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3. RECIPIENT'S CATALOG No.

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Control of Slope Erosion Using Fiberglass Roving with Vegetation

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7. AUTHOR(S)
M.E. Nolan, R.J. Spring, R.B. Howell

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Sacramento, California 95819

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15. SUPPLEMENTARY NOTES
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This study demonstrated the us of fiberglass roving with vegetation for erosion control of severely eroding slopes. A total of three sites were treated. Route 50, Camino and Route 41, Creston were treated in November 1977, and Route 101, Asti was treated in January 1978. The sites were selected on the basis of varying soil types and different climatological conditions. Four additional sites that were previously treated under other projects were also evaluated. The test sites were monitored with photographs, sediment troughs to determine erosion rates, field observation for vegetation emergence, and precipitation measurements during a period from the fall of 1977 to the summer of 1978. Aesthetic evaluations were performed at the Camino site on Route 50 by a review team composed of representatives from Caltrans, Department of Conservation, Division of Mines and Geology and FHWA.

The fiberglass roving with vegetation was effective in reducing erosion at all the sites. Grasses, seeded prior to treatment, emerged through the fiberglass mat with little difficulty.

The installed cost of the treatment is high (approximately $4,500 per acre) and should only be used in problem areas and special cases.

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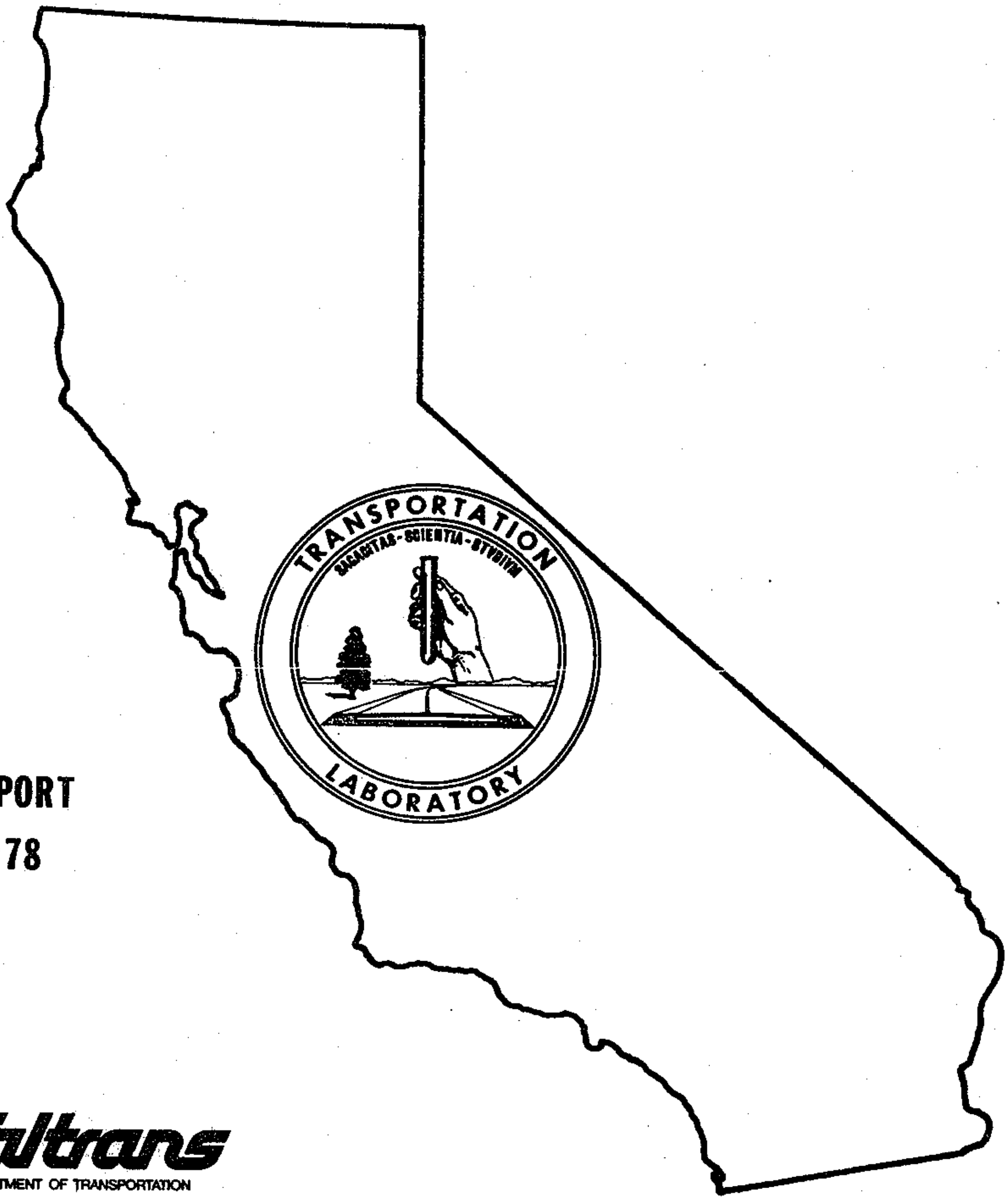
78-04.pdf

Control Of Slope Erosion Using Fiberglass Roving With Vegetation



FINAL REPORT

OCT. 1978

Caltrans

CALIFORNIA DEPARTMENT OF TRANSPORTATION

TECHNICAL REPORT STANDARD TITLE PAGE

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STATE OF CALIFORNIA
DEPARTMENT OF TRANSPORTATION
DIVISION OF CONSTRUCTION
OFFICE OF TRANSPORTATION LABORATORY

November 1978

FHWA No. F-5-18
TL No. 637293

Mr. C. E. Forbes
Chief Engineer

Dear Sir:

I have approved and now submit for your information this final research project report titled:

CONTROL OF SLOPE EROSION USING
FIBERGLASS ROVING WITH VEGETATION

Study made by	Enviro-Chemical Branch
Under the Supervision of	Earl C. Shirley, P.E.
Principal Investigator	Richard B. Howell, P.E.
Co-Investigator	Richard J. Spring, P.E.
Report Prepared by	Martin E. Nolan Richard J. Spring, P.E. Richard B. Howell, P.E.

Very truly yours,

NEAL ANDERSEN
Chief, Office of Transportation Laboratory

Attachment

RJS:lb

ACKNOWLEDGEMENTS

This study was conducted by the Transportation Laboratory of the Department of Transportation in cooperation with the Maintenance Branches of Districts 03, 04, and 05. Special recognition is given to Superintendents D. R. Frohreich District 03, D. F. Kiser District 04 and B. M. Moe of District 05 for their cooperation in conjunction with this project. Also, the work of the maintenance Supervisors John Krek (District 03), John Fields (District 04), and Tony Silva (District 05) is greatly appreciated.

The assistance of Del Hollinger, District 05 Assistant Materials Engineer during the application and monitoring of the Creston test site is appreciated.

The services of Raimond Clary and Robert Slayback of the U.S. Soil Conservation Service, Lockeford Plant Materials Center, in selecting and providing the seed used in planting the vegetation and for use of their hydromulcher at the test slopes, is greatly appreciated.

In addition, special thanks is also given to the following individuals for their cooperation in serving on the evaluation team for the Camino test site:

Richard Pryor, Office of Landscape Architecture (Caltrans)
Roy Chalmers, Office of Planning and Design (Caltrans)
Robert Skidmore, District 03 Environmental (Caltrans)
Charles Jackson, Office of Highway Construction (Caltrans)
Barry Brown, State Department of Conservation
Perry Amimoto, State Division of Mines and Geology
William Spearman, Federal Highway Administration

Special recognition is also given to Patrick Monahan of the Transportation Laboratory for his assistance during the application of the treatments and to James Racin of the Transportation Laboratory for his assistance with the data analysis.

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CONVERSION FACTORS

English to Metric System of Measurement

Quantity	English unit	Multiply by	To get metric equivalent
Length	inches (in)	25.4	millimetres (mm)
		.0254	metres (m)
	feet (ft)	.3048	metres (m)
	miles (mi)	1.6093	kilometres (km)
Area	square inches (in^2)	6.4516×10^{-4}	square metres (m^2)
	square feet (ft^2)	.092903	square metres (m^2)
	acres	4046.9	square metres (m^2)
		.40469	hectares (ha)
		.40469	square hectometres (hm^2)
		.0040469	square kilometres (km^2)
	square miles (mi^2)	2.590	square kilometres (km^2)
Volume	gallons (gal)	3.7854	litres (l)
		.0037854	cubic metres (m^3)
	million gallons (10^6 gal)	3785.4	cubic metres (m^3)
	cubic feet (ft^3)	.028317	cubic metres (m^3)
	cubic yards (yd^3)	.76456	cubic metres (m^3)
	acre-feet (ac-ft)	1233.5	cubic metres (m^3)
		.0012335	cubic hectometres (hm^3)
		1.233×10^{-6}	cubic kilometres (km^3)
Volume/Time (Flow)	cubic feet per second (ft^3/s)	28.317	litres per second (l/s)
		.028317	cubic metres per second (m^3/s)
	gallons per minute (gal/min)	.06309	litres per second (l/s)
		6.309×10^{-5}	cubic metres per second (m^3/s)
	million gallons per day (mgd)	.043813	cubic metres per second (m^3/s)
Mass	pounds (lb)	.45359	kilograms (kg)
	tons (short, 2,000 lb)	.90718	tonne (t)
		907.18	kilograms (kg)
Power	horsepower (hp)	0.7460	kilowatts (kW)
Pressure	pounds per square inch (psi)	6894.8	pascal (Pa)
Temperature	Degrees Fahrenheit (°F)	$\frac{tF - 32}{1.8} = tC$	Degrees Celsius (°C)

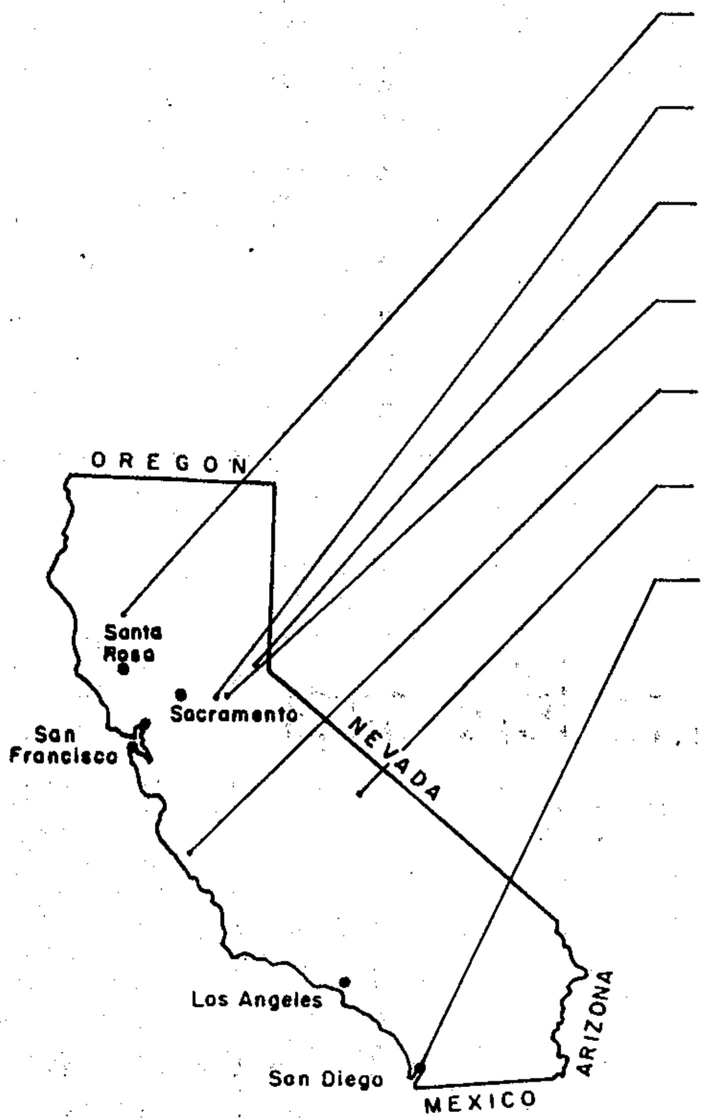
INTRODUCTION

The Transportation Laboratory (TransLab) of the California Department of Transportation (Caltrans) in cooperation with the Federal Highway Administration (FHWA) previously demonstrated the use of fiberglass roving with vegetation in treating ditch erosion problems at Ponderosa Road Interchange on U.S. Highway 50, near Placerville, California, during the 1973-74 winter season (1), and also at three separate ditch locations during the winter of 1975-76 (2). One application at the Ponderosa Road site included treatment of a shallow slope area within the northeast quadrant. During the winter seasons following these applications, erosion of the drainage ditches was controlled.

Because of the success of this treatment in ditches, TransLab began experiments on severely eroding road slopes. At the request of District 03, TransLab treated a highway cut slope in the Tahoe Basin on Route 89 (Newhall Cut) with fiberglass roving and vegetation in 1975. Erosion has stopped and the slope is stabilized with a good grass cover. Other sites receiving treatment include Route I-805 in San Diego and Route 395, Upper Sherwin Grade, in District 09.

The successful treatments at these sites led to the initiation of this study with FHWA to test the material on a slope in the central valley and central and north coastal areas. Figure 1 shows the locations of slopes that have been successfully treated.

This report presents the results of the field applications, monitoring, evaluation of the effectiveness of fiberglass roving with vegetation for erosion control of severely eroding



TEST SITES

1. ASTI
04-SON-101, P.M. 47.5

2. PONDEROSA ROAD
03-ED-50, P.M. 8.4

3. NEWHALL CUT
03-ED-89, P.M. 22.8

4. CAMINO
03-ED-50, P.M. 23.8

5. CRESTON
05-SLO-41, P.M. 23.4

6. UPPER SHERWIN GRADE
09-MONO-395, P.M. 9.0

7. SAN DIEGO
11-SD-805, P.M. 12.3
(removed July, 1977)

LOCATION MAP

FIBERGLASS ROVING
FOR EROSION CONTROL
OF SLOPES

CALIFORNIA DEPARTMENT OF TRANSPORTATION
TRANSPORTATION LABORATORY
ENVIRO-CHEMICAL BRANCH

Figure 1

slopes, and aesthetic evaluation of alternative treatments at the Camino site for the three treatments applied during the period from Fall 1977 to Spring 1978 and the previously treated slopes.

CONCLUSIONS AND RECOMMENDATIONS

The following conclusions were derived as a result of this research:

1. Fiberglass roving with vegetation was effective in controlling slope erosion at the three test sites installed during 1977-78 as well as at the four sites which were installed prior to this project.

2. Fiberglass roving treatment costs are high, approximately $4,500 per acre, compared to normally used Erosion Control Type D which runs around $600 per acre.

3. The installation of fiberglass roving with vegetation is a relatively simple procedure to use and presented no application problems. The installation on Route 395 in District 09 was made during construction by the contractor. Maintenance crews installed the treatments made during this study.

4. The equipment items needed for installation are all standard maintenance items, except for the nozzle that is used to apply fiberglass and the hydromulcher. The nozzle can be purchased for an estimated cost of $150 or TransLab has a nozzle that can be used by the Districts for non-contract work.

5. Aesthetically, the evaluation team found that fiberglass roving tacked with asphaltic emulsion was more pleasing than similar sections which were tacked with organic soil binders and wood fiber.

6. With the exception of the Creston site, within 6 months following application, vegetative growth, consisting mainly of Palestine orchardgrass, was sufficient to hide the fiberglass roving.

7. Woody plant material can be inserted through the fiberglass roving mat. Walking on the mat should be minimized so as not to damage the fiberglass mat while installing the plants.

8. For the existing eroding slope at San Diego, filling rills and gullies with top soil prior to application with fiberglass roving was more successful in stopping erosion than just applying the treatment over the existing eroded slope.

9. There appears to be no difference between asphaltic emulsion tacking agents SS-1, SS-1H or RS-1 in holding the fiberglass roving in place.

The following recommendations are hereby made as a result of the research:

1. Caltrans designers, in consultation with the Office of Landscape Architecture, should consider the use of fiberglass roving with vegetation in the design of slope treatments for severely eroding slopes. A specification guideline is provided in the Appendix.

2. It is recommended that a document, similar to Hydraulic Engineering Circular 15 produced by FHWA for ditches, be prepared for the use of fiberglass roving on slopes.

3. Fiberglass roving with vegetation should only be used on severely eroding slopes where more conventional means of erosion control treatments are not effective.

4. Slope angles should not exceed 1:1. Difficulty in holding material on the slope is experienced where gravitational forces are a major factor in downslope soil transport as opposed to forces exerted by surface water flow.

5. Weathering rock, such as decomposed granite, should be avoided. Surfaces that appear stable but weather or soften in time may undermine the stability of the mat.

6. Existing rilled or gullied slopes must be dressed or re-worked to allow contact between the roving and the soil. Loose rock must be removed by scaling. All brush and vegetation along with other matter protruding from the slope surface should be removed as part of the slope dressing operation before applying the fiberglass roving.

7. If partial treatment of a portion of a slope is planned, the upper and lower ends of the mat must be placed in cut-off trenches (6-8" deep) and backfilled.

Vegetation, such as tumbleweed, may blow under the mat and roll it up if the ends are not secured. From field experience, the sides do not appear to have this problem and, consequently, do not need to be secured unless a field investigation determines that it is necessary.

8. Treatments should be applied during the period most conducive to maximum seed germination and plant growth. Selection of seed mixtures and fertilizer should be done in cooperation with the Office of Landscape Architecture.

9. Broad leaf vegetation should not be used in seed mixtures for fiberglass roving installations. As found in previous research, the mat will be lifted off the ground surface as the broad-leaf vegetation emerges.

10. The application of the fiberglass roving should not be done during windy periods which could result in the fiberglass being blown off the treated area, or during periods of inclement weather.

11. Fiberglass roving should be applied at a rate sufficient to just cover the soil with a thin layer of roving. This usually amounts to an application rate of between 0.2 and 0.35 pounds per square yard. Thicker applications may be required for areas subjected to high surface water flows.

12. Asphalt emulsion tack coat should be applied at a rate just sufficient to cover the white of the roving without puddling of the emulsion. Either SS-1, SS-1H, or RS-1 can be used.

13. Fiberglass roving mats should not be used in the vicinity of hoofed animal passage ways or anticipated grazing areas. The hoofs punch holes in the mat and may become entangled in the strands.

14. The edge of the fiberglass roving mat should not encroach onto the edge of the pavement or extend to the base of a cut

slope if a mechanical blade is used to maintain sediment or drainages at the toe of slope. Although driving on the mat does not appear to have an adverse effect, there is a possibility of catching strands on the undercarriage or other mechanical parts and tearing the mat.

15. During the application of fiberglass roving, minute particles of the fiberglass were observed floating in the air. Although there has been no reports of any ill effects from the use of fiberglass roving, it is recommended that a respirator be worn by the operator during the application of the fiberglass roving. The National Institute of Occupational Safety and Health (NIOSH) has not determined at this time if a health hazard exists when working with fiberglass.

16. Fiberglass roving is nonbiodegradable, however, there appears to be no problem with the fiberglass fibers washing away. It is recommended that FHWA perform tests to determine any potential environmental problem associated with this.

IMPLEMENTATION

This report will be distributed to the Caltrans Headquarters Offices and the 11 Transportation Districts.

Implementation of this treatment will be handled through the Office of Landscape Architecture, Office of Highway Design and Office of Maintenance. The Enviro-Chemical Branch of the Transportation Laboratory will be available to provide technical assistance. A 15 minute slide/tape presentation has been prepared to show the process involved in applying fiberglass roving and will be available for showing to

District and Headquarters personnel. The slide presentation can also be shown to personnel who will be applying fiberglass roving for the first time. A movie produced by TransLab under previous research entitled "Control of Ditch Erosion Using Fiberglass Roving" is also available for showing (4). This movie depicts treatment of drainage ditches with fiberglass roving with vegetation and similar application principles pertain to the treatment of slopes. Two reports on application to ditches were also published and distributed to the districts (1 and 2) as was a report on the slope treatment at I-805 in San Diego (3).

A tentative specification developed by FHWA, the Transportation Laboratory and the Office of Office Engineer is included in the Appendix.

DISCUSSION

Fiberglass roving is a material formed from continuous fibers drawn from molten glass. These fibers are gathered together into strands to form a single ribbon. This slightly twisted ribbon is known as roving. It is commonly produced in a coiled package to be used in a variety of products and is commercially available (Plate 1).

The success of fiberglass roving and vegetative cover in reducing slope erosion appears to be related to a combination of factors. Raindrop impact is one of the initial major causes of erosion on bare slopes. For soils that have a low clay content, raindrop impact can precipitate rapid erosion. The fiberglass roving mat provides a protective cover on the slope face that is strong and absorbs much of the imparted raindrop energy.

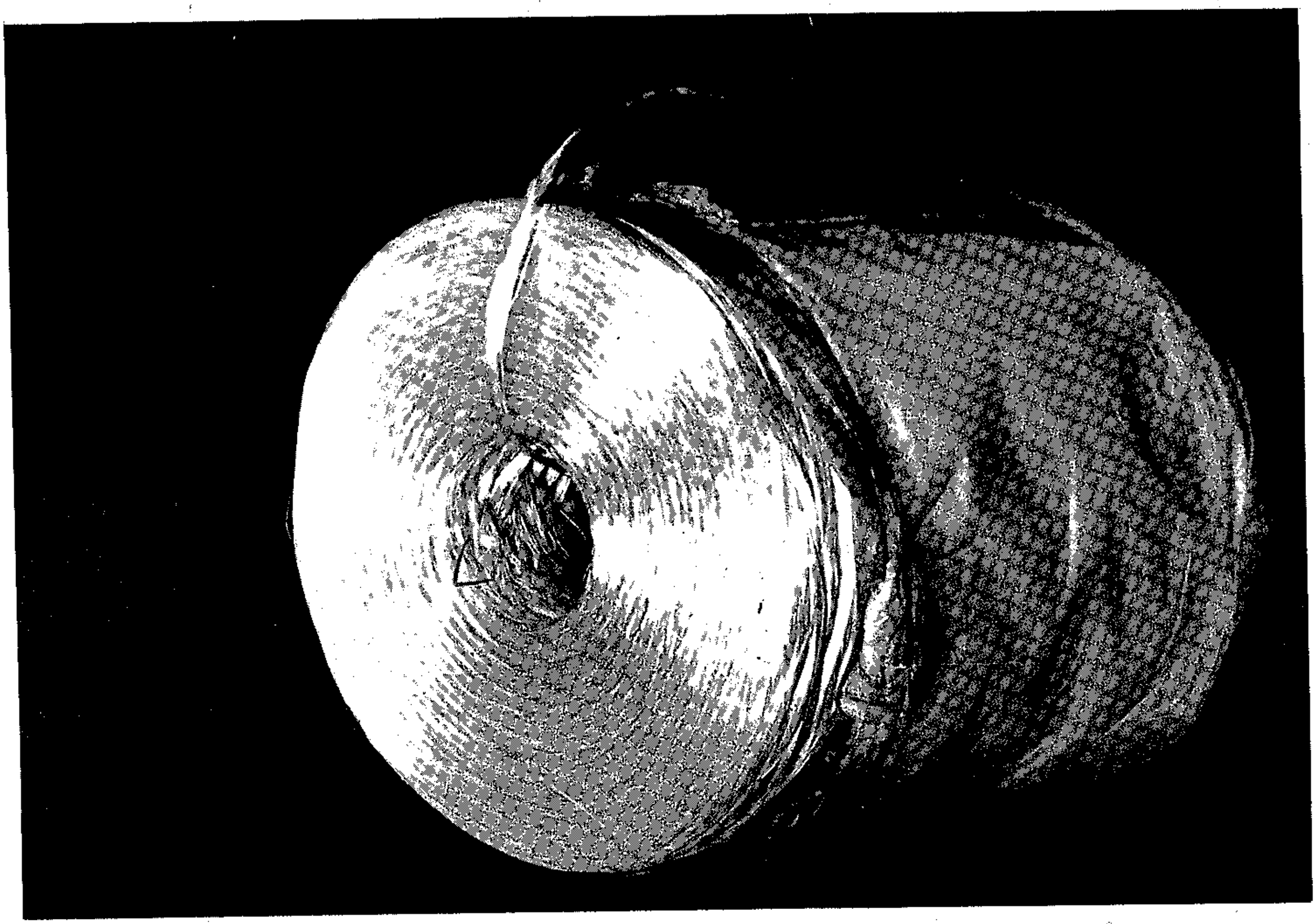


Plate 1. Fiberglass roving coil package.

Surface flows exert a tractive force (shear stress) over the slope face which tends to transport soil particles. Because the fiberglass roving is flexible and thus adheres to the configuration of the slope face, the mat tends to provide a resistance to the flowing water. In the technical literature, this is referred to as increasing the critical tractive force above which erosion would occur (5). The mat also tends to increase surface roughness which leads to slower runoff velocities. Thus, the seed is held in place long enough to allow germination.

