DISTRICT 7
EROSION CONTROL
PILOT STUDY

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INTRODUCTION

The objective of the Erosion Control Pilot study was to evaluate alternative soil stabilization methods designed to minimize the transport of sediment from cut and fill slopes within Caltrans District 7 rights-of-way to storm drain inlets in District 7. The basic assumptions of the pilot study were: (1) that erosion of cut and fill slopes within Caltrans rights-of-way is a significant source of sediment being transported to, accumulating in, and being discharged from storm drains; and (2) that erosion of slopes can be reduced by increasing the percentage of cover on cut and fill slopes to provide protection of the soil from wind and water.

The pilot study employed a systematic approach to identify alternative permanent soil stabilization methods to minimize sediment transport. The identification of potentially effective erosion control measures and practices took into account previous and ongoing studies by Caltrans and others.

The purpose of this final report is to provide an assessment of the effectiveness of the alternative tested permanent soil stabilization methods for geographic and climatic conditions encountered in Caltrans District 7, plus their associated costs. This assessment was performed through a series of field and laboratory tests that were carried out over a two-year period. The field and laboratory testing program was designed to evaluate the soil, rainfall, and vegetation conditions in Caltrans District 7.

Caltrans assembled a team of erosion control specialists to design and implement the ECPS, consisting of the following university and consulting professionals:

- Caltrans Environmental Program
- University of California – Davis
- URS Greiner Woodward Clyde (URS)
- Martha Blane & Associates
- Mike Harding, Great Circle International
- Dr. Mark Andersen, New Mexico State University
- Dr. Howard Chang, San Diego State University

URS provided consulting services related to the majority of ECPS activities related to overall project design, planning, and management; technical implementation; field monitoring; data review and analysis; and report writing. Mike Harding of Great Circle International directed the design and construction of the rainfall simulation facility at the Soil Erosion Research Laboratory at San Diego State University, as well as laboratory monitoring and outdoor myoporum testing. Martha Blane & Associates provided specialized expertise in native plants for purposes of the study design, field monitoring QA/QC, and data interpretation. Dr. Mark Andersen conducted the statistical analyses and interpretation of the data.

The team was guided throughout the course of the study by a Technical Advisory Group (TAG) that included participants from:

- Caltrans Headquarters
- Caltrans District 7

- Cal Poly - San Luis Obispo
- Texas Transportation Institute
- Utah Water Research Laboratory
- Colorado State University
- Purdue University

This report is presented in an order that generally parallels the "life cycle" of a slope from a newly-constructed bare cut or fill slope to a self-sustaining, permanent slope stabilized with mature, established vegetation. The field and laboratory-tests discussed in the report include:

- Laboratory evaluation of 5 soil roughness techniques on erosion rate and runoff on bare soil using simulated rainfall (e.g., newly constructed slope);
- Laboratory evaluation of erosion rate and water quality for 15 soil stabilization techniques plus bare soil using simulated rainfall (e.g., a newly constructed slope);
- Field evaluation of the effectiveness of these same 15 soil stabilization techniques plus bare soil on native plant establishment under both natural rainfall and irrigated cut and fill highway slope conditions (e.g., slope with newly planted to a 2-year old vegetation);
- Outdoor laboratory evaluation of the effect of increasing plant cover on erosion rate for one vegetation type using simulated rainfall (e.g., slope with vegetation in the process of growing to maturity); and
- Field evaluation of erosion rate and runoff for four vegetation types plus bare soil on cut and fill highway slopes plus one vegetation type on an highway undisturbed site (e.g., permanent slope with mature, established vegetation).

Although not specifically designed as a "life cycle" study, each section of the report presents data and comparative testing results that provide useful insights that are applicable to the slope stage addressed in the section.

The soil stabilization measures evaluated herein may be used to stabilize temporary construction slopes. However, since the focus of the study is on permanent slope stabilization, the soil stabilization measures were evaluated in the context of their use for permanent slope stabilization. Their role as such is twofold: (1) to enhance the establishment of the permanent vegetation; and, (2) to provide interim soil stabilization until the permanent vegetation is controlling erosion effectively.

EVALUATION OF SLOPE ROUGHNESS

Soil roughening is the creation of a soil surface roughness by mechanical means. Typically, the roughening is performed parallel to the slope contours and perpendicular to the direction of runoff. The benefits provided by soil roughening are too slow runoff, enhance infiltration, moderate soil temperature, trap moisture, and enhance seed germination and root penetration.

The slope roughness is complementary to most soil stabilization techniques, such as the hydraulic mulch evaluated herein, which can be applied over the surface roughness treatment.

The surface roughness provides a permanent slope surface configuration that works in conjunction with the short-term soil stabilization and permanent vegetation to provide an effective erosion control system.

Five surface roughness techniques were evaluated as part of this study: smooth-rolled, sheepsfoot-rolled, ripped, trackwalked, and imprinted. The results are presented in Section 4, and summarized in Section 9. By far, the technique that was the most effective in reducing erosion was imprinting. This was followed (in order) by sheepsfoot-rolling, trackwalking, ripping, and smooth-rolling.

EVALUATION OF TEMPORARY IRRIGATION

From examination of the study data, temporary irrigation has an initial positive effect on coastal sage scrub germination. This also applies to non-native vegetation. By spring of the first year, the effect of higher plant densities is no longer discernable between the irrigated and non-irrigated plots. In the long-term, initial irrigation shows no benefit to plant density.

Additionally, irrigation has no discernable effect on total cover after the first year. Therefore, there does not appear to any short-term cover benefit to applying temporary irrigation.

COLLECTIVE EVALUATION OF 15 SOIL STABILIZATION MEASURES

The results of the erosion rate and water quality tests and plant establishment testing for the 15 soil stabilization measures and are presented in Sections 5 and 6, respectively.

In order to develop a relative ranking of the 15 soil stabilization treatment techniques, a rating system was developed for each of the parameters that were evaluated in this study. Each of the 15 treatments was provided a rating for erosion rate and total cover after two years based on the results of the ECPS testing program.

To develop an overall ranking of the 15 soil stabilization measures, the criteria were given equal weighting. Each alternative was evaluated with respect to how it performed during the testing for each evaluation criteria, and given a numerical rating. The ratings were then totaled for each alternative, resulting in an overall numerical rating value for each alternative. This numerical rating was then converted to a relative ranking of the alternatives. The overall ranking matrices are shown on Tables 9-4 through 9-7 for non-irrigated fill, irrigated fill, non-irrigated cut, and irrigated cut slopes, respectively. Two additional criteria, water quality and native plant establishment were evaluated in a non-numerical way and are provided on the treatment ranking tables. Also shown on Tables 9-4 through 9-7 is an estimate of the installed cost for each alternative in dollars per hectare.

Additional Selection Criteria

The treatments in this study were ranked in accordance with the criteria that were evaluated as part of the ECPS testing program, as described above. However, there is other more subjective evaluation criteria that may be considered when selecting an appropriate erosion control measure for a given set of site conditions. Examples of other selection criteria include soil stabilization performance during vegetation grow-in period, long-term cost (maintenance), environmental compatibility, regulatory acceptability, availability, durability, longevity, feasibility, public acceptability, risk/liability, and suitability for the site.

OVERALL EVALUATION OF PLANT COVER TESTS

The value of the outdoor laboratory myoporum tests is to gain an understanding of how erosion rate varies with plant cover. This is important because vegetation takes time to grow to a degree where it can provide effective erosion control, and other erosion control measures should be provided until that effectiveness is achieved. The data from this study show that the erosion rate drops dramatically from 35 percent to 65 percent covers, and then tends to reduce more gradually or level off with increased cover.

OVERALL EVALUATION OF FIELD EROSION RATE TESTS

The value of the field erosion rate tests is in comparing non-irrigated grass/forb complex, irrigated myoporum, irrigated iceplant, and non-irrigated coastal sage scrub vegetation types in terms of their relative erosion control effectiveness at 95 to 100 percent cover on highway cut and fill slopes. The results of that evaluation showed that the non-irrigated coastal sage scrub and the irrigated iceplant were the most effective at controlling erosion on both cut and fill slopes. Myoporum ranked next in effectiveness. The least effective vegetation type was grass/forb.

Interestingly, three types of vegetation (coastal sage scrub, iceplant, and myoporum) on cut slopes and two types of vegetation (iceplant and coastal sage scrub) on fill slopes exhibited the same or less erosion than off-highway, undisturbed coastal sage scrub.

1.1 PURPOSE AND ORGANIZATION OF FINAL REPORT

The purpose of the Final Report is to present the results of the two year Erosion Control Pilot Study (ECPS). The ECPS has involved extensive field and laboratory studies that had the overall objective of evaluating alternative permanent soil stabilization methods for Caltrans District 7, (District 7) rights-of-way. The details regarding design, operation, and maintenance of the overall study, as well as the field test plots and laboratory facilities have been described in several other reports developed over the course of the study by URS Greiner Woodward Clyde (URS). These reports include:

- *Detailed Study Plan & Experimental Design,* dated May 15, 1998;
- *Training Manual*, dated November, 1998 – May, 2000;
- *Construction and Monitoring of Field Test Plots*, dated April 9, 1999;
- *Laboratory Manual: Soil Erosion Laboratory and Outdoor Test Plots*, San Diego State University, dated February 18, 2000; and
- *Operation and Maintenance Manual:* San Diego State University Soil Erosion Research Laboratory, dated January 21, 2000.

This report summarizes much of the material presented in these previous reports, and presents the findings of individual components of this study. This report is organized as follows:

Section 1	Presents an overall introduction to, and description of, the study design for the ECPS;
Section 2	Describes construction and maintenance of the erosion rate, plant establishment, and outdoor laboratory field test plots and construction of the laboratory testing facility;
Section 3	Describes an overview of field monitoring, test procedures, and quality assurance/quality control (QA/QC) programs;
Section 4	Presents the results of the soil roughness data collected from the Soil Erosion Research Laboratory tests;
Section 5	Presents the results of the erosion rate and water quality tests from the Soil Erosion Research Laboratory tests as well as some related tests conducted at the Texas Transportation Institute (TTI); and topsoil and mycorrhizal inoculation studies.
Section 6	Presents the results of the monitoring data collected from the plant establishment test plots;
Section 7	Presents the results of the monitoring data collected from the outdoor laboratory prostrate myoporum (*Myoporum pacificum)* test plots;
Section 8	Presents the results of monitoring data collected from the erosion rate test plots; and
Section 9	Presents an overall ranking of the individual control measures tested in this study.

The order in which Sections 4 through 8 are presented generally follow a progression from a newly-constructed bare slope through a self-sustaining slope that is stabilized with mature, established vegetation. Sections 4 and 5 address the application and erosion control effectiveness of soil roughening and soil stabilization products on a newly-constructed slope, which are two important first steps in the establishment of permanent erosion control vegetation. Section 6 addresses the effectiveness of alternative erosion control products in enhancing the germination and establishment of plants on the slope. Section 7 evaluates erosion control effectiveness through time as the vegetation grows to increasing plant cover percentages. Finally, in Section 8, the erosion control effectiveness of several mature, permanent plant types is compared.

Although the studies were conducted both in the laboratory and in the field, under both natural and simulated rainfall conditions, and using different slope and soil types, they provide insights into the use of erosion control techniques and products applicable to various stages in the "life-cycle" of a slope. Because the study (as outlined in the *Detailed Study Plan*) was not originally designed specifically as a "life-cycle" study, the reader should not assume direct connections between the sections of this report (e.g., the erosion rate results for mature vegetation reported in Section 8 are not the direct result of applying any of the specific methods discussed in previous sections of this report.). However, each section, considered independently, provides valuable data and comparative testing results that may provide useful insights when applied during the particular stage in a slope's life-cycle that was simulated in the test.

1.2 BACKGROUND AND STUDY OBJECTIVES

The ECPS is one of many ongoing programs undertaken by Caltrans to find ways to minimize the amount of sediment and other pollutants entering their highway storm drain systems. A basic assumption of the pilot study was that slope erosion can be reduced by increasing the vegetation cover to provide protection of the soil from wind and water. Therefore, the ECPS focused on evaluating alternative permanent soil stabilization methods for reducing erosion on cut and fill slopes in District 7. To test this assumption and to evaluate the effectiveness of alternative permanent stabilization methods, an experimental testing program was designed that included: a field-testing program designed to assess the effectiveness of different erosion control practices under actual District 7 slope, soil, and climatic conditions; and a laboratory testing program designed to assess the effectiveness of different erosion control treatments and slope roughnesses under a wide range of rainfall conditions likely to occur in District 7, some of which might not occur in the field during the study period, utilizing a rainfall simulator. The laboratory testing program was also designed to evaluate the effect of the tested erosion control treatments on water quality.

Caltrans assembled a team of university representatives and consultants to assist the Caltrans Environmental Program in the design and implementation of the ECPS, including:

- University of California – Davis
- URS Greiner Woodward Clyde (URS)
- Martha Blane & Associates
- Mike Harding, Great Circle International
- Dr. Mark Andersen, New Mexico State University
- Dr. Howard Chang, San Diego State University

URS has directed the overall study including project design, planning, and management; technical implementation; field monitoring; data review and analysis; and report writing. Great Circle International directed the design and construction of the rainfall simulators at the Soil Erosion Research facility at San Diego State University, as well as laboratory monitoring and outdoor myoporum testing. Martha Blane & Associates provided specialized expertise in native plants for purposes of the study design, field monitoring QA/QC, and data interpretation. Dr. Mark Andersen conducted the statistical manipulations and interpretation of the data.

In addition, the team was guided by a Technical Advisory Group (TAG) which included:

- Caltrans Headquarters
- Caltrans District 7
- Cal Poly - San Luis Obispo
- Texas Transportation Institute
- Utah Water Research Laboratory
- Colorado State University
- Purdue University

1.3 STUDY DESIGN

The development of the overall pilot study design is described in the *Detailed Study Plan & Experimental Design* (Woodward-Clyde, 1998). A Technical Advisory Group assembled by Caltrans reviewed, provided input to, and approved, the *Detailed Study Plan.* The *Detailed Study Plan* describes the systematic approach that was used to identify both existing erosion problems in District 7, as well as erosion control practices that could be effective in reducing sediment discharges to the storm water drainage systems. The nine steps of the study design process were as follows:

Step 1. Identify existing erosion problems within District 7;
Step 2. Evaluate erosion control practices of Caltrans and other state or federal agencies;
Step 3. Evaluate the findings of field and laboratory tests conducted by others;
Step 4. Identify data gaps and define the scope of the pilot study;
Step 5. Nominate and select candidate measures and practices for evaluation;
Step 6. Design an experimental testing program;
Step 7. Estimate the cost, time, and staffing needs for the experimental program;
Step 8. Evaluate the selected alternative soil stabilization methods and practices; and
Step 9. Summarize the results of the pilot study in a final report.

Steps 1 through 6 of this study design process are summarized below to provide a context for understanding the results that are reported in subsequent sections.

1.3.1 Identify Existing Problems (Step 1)

The first step in the study design process was to identify existing erosion problems that could be mitigated by improved soil stabilization techniques within District 7. This was accomplished through interviews with Caltrans personnel, a review of relevant Caltrans studies, and systematic field observations.

1.3.1.1 Structured Interviews

Interviews were conducted between November 11, 1997 and January 13, 1998 with District 7 planning and design, construction, and maintenance staff. During the interviews, Caltrans staff identified a number of factors that have contributed to erosion and sedimentation problems in District 7 that included:

- Lack of vegetative cover on soil;
- Erodible soil type; and
- Slope steepness.

Less widespread, but locally important factors that were identified by District 7 staff as contributing to erosion included: inadequate drainage design; groundwater intrusion causing deep gullying; inadequate or uncontrolled irrigation due to vandalism of irrigation equipment; gopher-related slope damage; poor compaction of embankment slopes resulting in slope instability; and inappropriate slope steepness given the soil type.

1.3.1.2 Relevant Caltrans Erosion-Related Studies

A number of Caltrans erosion-related study plans and reports were reviewed, with a twofold purpose: (1) to evaluate the scope of the other studies to prevent overlap; and (2) to identify data and results from the other studies pertinent to the ECPS.

Recently completed District 7 erosion and sedimentation studies were reviewed (*Drain Inlet Monitoring Report and Effectiveness Assessment, Caltrans District 7*, prepared by Woodward-Clyde, 1997; *Drain Inlet Sediment Sampling Program, Caltrans District 7*, prepared by Camp Dresser & McKee, 1997; *California Roadsides, A New Perspective*, prepared by Jones & Stokes Associates, 1997; and *Statewide Roadside Erosion Review* prepared by Brown & Caldwell), as well as ongoing erosion and sedimentation studies of relevance to District 7 (*Erosion Control Effectiveness Study* by Kinnetic Labs, Inc.; *BMP Retrofit Pilot Program* by Robert Bein, William Frost & Associates; and *Solids Transport and Deposition Study* by Camp Dresser & McKee).

1.3.1.3 Independent Field Observations

Systematic field observations were made of typical erosion problems and erosion control measures currently in place on cut and fill slopes and at-grade roadsides and medians within and adjacent to District 7 rights-of-way.

Observations of erosion and sedimentation problems were made and documented on virtually all the freeway rights-of-way in the Los Angeles coastal area (i.e., non-mountain, non-desert) of District 7. To facilitate the identification of trends in erosion problems, field data were compiled into a Microsoft Access™ database.

1.3.1.4 Consistent Erosion Problems

A number of consistent erosion problems were identified in District 7 during Step 1 of the study design process. Erosion resulting from poorly vegetated, steep, cut and fill slopes was identified as a significant source of sediment and became the design focus of the ECPS.

1.3.2 Evaluate Practices of Caltrans and Other Agencies (Step 2)

Selected state and Department of Transportation (DOT) erosion control programs were reviewed either because of their status as strong programs, or the similarity of certain climatic or physiographic conditions to District 7 conditions, or both. The selected programs reviewed were from Arizona DOT, Colorado DOT, State of Delaware, State of Maryland, Nevada DOT, New Mexico DOT, State of North Carolina, State of Oregon, Utah DOT, and Washington State DOT and Washington State Department of Ecology.

The Caltrans approach to the design of erosion control measures is generally consistent with the programs established by the other state agencies and DOTs that were reviewed in that: (1) there is an emphasis on vegetative solutions for erosion control; and (2) guidelines and/or standard specifications for both vegetative and non-vegetative erosion control measures are provided for reference by the designers and planners.

1.3.3 Evaluate Field and Laboratory Test Results (Step 3)

The third step in the study design process was to review the results of field and laboratory tests conducted by others and evaluate the findings for relevancy to the ECPS, and applicability in southern California. The evaluation of available information focused on its relevance to physiographic and climatic conditions similar to those found in District 7.

For this review, a bibliography was compiled of available published information, an Internet search was conducted for relevant erosion control information, and erosion test facilities were contacted for documentation of their testing programs.

1.3.3.1 Native Plant Establishment Techniques

All of the facilities that conduct comparative testing of erosion control products and technologies are located outside of California, and as a result, none of the plant species tested are native to southern California. Furthermore, the tests conducted by others did not simulate the climatic and physiographic conditions of southern California.

While valuable information is contained in the other studies reviewed, there are no directly parallel studies that provide information on the use of southern California native vegetation and ornamentals for erosion control on highway cut and fill slopes in the study area.

1.3.4 Identify Data Gaps and Define Pilot Study Scope (Step 4)

The fourth step in the study design process was to identify data gaps and define the scope of the pilot study based on the information gathered in the previous design steps. Our review of the current erosion control practices of Caltrans and other state and federal agencies, and our evaluation of the field and laboratory tests performed by others indicated that data gaps exist in three areas specifically related to District 7:

- Long-term erosion control effectiveness;
- Native plant establishment techniques; and
- Erosion rates.

1.3.4.1 Summary of Data Gaps

The following data gaps relevant to District 7 erosion control were identified that have not been adequately addressed in previous tests and were evaluated as part of this ECPS:

- A comparison of erosion rates for southern California highway cut and fill slopes that are currently well vegetated with native plants or ornamentals with erosion rates for bare slopes.
- Quantitative measurements of erosion rates for southern California non-highway slopes that are currently well vegetated with native plants.
- An assessment of erosion rates on steep (i.e., 1 V:2 H or steeper) slopes.
- An assessment of the effect of slope roughness on erosion rates.
- A comparison of erosion rates for slopes treated with straw mulch (applied with tackifier on cut slope surfaces, and applied by crimping on fill slopes) to erosion rates using other erosion control techniques.
- An assessment of plant establishment techniques for native southern California vegetation, including the use of mulches, compost, erosion control blankets, and temporary irrigation.
- An assessment of the effect of percent vegetation cover on erosion rates.
- An assessment of the effect of typical southern California rainfall intensities and durations on erosion rates.

1.3.4.2 Scope of Pilot Study

While not implicit in the pilot study definition, the Technical Advisory Group indicated that the overriding goal of this study was to identify methods for stabilizing highway slopes with well-covering, long-lasting vegetation. Therefore, the scope of the ECPS was to identify slope stabilization techniques that successfully establish vegetative cover in a short period of time, and reliably maintain the established cover on the steep cut and fill slopes in the study area, and thereby reduce erosion.

The scope of the pilot study also included conducting a review of relevant studies on the effects of topsoil and mycorrhizal inoculation on native plant establishment to expand upon the information obtained during the literature review conducted during Step 3 of the study design process.

1.3.5 Nominate and Select Candidate Measures for Evaluation (Step 5)

Once the data gaps and the scope of the pilot study had been identified in Step 4, the fifth step in the study design process was to nominate and then select candidate measures and practices to be evaluated on a pilot basis. The following selected measures were identified:

- To evaluate reference erosion rates for existing vegetated highway cut and fill slopes in the study area, untreated bare soil (control) plus the following candidate vegetation types were selected:
  - Coastal sage scrub, the dominant native plant community found in the study area;
  - Two ornamental ground covers, iceplant (*Carpobrotus* spp.) and prostrate myoporum (myoporum), which represent previous and current District 7 trends, respectively, for ornamental ground covers; and
  - Non-native grass/forb complex, which is the most commonly observed ground cover within District 7 rights-of-way in the study area.
- To evaluate research erosion rates for existing vegetated non-highway (undisturbed) slopes in the study area, the candidate vegetation selected for study was coastal sage scrub.
- To evaluate the effect of slope roughness on erosion rates for highway fill slopes in the study area, the four most commonly used methods of slope roughening, including ripping, sheepsfoot rolling, trackwalking, and imprinting, were identified.
- To evaluate the effect of the percent of vegetation cover on erosion rates for highway cut and fill slopes in the study area, the ornamental ground cover myoporum was selected as the vegetation type.
- To evaluate the effect of Caltrans existing erosion control practices on erosion rates, straw mulch (with tackifier on cut slopes and crimped on fill slopes) was selected. This erosion control practice currently used by District 7 was the only technique that has not previously been tested in other studies, and was therefore selected for this study.
- To evaluate the effect of erosion control/plant establishment practices on plant establishment for highway cut and fill slopes, one native seed mix and 15 erosion control measures, plus untreated bare soil were selected for testing. All but two of these erosion control measures (bonded fiber matrix and coir netting) are currently used by District 7.
- To evaluate the effect of temporary irrigation on native plant establishment for highway slopes, a three-month irrigation period was identified as being most commonly used.

1.3.6 Design an Experimental Testing Program (Step 6)

The sixth step in the study design process was to design the experimental testing program. Based on the scope of the ECPS and the identified areas requiring additional study, a pilot study was designed with a field testing component and a laboratory testing component. A review of studies conducted by others on the effects of topsoil and mycorrhizal inoculation was also performed as part of this study.

The field pilot studies were designed to be representative of District 7 slope, soil, and climatic conditions. This was particularly important for cut slope evaluations, which cannot be simulated in the laboratory. However, the field plots were exposed only to natural storms that occurred during the two rainy seasons of the study period. Precipitation rates were below average for both monitored wet seasons. For this reason, the rates of soil erosion and vegetative growth for the field plots may or may not reflect typical values found under normal climatic conditions.

Laboratory studies, using a rainfall simulator, simulated a wider range of rainfall conditions than occurred in the field during the two-year study period. The laboratory allowed for better control of experimental conditions, including test replications, and provided the opportunity to study the effect of each individual test parameter on erosion rates.

1.3.6.1 Field Testing Component

The field testing program consisted of two program components; erosion rate and plant establishment. The erosion rate component included testing runoff and erosion rates on cut, fill, and undisturbed slopes with selected vegetation types under natural rainfall conditions. The plant establishment component included an evaluation of the effects of specific erosion control treatments on plant establishment, with and without supplemental irrigation. Therefore, two types of test plots were required for the field test program: (1) test plots for measuring erosion; and (2) test plots for evaluating plant establishment, with and without irrigation.

Erosion Rate Test Plots. Tests conducted at erosion rate test plots included measuring sediment and runoff during natural rain events to evaluate the effect of vegetation type and slope type on erosion rates. Three types of plots were utilized to test erosion rates:

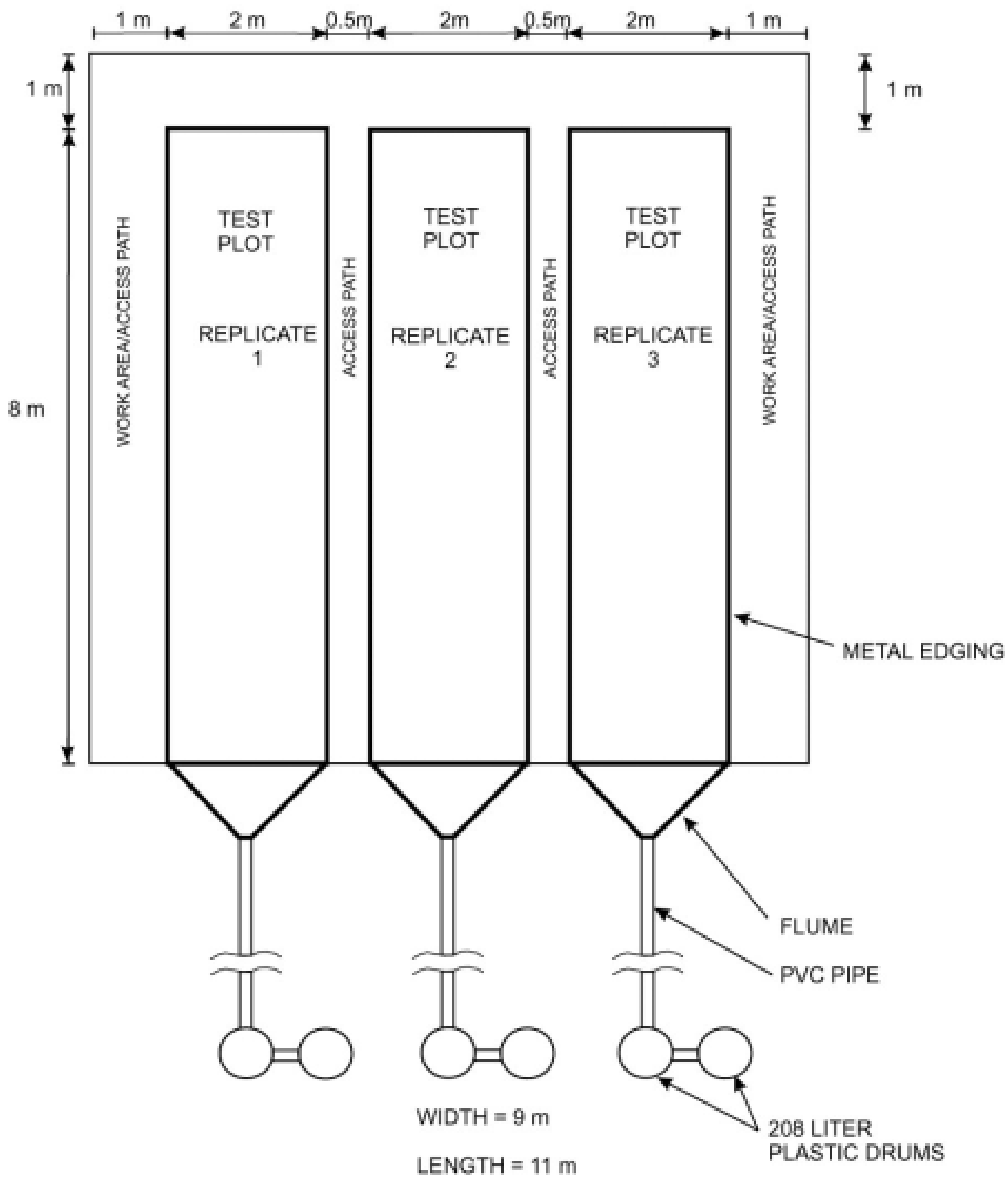
- Bare slopes;
- Reference (highway slopes well-vegetated with established, mature coastal sage scrub, grass/forb complex, iceplant, or myoporum); and
- Research (non-highway slopes with relatively undisturbed native coastal sage scrub vegetation).

Field erosion rates were measured in a factorial experimental design with three slope types (cut, fill, and undisturbed), four vegetation cover types (coastal sage scrub, grass/forb complex, iceplant, and myoporum), and an unvegetated bare slope. Rainfall was treated as a covariate in the statistical analysis because of the geographic variation of the test sites. To implement the erosion rate study, data were collected on slope gradient and aspect, vegetation characteristics (vegetation cover, plant density, and species diversity), rainfall volumes, erosion rates, and soil microbial and chemical properties (including organic matter).

The erosion rate field test plots consisted of three replicate rectangular-shaped test plots delineated, and isolated from the adjacent slope, by metal edging. A sediment collection system was located at the base of each test plot to collect runoff during storm events. A detailed description of the dimensions and construction of the erosion rate test plots is presented in Section 2. A typical erosion rate field test plot layout is schematically shown in Figure 1-1.

Photographs showing the erosion rate test plots with bare soil and each of the four vegetation types are provided as Figures 1-2 through 1-4.

Within 36 hours after every rainfall event of 6 millimeters (mm) (0.25 inches [in.]) or more of precipitation occurring within a 24-hour period, the water and sediment collected in the drums was transported to URS's laboratory in Santa Ana, California for analysis. Rainfall events of less then 6 mm of precipitation within a 24-hour time period were documented. However, sediment and/or runoff collected in the collection systems during these lower intensity storm events were not analyzed and were placed on the adjacent slopes.



Note: Access paths will not be created at sites where vegetation disturbance must be minimal (e.g., Coastal sage scrub sites)

EROSION TEST PLOT LAY OUT (PLAN VIEW)			
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Fig_1-1.cdr 3/30/00

(a) Erosion rate test plot with bare soil (control).

(b) Erosion rate test plot with coastal sage scrub (CSS) vegetation.

(a) Erosion rate test plot with grass/forb complex vegetation (cut slope).

(b) Erosion rate test plot with grass/forb complex vegetation (fill slope).

(a) Erosion rate test plot with iceplant vegetation.

(b) Erosion rate test plot with myoporum vegetation.

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Plant Establishment Test Plots. Testing conducted at the plant establishment test plots consisted of monitoring the effects of various erosion control treatments on germination and initial establishment of a native coastal sage scrub vegetation seed mix (Table 1-1). The erosion control treatments are listed in Table 1-2.

Establishment of the coastal sage scrub seed mix was measured in a factorial experimental design with 15 erosion control treatments, untreated bare soil (control), two slope types (cut and fill), and two irrigation regimes (irrigated and non-irrigated). Rainfall was treated as a covariate in the statistical analysis because of the geographic variation of the test sites. To implement the plant establishment study, data were collected for soil microbial and chemical properties (including organic matter), vegetation characteristics (vegetation cover, plant density, species diversity, seedling vigor and growth rate, and root depth), and rainfall volumes.

Each plant establishment field test plot consisted of 48 subplots. The test subplots for the 15 erosion control treatments, plus untreated bare soil, were laid out adjacent to each other in rows. There were three replications of each treatment, so that each plant establishment test plot site consisted of 3 rows of 16 subplots. The locations of the various erosion control treatments within each row were randomly assigned. A detailed description of the dimensions and construction of the plant establishment test plots is presented in Section 2. The general plant establishment field test plot layout is shown in Figure 1-5. Photographs with examples of each of the 15 treatments, including the untreated bare soil, are provided as Figures 1-6 through 1-13.

1.3.6.2 Laboratory Testing Program

The laboratory testing component of the pilot study included both indoor and outdoor testing facilities. The indoor laboratory facility consists of a tilting soil test bed; portable, overhead rainfall simulators; and a water treatment and storage system. This facility is located at San Diego State University (SDSU), and is referred to as the Caltrans/SDSU Soil Erosion Research Laboratory. This facility is the only one of its kind in California and is available for future Caltrans research.

Testing at the indoor laboratory was designed to evaluate the effect of slope roughness on erosion rates and the effect of erosion control treatments on runoff water quality and sediment loss. For the slope roughness tests, five different methods were applied to the soil in the test bed, including smooth rolling, ripping, sheepsfoot rolling, trackwalking, and imprinting. One soil type and one slope inclination (1V:2H) was used. Three different storm frequencies (5-year, 10-year, and 50-year) were each run at two different intensity/duration combinations. Three replicates were conducted for each test, for a total of 90 sampling events.

For the erosion control treatment/water quality evaluation, 15 different erosion control treatments; plus one untreated bare soil surface, were used, with one slope roughness (smooth rolled), one soil type, one slope inclination (1V:2H), and one storm event (10-year). Three replications were conducted for each test, yielding a total of 48 sampling events. Each of the runoff samples was tested for a suite of 15 water quality parameters, including total suspended solids.

Table 1-1
NATIVE SEED MIX FOR PLANT ESTABLISHMENT TEST PLOTS

Scientific Name (Designation)(1)	Common Name	% Purity(2) / % Germination(3)	Rate (kg/ha)
Shrub Species			
Artemisia californica (ART CAL)	California sage brush	15/50	2.2
Encelia californica (ENC CAL)	Bush sunflower	40/60	1.7
Eriogonum fasciculatum (ERI FAS)	California buckwheat	10/65	6.7
Isocoma menziesii (ISO MEN)	Goldenbush	20/40	1.1
Lotus scoparius var. *scoparius* (LOT SCO)	Deerweed	90/60	5.6
Salvia mellifera (SAL MEL)	Black sage	70/50	1.7
Perennial Grasses			
Hordeum californicum (HOR CAL)	California barley	90/80	3.4
Nasella pulchra (NAS PUL)	Purple needlegrass	70/60	3.4
Annual Grass/Forb Species			
Lasthenia californica (LAS CAL)	Goldfields	50/60	2.8
Lupinus bicolor (LUP BIC)	Lupine	98/80	4.5
Vulpia ocotoflora (VUL OCT)	Six-week fescue	60/40	2.8

(1) Botanical names are consistent with *The Jepson Manual: Higher Plants of California* (Hickman, 1993).
(2) % Purity = percentage by weight of clean seed in a pound; the remaining percentage is primarily made up of crushed plant parts, including stems and flowers.
(3) % Germination = percentage of viable or "live seed" per pound, and is dependent on the normal seed viability as produced by the plant; not all seeds mature and become viable, particularly those collected in the wild.

Table 1-2
TEMPORARY EROSION CONTROL TREATMENTS

DESIGNATION	TREATMENT[1]
BARE	Bare (no treatment)
BFM	Bonded Fiber Matrix
CB	Coconut Erosion Control Blanket
COIR	Coir Netting
COMP	Compost
CWFB	Curled Wood Fiber Erosion Control Blanket
GYP1	Gypsum, Rate 1
GYP2	Gypsum, Rate 2
PMG	Paper Mulch with Psyllium Tackifier
PMP	Paper Mulch with Polymer Tackifier
RS { RSG	*Cut Slope*: Wheat Straw with Psyllium Tackifier [2]
RS { RSI	*Fill Slope*: Wheat Straw, Incorporated
SB	Straw Erosion Control Blanket
SCB	Straw/Coconut Erosion Control Blanket
WFB	Wood Fiber Erosion Control Blanket
WMG	Wood Mulch with Psyllium Tackifier
WMP	Wood Mulch with Polymer Tackifier

(1) Treatments used on Plant Establishment Field Test Plots and Soil Erosion Research Laboratory Erosion Rate/Water Quality Tests.

(2) Wheat straw was used instead of rice straw (Section 2.4).

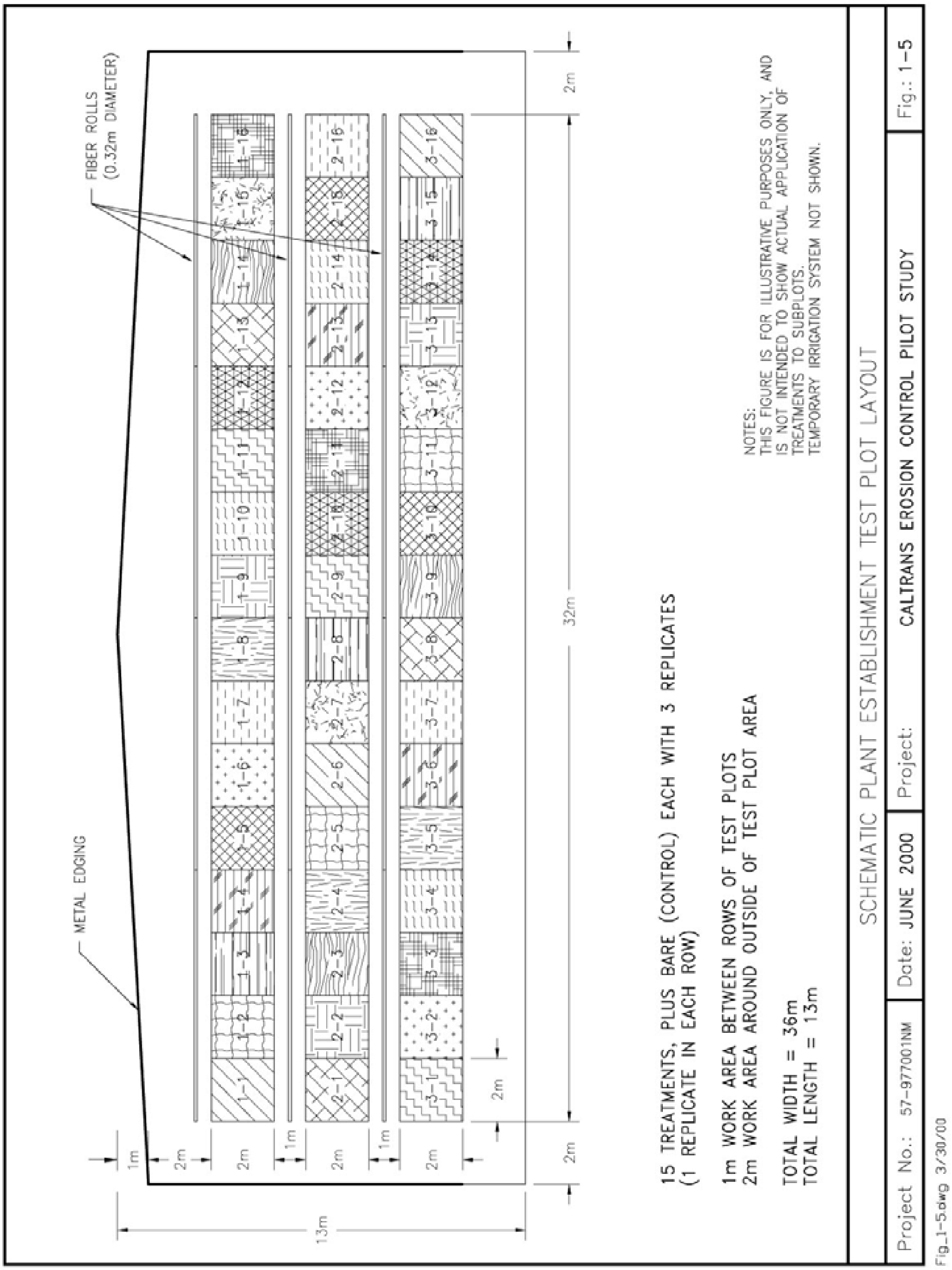

FIBER ROLLS
(0.32m DIAMETER)
METAL EDGING
15 TREATMENTS, PLUS BARE (CONTROL) EACH WITH 3 REPLICATES
(1 REPLICATE IN EACH ROW)
1m WORK AREA BETWEEN ROWS OF TEST PLOTS
2m WORK AREA AROUND OUTSIDE OF TEST PLOT AREA
TOTAL WIDTH = 36m
TOTAL LENGTH = 13m
NOTES:
THIS FIGURE IS FOR ILLUSTRATIVE PURPOSES ONLY, AND
IS NOT INTENDED TO SHOW ACTUAL APPLICATION OF
TREATMENTS TO SUBPLOTS.
TEMPORARY IRRIGATION SYSTEM NOT SHOWN.
32m
13m
SCHEMATIC PLANT ESTABLISHMENT TEST PLOT LAYOUT
Project No.: 57-977001NM
Date: JUNE 2000
Project:
CALTRANS EROSION CONTROL PILOT STUDY
Fig.: 1-5
Fig_1-5.dwg 3/30/00

Figure 1-5

(a) Plant establishment test subplot with no treatment (BARE).

(b) Plant establishment test subplot with bonded fiber matrix (BFM).

(a) Plant establishment test subplot with coconut blanket (CB).

(b) Plant establishment test subplot with coir netting (COIR).

(a) Plant establishment test subplot with compost (COMP).

(b) Plant establishment test subplot with curled wood fiber blanket (CWFB).

(a) Plant establishment test subplot with gypsum, rate 1 (GYP1).

(b) Plant establishment test subplot with gypsum, rate 2 (GYP2).

(a) Plant establishment test subplot with paper mulch and psyllium tackifier (PMG).

(b) Plant establishment test subplot with paper mulch and polymer tackifier (PMP).

(a) Plant establishment test subplot with wheat straw (RS). Fill slope shown (RSI).

(b) Plant establishment test subplot with straw blanket (SB).

(a) Plant establishment test subplot with straw-coconut blanket (SCB).

(b) Plant establishment test subplot with wood fiber blanket (WFB).

(a) Plant establishment test subplot with wood mulch and psyllium tackifier (WMG)

(b) Plant establishmentt test subplot with wood mulch and polymer tackifier (WMP)

The indoor laboratory soil test bed is 3 meters (m) wide by 10 m long, (10 feet [ft.] by 33 ft.) however, edging was used to delineate a 2 m wide by 8 m long (7 ft. by 26 ft.) area to match the size of the field erosion rate and outdoor myoporum test plots. A schematic drawing of the soil test bed apparatus is shown on Figure 1-14.

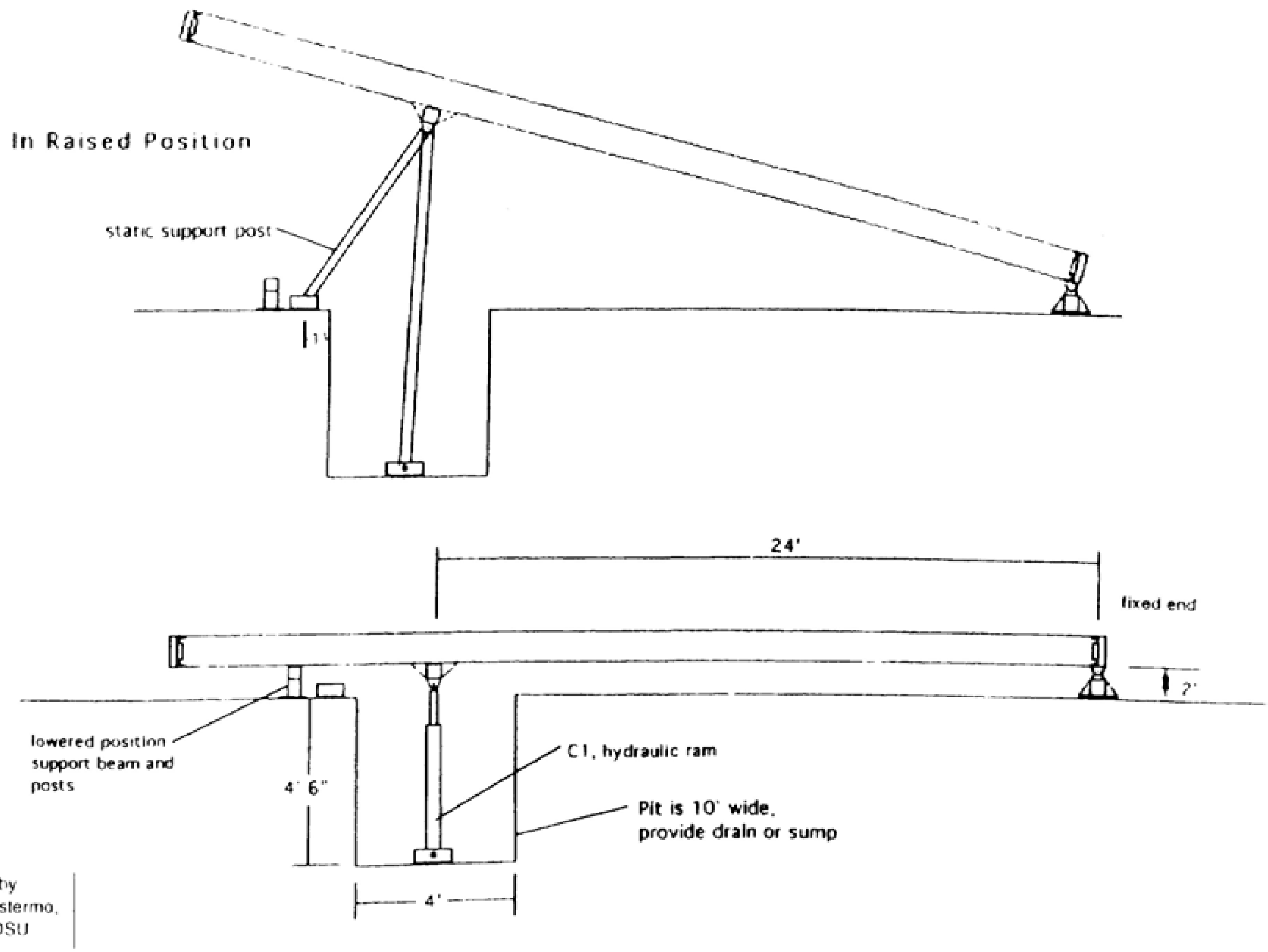
The outdoor laboratory facility consisted of field test plots vegetated with myoporum. Testing at the outdoor laboratory facility was designed to evaluate the effects of erosion rates for Caltrans slopes with differing amounts of vegetative cover.

The outdoor laboratory myoporum test plots were fertilized and irrigated to enhance growth. Rainfall simulations (through the use of portable rainfall simulators) were conducted on five different percentages of vegetative cover of approximately 35, 50, 65, 80, and 95 percent. Tests were conducted for each of the five cover values using the 10-year(2) storm event, two slope types (cut and fill), and three replicates, yielding a total of 30 sampling events.

The outdoor laboratory myoporum test plots were located at the same site locations as the erosion rate and plant establishment test plots. The outdoor laboratory myoporum test plots were constructed with the same dimensions and layout as the erosion rate test plots (Figure 1-1).

1.3.6.3 Topsoil and Mycorrhizal Inoculation Studies

Relevant field and laboratory studies that are being performed by others in California related to the effect of topsoil on native plant establishment, and the effect of mycorrhizal inoculation on native plant establishment were reviewed to expand upon the information obtained during the literature review conducted during Step 3 of the study design process.



SOIL TEST BED: RAISED AND REST POSITIONS

Project No 57-977001NM 00	Date JUNE 2000	Project CALTRANS EROSION CONTROL PILOT STUDY	Fig. 1-14

Based on the study design described in Section 1, field sites were selected for construction of the erosion rate, plant establishment, and outdoor laboratory myoporum test plots. This section provides an overview of the site selection process, and describes construction and maintenance procedures implemented for the field and outdoor laboratory test plots. A discussion of the construction and maintenance procedures implemented for the indoor laboratory test bed is also included in this section.

The site selection process was originally presented in the *Detailed Study Plan* (Woodward-Clyde, 1998) and is summarized below in Section 2.1. A description of test plot construction and the maintenance program was originally presented in the report *Construction and Monitoring of Field Test Plots* (URS Greiner Woodward Clyde, 1999a) and is summarized below in Sections 2-2 through 2-4. A description of the indoor and outdoor laboratory test plot construction and maintenance procedures was originally presented in *Laboratory Manual, Soil Erosion Laboratory and Outdoor Test Plots, San Diego State University* (URS Greiner Woodward Clyde, 2000b) and is summarized below in Sections 2.5 and 2.6.

2.1 SITE SELECTION

2.1.1 Criteria for Selection of Candidate Field Test Sites

To begin the site selection process, general criteria were developed to help identify candidate field test sites (erosion rate, plant establishment, and outdoor laboratory myoporum test plots). A mandatory criterion for all field sites, except the research site, was to be located within Caltrans rights-of-way, preferably in District 7. Other criteria addressed factors such as slope accessibility and area, geology of cut slopes, and existing vegetation. In addition, sites needed to fit the various combinations of slope characteristics that were required by the field test program. For the erosion rate test sites, these characteristics included slope angle (1V:2H or steeper), slope type (cut or fill), and vegetation type (bare, coastal sage scrub, grass/forb complex, iceplant, or myoporum). The permutations resulted in the need for a total of 10 bare and reference slopes, in addition to one research slope. For the plant establishment and the outdoor myoporum laboratory test sites, these characteristics included slope angle (1V:2H or steeper) and two slope types (cut and fill).

2.1.2 Identification of Candidate Field Sites

The initial identification of candidate field test sites was based on information contained in the field observation database of District 7 rights-of-way developed during Step 1 of the design process. The field observations database included slope characteristics that were required for site selection, including the estimated slope angle, cut/fill designation, and vegetation cover (if any). Photographs taken during the field observations were also an important resource for initial identification of potential test sites.

