Creek soils - deep phase (Ow-fl-Cr3)¹

Deep (1.0-1.5 m) well-drained Inceptisols overlying weathered and highly fractured schist residuum.

- A horizon is yellowish or olive brown light clay loam.
- B horizon is gravelly brownish or olive yellow gravelly or very gravelly clay loam.
- C horizon is olive, very gravelly light clay loam.

¹Soils in this population with more olive hues (between 2.5Y and 10YR) may fall slightly outside the range of hues defined for Copper Creek (10YR to 7.5YR).

Management. These soils are mainly on stable landscape positions such as ridges. They are of limited occurrence in this lower portion of the watershed. The vegetation is similar to that in Lacks. The mass erosion hazard is low as long as material is not oversteepened or slope overloaded. Gully erosion is a moderate hazard on this soil where it is disturbed. The soil is relatively non-cohesive and has moderate coarse fragment content. Maintaining infiltration capacity and keeping water from concentrating on it will lower the probability of gullyng.

These soils present no special revegetation problems.

Unnamed minor Inceptisols (Ow-f1-R2)

Moderately deep (0.5-1.0 m) well-drained Inceptisols formed in colluvium and residuum from schist.

- A horizon is brown, gravelly loam or light clay loam.
- B horizon is strong brown to yellow, gravelly clay loam.
- C horizon is olive or olive brown very gravelly clay loam.

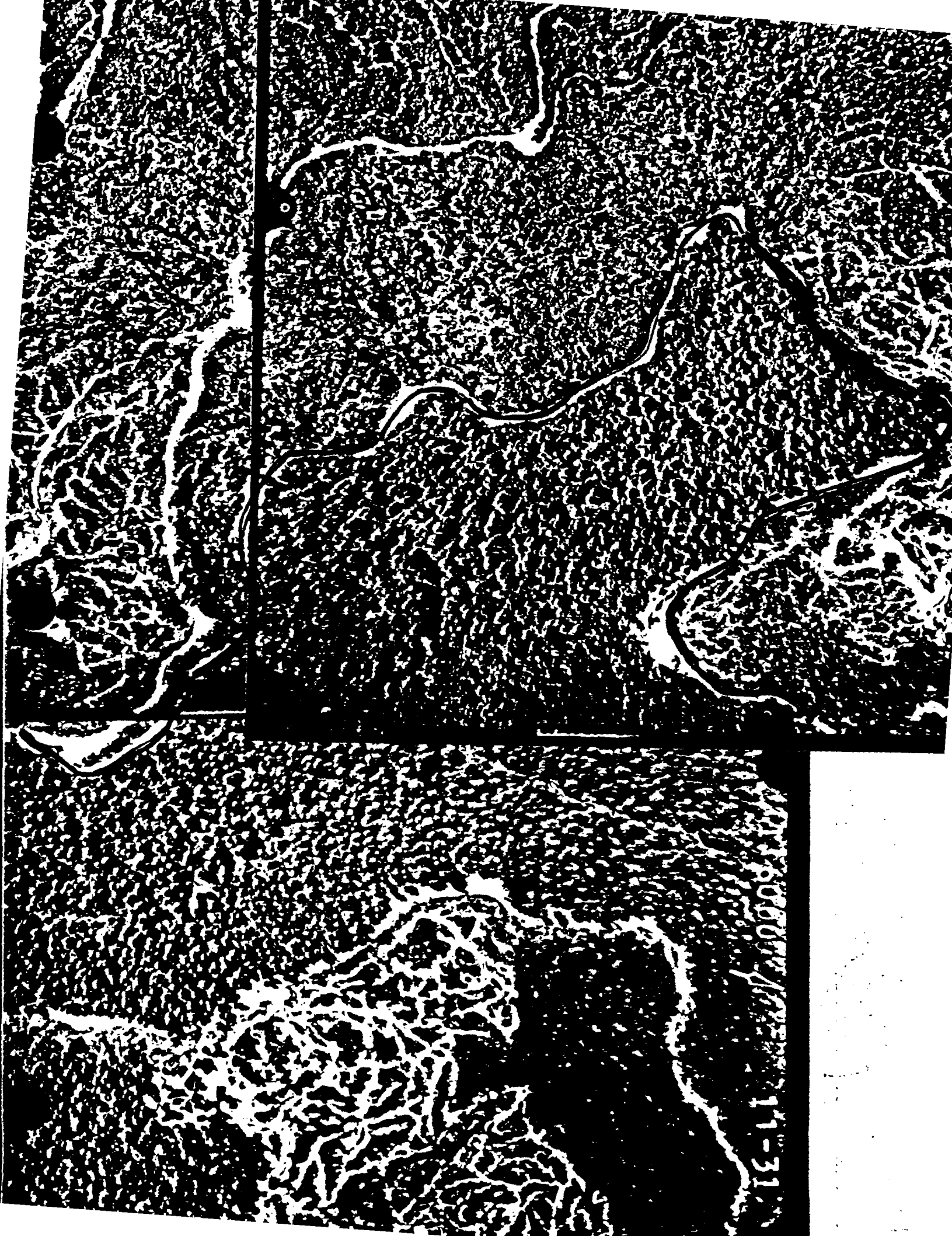
Management. These soils may be managed similarly to Copper Creek deep phase soils.

Unnamed minor soils with argillic horizons (Ot-f1-R2)

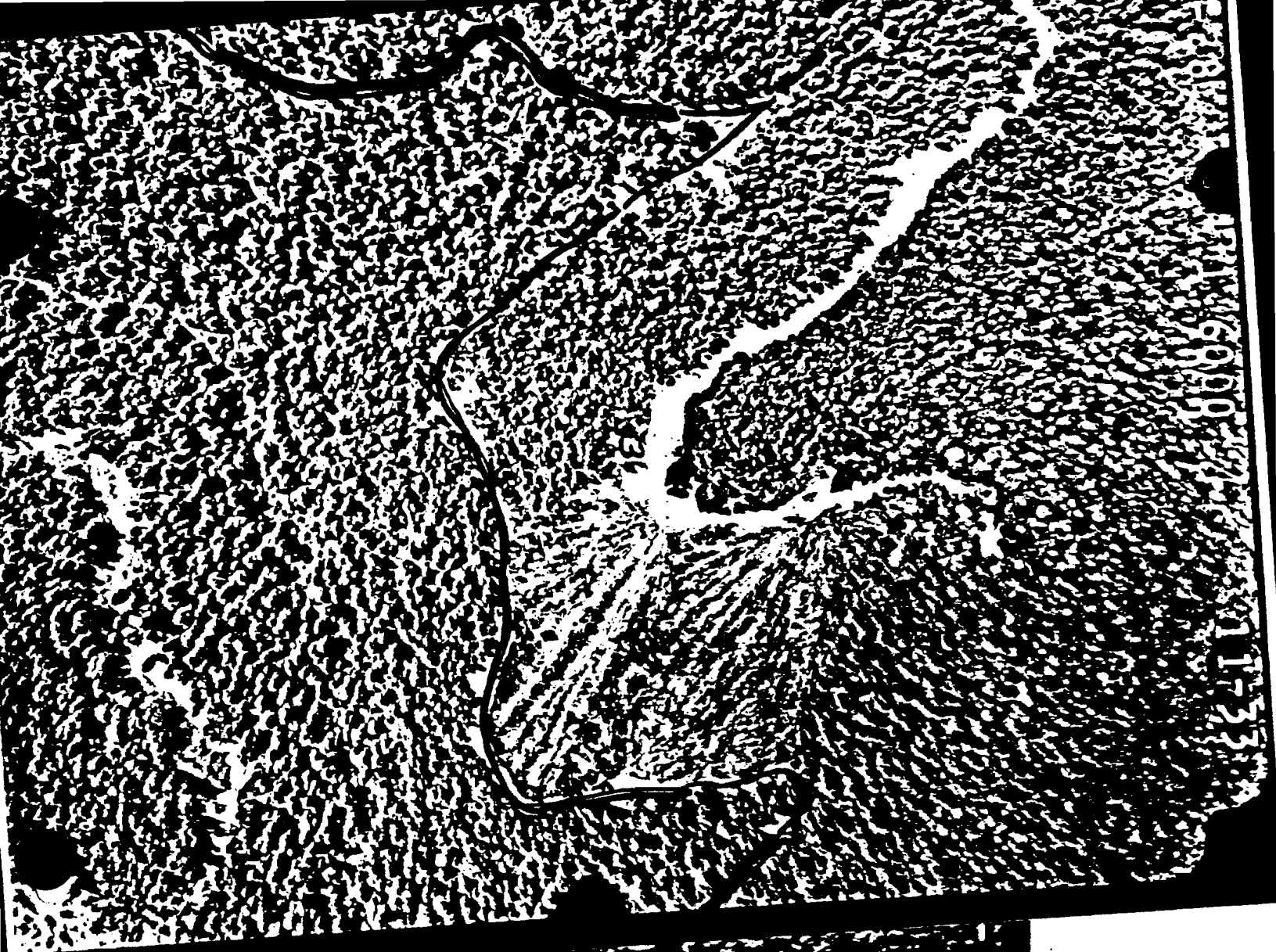
Moderately deep (0.5-1.0 m) well-drained Ultisols (or possibly Alfisols) formed in residuum from schist.