As the vegetation emerges, additional protective cover of the soil is provided which further reduces the possibility of erosion due to raindrop impact. The vegetative cover, in combination with the mat, increases the critical tractive force even more. The result is a good slope protection against erosion.

Before the fiberglass roving is applied to an existing eroding slope, the slope should be redressed to a uniform condition. If any vegetation exists on the slope, it is removed during the slope dressing. A layer of topsoil may be spread over the slope surface to fill in rills and gullies.

During the slope dressing stage, a 6-8 in. deep anchor trench is excavated along the top of slope, above the break, in order to anchor the fiberglass roving and prevent undermining of the mat by surface flows (Plate 2).

Plate 2. Construction of anchor trench.

The slope is first hydromulched with a mixture of water, woodfiber, grass seed and fertilizer, and then covered with a layer of fiberglass roving. Although it is not necessary to hydromulch the slope, it provides additional support to assist the vegetative establishment. The fiberglass is applied using a special nozzle connected to an air compressor (Plate 3). The air propels the fiberglass ribbon through the nozzle and at the same time separates the strands into individual fibers to form a random mat of continuous fibers. The inplace fiberglass then has the appearance of "ANGELS HAIR". Finally a tack coat of asphalt emulsion (SS-1 or equivalent) is uniformly sprayed over the roving to bind the fibers together and to adhere the fiberglass mat to the soil. Figure 2 shows a typical cross-section of treatment on a slope.

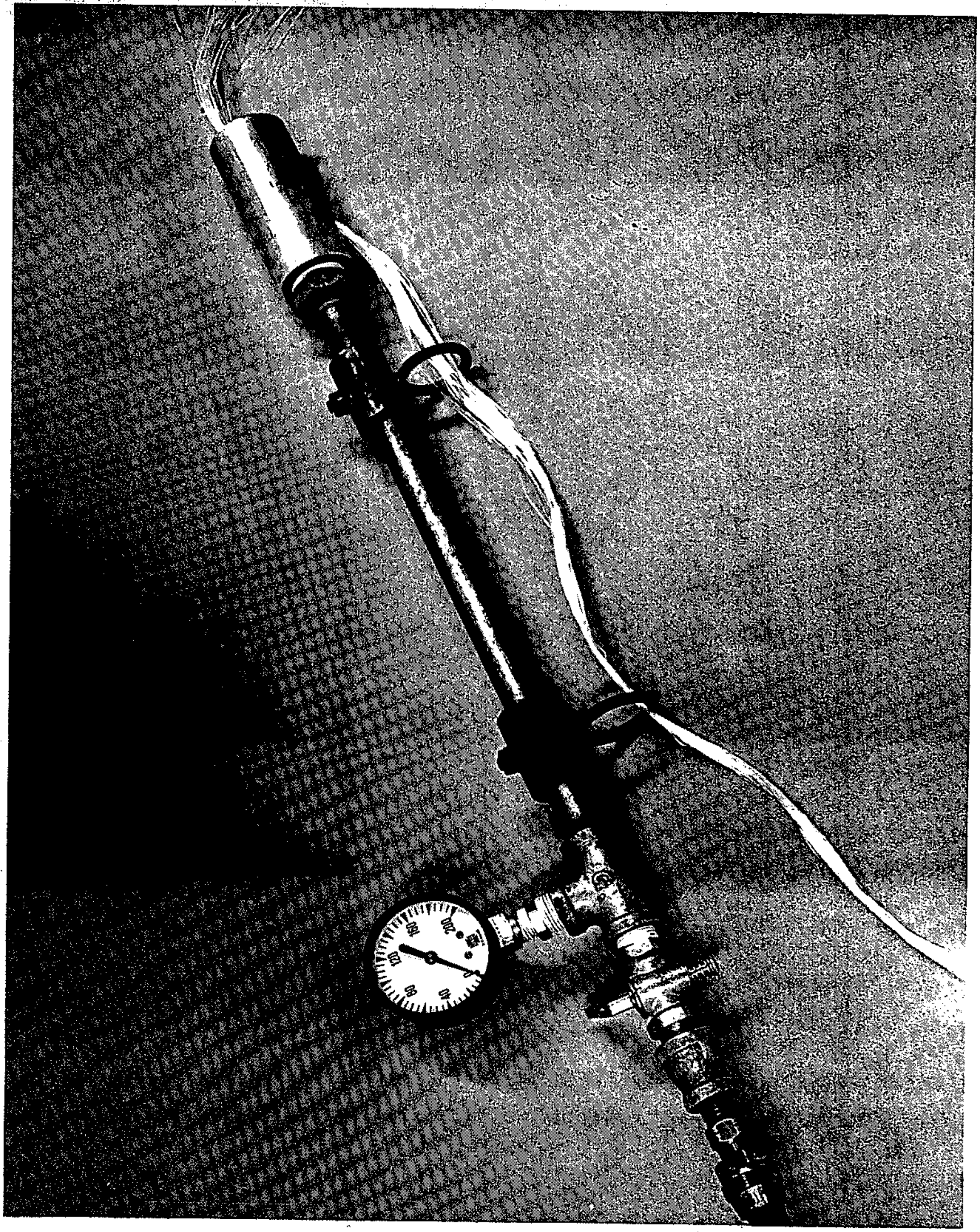


Plate 3. Nozzle for application of fiberglass roving.

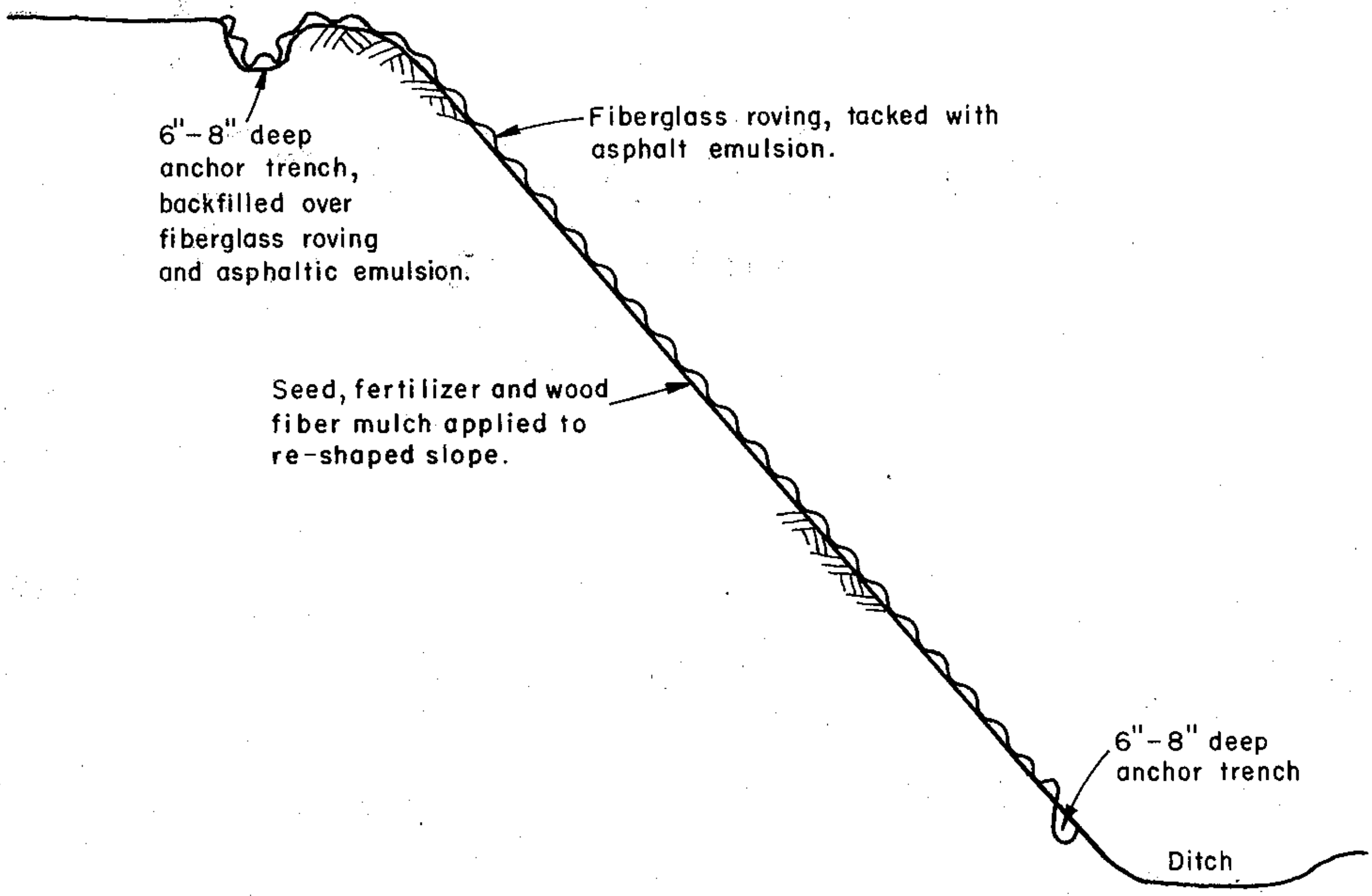
Site Locations

A total of seven locations were monitored throughout the State. The sites represented a variety of climatological conditions and soil types. Fiberglass roving was installed at three of these locations under this research project: Route 50 in District 03 near Camino, Route 101 in District 04 near Asti, and Route 41 in District 05 near Creston. The other four locations treated previously are located on Route 89 in District 03 in the Lake Tahoe Basin, Route 395 in District 09 at Upper Sherwin Grade, I-805 in District 11 in San Diego and Route 50 near Placerville (see Figure 1).

The three sites that were treated and monitored in this study are as follows:

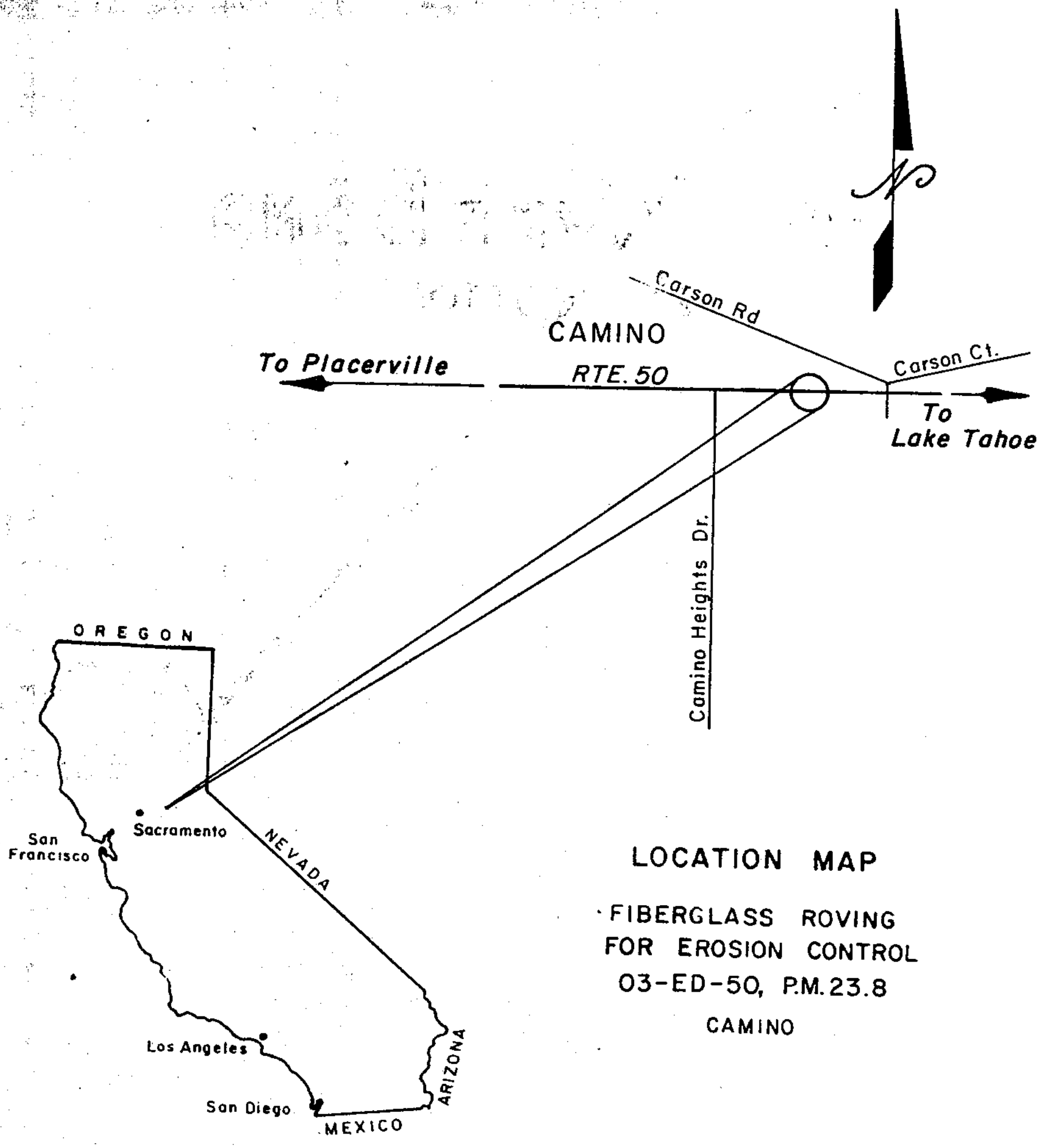
Camino, Route 50

The first slope treated under this research project is located on Route 50 near Camino in El Dorado County (03-ED-50, PM 23.8) about 6 miles east of Placerville. The soil at this location consists of a red silty clay. The slope faces south and was constructed in 1963 on a 2:1 angle. The site is situated about 3,000 feet above mean sea level (MSL) in the foothills of the Sierra Nevada Mountains (Figure 3). The climate is typically mediterrean with an average annual rainfall of nearly 45 inches, with occurs mainly during the period from October to May. Sheet erosion on this slope is severe as evidenced by the removal of soil from around the concrete at the base of some fence posts located near the upper portion of the slope (Plate 4).



TYPICAL CROSS SECTION OF
FIBERGLASS ROVING TREATMENT
ON SLOPE

Figure 2



CAMINO
To Placerville
RTE. 50
Carson Rd
Carson Ct.
To
Lake Tahoe
Camino Heights Dr.
OREGON
Sacramento
San
Francisco
NEVADA
Los Angeles
San Diego
MEXICO
ARIZONA
LOCATION MAP
FIBERGLASS ROVING
FOR EROSION CONTROL
03-ED-50, P.M. 23.8
CAMINO

Figure 3

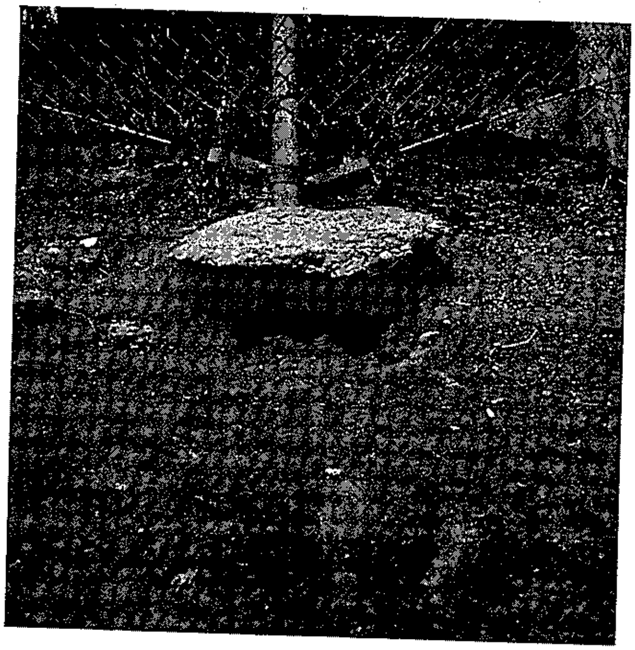


Plate 4. Erosion at base of fence post (Camino, Route 50).

Asti, Route 101

A second slope treated under this project is located on Route 101 near Asti in Sonoma County (04-Son-101, PM 47.5) about 31 miles north of Santa Rosa (Figure 4). The site is located in a small valley at an elevation of 360 feet above MSL. The soil is a brownish-red silty clay which contains some gravel. It faces to the west and was built in 1965 on a 2:1 angle. The climate is relatively mild with an average annual rainfall of about 40 inches. Sheet erosion from this slope was severe enough to prevent the natural establishment of vegetation (Plate 5).

Creston, Route 41

The third slope is located on Route 41 in San Luis Obispo County (05-SLO-41, PM 28.4) about 13 miles east of Atascadero near Creston (Figure 5). The slope is located in rolling hills and is at an elevation of about 1,000 feet above MSL. The soil is a light brown sandy silt and is highly erodible. It faces to the south and was built in 1962 on a 2:1 angle. The climate is typical of the central marine coastal zone with an average annual rainfall of 20 inches. Erosion at this site was very severe consisting of gulleys and rills (Plate 6).

The four sites that were monitored from previous treatments under different projects are as follows:

Newhall Cut, Route 89

Of the remaining four sites that were monitored in conjunction with this project, one was located in the Lake Tahoe Basin (Figure 6) on Route 89 called Newhall Cut (03-ED-89, PM 22.8). The cut slope is on the west side of Lake Tahoe, approximately

Plate 5. Natural slope at Asti, Route 101.

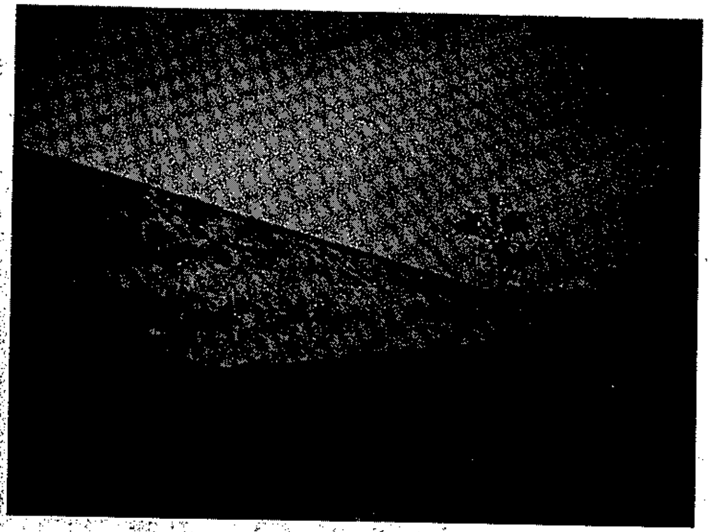


Plate 6. Rill and gully erosion of slope at Creston, Route 41.

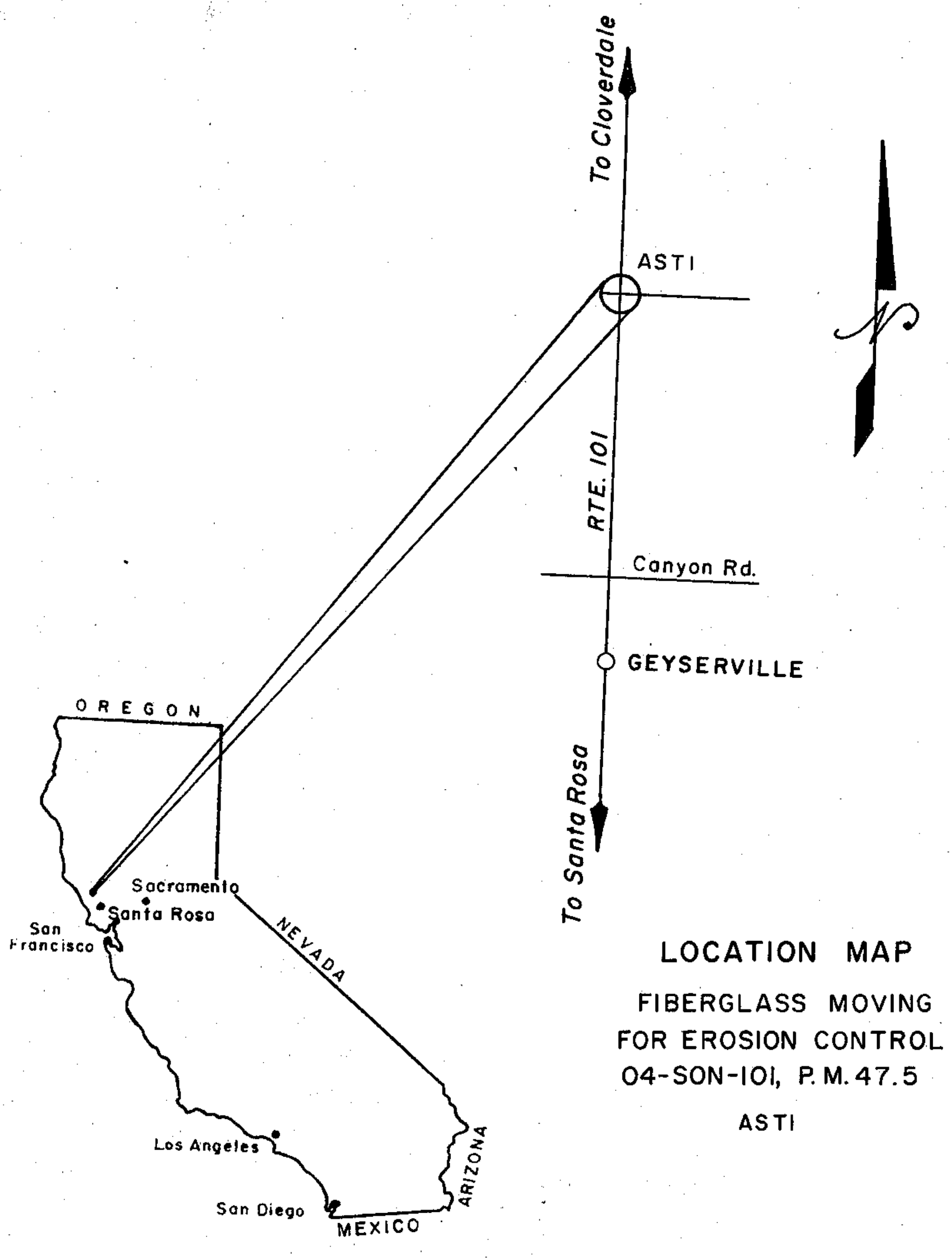
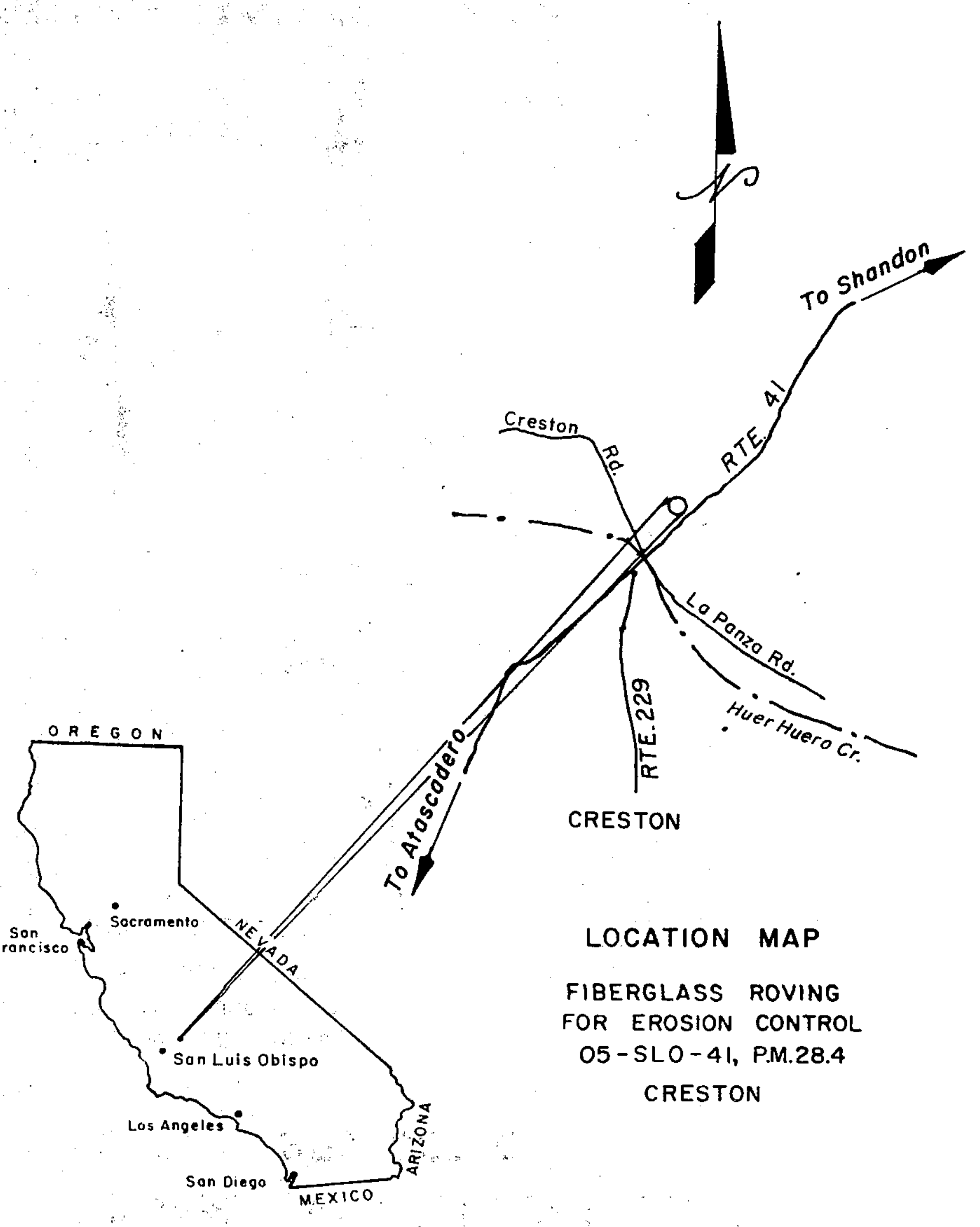