Potential sites were visited to evaluate whether they satisfied the site selection criteria. To identify additional candidate sites, targeted observations were made of District 7 roadsides, similar to the process used to document roadside erosion problems. The final culling of candidate test sites was based on a comparative visual assessment of the existing vegetation quality. This process resulted in two to five candidate locations for each proposed site. Final selection of the test sites from the candidate sites was based on the soil classifications as well as site access considerations.

Figure 2-1 presents a listing and map of the selected test sites. Table 2-1 lists the characteristics of the test site locations with corresponding information on the type of plot, existing vegetation, slope type (cut/fill or natural), slope angle, geology, soil type, and access.

2.2 FIELD SITE PRE-CONSTRUCTION ACTIVITIES

Pre-construction activities included vegetation and soil removal from the erosion rate bare test plots, plant establishment test plots, and outdoor laboratory myoporum test plots. A survey was conducted to delineate each of the subplots.

2.2.1 Field Sites Vegetation/Soil Removal

For test plots that required an unvegetated slope surface, specifically the erosion rate bare test plot, plant establishment, and outdoor laboratory myoporum test plots, a trackloader was used to remove vegetation, topsoil, and surface roots to a depth of approximately 8 cm (3 in.). Upon completion of the vegetation/soil removal at each test plot area, the trackloader finished the slope by trackwalking in an upslope-downslope direction. Scraped material was transported to the local landfill.

The purpose of scraping and removing the surface layer was two-fold: (1) to reduce the weed seed bank in the soil; and (2) to remove any topsoil that may have developed to eliminate a potentially significant source of variation in the quality of the soils at the different sites. Removal of existing topsoil also more realistically modeled slope conditions that would normally exist at the conclusion of a Caltrans construction project.

2.2.2 Field Sites Test Plot Survey

During the final site selection process, members of the study design team set a single stake at one corner of each test plot. Survey crews then staked each test plot area with both outer boundary corner stakes, and offset stakes to delineate the separate subplots.

2.3 EROSION RATE TEST PLOTS

2.3.1 Erosion Rate Test Plot Site Descriptions

The selected erosion rate test plot sites were established on slopes with existing, mature vegetation of one of the four selected vegetation types (iceplant, coastal sage scrub, grass/forb complex, and myoporum), and met the other conditions described above in Section 2.1.1. Erosion rate test plots were installed at nine site locations, including four cut slopes, four fill slopes, and one undisturbed slope. Each test plot consisted of three replicate plots, yielding a total of 27 subplots. A map showing test site locations is provided as Figure 2-1. The test site locations are as follows:

Table 2-1
TEST SITE CHARACTERISTICS

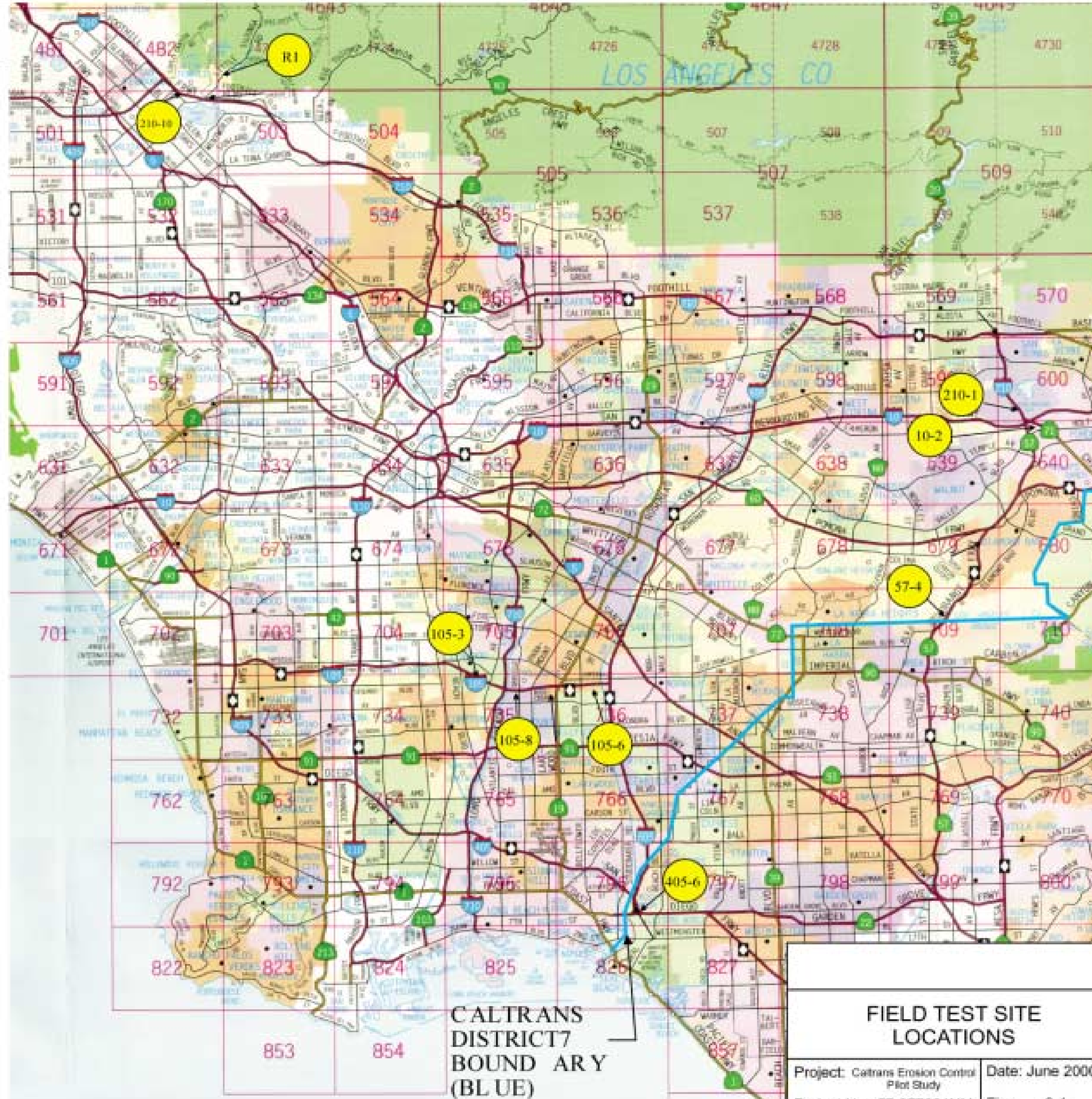
Site Number	Type of Plot(1)	Route	Dir.	Post Mile	Vegetation	Cut/Fill or Natural	Slope Angle (V:H)	Slope Aspect	Geology(2) (Cut Slopes)	Soils Classification USCS(3)	Soils Classification USDA System(4)	Thomas Guide (1998)	Site Location	Slope Access
10-2	Reference, Base, Test, Laboratory	10 to 71	E/B	42	Grass/Forb Complex	Fill	1:2	S/SE 160 degrees	Fill slope	Clayey sand	Sandy clay loam	640-C1	Corporate Center Dr	Gate at bottom
57-4	Reference, Base, Test, Laboratory	57	S/B	1.0	Grass/Forb Complex	Cut	1:2	E/SE 121 degrees	Puente Formation (siltstone/shale and thin interbedded sandstone)	Silty sand w/ gravel	Sandy loam	709-F2	Park on Brea Canyon Rd	Road near bottom
405-6	Reference	405	N/B	22.5	Iceplant	Fill	1:2	S/SE 171 degrees	Fill slope	Silty sand	Sandy loam	796-G6	South of 605 interchange (in Orange County)	Shoulder at bottom
105-6	Reference	105	E/B	17.5	Iceplant	Cut	1:2	N/NW 336 degrees	Alluvium (gravel, sand, silt and clay)	Silty sand	Sandy loam	736-C1	Woodruff St	Soundwall gate at top
105-3	Reference	105	W/B	12.5	Myoporum	Fill	1:2	N/NE 10 degrees	Fill slope	Silty sand	Sandy loam	735-D1	Fernwood St @ Harris St	Gate at bottom
105-8	Reference	105	W/B	14.1	Myoporum	Cut	1:2	N/NW 351 degrees	Alluvium (gravel, sand, silt and clay)	Sandy silt	Sandy loam	735-F2	Garfield Ave	Wide shoulder at bottom
210-10	Reference	210	E/B	47.3	Coastal Sage Scrub	Fill	1:2	S/SW 241 degrees	Fill slope	Clayey sand	Sandy loam	482-F7	Van Nuys Blvd	Gate at bottom
210-1	Reference	210	E/B	6.0	Coastal Sage Scrub	Cut	1:2	W/SW 241 degrees	Puente Formation (siltstone/shale and thin interbedded sandstone)	Sandy clay w/ gravel	Loam	600-A6	Via Verde	Road at bottom
R1	Research	LTR(5)	-	-	Coastal Sage Scrub (undisturbed)	Natural	1:2	W/NW 280 degrees	Monterey Formation (thin bedded shale; bedded sandstone with minor shale)	Clayey sand	Sandy clay loam	4643	Little Tujunga Rd (Middle Canyon Ranch)	Path at bottom

(1) "Reference" and "Baseline" refer to erosion rate test sites, "Test" refers to plant establishment test sites (both with and without temporary irrigation), and “Laboratory” refers to Outdoor Laboratory test sites.
(2) References: Durham and Yerkes, 1964; Yerkes, 1972; California DWR, 1961; Dibblee, 1971, 1989, 1991a, 1991b.
(3) Unified Soil Classification System, per ASTM D2487.
(4) Textural classification per American Society of Agronomy and Soil Science Society of America.
(5) Little Tujunga Road.

FIELDTESTSITES

Site Number	Type of Site[1]	Vegetation	Cut/Fill/ Natural	Thomas Guide	Site Location
10-2	Reference, Bare, Test, Lab	Grass/Forb Complex	Fill	640-C1	Corporate Center Dr
57-4	Reference, Bare, Test, Lab	Grass/Forb Complex	Cut	709-F2	Park on Brea Canyon Rd
105-3	Reference	Myoporum	Fill	735-D1	Fernwood St @ Harris St
105-6	Reference	Iceplant	Cut	736-C1	Woodruff St
105-8	Reference	Myoporum	Cut	735-F2	Garfield Ave
210-1	Reference	Coastal Sage Scrub	Cut	600-A6	Via Verde
210-10	Reference	Coastal Sage Scrub	Fill	482-F7	Van Nuys Blvd
405-6	Reference	Iceplant	Fill	796-G6	South of 605 interchange
R1	Research	Coastal Sage Scrub	Natural	4643	Little Tujunga Rd

[1] "Reference, Bare and Research" refer to erosion rate test plots.
"Test" refers to plant establishment test plots.
"Lab" refers to outdoor laboratory myoporum test plots.



0 4.5 9.0

Approximate Scale, miles

FIELD TEST SITE LOCATIONS

Project: Caltrans Erosion Control Pilot Study	Date: June 2000
Project No.: 57-977001NM	Fig.: 2-1

- The fill slope with bare and grass/forb complex test plots (Site 10-2) is located on the transition from Interstate 10 eastbound to State Route 71 southbound in the city of Pomona.
- The cut slope with bare and grass/forb complex test plots (Site 57-4) is located on State Route 57 southbound in the city of Diamond Bar.
- The fill slope with myoporum test plots (Site 105-3) is located on Interstate 105 westbound in the city of Lynwood.
- The cut slope with myoporum test plots (Site 105-8) is located on Interstate 105 eastbound in the city of Paramount.
- The fill slope with iceplant test plots (Site 405-6) is located on the transition from Interstate 405 northbound to State Route 22 westbound in the city of Seal Beach.
- The cut slope with iceplant test plots (Site 105-6) is located on Interstate 105 eastbound in the city of Bellflower.
- The fill slope with coastal sage scrub test plots (Site 210-10) is located on Interstate 210 eastbound in the Lake View Terrace area of the city of Los Angeles.
- The cut slope with coastal sage scrub test plots (Site 210-1) is located on Interstate 210 eastbound in the city of San Dimas.
- The undisturbed slope with coastal sage scrub test plots (Site R1), the research site, is located on Middle Ranch in the Lake View Terrace area of the city of Los Angeles.

2.3.2 Erosion Rate Test Plot Construction

This section describes the construction and maintenance of the erosion rate test plots, including the bare, reference, and research sites. As described above in Section 1.3.6.1, the erosion rate test plots were constructed on slopes with existing mature vegetation of one of the four selected vegetation types. The erosion rate test plots measured 2 m wide by 8 m long (7 ft. by 26 ft.). There were three replication plots at each test site, separated with a minimum 0.5-m (2-ft.) wide access path. Each replicate plot was delineated, and isolated from the adjacent slope, by metal edging. In order to minimize disturbance to the surrounding vegetation, work was limited to a 2-m (7-ft.) wide zone around the perimeter of the test plot area. A sediment collection system was located at the base of each test plot. The sediment collection system consisted of a metal flume that was connected by PVC pipe to 208-liter (L) (55-gallon [gal.]) plastic drums used for collection of runoff and sediment during rainfall events.

Construction activities were accomplished at all sites without the need for shoulder closures, lane closures, or other traffic control measures. Construction of the erosion rate test plots was conducted as follows:

1. *Site Documentation.* The site was photographed before and during construction.
2. *Upper Soil/Vegetation Removal.* The test plot area was scraped (bare test plots only), as described in Section 2.2.1.

3. *Metal Edging Installation.* Metal edging was installed around the top and sides of each test plot as shown on Figure 1-1. The metal edging used for the erosion rate test plots consisted of 20.3 centimeter (cm) (8 in.) tall by 1.5 m to 2.8 m (5 ft. to 9 ft.) long pieces of 11-gauge steel sheet. Angle sections measuring 2.5 cm by 2.5 cm (1 in. by 1 in.) were welded on the outside of each plate at mid-height to provide additional stiffness and act as a guide for depth of installation into the soil.
4. *Metal Collection Flume.* A metal collection flume was installed at the lower end of each plot. The purpose of the metal collection flume was to funnel runoff and sediment from the 2-m (7-ft.) wide test plot into the 10.2-cm (4-in.) diameter piping system and collection drums. In addition, the flume was designed to provide storage capacity, if needed, during a large storm or if the flume exit pipe becomes plugged. Mortar was placed beneath the interface of the test plot and flume to establish a smooth, even surface.
5. *Collection Area.* A suitable collection area was located down-slope from the test plots, and a string was extended from the center of each plot. The primary drum was located along the string line.
6. *Wood Pallets.* Wood pallets were placed on the ground and stabilized. When necessary, gravel was placed below the wood pallets for increased stability. Two metal stakes were installed adjacent to the long sides of the pallet. Stakes were attached to the pallets using nails through pre-drilled holes in the metal stakes. For sites with insufficient slope length, excavation was required to situate the drums below the elevation of the metal collection flume. In such cases, a wood pallet was not necessary beneath the drums.
7. *PVC Collection System.* 10.2-cm (4-in.) diameter PVC conduit, pipe, and fittings were glued together to connect the flumes to the 208-L (55-gal.) plastic collection drums. Tie wire was used to secure the drums to the pallets.
8. *Rain Gauge Installation.* A rain gauge was installed on a 1.5-m (5-ft) metal fence post adjacent to each test plot area (one per three replicate plots). The rain gauge was installed in a manner that facilitated easy removal for reading and emptying.
9. *Site Documentation.* Following construction, each site was photographed for documentation.

Photographs showing various aspects of erosion rate test plot construction are provided as Figures 2-2 through 2-4.

2.3.3 Erosion Rate Test Plot Site Maintenance

Throughout the 20-month course of the project, from September 1998 through June 2000, weekly inspections were made of all erosion rate test plots. The inspections included observations of the condition of the test plots and the sediment collection systems, and maintenance and repairs as required. Activities performed as part of the weekly inspections included, but were not limited to:

- Observations of the condition of each test plot, with photo documentation and notation on the inspection forms of damage to the test plots by animals (e.g., gophers, deer, and coyotes), humans (unintentional damage and/or vandalism), and traffic mishaps.

- Inspection and repair of sediment collection systems. Removal of foreign objects from the sediment collection systems, including leaves and other debris, rodents and other small animal carcasses, and insects and spiders.

(a) Site No. 105-6, Plot RA. Workers have run string lines, separated the iceplant, and trenched prior to metal edging installation (October 1998).

(b) Site No. 405-6. Metal edging is installed with iceplant pulled up and off the plot area. Once the edging was in place, the iceplant was returned to its original position (November 1998).

(a) Site No. 10-2, Plot RB. Mortar is placed to prevent runoff from flowing below the collection flume (11/98).

(b) Site No. 57-4. Sediment collection systems for reference and base erosion rate plots (9/23/98).

(a) Site No. 210-1. Completed reference erosion rate test plots (coastal sage scrub on cut slope), 11/98.

(b) Site No. 57-4, Plot RA. Downslope view of completed grass/forb cut-slope erosion rate test plot (2/99).

- Inspection and repair of edging around test plots, particularly after rainfall events during which erosion adjacent to the edging may have undermined the integrity of the edging.
- Inspection/testing of integrity of rain gauges and repair/replacement, as required.
- Repair of erosion of areas adjacent to, but outside of, test plots that might have threatened the integrity of the test plots, or that may hinder access to the test plots for study purposes.
- Control of emergent vegetation on bare test plots. All emergent vegetation was removed by cutting.

2.4 PLANT ESTABLISHMENT TEST PLOTS

2.4.1 Plant Establishment Test Plot Site Descriptions

Plant establishment test plots were installed on two slope types (cut and fill). Each site had one irrigated test plot and one non-irrigated test plot. Each test plot was comprised of 48 subplots, 3 replicates of each of the 15 treatments, plus untreated (bare) soil, yielding a total of 192 subplots for both sites. The fill slope (Site 10-2) is located on the transition from Interstate 10 eastbound to State Route 71 southbound in the city of Pomona. The cut slope (Site 57-4) is located on State Route 57 southbound in the city of Diamond Bar. A map showing site locations is provided as Figure 2-1.

2.4.2 Plant Establishment Test Plot Construction

This section describes the construction procedures of the plant establishment test plots, including irrigated and non-irrigated sites. As described above in Section 1.3.6.1, each plant establishment field test plot consisted of 48 subplots, each measuring 2 m by 2 m (7 ft. by 7 ft.) in area. The test subplots for the 15 erosion control treatments, plus an untreated (bare) soil subplot, were laid out adjacent to each other, forming a 32-m (105-ft.) long row. There were three replications of each treatment, so that each plant establishment test plot site consisted of 3 rows of 16 subplots. The locations of the various erosion control treatments within each row were randomly assigned. One-meter wide access paths were constructed between the three horizontal rows of subplots, and a 2-m (7-ft.) wide work area/access path surrounded the outside edges of the test plot area. To minimize runoff from the upslope work areas, fiber rolls were installed horizontally 0.5 m (2 ft.) above each row. To minimize and deflect sediment and runoff from slope areas above the test subplots, metal edging was installed around the outside of the work area.

Construction activities were accomplished without the need for shoulder closures, lane closures, or other traffic control measures. A detailed description of the plant establishment test plot construction activities was presented in *Construction and Monitoring of Field Test Plots* (URS Greiner Woodward Clyde, 1999). In summary, these construction activities were as follows:

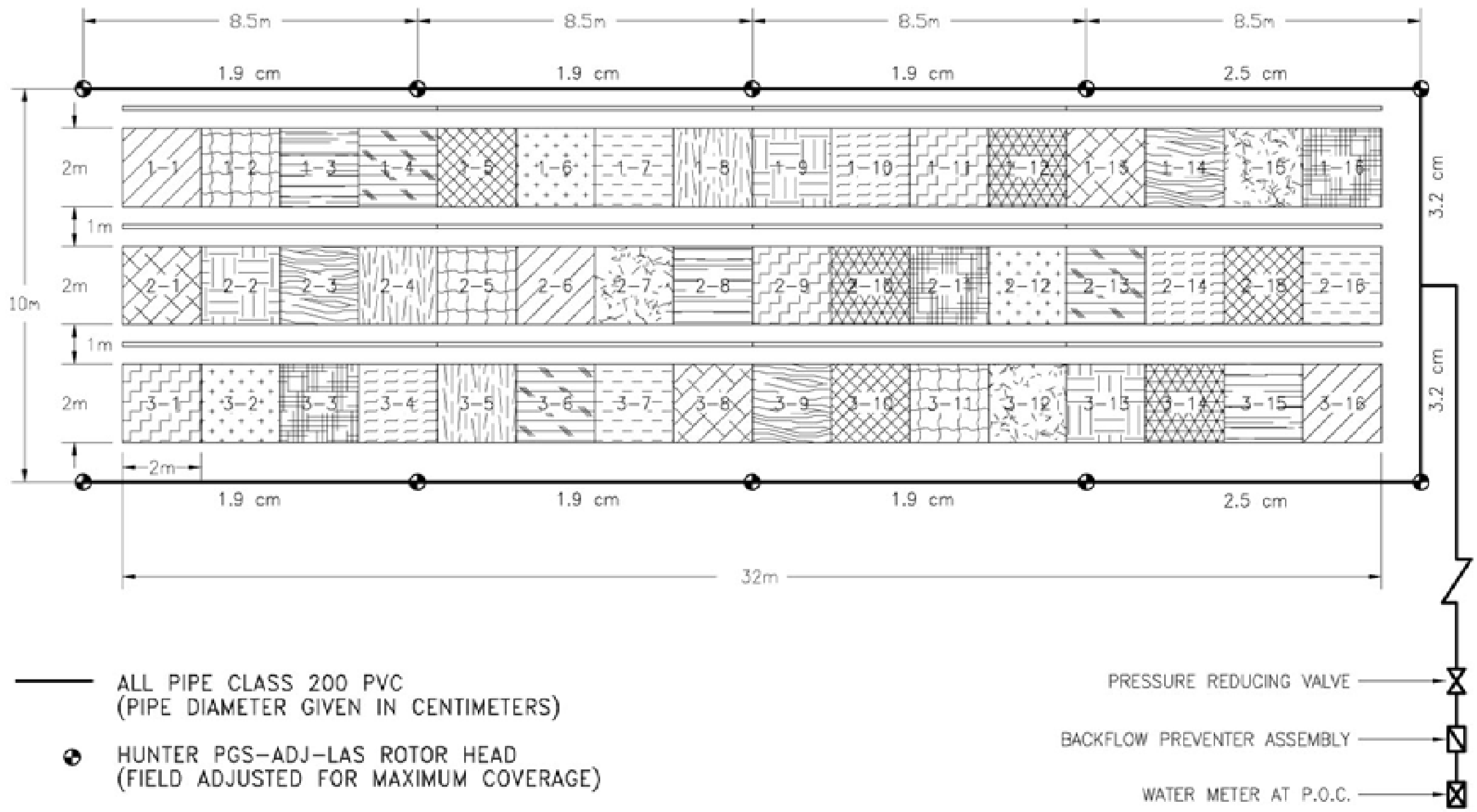
1. *Site Documentation.* Each site was photographed before and during construction.
2. *Upper Soil/Vegetation Removal.* Each test plot area was scraped as described in Section 2.2.1.

3. *Subplot Delineation, Part 1.* String lines were run horizontally across the test plot area to delineate each of the three test plot rows (2 strings for each row). String lines were tied with good tension, just above the bare ground. The string lines were adjusted to match the surveyed plot, using a plumb bob placed on each survey nail.
4. *Fiber Roll Installation.* Fiber rolls were installed 0.5 m (2 ft.) above each row of subplots, using the horizontal string lines as a guide for placement of the fiber rolls. Workers avoided walking within the subplot boundaries while installing the fiber rolls.
5. *Temporary Irrigation System Installation.* A temporary irrigation system (as shown on Figure 2-5) was installed at one of the two plant establishment test plots located at each site. The operation and uniform application of the irrigation system was tested at each site, using small irrigation/rain gauges spaced throughout the test plot area.
6. *Subplot Delineation, Part 2.* Vertical string lines were run across the plot to delineate each of the 48 subplots in the same manner as the horizontal string lines. The subplot number (e.g., 1-1), and treatment designation code (e.g., PMP for paper mulch with polymer tackifier) were written on a stake for each subplot. Each stake was installed above the subplot, immediately downslope of the fiber roll.
7. *Metal Edging Installation.* Metal edging was installed around the top and sides of the test plot area as shown on Figure 1-5. Mortar was placed on the upslope side of the top edging to form a 10-cm to 15-cm (4-in. to 6-in.) wide drainage ditch.
8. *Rain Gauge Installation.* A removable rain gauge was installed adjacent to the test plot area (one for each irrigated/non-irrigated pair).
9. *Seed Mix Application.* A hydroseeder was calibrated and used to apply the coastal sage scrub seed mix to each of the 48 subplots. The uniformity of the coastal sage scrub seed mix application was confirmed through visual observation.
10. *Treatment Application and Erosion Control Blanket Installation.* All treatments were applied according to the randomized block design shown on Figures 2-6 through 2-9 for the each of the four plant establishment test plots. The procedure for applying treatments (both hydraulically applied and manually applied) is described in detail below. The procedure for installing the erosion control blanket treatments is also described in detail below.
11. *Site Documentation.* Following construction, each site was photographed for documentation.

Figures 2-10 through 2-12 provide photographs of plant establishment test plot construction.

2.4.3 Plant Establishment Test Plot Erosion Control Treatment Application

The following section describes the application of all non-blanket treatments. Calibration of the hydroseeder application rates was required for each of the treatments because the flow rate varied as a function of material viscosity and density. In addition, the flow rate of the material decreased as the nozzle height on the slope increased (due to an increase in elevation head for the hydroseeder pump to overcome). Therefore, for each material, calibration was conducted on the work path where the application was made, rather than on level ground near the hydroseeder. The erosion control treatments were applied as follows:



NOTE:
THIS FIGURE IS FOR ILLUSTRATIVE PURPOSES ONLY, AND IS NOT INTENDED TO SHOW ACTUAL APPLICATION OF TREATMENTS TO SUBPLOTS.

IRRIGATION LAYOUT FOR IRRIGATED PLANT ESTABLISHMENT TEST PLOTS

Project No.: 977001NM.00	Date: JUNE 2000	Project: CALTRANS EROSION CONTROL PILOT STUDY	Fig.: 2-5

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1–1 BFM	1–2 GYP2	1–3 CWFB	1–4 BARE	1–5 SB	1–6 WMP	1–7 GYP1	1–8 CB	1–9 PMP	1–10 WMG	1–11 SCB	1–12 COMP	1–13 PMG	1–14 WFB	1–15 RSG	1–16 COIR

2–1 WMG	2–2 GYP2	2–3 SB	2–4 PMP	2–5 BFM	2–6 GYP1	2–7 CWFB	2–8 COMP	2–9 SCB	2–10 CB	2–11 BARE	2–12 PMG	2–13 WMP	2–14 COIR	2–15 RSG	2–16 WFB

3–1 CWFB	3–2 PMP	3–3 WMG	3–4 GYP1	3–5 CB	3–6 SB	3–7 SCB	3–8 WFB	3–9 COMP	3–10 GYP2	3–11 WMP	3–12 RSG	3–13 PMG	3–14 COIR	3–15 BFM	3–16 BARE

LEGEND

PLOT NO. = ROW NO.–COLUMN NO.–TREATMENT
(E.G., 2–3–GYP1)

TREATMENTS
BARE=Bare, No Treatment
BFM=Bonded Fiber Matrix
CB=Coconut ECB
COIR=Coir Netting
COMP=Compost
CWFB=Curled Wood Fiber ECB
GYP1=Gypsum, Rate 1
GYP2=Gypsum, Rate 2
PMG=Paper Mulch with Psyllium Tackifier
PMP=Paper Mulch with Polymer Tackifier
RS=Wheat Straw with Psyllium Tackifier
SB=Straw ECB
SCB=Straw–Coconut ECB
WFB=Wood Fiber ECB
WMG=Wood Mulch with Psyllium Tackifier
WMP=Wood Mulch with Polymer Tackifier

TREATMENT LAYOUT FOR IRRIGATED CUT SLOPE (SITE 57–4)

Project No.: 57977001NM	Date: JUNE 2000	Project: CALTRANS EROSION CONTROL PILOT STUDY	Fig.: 2–6

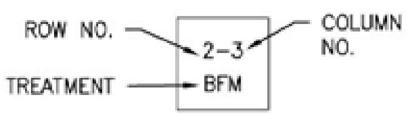
Fig_2-6.dwg 3/30/00

1–1	1–2	1–3	1–4	1–5	1–6	1–7	1–8	1–9	1–10	1–11	1–12	1–13	1–14	1–15	1–16
PMP	CWFB	BARE	BFM	WMP	SB	SCB	WFB	CB	COIR	CYP1	WMG	RSG	COMP	CYP2	PMG

2–1	2–2	2–3	2–4	2–5	2–6	2–7	2–8	2–9	2–10	2–11	2–12	2–13	2–14	2–15	2–16
COIR	COMP	BARE	GYP1	RSG	PMG	WMG	CWFB	WFB	PMP	GYP2	BFM	WMP	SB	CB	SCB

3–1	3–2	3–3	3–4	3–5	3–6	3–7	3–8	3–9	3–10	3–11	3–12	3–13	3–14	3–15	3–16
PMP	SB	WMP	COMP	GYP1	COIR	WMG	GYP2	WFB	PMG	SCB	BARE	RSG	CB	BFM	CWFB

LEGEND



PLOT NO. = ROW NO.–COLUMN NO.–TREATMENT
(E.G., 2–3–GYP1)

TREATMENTS
BARE=Bare, No Treatment
BFM=Bonded Fiber Matrix
CB=Coconut ECB
COIR=Coir Netting
COMP=Compost
CWFB=Curled Wood Fiber ECB
GYP1=Gypsum, Rate 1
GYP2=Gypsum, Rate 2
PMG=Paper Mulch with Psyllium Tackifier
PMP=Paper Mulch with Polymer Tackifier
RS=Wheat Straw with Psyllium Tackifier
SB=Straw ECB
SCB=Straw–Coconut ECB
WFB=Wood Fiber ECB
WMG=Wood Mulch with Psyllium Tackifier
WMP=Wood Mulch with Polymer Tackifier

TREATMENT LAYOUT FOR NON–IRRIGATED CUT SLOPE (SITE 57–4)

Project No.: 57–977001NM	Date: JUNE 2000	Project: CALTRANS EROSION CONTROL PILOT STUDY	Fig.: 2–7

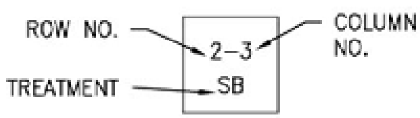
Fig_2-7.dwg 3/30/00

1–1 WFB	1–2 PMG	1–3 CWFB	1–4 BFM	1–5 GYP2	1–6 GYP1	1–7 CB	1–8 WMG	1–9 PMP	1–10 SB	1–11 COMP	1–12 SCB	1–13 WMP	1–14 RSI	1–15 COIR	1–16 BARE

2–1 PMG	2–2 CWFB	2–3 COIR	2–4 SB	2–5 SCB	2–6 CB	2–7 GYP1	2–8 BARE	2–9 WFB	2–10 GYP2	2–11 PMP	2–12 WMP	2–13 RSI	2–14 WMG	2–15 BFM	2–16 COMP

3–1 WMP	3–2 SB	3–3 WMG	3–4 RSI	3–5 GYP1	3–6 WFB	3–7 PMG	3–8 CB	3–9 SCB	3–10 COMP	3–11 CWFB	3–12 GYP2	3–13 COIR	3–14 BARE	3–15 BFM	3–16 PMP

LEGEND



PLOT NO. = ROW NO.–COLUMN NO.–TREATMENT
(E.G., 2–3–GYP1)

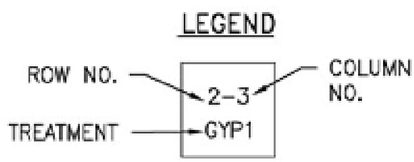
TREATMENTS
BARE=Bare, No Treatment
BFM=Bonded Fiber Matrix
CB=Coconut ECB
COIR=Coir Netting
COMP=Compost
CWFB=Curled Wood Fiber ECB
GYP1=Gypsum, Rate 1
GYP2=Gypsum, Rate 2
PMG=Paper Mulch with Psyllium Tackifier
PMP=Paper Mulch with Polymer Tackifier
RS=Wheat Straw Incorporated
SB=Straw ECB
SCB=Straw–Coconut ECB
WFB=Wood Fiber ECB
WMG=Wood Mulch with Psyllium Tackifier
WMP=Wood Mulch with Polymer Tackifier

TREATMENT LAYOUT FOR IRRIGATED FILL SLOPE (SITE 10–2)

Project No.: 57–977001NM	Date: JUNE 2000	Project: CALTRANS EROSION CONTROL PILOT STUDY	Fig.: 2–8

Fig_2–8.dwg 3/30/00

1–1 GYP2	1–2 RSI	1–3 CB	1–4 BFM	1–5 WMP	1–6 COMP	1–7 COIR	1–8 SB	1–9 CWFB	1–10 BARE	1–11 CYP1	1–12 PMG	1–13 SCB	1–14 WFB	1–15 PMP	1–16 WMG
2–1 WMP	2–2 PMG	2–3 COIR	2–4 RSI	2–5 GYP2	2–6 WMG	2–7 WFB	2–8 CB	2–9 BARE	2–10 COMP	2–11 SCB	2–12 SB	2–13 GYP1	2–14 CWFB	2–15 PMP	2–16 BFM
3–1 COIR	3–2 GYP1	3–3 PMG	3–4 COMP	3–5 CB	3–6 WFB	3–7 WMG	3–8 BARE	3–9 GYP2	3–10 SB	3–11 SCB	3–12 WMP	3–13 RSI	3–14 PMP	3–15 CWFB	3–16 BFM



PLOT NO. = ROW NO.–COLUMN NO.–TREATMENT
(E.G., 2–3–GYP1)

TREATMENTS
BARE=Bare, No Treatment
BFM=Bonded Fiber Matrix
CB=Coconut ECB
COIR=Coir Netting
COMP=Compost
CWFB=Curled Wood Fiber ECB
GYP1=Gypsum, Rate 1
GYP2=Gypsum, Rate 2
PMG=Paper Mulch with Psyllium Tackifier
PMP=Paper Mulch with Polymer Tackifier
RS=Wheat Straw Incorporated
SB=Straw ECB
SCB=Straw–Coconut ECB
WFB=Wood Fiber ECB
WMG=Wood Mulch with Psyllium Tackifier
WMP=Wood Mulch with Polymer Tackifier

TREATMENT LAYOUT FOR NON–IRRIGATED FILL SLOPE (SITE 10–2)

Project No.: 57–977001NM	Date: JUNE 2000	Project: CALTRANS EROSION CONTROL PILOT STUDY	Fig.: 2–9

Fig_2–9.dwg 3/30/99

(a) Site No. 10-2, Irrigated. Plant establishment test plot area with irrigation system and fiber rolls installed prior to hydroseeding, October 1998

(b) Site 57-4, Non-Irrigated. Close-up of 2-meter by 2-meter plant establishment test subplots prior to application of erosion control treatments, October 1998.

(a) Site No. 57-4, Non-Irrigated. Native seed with mulch is applied to a test plot. Holding the hose over the shoulder allows better control of the spray nozzle. November 1998.

(b) Site No. 57-4, Irrigated. Newly applied erosion control treatments following a rainstorm, 11/18/98.

(a) Site No. 10-2, Non-Irrigated. Hydraulic application of treatments is nearly completed at the non-irrigated plant establishment test plot. November 1998.

(b) Site No. 57-4, Irrigated. To irrigate the test plot (located high on slope), water is pumped into this 1136 L tank. The booster pump provides the required pressure for irrigation. October 1998.

1. For each treatment, plywood sheets were placed over adjacent test plots to protect from overspray.
2. Compost was spread evenly on the compost (COMP) subplots at a rate of 2,240 kilograms (kg)/hectacre (ha) (2,000 pounds (lb)/acre).
3. Straw was spread evenly on the straw (RSI/RSG) subplots at a rate of 4,480 kg/ha (2 tons/acre). A shovel was used to crimp the straw on fill slopes (RSI only).
4. The hydroseeder tank was filled with 378 L (100 gal.) of water. With the re-circulation valve closed, the motor was started and the throttle rpm was adjusted until spray from the nozzle extended 1.8 to 2.4 m (6 to 8 ft) from the end of the hose. The motor was then shut off, keeping the throttle set.
5. For each treatment (except psyllium tackifier for straw), the hydroseeder tank was filled with water to the 378-L (100-gal.) mark. For the psyllium tackifier applied on straw (RSG), 189 L (50 gal.) of water was placed in the tank.
6. Depending on which treatment was being applied, one of the material amounts listed below was measured and placed in the tank:
   a) 23 kg (50 lb) of bonded fiber matrix (BFM).
   b) 11 kg (25 lb) paper mulch with 2.9 kg (6.5 lb) polymer tackifier (PMP).
   c) 11 kg (25 lb) wood mulch with 2.9 kg (6.5 lb) polymer tackifier (WMP).
   d) 11 kg (25 lb) of paper mulch with 1.1 kg (2.5 lb) psyllium tackifier (PMG).
   e) 11 kg (25 lb) of wood mulch with 1.1 kg (2.5 lb) psyllium tackifier (WMG).
   f) 23 kg (50 lb) of gypsum with 5.7 kg (12.5 lb) wood fiber mulch (GYP1).
   g) 23 kg (50 lb) of gypsum with 5.7 kg (12.5 lb) wood fiber mulch (GYP2).
   h) 1.1 kg (2.5 lb) of psyllium tackifier for straw on cut slope only (RSG).
7. The mixture was agitated for at least five minutes to create a consistent, homogeneous mix.
8. Prior to application of the mixture on the subplots, the pumping rate (and thereby the application rate) was determined for each material by separately timing the filling of three 19-L (5-gal.) buckets to the 15-L (4-gal.) mark. An average fill time was calculated for the three buckets.
9. The application rate for each of the erosion control treatments was as follows:
   (a) BFM was applied at a rate of 3,360 kg/ha (3,000 lb/ac).
   (b) PMP was applied at a rate of 2,240 kg/ha (2,000 lb/ac).
   (c) WMP was applied at a rate of 2,240 kg/ac (2,000 lb/ac).
   (d) PMG was applied at a rate of 2,240 kg/ac (2,000 lb/ac).
   (e) WMG was applied at a rate of 2,240 kg/ac (2,000 lb/ac).
   (f) GYP1 was applied at a rate of 5,040 kg/ha (4,500 lb/ac).
   (g) GYP2 was applied at a rate of 6,720 kg/ac (6,000 lb/ac).
   (h) RSG was applied at a rate of 224 kg/ha (200 lb/ac).

10. Based on the application rate, water-to-material ratio, and average fill time, the application time, t [sec], was calculated as follows:

$$t = \frac{W_{hydro} MAT_{subplot} \bar{t}_4}{(15.14 \text{ liters}) MAT_{hydro}}$$

where W_{hydro} = volume of water added to the hydroseeder (liters); $MAT_{subplot}$ = weight of treatment material to be applied on each subplot [kg], as calculated from the application rate and subplot area; $\bar{t}_4$ = time required to fill a standard bucket to a 15-L (4-gal.) mark (sec); and MAT_{hydro} = weight of treatment material added to the hydroseeder (kg).

11. The treatment was applied under the supervision of a field inspector who verified that the treatment was applied at the calculated rate.

12. Prior to mixing a new batch of material for application, the inside of the hydroseeder was sprayed with clear water to remove all trace material, and the hose was flushed in preparation for the next series of tests and applications. On-the-slope calibrations were conducted prior to application of each erosion control treatment.

Exceptions

Exceptions to the prescribed treatment applications were as follows:

- Bonded fiber matrix (BFM) application at Site 57-4, Row 3 subplot only: This subplot mistakenly received twice as much BFM as the specified application rate for the study.
- Wheat straw used instead of rice straw: During the procurement of materials, it was found that rice straw was not readily available in southern California, and that wheat straw is typically used for erosion control in District 7. Therefore, wheat straw was used in lieu of rice straw. However, the treatment designations, RSG and RSI, were retained due to their prevalence in study reports, data collection forms, and other study documentation.
- Straw application at Site 10-2: Straw was crimped by tamping it down with a shovel. The ground was too hard to incorporate the straw into the soil with a shovel point, which would have cut the straw into smaller, less effective pieces.
- A psyllium- (or plantago) based tackifier was used in place of guar tackifier. The psyllium tackifier used by W-Binder brand and consisted of 100 percent pure plantago seed husk. The use of the "G" in the erosion control treatment designations (e.g., PMG) was used to avoid confusion with the polymer erosion control treatment designation (e.g., PMP).

2.4.4 Plant Establishment Test Plot Erosion Control Blanket Installation

For each test plot area, there were three subplots each with straw blanket (SB), straw/coconut blanket (SCB), coconut blanket (CB), coir netting (COIR), wood fiber blanket (WFB), and curled wood fiber blanket (CWFB). A summary of the erosion control treatments used is presented in

Table 1-2. All the blankets were manufactured with a width of approximately 2 m (7 ft.), so they only needed to be cut to the correct length. The blankets were prepared and installed as follows:

1. The blankets were cut slightly longer than the 2 m (7 ft.) subplot length (approximately 2.3 m [7.5 ft.]) in order to cover the bare area between the subplot and the fiber roll. The straw/coconut blanket (SCB), coconut blanket (CB), and coir netting (COIR) were rolled out on the ground and pre-cut to size; all other blanket types were cut to size on the subplot.
2. Rubber mallets were used to hammer 13 staples into each blanket, using the following pattern on the 2-m (7-ft.) square subplot:

X X
X
X X
X X
X

2.4.5 Plant Establishment Test Plot Maintenance and Irrigation

Throughout the 20-month course of the project, from September 1998 through June 2000, weekly inspections were made of all plant establishment test plots. The inspections included observations of the condition of the test plots, and maintenance and repairs as required. Through February 11, 1999, the inspections also included observations of soil moisture and the temporary irrigation systems at the two irrigated plant establishment test sites.

Activities performed as part of the weekly inspections included, but were not limited to:

- Observations of the condition of each test plot, with photo documentation and notations on the inspection forms and/or plot plan of damage to the test plots by animals (e.g., gophers, deer, and coyotes), humans (unintentional damage and/or vandalism), and traffic mishaps.
- Inspection and repair of fiber rolls.
- Inspection/test of integrity of rain gauges and repair/replacement as required.
- Measurements to verify that rain gauge installations were plumb. Adjustments were made as necessary.
- Repair of erosion in areas adjacent to, but outside of, test plots that may threaten the integrity of the test plots, or that may hinder access to the test plots for study purposes.

2.4.5.1 Weeding

The *Training Manual* (URS Greiner Woodward Clyde, 1998b) indicated that weed (self-seeding, non-native species) control would be performed after each monitoring period within each 2-m by 2-m test plot. However, due to the assumption that the removal of the upper layer of topsoil, roots, and vegetation during test plot construction would remove the weed seed bank, plans for controlling weeds on the plant establishment plots were not included in the original project design. However, in spite of the upper soil removal, a significant weed seed bank remained. Therefore, a one-time extensive weeding effort was performed within the 1-m by 1-m (3-ft. by 3-ft.) monitoring quadrat area of each 2-m by 2-m (7-ft. by 7-ft.) plant establishment test subplot during the first monitoring period. The weeding was conducted to compensate for the fact that the plant establishment test plots had not been installed on bare, newly graded highway slopes and to reduce competition for sunlight and moisture for the slower growing native coastal sage scrub species. A four-week weeding episode was conducted between December 15, 1998 and January 8, 1999. The weeds were removed by cutting the undesired plants close to their base. Further weeding was not performed because weeding is labor intensive, not a Caltrans standard maintenance practice on erosion control sites, and newly graded slopes will exhibit weed growth due to seed blow-in and other sources.

2.4.5.2 Irrigation

The temporary irrigation system for the irrigated plant establishment test plots was manually operated for 90 days after planting (November 13, 1998 to February 11, 1999). The irrigation was performed to test the effectiveness of supplemental irrigation and to enhance the natural rainfall in order to obtain optimal germination and establish early season vegetation. Rain gauges were used to measure the amount of water applied during each irrigation event. The rain gauge readings were recorded and the gauges reset (i.e., emptied and replaced) after each irrigation event.

During the initial irrigation event, soil was irrigated to full field capacity to a depth of about 30 cm (12 in.). Thereafter, soil was allowed to dry to approximately 50 to 60 percent of field capacity moisture in the top 15 to 20 cm (6 to 8 in.) of soil, before the next irrigation cycle. A soil auger or shovel was used to examine soil moisture content at the required depths within the access paths. The moisture content was tested by tightly squeezing a handful of soil. If the soil did not stick together or moisture could not be felt in the soil, then irrigation was applied.

The frequency and duration of irrigation, and the number of cycles needed, was assessed by observations of soil moisture levels. For a typical irrigation event, the irrigation system was turned on for two periods of 10 to 12 minutes each, with approximately an hour in between the two irrigation periods.

A fire hydrant was used to supply irrigation water at Site 10-2. For each irrigation event, a water meter and fire hose were used to connect the hydrant to the irrigation system. At Site 57-4, which had no available water supply nearby, irrigation water obtained from a fire hydrant was brought to the site in a 1,893-L (500-gal.) “water wagon”, and pumped to a storage tank on the slope. A separate booster pump then pumped water from the tank to the irrigation system.

Form 4 was used to record the date, duration, amount of water applied, and description of general soil conditions during each irrigation event. A sample of Form 4 is included in Appendix A.

2.5 SOIL EROSION RESEARCH LABORATORY

2.5.1 Soil Erosion Research Laboratory Facility Description

As discussed in Section 1.3.6.2, the Caltrans/SDSU Soil Erosion Research Laboratory is located on the campus of SDSU. The Soil Erosion Laboratory is an indoor testing facility that consists of a tilting soil test bed, portable overhead rainfall simulators, and a water treatment and storage system. A detailed description of this equipment was presented in the *Laboratory Manual* (URS Greiner Woodward Clyde, 2000b). A summary of the facility equipment is presented below.

2.5.2 Design and Construction of Soil Erosion Research Laboratory Facilities

2.5.2.1 Norton Ladder Rainfall Simulator

The pre-fabricated Norton Ladder Rainfall Simulator devices were purchased from Advanced Design & Machine (Clarks Hill, Indiana) and were used to simulate rainfall for both the indoor and outdoor laboratory tests. The rainfall simulator devices are self-contained units that consist of nozzles, an oscillating mechanism, drive motor, pump, float valve, piping, and sump. Multiple rainfall simulators were installed in parallel on an aluminum frame above the soil test bed to uniformly apply precipitation over the entire test plot area. Initial calibrations demonstrated the need for using four (4) simulators to achieve even distribution of rainfall on the plot at the desired intensities. The nozzles were placed at least 2.5 m (8 ft.) above the soil surface to create an impact velocity nearly equal to that of a natural raindrop (Meyer and McCune, 1958). Rainfall intensity could be changed instantaneously with the simulator in operation, up to a maximum intensity of 135 mm/hr (5 in./hr). The simulators were transported to the outdoor laboratory myoporum test plots for vegetation cover testing.

2.5.2.2 Indoor Laboratory Soil Test Bed

The soil test bed is a 3-m wide by 10-m long (10-ft. by 33-ft.) metal frame which rests on a series of pivots located at the lower end of the bed, and is supported by two hydraulic cylinders near the upper end of the bed (Figure 1-14). The soil test bed was raised from a horizontal position to the 1V:2H slope gradient that was used during the tests. The test bed is designed to support a 30.5-cm (1-ft.) thickness of soil. This soil thickness is sufficient to allow placement and compaction of soil and apply the various surface roughnesses to evaluate their effect on erosion rates.

The sides and ends of the soil test bed are constructed of steel frame-supported 1.0-cm (0.4-in.) thick Plexiglas which allows ambient light onto the soil surface to facilitate viewing of the effects of rainfall impact and runoff. The total usable surface area of the soil bed was prepared and treated with the various surface roughnesses. However, only a 2 m wide by 8 m long (7 ft. by 26 ft.) portion of the treated bed was delineated for evaluation for the slope roughness tests by the use of plastic edging. For the water quality test, the 2-m wide by 8-m long (7-ft. by 26-ft.) area was divided into three equal parts each 0.6-m wide by 8-m long (2 ft. by 26 ft.). For the slope roughness/erosion rate evaluation, the plastic edging was installed following implementation of the surface roughness. For the erosion control treatment/water quality evaluation, the plastic edging was installed prior to application of the erosion control treatment.

Water and soil runoff from the test bed were directed into a collection system consisting of plastic edging, a flume, and collection containers. The components of the sediment collection system on the test bed were installed prior to each rainfall simulation. Drainage grates were installed in the floor at the front and sides of the soil bed, and all runoff not collected was directed to a sanitary sewer. As a safety precaution, stationary steel support posts were placed beneath the bed when it was raised for rainfall simulations. The floor of the test bed is constructed of metal grating covered with three-dimensional drainage composite.

2.5.2.3 Indoor Laboratory Water Treatment and Storage

Prior to use in the rainfall simulators, the municipal water supply was run through a water treatment system to soften and remove minerals to produce water that is more similar in quality to natural rainfall. Without treatment, the municipal water supply would likely cause a decrease in the sediment load due to minerals in the water acting as soil binders.

The water treatment system consists of a reverse osmosis unit, preceded by one activated carbon vessel and two softening vessels arranged in series (i.e., carbon/softener/softener). The system, which is capable of producing 1,140 to 2,270 L per day (300 to 600 gal. per day), also includes a pre-filter to remove particulates greater than 5 microns in size that may escape the service vessels.

Water was pumped through flexible hoses to the rainfall simulators positioned above the soil test bed. Unused water from the simulators was returned via flexible hoses to the holding tank for reuse. For quality assurance purposes, water samples were collected from the water treatment system for alkalinity and hardness analysis and the unit was serviced on a monthly basis.

Treated water was stored in a 3,785-L (1,000-gal.) polyethylene storage tank for use in the indoor laboratory simulations. For the outdoor laboratory myoporum test plots, truck-mounted tanks were used to deliver treated water for rainfall simulations.