- A horizon is brown, gravelly loam.
- B horizon is strong brown to reddish yellow gravelly clay loam.

Management. The portion of the road marked in red is transitional to a large area of old red clayey, soils (Trailhead series) which occurs on the north-east side of Bridge Ridge. The vegetation is similar to that on Lacks soils. This transitional area, although redder than the preceding two soil types is still quite similar in texture, rock content, drainage characteristics, and pH. Its management interpretations can be considered to be the same for rehabilitation.



11-31



11-3333
6000

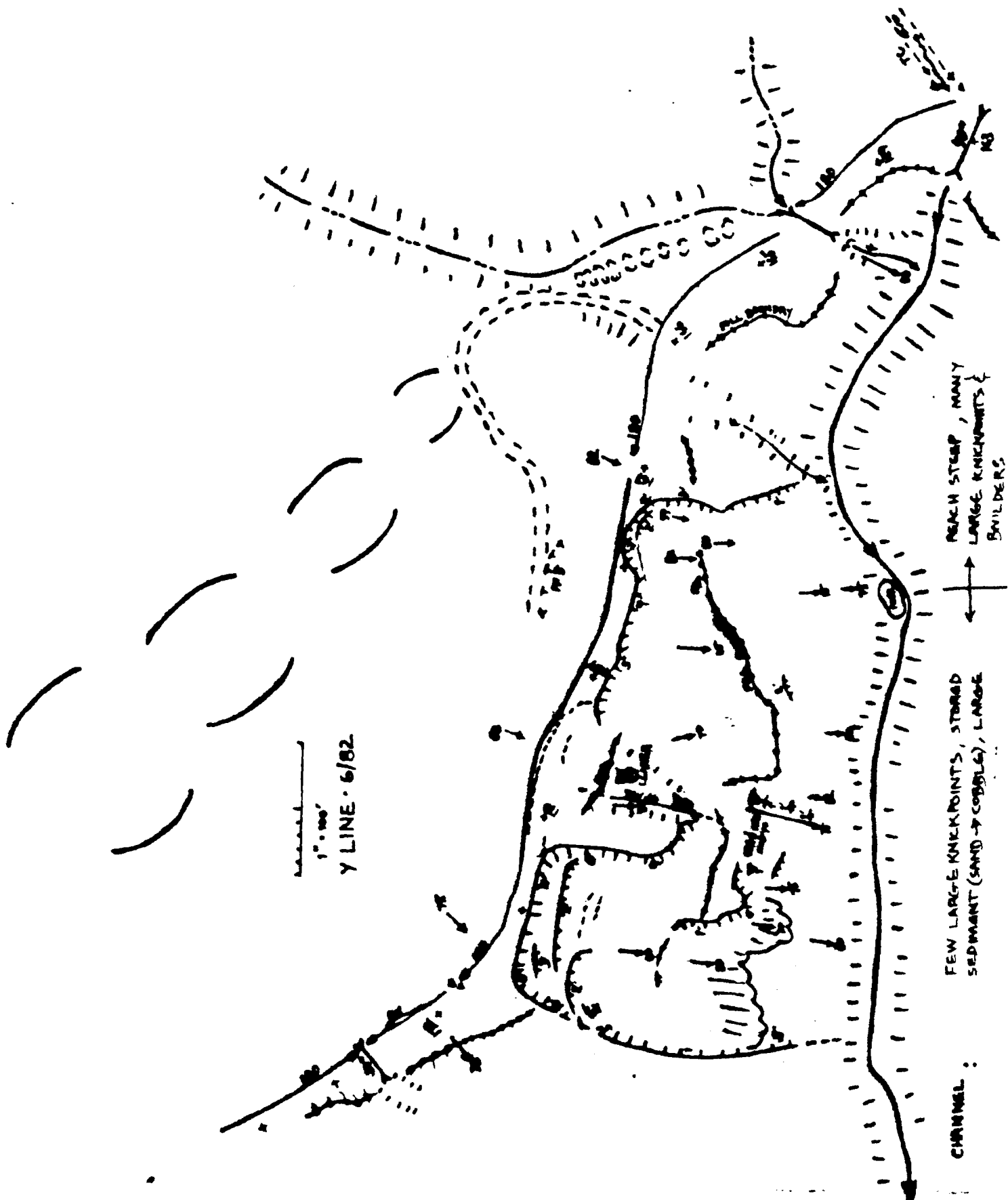


-78

1:6000

11-3333

APPENDIX 2





APPENDIX 4.

SURVEYING PROCEDURES FOR POSITIVE

GRADE CONTROL DURING EXCAVATION

By

Ed Wosika

1981

INTRODUCTION

The goal of surveying work is to provide positive control of all rehabilitation work during both the planning and the execution phases. Remaining depth to grade is easily obtained in the field, which is very useful for finishing up a partially excavated crossing. Fill areas are laid out ahead of time and their volume is known to be adequate. Achieving straight-line channel and sideslope gradients is simple. The volume of material to be endhauled (if any) is known beforehand, facilitating planning and sequencing of any trucks. The control provided by surveying is easily worth the small preparation time it now requires.

The techniques described herein have all been used through one field season (the Y-2 contract). This experience pointed out both the weak and strong points and provided a basis for finalizing the procedure and format. The main problems which surfaced were: 1) the excessive time needed to survey and draft the plans, 2) the lack of flexibility to absorb changes necessitated by obstacles encountered during excavation, and 3) insufficient grade control during excavation. These difficulties have all been solved. The updated techniques described here will give maximum control and flexibility for a minimum of time expended. Although this paper describes how to set up an entire project site, the techniques may also be used piecemeal, such as for large, difficult stream crossing excavations.