To Cloverdale
ASTI
RTE. 101
Canyon Rd.
GEYSERVILLE
To Santa Rosa
OREGON
Sacramento
Santa Rosa
San Francisco
NEVADA
Los Angeles
San Diego
MEXICO
ARIZONA
LOCATION MAP
FIBERGLASS MOVING
FOR EROSION CONTROL
04-SON-101, P.M. 47.5
ASTI

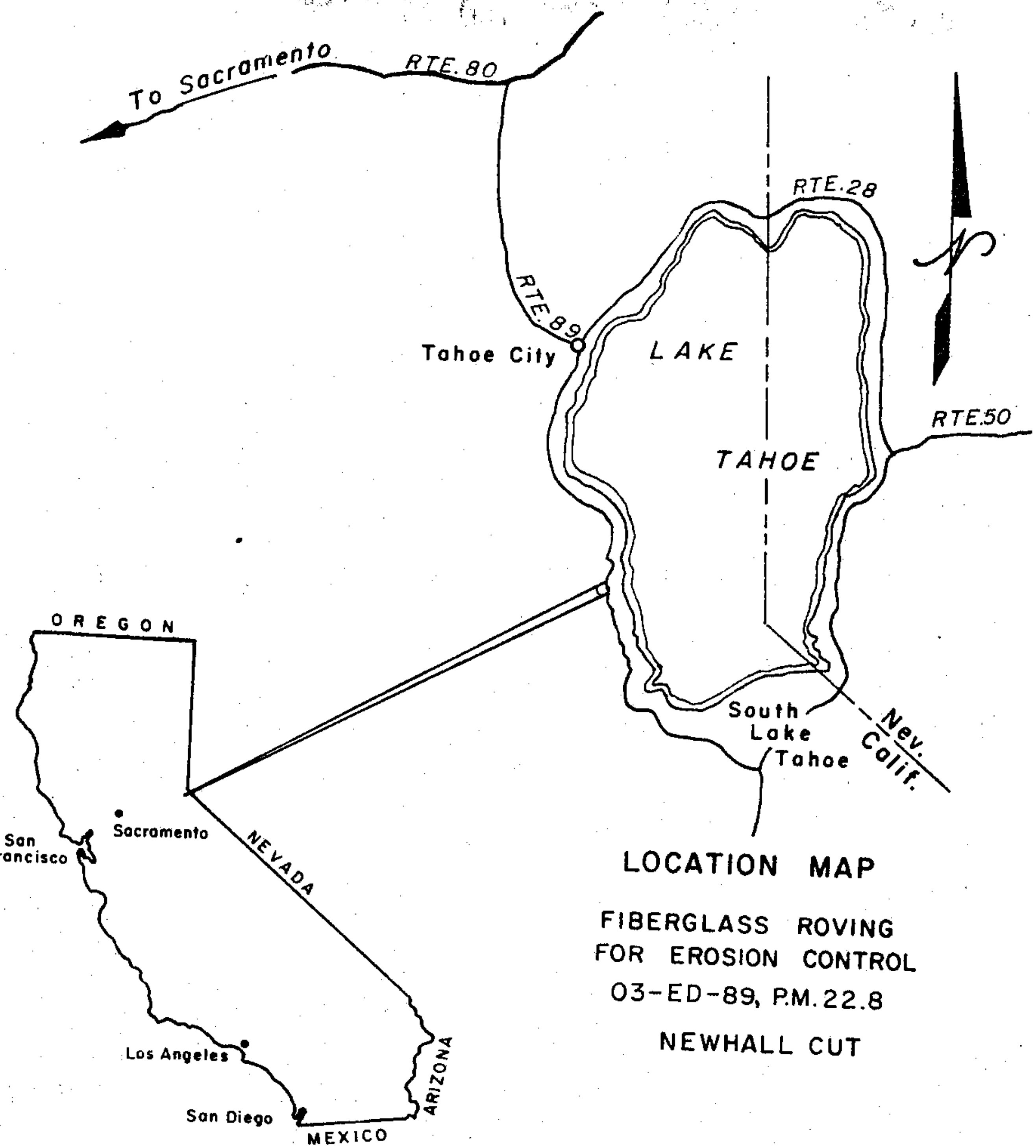
Figure 4



LOCATION MAP

FIBERGLASS ROVING
FOR EROSION CONTROL
05-SLO-41, P.M.28.4
CRESTON

Figure 5



To Sacramento
RTE. 80
RTE. 28
RTE. 89
Tahoe City
LAKE
TAHOE
RTE.50
South
Lake
Tahoe
Nev.
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OREGON
Sacramento
San
Francisco
NEVADA
Los Angeles
San Diego
MEXICO
ARIZONA
LOCATION MAP
FIBERGLASS ROVING
FOR EROSION CONTROL
03-ED-89, P.M. 22.8
NEWHALL CUT

Figure 6

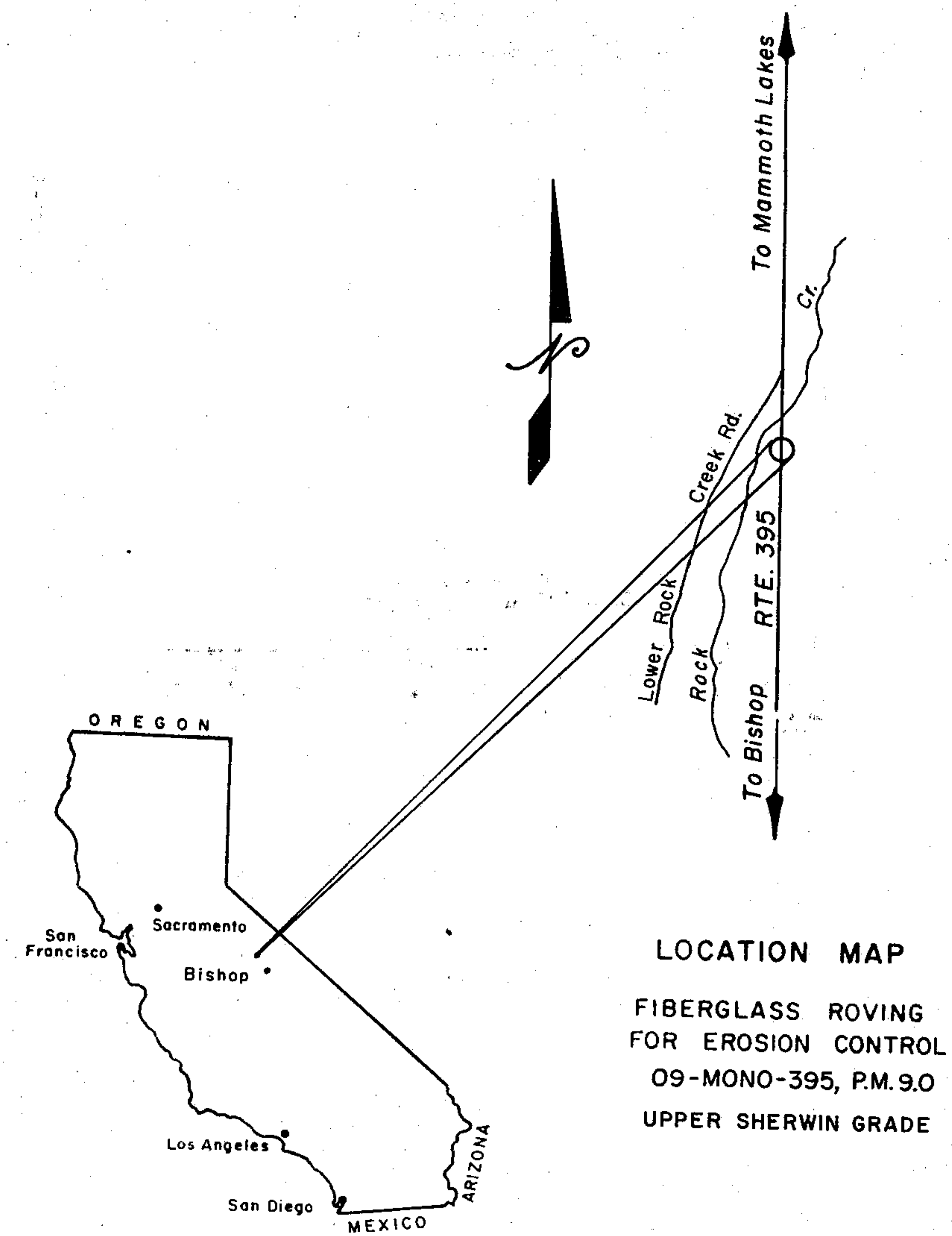
13 miles south of Tahoe City, at an elevation of 6,260 feet above MSL. The soil is a greyish tan decomposed granite with little or no clay, making it highly erodible. The slope, built in 1929, faces to the south and is on a 2:1 angle. The climate varies from below zero winters to mild summer temperatures. The growing season is relatively short, occurring between May and October. The annual average precipitation is 20 inches which falls mostly as snow during the winter months although intense summer thunder showers are not uncommon.

Upper Sherwin Grade, Route 395

A second site is located near the top of Sherwin Grade on Route 395 in Mono County about 22 miles north of Bishop (09-Mno-395, PM 9.0) (Figure 7). This fill slope is at an elevation of 7,000 feet above MSL. The soil is a volcanic tuff and is highly erodible. It faces to the west and was built as part of roadway construction in 1977 on a 1 1/2:1 angle. The climate is arid with a yearly average precipitation of about 10 inches which is typical of the high desert. Most of the precipitation is in the form of snow and falls during the winter months of December to February. Summers are very hot with temperatures approaching 100°F during mid-afternoon. The slope is located in the rain shadow of the Sierra Nevada mountains which rise to elevations of 12-13,000 feet to the west.

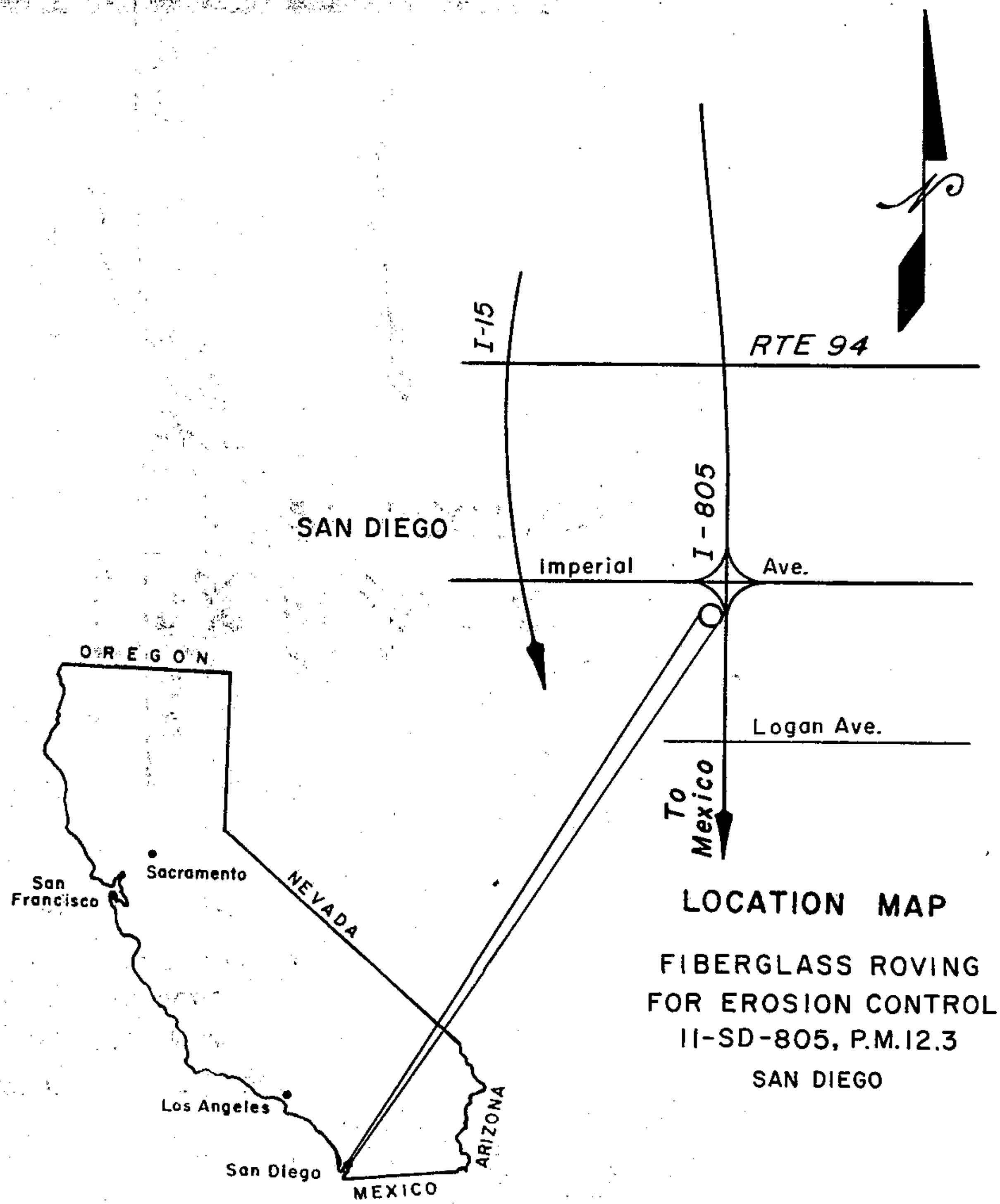
San Diego, Route I-805

The third project monitored is located on a cut slope in the city of San Diego on Interstate 805 (Figure 8), near the south bound on-ramp from Imperial Avenue (11-SD-805, PM 12.3). This



To Mammoth Lakes
Cr.
Creek Rd.
Lower Rock
Rock
RTE. 395
To Bishop
OREGON
Sacramento
San Francisco
Bishop
Los Angeles
San Diego
MEXICO
ARIZONA
LOCATION MAP
FIBERGLASS ROVING
FOR EROSION CONTROL
09-MONO-395, P.M. 9.0
UPPER SHERWIN GRADE

Figure 7



LOCATION MAP

FIBERGLASS ROVING
FOR EROSION CONTROL
11-SD-805, P.M.12.3
SAN DIEGO

Figure 8

200 feet above MSL. The soil is a marine deposited silty sand which is highly erodible. The slope faces east and was constructed on a 2:1 angle in 1975. The climate is typical south coastal marine with mild winters and warm summers. Average annual rainfall is about 10 inches which occurs mostly between September and April.

Ponderosa Road, Route 50

The first California test site was an 11% slope treated on October 19, 1973 in the northeast quadrant of the interchange, built in 1969, on Route 50 at Ponderosa Road (03-ED-50, PM 8.4) approximately 30 miles east of Sacramento (Figure 9). The soil is comprised of silty clays. The underlying geologic formation is Jurassic-Triassic metavolcanic rock. The climate is typically mediterranean with an annual rainfall of 30 inches which occurs mostly from October to May. The summers are very hot and dry with average maximum temperatures approaching 100°F during mid-afternoon.

Slope Preparation

Preparatory work at the three test sites treated under this project (Camino, Asti and Creston) consisted of reshaping the slope to a uniform surface and removing any existing vegetation. In most cases, there was very little vegetation on the slope. All rills and gullies were regraded.

Seed and Fertilizer

Following the redressing of the slopes and prior to placing the fiberglass roving, the cut slopes at the Camino, Asti and Creston test sites were hydromulched with a mixture of seed,

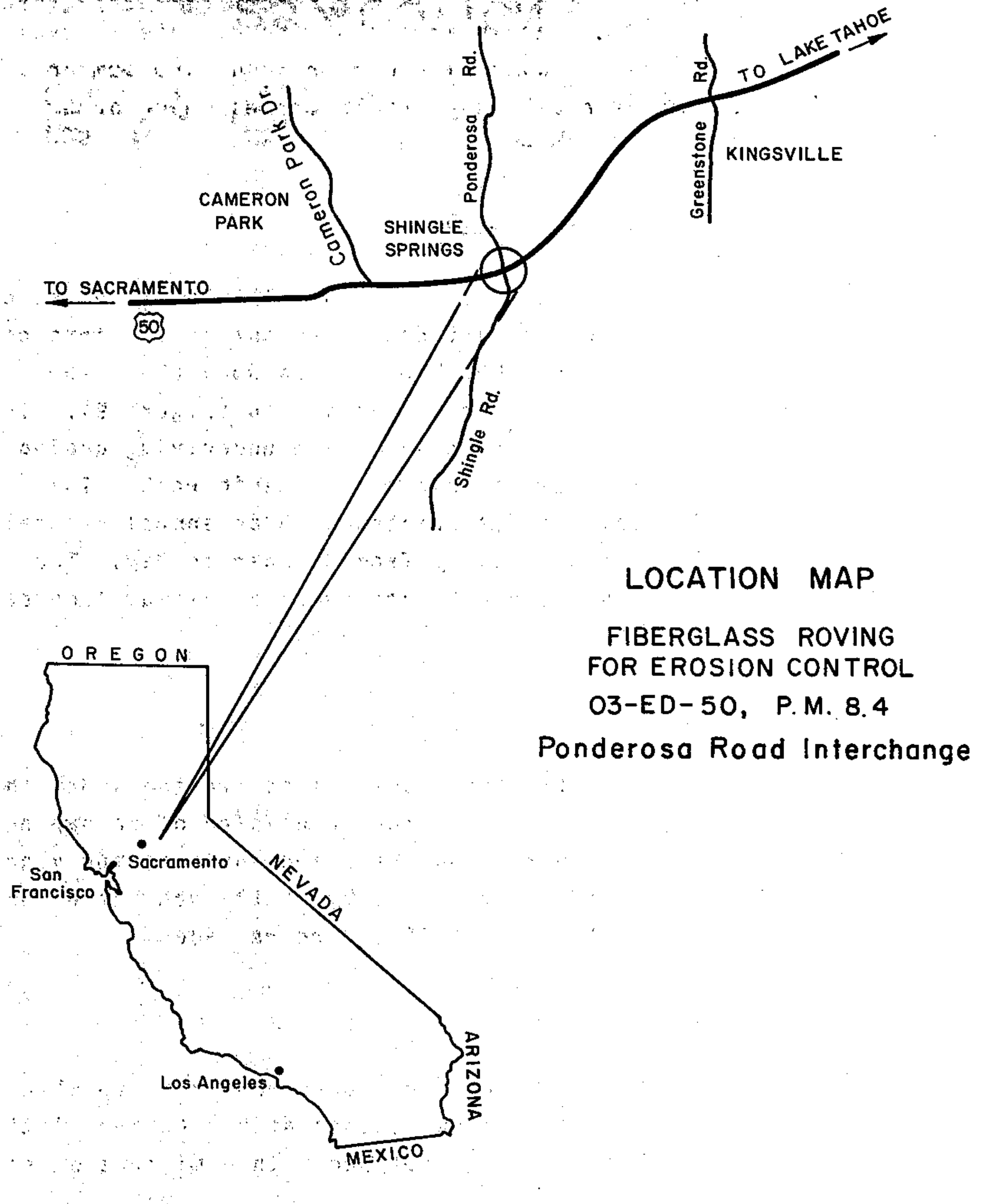

TO LAKE TAHOE
Greenstone Rd.
KINGSVILLE
Ponderosa Rd.
Cameron Park Dr.
CAMERON PARK
SHINGLE SPRINGS
TO SACRAMENTO
50
Shingle Rd.
LOCATION MAP
FIBERGLASS ROVING
FOR EROSION CONTROL
03-ED-50, P.M. 8.4
Ponderosa Road Interchange
OREGON
NEVADA
ARIZONA
MEXICO
Sacramento
San Francisco
Los Angeles

Figure 9

fertilizer, wood fiber and water (Plate 7). The hydromulcher was loaned to TransLab by the U.S. Soil Conservation Service (SCS) Lockeford Plant Materials Center. The seed mixture for all three sites was recommended by the SCS and consisted of:

Luna pubescent wheatgrass	50%
Blando brome	30%
Rose clover	10%
Palestine orchardgrass	10%

Plate 7. Hydromulching Slope

This grass seed mixture contained grasses that basically have a thin blade structure, with only a minimum composition of broad leaf vegetation. Broad leaf vegetation has a tendency to lift the mat off the ground as it emerges. The grass seed was applied as part of the hydromulch mixture at a rate of 50 pounds per acre.

The fertilizer consisted of:

Ingredient	Percentage (Min)
Nitrogen	16
Prosphoric Acid	20
Water Soluble Potash	0

The fertilizer was applied as part of the hydromulch at a rate of 500 pounds per acre.

The wood fiber was Silva-Fiber, applied at the rate of 500 pounds per acre. The amount of water used was sufficient to make a slurry that could be sprayed onto the slope at a uniform rate. The approximate ratio for the wood fiber and water was 1 pound of fiber to 3 gallons of water.

At the four additional sites that were being monitored (Newhall Cut, Upper Sherwin Grade, San Diego, and Ponderosa Road) the following materials and application rates were used:

Upper Sherwin Grade (09-Mno-395, PM 9.0)

Grass seed at 54 pounds per acre

Luna pubescent wheatgrass	39%
Indian ricegrass	19%
Fairway crested wheatgrass	19%
Blando brome	19%
Bitterbrush	2%
Rabbitbrush	2%

Fertilizer (16-20-0) at 200 pounds per acre

Newhall Cut (03-ED-89, PM 22.8)

Grass seed at 50 pounds per acre

Topar pubescent wheatgrass	40%
Oahe intermediate wheatgrass	30%
Potomac orchardgrass	30%

Fertilizer (16-20-0) at 500 pounds per acre

San Diego (11-SD-805, PM 12.3)

Grass seed at 42 pounds per acre

African daisy	41%
Blando brome	18%
Annual ryegrass	12%
Palestine orchardgrass	12%
Smilograss	12%
Hykon rose clover	5%

Fertilizer (14-14-7) at 440 pounds per acre

Ponderosa Road (03-ED-50, PM 8.4)

Grass seed at 50 pounds per acre

Luna pubescent wheatgrass	25%
Palestine orchardgrass	20%
Foxtail fescue	20%
Red brome	15%
Rose Clover	10%
Crimson clover	10%

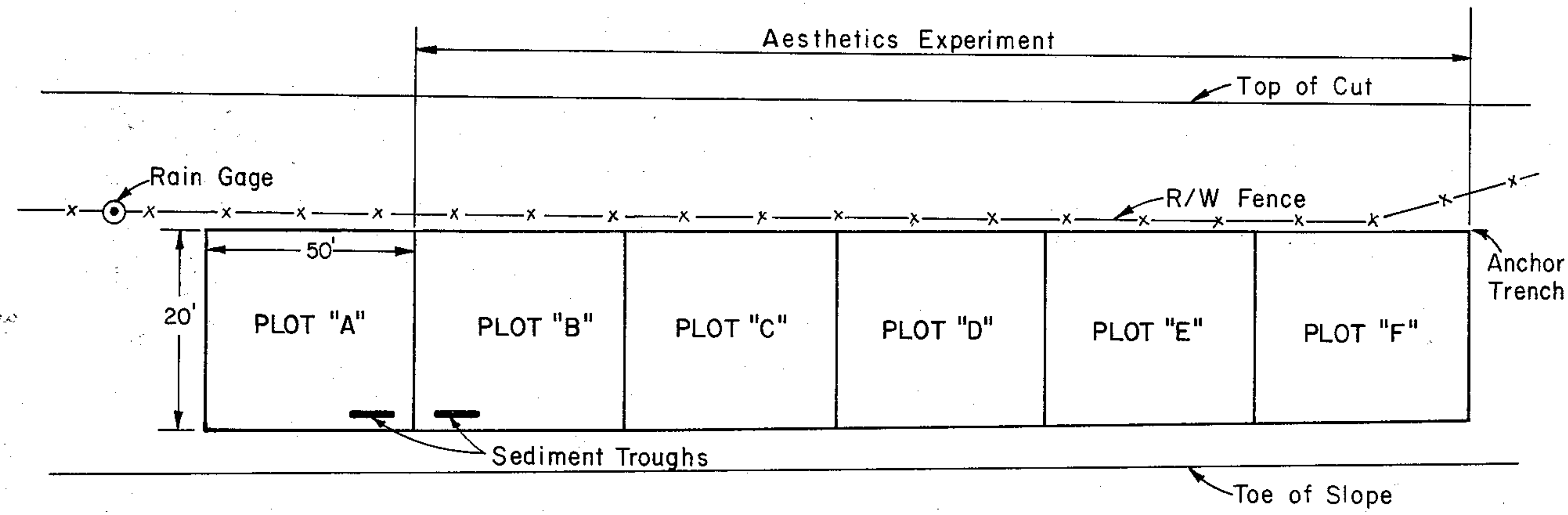
Fertilizer (16-20-0) at 500 pounds per acre

Fiberglass Roving Application

Fiberglass roving was applied at all seven sites by using a special nozzle connected to an air compressor (Plate 3). The air compressors used were rated at 40-100 cubic feet per minute (cfm) at 100 pounds per square inch (psi). The roving was propelled through the nozzle by compressed air, which is regulated at the nozzle to an approximate pressure of 60 psi. The compressed air then propels the fiberglass out of the nozzle, separating the strands into individual fibers. The fibers are spread over the slope starting from the top and working to the bottom in a up and down motion rather than back and forth across the slope, to form a random mat of continuous fibers. The fiberglass then has the appearance of "ANGELS HAIR" or an open woven cobweb. To insure proper adhesion of the fibers to the soil, a uniform tack coat is applied. Usually this tack coat consists of an asphaltic emulsion, such as a SS-1 or SS-1H. The emulsion leaves the treated area with a temporary blackened appearance.