2.5.3 Indoor Laboratory Facility Maintenance

Maintenance procedures for the indoor laboratory facility were outlined in the *Operations & Maintenance Manual* (URS Greiner Woodward Clyde, 2000a) for the following systems and/or equipment:

- Rainfall simulator pumps, motors, nozzles and water supply system;
- Soil test bed;
- Hydraulic motor, pump and cylinders;
- Water treatment system; and
- Routine housekeeping.

Where information was available from the equipment manufacturers or suppliers, it was incorporated into operation and maintenance procedures.

2.5.3.1 Indoor Laboratory Facility Daily Inspections

At the beginning of each day of operation, lab personnel visually inspected the work area to ensure that it was in a safe condition. A pre-operation checklist was completed as part of this visual inspection.

Before operation of any system component (i.e., hydraulic motor, water treatment system, etc.), the applicable section of the *Operation & Maintenance Manual* and maintenance log were reviewed, updated, and routine servicing was noted. Major maintenance or repair needs were brought to the attention of Mr. Michael Harding, Field and Laboratory Manager and/or Dr. Howard Chang, the Laboratory QA/QC Manager.

2.5.3.2 Indoor Laboratory Facility Weekly Inspections

At the end of each week of operation the Erosion Control Laboratory Manager reviewed the maintenance log of each component to ensure that the equipment was in safe operating condition and that any major repair or maintenance items had been addressed.

2.5.3.3 Indoor Laboratory Facility Logbooks

In addition to the maintenance logs, a separate logbook was kept to record work activities (testing, etc.) conducted at the SDSU laboratory. The SDSU QA/QC Manager was responsible for ensuring that these logs were kept accurate and up-to-date.

2.6 OUTDOOR LABORATORY MYOPORUM TEST PLOTS

2.6.1 Outdoor Laboratory Myoporum Test Plot Site Descriptions

Outdoor laboratory myoporum test plots were installed on two slope types; on one cut slope and one fill slope. Each test plot consisted of three replicate plots, yielding a total of 6 subplots. The fill slope myoporum test plot (Site 10-2) was located next to the DeVry Institute in the city of Pomona, adjacent to the transition from eastbound I-10 to southbound SR 71. The cut slope myoporum test plot (Site 57-4) was located near Brea Canyon Road in the city of Diamond Bar, adjacent to southbound SR 57. A map showing the outdoor laboratory myoporum test plot locations is provided as Figure 2-1.

2.6.2 Outdoor Laboratory Myoporum Test Plot Construction

The outdoor laboratory test plots were constructed in the same manner and layout as the erosion rate test plots described above in Section 2.3.2. In summary, these test plots each consisted of three replicate subplots measuring 2 m by 8 m (7 ft. by 26 ft.) in area, that were delineated by metal edging. Each of the subplots was separated from each other by 0.5 m (2 ft.). A collection system consisting of a flume, PVC piping and conduit, and collection drums were located at the base of each subplot. Like the bare erosion rate test plots, the existing vegetation and topsoil was removed in the manner described in Section 2.2.1. A description of the procedures used to plant the myoporum seedlings is presented below in Section 2.6.4.

Construction activities were accomplished at all sites without the need for shoulder closures, lane closures, or other traffic control measures.

2.6.3 Outdoor Laboratory- Simulated Rainfall Equipment Construction

Scaffolding designed to support the rainfall simulation devices was installed over the three replicate myoporum test plots at each of the two outdoor laboratory test sites partially through the testing program. For the first several rainfall simulation events, temporary scaffolding was manually assembled at the test plots. Due to the labor intensiveness associated with assemblage of the temporary scaffolding, permanent scaffolding was constructed over each test plot. The permanent scaffolding was anchored to the slope with geotextile pins, rebar, or other appropriate metal fastening devices and was positioned so that it allowed a drop distance of 2.5 m (8 ft.) from the rainfall simulators to the soil surface. The rainfall simulators were installed to the scaffolding in the manner described above in Section 2.5.2.1

2.6.4 Outdoor Laboratory- Myoporum Seedling Planting

The procedures for planting the myoporum seedlings outlined in the *Laboratory Manual* (URS Greiner Woodward Clyde, 2000b) were followed. The myoporum seedlings were planted in such a manner to minimize disturbance to the test plot soil surface. In summary, 25.4-cm (10-in.) deep holes were dug according to the diamond pattern shown on Figure 2-13. The side of the hole was roughened, and the hole was saturated with water prior to planting. The myoporum seedling was placed in the hole without trimming the roots. Controlled-release 16-6-8 (nitrogen-phosphorus-potassium) fertilizer was placed at mid-depth in the hole, against the upslope edge of the hole away from the roots to enhance root development and seedling growth. Upon completion of backfilling the hole, the surface was raked smooth.

2.6.5 Outdoor Laboratory Myoporum Test Plot Maintenance and Irrigation

2.6.5.1 Maintenance Inspections

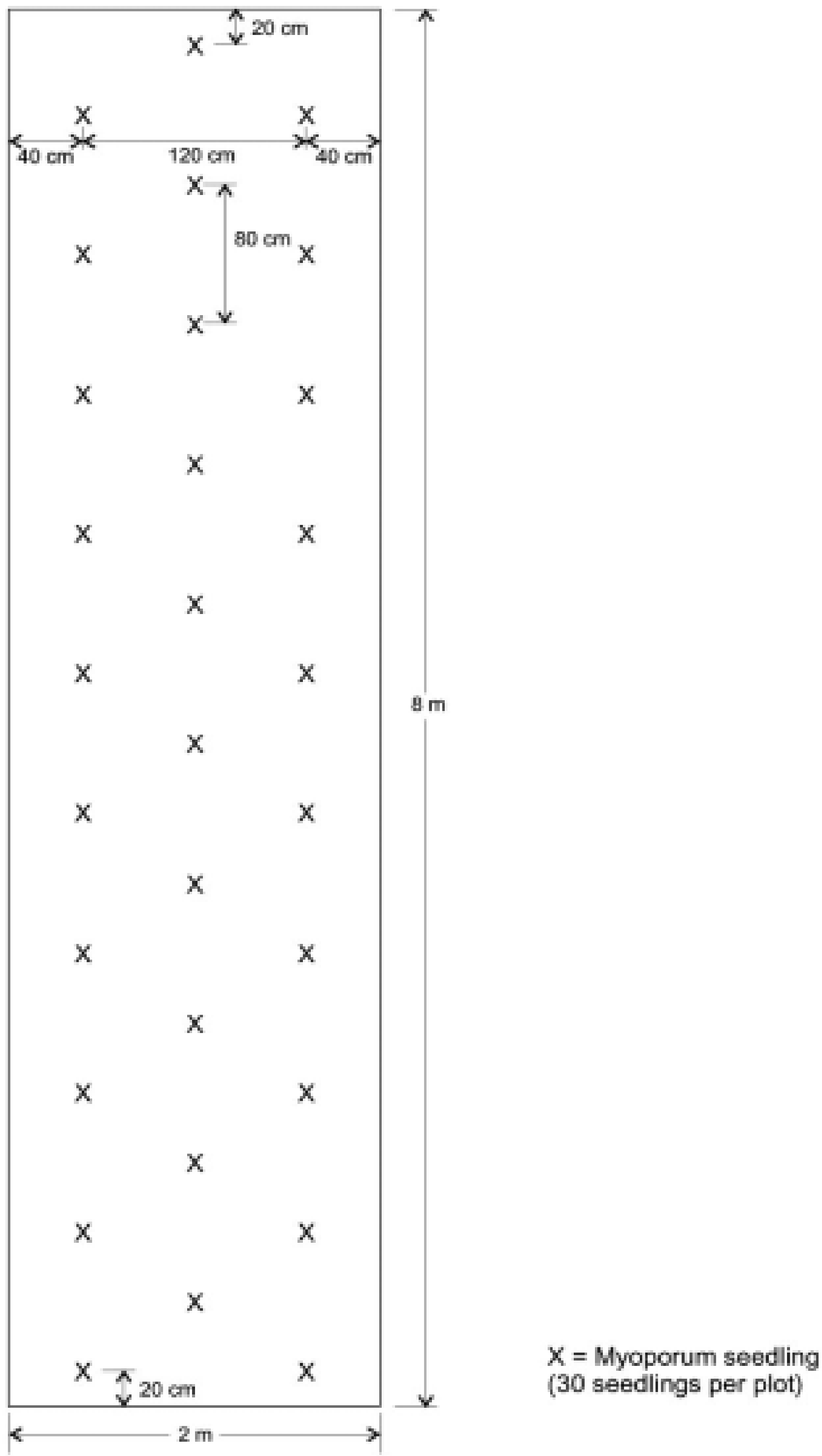
Weekly maintenance inspections were conducted to observe the condition of the test plots and the sediment collection systems. The inspections included observations of soil moisture and irrigation systems. Maintenance, irrigation, and repairs were completed as required. The conditions of the test plots were documented on a site inspection form (Form 11) and with photographs.

Activities performed as part of the weekly inspections included, but were not limited to:

- Observed the condition of each test plot, with photo documentation and notation on the inspection forms and/or plot plan of damage to the test plots by animals (e.g., gophers, deer, and coyotes), humans (unintentional damage and/or vandalism), and traffic-related mishaps.
- Removed foreign objects from the sediment collection systems, including leaves and other debris, rodent and other small animal carcasses, and insects and spiders.

- Inspected edging around test plots, particularly after a rainfall event. Repaired edging undermined by erosion.
- Inspected and repaired sediment collection systems.
- Repaired erosion of areas adjacent to, but outside of, test plots that threatened the integrity of the test plots, or that hindered access to the test plots for study purposes.
- Inspected for weed growth. Removed weeds in a manner that did not cause ground disturbance.
- Inspected and repaired rain gauge equipment.

A sample of Form 11 used during the site inspections is included in Appendix B.



PLANTING PATTERN FOR MYOPORUM SEEDLINGS

Project No.: 57-977001NM.00	Date: JUNE 2000	Project: CALTRANS EROSION CONTROL PILOT STUDY	Fig.: 2-13

Fig_13.cdr 5/30/00

2.6.5.2 Weed Control

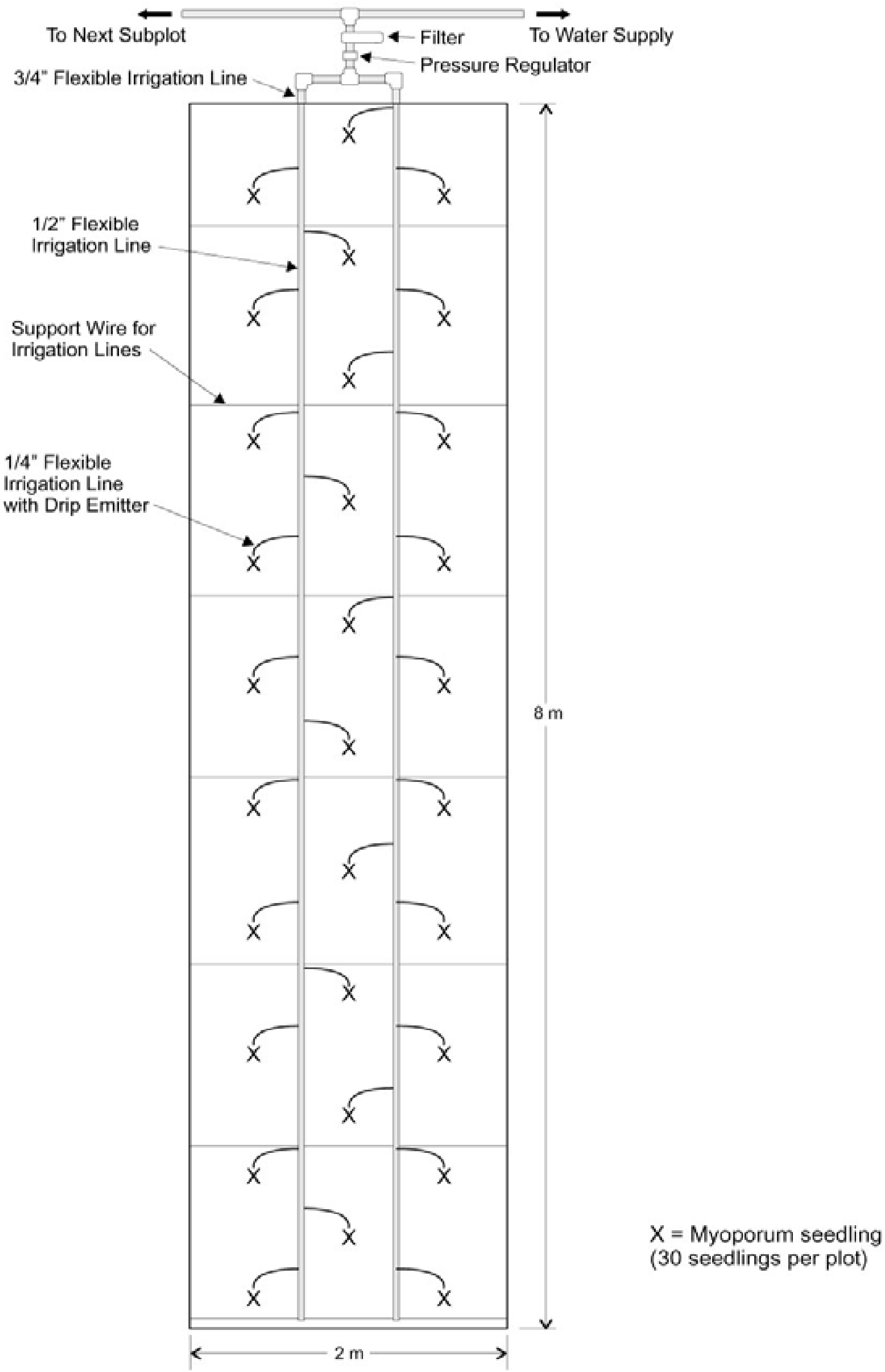
Weeds were removed from the myoporum test plots by cutting as opposed to pulling, to minimize disturbance to the soil surface.

Weed control outside of the test plots was performed only as necessary to maintain working access to the test plots.

2.6.5.3 Irrigation Procedures

The plants within the myoporum test plots were irrigated individually with drip irrigation systems. The water source that had previously been used at both sites for irrigating the plant establishment test plots was used to irrigate the myoporum test plots. The main supply lines were connected to the existing irrigation systems. A description of the drip irrigation construction procedures was provided in the *Laboratory Manual* (URS Greiner Woodward Clyde, 2000b). A schematic plan view of the drip irrigation system is provided as Figure 2-14.

The frequency and duration of irrigation, and the number of cycles needed, was assessed by observations of soil moisture levels. The soil was allowed to dry to approximately 50 to 60 percent of field capacity moisture in the top 15 cm to 20 cm (6 in. to 8 in.) of soil, before the next irrigation cycle. A soil auger or shovel was used to examine soil moisture levels at the required depths within the access paths. The moisture content was tested by tightly squeezing a handful of soil. If soil did not stick together or moisture could not be felt in the soil, then irrigation was applied. For a typical irrigation event, the drip irrigation system was turned on for approximately 1½ to 2 hours. The date and duration of each irrigation event were recorded on Form 10 included in Appendix B.



DRIP IRRIGATION SYSTEM LAYOUT			
Project No.: 57-977001NM.00	Date: JUNE 2000	Project: CALTRANS EROSION CONTROL PILOT STUDY	Fig.: 2-14

Fig_14.cdr 5/30/00

This section describes the monitoring and test procedures for the erosion rate test plots, plant establishment test plots, indoor laboratory test beds, and outdoor laboratory myoporum test plots. In addition, this section describes the QA/QC program that was implemented for each phase of the testing and monitoring program. Table 3-1 presents the monitoring schedule for the field test plots and the laboratory program test schedule.

3.1 QUALITY ASSURANCE/QUALITY CONTROL PROGRAM

The QA/QC program for the field test plots was described in the *Construction and Monitoring of Field Test Plots* (URS Greiner Woodward Clyde, 1999). The QA/QC program for the laboratory testing was described in the *Laboratory Manual* (URS Greiner Woodward Clyde, 2000b). A copy of the Quality Assurance Program Guide developed for the analytical testing program is included in Appendix C. The objective of the QA/QC program was to implement the procedures necessary to obtain consistent data and scientifically valid, repeatable results. The data quality and reported results were assured by the use of accepted, standardized field and laboratory sampling procedures, and appropriate statistical tests. Monitors were trained and retrained as needed prior to each data collection event.

The following QA/QC procedures were followed to assure that comparable data was collected:

- Test plot layouts were randomized for each site.
- Field monitoring staff received training on coastal sage scrub vegetation identification and measurement prior to every sampling event.
- Field monitoring staff received training on vegetation monitoring including species identification, evaluating species diversity, seedling vigor, seedling growth rate, root depth sampling, estimating vegetation cover and vegetation density, and use of the Daubenmire cover scale. Photos of the native plant seedlings and dominant weed species seedlings were used to train field monitoring staff on species identification. Copies of these training photos are included in Appendix D.
- Training sessions were conducted for all staff collecting rainfall measurements, sediment samples, runoff samples, and operating and calibrating the rainfall simulators, soil test bed, and other laboratory equipment.
- Training sessions were conducted for all staff on mixing and placing soil into the laboratory test beds, test procedures for obtaining moisture content, dry density, and compaction, operation of the hydraulic lifts, and operation of the water treatment system.
- Data were recorded on task specific forms using consistent methods and units of measure.
- Quality Control personnel observed testing and sampling procedures and reviewed data regularly to assure consistency and quality.

Table 3-1
MONITORING SCHEDULE[1]

	1998				1999												2000				
ACTIVITY NAME	**Sep**	**Oct**	**Nov**	**Dec**	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**	**Oct**	**Nov**	**Dec**	**Jan**	**Feb**	**Mar**	**Apr**	**May**
ALL FIELD TEST PLOTS																					
Record site characteristics			Mon, Nov 30																		
Soil sampling		Mon, Oct 19							Mon, May 17											Mon, Apr 17	
EROSION RATE TEST PLOTS																					
Vegetation cover data			Mon, Nov 30						Mon, May 17						Mon, Nov 1					Mon, Apr 17	
Species diversity data			Mon, Nov 30						Mon, May 17						Mon, Nov 1					Mon, Apr 17	
Photo documentation			Mon, Nov 30						Mon, May 17						Mon, Nov 1					Mon, Apr 17	
Plant density data																				Mon, Apr 17	
PLANT ESTABLISHMENT TEST PLOTS (IRRIGATED & NON-IRRIGATED)																					
Vegetation cover data				Mon, Dec 7			Mon, Mar 1		Mon, May 24			Mon, Aug 9			Mon, Nov 8		Mon, Jan 31			Mon, Apr 24	
Seedling growth rate and vigor data				Mon, Dec 7			Mon, Mar 1		Mon, May 24			Mon, Aug 9			Mon, Nov 8		Mon, Jan 31			Mon, Apr 24	
Plant density data				Mon, Dec 7			Mon, Mar 1		Mon, May 24			Mon, Aug 9			Mon, Nov 8		Mon, Jan 31			Mon, Apr 24	
Species diversity data				Mon, Dec 7			Mon, Mar 1		Mon, May 24			Mon, Aug 9			Mon, Nov 8		Mon, Jan 31			Mon, Apr 24	
Photo documentation				Mon, Dec 7			Mon, Mar 1		Mon, May 24			Mon, Aug 9			Mon, Nov 8		Mon, Jan 31			Mon, Apr 24	
Root depth sampling																				Mon, Apr 24	
INDOOR LABORATORY SOIL TEST BED[2]																					
Smooth-Rolling																		Feb 18 (start)	March 14 (end)		
Ripping																			March 16 (start)	April 4 (end)	
Trackwalking																				April 7 (start)	May 16 (end)
Sheepsfoot-Rolling																					May 11- 23
Imprinting																				April 10 (start)	May 12 (end)
Water Quality																				April 28 (start)	May 16 (end)
OUTDOOR LABORATORY MYOPORUM TEST PLOTS[2]																					
Simulated Rainfall/Vegetation Cover												Aug 9 - 17					Jan. 12- 27	Feb. 5	March 18	April 16	May 6-7

(1) Actual monitoring/sampling began within one week of dates shown and was completed within 2 weeks of start date, weather permitting.

(2) Indoor and outdoor laboratory test dates indicate start and stop date of each series of tests.

A system of training and oversight of sampling procedures was followed in all phases of the ECPS to document QA/QC. Performance and systems audits were conducted on an as-needed basis at the discretion of the Erosion Laboratory Manager or Field Manager.

The monitoring and sampling events were all performed in a manner consistent with the QA/QC program. Different elements of the QA/QC program applicable to the field and laboratory program are discussed below.

3.2 INITIAL SITE CHARACTERIZATION

Initial characterization of the erosion rate and plant establishment test plot sites was conducted in December 1998, following construction. Information on the physical conditions of each test site (i.e., type of test and test plot/site number, cut/fill or natural, slope gradient and aspect, and soil type) was recorded. Form 1 was used for initial site characterization of erosion rate test plots, and Form 2 was used for initial site characterization of plant establishment test plots. Initial site characterization was a one-time only data collection effort (Table 3-1). Samples of these forms are included in Appendix A. Initial site characteristics are documented in Table 2-1.

3.3 RAINFALL MEASUREMENTS

Rainfall was monitored at each of the field sites during the wet seasons (November through April) of the two-year monitoring period. During the 1998-1999 monitoring season one precipitation event was recorded that occurred outside of the wet season monitoring period. This precipitation event occurred on June 2, 1999.

Rainfall was measured with rain gauges located at each site. The rain gauges were mounted approximately 1.5 m (5 ft) above the ground surface on posts located near the test plots. One gauge was mounted per erosion rate test plot type, and one gauge was mounted per irrigated/non-irrigated pair of plant establishment test plots.

Rainfall measurements were made during daytime hours at approximate 24-hour intervals following the observed, or otherwise reported, start of a rainfall event. Reports of the start of a rainfall event were obtained from television or radio broadcasts, or other reliable sources, such as the National Weather Service and the Los Angeles County Department of Public Works. After each reading, the rain gauge was emptied and reset for additional collection. Rainfall measurements were recorded on Form 3. A sample of Form 3 is included in Appendix A.

3.4 EROSION RATE TEST PLOTS

Erosion rate test plots were monitored to evaluate the effectiveness of four vegetation types on controlling erosion and runoff on cut and fill slopes. As part of this evaluation, vegetation was monitored within the erosion rate test plots for cover, density, and diversity. Finally, due to the presence of gophers in several of the grass/forb complex erosion rate test plots during the study period, the impact of gopher activity on soil loss on both cut and fill slopes was evaluated.

3.4.1 Erosion Rate Test Plot Sediment/Runoff Collection

Rainfall events qualified for sediment/runoff sampling when more than 6 mm (0.25 in.) of rain was recorded within a 24-hour period. A rainfall event was considered to have ended when no subsequent measurable precipitation occurred within a 24-hour period. Within 36 hours after every sampled rain event, sediment discharges were collected from the three replicate test plots at each test site.

Following the end of each qualifying rainfall event, water and sediment that had accumulated in the sediment collection system (i.e., collection flume, piping system, and collection drums) at each erosion rate test plot was collected from the test sites. Dry sediment that was retained within the flume and PVC piping system was collected with a hand brush and pan. To assure that all sediment retained in the collection system was obtained, the flume and/or piping system was flushed into the collection drum with clear water following each rainfall event. The amount of water added to the runoff was carefully measured and documented on the sample label and recorded on Form 5.

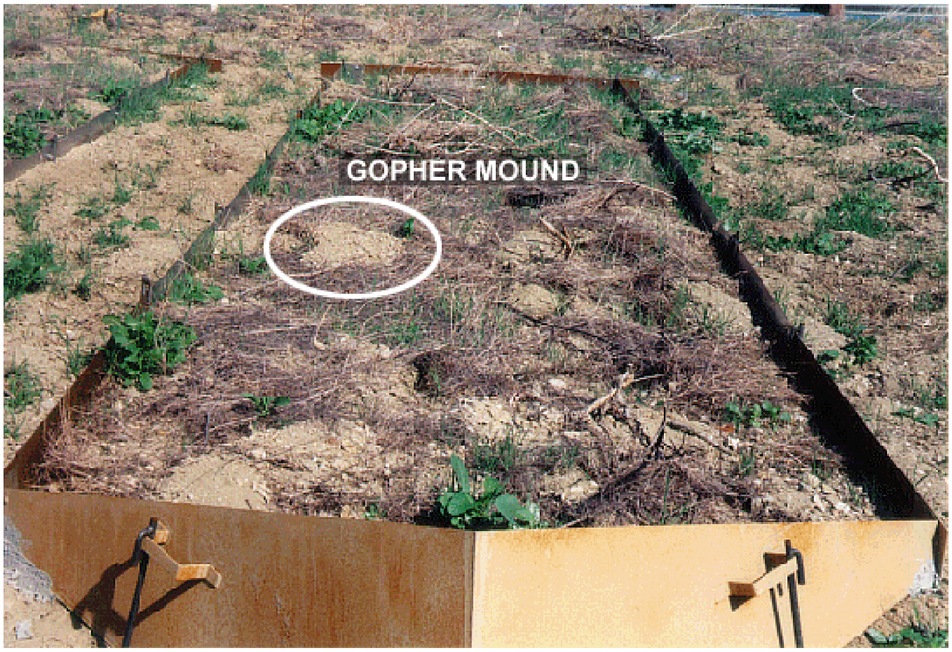
For a rainfall event of less than 6 mm (0.25 in.) in a 24-hour period, the collected runoff and sediment were placed on the slope in the vicinity of the test plots, but outside of the test plot area, in a manner that facilitated infiltration into the slope.

From the outset of the study, soils within all three replicates at both cut and fill grass/forb complex test plots were notably disturbed by gopher activity (Figure 3-1(a)). Occasionally, the gopher activity was concentrated near the flume and resulted in additional soil accumulation in the flume, under both storm and non-storm conditions (Figure 3-1(b)). In an effort to quantify the volume of sediment that was being contributed by gopher activity, the portion of soil retained on the flume was collected and labeled as either “runoff soil” if it appeared to have been deposited as a result of general runoff, or “gopher soil,” if it appeared to have originated from gopher activity. This procedure was only conducted during the 1998-1999 season. During the 1999-2000 season, all soil retained on the flume was combined and “gopher soil” was not differentiated from the “runoff” soil. Form 5 was used to record runoff and sediment collection data. A sample of Form 5 is included in Appendix A.

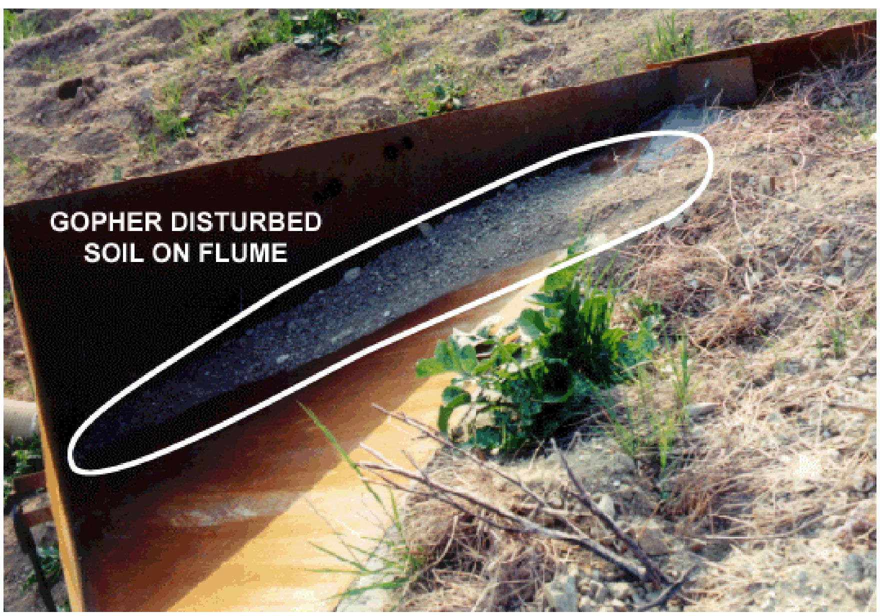
The runoff and soil samples were transported to URS’s Santa Ana laboratory, where they were weighed, the water was evaporated, and the dry weight and gradation of the soil were measured. Results were analyzed to evaluate the volume of runoff and soil eroded from each test plot during each sampled rain event and to evaluate the volume of soil contributed from gopher activity. For quality assurance purposes, approximately 5 percent of the sediment samples collected for each rain event were reweighed and retested for gradations. The samples for retesting were randomly selected.

3.4.2 Erosion Rate Test Plot Vegetation Monitoring

Two fall and two spring vegetation monitoring events were conducted at the erosion rate test plots, on the scheduled dates of November 30, 1998, May 17, 1999, November 1, 1999, and April 17, 2000 (Table 3-1). During each of the monitoring events, vegetation was monitored for vegetation cover and species diversity. Plant density data were also collected during the last (April 2000) monitoring event. Data were collected from the three replicate test plots at each site. The same vegetation data were also collected for the reference and research test plots. No vegetation monitoring was conducted in the non-vegetated bare test plots, per the experimental study design.



(a) Grass/forb erosion rate test plot with significant gopher damage (Site 10-2, Fill Slope, Plot RC).



(b) Close-up of a gopher mound trailing onto the collection flume at a grass/forb test plot (Site 10-2, Fill Slope, Plot RC).

Data were collected from the three replicate test plots at each site. Vegetation monitoring for the erosion rate test plots was performed by the training personnel. Therefore, no resampling was performed.

3.4.2.1 Vegetation Cover

Vegetation cover is the percentage of ground surface covered by vegetation material (Bonham, 1989). Within the erosion rate test plots, vegetation cover was visually estimated for the entire test plot as well as for each plant species within each test plot.

The visual observations of percent cover were expressed using the Daubenmire cover scale (Daubenmire, 1959) to assure reproducible results suitable for statistical analysis (Bonham, 1989). The Daubenmire cover scale is presented in Table 3-2. Form 6 was used for recording vegetation cover data. A sample of Form 6 is included in Appendix A.

3.4.2.2 Species Diversity

Species diversity was assessed by identifying and recording species observed within the boundaries of each of the three replicate subplots. A list of shrub, perennial, and annual grass/forb species were complied for each subplot. Form 6 was used for recording species diversity data. A sample of Form 6 is included in Appendix A.

3.4.2.3 Plant Density

Plant density is the number of plants rooted within a given area. Plant density in each test plot was estimated by counting the total number of plants of each species in four 0.25-m by 0.25-m (0.8-ft. by 0.8-ft.) quadrates, randomly placed within each test plot.

Within the erosion rate test plots, it was not necessary to measure plant density more than once during the relatively short test period because the erosion rate test plots are located in existing, mature vegetation, and the density was not likely to change over the study period. Determination of the density of these plots required some plant damage, particularly to the iceplant and myoporum Therefore, measurements of plant density were conducted only during the last monitoring event (April 2000) in order to minimize damage to the vegetation during the monitoring period. Form 7 was used for recording plant density data. A sample of Form 7 is included in Appendix A.

3.5 PLANT ESTABLISHMENT TEST PLOTS

Vegetation within the plant establishment test plots was monitored to evaluate the effects of the 15 temporary erosion control treatments, plus untreated (bare) soil surface, on plant germination and growth. The temporary erosion control treatments are documented on Table 1-2. Monitoring was also performed to evaluate the effects of supplemental irrigation on plant establishment.

Table 3-2
DAUBENMIRE COVER CLASSES

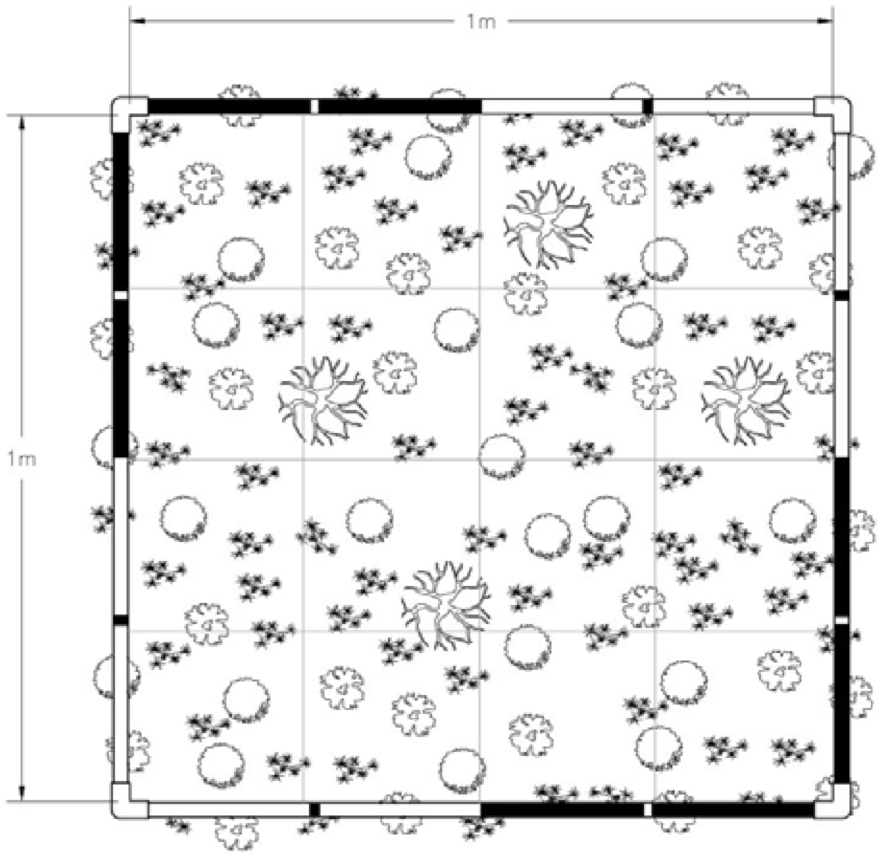
Cover Class	Range of Cover (%)	Class Midpoints (%)
0	None observed	
1	0^+ – 5	2.5
2	5 – 25	15.0
3	25 – 50	37.5
4	50 – 75	62.5
5	75 – 95	85.0
6	95 – 100	97.5

3.5.1 Plant Establishment Vegetation Monitoring

Seven vegetation monitoring events were conducted on December 7, 1998, March 1, 1999, May 24, 1999, August 16, 1999, November 8, 1999, January 31, 2000, and April 24, 2000 (Table 3-1). Vegetation was monitored for vegetation cover, plant density, species diversity, seedling vigor and growth rate. Root depth data was also collected during the last (April 2000) monitoring event.

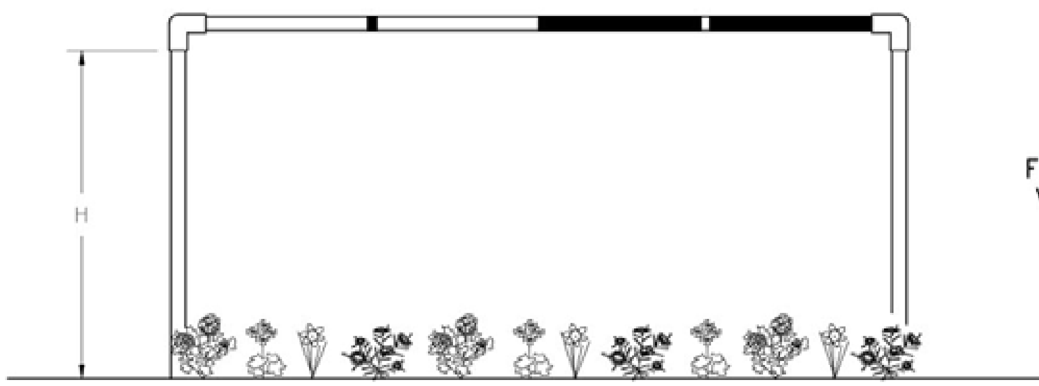
Vegetation monitoring for the plant establishment test plots was conducted within a 1-m by 1-m (3-ft. by 3-ft.) subset of each 2-m by 2-m (7-ft. by 7-ft.) test subplot. Each monitoring area was delineated by a modified Daubenmire cover frame, also known as a “quadrat” (Figure 3-2), which was placed 0.3 m (1 ft.) in from the right lower side of the subplot. As shown on Figure 3-2, bungee cords were used to divide the quadrat area into 16 equal sections as an aid to estimate percent cover.

Data were collected from each of the three replicate test plots at each site and the sampling sequence of all replicates was randomized during each monitoring event. Sampling methods were the same for all plant establishment test plots. During each vegetation monitoring event, experienced training personnel were present to observe the monitoring staff’s field techniques and to provide additional instruction and/or clarification of the monitoring methods, and to perform site reviews as requested by monitoring staff. For each monitoring event, trained personnel randomly sampled approximately 5 percent of the subplots measured by the data collection teams. The data from these subplots were used to confirm that the field monitoring staff accurately collected data during each sampling event.



PLAN VIEW

OUTER FRAME: 2.54 cm DIAMETER PVC PIPE & FITTINGS
INNER GRID: BUNGEE CORDS



FRONT VIEW

HEIGHT (H) OF REMOVABLE LEGS WERE ADJUSTED TO ACCOMMODATE PLANT HEIGHT

PLANT ESTABLISHMENT SUBPLOT AND QUADRAT MONITORING AREA AND MODIFIED DAUBENMIRE COVER FRAME

Project No.: 57-977001NM	Date: JUNE 2000	Project: CALTRANS EROSION CONTROL PILOT STUDY	Fig. 3-2

Fig_3-2.dwg 3/30/00

3.5.1.1 Vegetation Cover

The percentage of ground surface covered by vegetation material was visually estimated for each species identified within the 1-m by 1-m (3-ft. by 3-ft.) subset area and was expressed using the Daubenmire cover scale. Form 8 was used for recording vegetation cover data. A sample of Form 8 is included in Appendix A.

3.5.1.2 Plant Density

Plant density refers to the number of plants within a given area. The number of each species of plant identified within the 1-m by 1-m (3-ft. by 3-ft.) subset area was counted to determine total density. Data on plant density were gathered concurrently with vegetation cover data and were recorded on Form 8.

3.5.1.3 Species Diversity

Species diversity was assessed by identifying and recording species observed within the plant establishment test 1-m by 1-m (3-ft. by 3-ft.) subset area. A list of shrubs, perennials, and annual grass/forb species was compiled for each subplot and recorded on Form 8.

3.5.1.4 Seedling Vigor

The vigor of each seedling/plant species identified within the 1-m by 1-m (3-ft. by 3-ft.) subset area was assessed during each sampling event by visual observations of the overall appearance and condition of each species. This was accomplished by assigning one of the ten descriptors presented in Table 3-3 to the sampled area. Form 9 was used for recording seedling vigor data and a sample of this form is included in Appendix A.

3.5.1.5 Seedling Growth Rate

The heights of representative seedlings/plants of the shrub species within the coastal sage scrub seed mix were measured within the 1-m by 1-m (3-ft. by 3-ft.) subset area during each sampling event. Plants were selected for measurement using a stratified random method. Each sampling quadrat was divided along one diagonal with a line. The three plants of each shrub species nearest the line were measured and tagged. "Tagging" consisted of securing a metal tag to the ground with a nail at the base of each measured plant. The tag included the specie's code name and an identification number (1, 2, or 3). The same plants were measured during each monitoring event. The locations of the tagged plants were noted on a plot plan prepared for the subset area within each 2-m by 2-m (7-ft. by 7-ft.) test subplot. Form 10 was used for recording growth rate. Form 10A was used for recording the location of tagged plants. Samples of these forms are included in Appendix A.

Table 3-3
PLANT VIGOR SCALE

Plant Vigor	Descriptor
None observed	M
Dead	0
Stunted growth/declining vigor	1
Vigorous/robust growth	2
Stunted growth/flower production	3
Vigorous growth/flower production	4
Stunted growth/seed production	5
Vigorous growth/seed production	6
Life cycle complete (annual species only)	7
Summer dormant (shrubs/perennials only)	8

3.5.1.6 Root Depths

Root depth samples were collected from the plant establishment test plots to evaluate the effect of the site conditions (i.e., cut/fill and soil type), erosion control treatments and supplemental irrigation on the subsurface growth of plants. Because sampling techniques disturbed the soil around the plant roots, root depth samples were only collected at the end of the final vegetation data collection event in April 2000 (Table 3-1).

Root depth samples were collected from the same shrub species that were measured for height. In addition, because there were fewer than expected shrub species available for measurements, grass and broadleaf species were also sampled to allow for comparisons of their root depths to the shrub species. Three mature (with flowers or seed) grass plants and three broadleaf plants were sampled from the same plots where shrubs were sampled. The most dominant grass and broadleaf species, nearest a diagonal line across the quadrat, were chosen for sampling (Figure 3-3). Plant root depths were measured with plants *in situ*. Using a trenching shovel, the soil near the plant stem was carefully removed in a trench-like fashion (with vertical sides) (Figure 3-4). Soil was removed to the maximum root depth or to a maximum depth of 61 cm (24 in.). Soil compaction precluded digging/trenching deeper than 61 cm (24 in.).

Total root depth and the corresponding plant height were measured and photographed. After measurements were taken, the removed soil was replaced in the trench and tamped down. The location of each root depth sample was noted on a plot plan. Form 10 was used to record root depth data. Form 10A was used to record the sampled plant locations.

(a) Plants selected for root depth measurement (Site 10-2 Irrigated, Plot 1-12 straw-coconut blanket).

(b) Non-native plants selected for root depth measurement (Site 57-4 Irrigated, Plot 1-2 gypsum, rate 2).

(a) Lupin specimen 1 showing roots in-situ, Site 57-4, Irrigated, Plot 1-1 bonded fiber matrix).

(b) Excavation in progress to expose the root of California buckwheat (Site 57-4 Irrigated, Plot 1-2 gypsum,rate 2).

3.5.2 Photo Documentation

Photographs of the test plots were taken during each vegetation monitoring event to document chronological changes in vegetation, growth monitoring methods, plant characteristics, and other pertinent features and activities. The 35-mm print photographs were taken from permanent photo vantage points established at each test plot. The photos were labeled with the location (site/subplot number), date, photographer, and event/feature photographed, and stored in clear plastic pockets suitable for placement in 3-ring binders. The vantage points and photo direction were marked on the plot plans.

Figures 3-5 through 3-8 are examples of chronological photographs taken between November 1998 and August 1999 of the irrigated plant establishment test plot (Site 57-4), documenting vegetation changes during this time period. Specifically, Figures 3-5 and 3-6 are photographs of an irrigated coconut erosion control blanket (CB) subplot and Figures 3-7 and 3-8 are photographs of a gypsum rate 2 (GYP2) subplot.

3.6 EROSION RATE AND PLANT ESTABLISHMENT TEST PLOT SOIL TESTING

Soil samples were collected from all vegetated erosion rate and plant establishment test plots and analyzed for factors relevant to plant growth. These factors included microbial assays (i.e., bacteria, fungi, protozoa, and VAM [vesicular-arbuscular mycorrhiza] colonization), chemical analyses (pH, sodium absorption ratio [SAR], electrical conductivity [EC_e], boron [B], nitrogen [N], phosphorus [P], potassium [K], calcium [Ca], and magnesium [Mg]), and organic matter (loss on ignition), per the study plan (URS Greiner Woodward-Clyde, 1998). In addition, standard soil analysis included tests for sodium (Na), chloride (Cl), manganese (Mn), zinc (Zn), iron (Fe), copper (Cu), and free lime.

Three soil sampling events were conducted, as documented in Table 3-1. The first sampling event took place on October 19, 1998 during the setup of the test plots and prior to the application of any erosion control treatment on the plant establishment plots. The second sampling event took place on May 17, 1999 and the third and final soil sampling event occurred on May 22, 2000.

For quality assurance purposes, duplicate soil samples were collected from approximately 5 percent of the test subplots, and were analyzed in the same manner as the original samples. The subplots used for duplicate sampling were selected randomly.

3.6.1 Soil Sample Collection Procedures

All soil samples were collected according to the procedures outlined in *Construction and Monitoring of Field Test Plots* (URS Greiner Woodward Clyde, 1999). For erosion rate test plots, three soil samples were collected near the top edge of each subplot to minimize plant disturbance. The three samples were combined to create one composite sample for each erosion rate subplot. For plant establishment test plots, soil samples were collected near the upper and lower left corners and upper right corner of each of the 2-m by 2-m (7-ft. by 7-ft.) test subplots, but outside of the 1-m by 1-m (3-ft. by 3-ft.) vegetation monitoring sampling quadrat. These three samples were also combined to create a composite sample for each plant establishment subplot.

(a) Site 57-4 (cut slope)-Irrigated subplot with coconut erosion control blanket (CB) following installation, 11/18/98.

(b) Site 57-4 (cut slope)-Irrigated subplot with coconut erosion control blanket (CB) after one month, 12/16/98.

(a) Site 57-4 (cut slope)-Irrigated subplot with coconut erosion control blanket (CB) after 4 months, 3/15/99.

(b) Site 57-4 (cut slope)-Irrigated subplot with coconut erosion control blanket (CB) after 9 months, 8/16/99.

(a) Site 57-4- (cut slope)-Irrigated subplot with gypsum, rate 2 (GYP2), following installation, 11/18/98.

(b) Site 57-5 (cut slope)-Irrigated subplot with gypsum, rate 2 (GYP2), one month after installation, 12/16/98.

(a) Site 57-4 (cut slope)-Irrigated subplot with gypsum, rate 2 (GYP2), 4 months after installation, 3/15/99.

(b) Site 57-4 (cut slope)-Irrigated subplot with gypsum, rate 2 (GYP2), 9 months after installation, 8/16/99.

When sampling, the surface leaf litter/debris, treatment materials (plant establishment test plots), and about 1.5 cm (0.6 in.) of soil was scraped from the surface and saved for replacement after the soil sample had been collected. Approximately 2 liters (0.5 gal.) of soil were manually removed from each test subplot to a depth of approximately 15 cm to 18 cm (6 in. to 7 in.). Each sample was then divided into approximately equal parts (about 1 liter [0.26 gal.] each), and placed in labeled, sealable, plastic bags that included site, subplot, and sample numbers; sample date; and collector's name. The soil samples were then stored in a dark, cool location until shipment to the laboratory within 24 hours of collection.

Microbial assays of the soil samples were performed by Soil Foodweb, Inc. located in Corvallis, Oregon. Chemical and organic content analyses were performed by Agri Service, located in Vista, California (Table 3-4).

3.6.2 Soil Analysis Protocols

Most microbial assays were completed within 72 hours of collection. Samples that were not analyzed within 72 hours were specially preserved for later analysis. The soil chemical and organic matter analyses are not time-sensitive if the samples are maintained in a sealed container. Soil microbial assays were conducted in accordance with protocols described by Ingham (1998). Chemical and organic matter analyses were performed in accordance with protocols described by Western States Laboratory (1998). Table 3-4 provides a listing of the soil testing protocols that were used for the study. The full text of these protocols is provided in Appendix G of the *Detailed Study Plan* (URS Greiner Woodward-Clyde, 1998).

3.7 SOIL EROSION RESEARCH LABORATORY TESTING

The procedures for soil selection, soil placement in the test bed, surface roughing, erosion control treatment application, sediment and runoff sample collection, and operation of the simulated rainfall equipment were described in the *Laboratory Manual* (URS Greiner Woodward Clyde, 2000b). The monitoring schedule of the laboratory testing is summarized in Table 3-5. A summary of these monitoring and test procedures is presented in the following sections.

3.7.1 Laboratory Test Bed Soil Material Selection and Placement

The soil type selected for use in the indoor laboratory test program was clayey sand. This soil type was selected to approximate the soil type found at the outdoor laboratory myoporum fill slope test plots (Site 10-2). Candidate soil samples were identified through particle size distribution analysis in accordance with ASTM methods D2487 and D1140 and Atterberg Limits (liquid limits, plastic limits, and plasticity index) in accordance with ASTM method D4318. The selected soil was stored under cover inside of the laboratory until use in the soil test bed. For quality assurance purposes, a grain-size distribution (gradation) test was conducted on a sample of the selected soil prior to placement on the test bed.

Table 3-4
SOIL TESTING PROTOCOLS

Soil Test -- Soil Laboratory	Method No.	Test Method Description[1]
Chemical Soil Analysis[2] -- Agri Service (Vista, CA)		
Saturation Percentage	S 1.00	Saturation Percentage - Saturation Paste Extract
Soil pH	S 1.10	Saturation Paste Soil pH
Electrical Conductivity	S 1.20	Saturation Paste Soil Soluble Salts Ece
Boron	S 1.50	Saturation Paste Extract Soluble Boron – Azomethine-H Spectrophotometric
Sodium Adsorption Ratio (SAR)	S 1.60	Saturation Paste Extract Soluble Calcium, Magnesium, Sodium, and SAR - Atomic Adsorption Method
Soil Nitrate-N	S 3.10	Soil Nitrate Nitrogen - KCl Extraction / Cd-Reduction Method
Bicarbonate Phosphorous	S 4.10	Estimation of Available Soil Phosphorous - Sodium Bicarbonate (Olsen et al.) Method
Extractable K, Ca, Mg, Na	S 5.10	Extractable Potassium, Calcium, Magnesium, and Sodium - Ammonium Acetate Method
Soil Organic Matter	S 9.20	Soil Organic Matter - Loss on Ignition Method
Microbial Soil Analysis – Soil Foodweb (Corvallis, OR)		
Active Fungi		Standard Operating Procedure for Microbial Population Dynamics
Active Bacteria		Standard Operating Procedure for Total Bacteria
Protozoa		Standard Operating Procedure for Protozoa
VAM Mycorrhizal Root Colonization		Standard Operating Procedure for Determining VAM Mycorrhizal Colonization of Roots and Total Root Length

(1) The full text of the chemical and microbial soil testing protocols is given in Appendix G of the *Detailed Study Plan* (Woodward-Clyde, 1998a).

(2) Test methods for chemical soil analysis are from the Western States Laboratory Proficiency Testing Program, Soil and Plant Analytical Methods, 1998, Version 4.10. Agri-Service's standard soil analysis also includes tests for sodium, chloride, manganese, zinc, iron, copper, and free lime.