The basic surveying technique, using tape, clinometer, and Jacob's staff, was the brainchild of Pat Teti. The best of his procedures were combined with the best of ours. Hopefully, the result will be of use to all Redwood National Park geologists and hydrologists. All techniques are described in enough detail to permit anyone to implement and adapt them to their own uses. This was done at the expense of brevity, but will save the user time in the long run by highlighting pitfalls and useful tricks.

THE TOOLS AND THEIR USE

Field Tools

The following tools are required for a two or (preferably) three person survey crew: 1) cloth tape, 2) clinometer, 3) Silva quadrant compass, 4) two 5.3 foot long Jacob's staffs (alder or broom handle), 5) stadia rod (occasional use), and 6) notebook (ring binder type with waterproof paper). All bearings are true. To maximize the precision of compass bearings, the compass should be gripped to the far end of a survey stake, with the near end of the stake pressed to the face at a point just under the eye. Once the centerline of the compass is aligned in the compass' mirror, the body is held rigid with all rotation done from the waist only. This technique yields very consistent readings since a long site-radius is created. All clinometer readings are done with the instrument firmly hand-clamped to the top of the Jacob's staff (hereafter called rod) and with the staff braced by the user's body. Vertical angles to within ± 0.1 degrees can be achieved in this manner. Eliminate clinometer errors by always starting at 0 degrees, then tilting up or down as needed to site the rod tip, and subvocalizing as every 10 degrees is passed (i.e., "plus 10⁰, plus 20⁰, plus 22.3⁰"). This avoids the common error of calling + for - or calling 22⁰ for 18⁰. Be sure to test all members of the field crew by shooting vertical

angles from the rod to a distant point, as visual disorders can cause aberrant readings. If one person on the crew is unable to reproduce the identical readings of the other two, then the "odd man out" will be the note-taker, while the other two can trade off being instrumentman and rodman as needed. All initial measurements are from rod tip to rod tip. A distance and a vertical angle measurement are required for every shot and sometimes a bearing. First call out the distance, then the vertical angle, then the bearing (if needed), so that the notes read like: "+20⁰ feet @ -13.4⁰ ON N30⁰W". Note that the tenths of feet are superscripted and underlined (standard engineering convention), while tenths of degrees merely follow a decimal point. The note taker should repeat each reading (including sign and units) out loud as it is given, then enter it while the next is measured. Several types of field survey notes are used. Each note format will be explained in its appropriate section. The use of the small ring-binder style of notebook permits all work to be done in any order desired, then ordered by station number.

Drafting Tools

All drafting is done with a drafting machine on 18" x 24" "clearprint". If you are familiar with drafting machines, skip to the next paragraph, otherwise: tape down the corners of the clearprint onto the drafting table, then set the machine so it reads 0⁰ when it is parallel with the horizontal lines on the paper. This adjustment is achieved as follows: one lever releases the rule to rotate free of the protractor scale. Set the rule reference mark opposite 0⁰ and reset the lever. Now release the other lever and the rule and protractor scale will move together. Align the rule with the paper's ruling and reclamp the lever. Now whenever the protractor reads 0⁰, the rule will be parallel to the horizontal line on the paper. To measure an angle, release the first lever, set the desired angle, and reclamp, then draw the line.

Clearprint reproduces well in blue-line and the 10 x 10 ruled lines on the paper do not appear on the reproduction. The clearprint we use has heavy fadeout lines every inch, while the intervening lines are light. Thus, all lines are 1⁰-foot apart using a 10-scale (1" = 10') and 2⁰-feet apart using a 20-scale (1" = 20'). These are the only two scales used in the drafting. An engineering scale and triangle are needed. The machine should be fitted with a 10-scale rule. The following tools are also useful: compass or circle template, french curves, dividers, 30⁰ and 45⁰ triangles, pocket calculator.

Sign Conventions

Several arbitrary conventions are useful. Anytime distance is measured in the direction of the outboard edge of the road, it carries a positive (+) sign, while distance measurements toward the cutbank carry a negative (-) sign. Thus the inboard ditch is in a negative direction from the road's outboard edge, but is in a positive direction from any point up on the cutbank. For stream cross sections, face downstream to determine left and right. From wherever you are standing on the cross section, all shots along it that are to your left are labeled "L", while all shots to the right of you are labeled "R". So all numbers entered in the notes (except for bearings) have a prefix (+ or -), a numerical value and a suffix (feet or degrees).

Types of Stakes

Several types of stakes are used. The first are "station laths". The road is measured along the road centerline (ϵ) from the beginning of work and a station lath is placed on the cutbank every 100⁰ feet. A nail with bright flagging tied to it is also hammered into the road center at every 100⁰ foot station (opposite the station lath). For example, a lath reading "Sta. 53 + 00" is situated 5300 feet or 53 stations from the beginning of the road work. These laths are very quick to set up along a road and make worksite identification both brief and precise. Thus R/X A23 + 94 is a stream crossing 2,394 feet from the beginning of road "A". The second type of stake is the slope stake (SS). A SS tells how deep to cut (C) or fill (F), in what direction, at what slope, and how long the finished slope will be. Examples of slope stakes are given in the stream crossing section of this report. They are very simple to use. The third type is the Reference Point (RP) stake. This stake is on the same survey line as the SS, but situated in a location which won't be disturbed. It is used to relocate the SS position. Its placement will be discussed in the stream crossing (R/X) section, but they may be used for any SS you will need to relocate. The fourth stake type is the endstake. These are placed during the initial field survey and are used to delineate the ends of cross sections (use white wooden stakes) or longitudinal stream profiles (use 3 foot long piece of rebar painted white). The fifth type of stake is the "Cut to Here" stake used in road outsliping for non-surveyed road reaches and fully described in that section. All station laths are natural wood color, while all endstakes and SS are white and all RP are red. Use the roughest color of flagging you can find on all survey stakes so they are easy to find after leafout.

Surveying Procedures For Various Prescription Types

Deep Dish--a format for simple stream crossings draining <30 acres.

The deep dish (DD) prescription format is used for all small or simple stream crossing excavations. It provides an accurate volume estimate and positive grade control with an absolute minimum of time expended. No more than 2.5 hours is required for all surveying, drafting, and final stake setting for a DD and its fill site. Final channel grade is controllable to within $\pm$ 0.1 foot.

First, determine where the centerline of the finished channel should be, then set the upper and lower endstakes (3 foot sections of 1/2 inch rebar) on the ϵ and far enough up and downstream to avoid disturbance. Note the station number where the stream ϵ crosses the road ϵ and use this to name the crossing, as in "DD 23 + 42". Next place a stake labeled "Top of DD" at the point on the ϵ where you want excavation to begin. Usually this is at the inboard ditch, but will be further upstream on crossings where sediment is backed up. Then set a stake labeled "Base of DD" at the point on the ϵ where you want your DD to end (lower $\leftarrow$ end of channel). Now survey in the longitudinal profile, using the same procedure as that delineated for the longitudinal profile of R/X-type crossings. Be sure to "shoot" all stakes as well as all major breaks-in-slope, inboard ditch, and road edges. A set of sample DD survey notes are shown in Figure 1.