Camino Site Installation

The Camino test site was used as an evaluation of appearance of the fiberglass roving tacked with asphaltic emulsion and other materials in addition to testing the erosion control effectiveness. The test site near Camino was approximately 300 feet long, and was treated November 1, 1977. The slope was divided into 6 sections, approximately 50 ft. wide and 20 ft. high (Figure 10). Five of these six sections received a different tacking treatment. Plot "A", which served as a control section, was untreated. Plots "B" thru "F" received the hydromulch seed and fertilizer mixture and were treated with fiberglass roving at a rate of 0.33 pounds per square yard. Plots "B", "C", and "D" had the fiberglass roving tacked with asphaltic emulsion (SS-1 at the rate of 0.26 gallons per square yard). Following the tacking, Plot "B" received no addition treatment, Plot "C" had coarse sand spread over the SS-1 tack coat, and Plot "D" had native soil from a portion of the slope spread over the tack coat. Plot "E" had the fiberglass roving tacked with a mixture of water,



CAMINO SITE
04 – ED – 50, P.M. 23.8
2:1 SLOPE
SOUTH FACING ASPECT
Figure 10

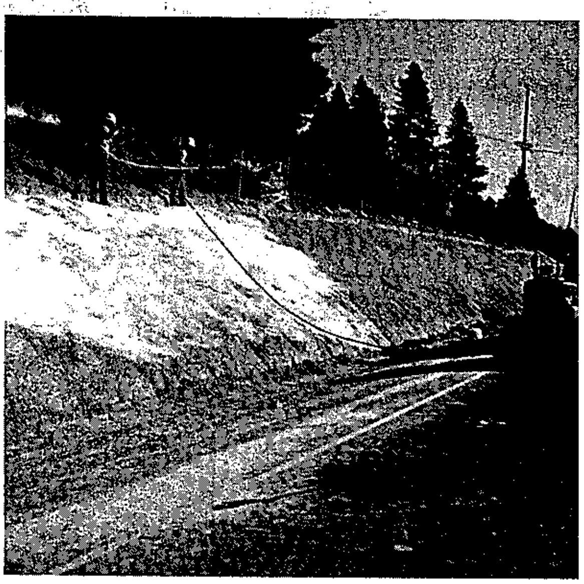


Plate 8. Fiberglass applied to slope at Camino.

Ecology Controls M-Binder and processed fiber mulch applied with the hydromulcher at a rate of 0.34 pounds per square yard. Ecology Controls M-Binder is a free-flowing non-corrosive powder produced from a natural plant gum (Plantago insularis). It is used in hydraulic seeding to hold seed in-place, promote germination and control erosion. Plot "F" had the fiberglass roving tacked with a mixture of water, Terra Tack II, and processed fiber mulch applied with the hydromulcher at a rate of 0.24 pounds per square yard. Terra Tack II is a free-flowing powder produced from semi-refined seaweed extracts and is used for soil erosion control. Table 1 shows a summary of treatments.

Sediment collection troughs (10' x 1' x 1') were installed at the base of Plots "A" and "B" to collect eroding material. A post mounted rain gage was also installed on the fence above the test site.

TABLE 1

Aesthetic Treatments at Camino

Plot	Hydromulch	Seed	Fertilizer	Fiberglass Roving	Tacking Agent Asphalt Emulsion	Tacking Agent Other	Cover
A			Control				
B	500 lbs/ac	50 lbs/ac	500 lbs/ac	0.33 lbs/sy	0.26 gal/sy	-	-
C	"	"	"	"	"		
D	"	"	"	"	"	-	Coarse Sand
E	"	"	"	"	"	-	Native soil
F	"	"	"	"	-	0.34 #/sy(1)	-
					-	0.24 #/sy(2)	—

(1) Ecology Controls M-Binder and processed fiber mulch

(2) Terra Tack II and processed fiber mulch

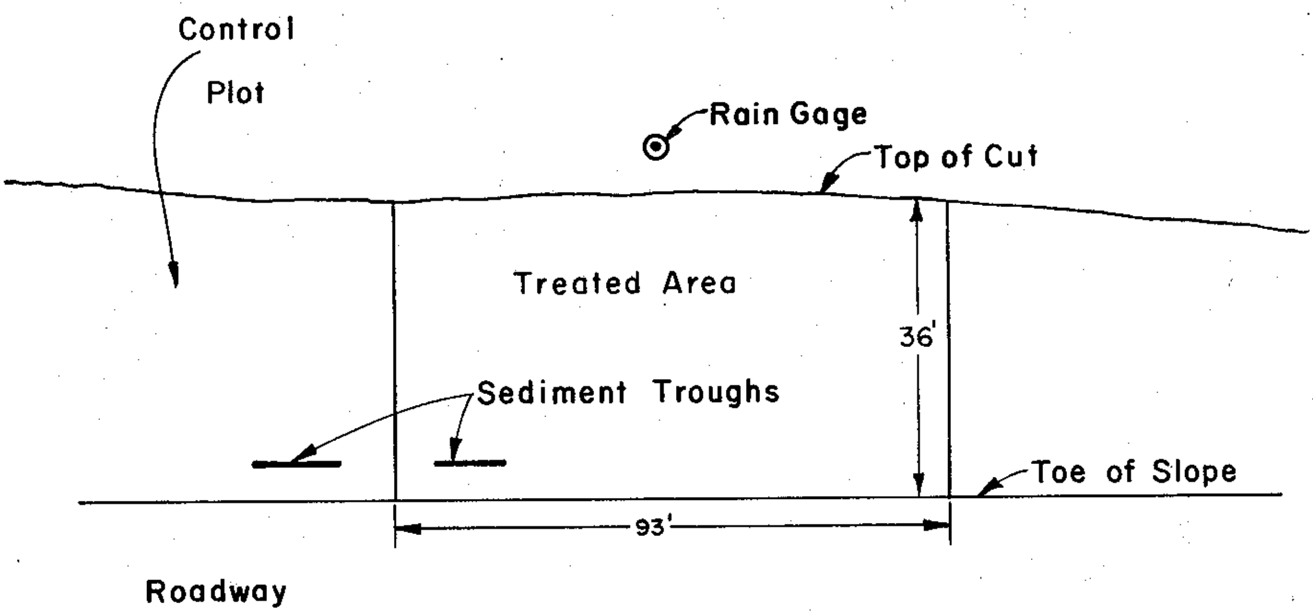
Asti Site Installation

The slope near Asti, which is approximately 93 feet long with an average height of 36 feet, was treated on January 11, 1978. The slope was first hydromulched with a seed and fertilizer mixture and then treated with fiberglass roving applied at a rate of 0.27 pounds per square yard. The fiberglass was tacked with SS-1 asphaltic emulsion at a rate of 0.18 gallons per square yard. In addition to the treated section, a section was left untreated to serve as a control (Figure 11).

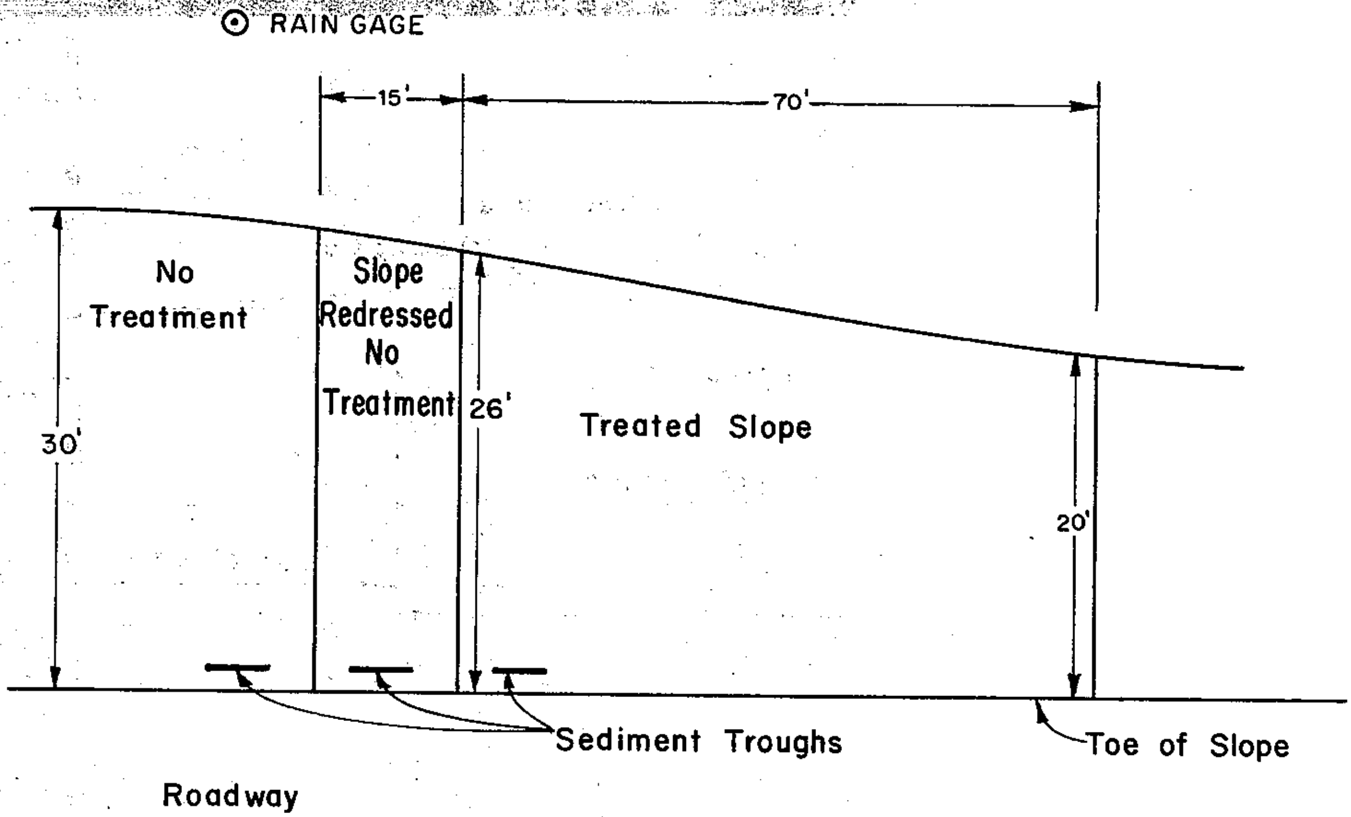
A sediment collection trough (10' x 1' x 1') was installed at the base of the treated and control sections and a post mounted rain gage installed on the Right of Way (R/W) fence above the cut.

Creston Site Installation

The test site near Creston which was treated on November 16, 1977, is 100 feet long with a varying height of 20 to 30 feet (Figure 12). A 70 foot long section was treated with a hydromulch seed and fertilizer mixture after the slope had been redressed to remove the overhang and rills. The fiberglass roving was placed on the slope over the hydromulch mixture at a rate of 0.25 pounds per square yard. The roving was tacked with asphalt emulsion RS-1 at a rate of 0.20 gallons per square yard. A 15 foot wide control section of the slope was also redressed, but no other treatment was applied. A third 15 foot wide control section was left in its natural condition.



ASTI SITE
04 – Son – 101, P.M. 47.5
2:1 SLOPE
WEST FACING ASPECT
Figure 11



CRESTON SITE

05-SLO-41, PM 28.4

$1\frac{1}{2}:1$ SLOPE

SOUTH FACING ASPECT

Figure 12

The three test sections had sediment collection troughs (10' x 1' x 1') installed at the toe of slope. A post mounted rain gage was mounted on the right-of-way fence in back of the cut. A rain gage was also placed across the road on the R/W fence.

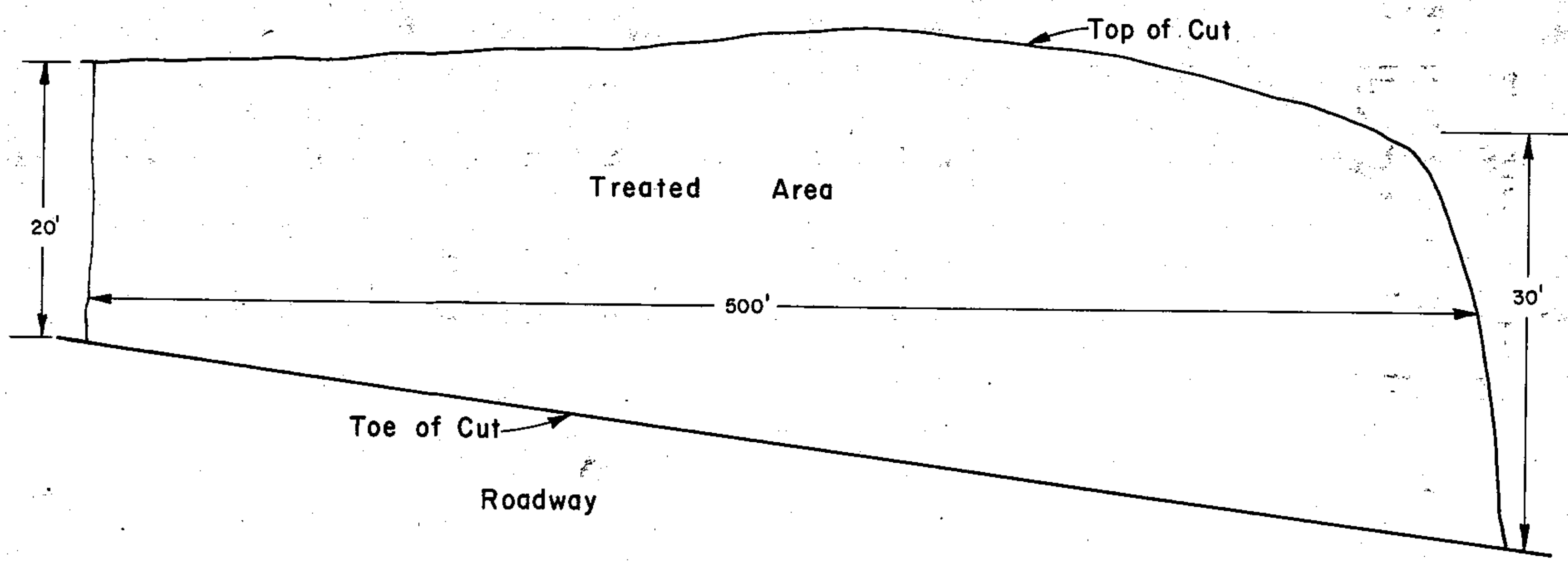
Other Site Installations

Four slopes were also monitored, but not installed as part of this project.

1. Newhall Cut

The slope in District 03 (03-ED-89, PM 22.8) was treated at the request of District 03, on July 9, 1975 (Figure 13). The soil is decomposed granite and is highly erodible. District 03 requested treatment of the slope as part of their Lake Tahoe Basin program to reduce highway slope erosion in the environmentally sensitive area.

The overhang at the top of cut, which was being undermined, was removed. Some trees whose roots were exposed were also removed. The slope was then seeded at the rate of 50 pounds per acre and fertilized at the rate of 500 pounds per acre after which the fiberglass roving was applied at a rate of 0.20 pounds per square yard. It was anchored at the top in a trench that was dug parallel to the slope. The roving was tacked with a product called "Chevron Walktop Egreen". This product, which is normally used to rejuvenate asphalt concrete surfaces, was used because it was green in color and was felt to be aesthetically more pleasing than the temporary black color of asphalt emulsion. The tack coat was applied with a "Spray Baby" hydromulcher at a rate of 0.36 gallons per square yard.



NEWHALL CUT
03-ED-89, P.M. 22.8
2:1 SLOPE
NORTH FACING ASPECT

Figure 13

During July 1977, a portion on the westerly end of the treated slope was planted with 63 woody seedlings and rooted cuttings supplied by the University of California at Davis (UCD). The transplants consisted of the following:

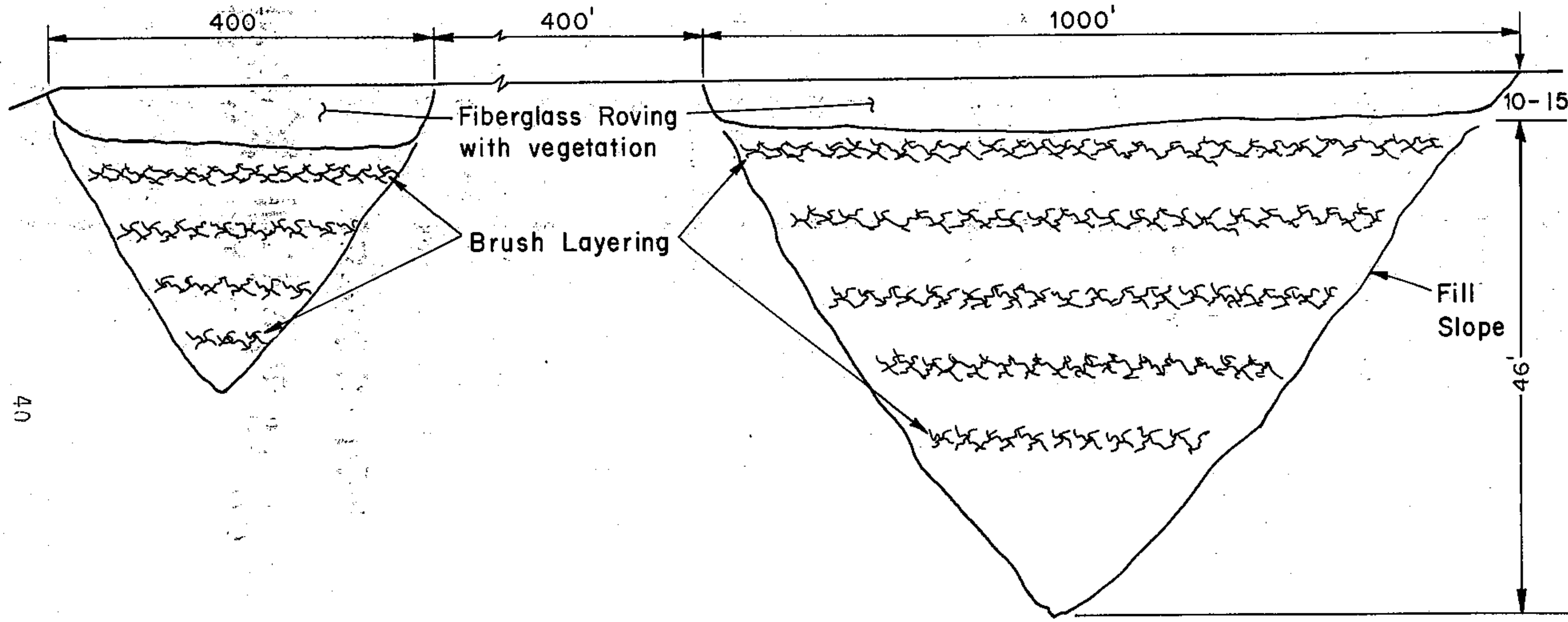
20 Salix rigida, yellow willow
14 Cornus stolonifera, american dogwood
11 Salix lemmonii, lemmon willow
10 Prunus emarginata, bitter cherry
8 Abies concolor, white fir

In addition to the above transplants, approximately 200 additional new cuttings of Salix lemmonii (lemmon willow) were taken from a nearby creek and planted through the fiberglass roving.

The fiberglass mat shifted and broke during the planting operation due to the heavy foot traffic on the steep sloping unconsolidated soil below the mat. This could have been minimized by using a ladder placed on the slope or other means of support during the planting operation.

2. Upper Sherwin Grade

Another site monitored, but not installed as part of this project, was the construction project located at Upper Sherwin Grade in Mono County (09 Mno-395, PM 9.0). The fill slopes were near the Rock Creek crossing and, as part of the District 09 erosion control plan, a small strip along the top portion of two fill slopes was treated with seed, fertilizer and fiberglass roving in late July 1977 (Figure 14). The rate of application was 54 pounds per acre for the seed, 200 pounds per acre for the fertilizer and 0.35 pounds per square yard for the fiberglass roving. The treated area, which ran the length of the fill, varied



UPPER SHERWIN GRADE

09-MONO-395, P.M. 9.0

$1\frac{1}{2}$:1 SLOPE

WEST FACING ASPECT

Figure 14

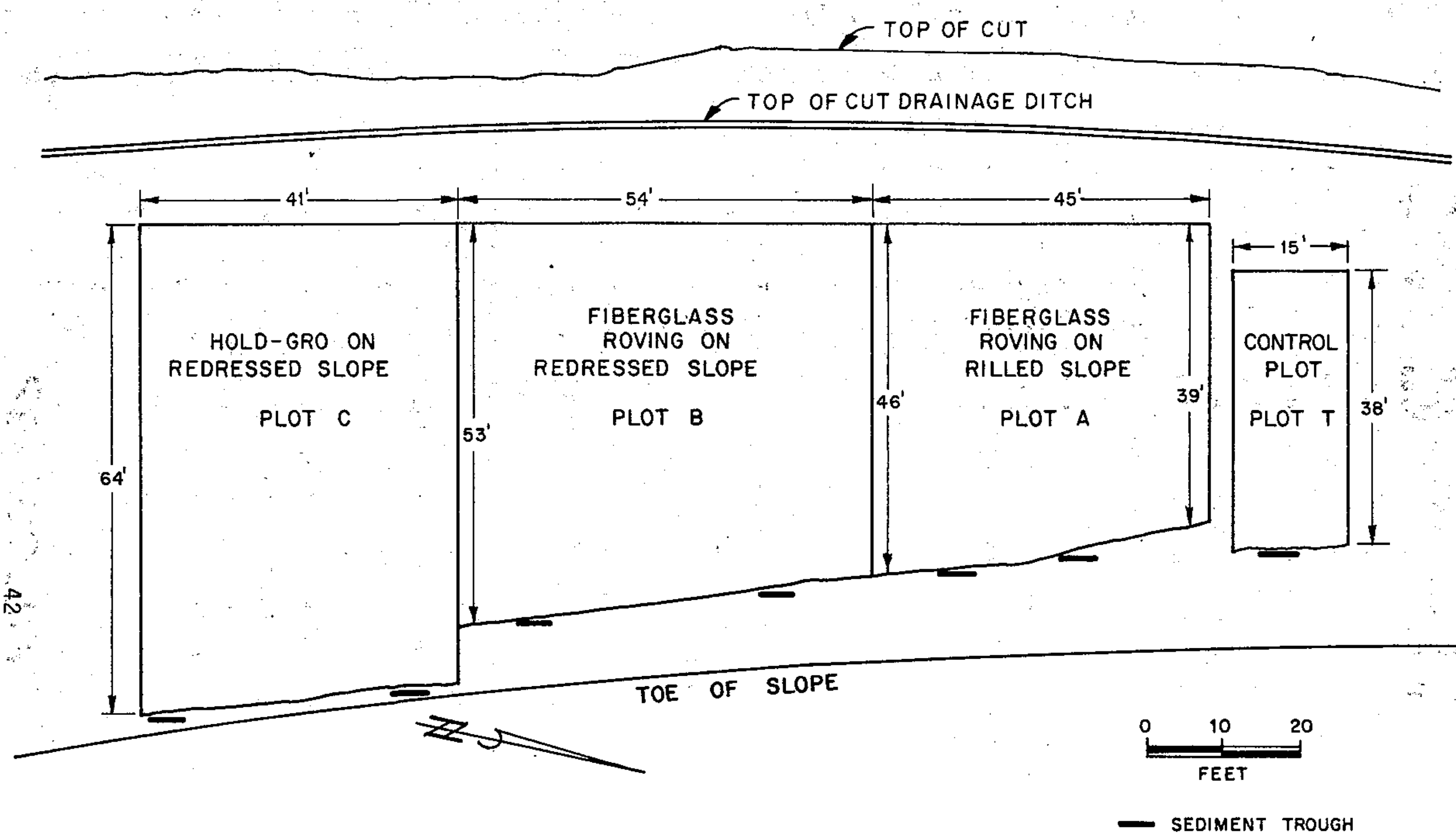
in slope height from 10-15 feet. A section about 10 feet wide at the top, between the guard rail and slope hinge point was also treated. The contractor first seeded and fertilized the slope before applying a layer of fiberglass roving. It was anchored in a trench at the top of the slope and tacked with SS-1 asphaltic emulsion at the rate of 0.32 gallons per square yard. Because this slope was part of a newly constructed fill, it did not require redressing.