Table 3-5
EROSION RATE AND WATER QUALITY LAB MONITORING SCHEDULE

Treatment	Storm Type	Replicate Test Date		
		1	2	3
Smooth-Rolled	5-yr (2)	2/22/00	2/22/00	3/2/00
	10-yr (1)	3/10/00	3/13/00	3/14/00
	10-yr (2)	2/25/00	2/28/00	2/29/00
	50-yr (1)	3/7/00	3/8/00	3/9/00
	50-yr (2)	3/3/00	3/4/00	3/6/00
	5-yr (1)	2/18/00	2/19/00	2/21/00
Imprinted	50-yr (1)	4/21/00	4/24/00	4/25/00
	50-yr (2)	4/12/00	4/14/00	4/20/00
	10-yr (2)	4/13/00	4/13/00	4/14/00
	10-yr (1)	4/26/00	4/26/00	5/12/00
	5-yr (2)	4/20/00	4/24/00	4/25/00
	5-yr (1)	4/10/00	4/10/00	4/12/00
Ripped	5-yr (2)	3/28/00	3/29/00	3/30/00
	10-yr (1)	3/31/00	4/1/00	4/4/00
	10-yr (2)	3/22/00	3/23/00	3/23/00
	50-yr (1)	3/29/00	3/29/00	3/31/00
	5-yr (2)	3/20/00	3/21/00	3/22/00
	5-yr (1)	3/16/00	3/17/00	3/21/00
Sheepsfoot-Rolled	50-yr (1)	5/19/00	5/19/00	5/19/00
	10-yr (2)	5/22/00	5/22/00	5/23/00
	5-yr (1)	5/13/00	5/22/00	5/22/00
	5-yr (2)	5/10/00	5/11/00	5/17/00
	50-yr (2)	5/20/00	5/21/00	5/21/00
	10-yr (1)	5/18/00	5/18/00	5/18/00
Trackwalked	5-yr (1)	4/7/00	4/10/00	4/11/00
	5-yr (2)	5/15/00	5/16/00	5/16/00
	10-yr (1)	5/10/00	5/11/00	5/15/00
	10-yr (2)	4/13/00	4/19/00	4/19/00
	5-yr (1)	4/28/00	5/9/00	5/9/00
	5-yr (2)	4/8/00	4/11/00	4/12/00
Bare (BARE)	10-yr (2)	4/28/00	4/28/00	4/28/00
Bonded Fiber Matrix (BFM)	10-yr (2)	5/5/00	5/5/00	5/5/00
Coconut Blanket (CB)	10-yr (2)	5/3/00	5/3/00	5/3/00
Coir (COIR)	10-yr (2)	5/8/00	5/8/00	5/8/00
Compost (COMP)	10-yr (2)	5/1/00	5/1/00	5/1/00
Curled Wood Fiber Blanket (CWFB)	10-yr (2)	5/8/00	5/8/00	5/8/00
Paper Mulch With Polymer (PMP)	10-yr (2)	5/13/00	5/13/00	5/13/00
Paper Mulch with Psyllium (PMG)	10-yr (2)	5/10/00	5/10/00	5/10/00
Straw Blanket (SB)	10-yr (2)	5/1/00	5/1/00	5/1/00
Straw-Coconut Blanket (SCB)	10-yr (2)	5/3/00	5/3/00	5/3/00
Wood Fiber Blanket (WFB)	10-yr (2)	5/16/00	5/16/00	5/16/00
Wood Mulch With Polymer (WMP)	10-yr (2)	5/14/00	5/14/00	5/14/00
Wood Mulch with Psyllium (WMG)	10-yr (2)	5/12/00	5/12/00	5/12/00
Wheat Straw Incorporated (RS)	10-yr (2)	5/2/00	5/2/00	5/2/00

Soil was placed on the soil test bed in accordance with Caltrans Standard Specifications for compaction of embankments, Section 19-5.04 (California Department of Transportation, 1995). Before the soil was placed in the test bed, a three-dimensional geotechnical drainage composite was installed in the bottom of the test bed. The geotechnical fabric extended approximately 15.2 cm (6 in.) up the sides of the test bed, above the estimated final height of soil. The soil was mixed with small quantities of water until the correct moisture content was obtained for compaction. Soil was hoisted into the test bed using a rope and pulley system (Figure 3-9a). The soil was placed on the test bed and spread with hand tools over the test bed surface to a uniform depth of approximately 31-cm (12 in.) (Figure 3-9b). The soil was roto-tilled to uniform consistency and then raked smooth for compaction (Figures 3-10a and 3-10b). The soil was compacted with a mechanical tamper until a minimum relative compaction of not less than 90 percent was achieved (Figure 3-11a). The weight of the tamper and the number of passes/applications was determined by trial-and-error until the desired degree of compaction was achieved. This procedure was repeated until a 31 cm (12 in.) depth of soil bed was compacted. On the bare soil plots, the compacted soil was lightly raked prior to simulated rainfall (Figure 3-11b). The in-place moisture content and dry density of the compacted soil were measured using the sand-cone test method (Figure 3-12) (ASTM D1556) and drive-cylinder test method (ASTM D2937).

For quality assurance, the placement of the soil was periodically observed by Quality Control personnel to ensure that the standard methods and procedures were consistently followed.

3.7.2 Soil Test Bed Preparation

3.7.2.1 Soil Surface Roughening

Due to access restrictions from the rainfall simulator support frame, a backhoe could not be used to implement the surface roughness techniques. Consequently, all surface practices were applied over the entire soil bed as follows:

- **Smooth-rolling** was accomplished by utilizing a hand compactor and lightly raking the soil surface to simulate field conditions following grading.
- **Ripping** was performed using the shank of a 15.2-cm (6-in.) handpick. The soil was ripped to a depth of 10 cm (4 in.). Ripping was conducted across the width of the slope, perpendicular to the flow of water (Figures 3-13a through 3-14b).
- **Sheepsfoot rolling, trackwalking, and imprinting** were accomplished using metal templates designed to mimic trackwalking, sheepsfoot rolling, etc. The trackwalking was alternately placed on the soil surface and tamped into place using a mechanical compactor, then removed and replaced until the entire test plot was treated (Figures 3-15a through 3-16b). The sheepsfoot and imprinting devices were modeled after actual mechanical devices used in the field, but consisted of hand-held implements that were pounded into the soil surface at specified intervals (Figures 3-17a through 3-21b).

After each soil roughening practice was completed (and prior to any rainfall simulation), the soil surface was examined for consistency in treatment, and photos were periodically taken to document the pre-test condition.

3.7.2.2 Installation of Edging and Flume

The entire soil test bed (3 m by 10 m [10 ft. by 33 ft.] area) was filled to a depth of 31-cm (12-in.) of soil and was roughened, in the manner described. However, the area actually sampled during rainfall events was a 2-m by 8-m (7-ft. by 26-ft.) subset of the entire test bed area to match the size of the erosion rate and outdoor laboratory myoporum test plots.

The sample area within the soil test bed was delineated in a similar manner as the outdoor myoporum test plots. For soil surface roughening tests, plastic edging was installed to delineate a 2-m (7-ft.) wide by 8-m (26-ft.) long area, located in the center of the soil test bed (Figure 3-24a). This allowed 0.5-m (2-ft.) wide work areas on each side of the test plot, and a 2-m (7-ft.) wide work area at the top of the test plot. Runoff and sediment from simulated precipitation that fell within the test area was directed by a flume into the collection containers located at the bottom of the test bed (Figures 3-14b, 3-20b, 3-21b, and 3-24b).

For the water quality tests, the 2 m x 8 m plot (7 ft. by 26 ft.) was segregated by plastic edging into three equivalent-sized plots, 0.67 m wide by 8 m long (2 ft. by 26 ft.)(Figures 3-22a and 3-22b). This configuration allowed for the simultaneous collection of runoff samples from three separate plots, labeled in the data reports as plots A, B, and C. Runoff from each plot was directed by three flumes to the collection containers located at the bottom of the test bed at the base of each plot (Figures 3-23 and 3-25).

3.7.2.3 Erosion Control Treatments Calibration and Application

Fifteen erosion control treatments were applied to the laboratory test beds for the water quality test in accordance to the methods presented in the *Laboratory Manual* (URS Greiner Woodward Clyde, 2000b). The calibration, application rates and procedures were the same as those used for the plant establishment test plots described above in Section 2.4.2. The erosion control treatments used are shown on Table 1-2. Form 1 was used to calculate the erosion control treatment application for the laboratory test. A sample of Form 1 is included in Appendix B.

3.7.2.4 Soil Preparation for Next Test

At the completion of each test, the soil surface for the subsequent test was prepared in accordance with the procedures outlined in the *Laboratory Manual* (URS Greiner Woodward Clyde, 2000b). The erosion control treatment was removed from the soil surface for the erosion control treatment/water quality tests. The edging and flumes were also removed. The top 5 cm to 10 cm (2 in. to 4 in.) of eroded soil from the test area was manually removed and replaced with new soil (Figures 3-26a and 26b). The upper 10 cm (4 in.) of the soil in the test bed was then tilled with a roto-tiller, and hand compacted. The in-place moisture content and dry density of the compacted soil were periodically obtained. Discarded soil was placed in a storage bin for eventual removal by a skip loader (Figure 3-27a). Soil to be reused was hauled away using a pick-up truck (Figure 3-27b).

3.7.3 Rainfall Simulation Indoor Laboratory Test Procedures

Simulated storm events were designed using Los Angeles County rainfall intensity-duration-frequency curves (Los Angeles County Department of Public Works, 1990). The criteria used for simulating natural rainfall (including drop size and drop size distribution, drop velocity, and rainfall intensity and duration) was detailed in the *Laboratory Manual* (URS Greiner Woodward Clyde, 2000b). The rainfall simulation set-up, tests, and shut-down procedures were conducted in accordance with the methods presented in the SDSU Soil Erosion Research Laboratory *Operation & Maintenance Manual* (URS Greiner Woodward Clyde, 2000a) and the *Laboratory Manual* (URS Greiner Woodward Clyde, 2000b).

Simulated rainstorm events for the laboratory program had an initial period (Part 1) of low intensity rainfall, followed by a period (Part 2) of relatively high intensity rainfall, and ended with a period (Part 3) of relatively low intensity rainfall. Three storm types, 5-year, 10-year, and 50-year were simulated at different intensities and durations for the slope roughness test. One storm type; the 10-year storm event, was simulated at different intensities and durations during the second period (Part 2) of the erosion control treatment/water quality tests and for the outdoor laboratory myoporum test. The selection of the 10-year storm event characteristics was based on results from the slope roughness/erosion rate evaluation.

A list of intensities and durations for the simulated storm events used in the slope roughness tests is provided in Table 3-6. Forms 2 and 4 were used to record details of the simulated rainfall events for the soil roughness/erosion rate and erosion control treatment/water quality evaluation, respectively. Samples of these forms are provided in Appendix B.

3.7.4 Indoor Laboratory Runoff and Sediment Sampling Procedures

Runoff and sediment samples from each of the three storm parts were collected in separate containers positioned at the lower end of the test bed (Figure 3-14b and 3-21b). In order to facilitate settlement of the fine grained sediment, 500 g (1.1 pound [lb.]) of finely ground gypsum was added to each container and allowed to set overnight (Figure 3-28a). The clear supernatant was decanted off and the runoff volume was recorded (Figure 3-28b). The weight of the remaining sediment and water was recorded. A representative sample of the wet sediment was collected for moisture content analysis. Based on the calculated moisture content of this sample, the dry weight of the total sediment sample was calculated. Samples of wet sediment were weighed then dried in an oven to determine gross sediment discharge and erosion rate (Figure 3-29). For quality assurance purposes, approximately 5 percent of the sediment samples collected for each rain event were re-weighed. The samples that were reweighed and retested were randomly selected. A complete list of re-sampling requirements is provided as Table 3-7.

Sediment and water quality data were recorded on forms developed by the laboratory for that purpose. Form 3 was used to document samples collected during each slope roughness/erosion rate test. Form 5 was used to document samples collected during each of the erosion control treatment/water quality test. Samples of these forms are provided in Appendix B.

Table 3-6
INTENSITIES AND DURATIONS FOR SIMULATED STORMS

Storm Frequency	INTENSITY AND DURATION			Storm Designation
	Part 1 (1)	Part 2	Part 3	
5-year	5 mm/hr, 30 min	40 mm/hr, 20 min	5 mm/hr, 30 min	5-yr (1)
5-year	5 mm/hr, 30 min	27 mm/hr, 40 min	5 mm/hr, 30 min	5-yr (2)
10-year	5 mm/hr, 30 min	50 mm/hr, 20 min	5 mm/hr, 30 min	10-yr (1)
10-year	5 mm/hr, 30 min	40 mm/hr, 40 min	5 mm/hr, 30 min	10-yr (2)
50-year	5 mm/hr, 30 min	55 mm/hr, 25 min	5 mm/hr, 30 min	50-yr (1)
50-year	5 mm/hr, 30 min	38 mm/hr, 50 min	5 mm/hr, 30 min	50-yr (2)

(1) Duration and/or intensity of Part 1 were adjusted on the basis of initial test results to achieve saturation without runoff.

Table 3-7
RANDOM RESAMPLING METHODS

Type of Sampling Event	Number of Resamples (1)	Resampling Percentage	Responsibility for Resampling or Retesting
Sediment Analysis Surface Roughness Evaluation	5 resamples out of 90 total sampling events	5.6%	SDSU Soil Mechanics Laboratory
Sediment Analysis Myoporum Cover Evaluation	2 resamples out of 30 total sampling events	6.7%	SDSU Soil Mechanics Laboratory
Water Quality Analysis Erosion Control Treatment Evaluation	3 resamples out of 48 total sampling events	6.3%	SDSU Water Quality Laboratory

(1) Events to be resampled were selected with the use of a random number generator.

3.7.5 Indoor Laboratory Water Quality Testing

Water quality testing was performed on the runoff samples collected from the bare untreated soil to measure baseline water quality, and from the 15 surface erosion control treatments to assess the potential effect of each of the soil stabilizer on water quality, as well as to measure the amount of suspended sediment transported in the runoff (Figures 3-30a through 3-31a). Flow-weighted composite samples were collected for water quality testing (Figure 3-31b). The analyses were conducted in SDSU's analytical laboratory using EPA laboratory methods. A copy of the Quality Assurance Guide developed for the analytical testing program is included in Appendix C.

For all hydraulic applications, a Finn T-30, 300 gallon hydromulcher was used (Figure 3-32a). Uniform application was achieved by using a 4 cm (1.5 in.) hose and a spray nozzel with a small orifice (Figure 3-32b). Applications were timed in order to achieve the exact application rate of the material (Figure 3-33a). Following the application, the hydromulcher was flushed and cleaned with treated water (Figure 3-33b).

All rolled erosion control products (RECP) were unrolled downslope in the direction of water flow (Figure 3-34a). The outside edges of each RECP were secured using wire staples (Figures 3-34b and 3-35a). With the lighter RECPs, edging was inserted into the soil directly through the blanket (Figure 3-35b). With the heavier RECPs, such as coconut fiber, the RECP had to be cut prior to installation of the edging (Figure 3-36). Refer to figures 3-37a through 3-39b for illustrations of the RECPs used for water quality tests.

Wheat straw was carefully weighed and evenly distributed among the three replicate plots for water quality testing (Figure 3-40a). The wheat straw was punched into the ground using hand tools (Figure 3-40b). Figures 3-41a and 3-4b show completed replicate plots of wheat straw.

Collection and analysis of runoff samples for water quality tests were conducted in accordance with the procedures outlined in the *Laboratory Manual* (URS Greiner Woodward Clyde, 2000b). A grab sample of the runoff was collected from each of the three intensity/duration storm components of each test event for analysis. The volume of runoff collected from each of the three storm components was proportional to the volume of water applied during each storm part to simulate a flow-weighted composite sample. The volume of runoff collected for each storm part was as follows:

- Storm Part 1 – 0.5 L (0.1 gal.) (one sample at 15 minutes into the first part of the storm)
- Storm Part 2 – 4 L (1gal.) (three samples at 10, 20, and 30 minutes into the second part of the storm)
- Storm Part 3 – 0.5 L (0.1 gal.) (one sample at 15 minutes into the third part of the storm)

The laboratory combined the three samples collected from each test to create a flow weighted composite sample for analysis (Figure 3-42). Appropriate preservatives were added by the laboratory and all analysis were conducted within the required holding times.

Based on a review of the Material Safety Data Sheets (MSDS) for the 15 erosion control treatments, and to obtain general water quality data, the following analysis were performed on the runoff samples:

- pH - EPA Method 150.1
- Biological Oxygen Demand (BOD) - EPA Method 405.1
- Chemical Oxygen Demand (COD) - EPA Method 410.4
- Sixteen metals (Al, As, Ba, Cd, Ca, Cu, Cr, Fe, Pb, Li, Mg, Hg, Ni, Tm, V, Zn) - Atomic Absorption Spectrophotometry
- Total Organic Carbon (TOC) by TOC Analyzer - EPA Method 415.2
- Total Suspended Solids (TSS) - EPA Method 160.2
- Phosphorous - EPA Method 365.2
- Total Kjeldahl Nitrogen (TKN)- EPA Method 351.4
- Nitrate + Nitrite Nitrogen - EPA Methods 353.3/354.1

The general water quality analyses including pH, BOD, and COD provided an indication of the relative acidity/basicity of the water, as well as an indication of the presence of substances that would require oxygen to break them down. Total suspended solids were analyzed to evaluate the erosion rate.

3.7.5.1 Baseline Water Quality

Water quality samples of the reverse osmosis treated water were analyzed for the same constituents as the test runoff to establish the baseline water quality of the water being used for the rainfall simulation. Additionally, the treated water was analyzed monthly for alkalinity and hardness to confirm the treatment system's operational effectiveness.

3.7.5.2 Sample Quality Assurance and Quality Control Program

The sampling QA/QC program for the laboratory tests were conducted in accordance with procedures outlined in the Laboratory Manual (URS Greiner Woodward Clyde, 2000b). The objective of this program was to implement the procedures necessary to obtain consistent, high-quality data by testing and laboratory analysis, which were representative of actual testing conditions. Standardized procedures were followed in all phases of the testing program including sampling, laboratory analysis, and data reporting/validation. To evaluate potential sources of contamination, variability in the sampling process, and laboratory accuracy, sufficient procedures were followed during the course of the investigation

Matrix spike and matrix spike/matrix spike duplicate analysis were performed and met the appropriate levels of acceptance. Blanks were evaluated for the potential presence of constituents introduced as a result of sampling equipment and techniques. Blanks consisted of laboratory water that was analyzed with every batch of samples. Samples were handled and analyzed by the analytical laboratory in accordance with the approved procedure that was used for the actual sample.

For the indoor laboratory study, duplicate or split samples were not collected which was partly due to a limited sample volume. However, since three samples were collected from each treatment experiment, these data could be evaluated for variability. The standard deviations for the water quality parameters are reported in Appendix C.

3.7.5.3 Analytical Laboratory QA/QC

The analytical laboratory reports were reviewed to evaluate for completeness, sample identification accuracy, media and conditions measured, results of all requested analyses and test methods, sufficient number of laboratory duplicate and matrix spike analyses, and presence of laboratory QA/QC report. The laboratory QA/QC report was reviewed to evaluate the results of the blank spikes, reagent blanks, and laboratory control standards. Additionally, the laboratory reports were reviewed to assess if the analyses had been completed within the established holding time. A complete description of the laboratory QA/QC tests procedures is included in the *Laboratory Manual* (URS Greiner Woodward Clyde, 2000b).

3.8 OUTDOOR LABORATORY MYOPORUM TEST PLOT TESTING

The procedures for testing and data collection at the outdoor laboratory myoporum test plots including vegetation cover estimation, rainfall simulation, sample evaluation and data handling were described in the *Laboratory Manual* (URS Greiner Woodward Clyde, 2000b). A summary of these monitoring and test procedures is presented in the following sections.

For quality assurance purposes, system audits were conducted by the Field Manager to verify that data collected from runoff sampling and analysis were completed accurately and were documented on the correct forms. The audits also verified that monitoring and inspection forms, equipment maintenance logs and health and safety records were all completed accurately.

3.8.1 Outdoor Laboratory Vegetative Cover Estimate

The myoporum was grown to 100% coverage. Prior to each rainfall/erosion rate test, the plant cover on each plot was visually estimated and the plants were trimmed back to the desired test coverage, beginning with 95% cover. Subsequent tests were performed at 80%, 65%, 50% and finally 35% plant cover. For each site, the mean of three cover values was used to determine when each of the five cover values had been reached.

Cover data was recorded on Form 6. A sample copy of Form 6 is provided in Appendix B.

3.8.2 Outdoor Laboratory Rainfall Simulation Testing Procedures

The outdoor laboratory rainfall simulation set-up, tests, and shut-down procedures were conducted in accordance with the methods presented in the SDSU Soil Erosion Research Laboratory *O&M Manual* (URS Greiner Woodward Clyde, 2000a) and the *Laboratory Manual* (URS Greiner Woodward Clyde, 2000b) and are summarized below.

As discussed in Section 2.6.3, temporary scaffolding designed to support the rainfall simulation devices was initially assembled over the three replicate test plots at one of the two outdoor laboratory test sites for the first several simulated rainfall events. Due to the labor intensiveness associated with assemblage of the temporary scaffolding, permanent scaffolding was eventually constructed over each test plot and was utilized for the remainder of the testing program. Refer to Figures 3-43a through 3-50a for rainfall simulator installation at the DeVry and Brea Canyon test sites.

The rainfall simulators were installed on the scaffolding at the test locations. Prior to conducting any rainfall simulation event, sediment or other debris was removed from the metal collection flume, using a small broom and dustpan and the flume exit plug was removed. A plastic sheet or tarp was placed over the entire soil surface to protect it from intermittent precipitation during simulator calibration and setting. The simulators were adjusted to a pre-determined water pressure for a minimum of five minutes in order to obtain a uniform flow and to purge any air out of the system. Upon stabilization of the water pressure in all four (4) simulates, the testing period commenced.

Like the indoor laboratory program, simulated rainstorm events for the outdoor laboratory program had an initial period (Part 1) of low intensity rainfall, followed by a period (Part 2) of relatively high intensity rainfall, and ended with a period (Part 3) of relatively low intensity rainfall. One storm type, the 10-year (2) storm event, was simulated at the outdoor laboratory myoporum test. As stated earlier, the selection of the 10-year storm event characteristics was based on results from the slope roughness/erosion rate evaluation.

Prior to each test, the in-place moisture content was obtained. As shown on Table 3-6, the rainfall intensity was set to Part 1 intensity (5 mm/hr [0.2 in./hr]) and run for 30 minutes. At the completion of Part 1, the rainfall intensity was increased to Part 2, 40 mm/hr (1.6 in./hr) run for 40 minutes. At the completion of Part 2, the rainfall intensity was decreased to Part 3 (5 mm/hr [0.2 in. /hr]) and run for 30 minutes. Runoff was collected at the completion of each of the three rainfall parts. At the completion of each test, the water supply pump was shut off. At the completion of all tests, the rainfall simulators were removed from the scaffolding and returned to the laboratory.

Form 7 was used to record details of the outdoor laboratory myoporum simulated rainfall events. A sample copy of this form is provided in Appendix B.

3.8.3 Outdoor Laboratory Runoff and Sediment Sampling Procedures

Runoff and sediment samples were segregated into three rainfall intensity/duration parts (Parts 1, 2, and 3). All water and sediment accumulated in the sediment collection system was collected in separate 19-L (5-gal.) plastic sample containers positioned at the lower end of the test plot (Figures 3-50b and 3-51). The sample containers were labeled sequentially for storm parts 1, 2, and 3 (Figure 3-52a). Following rainfall simulation, the plot was allowed to drain completely. Any sediment remaining in the flume and piping was flushed with 19 L (5 gal.) of clear water. The amount of flush water used was documented on the sample label. The sample containers were sealed to prevent leakage and evaporation, uniquely labeled for identification and transported to the laboratory.

Once the samples had been received in the laboratory (Figure 3-52b), the same sampling methodology used for the indoor laboratory samples described in Section 3.8.4 were utilized except that the addition of 500 g (1.1 lb.) of gypsum to each container was excluded. The clear supernatant was decanted off and the runoff volume was recorded. The weight of the remaining sediment and water was recorded. A representative sample of the wet sediment was collected for moisture content analysis. Based on the calculated moisture content of this sample, the dry weight of the total sediment sample was calculated. For quality assurance purposes, approximately 5 percent of the sediment samples collected for each rain event were re-weighed. The samples that were reweighed and retested were randomly selected. A complete list of re-sampling requirements is provided as Table 3-8.

3.9 DATA HANDLING

The originals of all forms containing new data were submitted to the database manager and entered into a Microsoft Access™ database. The Microsoft Access™ database is provided in the end pocket of this document. The database manager was responsible for distribution of the data to appropriate team members for analysis.

3.10 STATISTICAL DATA ANALYSIS

Data analysis consisted of two phases, exploratory data analysis (EDA) and confirmatory data analysis (CDA). EDA consisted of data analysis in which the properties of the data were summarized. In addition, the scientific hypothesis of the research study were translated into statistical hypotheses. CDA consisted of statistical model-building and statistical hypotheses testing. In the model-building phase, the parameters of the statistical model proposed for the data during the EDA phase were estimated, and the aptness of the model was assessed. In the hypothesis testing phase, specific statistical hypotheses derived from the statistical model were tested.

The standard deviation is the square root of population variance; thus, it is an estimate of the overall variability of the sampled population. In instances in which repeated sampling is conducted within the same population and the mean of each repeated sample is calculated, each of those sample means is an estimate of the population mean. However, because of sampling variability, they will all be slightly different in value. The probability distribution of these means is called the "sampling distribution" (not to be confused with the sample distribution) of the sample mean (as an estimate of the population mean). The standard error of the mean is the standard deviation of the sampling distribution of the mean. Thus, the standard deviation provides a measure of the overall variability of the sampled population. The standard error of the mean gives an indication of the reliability of the computed mean as an estimate of the true population mean. The standard deviation was calculated when the overall population variability was of concern, and the standard error was calculated in instances where it supported the reliability of the calculated sample means as estimates of the true population mean.

3.10.1 Exploratory Data Analysis

EDA methodologies included three basic data manipulations. First, descriptive summary statistics were prepared, including means, standard deviations, standard errors of the means, coefficients of variations, medians, and first and third quartiles, in a by-group breakdown of the data according to the factorial treatment structure of the experimental design. Second, univariate graphical summaries of the data were prepared, including histograms and normal probability plots, and box plots, again following the factorial treatment structure. Finally, bivariate descriptive summary statistics (e.g., correlation-covariance matrices) and bivariate graphical summaries (e.g., scatterplot matrices and locally-weighted smoother [lowess] plots) were prepared. The summary statistics were used to assess the assumptions of the linear model for both the erosion rate data and the plant establishment data.

3.10.2 Confirmatory Data Analysis

CDA methodologies included the standard effects-based statistical models for a factorial analysis of variance model with covariates and a (possible) trend effect. The analysis of covariance was used for statistically modeling the data obtained from the erosion rate study. The analysis of variance (ANOVA) was used for statistically modeling the data obtained from the plant establishment and Soil Research Laboratory studies. A more detailed description of these two statistical methods is presented below.

3.10.2.1 Analysis of Covariance

The analysis of covariance is used for assessing the relationship between a numerical response variable and a categorical explanatory variable or set of explanatory variables, when there are additional numerical "auxiliary" variables (or covariates) that are believed to influence the values of the response variable in addition to the influence of the treatments. An example would be an agricultural experiment in which we were interested in the effects of insecticide application (the treatments) on level of insect infestation (the response), but we also had data on pre-treatment levels of insect infestation (the covariate). The test statistic for the analysis of covariance is the F-ratio, which is roughly the ratio of the variability in the data explained by the treatments and covariates to the variability in the data that is not explained by the treatments and covariates. The larger this ratio is, the stronger are the effects of the treatments relative to background variability in the experimental units. The significance of an F-ratio is assessed by the associated p-value, which is the probability of observing an F-ratio as large as the observed value, given that the treatments have no effect at all. Thus, the smaller this value is the more likely it is that the result obtained represents a real effect rather than just random variation in the experimental units. F-ratios and p-values may be computed for individual treatment factors in multifactor experiments, and for each covariate in the analysis. Additional information on the analysis of covariance may be found in Neter and Wasserman (1974) and Weisberg (1980).

For the erosion rate testing, the purpose of the analyses of covariance was to establish relationships between rainfall volumes and amounts of sediment eroded, and to determine whether these relationships vary for different vegetation/slope combinations. To conduct the analyses, combinations of slope and vegetation type were combined into a single classification, since the "natural" slope type only occurs with the "coastal sage scrub" vegetation type. The potential covariate and three potential response variables (total dry weight excluding flume sediment, total dry weight including flume sediment, and total runoff volume) make for 6 possible analyses. The results of the statistical analyses of the erosion rate study data are discussed in Section 4.

3.10.2.2 Analysis of Variance (ANOVA)

The analysis of variance is a statistical method for assessing the relationship between a numerical response variable and a categorical explanatory variable or set of explanatory variables. A typical application of analysis of variance is in the analysis of data resulting from designed experiments, where the response variable is some measurement of interest (e.g., yield in agricultural experiment) and the explanatory variable represents various treatment applied to the experimental units (e.g., fertilizer and/or insecticide treatments in an agricultural experiment). The test statistic for the analysis of variance is the F-ratio, which is roughly the ratio of the variability in the data explained by the treatments to the variability in the data that is not explained by the treatments. The larger this ratio is, the stronger are the effects of the treatments relative to background variability in the experimental units. The significance of an F-ratio is assessed by the associated p-value, which is the probability of observing an F-ratio as large as the observed value, given that the treatments have no effect at all. F-ratios and p-values may be computed for individual factors and their interactions in multifactor experiments. Thus, the smaller this value is the more likely it is that the result obtained represents a real effect rather than just random variation in the experimental units. Additional information on the analysis of variance may be found in Sokal and Rohlf (1969), Neter and Wasserman (1974), and Mead and Curnow (1983).

The possible violations of the assumptions of the analysis of variance include:

- Unequal variance among the group (i.e., treatment combinations). The standard analysis is very robust to this assumption (in other words, violations of it do not matter much). This is good since the standard tests for unequal variances are more sensitive to unequal variances than the analysis of variance is itself. Violations of this assumption can almost always be dealt with by variance-stabilizing transformation of the data (for example, taking the logarithms of the data and analyzing those). See below for what to do when variance-stabilizing transformations will not work.
- Asymmetry in the within-group distributions (in other words, the mean is not in the middle of the distribution for each treatment combination). The same transformation that restores equal variances practically always symmetrizes the group distributions.
- Some kind of relationship between group (i.e., treatment combination) means and group standard deviations (for example, an increase in standard deviation with increasing mean). Again, a well-chosen transformation of the data almost always can take care of this problem.
- Gross outliers in the data (in other words, data values that clearly are not from the same distribution as the rest of the data). If outliers can reliably be identified (there are standard methods for doing so), they can be deleted from the data, and the rest of the data can be

analyzed. In these cases, it's usually worthwhile to try to account for the origin of the outlier(s) on a case-by-case basis (data-recording error, soil anomaly, etc.).

Given the sort of remedial measures described above, most violations of the assumptions of analysis of variance can be dealt with, and one can still use analysis of variance to analyze the data once they have been properly transformed and the outliers, if any, removed. Still, occasionally (note that this is very rare) transformations and outlier-deletion do not help. In those rare cases, there are two alternatives to the analysis of variance. One is to use non-parametric methods to analyze the data. These methods, in spite of the widespread misperception that they are "free of assumptions", are usually not suitable except in cases of extremely poor data quality. This is true for two reasons. One is that non-parametric methods always assume distributional symmetry thus, if proper transformation of the data did not produce a data set that meets the assumptions of the analysis of variance, the assumptions of non-parametric analysis will not be met either. The second is that non-parametric alternatives to the analysis of variance cannot accommodate the kind of complex factorial treatment structure found in many experiments.

The other alternative to the analysis of variance is to use linear or nonlinear mixed-effect models. These methods, however, cannot be considered standard as they are not in widespread use, and are an active area of research in statistical methodology. Nevertheless they are an alternative if all else fails.

In this study, graphical summaries of the data revealed no problems that would alter plans to use standard ANOVA techniques to analyze the data. Factorial analysis of variance was used, with irrigation and treatment as factors, and monitoring event as a covariate. Response variables included density of native and non-native plants. Results of the statistical analyses of the plant establishment study data and Soil Erosion Research Laboratory data are presented in Sections 5 through 7.

(a) Soil was hoisted into the text bed using a rope and pulley system.

(b) Soil was evenly distributed over the test bed.

(a) Soil was roto-tilled to uniform consistency.

(b) Soil was raked smooth for compaction.

(a) The test surface of soil was hand compacted prior to each surface treatment.

(b) As was the case in preparing the soil for each test, new soil was imported, roto-tilled and hand compacted. On the bare soil (control) plots, the compacted soil was lightly raked prior to

Sand cone testing was periodically conducted to determine compaction achieved by hand methods.

Project No.: 57-977001NM.00	Report Date: JUNE 2000	Project: CALTRANS EROSION CONTROL PILOT STUDY	Fig.: 3-12

(a) Following hand compaction, the soil surface was ripped to a depth of 10 cm (4 inches) using a hand tool.

(b) The ripped test bed before rainfall, showing contour trenches.

(a) The contour trenches slowed down runoff and settled out some sediments during rainfall events.

(b) Typical runoff quality resulting from ripping treatment.

(a) Three tracks from a Caterpillar D-9 were welded together to form a template for the trackwalking procedure.

(b) The template was set in place using lifting chains; plywood panels were used to preserve previously treated areas.

(a) A small gasoline powered compactor was used to compress the tracks into the soil surface.

(b) The finished trackwalked slope.

(a) Imprinting devices were constructed using the dimensions from an actual machine.

(b) The imprinting tools were used to reproduce the depth and spacing of the field machine.

Project No.: 57-977001NM.00	Report Date: JUNE 2000	Project: CALTRANS EROSION CONTROL PILOT STUDY	Fig.: 3-17

(a) Sand cone tests were conducted periodically to determine the compaction of the soil before imprinting.

(b) Side view of the imprinting pattern.

Finished slope showing completed imprinting pattern.

Project No.: 57-977001NM.00	Report Date: JUNE 2000	Project: CALTRANS EROSION CONTROL PILOT STUDY	Fig.: 3-19

(a) Hand tools were created which reproduced the impression of a sheepsfoot roller.

(b) The pattern produced for each sheepsfoot rolled test.

Project No.: 57-977001NM.00	Report Date: JUNE 2000	Project: CALTRANS EROSION CONTROL PILOT STUDY	Fig.: 3-20

(a) The completely treated sheepsfoot rolled slope during a rainfall event.

(b) Typical runoff trom the treated sheepsfoot rolled slope.

(a) Three plots and flumes were constructed to create replicate plots for the water quality tests.

(b) The bare soil (control) treatment showing the three replicate plots and flumes of the water quality testing configuration.

Runoff from bonded fiber matrix (BFM).

Project No.: 57-977001NM.00	Report Date: JUNE 2000	Project: CALTRANS EROSION CONTROL PILOT STUDY	Fig.: 3-23

(a) The bare soil (control) treatment illustrating the 2 meter x 8 meter plot size constructed for the soil roughness tests.

(b) One flume was used to collect runoff from the 2 meter x 8 meter soil roughness plots.

At the indoor laboratory, runoff was collected in 35-gallon poly-lined barrels.

(a) Following each rain event, eroded soil was removed by hand.

(b) Soil was removed to a depth of non-saturation.

(a) Discarded soil was placed in a storage bin for eventual removal by skip loader.

(b) Soil was hauled off using a pickup truck.

(a) Powdered gypsum was added to the runoff water to aid the settlement of fine-grained sediments.

(b) Procedures for analyzing runoff volumes and sediment weight included the decanting of the clear (supernatant) water once the sediments had settled.

Samples of wet sediment were weighed, then dried in an oven to determine gross sediment discharge and erosion rate.

(a) Typical paper mulch application.

(b) Typical wood fiber mulch application.

(a) Bonded fiber matrix (BFM) application.

(b) In addition to analyzing runoff water and sediments, flow-weighted composite samples were collected for water quality analysis on the different surface mulching practices.

(a) For all hydraulic applications, a Finn T-30 1136-liter hydromulcher was used.

(b) Uniform application was achieved by using a 3.81-cm hose and a spray nozzle with a small orifice.

(a) Applications were timed in order to achieve exact application rate of material. The student in the back is holding the stopwatch.

(b) Following application, the hydromulcher was flushed and cleaned with treated water. The mulch was decanted into garbage bags for disposal and the water was discharged into the

(a) Rolled erosion control products (RECP) were unrolled downslope in the direction of water flow.

(b) The outside edges of each RECP were secured using wire staples.

(a) The manufacturer's recommended staple pattern was used across the entire test area.

(b) With the lighter RECPs, edging was inserted into the soil directly though the blanket.

With the heavier RECPs, such as coconut fiber, the RECP had to be cut prior to installation of the edging.

(a) Wood fiber blanket (WFB).

(b) Straw blanket (SB).

(a) Straw-coconut blanket (SCB).

(b) Curled wood fiber blanket (CWFB).

(a) Coconut blanket (CB).

(b) Coconut fiber netting (COIR).

(a) Wheat straw was carefully weighed and evenly distributed among the three replicate plots.

(b) The wheat straw was incorporated into the ground using hand tools.

(a) Completed replicate plots of incorporated wheat straw.

(b) Close-up of wheat straw showing incorporation into soil.

Following collection, the flow-weighted composite samples were immediately transferred to the SDSU Environmental Laboratory for analysis.

(a) All materials and apparatus, including rainfall simulators and water supply, were transported to the site using a stake bed truck

(b) Electrical and plumbing connections were attached to the simulators before they were lifted into place above

(a) At the DeVry site (10-2) the Finn T-30 was used to pump water to the simulators and to collect and re-circulate the water from the overflow boxes..

(b) installing the simulators on the permanent scaffolding over the first plot.

(a) Ropes were used to hoist the simulators into position, where they were hung from metal hooks.

(b) Prior to each rainfall event, the water pressure to each simulator was carefully adjusted using valves along the supply manifold.

Project No.: 57-977001NM.00	Report Date: JUNE 2000	Project: CALTRANS EROSION CONTROL PILOT STUDY	Fig.: 3-46

(a) The Brea Canyon site (57-4) was more remote and required that all materials, including water supply, be transported up the slope.

(b) Raising the first row of simulators into position by rope.

(a) Hanging the simulators from S-hooks.

(b) Assembling the water return piping.

(a) Water supply and re-circulation system showing remote tank, supply line and re-circulation plumbing. Note the gasoline pump (partially hidden behind water tank) that powers the system.

(b) Adjusting the water pressure of each simulator to achieve accurate rainfall intensities.

(a) The Brea Canyon (54-7) test plots as they appear from a distance.

(b) Collection of the samples was accomplished using the existing flume and pipe system.

Runoff at the outdoor vegetative coverage plots was collected in 5-gallon containers which were sealed and shipped to SDSU for analysis.

Project No.: 57-977001NM.00	Report Date: JUNE 2000	Project: CALTRANS EROSION CONTROL PILOT STUDY	Fig.: 3-51

(a) Samples were collected in 5-gallon buckets, labeled, sealed and shipped to SDSU for analysis.

(b) Samples from the vegetative coverage plots were analyzed at the SDSU Soil Erosion Research Laboratory.

This section presents the results and analysis of laboratory roughness testing conducted using the rainfall simulators and tilting soil test bed at the Soil Erosion Research Laboratory at San Diego State University. Soil roughening is an important first step in the establishment of permanent erosion control vegetation on a newly constructed bare slope. Soil roughening is the creation of a soil surface roughness by mechanical means. Typically, the roughening is performed parallel to the slope contours and perpendicular to the direction of runoff. The benefits provided by soil roughening are to slow runoff, enhance infiltration, moderate soil temperature, trap moisture, and enhance seed germination and root penetration.

To evaluate the effectiveness of different roughness techniques in reducing erosion rates for different storm events, the roughness tests were conducted using simulated storm events corresponding to the 5-year (yr), 10-yr, and 50-yr storm for the Los Angeles area. All tests were run using a clayey sand soil, on a 1V:2H slope. Roughness types that were tested included:

Smooth-rolled soil

The characteristics of a smooth-rolled, compacted surface were simulated by placing soil in the test bed (Figure 3-7), tilling it to uniform consistency (Figure 3-8), compacting it with hand tools, and lightly raking the surface (Figure 3-9).

Trackwalking

The characteristics of a trackwalked surface were simulated by first preparing the soil to a smooth-rolled condition, then placing a metal template on the surface to produce the required roughness (Figure 3-13). Three tracks from a Caterpillar D-9 bulldozer were welded together to form a template for the trackwalking procedure (Figure 3-13). A small gasoline-powered compactor was used to compress the tracks into the soil surface (Figure 3-14).

Sheepsfoot-Rolling

The roughness characteristic of a sheepsfoot-rolled slope was accomplished by designing and utilizing hand tools to create the appropriate impression in the soil surface (Figure 3-18). As with other roughness techniques, the soil surface was first tilled and compacted by hand before application of the sheepsfoot tool.

Ripping

To simulate the effect of ripping the surface with bulldozer tines, the soil was first tilled and compacted by hand (Figure 3-9). Following hand compaction, the soil surface was ripped to a depth of 10 cm (4 in.) using a hand pick (Figure 3-11). The ripping was done perpendicular to the flow of water down this slope, with each incision 30-35cm (12-14 in.) apart (Figure 3-1).

Imprinting

The roughness triangular characteristic of an imprinter/roller was accomplished by utilizing a hand tool designed and constructed to the dimensions of an actual imprinting machine (Figure 3-15). The orientation, depth, and spacing were monitored and adjusted for consistency of surface preparation (Figure 3-16).

Each of these methods (other than smooth-rolling) utilizes heavy equipment in the field to roughen the surface of the soil, either by the use of hand tools (ripping, sheepsfoot-rolling, and imprinting) or by driving a caterpillar-type tractor on the slope to compact the soil and provide texture (trackwalking). These techniques provide erosion control by slowing down runoff velocity, increasing the soil surface area to enhance infiltration, and reducing runoff volume through storage in surface depressions.

Roughness techniques are important for permanent stabilization in three ways:

1) Most techniques can be accomplished with existing on-site equipment so that finished slopes have a margin of temporary protection until permanent vegetation is established.
2) Roughness techniques complement most erosion control methodologies (i.e., hydraulic soil stabilization), making them perform better.
3) Roughness techniques, through increased infiltration and less runoff of water, improve vegetation establishment

4.1 EVALUATION OF LABORATORY TESTING OF SOIL ROUGHNESS

4.1.1 Soil Roughness Erosion Control Effectiveness

The results of the soil roughness tests (normalized erosion rate and runoff) are summarized in Table 4-1. Figure 4-1 shows average normalized soil erosion rates by storm type.

When making a decision as to which soil stabilization practice to implement on a site, it is important to compare the performance of a particular technique (to the untreated condition) over a broad range of storms that might be encountered during the construction period (e.g., 5-yr, 10-yr, 50-yr). Therefore, a practical interpretation of the roughness data is expressed in the last column of Table 4-1. This column shows the average, relative increase or decrease in erosion or runoff for a particular roughness practice, as compared to smooth rolled, over a wide range of storm events. Figure 4-2 compares the average percent erosion control effectiveness of the four roughness techniques in terms of percent reduction of soil loss as compared to the smooth-rolled (baseline) condition. Figure 4-3 compares the average percent changes in runoff volume by storm type from the four roughness techniques to the baseline condition. Values of positive percent on this figure correspond to percent decreases in runoff, relative to baseline, while negative percent values reflect increased runoff relative to baseline.

From the table and figures, some general statements can be made:

- The imprinting technique appears to be the most effective practice in reducing erosion (76 percent decrease in soil loss);
- Sheepsfoot-rolling and trackwalking provide a good level of erosion control (55 percent and 52 percent decreases in soil loss, respectively);
- Ripping provides the least effective erosion control (12 percent decrease in soil loss), but is most effective in reducing runoff (19 percent decrease in runoff).

4.1.2 Statistical Evaluation of Soil Roughness Tests

Dry sediment weight was subjected to an analysis of covariance with roughness treatment and storm type as treatment factors and total runoff volume as the covariate. Storm type and roughness treatment were highly significant, as was the interaction between the two. Thus, both storm type and roughness treatment influenced sediment weight, with the effects of different roughness treatments depending significantly on storm type. The covariate effect was not statistically significant, but was strongly related to storm type. This may reflect the fact that storm type is affected by factors other than just runoff (e.g., rainfall intensity) that were not specifically addressed in this study.

The weight of discharged sediment was normalized based on the unit surface area of the test bed and rainfall volume. Figure 4-4 illustrates the mean values of normalized sediment weight for the different roughness treatments. Figure 4-5 illustrates mean values of normalized sediment weight for the different storm types. As shown on these figures, overall, sediment discharge increased more with increased storm intensity than increased storm volume (each Type (2) storm had a lower intensity and higher volume than the Type (1) storm for the same return period). Ripping produced slightly lower sediment yields than the smooth-rolled (baseline). Sheepsfoot-rolling and trackwalking produced even lower sediment yields, and were not significantly different from one another. Imprinting produced significantly lower sediment yields than any other treatment considered in this experiment. The superiority of the imprinting treatment was roughly consistent across all the tested storm types.