107+88

END FLAGGED

DEEP DISH

* refers to deep dish that is not
⊥ to road (rebar w/ pink flagging)

107+88 X-sec along line defined by
end stakes. Stakes are on
unstable ground

From $\perp$ to:

IB edge rd -11.5' @ +1.0°

thalweg = middle

inboard ditch =

top end excavation -14.5' @ -9.0°

upper end stake = thalweg -33.1' @ +6.0°

OB edge rd +13.4' @ -5.0°

from $\perp$ to:

probable lower
end of excavation B/S +22.5' @ -37.5°

lower end stake +38.5' @ -35.3°

has 20' of culvert, 40' ball round
of 24" pipe

108+20 = END DS = BEGIN XRD = probable
upper end of deep dish excavation

Figure 1. Field notes for DD A107 + 88, as drawn in Plate II.

Next, estimate how much road will be required as a fillsite for the excavated material, and survey in road cross sections every 100 feet or so. For short fill sites, survey a cross section 30 feet from either end only. The survey techniques to be used are described in the fill site section.

The key to the simplicity and speed of the deep dish prescription format lies in the use of a standard cross section template, as shown in Plate I. Once the longitudinal profile and channel grade are drawn (see Plate II at sta. A107 + 88 and A118 + 00), the vertical distance to grade can be measured directly for any point on the ϕ . A pseudo cross section can then be created for each ϕ point desired, using the template. Pick a point and measure the depth to grade (say 10⁰ feet at the outboard edge of the road), then go to the template (Plate I) and find a point that is high above the template's channel ϕ (scale one inch up from the bottom center). The width of excavation and the cross sectional area of the excavation at that point can then be measured by ruler and planimeter respectively, right on the template. If this is done for all major breaks in slope on the between the "top of DD" and "base of DD" stakes, the total volume can be calculated by double-end-area as described in the R/X section. It is helpful to measure the (maximum) excavation width at its deepest point (usually at the outboard edge of the road) and locate a stake reading "edge of DD" one on either side of this point in the field. In our example, these stakes would be placed on the outboard edge of the road 27 feet on either side of the . This gives the heavy equipment operator one stake at each end of the channel plus one on either side showing the point of maximum width. This speeds up excavation because the limits of excavation are known beforehand.

One of the most useful aspects of a surveyed crossing is the ease with which grade checks can be made during excavation. Critical measurements of distance and vertical angle to grade are made on the drawing with the drafting machine. These measurements are printed on the plan sheet next to the drawing so they are readily available for field use. A set of grade check measurements are shown to the left of DD A118 + 00 (Plate II). "DD Grade Check (r.t.g.)" means that the values are to be measured from the tip of the rod (5³ ft.) to a point on the ground at the distance specified (r.t.r. = rod to rod; g.t.g. = ground to ground). The second grade check line down reads "U.E.S. $\rightarrow$ max = +33⁹ ft. @ -28.3⁰". This translates to "from the top of a 5.3 ft. high rod placed at the upper end stake, the channel ϕ grade at the maximum dig depth is 33.9 ft. downstream at an angle of -28.3⁰". Lets say we want to know how much further to dig at that point (excavation is partway done). To check grade, stretch 33.9 ft. of tape from the rod tip to the ground, along the channel ϕ , then measure the angle (r.t.g.) with the clinometer. If, say the angle is 25.6⁰, then the excavation is too shallow. The remaining depth to grade is equal to the taped distance times the difference in the sines of the angle = 33.9 ft x (sine 28.3⁰ - sine 25.6⁰) = 1.4 feet of depth remaining to grade. With a pocket calculator, the answer is available in seconds. A few such quick measurements as final grade is approached will guarantee that the end-product will be right in the button, eliminating the usual convex-up channel profile.

The fill profiles for the DD should be shown in sequence on the same plan sheet, as shown on Plate II. This will be discussed in the fill site section.

The total drafting time for a large DD and its fill area should be no more than one hour, yet the benefits in grade and fill control are precious. This prescription type should be limited to simple crossings which have a contributing area of less than 30 acres so that 25-year flood peaks yield no more than one foot of flow depth (design flow is 20 cfs, flowing at 3 fps). Measure the drainage area of all deep dishes (if the basin is discernable on the map) and write down the T_{25} peak flow and drainage area. Since all DD have small drainage areas, their Q_{25} is always 1.8 iph (for drainages in the Redwood Creek Basin), thus peak flow is simply: $Q_{25} = (.4)(1.8)(\# \text{ acres})$.

Larger Stream Crossings (R/X-format)

The fully-surveyed R/X format is used only on large or complicated stream crossings, where surveyed cross sections are needed. The total time involved for surveying, drafting and stake setting is from two to three team-days, but this effort produces a plan sheet containing all information necessary for total grade control during excavation of the channel and side slopes, as well as a useful survey net for any post-rehabilitation monitoring.

Plate III shows the completed plan sheet for R/X A53 + 00, a major crossing at station 53 + 00 on the Y-Line road of Devil's Creek. Three types of views are shown: 1) a plan view (scale 1":20'); 2) a longitudinal stream profile (scale 1":10'); and cross section views (scale 1":10'). Grade control notes are provided which permit vertical control ± 0.1 ft. for shots of <50 ft. in length and ± 0.2 ft. for shots up to 100 ft. away. The work is treated below in the order used in surveying. Figure 2 shows the actual field survey notes taken for this crossing (6 pages from the field notebook).

setting up the survey grid

Determine the position of the ∇ of the crossing and record its bearing in the downstream direction. Carefully set the lower and upper endstakes (rebar) on the ∇ and far enough up and downstream to avoid disturbance. Next set the white wooden ∇ stakes at the points where cross sections are needed, beginning with a stake labeled A ∇ at the upstream limit of excavation. Set the B ∇ , C ∇ , D ∇ , etc. stakes on the ∇ at all major breaks in slope, with the last stake set at the lower end of excavation. Normally only four cross sections are required (A $\rightarrow$ D), but up to six maybe needed. In our example (Plate III) the road bends strongly at the crossing (see plan view), so an extra section was required to avoid a gross misrepresentation. Look along the line of ∇ stakes to be sure they are lined up in a straight row. Now determine the bearing perpendicular to the ∇ and write it down, then set the endstakes for each of the cross sections. The left endstake of section A is labeled A $_{\perp}$, etc. Always use the compass-clamped-to-the-far-end-of-a-stake method to shoot bearings, as described earlier and beware of the magnetic effect of steel CMP! Set all cross section endstakes well beyond the probable limits of excavation, so that they will not be wiped out and also because they can then often double as RP stakes. Check each set of cross section stakes to be sure they align and are on the right bearing. Tie rude colored flagging (international colors) to the stakes. Now draw a freehand map of the survey grid, keeping all angles at 90° and lengths of cross sections roughly proportional. Sketch in the culvert, big trees, roadway, stream thalweg, and other

RA A53+00 cont.

A X-SEC.	From	A to edge comp. in let.
B/S edge rd	4.2 R	111.2°
B/S to left bank	11.3 R	117.0°
on CB	18.5 R	121.0°
B/S	22.5 R	125.0°
AR	28.4 R	123.0°
then 90° for 5R then 55°		
ICMP	33.2 L	121.3°
left bank to bottom	5.3 L	127.0°
top left bank	12.5 L	133.5°
B/S	18.9 L	130.0°
B/S on CB	25.1 L	134.3°
AL	31.0 L	133.0°
B X-SEC. From B to		
1B edge rd	4.6 R	121.0°
1B/D	4.30 R	120°
B/S above rd	10.2 R	110.4°
1B edge rd	11.0 L	116.3°
1B/D	15.2 L	118.0°
B/L	29.2 L	115°

RA A53+00 cont.