A precipitation gage was located near the slope as part of another TransLab research project entitled "Influence of Highways on Water Quality" (657081 A-8-6).

3. San Diego

A third slope that was monitored, but not installed as part of this project, was located in San Diego on Interstate 805 (11-SD-805, PM 12.3). This slope was part of a TransLab-District 11 erosion control experiment to evaluate fiberglass roving and a reinforced paper matting product called "Hold/Gro". The slope had previously been treated with Erosion Control Type D during construction in December 1975. However, due to intense rainfall following application, the Type D treatment was not successful. As a result, the fiberglass roving treatment was tried and the joint study was reported under the TransLab report " Slope Erosion Control Using Fiberglass Roving and Reinforced Paper Matting With Grass" (3).

The experimental test slope was divided into four test sections (Figure 15). All test sections, except for Plot "T", were approximately 50 feet wide and between 40 and 60 feet high. One section, Plot "T", 15 feet wide by 38 feet



SAN DIEGO SITE
11 - SD-805, P.M. 12.3

2 :1 SLOPE
EAST FACING ASPECT

Figure 15

in slope height from 10-15 feet. A section about 10 feet wide at the top, between the guard rail and slope hinge point was also treated. The contractor first seeded and fertilized the slope before applying a layer of fiberglass roving. It was anchored in a trench at the top of the slope and tacked with SS-1 asphaltic emulsion at the rate of 0.32 gallons per square yard. Because this slope was part of a newly constructed fill, it did not require redressing.

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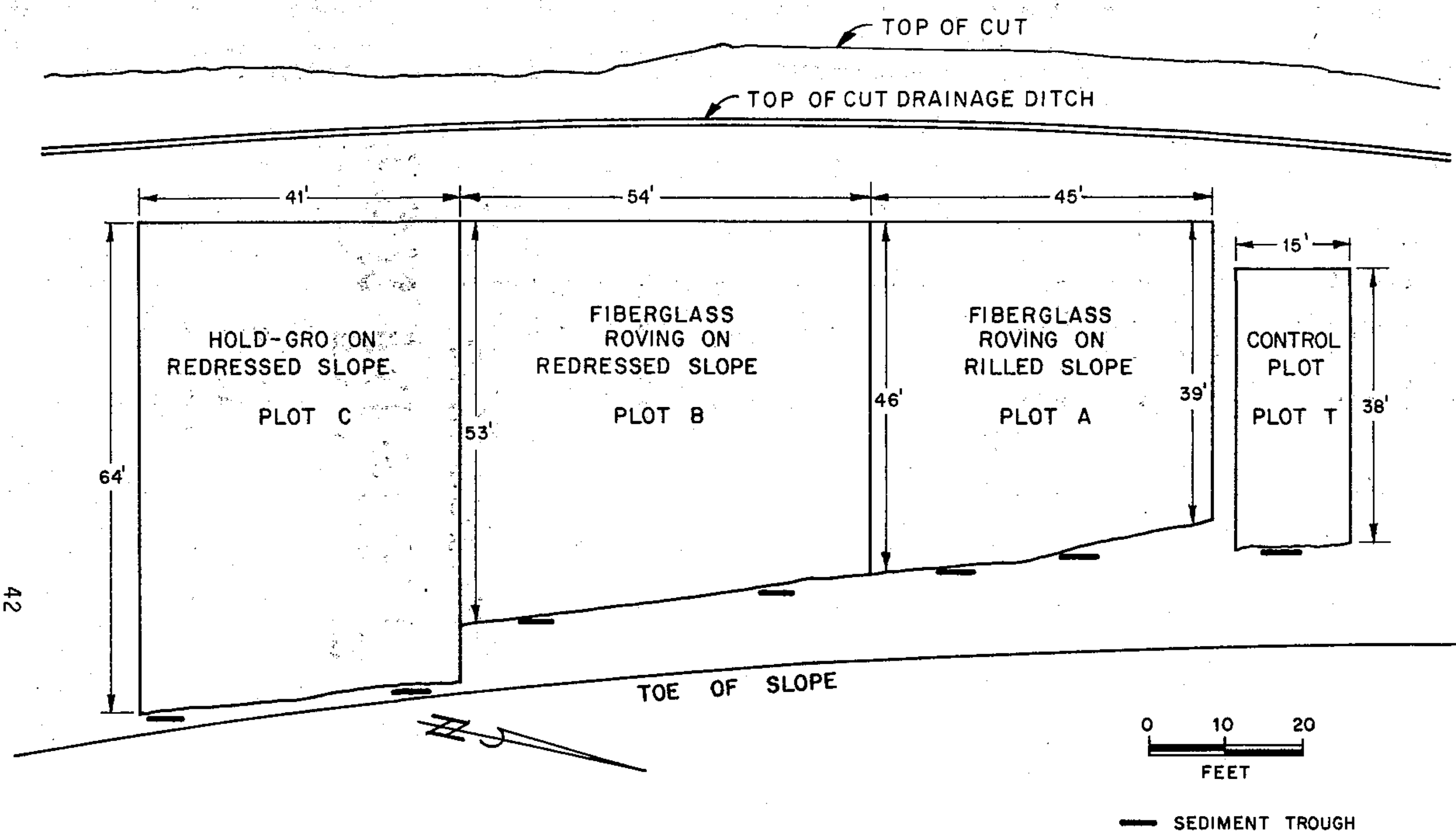


SAN DIEGO SITE
11 - SD-805, P.M. 12.3
2 :1 SLOPE
EAST FACING ASPECT
Figure 15

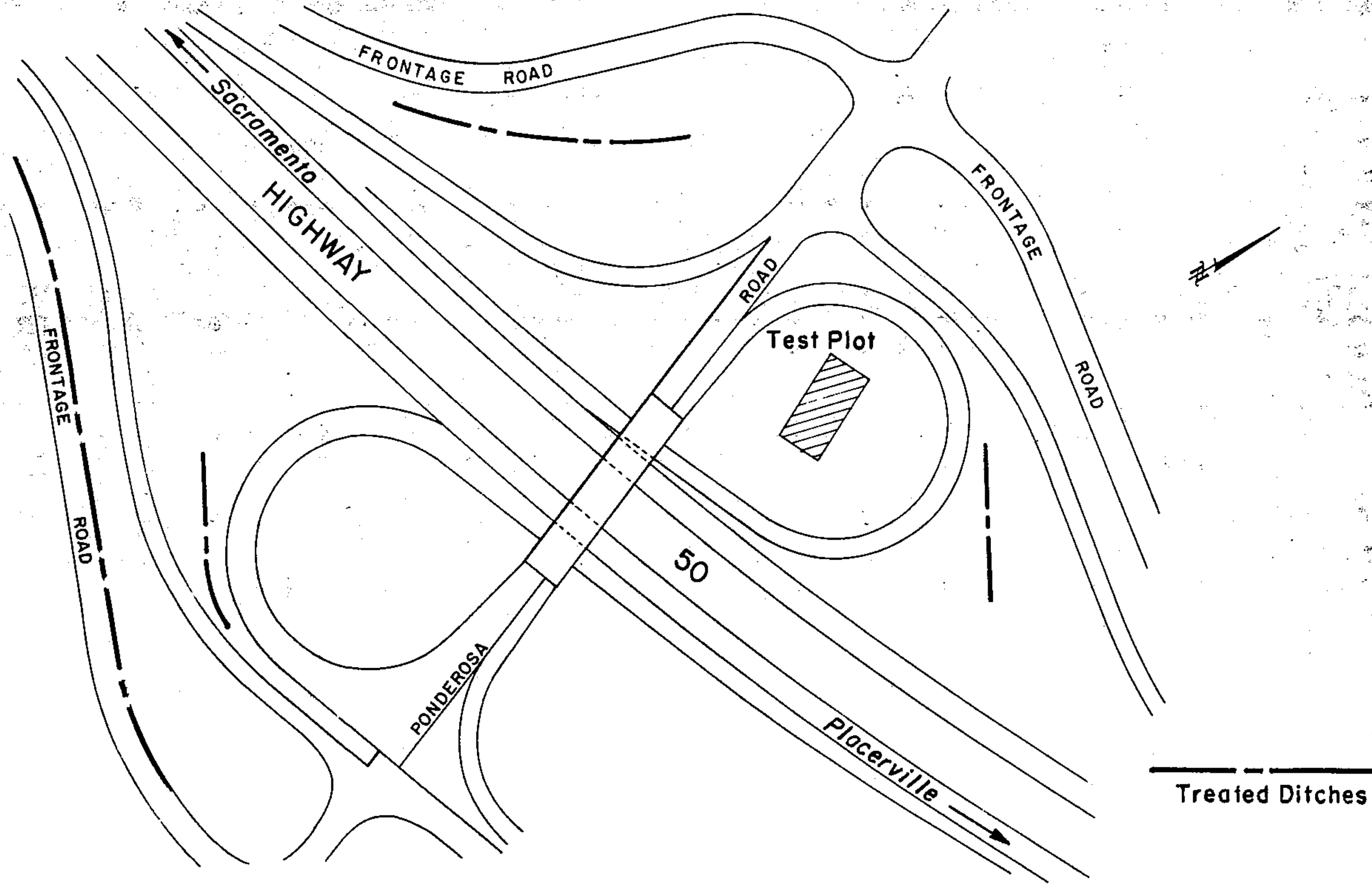
high, was left undisturbed and was used as a control section. Plot "A" had seed at the rate of 42 pounds per acre and fertilizer at the rate of 440 pounds per acre broadcast on the slope which was left in its original condition (rilled). Fiberglass roving was placed over this section and an attempt was made to get the roving into the rills. This attempt was only partially successful. The roving was tacked down with SS-1 asphalt emulsion.

Test Plots "B" and "C" were redressed and additional soil was added to the slope in order to fill in the gully and rill erosion and make the surface uniform. These tests plots ("B" and "C") received the same seed, fertilizer, and rate of application as Plot "A". Plot "B" had fiberglass roving applied over the seed and fertilizer at a rate of 0.19 pounds per square yard and was tacked with SS-1 asphaltic emulsion at the rate of 0.22 gallons per square yard. Plot "C" was covered with a reinforced paper matting product called "Hold/Gro".

Sediment collection troughs were installed at the base of the test plots as shown in Figure 15. The experiment was conducted from October 1976 to May 1977. In late 1977, the treatments were removed during a landscaping project.

4. Ponderosa Road

TransLab participated with FHWA Region 15 in Demonstration Project 26 "Use of Fiberglass Roving for Corrective Ditch Erosion Control" in October 1973 at the Ponderosa Road and Route 50 Interchange located about 30 miles east of Sacramento. Four ditches and one slope 52 feet wide and 100 feet long were treated as shown in Figure 16.



PONDEROSA ROAD
0.3-ED-50, P.M. 8.4
11% Slope
South Facing Aspect
Fig. 16

The 11% slope was first regraded, then seeded at a rate of 50 pounds per acre and fertilized at a rate of 500 pounds per acre. The area was then covered with fiberglass roving at a rate of 0.35 pounds per square yard and tacked with an asphalt emulsion SS-1 at 0.17 gallons per square yard. Results of the experiment were published by TransLab in June 1974 (1).

A summary of all the treatments is given in Table 2.

TABLE 2

Summary of Treatments

Location	Hydromulch (lbs/ac)	Seed (lbs/ac)	Fertilizer (lbs/ac)	Fiberglass Roving lbs/sy	Asphaltic Type	Emulsion Rate (gal/sy)
Camino, Rte 50	500	50	500	.33	SS-1	.26
Asti, Rte 101	500	50	500	.27	SS-1	.18
Creston, Rte 41	500	50	500	.25	RS-1	.20
Newhall Cut Rte 89	-	50	500	.20	Chevron Walk Top Egreen	.36
Upper Sherwin Grade, Rte 395	-	54	200	.35	SS-1	.32
San Diego, I-805	-	42	440	.19	SS-1	.22
Ponderosa Rd, Rte 50	-	50	500	.35	SS-1	.17

RESULTS

To determine the effectiveness of fiberglass roving with vegetation on reducing erosion, sediment was removed from the sediment troughs following storm periods. The dry weight of the eroded sediment that was collected for each rainfall period was compared to the eroded sediment from the non-treated (control) slope. The data were analyzed using a least squares regression procedure.

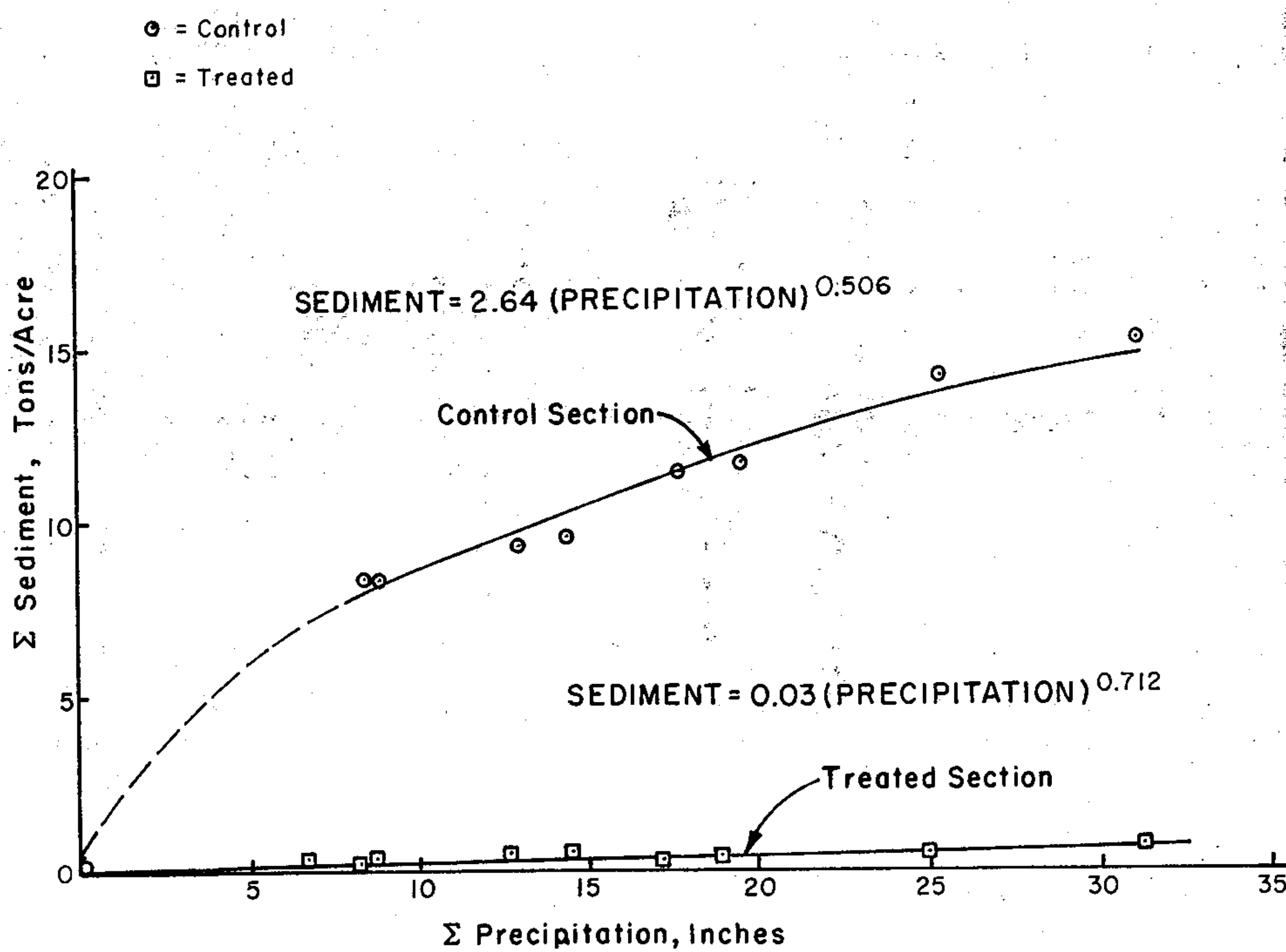
All three test sites showed a significant reduction in erosion for the treated sections as compared to the control sections. A photographic log of the Camino, Asti and Creston sites is included in the Appendix.

Camino, Route 50

The treatment at Camino was successful in reducing erosion from 16 tons/ac for no treatment to 1 ton/ac for fiberglass roving treatment for a normal rainfall of 45 in./year. The data are shown in Figure 17. As seen from the data, the rate of erosion declined following the initial 8 inches of precipitation.

Precipitation was above normal in the 1977-78 winter. Total rainfall for the season was reported as 63 inches compared to a normal of 45 inches. Of the 63 inches, 32 inches fell during the monitoring period.

The overall performance of the vegetation was excellent. The grass began to emerge through the fiberglass roving mat at about 4 weeks following application. Growth at this time was on the order of 1/2 in. to 3/4 in. in length.



Σ Sediment VS Σ Precipitation For Treated And Control Sections

<u>CAMINO TEST SITE</u>

(03-ED-50, P.M.23.8)

Fig.17

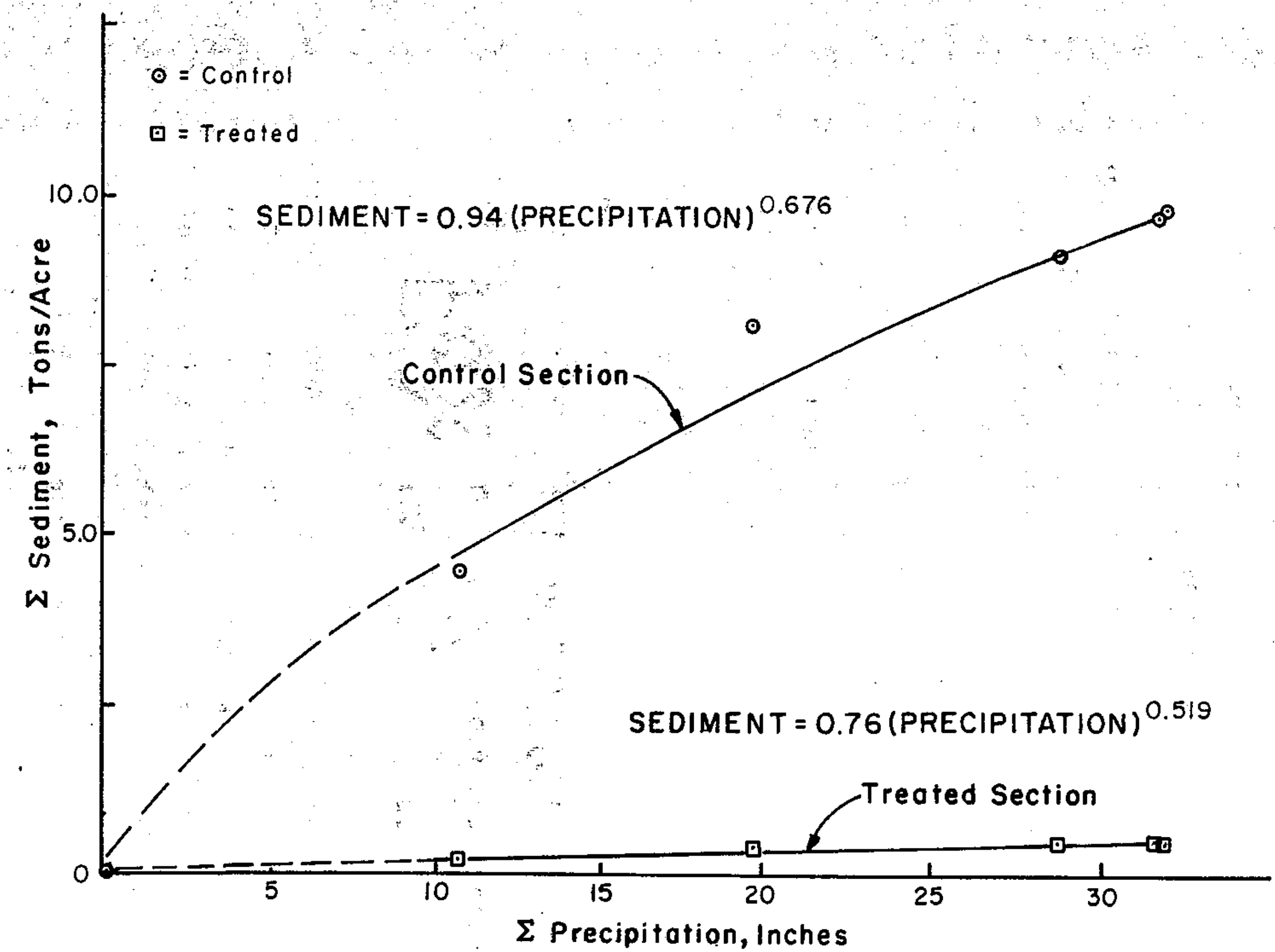
By the end of the 12th week, the grass had grown to about 1 1/2 inch to 2 inches in length and was fairly uniform. By the 24th week, growth has increased to approximately 18 inches with good uniform coverage.

Luna pubescent wheatgrass, Rose clover, and Palestine orchard-grass all emerged. The Blando brome was present at the end of 4 weeks but at the end of the monitoring period, it was not found.

Asti, Route 101

The treatment at Asti was successful in reducing erosion from 11 tons/ac for no treatment to less than 1 ton/ac for fiberglass roving treatment for a normal rainfall of 40 in./yr. The data are shown in Figure 18. Again, the rate of erosion declined following the initial 10 inches of precipitation. Precipitation was above normal in the 1977-78 winter. Total rainfall for the season was reported as 55 inches compared to a normal of 40 inches. Of the 55 inches, 31 inches fell during the monitoring period.

The overall performance of the vegetation was good. The grasses began to appear at the end of 4 weeks. Six weeks after application, vegetative growth was good except for the fringes of the treated area where coverage was less dense. All four of the grasses germinated. Blando brome was the first to appear but very little was present at the end of the monitoring period. The Luna pubescent wheatgrass and Palestine orchardgrass were the dominant vegetation. Rose clover was not observed at the end of the test period.