Table 4-1
RESULTS OF RAINFALL SIMULATION TESTING FOR ROUGHNESS

Treatment	Measurement	Statistic	Storm						Average Increase (+) Decrease (-)
			5-yr (1)	5-yr (2)	10-yr (1)	10-yr (2)	50-yr (1)	50-yr (2)	
Smooth	Normalized Erosion Rate (kg/m²/mm)	Mean	0.06	0.07	0.16	0.09	0.12	0.09	
		St. Dev.	0.03	0.07	0.04	0.01	0.02	0.02	
		% of Smooth	100%	100%	100%	100%	100%	100%	0%
	Runoff (L)	Mean	255.7	364.4	419.2	470.3	422.3	611.0	
		St. Dev.	11.9	35.1	19.6	9.7	10.6	20.3	
		% of Smooth	100%	100%	100%	100%	100%	100%	0%
Imprinted	Normalized Erosion Rate (kg/m²/mm)	Mean	0.03	0.02	0.03	0.02	0.03	0.02	
		St. Dev.	0.03	0.19	0.11	0.12	0.04	0.05	
		% of Smooth	49%	26%	18%	25%	22%	19%	76% (-)
	Runoff (L)	Mean	222.3	415.6	380.8	446.6	464.4	501.8	
		St. Dev.	13.3	96.1	49.4	84.0	21.1	37.8	
		% of Smooth	87%	114%	91%	95%	110%	82%	4% (-)
Ripped	Normalized Erosion Rate (kg/m²/mm)	Mean	0.04	0.07	0.12	0.08	0.15	0.06	
		St. Dev.	0.18	0.03	0.07	0.04	0.01	0.09	
		% of Smooth	66%	99%	75%	88%	121%	71%	12% (-)
	Runoff (L)	Mean	154.2	276.3	387.3	416.3	373.5	443.4	
		St. Dev.	75.6	17.0	29.8	24.7	7.0	79.2	
		% of Smooth	60%	76%	92%	89%	88%	73%	19% (-)
Sheepsfoot	Normalized Erosion Rate (kg/m²/mm)	Mean	0.03	0.03	0.02	0.05	0.06	0.04	
		St. Dev.	0.03	0.14	0.06	0.03	0.04	0.03	
		% of Smooth	58%	46%	14%	56%	51%	46%	55% (-)
	Runoff (L)	Mean	361.3	374.8	525.1	511.8	503.3	584.4	
		St. Dev.	11.9	71.3	26.7	22.5	26.0	24.3	
		% of Smooth	141%	103%	125%	109%	119%	96%	12% (+)
Trackwalked	Normalized Erosion Rate (kg/m²/mm)	Mean	0.04	0.04	0.05	0.04	0.04	0.07	
		St. Dev.	0.11	0.05	0.08	0.06	0.09	0.04	
		% of Smooth	80%	60%	30%	40%	30%	80%	52% (-)
	Runoff (L)	Mean	218.7	448.3	460.7	468.5	410.6	579.9	
		St. Dev.	48.0	26.8	35.5	38.4	49.7	36.0	
		% of Smooth	86%	123%	110%	100%	97%	95%	2% (+)

Figure 4-1
AVERAGE NORMALIZED EROSION RATES BY STORM TYPE

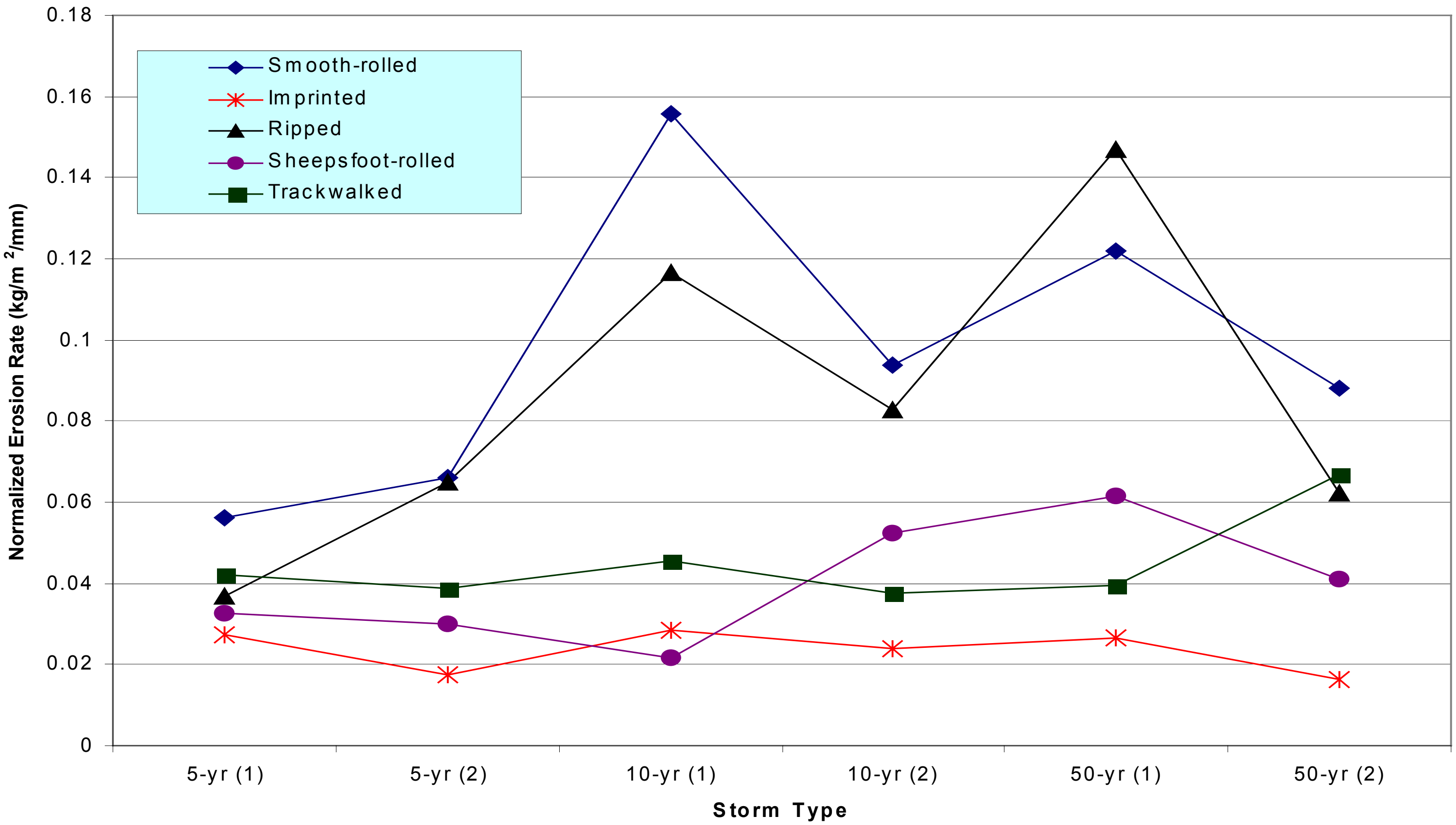


Figure 4-2
AVERAGE PERCENT EROSION CONTROL EFFECTIVENESS COMPARED TO EROSION RATE OF SMOOTH-ROLLED TREATMENT BY STORM TYPE

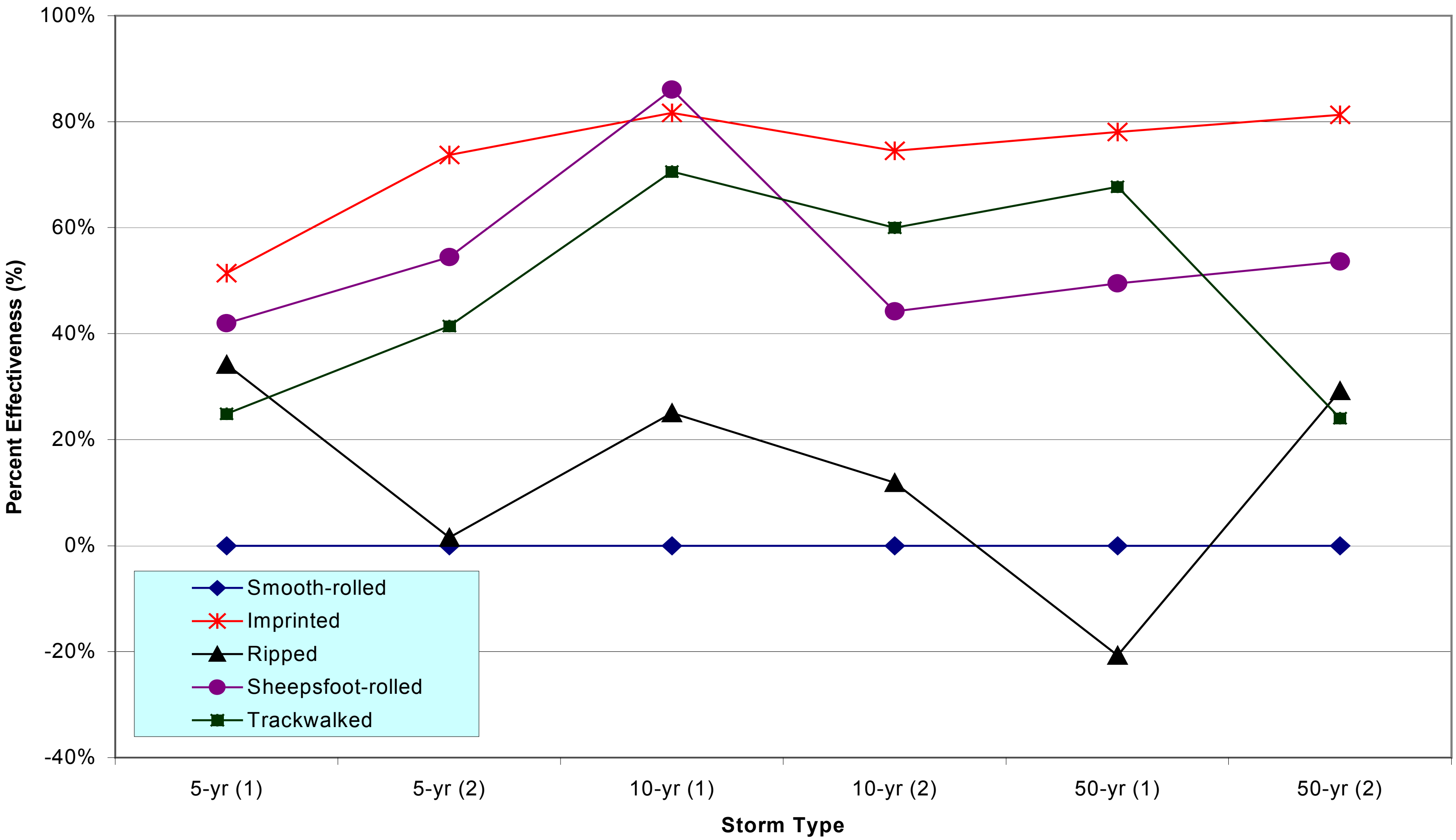


Figure 4-3
AVERAGE PERCENT INCREASE/DECREASE IN RUNOFF VOLUME BY STORM TYPE

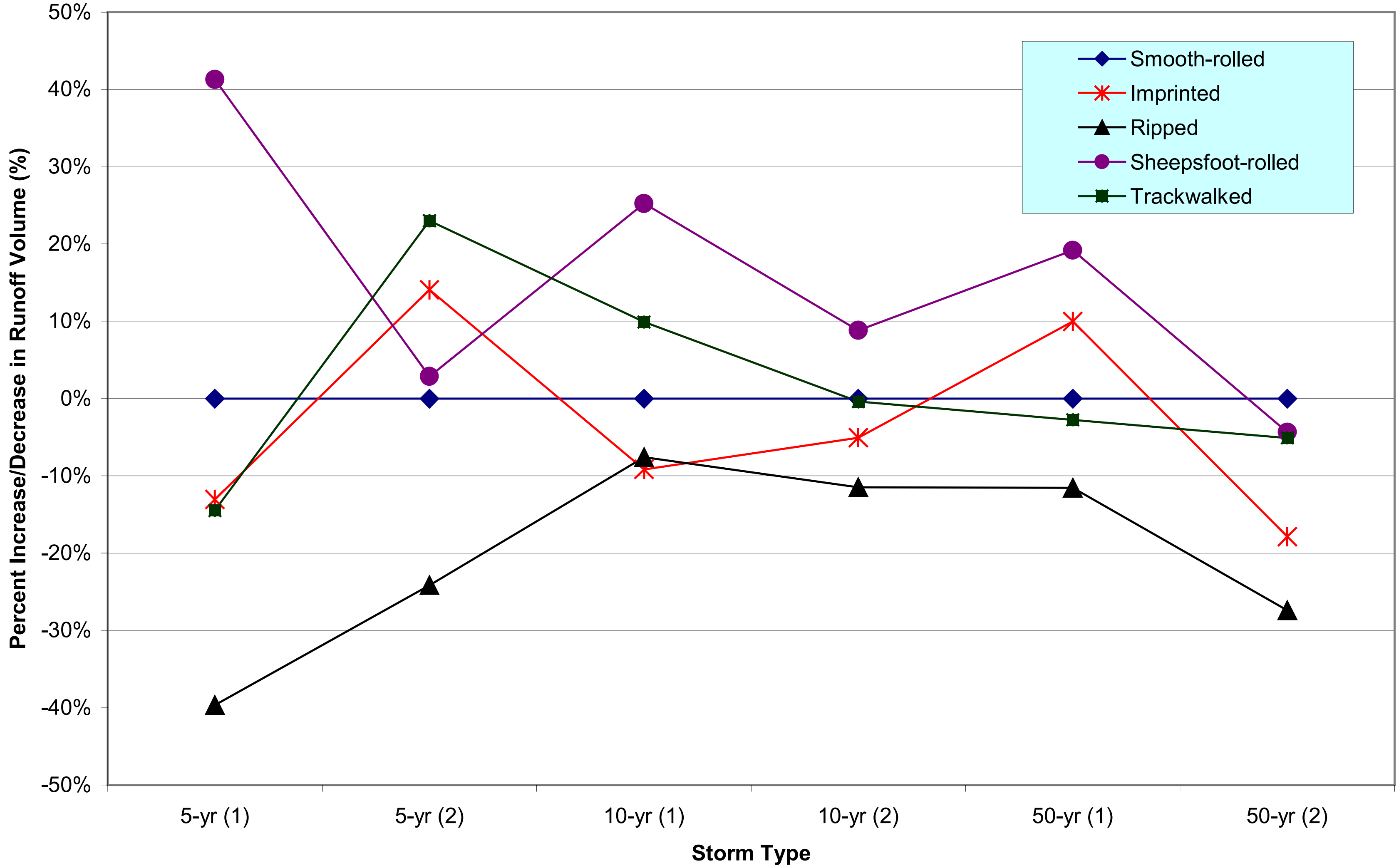


Figure 4-4
MEANS AND STANDARD ERRORS OF NORMALIZED EROSION RATE BY SURFACE ROUGHNESS TREATMENT

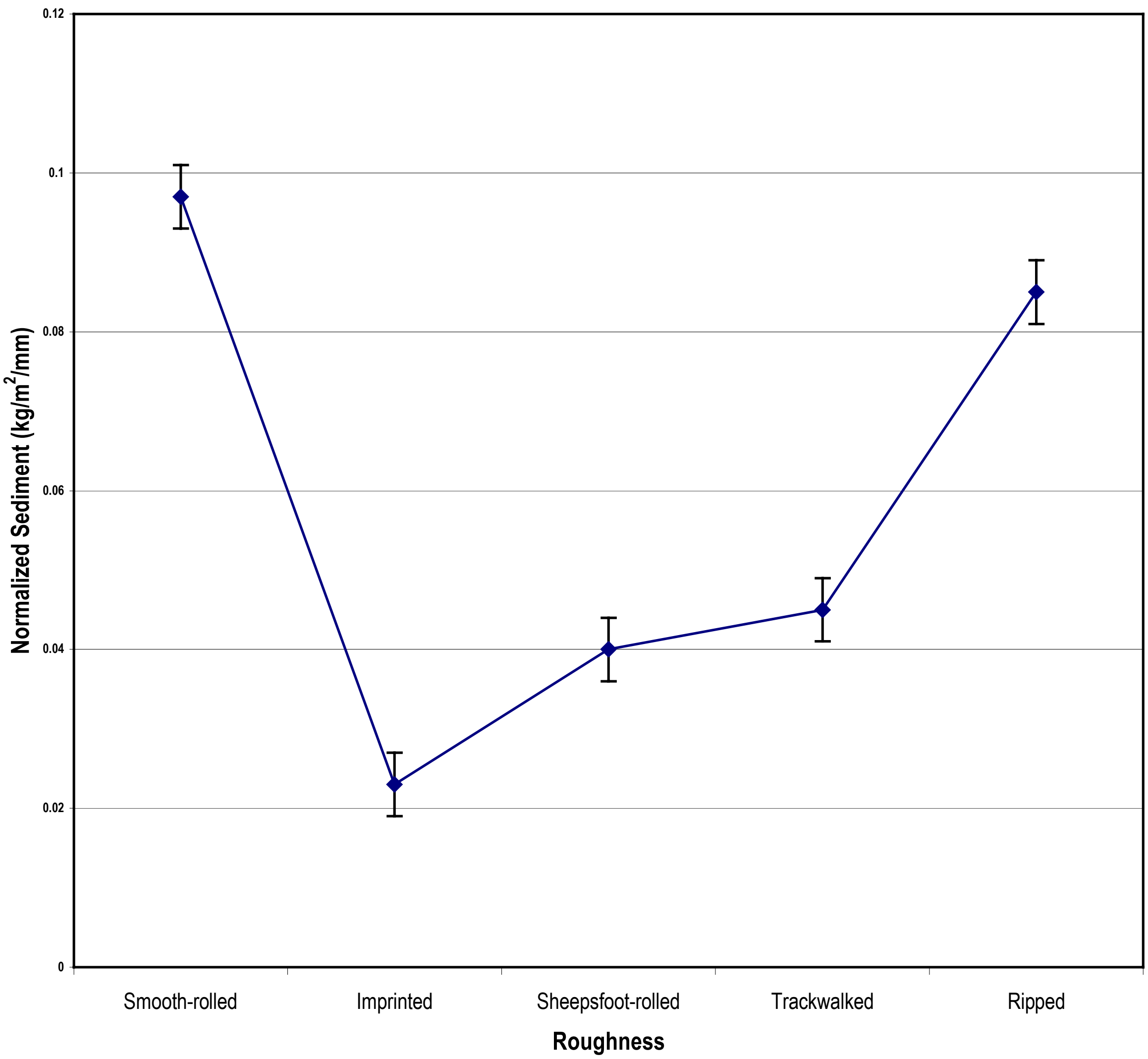
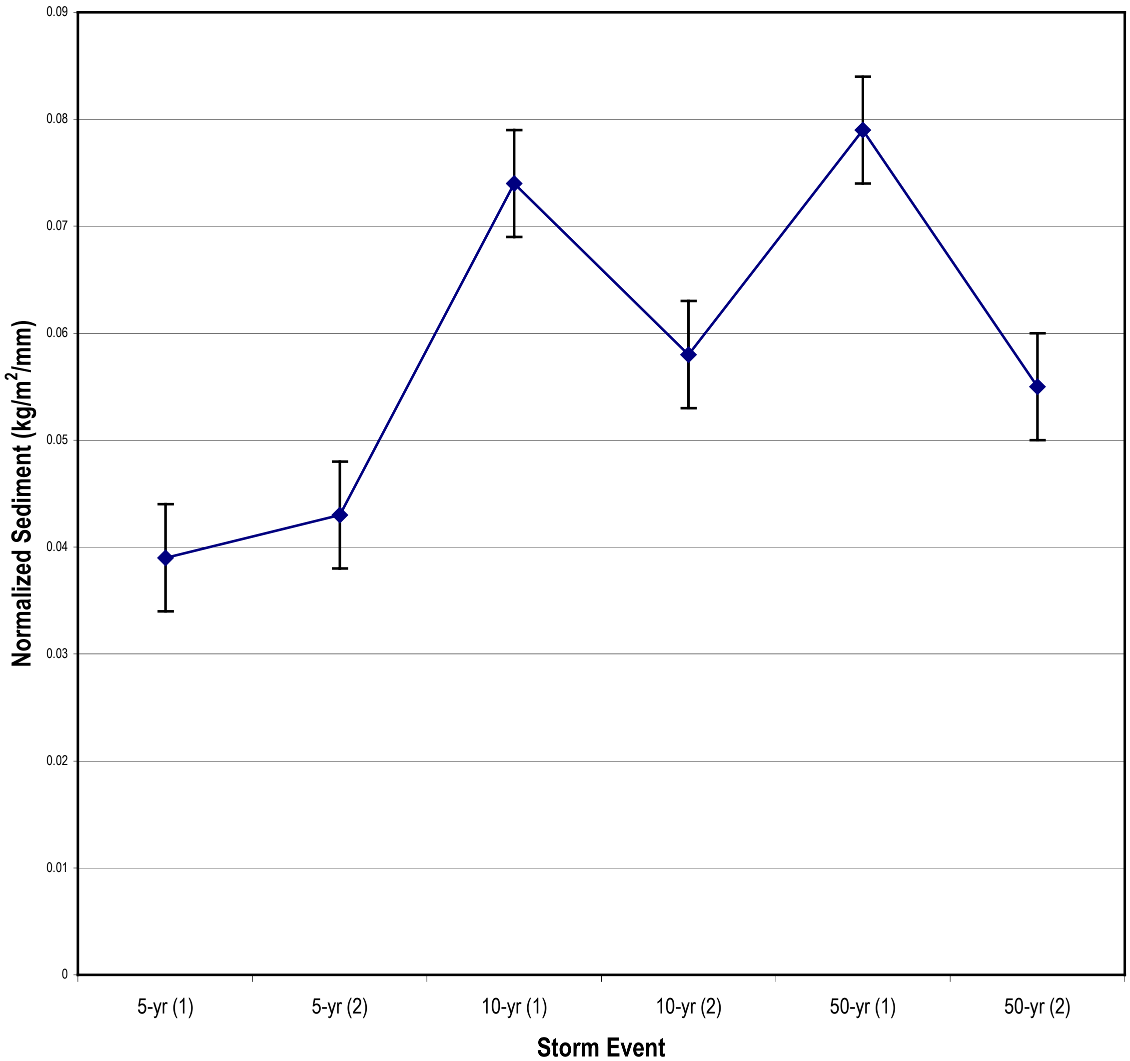


Figure 4-5
MEANS AND STANDARD ERRORS OF NORMALIZED EROSION RATE BY STORM TYPE



This section addresses the erosion control effectiveness of alternative erosion control products. The soil stabilization measures provide a second step (after soil roughening) in the process of establishing permanent erosion control vegetation. The 15 soil stabilization measures evaluated herein are of value in the early stages of slope stabilization. Since vegetation takes time to grow and may not provide effective erosion control for several months to years, the soil stabilization measures provide interim erosion control, and provide a nurturing environment for seeds and plants to become established. This section also presents the results of testing of crimped and tacked straw tested at the Texas Transportation Institute (TTI).

The water quality and erosion rate tests on 15 soil stabilization measures were performed using the 10-year (2) storm event (Table 3-6) for the Los Angeles area. These are the same soil stabilization measures used in the Plant Establishment Study (Section 6) and included the following:

- Bare soil (BARE)
- Bonded fiber matrix (BFM)
- Coconut blanket (CB)
- Coir blanket (COIR)
- Compost (COMP)
- Curled wood fiber blanket (CWFB)
- Gypsum treatment (GYP)
- Paper mulch with psyllium (PMG)
- Paper mulch with polymer (PMP)
- Wheat straw incorporated (RS)
- Straw blanket (SB)
- Straw-coconut blanket (SCB)
- Wood fiber blanket (WFB)
- Wood mulch with psyllium (WMG)
- Wood mulch with polymer (WMP)

Data collected during this portion of the study were evaluated to address the following questions:

1. How does the water quality of runoff from the treatment compare to typical urban runoff from the Los Angeles area?
2. How do the treatments rank in reducing erosion and runoff?

5.1 EROSION RATE TESTS

For the erosion rate tests, 15 different soil stabilization measures (including a bare soil control plot) were tested under simulated storm events corresponding to the 10-year (2) storm event in the Los Angeles area. Each test consisted of three replicate plots within the simulator test bed. During the test, all sediment and runoff were collected in buckets and were measured. The sediment was dried and weighed. Water samples collected during each test were delivered to the SDSU analytical laboratory for analysis.

5.1.1 Erosion Rate Tests

Results of the erosion rate study with respect to normalized erosion rate and percent change in runoff for the soil stabilization measures that were tested are shown in Table 5-1. Figure 5-1 shows the percent of reduction of sediment loss for each of the erosion control product test plots, as compared with soil loss from the bare soil plots. Overall, this figure illustrates that all of the erosion control products tested greatly reduced the amount of soil loss.

The range of erosion control performance in this study was consistent with what has been observed in previous rainfall simulation testing at both the Utah Water Research Laboratory (UWRL) and the Texas Transportation Institute (TTI):

- Erosion control effectiveness of most rolled erosion control products (RECPs) is in the 90-100% range;
- Hydraulic applications of bonded fiber matrix (BFM) perform in the same range of effectiveness as RECPs; and
- Hydraulic applications of mulch (wood fiber or paper) are notably less effective in controlling erosion, although in this study their performance appears to be substantially enhanced by the addition of a binder (psyllium or polymer).

Based on the results of this laboratory study, each of the treatments was rated according to its effectiveness in reducing erosion rate. The next chapter (Section 6) summarizes the results of on-site (field) studies of plant establishment effectiveness of these same erosion control products. A summary of the process used to compare both the laboratory and field data and develop an overall ranking of the individual control measures is presented in Section 9.

Figure 5-2 illustrates the increase or decrease in runoff from the plots tested as compared to runoff from the bare plots. Six of the products resulted in a decrease in runoff, with the largest decrease (approximately 90 percent) coming from the coconut blanket (CB) plot. Eight of the products resulted in increased runoff.

Evaluation of the percentage change in the runoff of the treated plots compared to the bare soil (control) condition yielded the anticipated results; that is, the more physically stable materials (i.e., RECPs, BFM, incorporated straw) were more successful at decreasing runoff. There were, however, some notable exceptions:

- The coconut blanket (CB) performed at a higher rate than expected. This is possibly due to retention of sediment and water at the toe of the plot. This phenomenon, observed in many field applications, creates a "pillow" of water and sediment behind the closely-woven fibers of coconut at the downslope portion of the blanket where it is trenched in or heavily stapled.
- The paper mulch with polymer binder (PMP) reduced runoff at a much higher rate than similar hydraulic applications. From the material's historic performance in similar tests (USWRL/TTI) one would have expected an increase in runoff similar to the paper mulch with psyllium (PMG), wood mulch with psyllium (WMG), and wood mulch with polymer (WMP) plots.

Table 5-1
RESULTS OF EROSION RATE TESTS FOR SOIL STABILIZATION MEASURES (NORMALIZED SEDIMENT DATA)

Treatment	Measurement	Statistic	Value
Bare	Normalized Erosion Rate (kg/m^2/mm)	Mean	0.116
		Std. Dev.	*0.038*
	Runoff (L)	Mean	153.9
		Std. Dev.	*0.3*
		% of Rainfall Volume	30%
Bonded Fiber Matrix (BFM)	Normalized Erosion Rate (kg/m^2/mm)	Mean	0.000
		Std. Dev.	*0.000*
	Runoff (L)	Mean	130.8
		Std. Dev.	*34.8*
		% of Rainfall Volume	26%
Coconut Blanket (CB)	Normalized Erosion Rate (kg/m^2/mm)	Mean	0.000
		Std. Dev.	*0.000*
	Runoff (L)	Mean	17.5
		Std. Dev.	*4.9*
		% of Rainfall Volume	3%
Coir (COIR)	Normalized Erosion Rate (kg/m^2/mm)	Mean	0.007
		Std. Dev.	*0.002*
	Runoff (L)	Mean	153.5
		Std. Dev.	*20.2*
		% of Rainfall Volume	30%
Compost (COMP)	Normalized Erosion Rate (kg/m^2/mm)	Mean	0.071
		Std. Dev.	*0.024*
	Runoff (L)	Mean	173.9
		Std. Dev.	*23.6*
		% of Rainfall Volume	34%
Curled Wood Fiber Blanket (CWFB)	Normalized Erosion Rate (kg/m^2/mm)	Mean	0.011
		Std. Dev.	*0.003*
	Runoff (L)	Mean	157.6
		Std. Dev.	*26.1*
		% of Rainfall Volume	31%
Gypsum (GYP)	Normalized Erosion Rate (kg/m^2/mm)	Mean	0.027
		Std. Dev.	*0.005*
	Runoff (L)	Mean	165.7
		Std. Dev.	*14.5*
		% of Rainfall Volume	24%
Paper Mulch with Polymer (PMP)	Normalized Erosion Rate (kg/m^2/mm)	Mean	0.029
		Std. Dev.	*0.003*
	Runoff (L)	Mean	94.6
		Std. Dev.	*8.2*
		% of Rainfall Volume	19%
Paper Mulch with Psyllium (PMG)	Normalized Erosion Rate (kg/m^2/mm)	Mean	0.045
		Std. Dev.	*0.016*
	Runoff (L)	Mean	195.7
		Std. Dev.	*10.8*
		% of Rainfall Volume	39%
Straw Blanket (SB)	Normalized Erosion Rate (kg/m^2/mm)	Mean	0.002
		Std. Dev.	*0.000*
	Runoff (L)	Mean	126.0
		Std. Dev.	*24.7*
		% of Rainfall Volume	25%
Straw-Coconut Blanket (SCB)	Normalized Erosion Rate (kg/m^2/mm)	Mean	0.004
		Std. Dev.	*0.002*
	Runoff (L)	Mean	157.1
		Std. Dev.	*6.8*
		% of Rainfall Volume	31%
Wood Fiber Blanket (WFB)	Normalized Erosion Rate (kg/m^2/mm)	Mean	0.002
		Std. Dev.	*0.000*
	Runoff (L)	Mean	182.7
		Std. Dev.	*14.3*
		% of Rainfall Volume	36%
Wood Mulch with Polymer (WMP)	Normalized Erosion Rate (kg/m^2/mm)	Mean	0.058
		Std. Dev.	*0.008*
	Runoff (L)	Mean	226.6
		Std. Dev.	*8.1*
		% of Rainfall Volume	45%
Wood Mulch with Psyllium (WMG)	Normalized Erosion Rate (kg/m^2/mm)	Mean	0.015
		Std. Dev.	*0.003*
	Runoff (L)	Mean	182.4
		Std. Dev.	*8.5*
		% of Rainfall Volume	36%
Wheat Straw Incorporated (RS)	Normalized Erosion Rate (kg/m^2/mm)	Mean	0.005
		Std. Dev.	*0.004*
	Runoff (L)	Mean	112.7
		Std. Dev.	*12.6*
		% of Rainfall Volume	22%

Note: Gypsum (GYP) erosion rate was tested as part of the Soil Stabilization for Temporary Slopes study that was performed between September and December 1999. Specific results for that study were presented in a *Field Guide* and supporting *Guidance Document*, dated November 30, 1999.

Figure 5-1
PERCENT EROSION REDUCTION FROM BARE SOIL

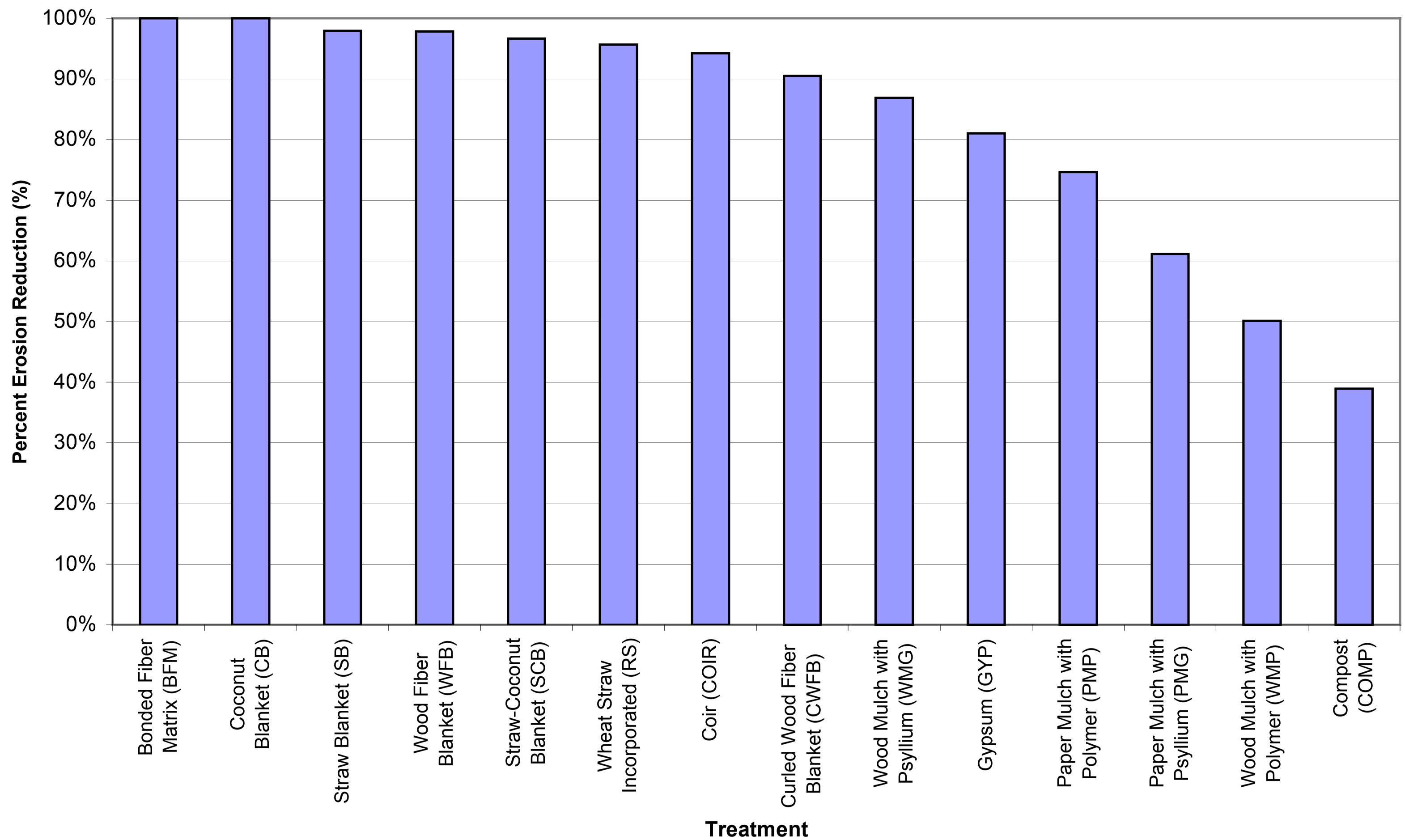
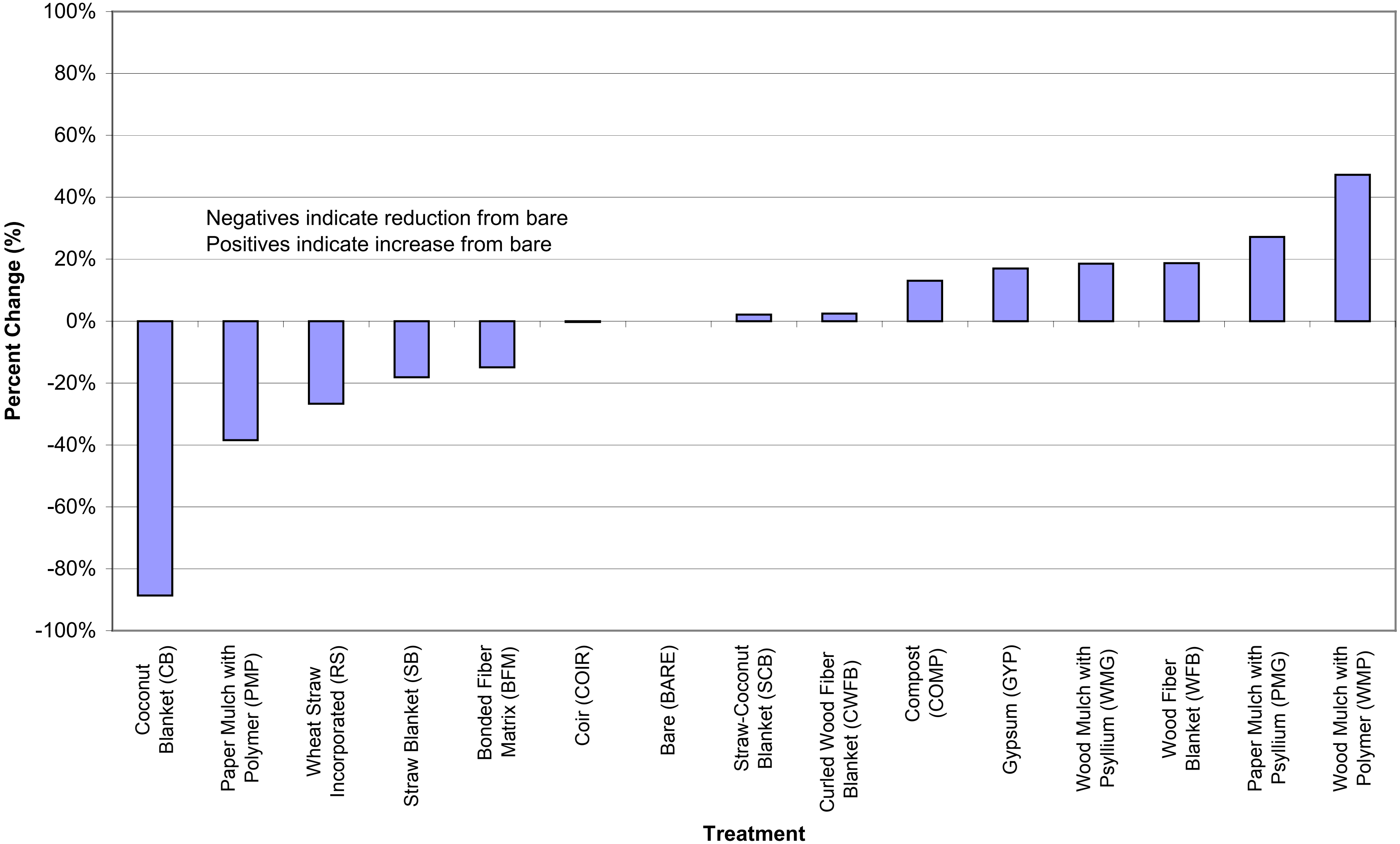


Figure 5-2
PERCENT CHANGE IN RUNOFF FROM BARE SOIL



5.2 WATER QUALITY TESTS

For the water quality tests, runoff from the 15 soil stabilization plots and bare control plot was collected and tested. The water samples were tested for a suite of constituents to determine the water quality impacts from the treatments themselves. The water quality analyses were performed at the SDSU water quality laboratory under the direction of Dr. Badrihya. The constituents which were tested included the following:

- pH
- Total Organic Carbon (TOC)
- Chemical Oxygen Demand (COD)
- 5-Day Biological Oxygen Demand (BOD_5)
- Nitrite
- Nitrate
- Nitrate + Nitrite Nitrogen
- Total Kjeldahl Nitrogen (TKN)
- Phosphorus
- Aluminum (A1)
- Arsenic (As)
- Barium (Ba)
- Cadmium (Cd)
- Calcium (Ca)
- Chromium (Cr)
- Copper (Cu)
- Iron (Fe)
- Lead (Pb)
- Lithium (Li)
- Magnesium (Mg)
- Mercury (Hg)
- Nickel (Ni)
- Thulium (Tm)
- Vanadium (V)
- Zinc (Zn)

This list of constituents was developed based on a review of the Material Safety Data Sheets (MSDS) for the soil stabilization products being tested in this study.

For each test, the results for the three replicates were averaged and compared to the bare slope control replicates and two sets of urban runoff water quality data:

1. Ranges of concentrations from Caltrans statewide storm water monitoring.
2. Mean concentrations from Los Angeles County land use-specific storm water monitoring data (including transportation land use).

The Los Angeles data tended to fall within the range of the Caltrans statewide data. A summary of the water quality results for the tests is provided in Tables 5-2 and 5-3. These data are for non-sediment water quality constituents. Total sediment (total suspended solids plus total settleable solids) were addressed separately and are discussed above in Section 5.1. As mentioned before, the water used to perform the rainfall simulations was treated in the laboratory using reverse osmosis. This water was tested for all of the same water quality constituents as the runoff. Results of the tests of the treated water are shown in the tables as “treated test water.” The test water was clear of all metals except calcium, and had low concentrations of TOC, COD, BOD_5 and phosphorous, relative to runoff from the test plots (Table 5-2).

Indicator Parameters

The pH of runoff from all treatments was below the bare soil control mean pH of 8.40, with five treatments below the Caltrans statewide lower range of 6.6. The mean biological oxygen demand (BOD_5) for all treatments except coir exceeded the bare soil mean of 1.03 mg/L. The BOD_5 in runoff from three of the samples (bonded fiber matrix, wheat straw incorporated, and straw blanket) exceeded the Caltrans statewide upper range concentration of 37 mg/L. Total organic carbon (TOC) was not measured in either the Caltrans statewide or the Los Angeles County studies.

The mean chemical oxygen demand (COD) for all treatments except coconut blanket were above the mean bare soil control COD of 13.6 mg/L. Runoff from two of the products (bonded fiber matrix and straw blanket) had concentrations above the Caltrans statewide upper range of 480 mg/L. The same treatments with high BOD_5 tended to have high COD.

Nitrite levels in the runoff from the treatments ranged from non-detect to 0.39 mg N/L. The bare soil control mean was 0.08 mg N/L. Nitrate levels ranged from 0.10 to 3.91 mg N/L, and the bare soil control mean was 0.78 mg N/L. Wood fiber blanket, bonded fiber matrix, coconut blanket, wheat straw incorporated, and straw blanket all exceeded 1 mg N/L, but were all within the range of typical urban runoff.

Dissolved Metals

Dissolved metals water quality data were compared to the bare soil control runoff as well as typical urban runoff values (Caltrans statewide data and Los Angeles Country Transportation data). The following comparisons were observed in the metals data (Table 5-3).

Aluminum. Runoff data ranged from 11.3 to 179.0 µg/L with a bare mean of 68.0 µg/L. Straw coconut blanket, straw blanket, and gypsum exceeded 119 µg/L, which is the mean concentration from the Los Angeles transportation monitoring data.

Arsenic. Runoff data from all treatments, including the bare plot, were below the laboratory detection limit of 2.0 µg/L.

Barium. Barium was present in runoff from all but one of the treatments (straw blanket), ranging from 41 to 150 µg/L. Barium was also present in runoff from the bare soil plot at 51 µg/L, so it is likely that the soil used in the test is one source of this metal. All detected values exceeded the Los Angeles transportation average (16 µg/L). No data for dissolved barium were available for the Caltrans statewide monitoring.

Cadmium. Runoff data from the bare plot and all treatments except compost (1.7 µg/L) were below the laboratory detection limit of 0.6 µg/L.

Calcium. Levels of calcium were not appreciably different in runoff from the different treatments or compared to runoff from the bare plot. Dissolved calcium was not measured in the Caltrans statewide or Los Angeles monitoring studies.

Copper. Copper was present in concentrations ranging from 0.5 to 15.3 µg/L. Copper was also present in runoff from the bare soil plot at 4.4 µg/L. All levels were below the Caltrans statewide and Los Angeles transportation concentration.

Table 5-2
WATER QUALITY DATA COMPARISONS FOR INDICATOR PARAMETERS

		Detection Limit	TREATMENT															Bare (BARE)	Caltrans Statewide	Los Angeles County Stormwater Monitoring				
			TREATED TEST WATER	Wood Fiber Blanket (WFB)	Wood Mulch with Polymer (WMP)	Paper Mulch with Polymer (PMP)	Wood Mulch with Psyllium (WMG)	Paper Mulch with Psyllium (PMG)	Coir (COIR)	Curled Wood Fiber Blanket (CWFB)	Bonded Fiber Matrix (BFM)	Straw — Coconut Blanket (SCB)	Coconut Blanket (CB)	Wheat Straw Incorporated (RS)	Compost (COMP)	Straw Blanket (SB)	Gypsum (GYP)			LA Vacant	LA Light Ind.	LA Retail / Comm.	LA Trans.	LA Mix. Res.
Parameter	**Unit**		**Value**	**Mean**	**Mean**	**Mean**	**Mean**	**Mean**	**Mean**	**Mean**	**Mean**	**Mean**	**Mean**	**Mean**	**Mean**	**Mean**	**Mean**	**Mean**	**Range**	**Mean**	**Mean**	**Mean**	**Mean**	**Mean**
pH	S.U.		6.9	6.67	7.31	7.09	6.49	6.65	8.07	6.73	6.43	6.25	7.37	5.27	7.61	5.94	7.25	8.40	6.6 - 17.3	n/m	n/m	n/m	n/m	n/m
TOC	mg/L	0.1	1.87	27.67	12.14	4.86	15.98	11.21	3.29	15.57	158.92	59.96	3.58	171.32	6.39	135.80	6.10	3.07	NA	n/m	n/m	n/m	n/m	n/m
COD	mg/L	2	9.00	120.79	42.79	22.20	65.08	42.27	20.67	62.18	628.33	85.85	12.93	310.56	18.57	522.00	43.70	13.59	10 - 480	14	82	78	45	65
BOD_5	mg/L	0.1	0.30	34.00	5.20	4.40	16.00	13.00	0.00	19.00	220.00	40.50	2.60	180.00	5.00	220.00	NA	1.03	3 – 37	14	23.3	27	22	18.4
Nitrite	mg N/L	0.05	ND	ND	0.39	0.17	ND	ND	0.25	ND	ND	ND	0.14	0.20	0.19	0.37	NA	0.08	0.2 – 8.3	0.0	0.1	0.2	0.1	0.1
Nitrate	mg N/L	0.09	ND	1.89	0.63	0.25	0.17	0.10	0.30	0.11	1.04	1.44	0.31	3.91	0.24	3.47	NA	0.38	0.1 – 1.7	4.6	4.1	2.7	0.6	2.2
Nitrite+Nitrate	mg N/L	0.05	ND	1.89	1.02	0.42	0.17	0.10	0.30	0.11	1.04	1.44	0.44	4.11	0.43	3.84	NA	0.46	NA	n/m	n/m	n/m	n/m	n/m
TKN	mg N/L	0.1	ND	ND	ND	0.28	0.56	ND	ND	ND	ND	0.59	5.04	1.49	ND	1.03	NA	ND	1 – 57	1.1	2.9	3.0	1.6	2.4
Phosphorus	mg P/L	0.03	0.08	0.36	0.79	1.00	0.75	0.49	0.47	0.27	0.63	3.61	0.60	3.91	0.31	4.29	NA	0.21	0.05 – 3.3	n/m	n/m	n/m	n/m	n/m

Notes:
NA = Not Analyzed
ND = Not Detected
n/m = "Not meaningful, not enough data for detection limit collected" based on Los Angeles County monitoring data.
NL = not listed
Caltrans = Load Assessment; CTSW-RT-99-078; November 1999: representative concentrations of freeway runoff, 1997-99.
S.U. = standard units
LA = LA County Stormwater monitoring data for 1994-1999.
Treated Test Water = Analysis of reverse osmosis-treated water used to conduct the water quality tests.
TOC = Total Organic Carbon
COD = Chemical Oxygen Demand
BOD_5 = Biological Oxygen Demand

Table 5-3
WATER QUALITY DATA COMPARISONS FOR DISSOLVED METALS

		Detection Limit	TREATMENT															Bare (BARE)	Caltrans Statewide	Los Angeles County Stormwater Monitoring				
			TREATED TEST WATER	Wood Fiber Blanket (WFB)	Wood Mulch with Polymer (WMP)	Paper Mulch with Polymer (PMP)	Wood Mulch with Psyllium (WMG)	Paper Mulch with Psyllium (PMG)	Coir (COIR)	Curled Wood Fiber Blanket (CWFB)	Bonded Fiber Matrix (BFM)	Straw — Coconut Blanket (SCB)	Coconut Blanket (CB)	Wheat Straw Incorporated (RS)	Compost (COMP)	Straw Blanket (SB)	Gypsum (GYP)			LA Vacant	LA Light Ind.	LA Retail / Comm.	LA Trans.	LA Mix. Res.
Parameter	Unit		Value	Mean	Mean	Mean	Mean	Mean	Mean	Mean	Mean	Mean	Mean	Mean	Mean	Mean	Mean	Mean	Range	Mean	Mean	Mean	Mean	Mean
Aluminum	µg/L	2.0	ND	11.30	50.5	23.25	18.6	34.8	39.6	77.5	37.0	136.6	106.0	39.3	13.9	138.0	179.0	68.0	25 - 2500	n/m	421	205	119	197
Arsenic	µg/L	10.0	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	<10.0	ND	1 - 15	n/m	n/m	n/m	n/m	n/m
Barium	µg/L	15.0	ND	33.60	113.9	76.9	90.3	101.4	45.5	72	96.2	99.0	56.8	41.2	149.5	ND	66.0	51.0	NA	38	27	27	16	20
Cadmium	µg/L	0.6	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	1.7	ND	<2.0	ND	0.5 – 6.1	n/m	n/m	n/m	n/m	n/m
Calcium	µg/L	10.0	38	133	188	251	191	261.3	117	222	173	216.7	220	244	262	180	NA	224	NA	n/m	n/m	n/m	n/m	n/m
Copper	µg/L	0.5	ND	0.5	7.0	4.4	4.97	6.5	1.6	2.5	7.5	15.3	3.6	11.1	4.4	9.4	6.0	4.4	2 –140	n/m	17.9	12.2	30.2	12.4
Chromium	µg/L	1.0	ND	7.8	4.6	ND	13.5	2.7	4.6	4.9	2.4	14.3	7.9	2.0	2.6	27.3	4.0	4.9	2 – 50	n/m	n/m	n/m	3.3	n/m
Iron	µg/L	0.9	ND	40.6	4.3	4.4	3.4	5.9	7.7	4.2	4.2	1.4	1.7	16.3	24.1	639	13.0	13.8	100 – 7500	n/m	822	382	202	490
Lead	µg/L	12.0	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	<10.0	ND	0.5 – 300	n/m	n/m	n/m	n/m	n/m
Lithium	µg/L	0.4	ND	ND	ND	0.5	0.7	ND	0.6	ND	ND	1.2	0.5	ND	1.8	2.5	<2.0	0.8	NA	n/m	n/m	n/m	n/m	n/m
Magnesium	µg/L	4.0	ND	ND	ND	ND	8	14.0	4	ND	19.8	8.5	7	18.7	87.4	4.3	NA	9.6	100 – 980	n/m	2000	6200.0	1500.0	1000
Mercury	µg/L	0.2	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	<2.0	ND	0.2 – 0.2	n/m	n/m	n/m	n/m	n/m
Nickel	µg/L	3.0	ND	ND	ND	ND	ND	4.6	ND	ND	ND	ND	ND	ND	ND	ND	4.3	ND	5 – 317	n/m	3.9	n/m	3.3	n/m
Vanadium	µg/L	34.0	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	12.2	ND	NA	n/m	n/m	n/m	n/m	n/m
Zinc	µg/L	0.1	ND	ND	0.2	0.2	0.2	0.2	0.2	0.5	0.4	0.3	0.2	ND	0.6	0.7	3.4	0.3	6.56 - 1300	51	326	152	181	132
Thulium	µg/L	0.5	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	<50	ND	NA	n/m	n/m	n/m	n/m	n/m

Notes:
NA = Not Analyzed
ND = Not Detected
n/m = "Not meaningful, not enough data for detection limit collected" based on Los Angeles County monitoring data.
NL = Not listed
Caltrans = Load Assessment; CTSW-RT-99-078; November 1999: representative concentrations of freeway runoff, 1997-99.
LA = LA County Stormwater monitoring data for 1994-1999.
Treated Test Water = Analysis of reverse osmosis-treated water used to conduct the water quality tests.

Chromium. Chromium in runoff from the treatments ranged from non-detect to 27.3 μg/L. Runoff from the bare soil plot, by comparison, had a chromium concentration of 4.9 μg/L. All detected levels were similar to those observed in Caltrans statewide and Los Angeles County data.

Iron. Iron concentrations ranged from 1.4 to 40.6 μg/L with straw blanket measuring 639 μg/L. The bare control mean was 13.8 μg/L. All values were within the range of the Caltrans statewide monitoring.

Lead. Runoff data from all treatments, including the bare plot, were below the laboratory detection limit of 12.0 μg/L.

Lithium. Lithium was below the detection limit in runoff from seven of the treatment plots. Lithium concentration was slightly higher in runoff from the straw blanket treatment (2.5 μg/L) as compared to the bare plot (0.8 μg/L). All other values were comparable to the bare soil plot. Lithium was not measured as part of the Caltrans statewide or Los Angeles monitoring studies.

Magnesium. Concentrations of magnesium observed in runoff from the test plots ranged from non-detect to 19.8 μg/L with compost measuring 87.4 μg/L. All concentrations were within the range for typical urban runoff.

Mercury. Runoff data from all treatments including the bare plot, were below the laboratory detection limit of 0.2 μg/L.

Nickel. Nickel was detected in runoff from two of the treatments, paper mulch with psyllium and gypsum. Both of these concentrations were within the range of concentrations observed in the Caltrans statewide study.

Vanadium. Runoff data from all treatments, including the bare plot, were below the laboratory detection limit of 34.0 μg/L.

Zinc. Low concentrations of zinc were detected in runoff from 12 of the treatments and the bare plots ranging from 0.2 to 3.4 μg/L. These concentrations were notably lower than zinc concentrations observed in typical urban runoff.

Thulium. Runoff data from all treatments, including the bare plot, were below the laboratory detection limit of 0.5 μg/L.

In summary, runoff from five of the products tested (wood fiber blanket, bonded fiber matrix, straw-coconut blanket, wheat straw incorporated, and straw blanket) contained elevated levels of TOC and COD, which suggested they are releasing organic materials that have an elevated oxygen demand (e.g., undergoing biodegradation). No exceedances above typical urban runoff were observed for dissolved metals. Consequently, these five products were categorized as having some potential impact to water quality, relative to the other products tested. None of the products tested resulted in a "fatal flaw" for water quality.