C X-SEC.

From C to

rd at 53+29

(From C to rd = 29.1 and 11.6°)

1B edge rd

1B/D

bottom C.B.

C/R

then 180° for 6R then 30°

rd at 52+

1B edge of rd

1B/D = bottom C.B.

C/L

D X-SEC.

From D to 1B edge of rd. to

D/L

left edge channel (not 53+00)

rd

B/S

1B/D (L)

1B edge rd

rd to

1B edge bottom

top turn

Figure 2. (cont.). Field notes for R/X A53 + 00 (note pages 3 and 4 of 6).

R/A53+00 cont	
DX sec point	
① EL = top left bank channel	383 R 17.50
top left bank channel	410 R -2.00
top right bank channel	429 R -2.00
(d) Camp outlet	411 R -17.0
2500 stream from road	
top left bank channel	453 R -15.0
OB edge of rd	117 R +2.60
ROAD EL	832 R +2.40
OB edge rd	950 R +2.60
ROAD = bottom 25	947 R +1.70
DR	1245 R +1.00
then 70° 85° 40°	871
E-X-SEC = E worked just above last at 17.50	
from EL to station	22 L 4.50
bottom bank below	49 L 0.00
3/3	52 L -10.00
top left bank	75 L +3.50
1/4 full slope	20 L 12.00
EL = bottom station	28 L +12.00
OB edge of rd.	57 R 12.40
ROAD EL	70 R +17.50
9/5	15 R +13.10
9/5	22 R +1.00

R/A53+00 cont
(E-X-SEC cont)

bottom of full slope
86 R +9.50
272 R +20.00
OB edge of rd
612 R +27.30

Figure 2. (cont.). Field notes for R/X A53 + 00 (note pages 5 and 6 of 6).

major features as per field page #1 of Figure 2 (use grid lined paper). Determine the distance, vertical angle and bearing (rod to rod) of all those features which will not be on a survey line, recording this data on the sketch (i.e. sample sketch shows that from the lower endstake to 10' dia. R.W. is 185 ft. @ 0° on N26W). Likewise locate the bottom of each end of the culvert, noting this on the sketch margin. Now proceed with the longitudinal profile.

Longitudinal profile

Choose a position on the ϵ from which you can see the top of a rod placed anywhere else along ϵ (usually the outboard road edge is best). Have the rodman start at either ϵ endstake and work through your position to the other endstake. A shot will be taken at each break in slope and at each cross section's ϵ , with the measurements recorded as shown on the second field note page of Figure 2. It helps if the tip of the rodman's rod is painted white so it stands out in heavy cover.

cross sections

Each cross section maybe shot from any point on that cross section, but drafting is easier if all shots are from the ϵ and this also keeps the maximum shot distances lower. Section D of R/X A53 + 00 (Plate III) had to be shot from the road edge at the top of the left bank from a point labeled TP (Turning Point) on the plan view and cross section. This was the only point on the cross section where all other points were visible. All other cross sections in the example were shot from their ϵ . For each shot, record distance followed by L or R (left or right of where you are, not left or right bank) an @ (= at angle of) and the angle (+ or -) as shown on pages 3 to 6 of Figure 2. Locate all major breaks in slope (B/S), road ϵ (if applicable), and cross section endstakes. The initial survey work will take approximately one day for a substantial crossing.

drafting the plan view

First, adjust the drafting machine as described earlier, then use the 20-scale to draw the plan view in the upper left corner of the sheet, just as in Plate III. The ϵ will be along a major vertical fadeout line (not visible on your copy) on the clearprint paper. To determine which vertical line to use, find which of the cross sections has the left endstake furthest from the ϵ . In the example it is D_L. Using pages 4 and 5 of Figure 2, the actual map distance is the distance from D_L to the T.P. plus that from the T.P. to D ϵ = $(570 \text{ ft.} \times \cos 3.5^\circ) + (383 \text{ ft.} \times \cos 17.5^\circ) = 93.4 \text{ feet}$. Normally it is much simpler, such as with C_L, which is about 68 feet away from the (notes say "685 L @ +5.80", but this low angle has little effect on map distance for rough placement). So, in the present case, scale right from the page edge 93.4 ft (= 9.34 on the 20-scale), then use the next dark vertical line to the right as your centerline. Vertical spacing is done similarly, by putting the lower endstake on the first dark horizontal line below the page top, on the chosen vertical line. Next locate the place from which you shot the ϵ profile (distance $\times \cos \angle$), scaling back down the ϵ the required distance from the lower endstake location. Locate the upper endstake and then each cross section centerline point, relative to this location on the ϵ . Figure the map distance (dist $\times \cos \angle$) of each cross section endstake from its ϵ stake and locate it on the paper (20-scale). Connect each pair of corresponding endstakes with a horizontal line through the ϵ point.

drafting the cross-sections

Draw the cross sections (scale 1":10') in the same sequence shown in the plan view (left on left, A on bottom of page). All ϵ points will be placed along a single heavy vertical fadeout line, with the widest profile not quite going off the right edge of the page. Measure off the plan view (20 scale) the longest cross section distance to the right of ϵ ($D_R = 87^0$ R of ϵ in the example). The heavy vertical line desired is thus 9 lines to the left of the page edge. The before-excitation ϵ position of each cross section (A_ϵ , for example) is positioned on this vertical line using its elevation on the longitudinal profile as a guide. A_ϵ here was at 1270 ft. elevation or 30 below the heavy horizontal 1300 ft. elevation line. Thus A_ϵ was scaled in 30 ft. below the first unused heavy horizontal line from the page bottom, then the heavy horizontal line was labeled (lightly in pencil) as 1300. [$B_\epsilon = 1324$ ft. elevation, $\therefore$ it is 24 ft. above a heavy line; $D_\epsilon = 1194$ ft. elevation, $\therefore$ it is spaced 06 ft. below a heavy line labeled 1200]. This trick permits the elevation of all points on the finished cross sections to be read directly from the fadeout lines. Once a cross section is finished, the heavy elevation lines are labeled on either side of the cross section. This provides a horizontal reference datum line for the blueline prints (which lack the handy grid pattern of fadeout lines). Draw the cross section using the ϵ point as a T.P. (in most cases) and shooting distances (L & R) and angles (+ & -) from the T.P. In the sample's D cross section, the T.P. is up on the road above the left bank. In such a case, locate the T.P. first, being sure the signs (L,R,+, -) read correctly from the T.P. to the ϵ , then draft the cross section relative to this non- ϵ T.P. Vertical spacing of each deeply cut cross section is done so as to leave enough room below the ϵ for the channel bottom (measure cut depth directly from the stream profile), without interfering with the next lower section. Cross sections A through E are drawn in sequence and spaced vertically as needed. If interference seems probable, move up one whole heavy line (scale up 100). The spacing of the cross sections along the vertical line on the paper has nothing to do with their relative spacing on the plan view, only the order and horizontal positioning (normal to the ϵ) are the same. Finally, label all pertinent points on the cross section.