Σ Sediment-VS- Σ Precipitation For Treated And Control Sections

ASTI TEST SITE

(04-SON-101, P.M. 47.5)

Fig. 18

Creston, Route 41

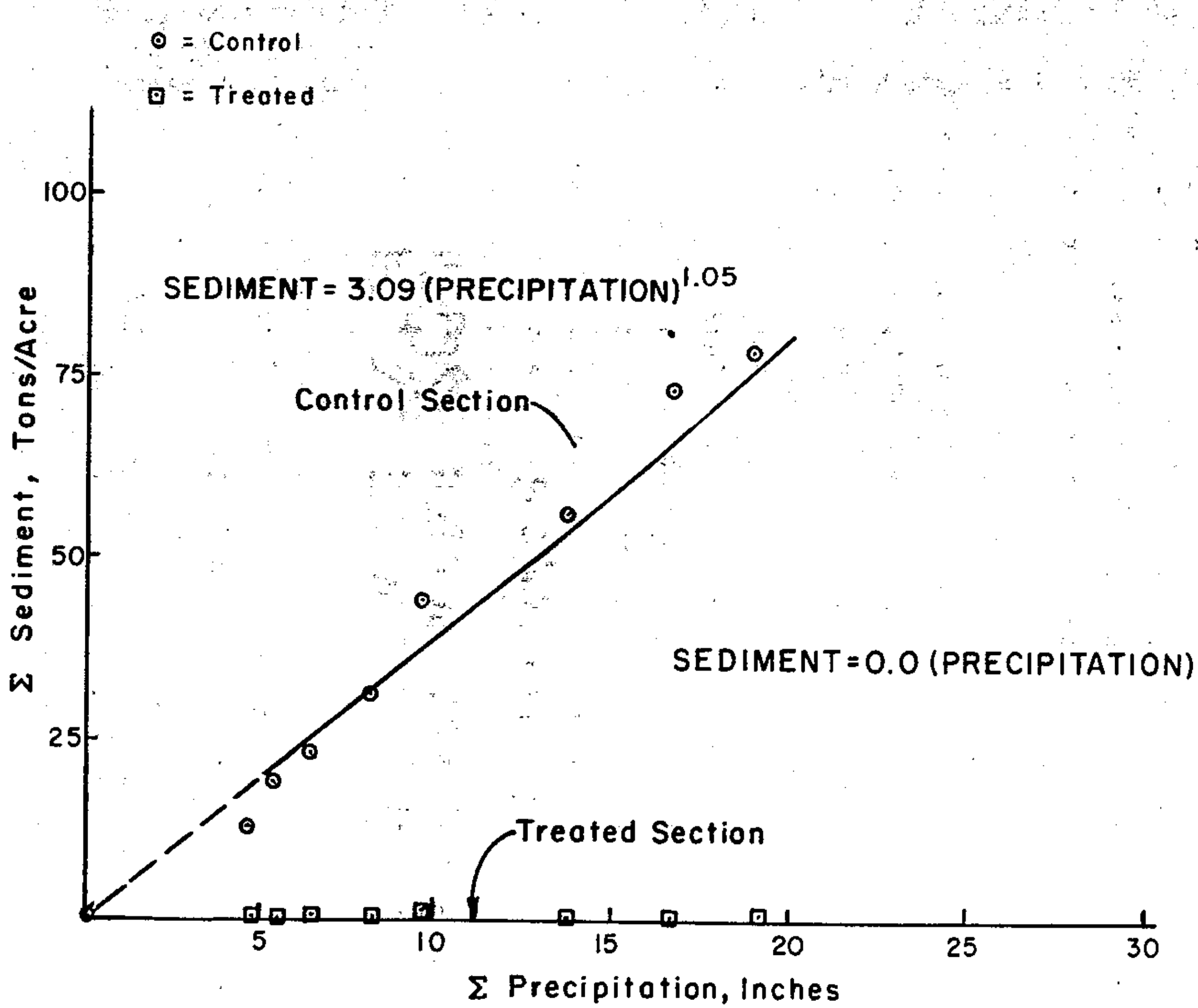
The treatment at Creston was successful in reducing erosion from 85 tons/ac for no treatment to zero erosion for the fiberglass roving treatment for a normal rainfall of 20 inches. The data are shown in Figure 19. This site showed a more consistent rate of erosion during the monitoring period, with the curve reflecting a slight increase in the rate over the monitoring period.

Precipitation was above normal in the 1977-78 winter. Total rainfall for the season was 48 inches compared to a normal of 20 inches. Of the 48 inches recorded, 19 inches fell during the monitoring period.

The overall performance of the vegetation was fair. The coverage was nonuniform with only about 50% of the slope being covered at the end of the monitoring period. The initial grass germination appeared to be uniform, but with time, became very spotty. Palestine orchardgrass was the only vegetation growing on the slope although it constituted only 10% of the seed mixture. The final height of the grass was 18 inches.

One area on the slope was used by deer as a passage way evidently in crossing the highway. Where the deer's hooves contacted the slope, holes were torn in the mat.

Because of the lack of good grass cover on the slope, a reseeding and fertilizer application will be made during the fall of 1978 by the District.



Σ Sediment VS Σ Precipitation For Treated And Control Sections

CRESTON TEST SITE

(05-SLO-41, P.M. 28.4)

Fig.19

Newhall Cut, Route 89

With respect to the transplant experiment conducted at the Newhall Cut site in June of 1977, a field review conducted during June of 1978 revealed the following:

1. The vegetation on the slope in terms of grass cover was excellent.

2. Of the 8 white fir seedlings planted, only 2 appeared to have survived. Three of the 14 dogwood seedlings showed signs of growing and 5 of the 10 bitter cherry seedlings survived.

3. None of the 200± willow cuttings which were installed were growing.

4. Walking around on the mat during placement of the transplants caused the loose soil underneath to shift and, subsequently, tear the mat. A device, such as a ladder, may be used as a working platform to reduce this negative effect.

In terms of damage to the fiberglass roving mat during the transplanting operation, there did not appear to be any adverse effect.

Upper Sherwin Grade, Route 395

The section of slope treated at the Upper Sherwin Grade site during July 1977 has proven to be successful. The fiberglass roving mat has a good grass cover and appears to be stabilizing the upper portion of the slope nicely.

There are several places on the mat which have been undermined by gullying on the fill slope below the treatment. The gullies were mostly formed during a rapid snow melt that occurred during a warm period in January 1978. The snowpack was well above normal for this slope.

The fiberglass roving mat was rolled up in places by tumbleweed that had blown up the fill slope and got caught under the mat, primarily in the gully areas. It is possible that this could be prevented by anchoring the lower end of the mat in a trench similar to the technique used for holding the upper slope end on the slope.

San Diego, I-805

The treatment at San Diego was successful in reducing erosion from over 170 tons/acre for no treatment to less than 1 ton/acre for the fiberglass roving treatment for a rainfall of 9 inches. During the monitoring period this was slightly less than the normal 10 inches of precipitation.

The overall performance of the vegetation, was very good. Twenty weeks after treatment, 75% of the slope was covered with a mixture of Blando brome, Perla/Ryegrass mix, Palestine orchardgrass and Smilograss. The coverage by these grasses was uniform over the entire slope area during the monitoring period.

Ponderosa Road, Route 50

The treatment at Ponderosa Road was successful in establishing vegetation and reducing erosion. During the monitoring period, 30.58 inches of precipitation occurred. Grass coverage was uniform over the entire slope area.

After 5 years, the treated area is in excellent condition with little erosion apparent.

AESTHETICS AND VEGETATION EVALUATION

Because of concern expressed by some over the temporary black color of the asphaltic emulsion on a newly treated slope, an evaluation was made of the tacking procedures used at the Camino (03-ED-50, PM 23.8) test site.

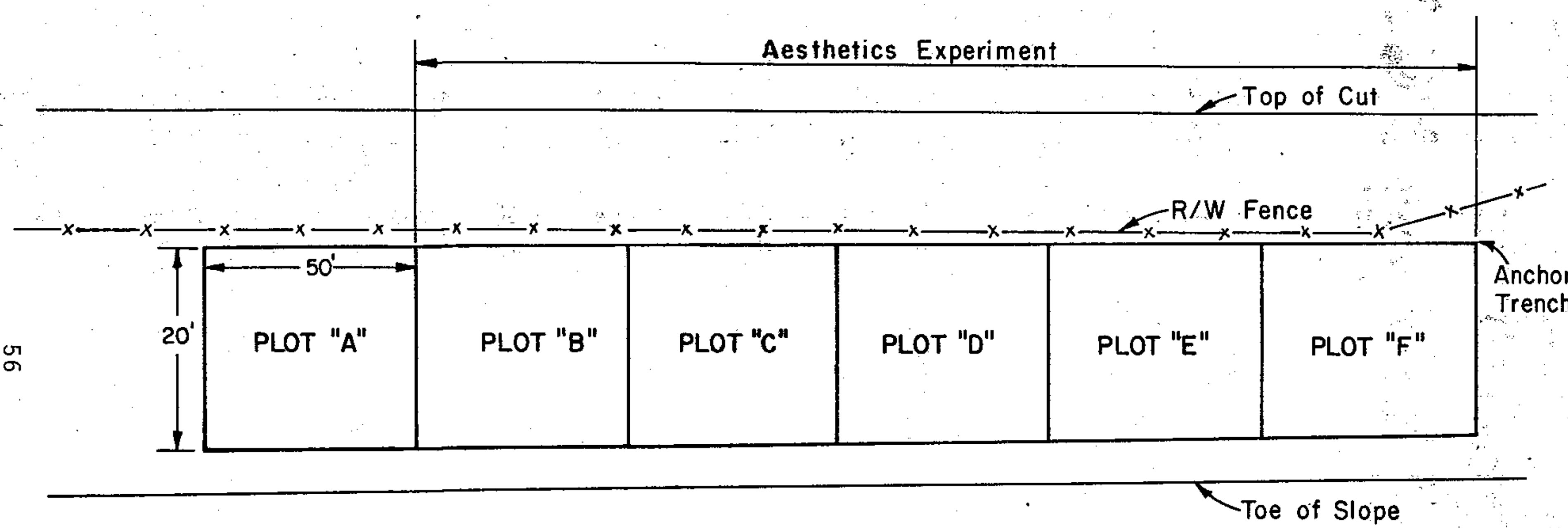
The tacking methods for each of the test plots are listed below:

Plot	Tacking Procedure
A	Control
B	Asphalt Emulsion, SS-1
C	Asphalt Emulsion, SS-1, Coarse Sand Cover
D	Asphalt Emulsion, SS-1, Native Soil Cover
E	Ecology Controls M-Binder & Processed fiber mulch
F	Terra Tack II & Processed Fiber Mulch

Figure 20 shows the test site.

The evaluation was conducted by a seven member evaluation team as follows:

Richard Pryor, Landscape Architecture (Caltrans)
Roy Chalmers, Office of Planning and Design (Caltrans)
Robert Skidmore, District 03 Environmental (Caltrans)
Charles Jackson, Office of Construction (Caltrans)
Barry Brown, State Department of Conservation
Perry Amimoto, State Division of Mines and Geology
William Spearman, Federal Highway Administration



CAMINO SITE

04 - ED - 50, P.M. 23.8

2:1 SLOPE

SOUTH FACING ASPECT

Figure 20

The team evaluated the Camino test site on three different occasions: 1) four weeks after installation, 2) twelve weeks after installation, and 3) twenty-four weeks following installation. The team was asked to evaluate each of the test plots in terms of vegetative growth, aesthetics, and vegetative cover. As part of the vegetative growth evaluation, the team was also asked to note if vegetation was emerging from the different test plots. This information was used to determine the first appearance of vegetation at each plot but was not necessary to determine amount of growth. Evaluation rating sheets were used (see Appendix "C" for evaluation sheets). Findings of the evaluations are listed in Figures 21, 22, and 23.

The following conclusions were based on the evaluation of the test sections.

1. No vegetative growth was apparent on the control plot "A" (untreated).

2. Plots "B", "C", and "D" all appeared to have about the same initial growth after 4 weeks, but "B" and "C" showed more growth after 24 weeks.

3. Plots "E" and "F", appeared to have an extra heavy coat of tacking material. This may have restricted growth on these two plots.

4. The black color of the asphalt emulsion tacking agent was not unpleasing to the evaluation team, except for one team member.

5. Vegetation growth was more abundant as well as uniform on plots "B", "C", and "D" than on plots "E" and "F".

CAMINO TEST SITE
VEGETATIVE GROWTH RATING FOR SLOPE

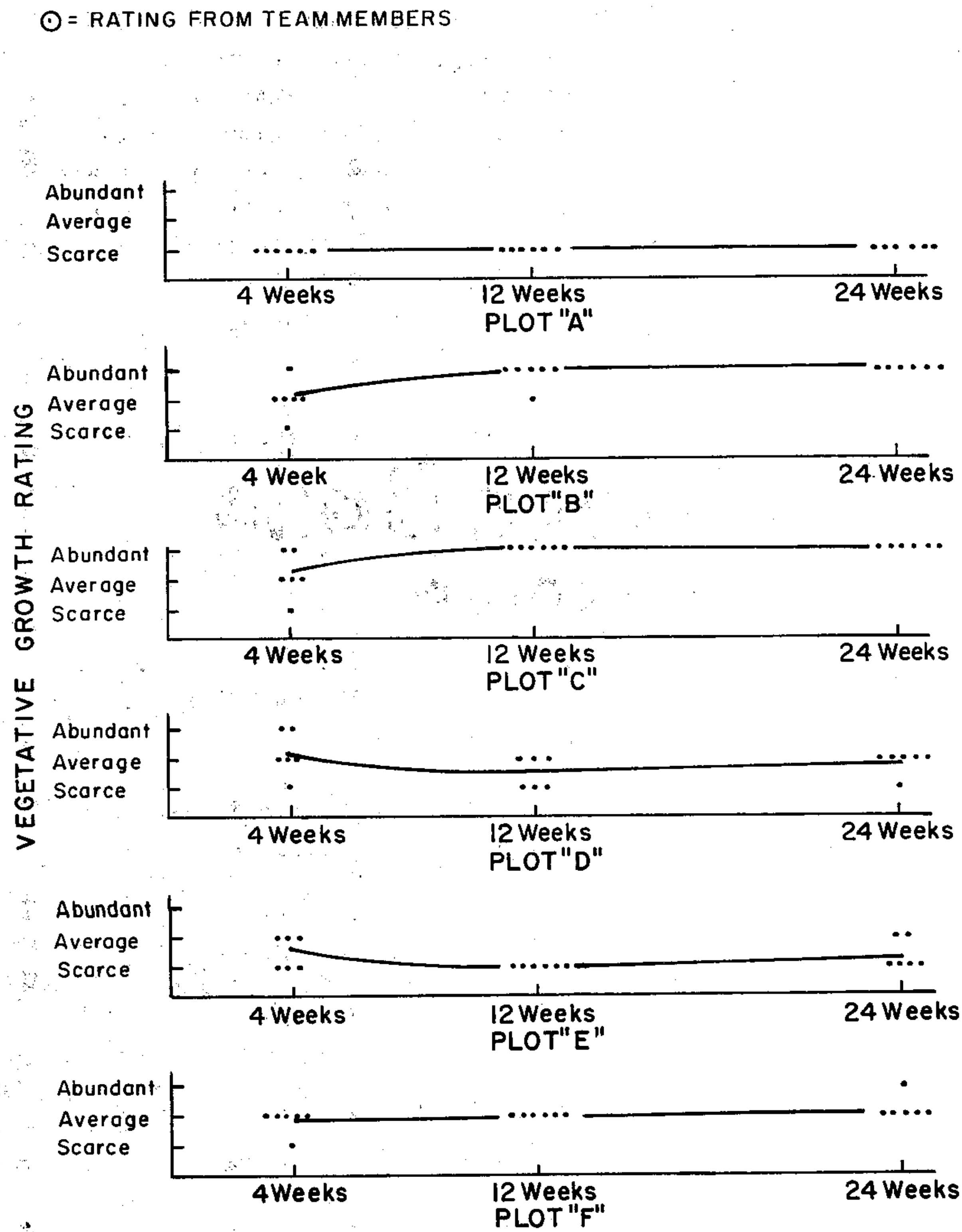


Fig. 21

CAMINO TEST SITE
AESTHETIC RATING FOR SLOPE

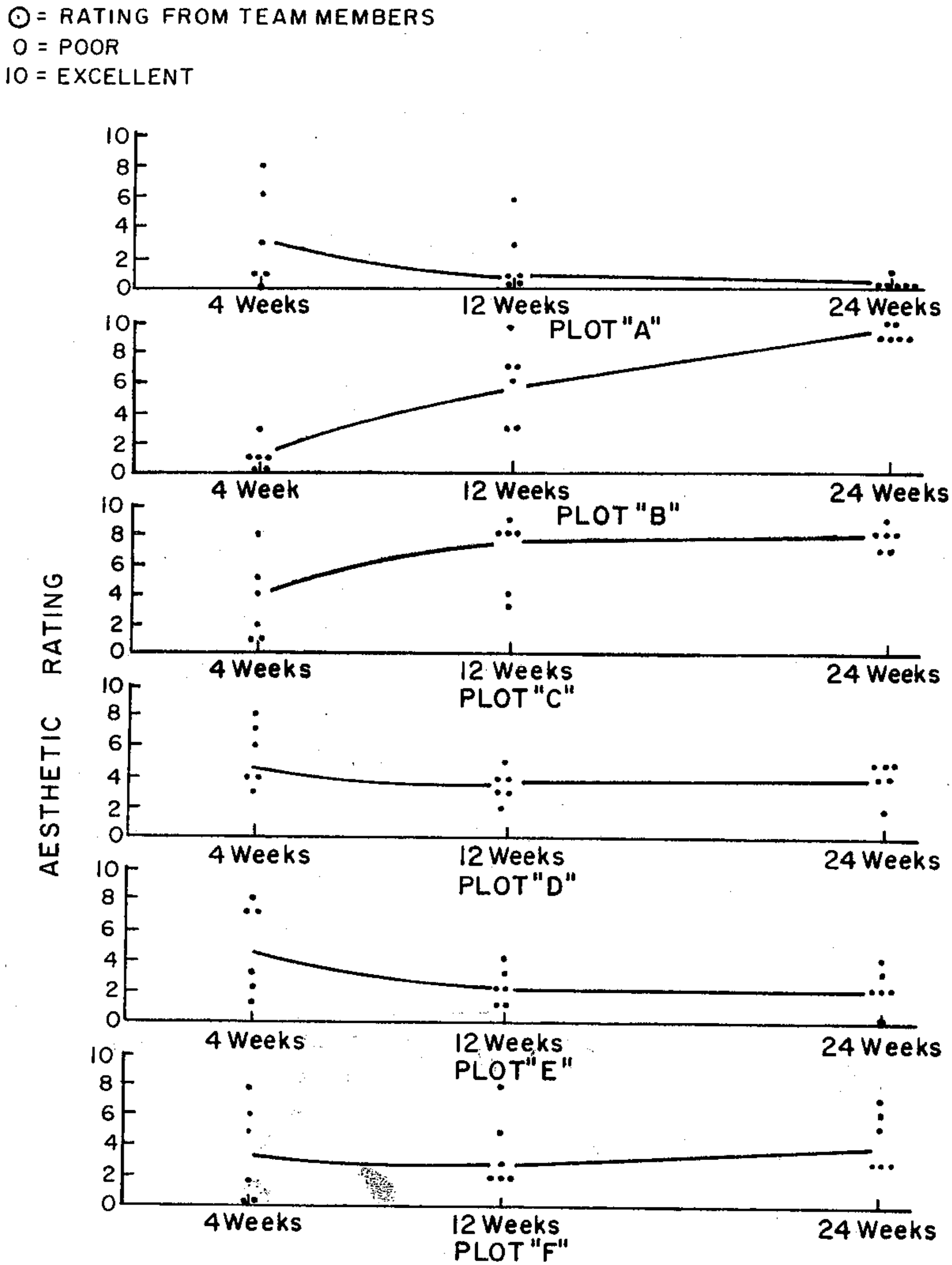


Fig.22

CAMINO TEST SITE
VEGETATIVE COVERAGE RATING FOR SLOPE

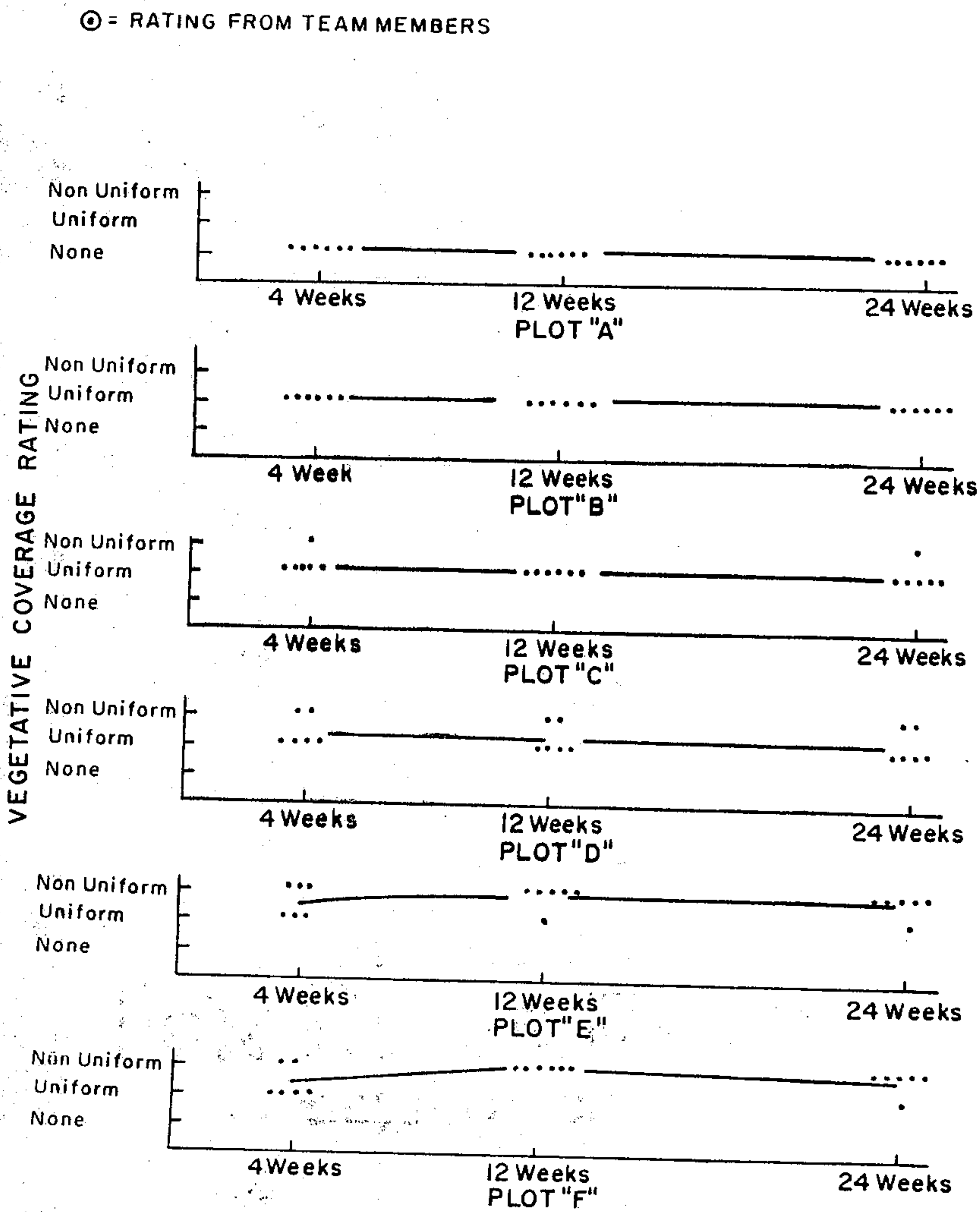


Fig. 23

6. Broadcasting soil material over the top of plot "D" and sand over plot "C" did not improve the appearance significantly. A majority of the soil and sand was removed during the first rainstorm following application.

7. Plot "B" appeared to have the best overall appearance in terms of growth and uniformity.

8. Plot "B" had a black appearance due to the asphalt emulsion tacking agent. However, this black appearance only lasted for a short time until the vegetation began to emerge at approximately 4 weeks.

ECONOMICS

Fiberglass roving with vegetation is expensive and would not be practical to use as a general treatment for all erosion problems on slopes. However, it may be economically feasible for use on slopes with severe erosion. Fiberglass roving can be readily purchased on the commercial market for about $0.60 per pound. The special nozzle needed to apply the fiberglass roving can be purchased for about $150 or can be fabricated in a machine shop. The asphalt emulsion used as a tacking agent costs $0.40 a gallon. All other equipment, except the hydromulcher, needed to perform the work consists of standard items, readily available at most maintenance stations or from contractors.

The cost of the fertilizer is approximately $0.11 per pound and the grass seed is approximately $1.00 a pound depending on the type of seed used in the mixture. The wood fiber used in the hydromulch mixture costs $5.00 per 50 pound bag.

The costs for installing the small experimental test plots were high and do not reflect the cost for treating large areas. The estimated cost for large areas done by contract is approximately $0.90 per square yard ($4,450 per acre). This cost also includes redressing the slope. The time required to complete a typical installation is approximately 2 days/acre. Table 3 shows a comparison of cost for different erosion control treatments.

Maintenance cost will vary depending on the amount of clean-up and remedial work required on a particular slope. However, based on an average erosion rate of 80 CY/AC/YR for severely eroding slopes and assuming $16/CY for maintenance removal and disposal, the annual cost for maintenance will amount to $1,280/acre.

Based on a discount rate of 7% (i) and annual disbursements over a time period of 20 years (n) this $1,280/acre annual cost will have a present worth of $13,560/acre.

[Present Worth = Annual Cost (Present Worth Factor for i=7%, n=20 years)]

[Present Worth = $1,280 (10.5940) = $13,560/acre]

The initial cost for the fiberglass roving with vegetation treatment is approximately $4,450/acre.

Thus, the cost savings for treating the slope initially with fiberglass roving with vegetation is on the order of 3:1.

There is a slight reduction in the unit cost of the fiber-glass roving if large quantities are purchased. This reduced cost (see Table 4) could lower the total cost to approximately

Table 3

Comparison of Cost for Different Erosion Control Treatments

Erosion Control Product	Cost of Material	Installation Cost	Total Cost
Erosion Control Type D	$300/acre	$200/acre	$500/acre
Woodfiber Mulch (2000 lbs/acre)	$450/acre	$200/acre	$650/acre
Incorporated Straw	$100/acre	$900/acre	$1,000/acre
Fiberglass Roving tacked with asphalt	$1,450/acre	$3,000/acre**	$4,450/acre
Excelsior Blanket	$1,800/acre*	$3,000/acre**	$4,800/acre
Reinforced Paper Matting	$2,250/acre*	$3,000/acre**	$5,250/acre
Jute Netting	$2,400/acre*	$3,000/acre**	$5,400/acre

* Price includes cost of staples to hold product in place on soil.