5.3 STATISTICAL EVALUATION OF WATER QUALITY TESTS

Table 5-4 shows the means of erosion rate and runoff volume by treatment. Analysis of variance of these data showed that treatments significantly influenced both erosion rate and runoff volume. Figure 5-3 shows normalized erosion rate by treatment; Figure 5-4 shows runoff volumes by treatment. Pairs of treatments for which the error bars do not overlap are significantly different.

Table 5-4
MEANS OF NORMALIZED EROSION RATE AND RUNOFF VOLUME BY TREATMENT

Treatment	Mean Normalized Erosion Rate ($kg/m^2/mm$)	Mean Runoff Volume (L)
Bare (BARE)	0.116	153.9
Bonded Fiber Matrix (BFM)	0	130.8
Coconut Blanket (CB)	0	17.5
Coir (COIR)	0.007	153.5
Compost (COMP)	0.071	173.9
Curled Wood Fiber Blanket (CWFB)	0.011	157.6
Paper Mulch with Polymer (PMP)	0.029	94.6
Paper Mulch with Psyllium (PMG)	0.045	195.7
Straw Blanket (SB)	0.002	126.0
Straw-Coconut Blanket (SCB)	0.004	157.1
Wood Fiber Blanket (WFB)	0.002	182.7
Wood Mulch with Polymer (WMP)	0.058	226.6
Wood Mulch with Psyllium (WMG)	0.015	182.4
Wheat Straw Incorporated (RS)	0.005	112.7

Figure 5-3
MEANS AND STANDARD ERRORS OF NORMALIZED EROSION RATES BY TREATMENT

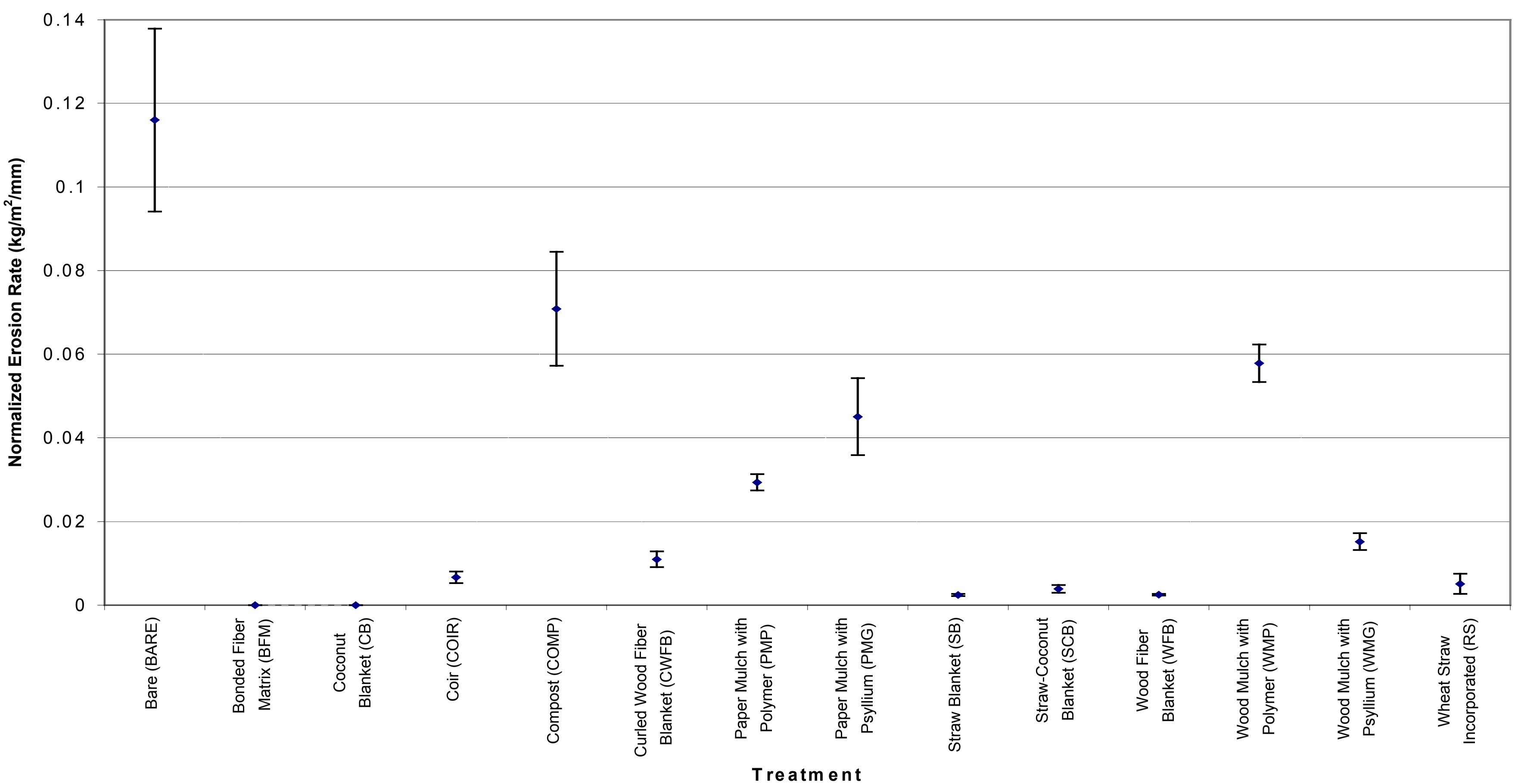
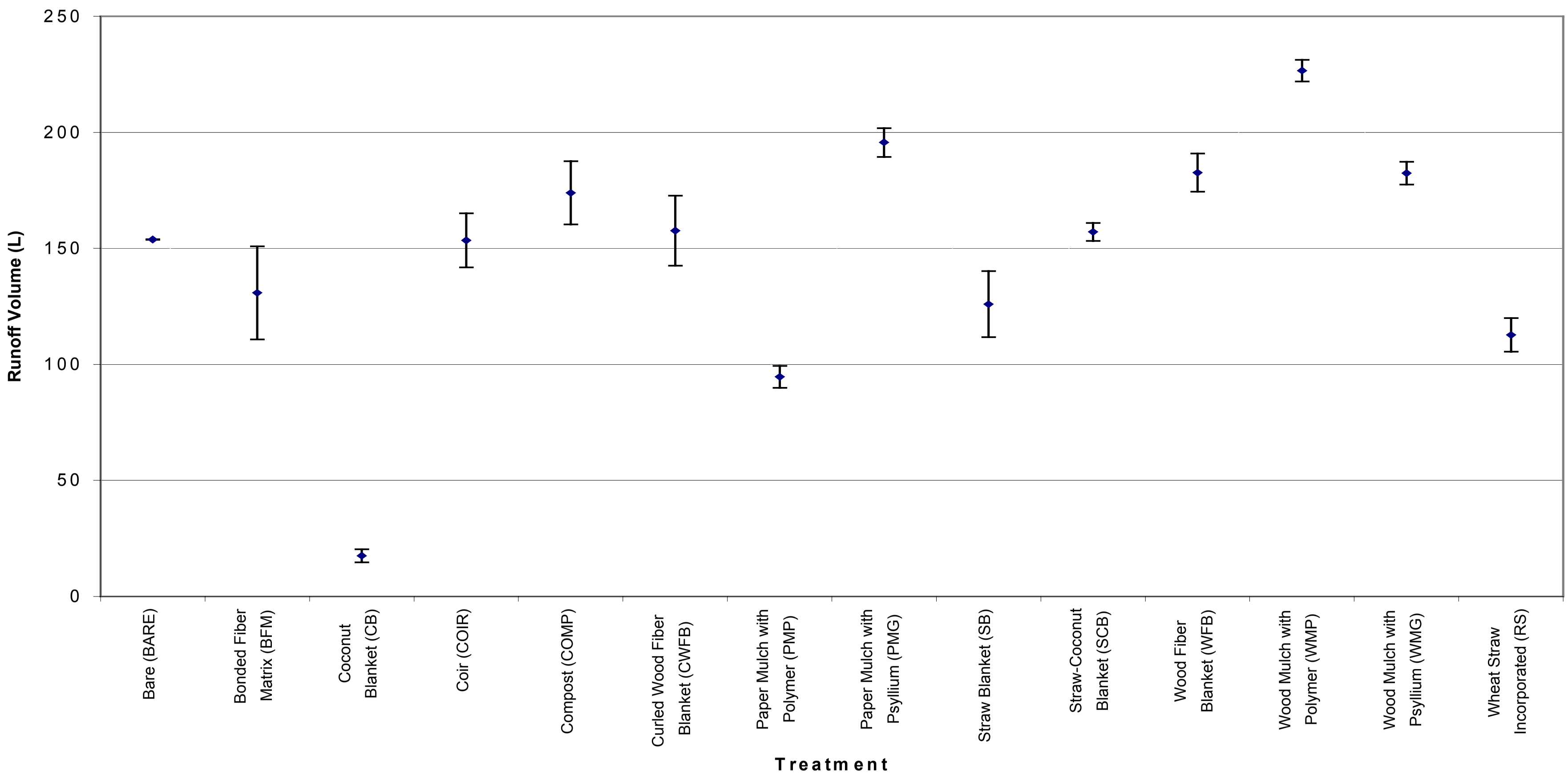


Figure 5-4
MEANS AND STANDARD ERRORS OF RUNOFF VOLUMES BY TREATMENT



5.4 COMPARISON OF ECPS WITH OTHER STUDIES

Considerable comparative testing of temporary erosion control measures has been performed by others. However, as described in the *Detail Study Plan* (URS Greiner Woodward Clyde, 1998) our review of this information pointed out the need for testing of one common Caltrans technique, straw mulch (with tackifier on cut slopes and incorporated on fill slopes) to establish comparable data to the erosion rate data for other technologies.

Rather than test the straw mulch under different conditions than the other technologies, tests of straw mulch was performed at TTI, which provided data on erosion rate that are comparable to the data on erosion rate that are available for the other technologies. A discussion of these test results is presented below.

5.4.1 Erosion Control Performance of Crimped and Tacked Straw

This section provides a comparison between the Caltrans ECPS and a TTI study evaluating the use of crimped straw and straw-tackifier applications as erosion control Best Management Practices (BMPs). The TTI study allowed a direct comparison between crimped and tacked straw with respect to erosion control and vegetation establishment performance. This information was then compared to the ECPS findings, which provides Caltrans a basis for the comparison of the performance of straw applications to other available erosion control BMPs that were tested in the ECPS.

5.4.2 Methods

<u>Study Methods and Procedures</u>

The purpose of testing the crimped and tacked straw applications at TTI was to compare the effectiveness of these practices against other products and procedures (i.e., RECPs, hydraulic mulches) previously evaluated at TTI under similar conditions. The study methods and procedures of the TTI study were conducted in accordance with the TTI Procedures and Evaluation Criteria for Erosion-Control Blankets, Flexible Channel Lining Material, and Hydraulically-Applied Mulch Products (provided in Appendix E).

Six plots were used for this study: two plots with 2H:1V clay, one plot with 2H:1V sand, two plots with 3H:1V clay, and one plot with 3H:1V sand. A soil analysis and description of the individual plots is provided in Appendix E.

Rice straw with a psyllium-based organic tackifier was obtained and certified for pure live seed content. Before installation, each test plot was cleared of vegetation, brought back to uniform grade, fumigated with a soil sterilant to reduce the native seed source, and fine graded. Each plot was then seeded according to the TxDOT Standard Specification, Item 164, *Seeding for Erosion Control* based on the sandy or cohesive characteristics of the soil. Seeding and fertilizer was applied hydraulically, followed by the application of the crimped straw and straw tackifier. Table 5-5 gives the straw application rates for each of the test plots.

Beginning two weeks after installation, a series of six simulated rainfall events of increasing intensities were conducted, each separated by two weeks. Each event lasted 10 minutes and was based on the intensity of a ten-minute storm with a Type III rainfall distribution. Sediment generated by the simulated rainfall events was collected, sampled, dried, weighed, and reported as the average for all simulated events. The vegetation density was determined using the "Vegetation Coverage Analysis Program" (VeCAP), developed by TTI. VeCAP uses digital photography and computer masking technology to determine the amount of vegetation cover for a sample area (Appendix E). Final vegetation density was reported as the percentage surface cover achieved at the end of a 9-month growing season.

TTI Results and Conclusions

The TTI test results in Table 5-6 provide vegetation cover achieved by November of the 1999 growing season and show the average sediment loss for each plot over the six test simulations.

Table 5-5
STRAW APPLICATION RATES BY SOIL TYPE

Plot	Slope/soil	Treatment
CL1	2H:1V Clay	4000 lbs./ac. Straw - crimped
CL11	2H:1V Clay	4000 lbs./ac. Straw – tacked
SA1	2H:1V Sand	4000 lbs./ac. Straw – crimped
C1	3H:1V Clay	4000 lbs./ac. Straw – crimped
C7	3H:1V Clay	4000 lbs./ac. Straw – tacked
S1	3H:1V Sand	4000 lbs./ac. Straw - crimped

Table 5-6
VEGETATION COVER AND SEDIMENT LOSS FOR STRAW-TACKIFIER AND CRIMPED STRAW APPLICATIONS

Plot	Slope/Soil	Treatment	Vegetation Cover (1) (%)	Sediment Loss (kg per 10 sq m)
CL1	2H:1V Clay	Crimped	58% (80%)(2)	1.9 (0.34) (2)
CL11	2H:1V Clay	Tacked	70% (80%)	2.0 (0.34)
SA1	2H:1V Sand	Crimped	44% (70%)	30.2 (26.84)
C1	3H:1V Clay	Crimped	63% (80%)	1.3 (0.34)
C7	3H:1V Clay	Tacked	74% (80%)	1.1 (0.34)
S1	3H:1V Sand	Crimped	49% (70%)	19.1 (12.20)

(1) Raw vegetation cover data is included in Appendix E.

(2) Values in parenthesis indicate TxDOT Approved Products List requirements

<u>Conclusions</u>

In Table 5-6, tacked straw appears to provide the best performance for both sediment reduction and vegetation cover. However, the figures also suggest, as demonstrated in Table 5-7, that crimped straw may perform as well or slightly better than tacked straw in more intense rainfall events. The early difference in sediment reduction performance between crimped straw and tacked straw may be due to loosening of the surface during crimping, which disturbs the soil and makes it more available for transport. The difference in vegetation density could also be related to the disturbance of soil particles during the crimping process. Since seed is applied prior to crimping a percentage of the seed could be pressed into the soil to a depth that reduces or prevents germination.

The results of the TTI evaluations indicate that crimped and tacked straw do not meet the numerical performance standards for the State of Texas. However, the minimum standards for Texas are not necessarily applicable to the State of California due to differences in soil type, vegetation, and the various intensities of rainfall used in the evaluation.

5.4.3 Comparison of SDSU And TTI Comparative Tests

Comparing the results of the TTI study against the testing performed as part of the ECPS at SDSU enables Caltrans to make a qualitative comparison of the performance of soil stabilization practices to rank the performance of crimped or tacked straw alongside other soil stabilization practices currently in the Caltrans specifications, and verify the relative performance of crimped or tacked straw against soil stabilization practices studied in other Caltrans evaluations.

Eight products or techniques were tested at both facilities. TTI does not evaluate soil loss from any hydraulic mulch applications; therefore, the four hydraulic mulch applications tested at SDSU cannot be compared to any TTI published results. Additionally, TTI does not have equivalent published tests to match the SDSU tests on coconut blankets or compost.

Table 5-8 presents a comparison of the eight products or techniques tested at both facilities. The TTI results represent the mean values for the 1991-1998 test cycles compared to their control plot (bare). The comparison shows that the TTI results are consistently lower than the SDSU results, with the lowest values being on 2H:1V sand slopes. However, the TTI tests were performed at intensities an order of magnitude higher than the SDSU tests (i.e., 146-184 mm/hr compared to 40 mm/hr). As illustrated, the data support expectations of higher erosion rates at higher intensity rainfall events.

None of the straw applications meet the TxDOT standards for the Approved Products List for erosion control materials. This is unexpected, particularly in the case of the straw-tack applications, which form a mat of connected fibers very similar in appearance to some rolled materials. Straw-rolled materials exhibit some of the best erosion control performance characteristics. The chief difference in the physical properties of the rolled material compared to the straw-tack mat is stem diameter, length, and overall flexibility. The stem size and overall gradation of the straw material in the blanket is small in comparison to baled rice

Table 5-7
SEDIMENT LOSS BY PLOT AND STORM TYPE

Plot	Sediment Loss in kg/10 sq m						
	1 Year Storm (1)		2 Year Storm(1)		5 Year Storm(1)		Avg.
2H:1V Clay	**Run 1**	**Run 2**	**Run 1**	**Run 2**	**Run 1**	**Run 2**	
Crimped	0.58	2.73	0.44	1.08	3.72	3.09	1.94
Tackifier	0.01	0.02	0.61	2.10	4.59	4.95	2.05
Difference	**0.57**	**2.71**	**-0.17**	**-1.02**	**-0.87**	**-1.86**	
2H:1V Sand							
Crimped	2.66	2.08	32.66	29.35	59.55	54.90	30.20
3H:1V Clay							
Crimped	0.11	0.08	0.52	0.43	3.49	3.36	1.33
Tackifier	0.05	0.06	0.48	0.60	2.81	2.45	1.08
Difference	**0.06**	**0.02**	**0.04**	**-0.17**	**0.68**	**0.91**	
3H:1V Sand							
Crimped	1.32	1.09	22.45	18.22	32.86	38.66	19.10

(1) Represent design storms in Texas.

Table 5-8
COMPARISON OF SDSU AND TTI TESTS

Soil Stabilization Measure	Average Percent Erosion Reduction from Bare Soil		
	SDSU	TTI	TTI
	2H:1V	2H:1V	2H:1V
	Clayey Sand	Clay	Sand
Bonded fiber matrix (BFM)	100%	84%	56%
Straw blanket (SB)	98%	84%	54%
Wood fiber blanket (WFB)	98%	86%	n/a
Straw-coconut blanket (SCB)	97%	84%	56%
Straw incorporated (RS)	96%	6%	40%
Coir (COIR)	94%	89%	56%
Curled wood fiber blanket (CWFB)	91%	86%	62%
Gypsum (GYP)	81%	n/a	45%
Rainfall:	Part 1 - 5 mm/hr, 30 min Part 2 - 40 mm/hr, 40 min Part 3 - 5 mm/hr, 30 min(1) One 3-part event (3 replicate plots)	30.2 mm/hr, 10 min (twice) (2) 145.5 mm/hr, 10 min (twice) (2) 183.6 mm/hr, 10 min (twice) (2) Six events run two weeks apart (plots not replicated)	

(1) Corresponds to 10-yr (2) storm in District 7.
(2) Correspond to 1-yr, 2-yr, and 5-yr storms in Texas, respectively.

straw, which is composed of longer thicker stems. This results in a very stiff mat that easily bridges small rills on the surface, which increases sediment.

Repeating the TTI study may confirm these patterns of soil loss and erosion rates, particularly with respect to the long-term performance of crimped straw. If initial rainfall events remove soil particles loosened during the crimping process, results could indicate that crimped straw actually holds the surface better in heavier rainfall events. Therefore, crimped straw could prove to be better practice. This would be particularly significant in areas of steep slope with shorter growing seasons and more frequent rainfall.

This section presents the results and analysis of field data from the plant establishment test plots over the two-year duration of the study. Well established, self-sustaining vegetative cover is the final goal for establishing permanent soil stabilization. In order to evaluate the effect of various erosion control treatments on the establishment of selected native plants under actual Caltrans slope, soil, and climatic conditions, a total of 15 different erosion control treatments (along with a control, which consisted of a bare soil plot with no erosion control treatment) were tested on cut and fill slopes. Well established, self-sustaining vegetative cover is the final goal for establishing permanent soil stabilization. As introduced in previous sections, two locations, sites 10-2 (De Vry fill slope) and 57-4 (Brea Canyon cut slope) were selected for the irrigated and non-irrigated test plots construction on highway cut and fill slopes. At each location, 3 replicates of each test plot type were installed. The plots were seeded with a seed mix consisting of 11 native species (Table 1-1) and then treated with the various erosion control types.

As described in Section 3, vegetation monitoring for the plant establishment test plots was conducted on seven occasions (December 1998; March, May, August and November 1999; and January and April 2000). During the monitoring events, data were collected on vegetation cover (measured using a modified Daubenmire scale; Table 3-2), plant density (number of plants per 1 m^2 quadrat monitoring area), species diversity, seedling vigor, and shrub growth rate. In addition, during the last monitoring event (May 2000), root depths were measured.

This study was designed to focus on the native species planted, rather than on non-native species, which likely migrated to the plots from surrounding areas or were present in the underlying soil's seed bank. However, the vast majority of plant cover and density within the test plots consisted of non-native annual species. Over the course of the study, only a small number of individual native plants germinated and became established. Therefore, the monitoring data collected included data on the individual species found in the native seed mix as well as other plants that also grew in the plots. Because of the overwhelming number of plants of non-native species, plants not in the seed mix were categorized as either non-native grasses (TGR) or non-native broadleaf species (TBR).

Additionally, the lower than average rainfall during the study period affected the germination and growth of native species, particularly shrubs and perennial grasses. Fewer native plants germinated than would have in a season with greater rainfall. The effect of low rainfall is most pronounced for native shrub and perennial species because they are slower to germinate than annual species. Non-native annual species germinate readily even in years of drought and are opportunistic, meaning that they have mechanisms for dispersal and establishment that can lead to displacement of native species. Whereas, native shrub species are adapted to germinate after significant moisture is present in the soil to ensure the survivorship of seedlings. Additionally, since non-native plant growth provided the majority of density and plant cover, there was strong competition for moisture, nutrients, and light in the study plots. The dominant non-native species observed within the test plots included black mustard (*Brassica nigra*), ripgut brome (*Bromus* spp.), yellow star thistle (*Centaurea melitensis*), thistle (*Cirsium occidentale*), filaree (*Erodium* spp.), short-pod mustard (*Hirschfeldia incana*), California chicory (*Rafinesquia californica*), milk thistle (*Silybum marianum*), and other annual grasses.

Data collected over the 2-year study were evaluated in order to address the following questions:

1. How did the two seasons of rainfall compare to the long-term average rainfall for the study area?
2. How much value was initial irrigation in plant establishment?
3. How did the treatments rank in facilitating plant establishment for irrigated vs. non-irrigated (cut and fill) slopes?
4. How did the growth rate of shrub species vary seasonally with each treatment type?
5. How did the root depths of the different species compare?
6. How did the treatments rank in terms of shrub seedling mortality?
7. How were the plots affected by other factors (e.g., animal and human disturbance)?
8. How did the treatments compare in terms of rate of success as well as ultimate success?

In addition to the field testing influencing plant establishment conducted in this study, a review of studies being conducted by others was performed. Specifically, this review focused on the effect of topsoil and mycorrhizal inoculation on native plant establishment. A summary of this review is included in Appendix F.

6.1 SOIL TESTING DATA

Soil samples were collected from all of the plant establishment test plots and analyzed for attributes relevant to plant growth. Data on soils were analyzed to correlate changes in the characteristics associated with the different treatment types over the duration of the study period. Sampling was conducted three times: in Fall 1998 during setup of the test plots, and twice during the test period (Spring 1999 and Spring 2000).

6.1.1 Chemical Soil Analysis

During each of the three soil sampling events, soil quality was evaluated in order to characterize chemical constituents that could affect plant growth. The data for each test plot were compared to evaluate for changes over time. The chemical constituents also provided another method of comparing the soils in the different test plots. The following chemical parameters were analyzed: pH, sodium adsorption ratio (SAR), electrical conductivity (EC_e), boron (B), nitrogen (N), phosphorus (P), potassium (K), calcium (Ca), magnesium (Mg), chlorine (Cl), zinc (Zn), copper (Cu), iron (Fe), manganese (Mn), sodium (Na), and organic matter (OM). Due to analytical suite groupings, analyses for Ca, Mg, and Na were performed by two methods: atomic absorption (S 1.60), which yields results in milliequivalents per L (me/L), and ammonium acetate (S 5.10), which yields results in parts per million (ppm) (Western States Laboratory, 1998). The means and standard deviations of soil chemistry data for irrigated and non-irrigated plant establishment test plots are shown in Table 6-1A and Table 6-1B, respectively. A comparison of the chemical data for the three soil sampling events indicates that each of the analyzed parameters stayed generally consistent over the course of the study period at each plant establishment test plot, with the exception of nitrogen. Average nitrogen values ranged from 12.00 to 49.67 ppm during Event 1 (Fall 1998). These values dropped over the study period to a range of 0.09 to 4.73 ppm in Event 3 (Spring 2000).

Table 6-1A
SOIL COMPOSITION AND CHEMICAL DATA - IRRIGATED PLANT ESTABLISHMENT TEST PLOTS
ALL SAMPLING EVENTS

				Loss on Ignition	Saturation Paste Extract								Potassium Chloride Extract	Olsen Extract	Ammonium Acetate Extract				DPTA Extract			
				OM	Saturation	pH	ECe	Ca	Mg	Na	Cl	B	N	P	K	Ca	Mg	Na	Zn	Mn	Fe	Cu
Treatment	Monitoring Event	Slope Type	Statistic	%	%		dS m-1	meq L-1	meq L-1	meq L-1	meq L-1	mg L-1	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm
No Treatment (Bare)	Event 1 - Fall 1998	Fill	Mean	3.70	30.67	6.74	0.87	4.00	4.10	0.90	1.97	0.30	28.00	30.00	197.00	2085.33	769.00	202.00	2.46	9.23	15.27	0.76
			Std. Dev.	2.00	4.19	0.30	0.11	0.54	0.93	0.14	0.48	0.00	10.20	24.10	51.41	297.11	127.38	43.83	1.11	0.45	5.73	0.27
		Cut	Mean	3.63	40.67	7.50	0.63	3.57	2.27	0.77	1.30	0.60	17.33	10.33	359.67	4838.33	673.33	95.33	0.76	1.57	1.47	0.51
			Std. Dev.	0.59	2.87	0.11	0.09	0.52	0.60	0.05	0.08	0.14	7.36	9.67	68.37	361.54	153.15	33.09	0.03	0.53	0.39	0.16
	Event 2 - Spring 1999	Fill	Mean	0.70	37.33	6.73	1.07	5.47	3.47	0.93	2.97	0.33	8.33	20.00	200.67	3401.67	778.33	92.67	3.48	7.70	16.13	0.71
			Std. Dev.	0.07	4.11	0.29	0.52	2.68	1.72	0.05	0.26	0.05	3.40	10.61	8.06	399.28	224.68	46.35	1.31	0.93	3.46	0.16
		Cut	Mean	0.95	48.00	7.37	0.47	2.17	1.23	0.60	2.17	0.43	4.00	2.33	252.67	4799.00	641.33	94.00	1.44	2.43	4.53	1.50
			Std. Dev.	0.25	4.90	0.12	0.05	0.49	0.19	0.14	0.26	0.12	1.41	0.94	66.85	976.65	171.08	48.26	0.59	0.34	0.59	0.44
	Event 3 - Spring 2000	Fill	Mean	N/A	31.17	6.98	0.53	3.37	2.00	0.71	0.66	0.08	2.63	11.00	151.18	2364.72	563.07	9.76	2.63	7.43	23.97	0.97
			Std. Dev.	N/A	3.47	0.17	0.05	0.59	0.14	0.06	0.20	0.01	0.58	1.41	22.65	439.36	110.64	10.98	0.63	0.86	5.33	0.05
		Cut	Mean	N/A	42.47	7.78	0.55	3.70	1.57	0.54	1.08	0.06	1.73	4.67	185.06	4408.80	571.17	9.00	1.30	2.33	4.47	1.17
			Std. Dev.	N/A	3.84	0.03	0.10	0.91	0.26	0.03	0.43	0.01	0.53	1.70	44.84	368.79	207.90	9.89	0.64	0.48	0.90	0.19
Bonded Fiber Matrix (BFM)	Event 1 - Fall 1998	Fill	Mean	2.02	33.67	6.73	1.00	4.47	4.87	0.83	2.93	0.23	37.00	17.00	228.67	2113.33	812.00	208.67	2.12	8.67	12.03	0.61
			Std. Dev.	0.50	3.77	0.44	0.12	0.92	0.95	0.19	0.09	0.05	8.64	5.35	21.79	153.23	107.00	15.11	0.40	2.17	2.52	0.09
		Cut	Mean	3.02	39.33	7.47	0.75	3.83	2.80	0.77	1.40	0.60	14.33	17.33	283.33	4866.00	483.67	86.00	0.74	1.30	1.47	0.57
			Std. Dev.	0.17	4.92	0.08	0.18	0.50	0.80	0.21	0.14	0.36	11.47	0.94	93.27	1037.51	227.65	12.83	0.17	0.24	0.21	0.24
	Event 2 - Spring 1999	Fill	Mean	0.85	35.00	6.73	1.00	5.60	3.77	0.90	3.53	0.37	8.67	13.67	207.00	2895.33	636.33	80.00	3.60	9.00	16.93	0.57
			Std. Dev.	0.24	2.94	0.33	0.14	0.85	0.90	0.08	0.48	0.09	5.25	5.73	24.91	378.41	201.66	20.85	0.71	2.59	5.38	0.23
		Cut	Mean	1.58	46.33	7.33	0.57	3.13	1.90	0.70	2.27	0.30	3.33	1.67	175.00	5135.33	559.33	105.67	0.92	2.43	4.10	1.15
			Std. Dev.	1.57	5.31	0.09	0.12	0.82	0.54	0.08	0.29	0.08	0.94	0.47	66.05	337.37	169.80	49.47	0.35	0.58	0.28	0.61
	Event 3 - Spring 2000	Fill	Mean	N/A	33.37	6.95	0.55	3.65	2.30	0.71	0.55	0.08	3.10	13.67	173.33	2197.72	563.07	8.23	3.23	8.40	27.17	1.00
			Std. Dev.	N/A	1.98	0.17	0.09	0.74	0.51	0.04	0.11	0.00	0.91	2.05	9.22	238.43	75.13	8.81	0.47	1.85	2.25	0.08
		Cut	Mean	N/A	36.60	7.81	0.45	2.97	1.33	0.57	0.48	0.06	1.20	2.40	127.72	3994.64	473.95	2.00	0.83	1.97	3.80	0.80
			Std. Dev.	N/A	3.80	0.11	0.06	0.40	0.31	0.07	0.07	0.01	0.79	1.61	17.58	288.25	159.69	0.00	0.12	0.21	0.57	0.14
Coconut ECB (CB)	Event 1 - Fall 1998	Fill	Mean	2.45	34.67	7.06	0.83	4.27	4.57	0.77	2.40	0.43	36.00	10.33	236.00	2443.00	1031.00	181.00	2.53	6.50	13.40	0.63
			Std. Dev.	1.30	2.49	0.26	0.24	1.34	1.32	0.17	0.62	0.21	5.10	1.89	35.86	104.81	66.88	24.04	0.73	0.94	5.10	0.04
		Cut	Mean	4.52	43.33	7.41	0.73	4.43	2.47	0.67	1.40	1.00	27.67	9.33	368.67	5030.00	790.33	95.00	0.85	1.33	1.23	0.46
			Std. Dev.	0.78	1.70	0.11	0.15	0.73	0.52	0.24	0.14	0.08	10.08	8.99	55.48	316.66	91.59	29.22	0.13	0.31	0.21	0.14
	Event 2 - Spring 1999	Fill	Mean	0.84	43.67	6.90	0.83	4.43	3.23	0.70	3.10	0.40	11.67	18.33	237.67	3582.00	840.33	161.33	3.97	6.77	19.13	0.83
			Std. Dev.	0.54	2.49	0.16	0.12	0.62	0.45	0.14	0.00	0.00	8.73	2.87	80.96	523.91	117.46	66.36	0.37	1.07	8.46	0.12
		Cut	Mean	1.93	45.00	7.30	0.63	3.83	1.63	0.77	2.47	1.10	4.33	3.33	272.00	5452.00	629.00	121.33	1.60	2.60	4.10	1.74
			Std. Dev.	1.27	1.63	0.00	0.05	0.12	0.21	0.05	0.84	0.71	2.36	2.05	35.33	68.98	37.97	47.32	0.60	0.43	0.37	0.11
	Event 3 - Spring 2000	Fill	Mean	N/A	37.33	7.11	0.51	3.18	2.20	0.56	0.47	0.06	3.87	16.67	202.01	2545.08	721.05	8.23	3.57	6.53	27.23	0.87
			Std. Dev.	N/A	2.49	0.11	0.04	0.34	0.16	0.04	0.13	0.01	0.94	4.19	56.78	184.40	24.97	8.81	0.74	0.60	6.43	0.05
		Cut	Mean	N/A	39.40	7.82	0.47	3.30	1.33	0.52	0.59	0.08	0.93	3.67	148.57	4362.04	461.80	9.00	1.00	1.90	3.63	0.97
			Std. Dev.	N/A	2.20	0.12	0.04	0.24	0.09	0.07	0.08	0.02	1.18	0.94	11.51	188.23	39.69	9.89	0.29	0.43	0.58	0.17

Table 6-1A (Continued)
SOIL COMPOSITION AND CHEMICAL DATA - IRRIGATED PLANT ESTABLISHMENT TEST PLOTS
ALL SAMPLING EVENTS

				Loss on Ignition	Saturation Paste Extract								Potassium Chloride Extract	Olsen Extract	Ammonium Acetate Extract				DPTA Extract			
				OM	Saturation	pH	ECe	Ca	Mg	Na	Cl	B	N	P	K	Ca	Mg	Na	Zn	Mn	Fe	Cu
Treatment	Monitoring Event	Slope Type	Statistic	%	%		dS m^{-1}	meq L^{-1}	meq L^{-1}	meq L^{-1}	meq L^{-1}	mg L^{-1}	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm
Coir Netting (COIR)	Event 1 - Fall 1998	Fill	Mean	2.17	27.67	6.67	0.84	4.10	3.73	0.83	2.17	0.37	24.00	16.67	187.67	2236.33	756.67	243.33	1.99	7.83	12.70	0.69
			Std. Dev.	1.38	6.02	0.43	0.04	0.37	0.58	0.17	0.21	0.05	8.49	1.70	45.62	528.96	132.63	24.23	0.64	0.99	3.23	0.13
		Cut	Mean	3.73	43.67	7.37	0.61	3.73	2.00	0.57	1.23	0.53	15.33	3.33	277.33	4683.67	587.67	75.67	0.72	1.47	1.17	0.37
			Std. Dev.	1.12	6.60	0.12	0.13	0.54	0.49	0.24	0.34	0.09	4.71	0.47	77.61	652.52	200.84	23.23	0.22	1.01	0.24	0.16
	Event 2 - Spring 1999	Fill	Mean	0.74	34.67	6.77	0.60	4.40	2.53	1.03	2.70	0.23	7.00	17.33	189.67	3289.67	567.33	64.00	2.68	8.10	14.53	0.64
			Std. Dev.	0.48	1.25	0.37	0.22	0.71	0.57	0.26	0.80	0.05	0.82	6.85	9.43	931.91	75.76	40.42	0.55	2.65	6.65	0.22
		Cut	Mean	1.93	42.67	7.37	0.53	2.93	1.20	0.87	2.07	0.47	4.00	5.00	226.67	5061.33	438.33	93.67	1.13	2.07	3.93	1.62
			Std. Dev.	1.54	6.02	0.05	0.09	0.41	0.16	0.09	0.05	0.12	2.16	0.82	70.99	374.86	134.59	18.37	0.30	0.21	0.50	0.34
	Event 3 - Spring 2000	Fill	Mean	N/A	28.97	7.07	0.58	3.98	2.13	0.83	0.75	0.08	3.13	13.00	153.79	2464.92	498.25	9.00	2.47	8.77	21.63	0.93
			Std. Dev.	N/A	3.84	0.21	0.08	0.85	0.26	0.12	0.50	0.01	1.61	1.63	38.49	672.06	69.46	9.89	0.56	2.00	4.07	0.09
		Cut	Mean	N/A	37.47	8.03	0.49	3.57	1.30	0.59	0.67	0.07	1.17	1.40	136.84	4128.24	449.64	16.76	0.83	2.20	3.90	1.00
			Std. Dev.	N/A	4.65	0.11	0.03	0.21	0.24	0.05	0.16	0.01	0.19	0.85	38.84	655.12	131.26	10.48	0.29	0.36	0.45	0.28
Compost (COMP)	Event 1 - Fall 1998	Fill	Mean	2.85	40.00	6.80	0.85	4.40	4.27	0.80	2.07	0.33	32.00	14.33	236.33	2260.00	760.00	196.00	1.87	7.83	12.33	0.61
			Std. Dev.	0.51	9.42	0.41	0.21	1.31	0.50	0.22	0.05	0.09	10.80	2.05	69.81	314.97	65.03	32.44	0.50	2.07	3.09	0.03
		Cut	Mean	3.80	45.33	7.32	0.68	4.07	2.30	0.67	1.17	0.80	34.67	5.67	339.33	5160.33	685.33	56.67	0.98	1.33	1.40	0.47
			Std. Dev.	1.67	3.30	0.17	0.06	0.82	0.24	0.09	0.05	0.22	7.59	3.86	103.62	277.94	61.13	23.80	0.38	1.19	0.08	0.13
	Event 2 - Spring 1999	Fill	Mean	0.77	38.67	6.43	0.93	5.10	3.40	0.80	3.70	0.33	6.67	14.00	228.33	3182.67	610.33	104.67	4.04	11.10	21.50	0.98
			Std. Dev.	1.02	2.87	0.29	0.29	1.93	0.90	0.28	1.16	0.05	1.25	3.56	98.39	876.58	130.79	12.92	2.22	2.65	7.32	0.09
		Cut	Mean	2.05	42.67	7.37	0.43	2.90	1.13	0.60	1.80	0.47	4.67	3.00	183.67	4960.33	555.33	106.00	1.17	1.47	3.70	1.40
			Std. Dev.	1.44	3.30	0.05	0.05	0.22	0.17	0.08	0.29	0.05	3.09	0.00	10.40	316.27	82.24	19.25	0.22	0.17	0.14	0.25
	Event 3 - Spring 2000	Fill	Mean	N/A	32.57	6.84	0.61	3.79	2.33	0.66	1.01	0.07	3.83	14.00	198.10	2384.76	563.07	8.23	3.37	8.70	25.73	0.97
			Std. Dev.	N/A	3.24	0.30	0.12	0.43	0.54	0.13	0.77	0.01	0.31	4.32	69.53	621.56	49.94	8.81	1.16	1.55	6.39	0.05
		Cut	Mean	N/A	39.13	7.95	0.44	3.07	1.30	0.52	0.46	0.06	0.83	2.67	143.36	4355.36	482.05	2.00	6.33	1.90	3.90	1.07
			Std. Dev.	N/A	3.72	0.05	0.02	0.12	0.14	0.09	0.08	0.00	0.52	0.94	33.53	191.05	101.35	0.00	7.83	0.28	0.88	0.33
Curled Wood Fiber (CWFB)	Event 1 - Fall 1998	Fill	Mean	3.30	30.00	7.09	1.36	6.67	5.80	0.83	2.77	0.37	43.67	13.00	214.33	2422.67	723.33	192.33	2.48	6.27	9.43	0.66
			Std. Dev.	0.11	4.55	0.11	0.61	2.95	3.40	0.24	0.54	0.05	16.50	1.63	80.88	195.66	94.33	15.86	0.92	1.28	2.41	0.06
		Cut	Mean	3.58	40.33	7.43	0.77	4.03	2.93	0.87	1.33	0.60	27.33	4.33	329.67	4586.00	733.00	63.67	0.79	1.27	1.27	0.44
			Std. Dev.	0.42	5.44	0.10	0.02	0.42	0.37	0.05	0.17	0.22	11.81	3.40	86.54	348.66	82.90	27.01	0.18	0.78	0.29	0.20
	Event 2 - Spring 1999	Fill	Mean	1.03	37.33	7.03	0.67	4.00	2.27	0.73	3.07	0.43	8.33	9.33	235.33	3371.33	681.67	63.00	3.97	7.07	12.33	0.67
			Std. Dev.	0.54	2.62	0.09	0.05	0.29	0.17	0.12	0.83	0.09	3.30	2.62	76.84	69.26	116.37	10.71	0.16	1.72	1.95	0.22
		Cut	Mean	1.85	45.33	7.33	1.20	6.23	3.40	0.90	2.43	0.40	5.00	10.67	249.67	5784.67	681.33	84.67	1.18	2.53	3.67	1.44
			Std. Dev.	1.60	2.87	0.09	0.99	4.67	2.15	0.43	0.50	0.14	1.41	10.21	43.03	613.19	271.13	37.17	0.20	0.25	0.47	0.54
	Event 3 - Spring 2000	Fill	Mean	N/A	31.57	7.15	0.61	4.10	2.20	0.63	0.39	0.07	3.70	12.67	174.64	2511.68	530.66	2.00	3.27	7.67	23.37	1.00
			Std. Dev.	N/A	1.65	0.10	0.07	0.42	0.28	0.03	0.07	0.00	1.66	1.25	31.98	118.37	46.89	0.00	0.40	1.52	3.74	0.00
		Cut	Mean	N/A	44.10	7.82	0.43	2.65	1.40	0.50	0.52	0.06	1.33	2.40	160.30	4555.76	656.24	9.76	0.93	2.03	4.43	1.00
			Std. Dev.	N/A	7.19	0.09	0.05	0.10	0.22	0.07	0.12	0.01	0.34	1.98	51.08	501.76	123.93	10.98	0.25	0.62	1.36	0.28

Table 6-1A (Continued)
SOIL COMPOSITION AND CHEMICAL DATA - IRRIGATED PLANT ESTABLISHMENT TEST PLOTS
ALL SAMPLING EVENTS

				Loss on Ignition	Saturation Paste Extract								Potassium Chloride Extract	Olsen Extract	Ammonium Acetate Extract				DPTA Extract			
				OM	Saturation	pH	ECe	Ca	Mg	Na	Cl	B	N	P	K	Ca	Mg	Na	Zn	Mn	Fe	Cu
Treatment	Monitoring Event	Slope Type	Statistic	%	%		$dS\ m^{-1}$	$meq\ L^{-1}$	$meq\ L^{-1}$	$meq\ L^{-1}$	$meq\ L^{-1}$	$mg\ L^{-1}$	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm
Gypsum, Rate 1 (GYP1)	Event 1 - Fall 1998	Fill	Mean	2.73	33.33	6.91	1.07	5.63	5.77	0.83	2.83	0.63	42.33	15.00	231.00	2401.67	1021.67	178.00	2.73	6.80	14.27	0.59
			Std. Dev.	1.55	3.40	0.42	0.07	1.17	0.54	0.12	0.09	0.12	5.73	0.00	18.55	80.34	89.63	35.14	0.86	1.49	6.83	0.08
		Cut	Mean	3.97	43.33	7.35	0.74	4.20	2.30	0.73	1.57	1.07	33.33	16.67	432.67	5177.33	708.67	110.67	1.14	1.70	1.40	0.48
			Std. Dev.	0.50	4.71	0.11	0.21	1.23	0.43	0.21	0.76	0.21	12.39	4.03	133.22	296.07	70.53	62.02	0.43	1.36	0.29	0.13
	Event 2 - Spring 1999	Fill	Mean	0.62	38.00	6.93	2.97	18.83	11.67	1.27	3.73	0.40	7.00	22.00	231.67	3472.33	893.67	132.33	3.82	7.43	16.00	0.69
			Std. Dev.	0.41	0.00	0.09	0.69	6.67	2.78	0.17	0.48	0.00	3.74	7.79	25.77	27.19	80.89	31.35	0.38	1.62	4.57	0.20
		Cut	Mean	1.72	43.67	7.37	1.07	6.40	2.83	1.00	2.10	0.47	3.33	2.33	238.67	5897.33	602.67	142.00	1.20	1.97	3.60	1.49
			Std. Dev.	1.69	3.30	0.09	0.37	2.36	0.86	0.08	0.22	0.05	1.25	1.25	51.07	613.19	206.65	17.57	0.20	0.17	0.41	0.35
	Event 3 - Spring 2000	Fill	Mean	N/A	33.67	7.15	0.62	4.05	2.47	0.55	0.47	0.07	3.23	14.00	165.51	2558.44	644.08	8.23	2.80	5.37	21.53	0.83
			Std. Dev.	N/A	2.81	0.14	0.04	0.37	0.21	0.04	0.05	0.00	0.90	1.63	29.66	68.12	17.19	8.81	0.22	0.25	4.96	0.05
		Cut	Mean	N/A	40.60	7.85	0.81	6.07	2.50	0.61	0.82	0.08	0.09	3.00	156.39	4342.00	510.41	9.00	1.03	2.00	4.20	1.03
			Std. Dev.	N/A	6.25	0.13	0.12	1.30	0.36	0.08	0.13	0.01	0.00	1.41	50.68	442.19	157.51	9.89	0.37	0.14	1.39	0.42
Gypsum, Rate 2 (GYP2)	Event 1 - Fall 1998	Fill	Mean	3.63	35.67	6.81	1.08	5.37	5.03	0.90	2.73	0.37	40.67	16.33	278.33	2486.67	837.00	180.33	3.73	8.10	12.50	0.64
			Std. Dev.	0.74	2.87	0.27	0.20	1.11	1.11	0.24	0.26	0.05	4.11	5.56	37.99	99.03	199.13	11.15	1.79	3.40	4.74	0.13
		Cut	Mean	2.80	44.00	7.50	0.93	4.43	3.10	1.27	1.97	0.63	27.67	19.67	349.33	4743.00	660.33	90.33	0.95	2.00	1.17	0.41
			Std. Dev.	0.88	0.82	0.04	0.19	0.92	0.50	0.41	0.52	0.12	6.94	19.40	99.17	499.82	165.39	7.93	0.15	1.00	0.21	0.17
	Event 2 - Spring 1999	Fill	Mean	0.80	40.00	6.87	3.30	23.47	11.47	1.10	3.67	0.30	8.67	11.67	204.67	3656.67	630.67	89.33	3.71	7.07	11.80	0.73
			Std. Dev.	0.14	0.00	0.21	0.36	5.29	2.21	0.08	1.03	0.08	3.77	0.94	9.81	593.74	139.83	30.92	0.22	1.19	1.96	0.20
		Cut	Mean	1.72	44.67	7.27	1.83	11.03	5.20	0.87	1.97	0.33	5.33	5.00	193.33	5495.67	697.67	106.33	0.86	2.23	3.63	1.15
			Std. Dev.	1.59	7.41	0.05	0.95	6.05	2.67	0.12	0.26	0.12	0.94	1.41	4.50	807.34	215.94	59.14	0.16	0.48	0.37	0.07
	Event 3 - Spring 2000	Fill	Mean	N/A	33.33	7.06	1.33	11.10	4.73	0.76	0.72	0.09	4.73	17.67	175.94	2919.16	502.30	11.30	3.50	6.93	22.53	0.90
			Std. Dev.	N/A	0.46	0.20	0.41	4.21	1.96	0.19	0.27	0.03	1.06	3.30	16.59	233.90	124.06	13.15	0.29	0.69	2.95	0.08
		Cut	Mean	N/A	40.90	7.73	1.07	9.07	3.63	0.55	0.39	0.06	0.46	2.40	122.51	4301.92	571.17	9.76	0.87	1.90	4.13	0.93
			Std. Dev.	N/A	6.77	0.12	0.41	4.17	1.31	0.08	0.08	0.01	0.52	1.98	32.76	573.94	268.46	10.98	0.31	0.57	1.22	0.25
Paper Mulch and Psyllium Tackifier (PMG)	Event 1 - Fall 1998	Fill	Mean	3.68	32.33	7.10	1.07	5.57	4.40	0.80	2.53	0.30	31.00	12.67	193.00	2672.00	778.33	175.33	1.86	5.57	8.83	0.66
			Std. Dev.	0.56	4.50	0.09	0.08	0.90	0.67	0.08	0.52	0.08	10.80	2.49	2.16	418.29	150.94	20.53	0.37	0.17	2.36	0.04
		Cut	Mean	3.18	41.00	7.14	0.76	4.37	2.43	0.67	1.70	0.70	26.67	7.67	453.67	4785.67	617.33	65.33	1.27	2.20	1.40	0.56
			Std. Dev.	1.54	5.72	0.27	0.10	0.39	0.45	0.05	0.29	0.08	4.99	0.94	74.85	301.69	79.44	17.99	0.30	1.19	0.29	0.14
	Event 2 - Spring 1999	Fill	Mean	1.28	37.67	7.13	0.77	4.50	2.50	0.77	3.43	0.30	6.00	10.67	185.33	3300.33	773.33	60.00	3.29	5.73	12.40	0.93
			Std. Dev.	0.86	2.05	0.12	0.09	0.36	0.79	0.09	0.21	0.00	1.63	5.91	28.29	219.00	220.28	38.50	0.70	1.23	2.89	0.10
		Cut	Mean	2.16	45.67	7.33	0.53	3.23	1.30	0.70	2.53	0.40	5.00	3.00	234.33	5518.67	625.00	122.33	1.18	1.93	3.83	1.81
			Std. Dev.	1.41	0.94	0.05	0.12	0.77	0.43	0.14	0.48	0.16	0.82	1.41	38.06	226.72	162.77	13.82	0.34	0.31	0.68	0.42
	Event 3 - Spring 2000	Fill	Mean	N/A	31.37	7.15	0.59	4.10	2.03	0.69	0.70	0.07	3.20	13.00	166.82	2571.80	538.76	15.23	3.07	6.13	22.73	1.00
			Std. Dev.	N/A	0.42	0.16	0.04	0.62	0.38	0.11	0.20	0.00	1.88	4.24	32.76	223.36	101.35	9.40	0.60	0.29	6.29	0.08
		Cut	Mean	N/A	41.17	7.97	0.45	3.23	1.30	0.49	0.72	0.06	1.67	2.40	156.39	4502.32	510.41	2.00	1.07	1.80	3.57	1.07
			Std. Dev.	N/A	3.18	0.11	0.00	0.09	0.14	0.09	0.19	0.00	0.60	1.98	33.33	260.95	103.59	0.00	0.25	0.28	0.50	0.26