figuring the channel width; drafting channel bottom and sideslopes

Measure the depth to grade at each cross section ϵ using the longitudinal profile as a guide. Mark this grade elevation reference point beneath the ϵ of each cross section. Now calculate the peak 25 yr. flow (83 cfs in the example). A bare channel can probably stand no more than a one foot depth of flow, so the channel width must be sufficient to carry the peak flow at a one foot depth. Look at the channel grade (on the longitudinal profile view) and estimate the velocity in fps for a one foot deep flow (usually from 1 to 4 fps, depending on steepness). In the example, a 3 fps flow velocity was assumed. Derive the channel width by:

$$Q = \text{ft}^3/\text{sec} = \text{fps} \times 1 \text{ ft. depth} \times \text{channel width}$$
$$\therefore \text{channel width} = Q/\text{fps} \times 1 \text{ ft.} = 83 \text{ cfs}/3 \text{ fps} \times 1 \text{ ft.} = \underline{28 \text{ ft. wide.}}$$

Include the flow and channel width determination on the plan sheet (shown to the left-center of Plate III). Draw in the (horizontal) channel width through the channel grade point below each cross section, excluding the highest and lowest cross section. Draft in the sideslopes at either 2:1 or 3:1 (26.4° or 18.6°, respectively), labeling each slope as it is drawn. Channel sides should be no steeper than 1.5:1, as with the left bank of the sample's B cross section. Make the channel width of the lower and upper cross sections as wide as possible without disturbing the existing sideslopes. Occasionally it will be desirable to prescribe a specific sideslope of fractional value (i.e. 2.6:1), as when laying back to a particular point. In this case draw the line as desired, then figure the slope (i.e. if desired slope = 23.4°, then $1/\tan 23.4^\circ = 2.31 \approx 2.3$, so call it 2.3:1). Specify the channel width and elevation at each cross section just below the channel bottom, and the elevation of the tops of the left and right banks. Find the horizontal (left or right, map distance) position of the culvert $\#$ at each cross section by direct measurement from the plan view (don't forget to use the 20 scale for this!) and read the $\#$ elevation from the longitudinal profile. Locate the culvert's center point on each cross section and draft it in to scale (compass or circle template).

volume of excavation

Planimeter the prescribed cut areas of each cross section with the Salmoiraghe planimeter scale set at 8.97 (reads in² and 1 in²=100 ft²), writing the ft.² value lightly in pencil within the cross section. Measure the map distance between each pair of cross sections on the plan view (20-scale!) and lightly pencil it in between the cross sectional views. Calculate the volume between each pair of adjacent cross sections by double-end-areas, as in:

$$BC \text{ Volume} = \frac{(\text{cut area of B} + \text{cut area of C})}{2} \times \frac{\overline{BC} \text{ map distance}}{27 \text{ ft}^2/\text{yd}^3}$$

Since the cut tapers essentially to a point at the upper and lower cross sections, use the following formula instead (for the volumes between A and B, D and E in the example):

$$AB \text{ Volume} = \frac{(\text{cut area of A} + \text{cut area of C})}{3} \times \frac{\overline{AB} \text{ map distance}}{27 \text{ ft}^2/\text{yd}^3}$$

Alternately, the R.N.P. calculator program may be used for the volume calculation, though in most cases fewer measurements are required for a double-end-area calculation. Permanently record the volumes obtained on the plan sheet as shown, then erase the lightly penciled data.

slope stakes, reference points, and grade checks

Draw in the slope stakes and print each slope stake inscription on the plan sheet. Slope stakes are read as follows (sample is from the top right bank of section D, Plate III, all SS having the same sequence):

SS "Beginning at the base of this slope stake,
 C19⁵ make a cut 19.5 feet in depth.
 2:1 The cut shall have a two to one slope and
 44⁰ the slope length of the cut shall be 44.0 feet long.
 ditch At the bottom of the cut, make a (horizontal) ditch
 28⁰ bottom 28.0 feet wide."

Not all SS require the lowest two lines. In this instance: the cut (C19⁵) is the change in elevation from top-of-bank to channel bottom; the slope (2:1) is already known; the slope length (44⁰) is measured directly on the cross section; and the channel (ditch) width is already known.

Reference point stakes (RP) are used to help relocate lost slope stakes and are also a good place from which to shoot grade, as long as the distance is less than 100 feet. In most cases, the cross section endstakes can also serve as RP stakes. Where this is the case, the endstake need only be so labeled on the cross section, with no further field work required, as with the left endstake of section D (labeled "DL = RP"). Otherwise a separate RP stake will be required, as on the left side of sample cross section B. Prescribe and print in the grade shots (r.t.g.) from each RP to its SS and also to the channel grade ϵ when possible (the channel grade ϵ cannot be seen from the top of a rod set at DL, so no ϵ grade shot is given). These values are all obtained with the drafting machine as described for the longitudinal profile grade shots.

Make up a set of slope stake location notes as shown in Figure 3, so that the stakes may be easily set in the field. Make a set of white slope stakes. Each stake has its SS information on the face, with the crossing number and stake name (i.e. BL, DR, etc.) on the side, near the top.

setting stakes

Locate and set each SS using the r.t.g. information in the slope stake notes (see Figure 3). For instance, to locate the B section's right slope stake (SS_R) using the notes, stand at B and stretch 30⁷ ft. of tape from the top of the rod to the ground, in the direction of B_R. Check the vertical angle at that point on the ground (it should be -10.4⁰) and set the stake. Any heavy equipment operator worth his salt will be able to read grade stakes. The desired cuts are self explanatory and the limits of excavation are known before work begins. This makes correct grade achievable on the first cut. Slope stakes (which always set on the edge of the cut or fill) are easy to relocate during excavation using the RP stakes, while the grade along the channel centerline can be checked either from the side of the channel or along the stream profile (from the up and downstream endstakes and their printed grade stakes).

finishing the plan view

Draw in the channel position and limits of excavation on the cross section lines of the plan view by transferring direct measurements from the cross sectional profiles (just switch scales back and forth). Connect the lines as shown on the plan view. The drafting is now done. Note that the finished

R/X 53+00 Slope Stakes			
X-Section	Location	Info	RP (stake) to SS (ground)
X-Section A Right Stake	from AL (rod) to ground = 7.2' @ -23°	SS	RP = AL
		C12	RP to SS = 22.5' @ -42.5°
		2:1	RP to AL = 30.2' @ -32.5°
		2.5 1.5 13°	
X-Section B Right SS	from BL (rod) to SS = 30.2' @ -10.4°	SS	RP = BL
		C12	RP to SS = 45.1' @ -52.8°
		2:1	RP to ground = 45.1' @ -28.0°
		1.5 2.5 28°	
Left SS	same as BL	SS	RP = BL
		C12	
		1.5:1	
		30.5 ditto 28°	
X-Section C Left SS	372' L of CL ground to ground	SS	RP = CL
		C12	RP to SS = 35.1' @ -23.7°
		2:1	RP to ground = 75.2' @ -20.4°
		2.5 1.5 28°	
Right SS	from CL (rod) to SS (ground) = 43.2' @ -4.8°	SS	RP = CL
		C12	RP to SS = 95.1' @ -30.5°
		2:1	RP to ground = 60.5' @ -24.0°
		2.5 1.5 28°	
X-Section D Left SS	from DL ground to ground (tough top) = 40.2' @ -10.4°	SS	RP = DL
		C12	RP to SS = 40.2' @ -10.4°
		2:1	
		35.2 ditto 28°	
Right SS	from DL ground to ground (tough top) = 36.2' @ -26.6°	SS	RP = DL
		C12	RP to SS = 36.2' @ -26.6°
		2:1	RP to ground = 21.0' @ -23.0°
		4.5 1.5 28°	
X-Section E Right SS	from EL ground to ground (tough top) = 19.2' @ -37.8°	SS	RP = EL
		C12	RP to SS = 21.0' @ -37.8°
		2:1	RP to ground = 29.2' @ -30.0°
		3.5 ditto 17°	

Note: all RP work is done already (from plan data) except for EL. Line data is on the plan, only record the RP data in this sheet (don't put on stake) pick the RP stake back to their own section & side ("RP DL")

Figure 3. Notes for placing SS at R/X A53 + 00.

series of cross sectional profiles progressing from the bottom to the top of the page gives the observer a pseudo-perspective view of the desired channel, as viewed from a point upstream (this is the reason for having the order as specified and keeping all ϕ points on the same vertical fadeout line).