** Installation Cost is estimated to include the following:

Slope Protection		Seeding & Fertilizing		Blanket Installation		Miscellaneous	
Labor	$500/acre	Seed	$125/acre	Labor	$500/acre	Per Diem & Travel	$300/acre
Equip.	300/acre	Fertilizer	75/acre	Equip.	50/acre	Profit & Overhead (30%)	$800/acre
		Labor	200/acre				
		Equip.	150/acre				

$3,450/acre. Based on this figure, the savings would be increased to nearly 4:1. Table 4 shows the unit cost for a variety of erosion control products.

In addition to the maintenance savings, there would be reduced sediment in adjacent waterways and improved highway slope appearance.

TABLE 4

Unit Cost for Different Erosion Control Materials

Erosion Control Product	Quantity	Unit Cost	Cost/Acre
Reinforced Paper Matting	0 -5,000 S.Y.	$ 0.46/S.Y.	$2230/acre
	Greater than 5,000 S.Y.	$ 0.44/S.Y.	$2130/acre
Excelsior Blanket	0-4,000 S.Y.	$ 0.34/S.Y.	$1650/acre
	4,000 -8,000 S.Y.	$ 0.32/S.Y.	$1550/acre
	8,000 - 16,000 S.Y.	$ 0.30/S.Y.	$1450/acre
	16,000 - 24,000 S.Y.	$ 0.28/S.Y.	$1350/acre
	Greater than 24,000 S.Y.	$ 0.27/S.Y.	$1300/acre
Jute Netting	0 - 100 S.Y.	$ 0.49/S.Y.	$2370/acre
	100 -600 S.Y.	$ 0.48/S.Y.	$2320/acre
	600 - 4,900 S.Y.	$ 0.45/S.Y.	$2180/acre
	Greater than 4,900 S.Y.	$ 0.44/S.Y.	$2130/acre
Fiberglass Roving (Including Asphalt Tacking Agent)	0 - 50,000 S.Y.	$ 0.30/S.Y.	$1450/acre
	Greater than 50,000 S.Y.	$ 0.28/S.Y.	$1350/acre
Straw	0 - 5,000 S. Y.	$ 0.02/S.Y.	$ 100/acre
	Greater than 5,000 S.Y.	$ 0.02/S.Y.	$ 100/acre

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1. "Fiberglass Roving for Erosion Control, Ponderosa Road and Highway 50 Interchange," Quint, M.; Howell, R. B.; Shirley, E. C.; Skog J. B.; California Department of Transportation, CA-DOT-TL-7158-1-74-19, June 1974.

2. "Control of Ditch Erosion Using Fiberglass Roving," Nolan, M. E.; Hatano, M. M.; Howell, R. B.; Shirley E. C.; California Department of Transportation, CA-DOT-TL-7225-1-76-41, July 1976.

3. "Slope Erosion Control Using Fiberglass Roving and Reinforced Paper Matting With Grass," Warn, G. F.; Egan, J.; Wagner, M.; Howell, R. B.; Caltrans Report No. CA-TL-7108-78-10, March 1978.

4. 16mm Film entitled "Control of Ditch Erosion Using Fiberglass Roving," produced by Caltrans and FHWA under a Type B Study, June 1977.

5. "Design of Stable Channels With Flexible Linings," Hydraulics Branch, Bridge Division, Federal Highway Administration, October 1975.

APPENDIX

GUIDE SPECIFICATIONS

FIBERGLASS ROVING FOR SLOPES

Description

This work shall consist of furnishing and installing fiberglass roving and asphaltic material for stabilization of soils on slopes where shown on the plans or as directed by the engineer.

Materials

Fiberglass Roving: The material shall be formed from continuous fibers drawn from molten glass, coated with a chrome-complex sizing compound; collected into strands and lightly bound together into roving without the use of clay, starch, or like deleterious substances. The roving shall be wound into a cylindrical package approximately one foot high in such a manner that the roving can be continuously fed from the center of the package through an ejector driven by compressed air and expanded into a mat of glass fibers on the soil surface. The material shall contain no petroleum solvents or other agents known to be toxic to plant or animal life.

The fiberglass roving shall conform to the following:

Property	Limits	Test Method
Fiber Diameter, in.	0.00035-0.00053	ASTM D 578
Yards/lb. of Rove	170-300	ASTM D 578
Organic Content, percent max.	1.65	ASTM D 578
Package Weight, lbs.	30-45	ASTM D 578

Asphalt Material: Asphalt shall be either an approved asphalt cement or an approved emulsified asphalt.

Construction Requirements

Fiberglass roving shall be applied starting at the top of slope and progressing to the bottom of the slope over the designated area within 24 hours after normal seeding and fertilizing operations have been completed. Fiberglass roving shall be spread uniformly over the designated area to form a random mat of continuous glass fibers. The exact rate of application shall be determined by the engineer.

Fiberglass roving shall be anchored to the ground with asphaltic material applied uniformly over the glass fibers at the rate of ____ to ____ gallons per square yard or as directed by the engineer.

The upgrade end of the mat shall be buried to a depth of 6"-8" to prevent undermining. The above instructions for slope protection may be varied by the engineer to fit field conditions.

Maintenance and Repair

The mat shall be repaired immediately, if damaged due to the contractor's operations. Soil in damaged areas shall be restroed to original grade, refertilized and reseeded if originally specified, all at no additional cost to the State.

Equipment

Equipment shall include:

1. Pneumatic ejector capable of applying fiberglass roving at the rate of 2 pounds per minute (approximately 8 square yards per minute).

2. Air compressor capable of supplying 40 -100 cfm at 60 psi measured at the nozzle. Acceptable air hoses necessary for supplying air to areas not accessible to the compressor.

3. Approved asphaltic material distributor with necessary hoses and hand spray bar for working on slopes and other areas not accessible to the distributor.

Measurement

Fiberglass roving will be measured by the pound, and the quantity to be measured will be that actually used on the project.

Asphalt cement or emulsified asphalt will be measured by the gallon at the temperature of 60°F, in accordance with temperature volume correction. The quantity of asphalt to be measured will be that actually used on the project.

Payment

The accepted quantities of fiberglass roving and asphalt material will be paid for at the respective contract unit prices.

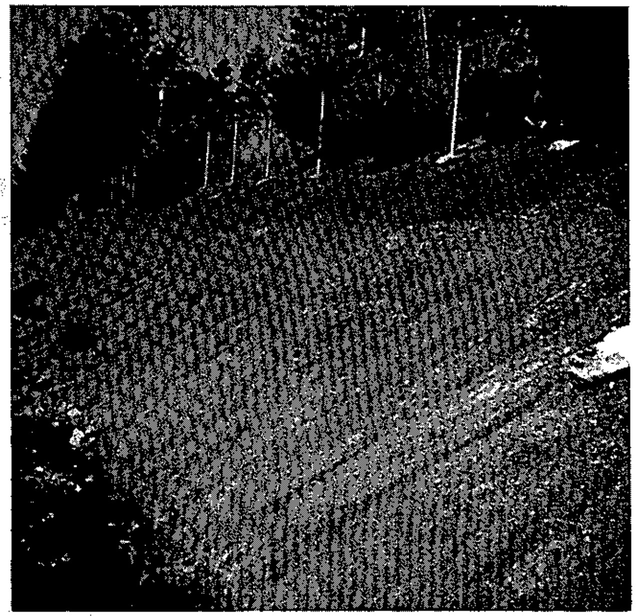

Plate 9 Eroded Cut Slope Before
Treatment November 1, 1977

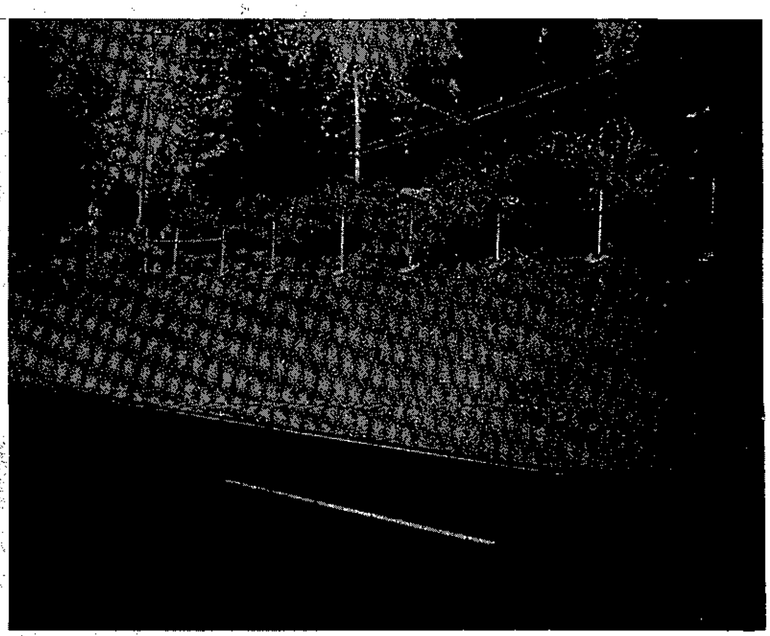

Plate 10 Eroded Cut Slope Before
Treatment

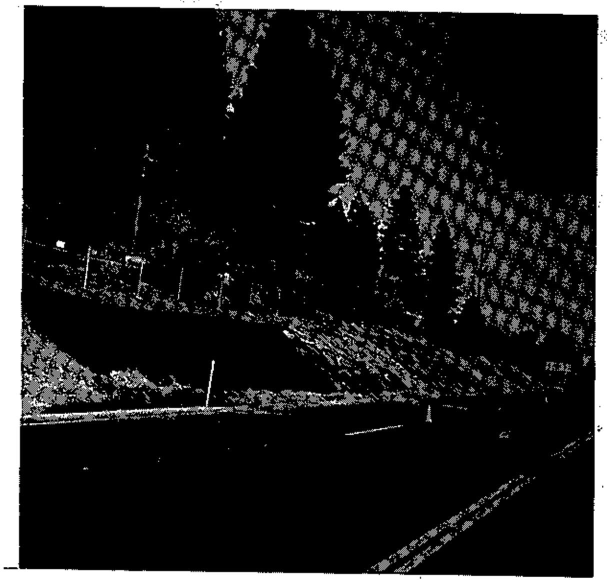

Plate 11 Slope Immediately After Treatment
November 2, 1977

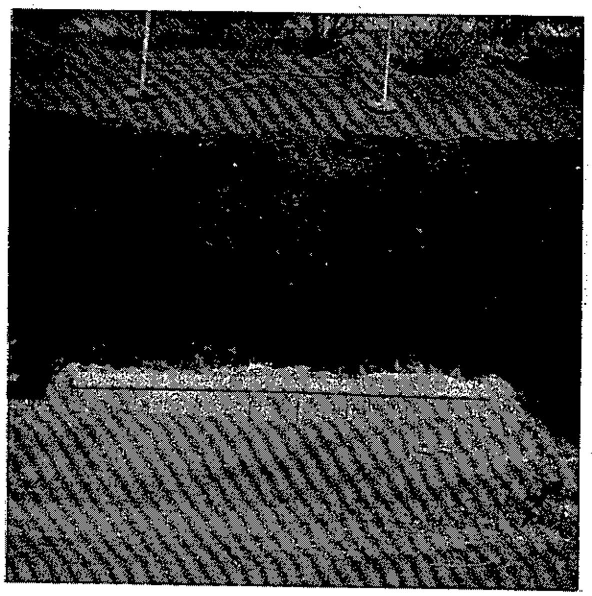

Plate 12 Fiberglass Roving Tacked With Asphalt Emulsion Above Sediment Collection Trough

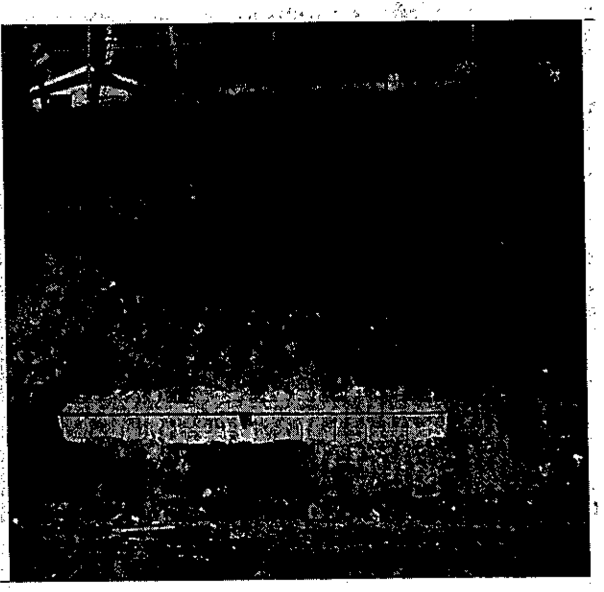

Plate 13 Control Section "A" With Sediment Collection Trough

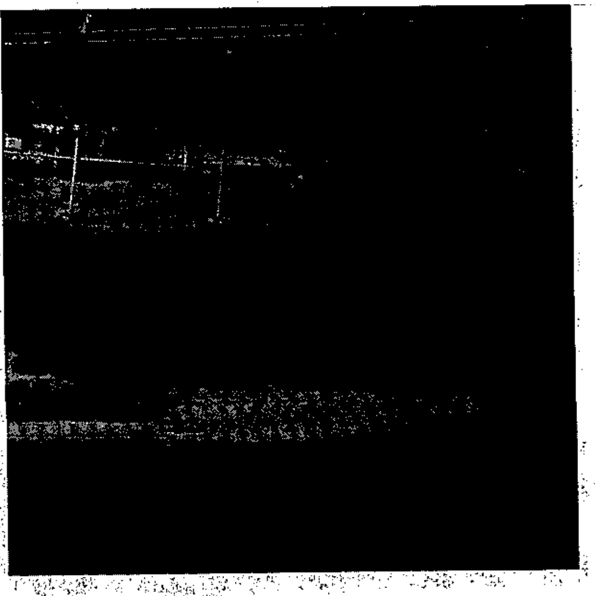

Plate 14 Section "B" Fiberglass Roving Tacked With Asphalt Emulsion

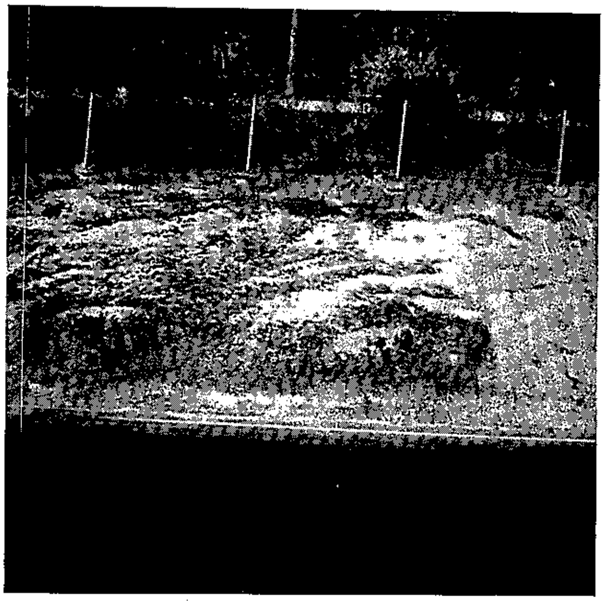

Plate 15 Section "C" Fiberglass Roving Tacked With Asphalt Covered With Sand

Plate 16 Section "D" Fiberglass Roving Tacked With Asphalt Covered With Native Soil

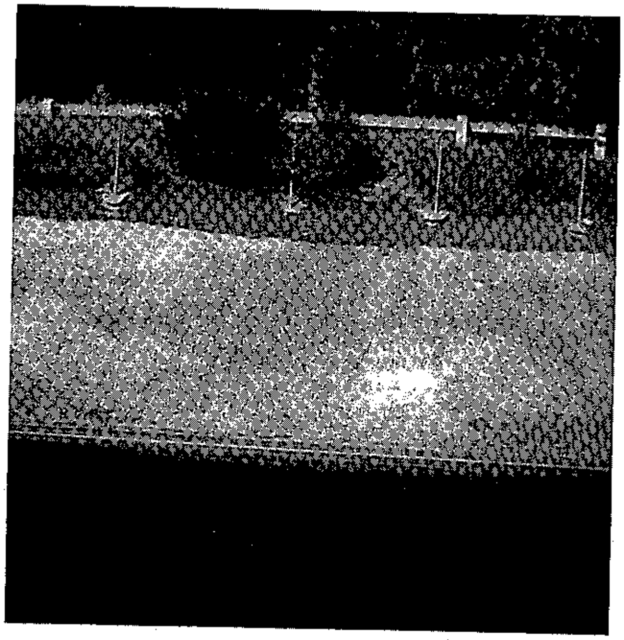

Plate 17 Section "E" Fiberglass Roving Tacked With Ecology Control M-Binder and Wood Fiber Mulch

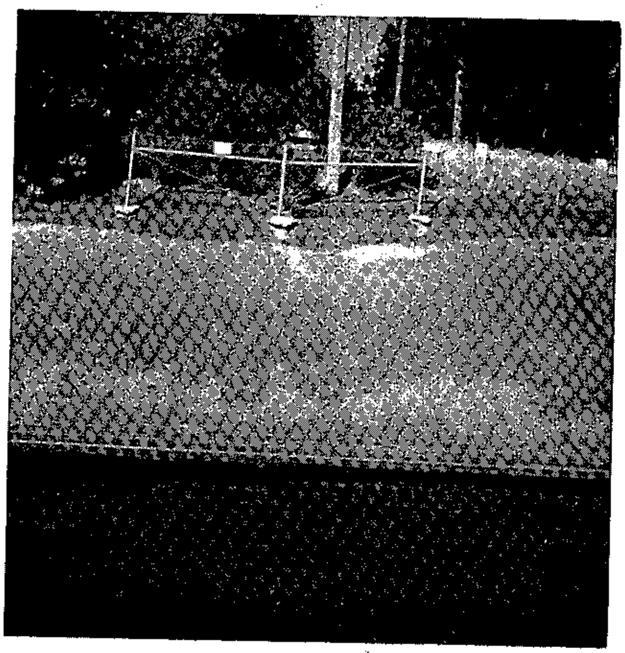

Plate 18 Section "F" Fibèrglass Roving Tacked With Terra Tack II and Wood Fiber Mulch