Table 6-1A (Continued)
SOIL COMPOSITION AND CHEMICAL DATA - IRRIGATED PLANT ESTABLISHMENT TEST PLOTS
ALL SAMPLING EVENTS

				Loss on Ignition	Saturation Paste Extract								Potassium Chloride Extract	Olsen Extract	Ammonium Acetate Extract				DPTA Extract			
				OM	Saturation	pH	ECe	Ca	Mg	Na	Cl	B	N	P	K	Ca	Mg	Na	Zn	Mn	Fe	Cu
Treatment	Monitoring Event	Slope Type	Statistic	%	%		dS m-1	meq L-1	meq L-1	meq L-1	meq L-1	mg L-1	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm
Paper Mulch and Polymer Tackifier (PMP)	Event 1 - Fall 1998	Fill	Mean	2.85	33.67	6.73	0.94	4.60	4.47	0.77	2.80	0.23	28.00	14.00	256.33	2236.67	777.00	232.67	2.86	8.93	12.90	0.56
			Std. Dev.	0.67	1.70	0.37	0.15	1.20	0.86	0.05	0.51	0.09	9.27	1.63	43.21	147.95	95.76	52.55	0.90	0.77	1.99	0.06
		Cut	Mean	3.10	42.67	7.06	0.85	5.00	3.47	0.60	1.60	0.67	28.67	13.67	292.67	5080.00	687.67	119.67	0.79	1.17	0.93	0.37
			Std. Dev.	0.76	5.91	0.26	0.30	1.57	1.25	0.14	0.36	0.24	10.62	8.38	68.52	140.86	132.50	55.65	0.21	0.88	0.33	0.12
	Event 2 - Spring 1999	Fill	Mean	2.09	39.33	6.67	0.77	4.50	2.90	0.87	2.90	0.37	6.67	19.33	216.00	3010.33	614.00	63.67	4.24	9.13	17.50	0.87
			Std. Dev.	2.19	2.87	0.12	0.09	0.82	0.50	0.09	0.45	0.12	1.70	7.54	37.48	345.49	78.11	54.26	1.40	0.77	1.06	0.29
		Cut	Mean	2.77	41.33	7.30	0.50	2.80	1.63	0.70	1.83	0.50	3.67	3.67	175.67	4877.00	533.33	169.67	0.92	1.77	3.70	1.23
			Std. Dev.	1.66	7.13	0.00	0.22	1.49	0.71	0.08	0.61	0.00	1.25	2.05	67.49	591.23	76.40	73.11	0.34	0.29	0.36	0.36
	Event 3 - Spring 2000	Fill	Mean	N/A	31.53	7.07	0.59	3.83	2.23	0.64	0.58	0.08	3.47	13.67	192.88	2378.08	554.96	2.00	3.17	7.53	21.97	0.93
			Std. Dev.	N/A	1.80	0.15	0.07	0.21	0.38	0.10	0.12	0.02	0.83	0.47	12.90	389.39	56.42	0.00	0.70	0.42	4.13	0.05
		Cut	Mean	N/A	40.50	7.84	0.40	2.53	1.27	0.40	0.41	0.05	0.70	1.40	129.02	4154.96	546.86	15.23	0.67	1.80	3.77	1.00
			Std. Dev.	N/A	3.45	0.13	0.03	0.21	0.17	0.02	0.10	0.00	0.43	0.85	25.34	423.64	85.93	9.40	0.09	0.08	0.38	0.33
Wheat Straw	Event 1 - Fall 1998	Fill	Mean	3.45	29.00	7.11	0.94	4.53	4.30	0.83	2.93	0.27	31.33	8.67	200.00	2311.00	753.00	212.00	2.06	8.23	12.77	0.62
			Std. Dev.	0.43	1.63	0.19	0.05	0.46	0.43	0.12	0.71	0.09	11.56	2.05	68.06	395.05	175.18	26.19	0.86	2.25	4.57	0.05
		Cut	Mean	3.55	41.33	7.48	0.63	3.60	2.00	0.77	1.33	0.57	24.67	5.00	348.33	4565.33	629.33	57.67	0.93	1.37	1.23	0.46
			Std. Dev.	1.28	2.49	0.11	0.22	0.92	0.57	0.21	0.34	0.21	11.44	4.24	95.58	254.86	139.87	28.39	0.38	1.08	0.33	0.20
	Event 2 - Spring 1999	Fill	Mean	1.33	37.00	6.80	0.77	4.60	2.73	0.90	2.53	0.33	5.67	15.00	204.67	3592.00	785.67	91.00	3.00	8.63	16.43	1.02
			Std. Dev.	0.87	1.41	0.29	0.09	0.73	0.87	0.00	0.34	0.12	0.47	8.64	15.28	673.50	218.32	39.90	0.58	1.47	5.85	0.08
		Cut	Mean	2.08	47.67	7.37	0.60	3.50	1.43	0.73	2.20	0.53	2.33	2.33	253.33	5647.00	661.00	82.00	1.13	2.13	3.87	1.78
			Std. Dev.	1.34	3.68	0.05	0.08	0.88	0.40	0.12	0.54	0.09	0.47	1.25	33.77	292.41	190.13	36.12	0.21	0.58	0.41	0.55
	Event 3 - Spring 2000	Fill	Mean	N/A	40.43	7.93	0.39	2.60	0.93	0.51	0.60	0.06	0.56	2.07	151.18	4522.36	506.35	16.76	0.97	1.87	3.87	1.07
			Std. Dev.	N/A	5.12	0.14	0.09	0.57	0.21	0.11	0.08	0.02	0.66	1.55	41.66	437.32	144.59	10.48	0.17	0.34	0.17	0.26
		Cut	Mean	N/A	31.00	7.13	0.54	3.47	1.97	0.66	0.46	0.07	3.30	14.33	175.94	2879.08	542.81	15.23	2.87	7.27	21.30	0.83
			Std. Dev.	N/A	1.24	0.22	0.05	0.37	0.39	0.05	0.12	0.01	0.36	4.03	38.31	1083.19	63.79	9.40	0.68	0.73	6.48	0.05
Straw ECB (SB)	Event 1 - Fall 1998	Fill	Mean	4.00	31.00	6.73	1.08	5.63	5.13	0.73	2.77	0.27	34.00	10.00	260.33	2650.33	848.33	181.67	2.62	7.43	11.13	0.66
			Std. Dev.	1.22	2.83	0.29	0.09	0.19	0.82	0.05	0.12	0.09	5.72	3.74	56.36	152.51	128.92	46.78	0.71	2.17	2.36	0.01
		Cut	Mean	3.02	45.00	7.48	0.76	4.17	2.93	0.73	1.73	0.70	24.00	9.67	347.67	4924.33	711.00	95.67	0.92	1.33	1.40	0.43
			Std. Dev.	0.80	3.27	0.05	0.23	1.10	0.87	0.09	0.48	0.16	10.03	4.99	95.00	440.20	138.83	23.58	0.21	0.83	0.14	0.15
	Event 2 - Spring 1999	Fill	Mean	0.91	36.33	6.97	0.93	4.67	3.33	0.87	3.40	0.30	7.00	13.33	195.67	3304.67	651.00	79.00	3.75	8.07	15.80	1.07
			Std. Dev.	1.04	0.47	0.17	0.29	1.37	1.13	0.05	0.96	0.00	0.82	1.70	14.52	308.80	178.53	10.03	0.37	1.46	2.94	0.17
		Cut	Mean	2.17	44.33	7.37	1.07	6.53	3.63	0.63	2.20	0.57	5.33	3.00	262.67	5665.00	752.67	122.33	1.36	2.57	3.73	1.46
			Std. Dev.	1.34	1.70	0.09	0.87	5.36	3.02	0.21	0.45	0.12	0.94	1.63	44.00	392.80	96.13	73.97	0.30	0.41	0.29	0.40
	Event 3 - Spring 2000	Fill	Mean	N/A	33.33	7.05	0.57	3.81	2.23	0.60	0.41	0.07	3.97	15.67	194.19	2705.40	640.03	9.00	3.77	8.03	23.60	1.00
			Std. Dev.	N/A	3.09	0.16	0.01	0.36	0.17	0.04	0.03	0.00	0.33	0.94	15.09	221.35	92.20	9.89	0.21	1.73	2.20	0.08
		Cut	Mean	N/A	43.17	7.67	0.45	3.00	1.33	0.42	0.61	0.05	1.20	2.33	173.33	4569.12	571.17	2.00	1.10	2.13	4.33	1.07
			Std. Dev.	N/A	2.74	0.06	0.06	0.33	0.26	0.04	0.13	0.00	0.16	0.47	8.03	86.58	69.46	0.00	0.14	0.31	0.56	0.05

Table 6-1A (Continued)
SOIL COMPOSITION AND CHEMICAL DATA - IRRIGATED PLANT ESTABLISHMENT TEST PLOTS
ALL SAMPLING EVENTS

Treatment	Monitoring Event	Slope Type	Statistic	Loss on Ignition	Saturation Paste Extract								Potassium Chloride Extract	Olsen Extract	Ammonium Acetate Extract				DPTA Extract			
				OM	Saturation	pH	ECe	Ca	Mg	Na	Cl	B	N	P	K	Ca	Mg	Na	Zn	Mn	Fe	Cu
				%	%		dS m^{-1}	meq L^{-1}	meq L^{-1}	meq L^{-1}	meq L^{-1}	mg L^{-1}	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm
Straw/Coconut ECB (SCB)	Event 1 - Fall 1998	Fill	Mean	3.53	32.00	7.05	1.03	4.90	4.70	1.27	2.53	0.27	31.67	10.33	226.00	2530.67	896.33	194.00	2.60	7.70	12.13	0.66
			Std. Dev.	2.21	3.27	0.06	0.19	0.94	0.14	1.08	0.53	0.05	11.56	2.49	55.23	169.80	119.15	41.21	0.89	1.21	2.58	0.02
		Cut	Mean	3.28	44.00	7.36	0.79	4.50	2.70	0.60	1.30	0.93	39.67	8.67	353.33	5058.00	687.33	86.67	1.05	1.27	1.37	0.51
			Std. Dev.	1.04	1.41	0.11	0.09	0.45	0.16	0.22	0.29	0.12	8.65	4.78	90.58	313.10	76.53	11.56	0.35	1.01	0.19	0.16
	Event 2 - Spring 1999	Fill	Mean	1.14	37.00	6.87	0.90	5.10	3.40	0.73	3.00	0.40	6.67	16.67	259.67	3118.00	593.00	157.00	4.59	6.83	13.80	1.00
			Std. Dev.	0.91	1.41	0.19	0.22	1.59	0.96	0.12	0.91	0.08	1.25	2.87	93.04	125.86	222.23	69.78	1.64	1.84	3.76	0.07
		Cut	Mean	2.09	45.67	7.33	0.50	3.23	1.23	0.70	2.03	0.57	5.67	6.67	258.00	5507.33	642.67	124.33	1.48	2.33	4.23	1.75
			Std. Dev.	1.47	1.89	0.05	0.00	0.34	0.05	0.08	0.39	0.09	2.62	1.89	38.74	195.86	17.59	30.40	0.28	0.21	0.50	0.14
	Event 3 - Spring 2000	Fill	Mean	N/A	34.27	7.12	0.57	3.79	2.27	0.56	0.42	0.07	3.50	16.67	226.77	3032.72	652.18	2.00	3.93	7.27	24.50	0.93
			Std. Dev.	N/A	2.09	0.14	0.08	0.49	0.37	0.07	0.12	0.01	0.90	4.64	53.70	918.69	46.89	0.00	1.28	0.76	5.73	0.12
		Cut	Mean	N/A	40.53	7.93	0.43	2.93	1.23	0.37	0.69	0.06	0.80	0.80	145.97	4522.36	514.46	2.00	1.10	1.97	3.93	1.07
			Std. Dev.	N/A	2.13	0.12	0.01	0.05	0.12	0.05	0.08	0.00	0.54	0.85	3.69	105.20	71.78	0.00	0.14	0.17	0.48	0.19
Wood Fiber ECB (WFB)	Event 1 - Fall 1998	Fill	Mean	5.07	32.00	6.89	1.06	5.60	4.73	0.80	2.70	0.30	33.67	21.67	229.33	2577.67	831.67	216.67	3.06	7.00	13.83	0.71
			Std. Dev.	0.75	3.74	0.32	0.35	2.62	0.58	0.14	0.29	0.00	6.18	6.60	15.08	305.30	153.27	35.41	1.18	2.41	5.62	0.07
		Cut	Mean	3.30	44.00	7.37	0.75	4.37	2.43	0.73	1.43	0.80	27.33	4.33	351.00	4421.33	655.00	88.33	1.03	1.50	1.40	0.50
			Std. Dev.	0.78	4.32	0.11	0.17	0.90	0.39	0.09	0.31	0.29	10.87	2.87	76.21	973.75	75.11	41.91	0.33	1.00	0.16	0.20
	Event 2 - Spring 1999	Fill	Mean	0.72	39.33	6.80	1.87	10.63	6.27	1.03	4.03	0.37	11.33	14.00	200.00	3326.33	651.00	75.67	4.28	9.23	17.97	1.17
			Std. Dev.	0.28	0.47	0.37	0.78	4.52	2.86	0.09	0.40	0.05	5.56	6.53	25.35	199.38	178.94	33.49	0.50	1.14	3.63	0.33
		Cut	Mean	2.03	45.00	7.37	0.50	3.10	1.30	0.63	1.73	0.53	4.33	1.67	249.00	5581.67	651.67	114.33	1.33	2.23	3.73	1.70
			Std. Dev.	1.50	4.32	0.05	0.08	0.29	0.29	0.05	0.21	0.09	1.25	0.47	21.21	177.36	102.42	40.75	0.18	0.29	0.05	0.30
	Event 3 - Spring 2000	Fill	Mean	N/A	35.30	7.02	0.61	4.10	2.30	0.66	0.62	0.07	3.17	16.00	181.15	2625.24	595.47	8.23	3.50	7.17	26.00	1.03
			Std. Dev.	N/A	4.25	0.16	0.02	0.79	0.36	0.09	0.11	0.01	1.39	2.94	16.38	393.04	111.82	8.81	0.57	1.16	9.05	0.05
		Cut	Mean	N/A	41.33	7.75	0.67	5.10	1.97	0.61	0.66	0.07	1.16	2.73	178.55	4549.08	498.25	9.00	1.20	2.20	4.37	1.27
			Std. Dev.	N/A	3.06	0.05	0.20	1.61	0.63	0.23	0.02	0.01	0.76	1.97	32.61	231.98	61.97	9.89	0.28	0.59	1.43	0.41
Wood Mulch and Psyllium Tackifier (WMG)	Event 1 - Fall 1998	Fill	Mean	3.42	32.33	6.71	1.20	5.43	5.87	0.80	2.87	0.20	49.67	21.33	233.33	2410.00	895.00	210.67	2.41	7.77	13.33	0.67
			Std. Dev.	0.39	0.94	0.36	0.28	1.13	1.45	0.08	0.26	0.00	26.61	7.76	29.80	210.35	159.89	43.39	0.76	1.39	2.56	0.06
		Cut	Mean	2.57	42.00	7.29	0.69	3.97	2.67	0.70	1.33	0.77	29.00	9.67	395.67	4996.67	826.67	68.67	1.02	2.13	1.43	0.48
			Std. Dev.	0.77	2.16	0.09	0.07	0.33	0.50	0.28	0.31	0.31	7.12	5.19	20.55	80.11	61.41	27.76	0.12	0.82	0.25	0.14
	Event 2 - Spring 1999	Fill	Mean	0.81	37.00	7.00	1.23	7.17	4.27	0.93	4.03	0.30	6.33	13.33	230.67	3165.67	628.67	111.67	3.31	7.30	13.73	0.93
			Std. Dev.	0.95	2.16	0.08	0.29	1.27	1.23	0.17	0.40	0.14	1.70	3.09	37.70	462.46	91.86	24.14	0.76	1.27	2.85	0.19
		Cut	Mean	2.55	46.00	7.33	0.57	3.30	1.43	0.77	2.03	0.53	4.00	5.33	201.00	5345.00	708.00	141.33	1.06	2.37	3.67	1.64
			Std. Dev.	1.45	3.74	0.09	0.09	0.28	0.26	0.12	0.76	0.09	2.16	2.87	20.07	524.40	169.67	37.35	0.02	0.31	0.12	0.38
	Event 3 - Spring 2000	Fill	Mean	N/A	32.87	7.08	0.59	4.01	2.37	0.71	0.79	0.07	2.67	12.67	166.82	2565.12	599.52	9.76	3.50	8.60	24.57	1.00
			Std. Dev.	N/A	4.35	0.10	0.02	0.13	0.26	0.09	0.09	0.01	0.45	1.25	12.09	315.59	110.64	10.98	0.78	0.37	5.00	0.00
		Cut	Mean	N/A	41.60	7.80	0.50	3.43	1.53	0.55	0.76	0.06	0.76	3.00	147.27	4515.68	575.22	17.53	1.00	2.40	3.93	1.03
			Std. Dev.	N/A	1.24	0.19	0.03	0.33	0.05	0.06	0.22	0.00	0.48	1.41	6.65	217.90	45.83	10.98	0.08	0.22	0.54	0.26

Table 6-1A (Continued)
SOIL COMPOSITION AND CHEMICAL DATA - IRRIGATED PLANT ESTABLISHMENT TEST PLOTS
ALL SAMPLING EVENTS

Treatment	Monitoring Event	Slope Type	Statistic	Loss on Ignition	Saturation Paste Extract								Potassium Chloride Extract	Olsen Extract	Ammonium Acetate Extract				DPTA Extract			
				OM	Saturation	pH	ECe	Ca	Mg	Na	Cl	B	N	P	K	Ca	Mg	Na	Zn	Mn	Fe	Cu
				%	%		dS m^{-1}	meq L^{-1}	meq L^{-1}	meq L^{-1}	meq L^{-1}	mg L^{-1}	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm
Wood Mulch and Polymer Tackifier (WMP)	Event 1 - Fall 1998	Fill	Mean	3.17	29.33	7.14	0.98	5.20	3.70	0.77	2.70	0.23	32.67	10.67	201.00	2775.67	626.67	220.33	1.81	6.87	9.40	0.68
			Std. Dev.	0.44	0.94	0.19	0.04	0.36	0.28	0.09	0.37	0.05	7.76	6.02	27.58	451.71	39.75	28.58	0.09	3.11	2.57	0.08
		Cut	Mean	3.92	43.67	7.52	0.75	4.60	2.43	0.80	1.63	0.93	32.33	8.67	424.67	4984.67	639.00	75.67	1.35	1.97	1.40	0.52
			Std. Dev.	0.65	1.25	0.03	0.10	0.08	0.12	0.14	0.34	0.19	9.43	2.87	122.49	622.99	109.86	32.19	0.56	1.37	0.22	0.16
	Event 2 - Spring 1999	Fill	Mean	2.35	34.67	6.97	0.73	5.23	2.30	0.83	2.77	0.33	7.33	20.33	160.67	2971.67	491.33	168.67	3.53	6.63	13.50	0.90
			Std. Dev.	2.67	1.25	0.09	0.17	1.15	0.36	0.19	0.86	0.09	1.25	13.22	73.41	749.09	311.40	80.17	0.95	1.25	2.22	0.11
		Cut	Mean	0.81	43.33	7.37	0.63	4.60	1.80	0.73	1.73	0.37	4.00	3.00	257.67	5611.00	544.33	116.67	1.35	2.03	3.83	1.35
			Std. Dev.	0.11	4.50	0.05	0.12	1.70	0.79	0.05	0.62	0.05	1.41	1.63	33.59	681.19	120.50	32.50	0.35	0.45	0.31	0.74
	Event 3 - Spring 2000	Fill	Mean	N/A	32.27	7.16	0.54	3.78	1.63	0.57	0.57	0.07	2.87	11.67	145.97	2758.84	453.69	2.00	2.73	7.33	17.60	0.97
			Std. Dev.	N/A	0.59	0.20	0.10	0.69	0.21	0.09	0.14	0.01	0.48	1.25	15.09	433.63	5.73	0.00	0.21	1.70	2.65	0.05
		Cut	Mean	N/A	39.83	7.96	0.42	3.03	1.13	0.50	0.61	0.06	1.57	2.73	160.30	4522.36	457.74	8.23	1.27	2.13	3.90	1.13
			Std. Dev.	N/A	4.65	0.18	0.02	0.17	0.09	0.04	0.01	0.01	0.40	2.42	31.44	288.25	83.21	8.81	0.60	0.73	1.07	0.24

Table 6-1B
SOIL COMPOSITION AND CHEMICAL DATA - NON-IRRIGATED PLANT ESTABLISHMENT TEST PLOTS
All SAMPLING EVENTS

Treatment	Monitoring Event	Slope Type	Statistic	Loss on Ignition	Saturation Paste Extract								Potassium Chloride Extract	Olsen Extract	Ammonium Acetate Extract				DPTA Extract			
				OM	Saturation	pH	ECe	Ca	Mg	Na	Cl	B	N	P	K	Ca	Mg	Na	Zn	Mn	Fe	Cu
				%	%		dS m-1	meq L-1	meq L-1	meq L-1	meq L-1	mg L-1	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm
No Treatment (Bare)	Event 1 - Fall 1998	Fill	Mean	5.62	30.67	7.16	0.83	4.30	3.77	0.67	1.50	0.20	29.00	10.67	181.00	2634.67	831.33	183.67	1.40	4.80	6.67	0.83
			Std. Dev.	2.18	0.47	0.25	0.11	0.67	0.61	0.12	0.00	0.08	1.63	1.25	34.84	167.38	39.37	9.10	0.05	1.36	1.49	0.13
		Cut	Mean	1.82	41.33	7.39	0.90	5.53	2.23	0.93	1.20	0.77	12.00	16.33	314.00	5094.67	428.00	92.67	0.63	1.23	2.13	0.73
			Std. Dev.	0.98	4.50	0.15	0.50	4.36	0.83	0.12	0.24	0.12	3.74	9.10	55.72	606.64	142.84	58.52	0.19	0.34	0.71	0.11
	Event 2 - Spring 1999	Fill	Mean	1.86	36.00	7.07	0.43	3.53	1.73	0.20	1.63	0.30	6.33	12.33	140.67	3721.67	841.67	61.33	20.41	4.90	7.07	1.86
			Std. Dev.	0.43	1.63	0.12	0.05	0.26	0.05	0.08	0.26	0.28	1.25	0.47	10.66	230.11	53.08	31.58	25.63	1.59	2.86	0.38
		Cut	Mean	2.06	48.33	7.33	0.83	9.03	1.63	0.70	1.43	0.20	8.00	9.00	318.00	7033.33	503.67	76.00	1.25	3.03	6.13	2.18
			Std. Dev.	1.03	3.30	0.09	0.50	3.25	0.33	0.08	0.05	0.00	2.45	7.87	29.70	367.12	169.20	19.82	0.13	0.50	1.69	0.37
	Event 3 - Spring 2000	Fill	Mean	N/A	31.87	7.22	0.43	3.60	1.80	0.48	0.74	0.06	1.90	10.00	148.57	2839.00	615.73	2.00	2.47	6.87	17.77	1.23
			Std. Dev.	N/A	2.64	0.21	0.12	0.86	0.36	0.02	0.05	0.01	1.32	0.82	16.89	376.81	31.90	0.00	0.34	0.74	1.59	0.05
		Cut	Mean	N/A	47.23	7.33	1.78	22.20	3.80	0.70	0.55	0.05	1.30	6.00	196.79	5631.24	384.83	2.00	1.13	2.07	7.30	1.87
			Std. Dev.	N/A	1.84	0.06	0.80	12.35	1.80	0.14	0.04	0.04	0.29	0.00	3.69	570.58	107.02	0.00	0.26	0.49	0.99	0.24
Bonded Fiber Matrix (BFM)	Event 1 - Fall 1998	Fill	Mean	5.08	37.67	6.56	0.68	3.77	2.93	0.73	1.47	0.30	23.00	13.67	267.67	3677.33	1172.00	196.00	2.08	10.70	14.13	1.26
			Std. Dev.	1.18	12.55	0.82	0.20	1.45	0.85	0.26	0.25	0.08	5.10	6.24	75.15	1157.99	265.59	67.53	0.85	7.78	9.23	0.38
		Cut	Mean	2.20	40.00	7.36	1.51	12.07	3.60	0.83	1.20	0.33	20.00	8.00	403.00	5319.33	375.67	103.33	0.96	1.77	2.13	0.73
			Std. Dev.	1.17	9.20	0.07	0.51	5.70	1.77	0.12	0.24	0.12	2.94	6.38	28.60	563.31	73.91	33.01	0.10	0.12	0.82	0.06
	Event 2 - Spring 1999	Fill	Mean	1.82	43.33	6.20	0.63	3.70	1.67	0.27	2.47	0.27	7.00	15.33	213.33	4570.33	953.33	68.33	2.02	11.83	22.20	2.82
			Std. Dev.	0.57	10.34	0.92	0.21	0.92	0.40	0.17	1.21	0.17	0.82	4.50	17.44	2309.82	276.28	24.36	0.32	6.39	13.45	0.32
		Cut	Mean	2.45	45.33	7.33	1.10	8.27	1.60	1.17	1.73	0.27	8.67	6.67	304.33	6922.33	409.33	57.00	1.37	2.97	5.37	2.02
			Std. Dev.	0.21	2.05	0.05	0.51	4.84	0.22	0.52	0.31	0.12	4.11	3.86	48.58	144.54	171.50	18.55	0.14	0.39	1.24	0.28
	Event 3 - Spring 2000	Fill	Mean	N/A	37.10	6.81	0.56	4.23	2.03	0.63	1.69	0.06	2.53	12.67	190.28	3740.80	717.00	19.82	2.27	12.60	28.60	1.83
			Std. Dev.	N/A	5.35	0.65	0.18	1.10	0.54	0.13	0.98	0.01	1.28	6.24	28.97	1244.45	154.04	12.64	0.24	6.60	11.60	0.54
		Cut	Mean	N/A	47.87	7.35	1.63	21.73	3.47	0.63	0.40	0.08	0.76	6.33	191.58	5524.36	307.86	2.00	1.67	2.67	7.80	1.77
			Std. Dev.	N/A	2.04	0.09	0.78	11.96	2.20	0.11	0.04	0.01	0.48	0.47	17.77	529.03	90.03	0.00	0.68	0.49	1.06	0.09

Table 6-1B (Continued)
SOIL COMPOSITION AND CHEMICAL DATA - NON-IRRIGATED PLANT ESTABLISHMENT TEST PLOTS
All SAMPLING EVENTS

				Loss on Ignition	Saturation Paste Extract								Potassium Chloride Extract	Olsen Extract	Ammonium Acetate Extract				DPTA Extract			
				OM	Saturation	pH	ECe	Ca	Mg	Na	Cl	B	N	P	K	Ca	Mg	Na	Zn	Mn	Fe	Cu
Treatment	Monitoring Event	Slope Type	Statistic	%	%		dS m-1	meq L-1	meq L-1	meq L-1	meq L-1	mg L-1	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm
Coconut ECB (CB)	Event 1 - Fall 1998	Fill	Mean	3.47	37.67	7.29	1.05	5.57	4.40	0.70	1.47	0.27	42.67	8.33	165.33	4050.67	1008.67	159.33	1.37	3.57	4.73	0.84
			Std. Dev.	2.15	5.73	0.35	0.29	1.45	0.85	0.08	0.05	0.05	12.92	3.30	21.30	1203.72	272.06	29.78	0.49	2.50	3.04	0.10
		Cut	Mean	4.15	39.00	7.44	1.13	7.17	2.37	0.77	1.63	0.57	15.33	10.33	369.67	5419.00	391.67	91.00	1.02	2.23	2.57	0.86
			Std. Dev.	0.54	6.38	0.13	0.35	2.53	0.33	0.29	0.37	0.05	2.87	0.94	72.61	363.74	164.65	15.58	0.10	0.45	0.79	0.10
	Event 2 - Spring 1999	Fill	Mean	2.01	41.00	7.30	0.57	4.17	1.53	0.43	1.57	0.23	8.00	7.33	195.33	5894.00	1129.00	46.67	2.10	4.57	4.20	2.11
			Std. Dev.	1.00	4.24	0.16	0.17	1.52	0.25	0.47	0.38	0.19	2.83	5.31	27.21	1664.43	180.05	8.34	0.31	1.31	2.22	0.13
		Cut	Mean	2.64	45.33	7.33	1.07	8.37	1.20	0.63	1.23	0.27	6.00	4.00	330.67	7258.67	328.00	70.67	1.50	3.13	5.33	2.12
			Std. Dev.	0.16	2.05	0.09	0.52	5.12	0.37	0.09	0.21	0.05	0.82	1.41	38.96	740.98	99.08	21.75	0.18	0.42	0.68	0.27
	Event 3 - Spring 2000	Fill	Mean	N/A	40.77	7.45	0.45	3.87	1.77	0.48	0.60	0.06	2.33	9.00	194.19	4235.12	757.51	12.83	2.57	5.47	15.40	1.43
			Std. Dev.	N/A	6.40	0.17	0.09	0.69	0.26	0.06	0.03	0.02	0.83	1.63	3.69	1131.90	132.13	15.31	0.50	1.47	2.05	0.09
		Cut	Mean	N/A	48.60	7.31	1.91	25.60	2.93	0.59	0.46	0.08	0.53	6.33	235.89	5718.08	291.66	2.00	1.33	3.40	8.37	2.10
			Std. Dev.	N/A	0.71	0.07	0.91	14.45	1.09	0.01	0.12	0.01	0.62	0.47	8.03	429.91	105.01	0.00	0.05	0.22	0.33	0.22
Coir Netting (COIR)	Event 1 - Fall 1998	Fill	Mean	3.63	38.00	7.45	1.08	5.33	4.23	0.60	1.43	0.23	44.00	7.33	178.00	4628.67	1323.67	190.33	1.01	4.23	2.90	0.81
			Std. Dev.	0.71	0.82	0.12	0.35	1.42	1.09	0.00	0.12	0.12	31.79	2.05	10.03	819.36	137.52	39.35	0.07	2.54	0.45	0.06
		Cut	Mean	3.92	41.67	7.37	0.97	6.37	1.97	0.90	1.33	0.60	23.00	8.33	435.67	6013.00	495.33	87.00	1.03	1.83	2.40	0.76
			Std. Dev.	0.47	2.05	0.07	0.61	4.76	0.45	0.22	0.12	0.37	16.99	4.11	24.44	199.53	196.35	9.20	0.05	0.09	0.57	0.05
	Event 2 - Spring 1999	Fill	Mean	2.33	46.00	7.27	0.83	6.73	3.17	0.20	2.27	0.17	10.00	8.33	175.67	5698.33	1009.33	52.00	24.45	13.60	4.63	2.00
			Std. Dev.	0.44	4.97	0.05	0.29	2.45	1.67	0.08	0.41	0.05	2.94	0.94	48.62	1469.60	197.27	1.41	31.96	12.16	2.72	0.26
		Cut	Mean	2.56	45.33	7.40	1.43	9.60	1.53	0.83	2.27	0.33	10.33	4.33	339.33	7522.00	391.00	91.00	1.60	3.53	5.00	1.80
			Std. Dev.	0.27	2.62	0.08	0.90	7.18	0.17	0.05	0.25	0.17	6.13	2.05	20.01	1473.46	139.45	6.48	0.38	0.63	0.49	0.27
	Event 3 - Spring 2000	Fill	Mean	N/A	39.37	7.51	0.42	3.70	1.67	0.46	0.46	0.06	1.06	7.67	162.91	4635.92	826.37	26.06	2.23	5.30	13.07	1.33
			Std. Dev.	N/A	4.08	0.15	0.06	0.37	0.09	0.04	0.26	0.01	0.78	0.47	13.29	883.02	86.50	1.08	0.09	1.84	2.85	0.05
		Cut	Mean	N/A	45.10	7.41	1.24	15.63	1.73	0.58	0.70	0.08	1.70	6.67	195.49	5217.08	324.07	2.00	1.10	2.80	8.57	1.73
			Std. Dev.	N/A	1.77	0.07	0.94	15.53	0.61	0.01	0.34	0.01	0.59	0.47	20.93	442.19	120.03	0.00	0.24	0.71	2.37	0.31

Table 6-1B (Continued)
SOIL COMPOSITION AND CHEMICAL DATA - NON-IRRIGATED PLANT ESTABLISHMENT TEST PLOTS
All SAMPLING EVENTS

				Loss on Ignition	Saturation Paste Extract								Potassium Chloride Extract	Olsen Extract	Ammonium Acetate Extract				DPTA Extract			
				OM	Saturation	pH	ECe	Ca	Mg	Na	Cl	B	N	P	K	Ca	Mg	Na	Zn	Mn	Fe	Cu
Treatment	Monitoring Event	Slope Type	Statistic	%	%		dS m-1	meq L-1	meq L-1	meq L-1	meq L-1	mg L-1	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm
Compost (COMP)	Event 1 - Fall 1998	Fill	Mean	5.82	36.00	7.32	1.05	5.53	4.40	0.77	1.47	0.27	42.00	11.00	200.00	3852.67	1060.33	197.00	1.36	3.03	4.23	0.78
			Std. Dev.	1.02	2.16	0.13	0.25	1.14	1.07	0.05	0.17	0.12	14.45	3.56	34.91	716.18	123.57	28.58	0.39	1.89	2.31	0.13
		Cut	Mean	2.22	35.67	7.40	0.92	6.27	1.77	0.70	1.03	0.40	15.67	8.33	382.33	5763.33	413.00	63.33	0.80	1.80	2.53	0.59
			Std. Dev.	0.85	8.34	0.04	0.37	3.66	0.12	0.08	0.12	0.08	2.05	4.50	86.88	752.82	198.42	26.23	0.13	0.22	0.21	0.09
	Event 2 - Spring 1999	Fill	Mean	1.42	34.33	7.37	0.50	3.63	1.57	0.37	1.70	0.30	8.00	7.67	160.00	4879.00	1014.00	78.00	2.08	4.47	5.17	2.13
			Std. Dev.	1.21	8.65	0.21	0.08	0.17	0.25	0.25	0.16	0.14	2.83	2.49	45.52	1257.94	145.40	16.51	0.47	1.32	2.40	0.18
		Cut	Mean	1.99	43.33	7.37	1.20	10.40	1.40	0.67	1.47	0.20	5.33	3.33	254.67	6210.67	285.33	104.00	1.14	3.37	5.47	1.47
			Std. Dev.	0.56	3.09	0.05	0.37	3.52	0.43	0.17	0.12	0.08	3.40	2.05	37.37	493.26	135.30	23.42	0.22	1.10	0.61	0.28
	Event 3 - Spring 2000	Fill	Mean	N/A	38.00	7.47	0.40	3.70	1.70	0.52	0.49	0.06	2.20	9.67	178.55	4181.68	745.35	24.52	2.70	5.07	14.87	1.47
			Std. Dev.	N/A	4.97	0.08	0.09	0.62	0.29	0.04	0.06	0.02	0.75	2.36	11.21	791.91	54.65	2.17	0.28	0.76	0.45	0.12
		Cut	Mean	N/A	43.43	7.37	1.39	17.13	1.90	0.65	0.48	0.09	1.37	5.67	166.82	4936.52	271.41	2.00	0.90	3.40	8.87	1.23
			Std. Dev.	N/A	3.58	0.04	0.87	14.48	0.51	0.05	0.20	0.01	0.34	0.47	28.97	304.07	124.06	0.00	0.24	1.42	0.54	0.21
Curled Wood Fiber (CWFB)	Event 1 - Fall 1998	Fill	Mean	3.18	30.00	6.29	0.70	3.47	3.07	0.80	1.63	0.30	22.33	17.00	221.67	2504.67	893.00	224.00	1.89	11.07	14.33	1.13
			Std. Dev.	0.80	1.63	0.52	0.03	0.17	0.29	0.14	0.33	0.00	5.44	10.98	58.95	180.08	76.41	18.83	0.41	4.25	6.30	0.17
		Cut	Mean	3.53	43.67	7.31	1.16	7.50	2.93	0.97	1.47	0.50	14.67	18.33	397.67	5623.00	632.33	80.00	1.01	2.10	2.40	0.66
			Std. Dev.	0.23	5.79	0.15	0.67	6.16	0.99	0.17	0.09	0.22	3.30	6.60	72.56	550.45	160.19	26.55	0.28	0.37	0.71	0.18
	Event 2 - Spring 1999	Fill	Mean	1.72	43.00	6.13	0.57	3.80	1.70	0.10	1.97	0.37	6.00	15.00	172.67	2698.00	676.00	60.00	21.25	15.33	24.07	2.73
			Std. Dev.	0.32	7.26	0.91	0.17	0.59	0.16	0.00	0.74	0.17	3.56	2.16	51.04	49.08	59.42	10.80	26.90	1.52	8.33	0.58
		Cut	Mean	2.42	45.67	7.27	0.63	5.40	1.13	0.80	1.40	0.17	5.67	10.00	316.67	6687.67	497.67	84.33	1.64	3.00	5.57	2.05
			Std. Dev.	0.50	2.05	0.12	0.26	2.20	0.05	0.14	0.24	0.09	2.05	2.94	49.36	795.53	232.71	29.94	0.13	0.45	1.11	0.52
	Event 3 - Spring 2000	Fill	Mean	N/A	30.40	6.58	0.41	2.93	1.50	0.54	0.78	0.07	2.83	14.33	172.03	2571.80	591.42	8.23	2.43	11.87	30.30	1.60
			Std. Dev.	N/A	1.02	0.43	0.09	0.37	0.22	0.14	0.18	0.02	1.27	3.86	41.75	188.23	31.90	8.81	0.52	3.72	8.27	0.28
		Cut	Mean	N/A	46.63	7.36	1.02	13.67	2.17	0.49	0.53	0.09	1.80	6.33	224.16	5370.72	401.03	2.00	1.57	2.63	8.43	2.07
			Std. Dev.	N/A	3.99	0.08	0.65	12.89	1.01	0.03	0.09	0.01	0.29	0.47	22.42	711.91	149.83	0.00	0.33	0.62	1.17	0.48

Table 6-1B (Continued)
SOIL COMPOSITION AND CHEMICAL DATA - NON-IRRIGATED PLANT ESTABLISHMENT TEST PLOTS
All SAMPLING EVENTS

				Loss on Ignition	Saturation Paste Extract								Potassium Chloride Extract	Olsen Extract	Ammonium Acetate Extract				DPTA Extract			
				OM	Saturation	pH	ECe	Ca	Mg	Na	Cl	B	N	P	K	Ca	Mg	Na	Zn	Mn	Fe	Cu
Treatment	Monitoring Event	Slope Type	Statistic	%	%		dS m-1	meq L-1	meq L-1	meq L-1	meq L-1	mg L-1	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm
Gypsum, Rate 1 (GYP1)	Event 1 - Fall 1998	Fill	Mean	3.10	32.67	6.67	0.78	3.80	3.30	0.70	1.30	0.33	38.00	6.67	177.00	3429.67	1010.33	176.67	1.12	5.83	8.17	0.85
			Std. Dev.	0.41	3.86	0.52	0.36	1.56	1.02	0.08	0.08	0.26	25.51	2.05	3.56	1582.83	262.89	10.08	0.18	2.96	4.08	0.12
		Cut	Mean	3.85	40.00	7.41	1.28	8.37	2.43	1.07	1.47	0.50	25.33	9.33	422.00	6223.00	324.67	121.33	0.94	1.90	2.87	0.83
			Std. Dev.	2.12	2.45	0.04	0.30	1.94	0.57	0.17	0.12	0.16	16.74	7.72	7.87	371.81	179.37	22.95	0.05	0.29	0.17	0.06
	Event 2 - Spring 1999	Fill	Mean	2.99	39.00	6.73	2.40	19.57	8.47	0.30	1.73	0.13	6.33	11.67	168.33	4583.67	847.00	80.67	5.39	8.03	8.97	2.08
			Std. Dev.	1.13	4.24	0.42	0.41	7.98	2.01	0.08	0.12	0.05	2.05	3.40	18.52	1777.42	219.46	28.24	5.20	3.52	4.93	0.09
		Cut	Mean	2.67	44.33	7.27	1.80	16.20	2.17	0.47	1.50	0.30	7.33	4.33	252.67	6716.67	248.67	90.00	1.23	2.97	4.63	1.61
			Std. Dev.	0.43	4.78	0.05	0.22	1.79	1.17	0.09	0.57	0.16	2.87	1.70	57.16	670.10	147.77	27.58	0.19	0.45	0.21	0.51
	Event 3 - Spring 2000	Fill	Mean	N/A	34.97	6.91	1.47	16.53	6.90	0.69	0.75	0.07	1.80	11.00	162.91	3527.04	599.52	2.00	2.17	8.30	20.90	1.40
			Std. Dev.	N/A	6.82	0.36	0.31	5.56	2.69	0.08	0.25	0.02	1.21	3.27	12.09	1487.92	126.03	0.00	0.17	3.09	8.50	0.08
		Cut	Mean	N/A	45.90	7.32	2.03	27.83	2.60	0.69	0.40	0.08	1.10	4.67	181.15	7154.28	247.10	2.00	1.03	2.47	7.10	1.80
			Std. Dev.	N/A	3.31	0.08	0.83	14.55	0.65	0.08	0.08	0.01	0.82	1.25	31.49	1790.41	135.45	0.00	0.21	0.12	1.42	0.57
Gypsum, Rate 2 (GYP2)	Event 1 - Fall 1998	Fill	Mean	3.82	40.00	7.46	1.07	5.87	4.83	0.90	1.40	0.43	42.33	8.00	198.33	4439.67	1277.67	166.67	1.30	3.37	3.67	0.84
			Std. Dev.	1.11	8.60	0.05	0.34	1.93	1.43	0.22	0.24	0.17	3.30	2.16	9.39	1065.19	314.28	20.07	0.21	0.96	1.24	0.12
		Cut	Mean	4.10	39.67	7.47	0.64	3.53	1.70	0.63	1.30	0.47	16.00	9.00	373.67	5482.33	384.33	104.67	0.89	1.67	2.27	0.72
			Std. Dev.	0.92	3.40	0.11	0.07	0.54	0.14	0.05	0.08	0.09	2.94	5.72	24.14	608.91	33.11	58.90	0.01	0.33	0.48	0.04
	Event 2 - Spring 1999	Fill	Mean	2.10	46.00	7.17	1.93	18.73	8.07	0.60	1.60	0.20	9.33	7.33	219.67	5846.00	1008.67	86.67	1.78	3.80	3.90	2.05
			Std. Dev.	0.10	6.48	0.17	0.53	5.72	2.90	0.41	0.50	0.14	6.94	1.25	67.80	1895.89	257.56	27.26	0.18	1.07	0.43	0.22
		Cut	Mean	2.40	44.00	7.30	2.10	16.90	2.93	0.87	1.27	0.27	5.33	11.33	273.00	7823.33	365.00	135.00	1.10	2.47	4.80	1.46
			Std. Dev.	0.95	2.16	0.16	0.71	5.33	0.74	0.12	0.25	0.17	1.70	11.81	26.19	713.70	119.91	37.67	0.14	0.74	1.13	0.41
	Event 3 - Spring 2000	Fill	Mean	N/A	42.57	7.45	1.03	10.93	4.90	0.72	0.41	0.04	1.70	8.33	182.46	4716.08	789.91	13.59	2.47	5.13	15.60	1.43
			Std. Dev.	N/A	5.20	0.18	0.45	6.14	3.28	0.35	0.03	0.03	0.65	1.25	24.38	1082.57	193.17	16.40	0.29	0.83	2.01	0.21
		Cut	Mean	N/A	50.00	7.38	1.16	12.03	2.23	0.57	0.41	0.08	1.03	6.67	202.01	5444.20	352.42	2.00	1.23	2.87	8.60	2.00
			Std. Dev.	N/A	4.26	0.10	0.48	5.82	0.90	0.17	0.06	0.01	0.71	0.94	19.51	73.78	68.74	0.00	0.21	0.68	0.50	0.29

Table 6-1B (Continued)
SOIL COMPOSITION AND CHEMICAL DATA - NON-IRRIGATED PLANT ESTABLISHMENT TEST PLOTS
All SAMPLING EVENTS

				Loss on Ignition	Saturation Paste Extract								Potassium Chloride Extract	Olsen Extract	Ammonium Acetate Extract				DPTA Extract			
				OM	Saturation	pH	ECe	Ca	Mg	Na	Cl	B	N	P	K	Ca	Mg	Na	Zn	Mn	Fe	Cu
Treatment	Monitoring Event	Slope Type	Statistic	%	%		dS m-1	meq L-1	meq L-1	meq L-1	meq L-1	mg L-1	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm
Paper Mulch and Psyllium Tackifier (PMG)	Event 1 - Fall 1998	Fill	Mean	4.95	35.00	7.25	0.88	4.70	3.77	0.60	1.43	0.13	42.00	9.67	181.33	4263.67	984.00	165.00	1.13	3.67	4.37	0.81
			Std. Dev.	0.82	4.97	0.36	0.17	0.73	0.58	0.00	0.05	0.05	14.17	2.87	17.97	1351.37	177.90	22.23	0.20	1.98	2.76	0.07
		Cut	Mean	3.22	43.00	7.35	0.72	3.97	1.93	0.77	1.47	0.60	18.33	8.00	439.67	5656.00	487.33	58.00	1.14	2.17	2.53	0.96
			Std. Dev.	1.71	1.63	0.06	0.15	1.03	0.37	0.17	0.12	0.08	7.54	0.82	30.09	254.95	75.48	12.25	0.25	0.53	0.87	0.02
	Event 2 - Spring 1999	Fill	Mean	2.49	43.00	6.90	0.63	5.23	2.23	0.17	1.63	0.10	7.67	7.00	165.33	5734.33	1018.33	51.67	1.49	6.70	6.00	2.15
			Std. Dev.	0.65	6.53	0.64	0.19	1.62	0.62	0.05	0.17	0.00	2.36	0.82	47.59	2234.78	297.44	31.03	0.42	4.06	3.54	0.23
		Cut	Mean	2.39	44.33	7.30	1.20	8.13	1.73	0.87	1.47	0.23	5.33	5.00	278.33	6538.00	331.33	118.67	1.59	3.03	5.13	1.63
			Std. Dev.	0.59	1.70	0.14	0.54	5.17	0.52	0.24	0.31	0.09	2.49	1.41	23.21	191.13	36.97	27.38	0.14	0.69	0.66	0.16
	Event 3 - Spring 2000	Fill	Mean	N/A	37.93	7.36	0.40	3.53	1.57	0.44	0.33	0.05	1.50	8.00	162.91	4308.60	753.46	9.00	2.20	5.63	16.43	1.40
			Std. Dev.	N/A	5.97	0.26	0.10	0.74	0.21	0.03	0.12	0.01	1.02	2.16	21.26	1309.31	168.68	9.89	0.37	1.96	4.81	0.08
		Cut	Mean	N/A	45.60	7.32	0.68	6.00	1.30	0.69	0.62	0.09	2.03	6.33	199.40	5003.32	332.17	10.53	1.90	2.77	7.83	1.80
			Std. Dev.	N/A	2.21	0.07	0.07	0.57	0.14	0.12	0.17	0.00	0.75	0.47	5.53	458.83	34.85	12.06	0.64	0.61	0.50	0.08
Paper Mulch and Polymer Tackifier (PMP)	Event 1 - Fall 1998	Fill	Mean	4.52	33.33	6.14	0.54	3.00	2.33	0.87	1.53	0.47	25.67	12.67	263.33	2741.67	981.33	214.00	2.07	13.47	19.77	1.40
			Std. Dev.	0.65	3.09	0.33	0.10	0.70	0.12	0.31	0.19	0.21	0.94	3.30	28.77	277.58	117.62	13.95	0.32	3.59	3.10	0.26
		Cut	Mean	3.35	36.00	7.38	0.79	4.00	2.13	0.83	1.87	0.47	14.00	10.67	390.67	4941.67	493.67	149.33	1.18	2.60	3.13	0.78
			Std. Dev.	0.47	6.68	0.14	0.23	1.57	0.31	0.33	0.21	0.05	2.16	3.40	39.62	147.77	150.82	65.94	0.13	0.54	0.17	0.09
	Event 2 - Spring 1999	Fill	Mean	2.17	38.00	5.37	0.80	5.83	2.43	0.10	2.20	0.23	14.33	16.67	196.33	2752.33	687.33	72.00	3.12	22.80	32.63	3.00
			Std. Dev.	0.58	3.56	0.12	0.16	1.37	0.70	0.00	0.14	0.05	10.87	2.62	47.13	921.27	102.50	33.74	1.07	10.27	6.05	0.56
		Cut	Mean	2.28	42.67	7.33	0.57	3.40	1.10	1.00	1.47	0.27	6.67	10.33	270.67	5871.33	417.33	102.33	1.62	3.43	5.20	1.24
			Std. Dev.	0.35	3.40	0.09	0.05	0.99	0.45	0.36	0.12	0.09	1.70	6.55	33.72	65.93	162.45	48.61	0.20	0.60	0.75	0.32
	Event 3 - Spring 2000	Fill	Mean	N/A	36.63	6.24	0.51	3.60	1.90	0.59	1.05	0.08	2.67	20.00	192.88	2738.80	615.73	15.99	2.93	16.37	38.30	1.93
			Std. Dev.	N/A	3.67	0.11	0.17	1.23	0.73	0.16	0.30	0.00	0.66	4.55	22.65	294.68	50.92	9.89	0.87	1.30	3.35	0.31
		Cut	Mean	N/A	42.03	7.35	0.62	5.07	1.50	0.52	0.54	0.09	2.13	7.33	182.46	4515.68	413.19	2.00	1.90	2.60	6.80	1.23
			Std. Dev.	N/A	4.58	0.07	0.02	0.24	0.28	0.07	0.12	0.01	0.49	1.89	18.71	560.24	126.68	0.00	1.18	0.29	0.50	0.25