Fill Sites (General)

planning the fill site

The following prescriptions require fill sites: Deep Bishes; R/X Crossing; Total Outslope (this last one is described later on in its own section).

All fill sites are approached in a similar manner. Estimate the amount of fill you will need to handle, then choose a place to put it (along a road, landing, etc.). Survey in parallel road cross sections as shown below, spacing them at every significant change in road width. If the road length required for the fill is indeterminant, then survey in more road length than you will need (the surveying and drafting are quick, so be sure you have enough).

surveying a cross section

The first cross section should be somewhere between 30 and 40 feet away from the probable edge of excavation, so that a full fill section can be drawn without requiring too fast a taper from the start. The fill areas shown on Plate II (Stations A105 + 80 → A107 + 63, and A116 + 00 → A116 + 80) both incorporate some outsloping as well. The surveying notes from which they were made are shown in Figure 4. The surveying and drafting are self-evident from the notes and cross sections. The only difference in the slope stake is that it prescribes fill rather than cut. The "Cut To Here" stake (if any) is set as described in the road outsloping section, except that its depth below the road edge is not usually the standard 6 or 10 feet.

Once the total fill volume required is known, convert it to cubic feet and divide by the length of the fill site. The resulting number, when divided by 100, is the number of square inches of plan sheet required at each cross section to achieve the fill volume desired. If, say, 3 in.² is needed (300 ft.²) at a cross section, then a tentative fillslope line is made and roughly planimetered. The fill line is then adjusted up or down accordingly. Final grade is usually achieved on the second attempt. If a cut (from the outboard road edge) is also desired, then the fill cross sectional area must be proportionally larger to suit it. For most fill, an expansion coefficient of 1.5 works well, to account for the fact that the soil increases in bulk as it is excavated. For example, say a crossing requires 2000 yd³ of excavation, then the fill area should be made to handle 3000 yd³. If a nearby 200 ft. long landing is to be the fill site, then the average fill area needed in each cross section is:

$$\frac{3000 \text{ yd}^3 \times 27 \text{ ft}^3/\text{yd}^3}{200 \text{ ft.}} = 405 \text{ ft}^2 = 4.05 \text{ in.}^2 \text{ (on each x-section).}$$

A106+00 from base CB to:
 top CB +60° for -30'
 then above +25°
 IBD +2.2' @ -45.0°
 IB edge rd +5.5' @ 0°
 OB edge rd +57.7' @ -2.8°
 then -35.0° for 00

A107+00 from IBD to:

top CB -50' @ 35°
 IB edge rd +3.0' @ 120°
 OB " " +21.3' @ +0.5°
 then -39° for +40'

A116+00 Upper fill area (begin fill)

A116+20 From IB side of IBD to:

Top of CB +40° for -30°
 above +30°
 bottom IBD +2.5' @ -13.0°
 IB edge rd +5.5' @ +4.0°
 OB edge fill +55.7' @ -3.8°
 then
 "a point" +45.0' @ -3.0°
 then -30° for 00

A116+50 From IB edge of IBD to:

top of CB +40° for -60°
 above +30°
 bottom IBD +2.5' @ -32.0°
 IB edge rd +4.7' @ 0°
 IB edge berm +51.0' @ -1.5°
 B/S, 3/5 +55.5' @ 0°, +13.2' @ 0°
 1/4 +91.3' @ -2.4°
 OB edge fill +13.7' @ -2.6°
 then -22° for 00

Figure 4. Field notes used to draft the two fill areas shown on Plate II.

Normal Outsloping

This prescription is simply one of removing material from the outboard edge of the road and placing it on the inboard edge, so as to produce a slope of uniform gradient from an unspecified point on the cutbank outward. This is rapidly achieved using "Cut To Here" stakes, which are placed on the fill-slope every 100 ft. or so and define the lower edge of excavation for the heavy equipment operators. Two standard depths of outsloping cut are used, as measured from the outboard edge of the road. The first is a "medium outslope", while the second is a "heavy outslope". The "Cut To Here" stakes for these are placed on the fill slope at elevations 6 ft. and 10 ft., respectively, below the road edge. All such stakes are identical and consist only of white stakes with "Cut To Here" printed on them. The "medium outslope" prescription can be used on roads as narrow as 18 feet (produces a 1.5:1 slope), while a "heavy outslope" must be restricted to road sections over 30 feet in width, to avoid an oversteepened fill. For narrow road sections, a smaller cut depth can be specified.

"Cut To Here" stakes are the last prescription to be layed out on any road reach, in order to avoid overlapping with other prescription types. Surveying and notetaking are simplicity itself. For a given road reach, set the first stake within 30 feet upstation from the beginning. Note the station number, then find the stake's location by setting the Jacob's staff on the outboard edge of the road and shooting a level line from the top of it to a stadia rod down the fillslope. Have the rodman move up or downslope to achieve the desired reading (113 ft. for medium, and 153 ft. for heavy). Set and flag the stake and record the number of feet of cut beside the station number, then proceed to the next location. Space the stakes from 70 to 100 feet apart. List the information in the plan sheet (as shown in the upper left corner of Plate III).

In practice, the operator cuts down to the stake, piling the fill up on the cutbank until a uniform slope is achieved. The final slope automatically adjust itself to the roadwidth, expansion ratio, and depth of cut. The 6-foot cut used in the medium outsloping was derived by going through all the road outsloping cross sections (Y-2 Contract) and measuring the total cut relative to the outboard edge of the road, then obtaining a mean value. The 10-foot cut value was derived trigonometrically as the greatest cut practical on a wide haul road if endhauling is to be avoided. These values were then fit to existing road cross sections, and the results looked just as good as those produced by the old, time consuming method requiring that each cross section be fully surveyed and drafted.

For use in a contract, an addition (RP) stake should be set further down the fillslope, using the same method and a consistent stadia rod reading throughout. A typical plan sheet prescription would then read:

"Cut To Here" A110 + 40 : C60 (RP=200 Stadia).

Thus, medium outsloping is to be done at station A110 + 40 and the RP stake is placed downslope so as to yield a 200 ft. rod reading from the "Cut To Here" stake (level shot from top of Jacob's staff). This helps to check a contractor's work quickly or to reset a cut-to-here stake if required. For simple equipment rental work, the RP is not necessary. All RP stakes are simply red stakes, with "RP" and the station number printed on them.