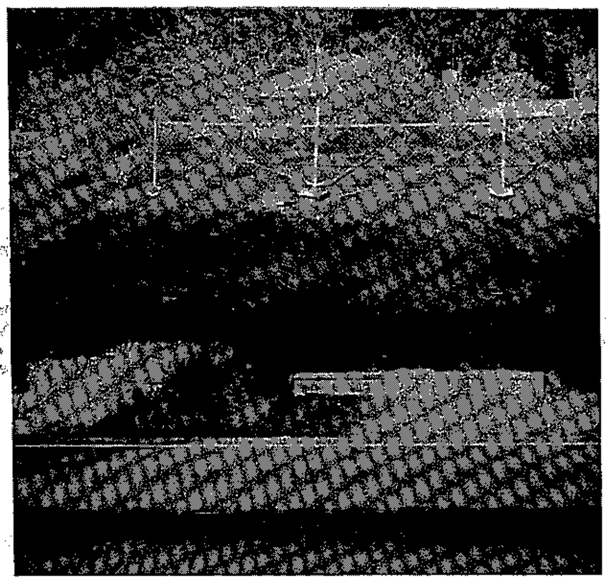

Plate 19 Section "B" 3 Months After Treatment February 1978

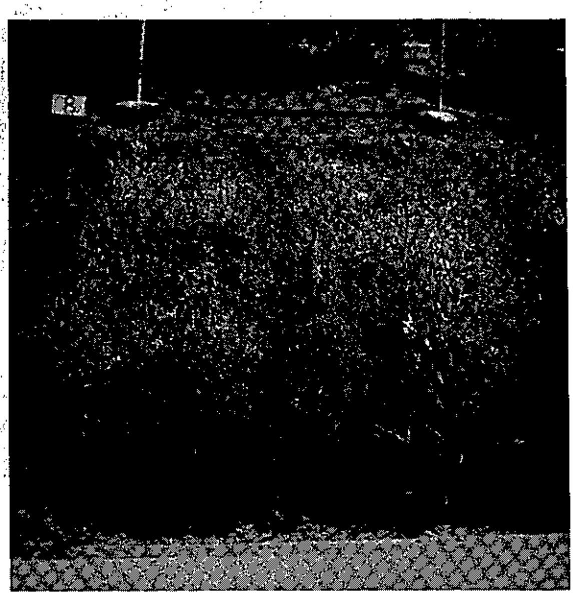

Plate 20 Section "B" 8 Months After Treatment June 1978

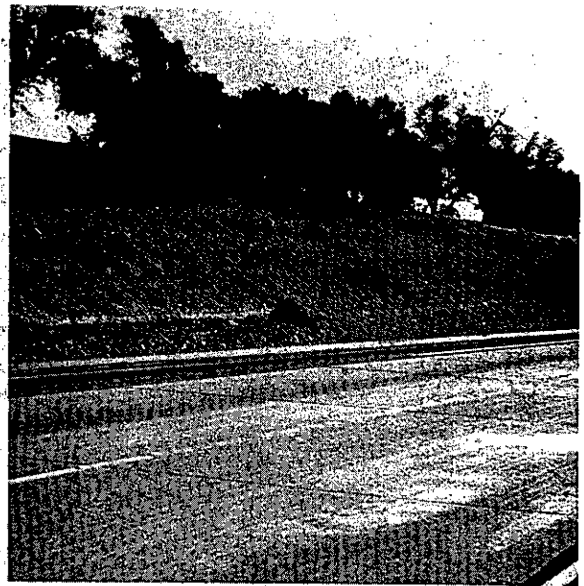

Plate 21 Cut Slope Before Treatment
January 10, 1978

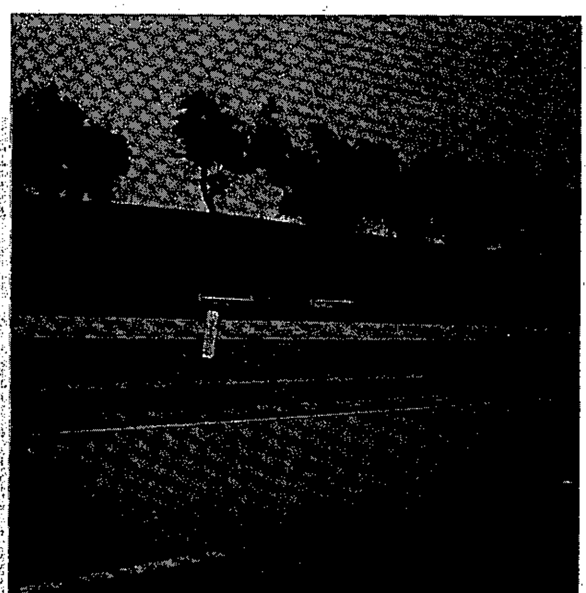

Plate 22 Cut Slope After Treatment
January 11, 1978

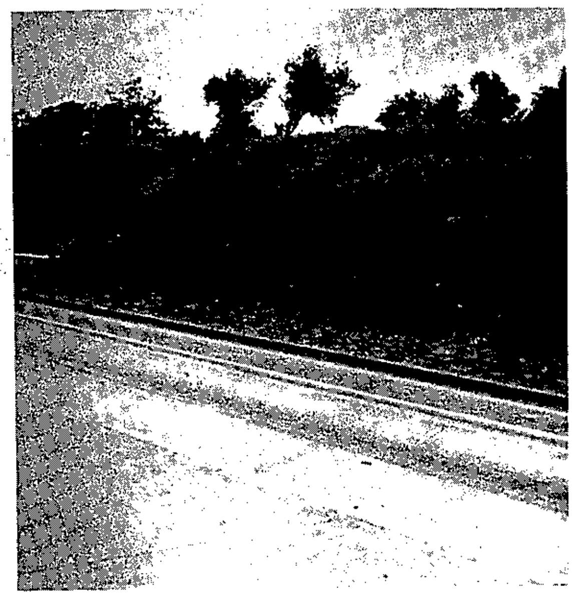

Plate 23 Cut Slope 13 Weeks After Treatment April 17, 1978

Plate 24 Cut Slope 20 Weeks After Treatment June 1 , 1978

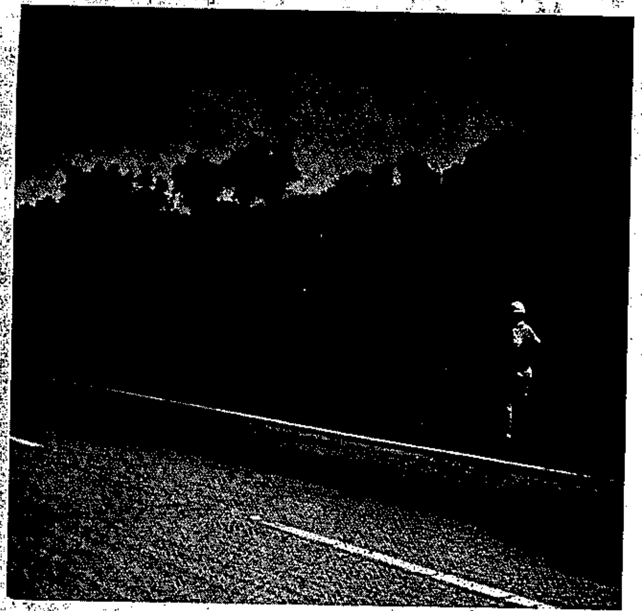

Plate 25

Cut Slope 24 weeks
after treatment,
June 30, 1978

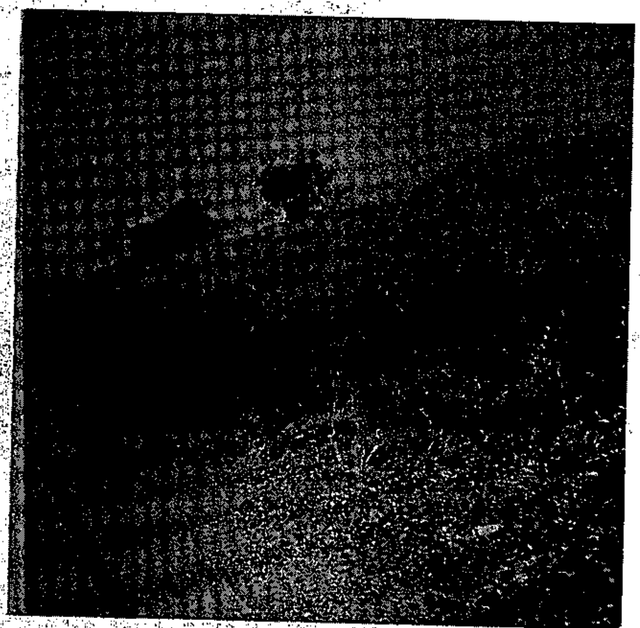

Plate 26

Cut Slope 24 Weeks
after treatment,
June 30, 1978

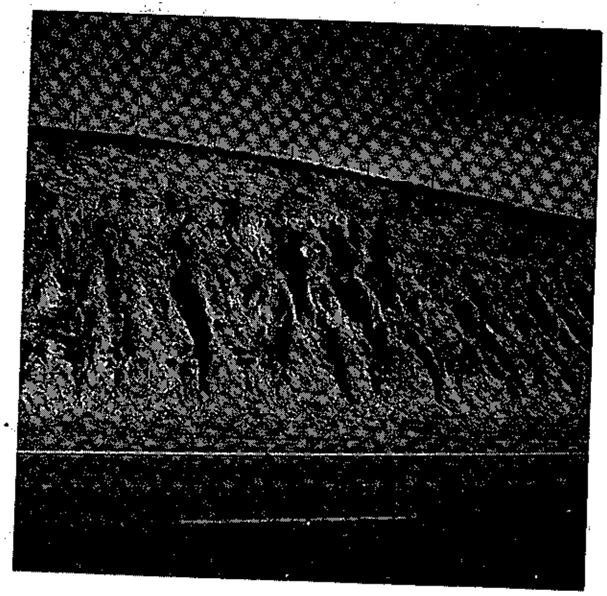

Plate 27 Cut Slope Before Treatment November 15, 1977

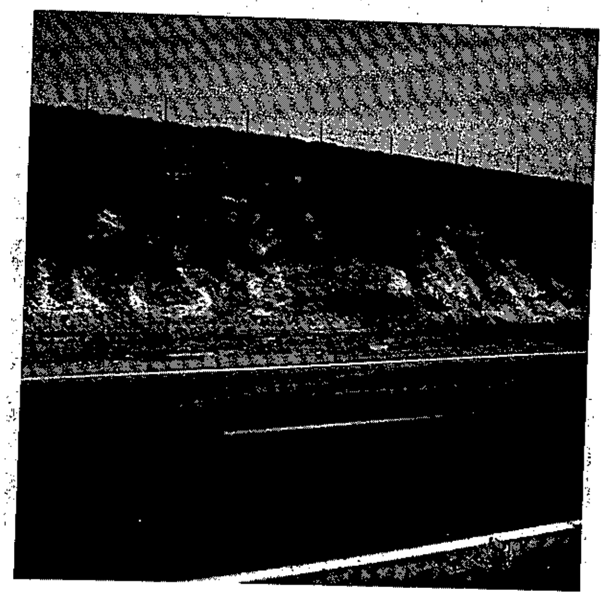

Plate 28 Cut Slope After Dressing Before Treatment November 15, 1977

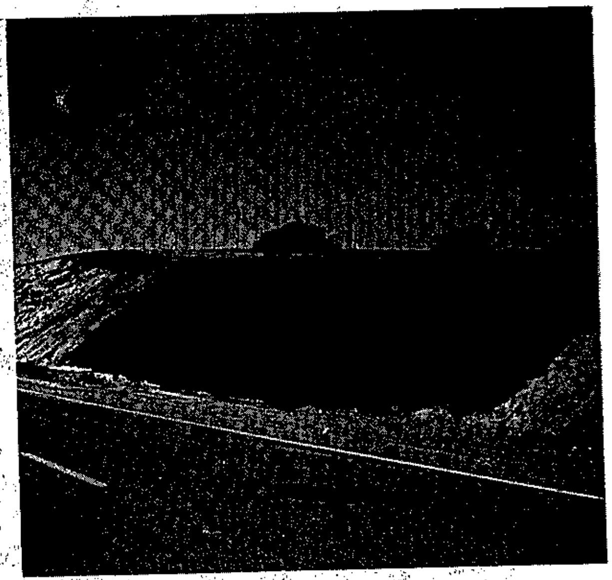

Plate 29 Cut Slope After Treatment
November 16, 1977

Plate 30 Cut Slope Showing 3 Test Sections
After Treatment November 16, 1977

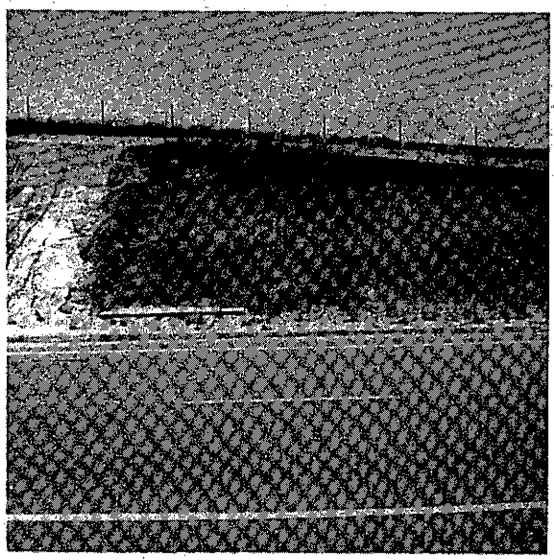

Plate 31 Cut Slope 28 Weeks After Treatment June 8, 1978

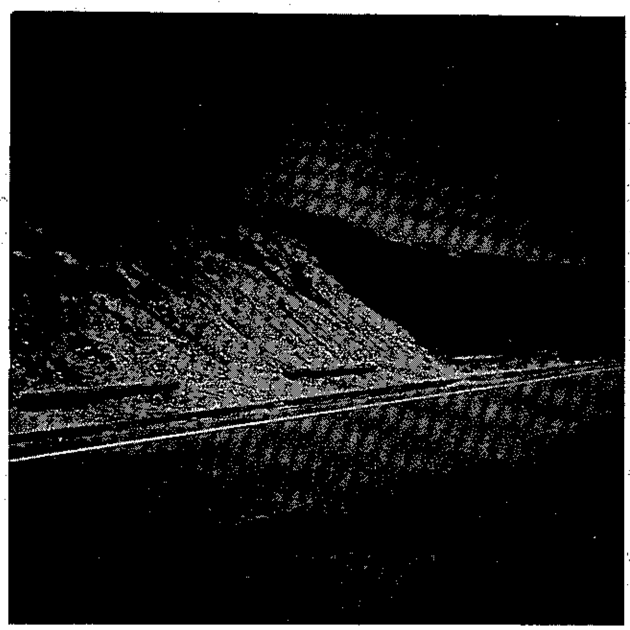

Plate 32 Cut Slope Showing 3 Test Sections After 28 Weeks June 8, 1978

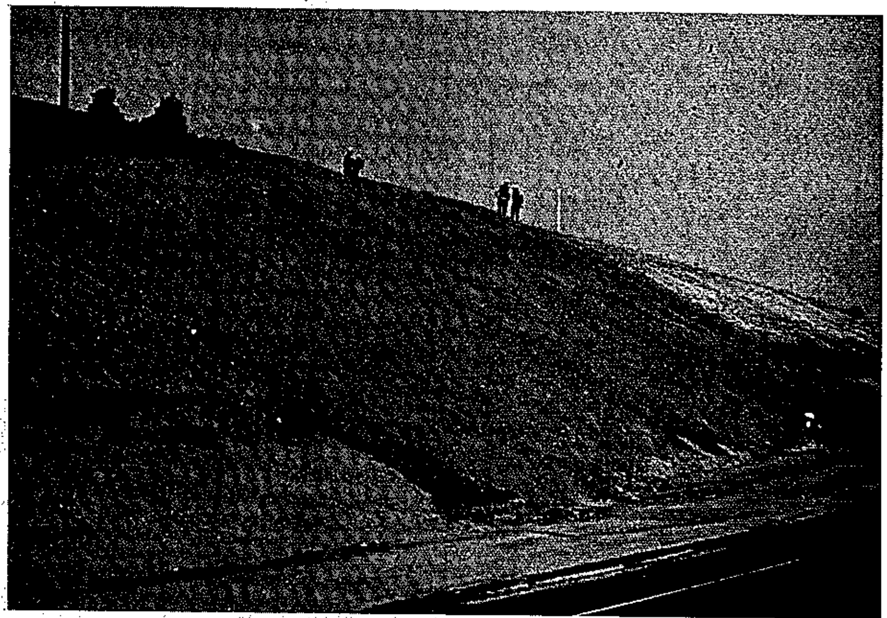

Plate 33 Cut Slope Before Treatment
October 18, 1976

Plate 34 Cut Slope Surface Showing Rills
Before Treatment October 18, 1976

Plate 35 Cut Slope After Dressing and Before Treatment October 18, 1976

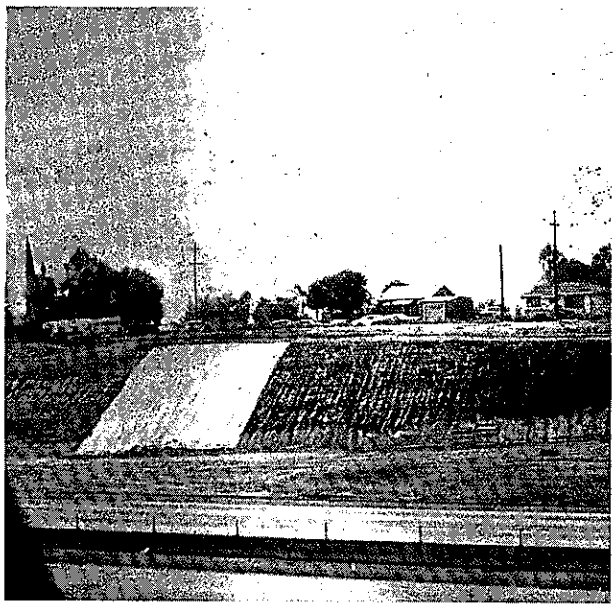

Plate 36 Cut Slope After Treatment October 19, 1976

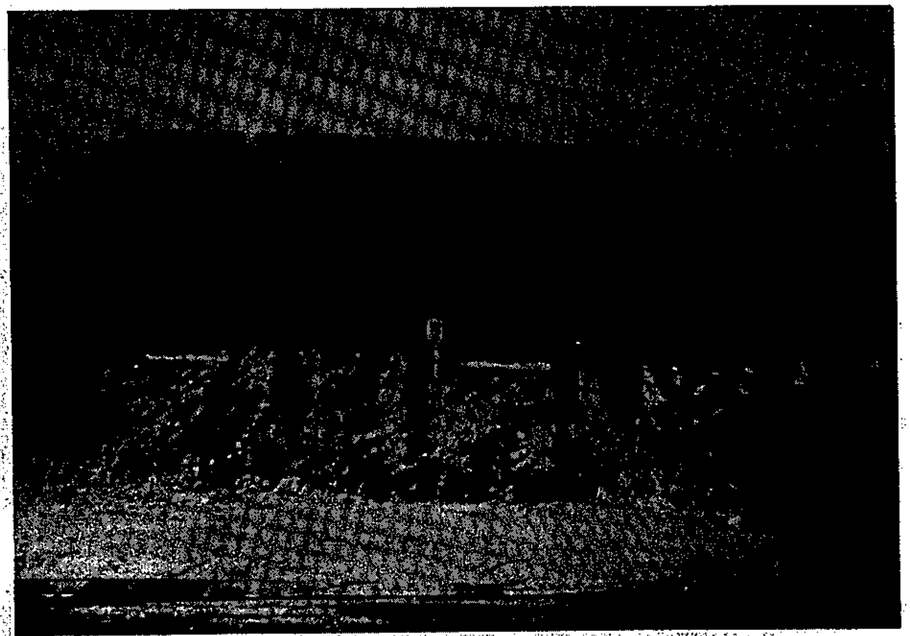

Plate 37 Cut Slope 6 months After Treatment April 20, 1977

Plate 38 Cut Slope Before Redressing

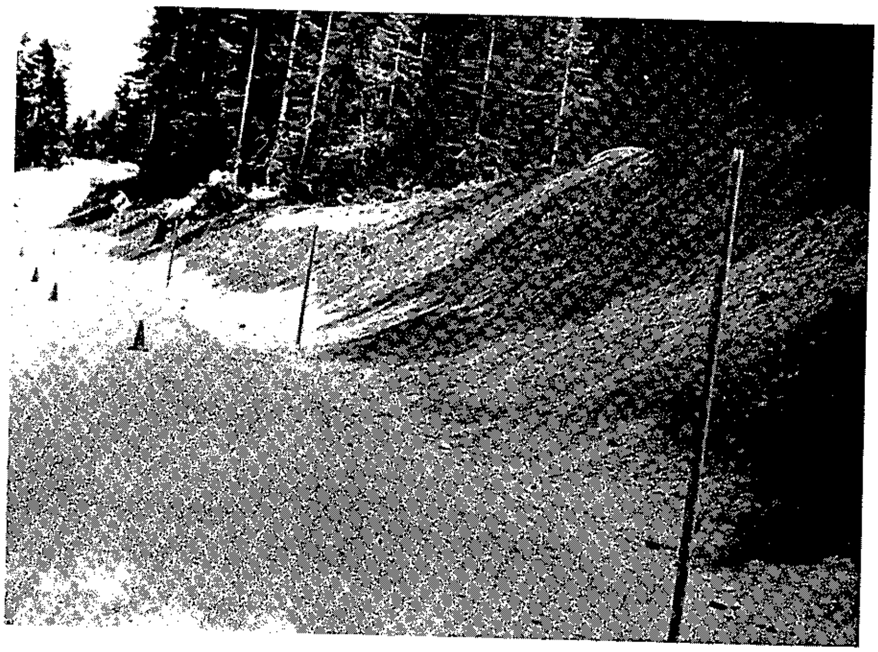

Plate 39 Cut Slope After Treatment
July 18, 1975

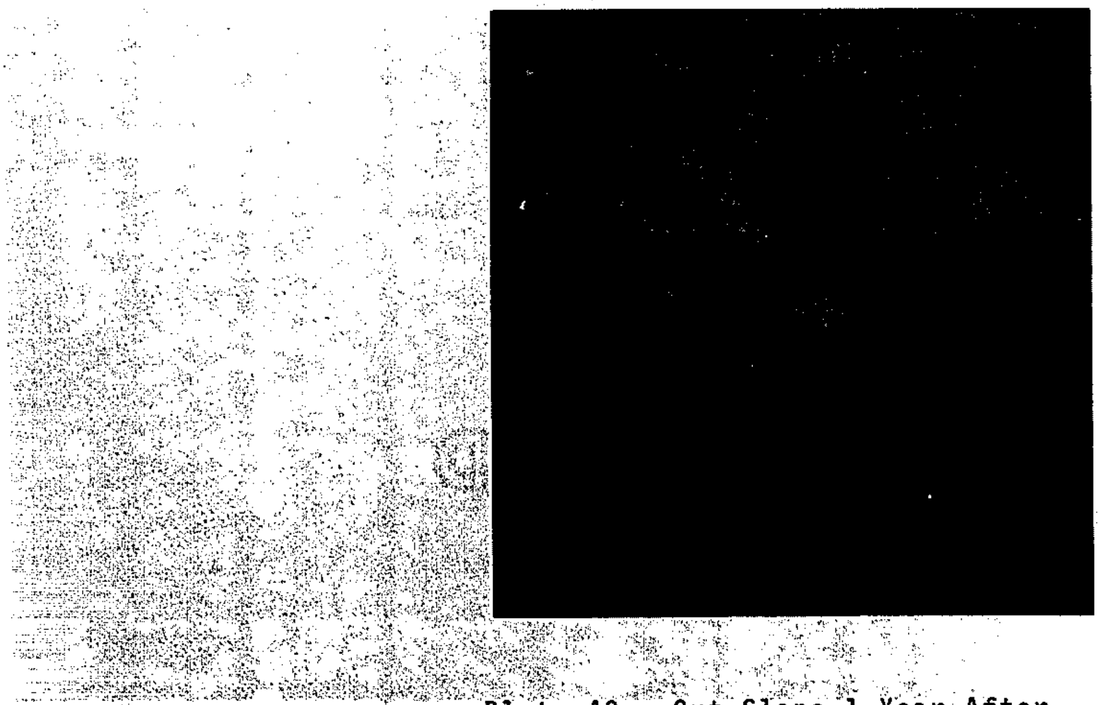

Plate 40 Cut Slope 1 Year After Treatment

Plate 41 Cut Slope 2+ years after Treatment

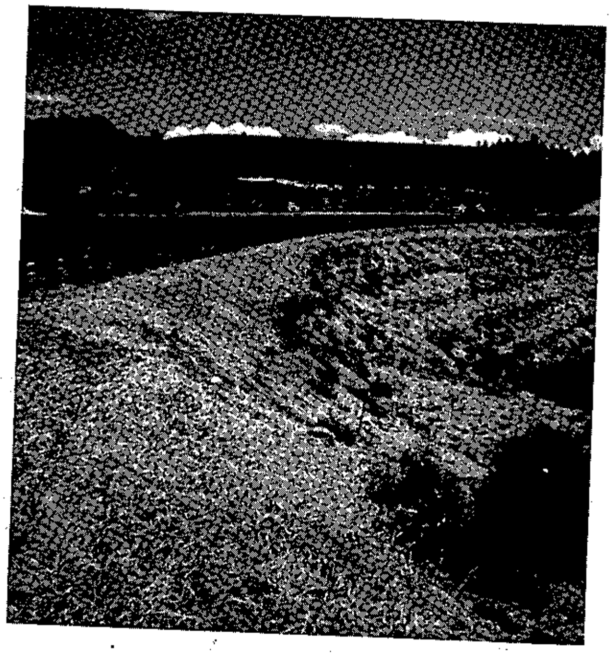

Plate 42 Fill Slope Before Treatment of Upper 25 Feet July 15, 1977

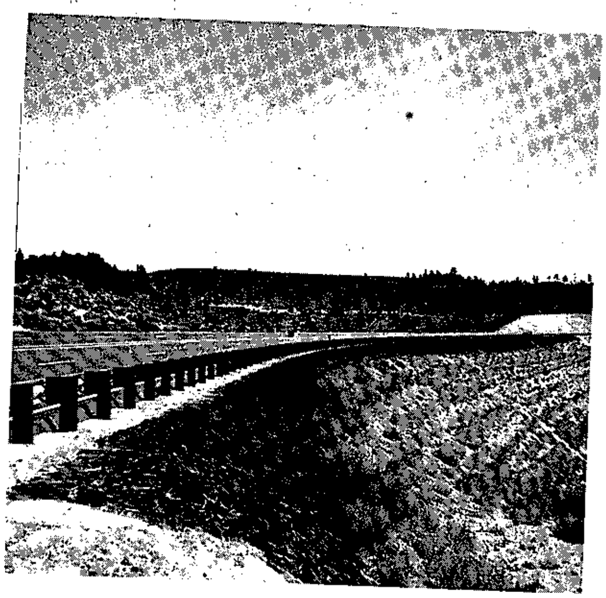

Plate 43 Fill Slope After Treatment of Upper 25 Feet September 13, 1977

09-Mon-395, P.M. 9.0, Sherwin Grade

Plate 44 Fill Slope, June 1978

Plate 45 Slope Before Treatment

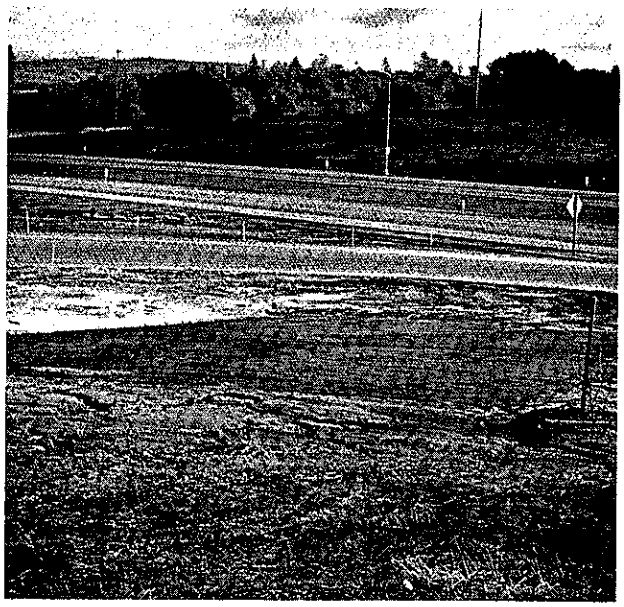

Plate 46 Slope After Treatment, October 19, 1973

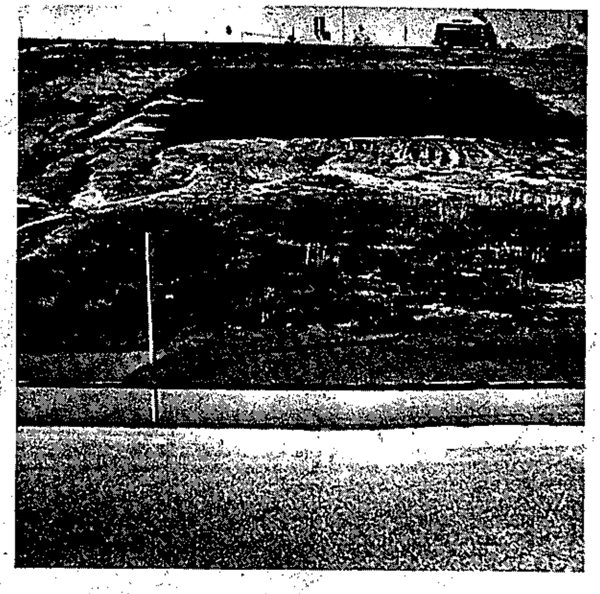

Plate 47 Slope 8 Months After Treatment

APPEARANCE EVALUATION

"Control of Slope Erosion Using Fiberglass Roving"

F-5-18 Type B Study

657293

Transportation Laboratory

EVALUATOR ______________________ Date ____________

ORGANIZATION ______________________ Time ____________

I AESTHETICS - Please rate each plot as to its appearance.

Plot "A" 0 1 2 3 4 5 6 7 8 9 10
Poor Excellent

Comment ______________________

____

Plot "B" - 0 1 2 3 4 5 6 7 8 9 10
Poor Excellent

Comment ______________________

____

Plot"C" - 0 1 2 3 4 5 6 7 8 9 10
Poor Excellent

Comment ______________________

____

Plot "D" - 0 1 2 3 4 5 6 7 8 9 10
Poor Excellent

Comment ______________________

____

Plot "E" - 0 1 2 3 4 5 6 7 8 9 10
Poor Excellent

Comment ______________________

____

Plot "F" - 0 1 2 3 4 5 6 7 8 9 10
Poor Excellent

Comment ______________________

____

II VEGETATION - please rate each plot according to vegetative take:

A- is vegetation emerging in

Plot		Yes	No
Plot	A	☐	☐
"	B	☐	☐
"	C	☐	☐
"	D	☐	☐
"	E	☐	☐
"	F	☐	☐

Comments ____

____

B- Is growth:

Plot	Scarce	Average	Abundant
A	☐	☐	☐
B	☐	☐	☐
C	☐	☐	☐
D	☐	☐	☐
E	☐	☐	☐
F	☐	☐	☐

Comments ____

____

C- Does the vegetation appear uniform or bunched:

Plot	Uniform	Non uniform
A	☐	☐
B	☐	☐
C	☐	☐
D	☐	☐
E	☐	☐
F	☐	☐

Comments ____

____

III Other comments ____

____

____