Total Outslope

The total outslope prescription is designed to permit outsloping to continue on through a short stretch of road where fill cannot be placed against the cutbank (usually due to springs low on the cutbank). The cut is made across the "total" road, beginning at the inboard ditch (see Sta. A115 + 00, Plate II) and all material is moved to an adjacent surveyed fill site either up or down-station. The fill site will usually have some cut as well, but it is smaller than the cut used in normal outsloping, leaving enough room for the fill (typical section shown at Sta. A107 + 00, Plate II). This is done as described in the section on fill sites.

In surveying, note down the beginning and ending station of the total outslope reach, and place stakes reading "begin total o.s." and "end total o.s." on the cutbank at the lower and upper station numbers, respectively. Figure 5 shows the field notes for the sample total-outslope road reach between station A114 + 00 → A116 + 00. This 200 ft. long section required only a single cross section, since the road was of uniform shape throughout the reach. The cross section is surveyed and drafted in the same way as described in the fill site section.

Once the cross section(s) is drawn, draft in the desired cut line beginning at the inboard ditch, using a slope from as steep as 4:1, to as shallow as 9:1. Planimeter the cut area and note it on the plan sheet as shown, then figure the volume by double-end-area and print that too. If only one cross section is used (as with the example), then simply project the cross sectional cut area through the entire total outslope reach to obtain the volume (in the sample: $80 \text{ ft.}^2 \times 200 \text{ ft. long} / 27 = 593 \text{ yd}^3$). Specify the mean endhaul distance on the plan (distance from the middle of the total outslope reach to the middle of the fill site). Fill in the slope stake information. Make up stakes and their field placement notes for the total outslope and fill reaches, as shown in Figure 6 (for the sample reach).

Cross Road Drains (CRD)

Two reaches of cross-road drains are shown on Plate II. Only the Station number, plus the length and grade of ditch are required in field notes or on the plan sheet. Merely set one rod in the I.B.D. where the XRD is to start and the other rod at its intended lower end. Stretch a tape and then shoot the vertical angle (r.t.r.), recording both numbers beside the station number of the upper end. Mark both ends with flags upon which is written the Station Number of the upper end. Merely copy the field survey notes onto the plan sheet in the usual order (bottom to top of page).

General Plan Sheet Layout (see Plate II)

All boundary points between two major prescription types should have a stake on the cutbank noting the change. For example, at Station A108 + 20 is a stake reading "End Outsloping, Begin XRD". All such critical change points are noted in the field notes and are boxed in on the plans as at the following stations on the sample plan sheet: A108 + 20; A110 + 30; A114 + 00; A116 + 00; A116 + 80; and A133 + 00. This policy avoids leaving any short road sections unprescribed and makes the plan sheet's organization stand out crisply at a glance. Except for R/X crossings the plan sheets are

~~A114+50 = END DS = BEGIN X RD~~

A114+00 = BEGIN TOTAL DS to A116+00

- * Use upper fill area (as of 116+00)
(this fill area also needed for deep ditch 118+00)
- * Use X-sec 113+40 thru 114+00 then
use A115+00 for total DS

A115+00 From IBD to:

top of C.B.	+40° for -30'
above ↑	+25°
1/8 edge rd.	+3.2' @ +16.0°
1/8 edge of berm	+18.6' @ +2.0°
top of berm	+21.0' @ +14.5°
then	-38° for +30'

Figure 5. Field survey notes for sample Total Outslope reach in Plate II.

Sample Slope Stake Installation Notes		
Sta. #	Location	SS info
A115+00	in IED	SS E48 5:1 302
	r.t.g. from outbd. edge of road = +14.5' @ -35.5°	"cut to here"
A116+20	r.t.g. from IED = -17' @ +22.9°	SS F152 5:1 822
	r.t.g. from outbd. road edge = +24.5'	match SP nail to Hwy
	r.t.g. from outbd. road edge = +10.5'	"cut to here"
A116+50	r.t.g. from IED = -40.2' @ +33.7°	SS F310 4:1 1302

Figure 6. Notes for setting grade stakes at the sample Total-Outslope road reach and its upstation fill site (as derived by drafting machine from Plate II).

drafted and read from the bottom to the top of the page on the left side first, then up the right side. Plate III illustrates an optional sequence, with the page turned sideways to accomodate some unusually wide cross sections. Draw all road cross sections as they look from their downstation side, giving a pseudo-perspective view of successive cross sections as the eye sweeps up the page (following the sequence of completion). In the sample, the fillslope is on the left when looking upstation (in the direction of increasingly higher station numbers), so all cross sections also have the fillslope on the left side. Your road section may have the fillslope on the right, when facing upstation. In this case draft in the fillslope on the right side.

The End-Product

Every bit of work between Stations A105 + 80 and A133 + 00 (over 1/2 mile of road) is recorded on a single plan sheet (Plate II) in the order it will be done. All this work is available at a glance and all points of interest are identified simply by Station Number, rather than by protracted verbiage. To present all the work for an entire rehabilitation site, a set of blue line plan sheets is sequenced numerically by station number, then stapled all along the narrow left page margin so that it opens like a comic book, permitting the unneeded sheets to be folded behind and out of the way. A set of plan sheets set up in this manner will last an entire field season. Make all notes about date, time, equipment, completion date, problems, etc. right on the plan sheets so that the work time and sequence at each site is automatically totaled and collated. Notes taken in this fashion are also more easily understood by others (Technical Services, etc.) than the usual terse comments scattered throughout a field notebook. All grade checks are on the plan sheets themselves and are very simple to use. Odd or problem crossings may be quickly resurveyed using the original survey grid and redrawn right over the original plan sheets for a useful comparison of before, planned-after, and actual-after. Having this type of data for most sites would greatly assist Technical Services in monitoring our work. The only prescription type requiring significant time input is the R/X-type stream crossing, but the high cost of these large crossings easily justifies the effort required to yield positive grade control. The XRD, DD, Fill Site, Total Outslope, and "Cut To Here" outslope prescriptions are now very rapid to prepare, yet they provide excellent control and documentation. The plan sheet set plus heavy equipment notes will save a lot of time in the report preparation phase, making up for much of the time spent in preparation. In short, the bound plan sheets are a powerful, flexible tool which ties together all facets of a rehabilitation project.

To extend the flexibility of the Deep Dish format, several types of cross sections could be drafted up capable of handling larger flows (Series I, Series II, etc.). Series I would be the one shown in Plate I (for T25 flows of up to 20 cfs), while the Series II template could handle 20 to 30 cfs, etc. This would make the R/X format necessary only in the most extreme cases.



Unit: 82-3 PP#7B Pre H.E.



Unit: 82-3 PP#7B Post H.E.



Unit: 82-3 PP#7B 8/14/84



Unit: 82-3 PP#9A 7/8/82 E.P.W.



Unit: 82-3 PP#9A 7/21/82



Unit: 82-3 PP#9A 8/14/84



Unit: 82-3 PP#10A 9/21/82



Unit: 82-3 PP#11B 7/8/82 E.P.W.



Unit: 82-3 PP#11B 9/21/82 E.P.W.



Unit: 82-3 PP#11B 8/14/84



Unit: 82-3 Ref. 1-A 7/8/82 PP#12B RXA 9B Y-Line E.P.W.



Unit: 82-3 Ref. 1-B 9/21/82 PP#12B RXA 9B Y-Line



Unit: 82-3 Ref. 2-A 7/8/82 PP#13A E.P.W.



Unit: 82-3 Ref. 2-B 9/21/82 PP#13A RXA 9B Y-Line E.P.W.



Unit: 82-3 Ref. 2-C 8/15/84 PP#13A D.A.S.