Table 6-1B (Continued)
SOIL COMPOSITION AND CHEMICAL DATA - NON-IRRIGATED PLANT ESTABLISHMENT TEST PLOTS
All SAMPLING EVENTS

				Loss on Ignition	Saturation Paste Extract								Potassium Chloride Extract	Olsen Extract	Ammonium Acetate Extract				DPTA Extract			
				OM	Saturation	pH	ECe	Ca	Mg	Na	Cl	B	N	P	K	Ca	Mg	Na	Zn	Mn	Fe	Cu
Treatment	Monitoring Event	Slope Type	Statistic	%	%		dS m-1	meq L-1	meq L-1	meq L-1	meq L-1	mg L-1	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm
Wheat Straw	Event 1 - Fall 1998	Fill	Mean	4.25	37.33	7.29	1.04	6.20	4.27	1.00	1.53	0.27	36.00	10.33	209.33	4469.67	1254.67	176.67	1.12	4.27	5.50	0.84
			Std. Dev.	1.21	8.38	0.22	0.30	1.02	1.28	0.28	0.25	0.05	9.93	6.18	34.32	1647.19	370.63	19.36	0.01	2.74	4.47	0.09
		Cut	Mean	4.18	41.67	7.36	1.46	10.47	2.73	0.73	1.23	0.43	17.67	6.67	432.33	5952.67	319.00	62.33	0.92	1.50	2.23	0.83
			Std. Dev.	0.57	1.70	0.07	0.79	6.50	1.32	0.09	0.12	0.12	3.40	4.92	37.35	395.12	112.54	30.65	0.11	0.08	0.59	0.15
	Event 2 - Spring 1999	Fill	Mean	2.29	47.33	7.10	0.53	3.70	1.67	0.63	1.67	0.33	4.67	8.00	216.00	6275.33	1172.33	105.33	2.10	5.67	9.47	2.45
			Std. Dev.	0.41	7.85	0.57	0.05	0.67	0.17	0.54	0.21	0.09	2.49	4.90	66.32	2355.45	330.67	34.18	0.24	2.74	8.02	0.31
		Cut	Mean	2.55	46.33	7.30	0.97	6.93	1.37	0.60	1.13	0.23	3.67	5.33	308.33	6672.33	298.00	57.67	1.36	2.57	4.63	1.61
			Std. Dev.	0.36	2.49	0.00	0.09	1.80	0.21	0.08	0.21	0.09	1.70	3.30	17.33	204.82	60.34	22.23	0.12	0.33	0.29	0.09
	Event 3 - Spring 2000	Fill	Mean	N/A	43.97	7.56	0.91	11.33	1.90	0.58	0.56	0.06	1.06	6.33	192.88	5350.68	717.00	22.89	1.80	3.87	11.10	1.57
			Std. Dev.	N/A	2.65	0.14	0.75	11.08	0.36	0.07	0.18	0.01	0.70	0.94	22.65	393.72	399.74	16.17	0.65	1.43	3.08	0.12
		Cut	Mean	N/A	41.13	7.18	1.04	10.70	2.00	0.70	1.04	0.08	2.00	9.67	199.40	4502.32	392.93	8.23	1.77	5.03	13.30	1.67
			Std. Dev.	N/A	7.36	0.21	0.68	9.41	0.78	0.12	0.50	0.01	0.16	4.50	20.93	1530.17	118.38	8.81	0.74	3.67	9.70	0.39
Straw ECB (SB)	Event 1 - Fall 1998	Fill	Mean	3.78	31.00	6.99	0.76	3.83	3.50	0.73	1.40	0.47	31.33	14.33	188.33	2408.67	820.00	214.00	1.70	7.00	8.30	0.87
			Std. Dev.	1.14	0.82	0.37	0.03	0.17	0.08	0.05	0.14	0.33	1.25	7.59	60.50	376.67	79.65	14.97	0.27	1.28	2.02	0.11
		Cut	Mean	3.48	31.00	7.44	1.76	12.07	3.40	0.93	1.60	0.33	17.33	9.67	395.00	5552.00	342.33	107.67	0.98	2.13	2.80	0.78
			Std. Dev.	0.45	7.87	0.18	0.70	6.09	0.70	0.17	0.08	0.09	3.40	2.49	59.54	634.12	209.78	18.45	0.17	0.37	0.08	0.16
	Event 2 - Spring 1999	Fill	Mean	4.13	35.33	7.07	0.47	3.77	1.73	0.27	1.57	0.27	6.67	12.00	154.00	3367.00	761.33	39.67	23.86	14.43	10.70	1.94
			Std. Dev.	2.98	2.05	0.12	0.09	0.74	0.34	0.17	0.12	0.12	3.86	2.94	22.73	326.59	51.67	4.92	31.08	9.48	5.30	0.37
		Cut	Mean	2.34	43.33	7.33	1.00	4.77	1.37	0.73	1.27	0.23	4.67	4.33	282.00	6497.33	318.00	76.33	1.29	2.70	5.13	1.83
			Std. Dev.	0.16	1.89	0.05	0.36	0.50	0.12	0.12	0.17	0.09	0.94	1.25	22.38	704.75	108.26	12.36	0.26	0.45	0.17	0.33
	Event 3 - Spring 2000	Fill	Mean	N/A	31.43	7.10	0.42	3.53	1.77	0.47	0.63	0.06	2.13	11.33	153.79	2645.28	575.22	8.23	2.50	8.23	19.93	1.20
			Std. Dev.	N/A	2.11	0.19	0.09	0.87	0.42	0.03	0.12	0.01	1.11	1.70	27.15	199.06	28.64	8.81	0.33	1.59	7.48	0.14
		Cut	Mean	N/A	42.57	7.40	1.37	17.60	2.67	0.56	0.49	0.09	1.00	5.67	178.55	4876.40	283.56	2.00	1.00	2.53	7.13	1.47
			Std. Dev.	N/A	3.43	0.10	0.77	10.58	1.13	0.10	0.13	0.01	0.08	0.47	18.15	516.48	104.23	0.00	0.16	0.05	0.52	0.49

Table 6-1B (Continued)
SOIL COMPOSITION AND CHEMICAL DATA - NON-IRRIGATED PLANT ESTABLISHMENT TEST PLOTS
All SAMPLING EVENTS

				Loss on Ignition	Saturation Paste Extract								Potassium Chloride Extract	Olsen Extract	Ammonium Acetate Extract				DPTA Extract			
				OM	Saturation	pH	ECe	Ca	Mg	Na	Cl	B	N	P	K	Ca	Mg	Na	Zn	Mn	Fe	Cu
Treatment	Monitoring Event	Slope Type	Statistic	%	%		dS m-1	meq L-1	meq L-1	meq L-1	meq L-1	mg L-1	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm
Straw/Coconut ECB (SCB)	Event 1 - Fall 1998	Fill	Mean	2.32	31.33	6.76	0.66	3.47	3.13	0.73	1.47	0.43	25.33	11.00	222.33	2606.67	874.67	209.67	1.56	8.00	9.60	0.90
			Std. Dev.	1.36	0.94	0.52	0.07	0.68	0.58	0.09	0.31	0.21	4.64	2.45	43.52	176.92	26.55	28.24	0.36	2.26	2.75	0.18
		Cut	Mean	3.95	39.33	7.46	1.09	6.73	2.60	0.70	1.37	0.37	17.67	10.33	446.67	5535.33	486.33	110.00	0.98	1.93	2.63	0.77
			Std. Dev.	0.70	8.65	0.17	0.67	5.14	1.20	0.08	0.12	0.12	1.25	11.09	30.47	83.81	53.58	46.01	0.03	0.50	0.82	0.15
	Event 2 - Spring 1999	Fill	Mean	2.12	37.33	6.60	0.63	4.73	2.27	0.37	2.27	0.17	8.67	13.00	180.33	2754.67	722.33	66.00	2.95	12.67	15.10	2.67
			Std. Dev.	0.19	0.94	0.51	0.12	0.66	0.49	0.24	0.45	0.05	3.30	3.56	76.34	311.15	29.33	11.43	0.95	6.51	10.42	0.60
		Cut	Mean	2.48	45.67	7.27	0.83	6.43	1.40	0.73	1.63	0.27	5.00	6.33	304.33	6720.67	426.33	55.00	1.64	3.07	5.20	1.79
			Std. Dev.	0.18	0.94	0.05	0.21	1.79	0.36	0.17	0.26	0.12	1.41	2.49	42.91	348.59	63.21	6.53	0.32	0.59	0.28	0.04
	Event 3 - Spring 2000	Fill	Mean	N/A	31.83	7.07	0.39	3.13	1.63	0.51	0.60	0.06	1.97	12.33	177.24	2692.04	583.32	2.00	2.30	8.67	19.67	1.30
			Std. Dev.	N/A	1.01	0.31	0.08	0.68	0.39	0.08	0.10	0.01	0.60	2.62	35.02	52.60	19.84	0.00	0.29	3.07	8.45	0.22
		Cut	Mean	N/A	44.70	7.33	1.38	16.17	2.53	0.60	0.62	0.09	0.80	6.33	212.43	6112.20	368.63	2.00	1.27	3.17	7.83	1.77
			Std. Dev.	N/A	2.06	0.12	0.92	13.82	1.22	0.03	0.10	0.00	0.51	0.47	13.29	1701.16	85.55	0.00	0.25	0.24	1.10	0.24
Wood Fiber ECB (WFB)	Event 1 - Fall 1998	Fill	Mean	4.55	36.67	6.89	0.87	4.53	3.63	0.80	1.53	0.23	36.67	16.00	195.00	3239.00	998.67	160.00	1.52	5.87	7.03	0.96
			Std. Dev.	1.14	0.94	0.60	0.20	0.88	0.60	0.16	0.12	0.05	13.72	7.26	34.88	718.19	122.39	39.22	0.11	3.30	4.43	0.13
		Cut	Mean	3.43	41.67	7.50	0.59	2.83	1.63	0.73	1.40	0.40	15.67	11.67	453.33	5153.33	504.67	86.33	1.32	2.27	2.43	0.88
			Std. Dev.	0.42	2.87	0.17	0.06	0.25	0.05	0.12	0.16	0.16	0.94	5.73	19.96	322.58	85.98	34.32	0.15	0.50	0.62	0.05
	Event 2 - Spring 1999	Fill	Mean	2.36	41.00	6.80	0.57	4.63	2.03	0.17	1.87	0.20	7.00	12.67	240.67	3892.00	953.00	41.33	5.21	14.50	12.33	2.49
			Std. Dev.	0.21	0.82	0.64	0.12	0.66	0.25	0.09	0.54	0.08	2.94	5.91	120.85	819.32	94.13	17.61	4.54	14.28	12.02	0.64
		Cut	Mean	3.21	46.67	7.33	1.03	6.37	1.67	0.73	1.73	0.17	6.00	17.67	274.67	6907.67	417.67	111.67	1.42	3.13	4.83	1.64
			Std. Dev.	0.41	3.09	0.05	0.68	3.44	0.90	0.09	0.42	0.05	1.41	11.44	22.23	1302.09	74.66	20.34	0.15	0.99	0.24	0.32
	Event 3 - Spring 2000	Fill	Mean	N/A	32.67	7.12	0.43	3.60	1.67	0.44	0.61	0.07	1.50	12.33	177.24	3273.20	648.13	8.23	2.37	7.43	19.57	1.43
			Std. Dev.	N/A	3.18	0.45	0.08	0.85	0.34	0.05	0.13	0.01	1.02	4.99	32.29	362.32	24.97	8.81	0.12	3.94	7.81	0.34
		Cut	Mean	N/A	45.20	7.34	0.74	6.53	1.67	0.56	0.69	0.09	1.26	6.67	208.52	4849.68	401.03	2.00	1.33	2.57	7.53	1.73
			Std. Dev.	N/A	0.54	0.15	0.20	2.16	0.34	0.02	0.40	0.01	0.85	0.47	9.75	212.71	29.77	0.00	0.09	0.34	0.45	0.17

Table 6-1B (Continued)
SOIL COMPOSITION AND CHEMICAL DATA - NON-IRRIGATED PLANT ESTABLISHMENT TEST PLOTS
All SAMPLING EVENTS

				Loss on Ignition	Saturation Paste Extract								Potassium Chloride Extract	Olsen Extract	Ammonium Acetate Extract				DPTA Extract			
				OM	Saturation	pH	ECe	Ca	Mg	Na	Cl	B	N	P	K	Ca	Mg	Na	Zn	Mn	Fe	Cu
Treatment	Monitoring Event	Slope Type	Statistic	%	%		dS m-1	meq L-1	meq L-1	meq L-1	meq L-1	mg L-1	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm
Wood Mulch and Psyllium Tackifier (WMG)	Event 1 - Fall 1998	Fill	Mean	4.22	37.33	6.83	0.84	4.27	3.50	0.70	1.50	0.40	37.33	15.67	227.33	3591.00	1070.67	208.67	1.79	7.67	9.23	1.14
			Std. Dev.	0.23	1.25	0.80	0.22	1.26	0.86	0.16	0.16	0.00	11.03	7.36	64.05	527.52	117.85	24.00	0.61	5.75	7.87	0.50
		Cut	Mean	3.97	40.67	7.54	1.24	8.40	2.87	0.70	1.27	0.53	16.67	7.33	394.67	6050.67	475.33	118.67	0.86	1.50	2.27	0.86
			Std. Dev.	0.20	2.36	0.14	0.83	6.93	1.52	0.24	0.12	0.29	3.68	3.30	47.40	773.59	140.87	20.29	0.12	0.16	0.63	0.04
	Event 2 - Spring 1999	Fill	Mean	2.37	45.00	7.37	0.73	5.83	1.87	0.10	2.07	0.20	15.67	13.67	204.33	4375.00	973.00	59.67	4.07	19.80	18.63	2.90
			Std. Dev.	0.45	4.55	0.12	0.21	1.08	0.53	0.00	0.58	0.08	11.32	6.80	64.43	882.83	31.19	20.07	3.19	21.43	20.55	1.02
		Cut	Mean	2.82	45.33	7.30	1.50	13.13	2.07	0.87	1.63	0.17	6.33	6.67	326.33	6976.67	386.00	101.00	1.31	2.70	4.90	1.98
			Std. Dev.	0.38	0.47	0.08	0.64	6.99	0.87	0.17	0.19	0.05	1.25	5.91	60.01	209.71	149.57	16.39	0.14	0.16	0.41	0.32
	Event 3 - Spring 2000	Fill	Mean	N/A	36.70	7.04	0.47	3.87	1.77	0.55	0.74	0.06	2.67	13.67	172.03	3867.72	737.25	26.06	2.60	11.23	24.33	1.73
			Std. Dev.	N/A	1.34	0.57	0.05	0.24	0.09	0.11	0.48	0.00	0.97	6.65	13.92	149.97	5.73	6.03	0.45	8.89	14.27	0.68
		Cut	Mean	N/A	44.57	7.36	1.35	16.50	2.40	0.61	0.72	0.06	1.30	6.33	207.22	5390.76	356.47	2.00	1.17	2.10	7.70	1.93
			Std. Dev.	N/A	3.06	0.05	1.05	16.33	1.56	0.07	0.23	0.04	0.22	0.47	9.58	114.54	107.02	0.00	0.12	0.28	1.35	0.26
Wood Mulch and Polymer Tackifier (WMP)	Event 1 - Fall 1998	Fill	Mean	6.35	37.67	7.48	0.77	5.63	4.23	0.80	1.43	0.40	46.00	15.00	217.67	4431.33	1152.00	194.00	1.36	3.40	4.37	0.82
			Std. Dev.	0.43	6.94	0.11	0.31	1.48	0.90	0.08	0.21	0.22	13.44	4.97	26.91	1019.82	159.12	18.99	0.28	2.34	3.03	0.04
		Cut	Mean	1.52	30.00	7.49	1.24	8.37	2.30	0.83	1.27	0.50	17.33	13.67	350.00	5315.33	384.33	82.33	0.75	1.43	2.63	0.64
			Std. Dev.	1.48	7.79	0.09	0.41	4.09	0.43	0.12	0.05	0.24	1.70	15.17	57.78	289.35	206.88	28.55	0.16	0.21	0.21	0.03
	Event 2 - Spring 1999	Fill	Mean	4.05	43.33	7.33	0.70	5.40	2.17	0.40	2.07	0.30	10.33	5.67	201.33	6053.00	1075.67	122.33	2.22	4.53	4.60	1.98
			Std. Dev.	2.29	7.41	0.29	0.14	1.59	0.84	0.42	0.48	0.14	4.03	3.30	77.91	1846.01	278.04	11.44	0.29	1.20	1.35	0.40
		Cut	Mean	2.10	44.67	7.27	1.27	10.13	1.87	0.70	1.40	0.17	11.33	8.00	295.33	6761.00	380.33	57.00	1.18	2.53	5.20	1.50
			Std. Dev.	0.70	2.62	0.05	0.09	1.11	0.78	0.14	0.16	0.05	7.59	4.55	68.19	607.79	232.90	15.56	0.09	0.40	0.08	0.44
	Event 3 - Spring 2000	Fill	Mean	N/A	39.23	7.46	0.42	3.53	1.57	0.58	0.41	0.06	0.83	8.33	185.06	4515.68	781.81	17.53	2.33	5.37	14.43	1.33
			Std. Dev.	N/A	4.51	0.17	0.12	0.69	0.33	0.17	0.09	0.00	1.04	3.40	3.69	1151.25	187.57	10.98	0.34	2.10	4.23	0.09
		Cut	Mean	N/A	43.87	7.33	1.41	15.57	2.57	0.58	0.35	0.09	1.06	6.33	177.24	4889.76	299.76	2.00	1.10	2.17	7.37	1.57
			Std. Dev.	N/A	2.53	0.03	0.44	6.64	1.19	0.11	0.19	0.00	0.87	0.47	27.15	322.31	129.50	0.00	0.24	0.26	0.78	0.34

6.1.2 Microbial Soil Analysis

The soils were analyzed for certain microbial parameters, including bacteria (number and biomass), fungi, protozoa (flagellates, amoebae, ciliates), and vesicular arbuscular mycorrhiza (VAM) colonization. For fungi, details regarding the length, active biomass, and hyphal diameter were also measured and recorded. The means and standard deviations of the microbial soil analysis data irrigated and non-irrigated plant establishment test plots by treatment and sampling event are included in Tables 6-2A and 6-2B, respectively. The results from this table show means and standard deviations which remain within the same order of magnitude for all three sampling events. The only exception to this observation is the average fungi length and biomass for the irrigated cut-slope plant establishment test plots treated with paper mulch and psyllium tackifier (PMG). The mean fungi length and biomass for this treatment and slope type during Event 1 (Fall 1998) were 1205.87 cm/g and 24.27 μg/g, respectively due to a single sample that had larger numbers of fungi during Event 1 than any other event or other sample.

6.1.1.1 Statistical Data Analysis

Tables 6-3 and 6-4 show analysis of variance results for the soil data from the plant establishment plots. Of the soil chemistry variables measured, all but Ece, Ca, Na, and Dry Weight differ significantly between the two sites. Only Ca, Mg, Cl, B, N, CA (ppm) Zn, Fe, and Cu differ significantly between irrigated and non-irrigated plots. None of the measured soil chemistry variables were significantly different between treatments. The effects of irrigation were different at different sites (i.e., there was a significant site * treatment interaction) for Mg, Cl, B, N, and Zn. Other variables whose p-values for the site * treatment interaction were less than 0.05 did not have significant effects due to both site and treatment considered separately, and thus are not considered further. Since none of the variables were significantly influenced by treatment, none of the interactions involving treatment effects (i.e., site * treatment, irrigation * treatment, and site * irrigation * treatment) are considered significant.

Of the soil microbiology variables measured, fungal biomass, flagellates, and VAM percent differed significantly between sites. Bacterial biomass, flagellates, and ciliates differed significantly between irrigated and non-irrigated plots. The only significant site * treatment interaction for which both site and treatment, considered separately, were significant was flagellates. There were no significant differences among the treatments in any of the soil microbiology variables.

6.2 RAINFALL DATA COMPARISONS

Rainfall was measured with onsite rain gauges for each plant establishment test plot during the wet seasons (November through April) of the two-year monitoring period, as described in Section 3.3. Due to the geographic separation of the two plant establishment test sites precipitation rates varied during the study. Rainfall measurements collected from the test sites were compared to historical average annual rainfall data.

As presented in Table 8-5A, the 1998-1999 rainfall amounts for the bare erosion rate test plots, located near the plant establishment test plots at Sites 10-2 and 57-4 were 159 mm (6.3 in.) and 154 mm (6.1 in.), respectively. The rainfall amount recorded at Site 10-2 was 64 percent below the historical annual average of 439 mm (17.1 in.). The rainfall amount recorded at Site 57-4

Table 6-2A
SOIL MICROBIAL DATA - IRRIGATED PLANT ESTABLISHMENT TEST PLOTS
ALL SAMPLING EVENTS

Treatment	Monitoring Event	Slope Type	Statistic	FUNGI Length, Active (cm per g soil)	FUNGI Biomass, Active (µg per g soil)	FUNGI Hyphal Diameter (µm)	BACTERIA Number, Active (count per g soil)	BACTERIA Biomass, Active (µg per g soil)	FUNGI/ BACTERIA RATIO	PROTOZOA Flagellates (count per g soil)	PROTOZOA Amoebae (count per g soil)	PROTOZOA Ciliates (count per g soil)	VAM(2) % Root
No Treatment (Bare)	Event 1 - Fall 1998	Fill	Mean	23.46	0.47	2.50	1.8E+07	3.52	0.10	2.4E+03	8.4E+02	9.6E+01	35.69
			Std. Dev.	33.18	0.67	N/A	5.3E+06	1.07	0.14	1.4E+03	7.6E+02	1.3E+02	11.46
		Cut	Mean	123.57	2.49	2.50	1.2E+07	2.41	1.03	1.2E+03	1.6E+03	1.6E+01	13.49
			Std. Dev.	27.10	0.55	N/A	2.6E+06	0.52	0.04	1.2E+03	1.9E+03	2.3E+01	14.33
	Event 2 - Spring 1999	Fill	Mean	86.50	0.84	1.17	3.0E+07	5.93	0.12	4.5E+03	3.5E+03	8.4E+01	12.33
			Std. Dev.	62.25	0.62	0.85	1.1E+07	2.27	0.09	2.1E+03	8.9E+02	4.3E+01	8.65
		Cut	Mean	134.39	2.00	1.67	2.6E+07	5.20	0.41	1.6E+05	9.5E+05	5.1E+01	34.67
			Std. Dev.	87.32	2.25	0.62	6.1E+06	1.24	0.48	2.2E+05	1.3E+06	1.2E+01	5.91
	Event 3 - Spring 2000	Fill	Mean	111.75	0.81	1.50	1.6E+07	3.25	0.25	5.6E+03	4.5E+03	2.9E+01	4.67
			Std. Dev.	17.41	0.13	0.00	2.3E+06	0.46	0.02	5.6E+02	1.3E+03	4.2E+01	6.60
		Cut	Mean	69.38	0.58	1.67	1.3E+07	2.70	0.19	2.4E+03	1.7E+03	1.7E+01	17.00
			Std. Dev.	63.18	0.43	0.24	2.9E+06	0.57	0.12	7.1E+02	9.5E+02	2.0E+01	5.66
Bonded Fiber Matrix (BFM)	Event 1 - Fall 1998	Fill	Mean	85.53	1.72	2.50	2.2E+07	4.37	0.28	2.1E+03	1.9E+03	2.0E+02	5.08
			Std. Dev.	84.12	1.69	N/A	1.1E+07	2.11	0.24	1.1E+03	1.3E+03	1.9E+02	3.67
		Cut	Mean	1.89	0.02	2.00	1.7E+07	3.45	0.01	1.1E+03	2.0E+03	2.1E+02	20.00
			Std. Dev.	2.67	0.03	N/A	6.3E+06	1.25	0.02	4.6E+02	1.7E+03	2.7E+02	23.73
	Event 2 - Spring 1999	Fill	Mean	96.25	0.86	1.67	2.3E+07	4.67	0.19	1.4E+03	3.4E+03	1.1E+02	16.00
			Std. Dev.	23.89	0.25	0.24	3.4E+06	0.68	0.07	1.0E+01	2.0E+03	5.4E+01	7.12
		Cut	Mean	220.30	2.57	1.83	2.7E+07	5.43	0.47	3.5E+03	6.9E+03	3.4E+01	26.33
			Std. Dev.	89.73	1.42	0.24	2.9E+06	0.58	0.27	8.8E+02	5.7E+03	1.4E+01	7.72
	Event 3 - Spring 2000	Fill	Mean	96.43	0.70	1.50	1.9E+07	3.78	0.18	1.2E+04	8.0E+03	2.1E+01	13.00
			Std. Dev.	68.26	0.49	0.00	3.0E+06	0.60	0.11	1.2E+04	4.6E+03	8.7E+00	7.48
		Cut	Mean	111.23	0.76	1.50	1.3E+07	2.50	0.33	2.0E+03	3.5E+03	2.1E+01	15.33
			Std. Dev.	25.86	0.23	0.41	5.3E+06	1.06	0.08	6.1E+02	1.9E+03	1.5E+01	1.25

Table 6-2A (Continued)
SOIL MICROBIAL DATA - IRRIGATED PLANT ESTABLISHMENT TEST PLOTS
ALL SAMPLING EVENTS

Treatment	Monitoring Event	Slope Type	Statistic	FUNGI Length, Active (cm per g soil)	FUNGI Biomass, Active (µg per g soil)	FUNGI Hyphal Diameter (µm)	BACTERIA Number, Active (count per g soil)	BACTERIA Biomass, Active (µg per g soil)	FUNGI/ BACTERIA RATIO	PROTOZOA Flagellates (count per g soil)	PROTOZOA Amoebae (count per g soil)	PROTOZOA Ciliates (count per g soil)	VAM(2) % Root
Coconut ECB (CB)	Event 1 - Fall 1998	Fill	Mean	28.56	0.83	3.00	2.8E+07	5.53	0.10	1.9E+03	2.5E+03	2.1E+01	5.28
			Std. Dev.	40.39	1.17	N/A	1.0E+07	2.05	0.14	2.0E+03	1.9E+03	2.0E+01	3.79
		Cut	Mean	18.79	0.38	2.50	1.1E+07	2.19	0.14	2.7E+03	2.5E+03	2.1E+02	27.25
			Std. Dev.	26.57	0.53	N/A	2.0E+06	0.41	0.20	1.7E+03	2.5E+03	2.6E+02	17.35
	Event 2 - Spring 1999	Fill	Mean	127.48	1.34	1.67	2.9E+07	5.73	0.20	4.6E+03	1.3E+03	6.9E+01	24.00
			Std. Dev.	68.29	1.07	0.24	1.3E+07	2.50	0.08	1.3E+03	1.2E+03	5.5E+01	14.97
		Cut	Mean	145.01	1.76	1.83	2.9E+07	5.77	0.29	2.6E+03	1.6E+05	1.4E+01	32.33
			Std. Dev.	62.35	0.96	0.24	2.4E+06	0.48	0.15	1.6E+03	2.2E+05	1.1E+01	11.67
	Event 3 - Spring 2000	Fill	Mean	64.24	0.47	1.50	1.9E+07	3.86	0.13	2.1E+03	2.5E+03	1.5E+01	18.67
			Std. Dev.	17.00	0.12	0.00	6.7E+06	1.34	0.02	6.2E+02	1.8E+03	1.7E+01	16.82
		Cut	Mean	85.16	0.80	1.67	1.4E+07	2.85	0.34	2.0E+03	1.1E+03	4.1E+00	10.33
			Std. Dev.	65.08	0.57	0.24	3.4E+06	0.69	0.24	7.1E+02	8.1E+02	2.9E+00	8.18
Coir Netting (COIR)	Event 1 - Fall 1998	Fill	Mean	94.15	1.89	2.50	2.3E+07	4.62	0.45	6.9E+02	1.8E+03	3.7E+01	12.02
			Std. Dev.	57.75	1.16	N/A	3.5E+06	0.69	0.33	5.4E+02	2.1E+03	2.3E+01	8.85
		Cut	Mean	79.58	1.60	2.50	8.5E+06	1.70	0.59	6.8E+02	9.5E+02	1.1E+02	16.29
			Std. Dev.	112.55	2.27	N/A	3.6E+06	0.72	0.83	6.0E+02	1.3E+03	1.3E+02	15.09
	Event 2 - Spring 1999	Fill	Mean	196.22	1.42	1.50	3.6E+07	7.20	0.20	6.5E+03	1.9E+03	2.8E+01	18.67
			Std. Dev.	28.94	0.21	N/A	3.0E+06	0.59	0.03	5.8E+03	9.5E+02	1.7E+01	12.26
		Cut	Mean	159.52	2.31	2.00	2.4E+07	4.70	0.53	1.6E+06	6.3E+03	3.2E+01	24.33
			Std. Dev.	44.28	1.50	0.41	5.8E+06	1.18	0.36	2.2E+06	6.1E+03	3.5E+01	4.50
	Event 3 - Spring 2000	Fill	Mean	98.96	0.72	1.50	1.9E+07	3.82	0.18	4.0E+03	8.3E+03	4.2E+01	8.67
			Std. Dev.	52.33	0.38	0.00	4.6E+06	0.93	0.06	1.9E+03	4.2E+03	3.3E+01	6.18
		Cut	Mean	36.17	0.26	1.50	8.5E+06	1.69	0.14	8.4E+02	1.4E+03	1.3E+01	17.67
			Std. Dev.	24.77	0.18	0.00	4.7E+06	0.93	0.05	405.59	1104.37	14.88	6.13

Table 6-2A (Continued)
SOIL MICROBIAL DATA - IRRIGATED PLANT ESTABLISHMENT TEST PLOTS
ALL SAMPLING EVENTS

Treatment	Monitoring Event	Slope Type	Statistic	FUNGI Length, Active (cm per g soil)	FUNGI Biomass, Active (µg per g soil)	FUNGI Hyphal Diameter (µm)	BACTERIA Number, Active (count per g soil)	BACTERIA Biomass, Active (µg per g soil)	FUNGI/ BACTERIA RATIO	PROTOZOA Flagellates (count per g soil)	PROTOZOA Amoebae (count per g soil)	PROTOZOA Ciliates (count per g soil)	VAM(2) % Root
Compost (COMP)	Event 1 - Fall 1998	Fill	Mean	14.18	0.18	2.00	2.1E+07	4.13	0.04	6.3E+03	3.5E+03	2.0E+01	14.72
			Std. Dev.	11.57	0.15	N/A	3.2E+06	0.64	0.03	5.8E+03	2.5E+03	2.0E+01	10.42
		Cut	Mean	76.72	1.54	2.50	1.2E+07	2.45	0.55	1.7E+03	1.6E+03	5.7E+01	19.68
			Std. Dev.	54.29	1.09	N/A	5.1E+06	1.01	0.42	9.7E+02	9.5E+02	4.7E+01	13.92
	Event 2 - Spring 1999	Fill	Mean	230.76	2.43	1.67	3.9E+07	7.87	0.28	3.1E+03	4.7E+03	1.2E+02	13.00
			Std. Dev.	122.95	1.95	0.24	6.4E+06	1.27	0.18	1.4E+03	3.4E+03	1.2E+02	9.27
		Cut	Mean	106.08	1.23	1.83	2.8E+07	5.57	0.21	1.9E+03	3.7E+03	1.5E+01	40.67
			Std. Dev.	30.22	0.55	0.24	6.5E+06	1.29	0.06	2.0E+03	1.7E+03	1.2E+01	9.18
	Event 3 - Spring 2000	Fill	Mean	178.26	1.29	1.50	2.7E+07	5.35	0.32	2.9E+03	6.8E+03	7.5E+00	14.33
			Std. Dev.	31.93	0.23	0.00	1.2E+07	2.40	0.18	1.4E+03	1.4E+03	2.1E+00	7.85
		Cut	Mean	77.98	0.57	1.50	1.1E+07	2.10	0.28	4.3E+03	2.9E+03	7.0E+00	15.33
			Std. Dev.	41.68	0.30	0.00	3.3E+06	0.67	0.14	2.9E+03	3.2E+03	6.0E+00	2.62
Curled Wood Fiber (CWFB)	Event 1 - Fall 1998	Fill	Mean	19.15	0.39	2.50	2.3E+07	4.57	0.08	2.1E+03	1.7E+03	7.3E+01	8.71
			Std. Dev.	27.09	0.55	N/A	6.1E+06	1.23	0.11	2.0E+03	2.1E+03	6.5E+01	6.55
		Cut	Mean	207.42	4.17	2.50	1.6E+07	3.29	1.18	6.4E+03	4.1E+02	3.3E+01	23.10
			Std. Dev.	273.46	5.50	N/A	3.8E+06	0.76	1.49	5.7E+03	1.9E+02	1.9E+01	12.30
	Event 2 - Spring 1999	Fill	Mean	160.09	1.93	1.83	3.1E+07	6.27	0.30	2.8E+03	4.6E+03	7.5E+01	19.00
			Std. Dev.	61.79	0.99	0.24	2.7E+06	0.52	0.15	1.4E+03	1.3E+03	1.9E+01	13.93
		Cut	Mean	173.46	1.96	1.83	2.7E+07	5.40	0.37	1.2E+04	2.3E+04	4.2E+01	29.33
			Std. Dev.	22.16	0.65	0.24	4.0E+06	0.78	0.15	1.2E+04	1.5E+04	3.6E+01	11.95
	Event 3 - Spring 2000	Fill	Mean	165.17	1.20	1.50	2.1E+07	4.16	0.28	3.9E+03	2.6E+03	2.0E+01	19.33
			Std. Dev.	74.96	0.54	0.00	3.4E+06	0.69	0.09	1.5E+03	1.6E+03	2.0E+01	10.34
		Cut	Mean	121.31	1.36	1.67	1.0E+07	2.08	0.61	4.3E+03	4.8E+03	3.3E+01	14.33
			Std. Dev.	93.61	1.35	0.24	2.6E+06	0.53	0.53	2.6E+03	3.3E+03	3.7E+01	7.04

Table 6-2A (Continued)
SOIL MICROBIAL DATA - IRRIGATED PLANT ESTABLISHMENT TEST PLOTS
ALL SAMPLING EVENTS

Treatment	Monitoring Event	Slope Type	Statistic	FUNGI			BACTERIA		FUNGI/ BACTERIA RATIO	PROTOZOA			VAM(2) % Root
				Length, Active	Biomass, Active	Hyphal Diameter	Number, Active	Biomass, Active		Flagellates	Amoebae	Ciliates	
				cm per g soil	µg per g soil	µm	count per g soil	µg per g soil		count per g soil	count per g soil	count per g soil	
Gypsum, Rate 1 (GYP1)	Event 1 - Fall 1998	Fill	Mean	28.68	0.51	2.25	2.2E+07	4.36	0.12	2.1E+03	1.6E+03	5.0E+02	5.88
			Std. Dev.	23.36	0.48	0.25	3.7E+06	0.74	0.10	2.0E+03	2.2E+03	6.6E+02	5.13
		Cut	Mean	94.23	1.90	2.50	1.5E+07	2.93	0.54	2.5E+03	1.6E+03	3.0E+01	18.01
			Std. Dev.	133.26	2.68	N/A	4.3E+06	0.86	0.76	1.5E+03	9.2E+02	1.5E+00	20.94
	Event 2 - Spring 1999	Fill	Mean	77.86	0.75	1.83	2.8E+07	5.63	0.15	6.7E+03	1.9E+03	6.6E+01	21.67
			Std. Dev.	48.39	0.32	0.47	7.0E+06	1.44	0.08	5.9E+03	6.9E+02	1.7E+01	4.64
		Cut	Mean	339.87	4.82	2.00	2.3E+07	4.57	1.14	2.7E+03	1.5E+05	2.0E+00	28.00
			Std. Dev.	182.65	2.76	0.41	4.5E+06	0.90	0.79	1.7E+03	2.0E+05	2.9E+00	11.22
	Event 3 - Spring 2000	Fill	Mean	82.82	0.60	1.50	1.7E+07	3.39	0.19	4.1E+03	1.1E+04	2.0E+00	20.33
			Std. Dev.	66.91	0.48	0.00	3.7E+06	0.75	0.16	3.4E+03	1.3E+04	2.9E+00	8.96
		Cut	Mean	55.84	0.63	1.17	1.4E+07	2.80	0.20	1.2E+03	1.8E+03	2.0E+00	41.00
			Std. Dev.	48.20	0.65	0.85	1.9E+06	0.38	0.19	4.0E+02	1.4E+03	2.9E+00	32.14
Gypsum, Rate 2 (GYP2)	Event 1 - Fall 1998	Fill	Mean	61.48	1.24	2.50	2.6E+07	5.21	0.32	1.6E+04	2.5E+03	8.8E+01	9.57
			Std. Dev.	46.83	0.94	N/A	9.8E+06	1.95	0.23	2.2E+04	1.9E+03	5.0E+01	8.19
		Cut	Mean	140.78	2.83	2.50	1.2E+07	2.36	1.01	2.6E+03	1.2E+04	3.5E+01	20.97
			Std. Dev.	105.06	2.11	N/A	3.2E+06	0.63	0.73	1.5E+03	1.2E+04	8.2E+00	22.62
	Event 2 - Spring 1999	Fill	Mean	194.42	1.91	1.67	3.0E+07	6.00	0.40	6.5E+03	2.7E+03	7.1E+01	21.33
			Std. Dev.	61.36	1.10	0.24	1.7E+07	3.40	0.26	5.9E+03	1.9E+03	5.3E+01	14.38
		Cut	Mean	67.42	0.49	1.50	2.7E+07	5.33	0.09	1.5E+03	2.5E+03	1.7E+03	30.33
			Std. Dev.	24.35	0.18	N/A	1.9E+06	0.37	0.03	1.1E+03	2.5E+03	2.3E+03	14.82
	Event 3 - Spring 2000	Fill	Mean	105.34	0.76	1.50	1.8E+07	3.61	0.21	1.1E+04	6.2E+03	1.0E+01	10.33
			Std. Dev.	24.94	0.18	0.00	3.0E+06	0.59	0.04	7.8E+03	3.4E+03	1.1E+01	9.10
		Cut	Mean	95.66	0.96	1.67	1.3E+07	2.58	0.39	1.6E+03	3.2E+03	2.9E+01	19.00
			Std. Dev.	32.42	0.61	0.24	4.2E+06	0.83	0.21	1.0E+03	2.2E+03	1.0E+01	0.82

Table 6-2A (Continued)
SOIL MICROBIAL DATA - IRRIGATED PLANT ESTABLISHMENT TEST PLOTS
ALL SAMPLING EVENTS

Treatment	Monitoring Event	Slope Type	Statistic	FUNGI Length, Active (cm per g soil)	FUNGI Biomass, Active (µg per g soil)	FUNGI Hyphal Diameter (µm)	BACTERIA Number, Active (count per g soil)	BACTERIA Biomass, Active (µg per g soil)	FUNGI/ BACTERIA RATIO	PROTOZOA Flagellates (count per g soil)	PROTOZOA Amoebae (count per g soil)	PROTOZOA Ciliates (count per g soil)	VAM(2) % Root
Paper Mulch and Psyllium Tackifier (PMG)	Event 1 - Fall 1998	Fill	Mean	9.58	0.19	2.50	2.4E+07	4.85	0.05	2.2E+03	4.3E+02	1.6E+03	4.35
			Std. Dev.	6.77	0.14	N/A	5.6E+06	1.12	0.04	1.8E+03	3.1E+02	2.2E+03	6.15
		Cut	Mean	1205.87	24.27	2.50	9.2E+06	1.84	10.21	3.0E+03	3.6E+03	1.6E+01	4.17
			Std. Dev.	1700.39	34.22	N/A	2.8E+06	0.56	14.40	1.3E+03	1.6E+03	2.2E+01	5.89
	Event 2 - Spring 1999	Fill	Mean	73.17	0.70	1.67	3.1E+07	6.30	0.12	8.5E+03	1.7E+03	5.2E+01	21.33
			Std. Dev.	11.88	0.31	0.24	2.7E+06	0.54	0.06	4.4E+03	3.7E+02	6.9E+00	8.99
		Cut	Mean	82.79	0.60	1.50	3.2E+07	6.30	0.09	8.5E+02	1.1E+04	1.1E+02	37.33
			Std. Dev.	25.76	0.19	N/A	7.4E+06	1.50	0.02	4.4E+02	1.3E+04	1.4E+02	11.26
	Event 3 - Spring 2000	Fill	Mean	96.27	0.70	1.50	2.5E+07	5.06	0.15	4.6E+03	3.8E+03	3.8E+01	15.00
			Std. Dev.	13.03	0.09	0.00	5.6E+06	1.12	0.05	1.3E+03	2.3E+03	7.9E+00	12.57
		Cut	Mean	66.15	0.48	1.50	1.5E+07	2.95	0.16	2.0E+03	8.2E+02	4.1E+00	21.33
			Std. Dev.	16.29	0.12	0.00	3.4E+06	0.67	0.01	7.1E+02	4.7E+02	2.9E+00	1.70
Paper Mulch and Polymer Tackifier (PMP)	Event 1 - Fall 1998	Fill	Mean	236.70	3.05	2.00	2.2E+07	4.32	1.46	2.0E+03	1.7E+03	1.1E+02	27.24
			Std. Dev.	334.75	4.31	N/A	1.1E+07	2.15	2.06	1.1E+03	2.1E+03	7.3E+01	18.91
		Cut	Mean	72.29	1.45	2.50	1.5E+07	3.08	0.32	2.7E+03	1.6E+03	2.1E+01	22.28
			Std. Dev.	102.23	2.06	N/A	7.1E+06	1.41	0.45	1.7E+03	9.2E+02	1.1E+01	11.49
	Event 2 - Spring 1999	Fill	Mean	195.72	2.07	1.67	3.2E+07	6.40	0.27	3.5E+03	3.7E+03	2.9E+01	17.33
			Std. Dev.	127.62	1.78	0.24	1.4E+07	2.85	0.17	9.0E+02	1.6E+03	8.2E-02	7.59
		Cut	Mean	95.32	1.09	1.83	2.9E+07	5.77	0.19	1.7E+04	1.7E+04	3.1E+01	31.33
			Std. Dev.	17.49	0.41	0.24	1.9E+06	0.39	0.07	2.2E+04	2.1E+04	3.5E+01	8.18
	Event 3 - Spring 2000	Fill	Mean	124.20	0.90	1.50	2.2E+07	4.37	0.20	1.7E+04	6.1E+03	2.5E+01	11.00
			Std. Dev.	48.80	0.35	0.00	2.2E+06	0.43	0.06	2.0E+04	1.8E+03	1.4E+01	3.56
		Cut	Mean	136.02	1.75	2.00	1.4E+07	2.73	0.67	2.0E+03	2.7E+03	2.1E+00	13.67
			Std. Dev.	82.80	1.07	0.00	2.2E+06	0.44	0.47	6.0E+02	2.5E+03	2.9E+00	10.08

Table 6-2A (Continued)
SOIL MICROBIAL DATA - IRRIGATED PLANT ESTABLISHMENT TEST PLOTS
ALL SAMPLING EVENTS

Treatment	Monitoring Event	Slope Type	Statistic	FUNGI Length, Active (cm per g soil)	FUNGI Biomass, Active (µg per g soil)	FUNGI Hyphal Diameter (µm)	BACTERIA Number, Active (count per g soil)	BACTERIA Biomass, Active (µg per g soil)	FUNGI/ BACTERIA RATIO	PROTOZOA Flagellates (count per g soil)	PROTOZOA Amoebae (count per g soil)	PROTOZOA Ciliates (count per g soil)	VAM(2) % Root
Wheat Straw	Event 1 - Fall 1998	Fill	Mean	90.11	1.50	2.17	2.1E+07	4.29	0.33	4.5E+02	1.1E+03	8.3E+01	0.00
			Std. Dev.	63.96	1.17	0.24	3.4E+06	0.68	0.24	1.3E+02	1.2E+03	6.8E+01	0.00
		Cut	Mean	14.19	0.29	2.50	8.1E+06	1.63	0.15	2.9E+03	3.6E+03	4.8E+02	20.33
			Std. Dev.	11.47	0.23	N/A	2.0E+06	0.40	0.13	2.1E+03	2.5E+03	6.6E+02	14.40
	Event 2 - Spring 1999	Fill	Mean	124.71	1.89	1.50	2.2E+07	4.33	0.36	3.7E+03	3.0E+03	4.7E+01	27.00
			Std. Dev.	105.60	1.40	1.08	1.6E+07	3.15	0.29	1.6E+03	1.4E+03	3.3E+01	24.91
		Cut	Mean	145.59	2.35	2.00	2.7E+07	5.47	0.42	4.3E+03	6.8E+03	2.9E+01	31.33
			Std. Dev.	76.25	1.89	0.41	4.9E+06	0.98	0.35	3.1E+03	5.5E+03	2.1E+01	7.36
	Event 3 - Spring 2000	Fill	Mean	34.13	0.25	1.50	1.3E+07	2.63	0.09	8.6E+02	1.3E+03	1.1E+01	19.67
			Std. Dev.	18.01	0.13	0.00	5.6E+06	1.12	0.02	4.3E+02	1.1E+03	1.2E+01	4.50
		Cut	Mean	117.76	0.85	1.50	1.6E+07	3.25	0.28	4.0E+03	1.3E+04	1.4E+01	14.00
			Std. Dev.	37.96	0.28	0.00	3.4E+06	0.69	0.13	8.0E+02	1.1E+04	6.8E+00	10.03
Straw ECB (SB)	Event 1 - Fall 1998	Fill	Mean	9.53	0.12	2.00	2.7E+07	5.31	0.05	1.8E+03	3.0E+03	2.7E+02	16.93
			Std. Dev.	13.48	0.17	N/A	9.9E+06	1.98	0.07	1.8E+03	2.4E+03	1.7E+02	12.07
		Cut	Mean	14.19	0.41	3.00	8.3E+06	1.66	0.31	7.2E+02	1.6E+03	2.8E+01	21.01
			Std. Dev.	20.06	0.58	N/A	1.2E+06	0.25	0.44	5.4E+02	9.4E+02	2.0E+01	15.37
	Event 2 - Spring 1999	Fill	Mean	203.90	2.74	2.00	3.5E+07	7.03	0.38	1.1E+04	3.5E+03	3.6E+01	24.00
			Std. Dev.	165.18	2.14	0.41	2.3E+06	0.48	0.27	1.3E+04	1.9E+03	8.9E+00	6.98
		Cut	Mean	121.65	0.88	1.50	3.0E+07	5.93	0.15	2.3E+03	3.6E+03	1.1E+02	34.33
			Std. Dev.	19.33	0.14	N/A	4.5E+06	0.90	0.01	1.8E+03	9.5E+02	1.3E+02	5.25
	Event 3 - Spring 2000	Fill	Mean	140.25	1.02	1.50	2.3E+07	4.50	0.23	3.5E+03	2.3E+03	2.9E+01	16.67
			Std. Dev.	48.18	0.35	0.00	1.7E+06	0.34	0.10	9.1E+02	1.8E+03	3.7E+01	3.30
		Cut	Mean	25.42	0.18	1.50	1.3E+07	2.70	0.06	5.7E+02	3.4E+03	7.0E+00	14.67
			Std. Dev.	17.28	0.13	0.00	2.4E+06	0.47	0.03	6.2E+01	3.9E+03	6.0E+00	5.56

Table 6-2A (Continued)
SOIL MICROBIAL DATA - IRRIGATED PLANT ESTABLISHMENT TEST PLOTS
ALL SAMPLING EVENTS

Treatment	Monitoring Event	Slope Type	Statistic	FUNGI Length, Active (cm per g soil)	FUNGI Biomass, Active (µg per g soil)	FUNGI Hyphal Diameter (µm)	BACTERIA Number, Active (count per g soil)	BACTERIA Biomass, Active (µg per g soil)	FUNGI/ BACTERIA RATIO	PROTOZOA Flagellates (count per g soil)	PROTOZOA Amoebae (count per g soil)	PROTOZOA Ciliates (count per g soil)	VAM[(2)] % Root
Straw/Coconut ECB (SCB)	Event 1 - Fall 1998	Fill	Mean	42.81	0.62	2.17	1.4E+07	2.75	0.22	3.2E+03	9.0E+02	2.1E+01	4.62
			Std. Dev.	31.01	0.38	0.24	2.5E+06	0.50	0.12	2.2E+03	9.4E+02	1.1E+01	4.39
		Cut	Mean	66.98	1.35	2.50	1.3E+07	2.65	0.52	1.2E+03	3.1E+03	5.8E+01	11.31
			Std. Dev.	6.25	0.13	N/A	1.7E+06	0.34	0.11	1.1E+03	2.2E+03	6.3E+01	8.21
	Event 2 - Spring 1999	Fill	Mean	126.28	0.87	1.33	3.4E+07	6.73	0.11	3.0E+04	1.1E+04	9.6E+01	16.67
			Std. Dev.	68.55	0.55	0.24	1.6E+07	3.12	0.06	4.1E+04	1.3E+04	6.1E+01	3.86
		Cut	Mean	107.14	1.25	1.83	3.1E+07	6.20	0.24	3.8E+03	8.5E+02	3.1E+01	26.33
			Std. Dev.	26.13	0.52	0.24	1.7E+07	3.33	0.13	2.3E+03	4.3E+02	1.4E+01	7.93
	Event 3 - Spring 2000	Fill	Mean	84.40	0.61	1.50	1.9E+07	3.73	0.17	1.0E+04	3.3E+03	4.0E+01	18.00
			Std. Dev.	11.57	0.08	0.00	5.7E+06	1.13	0.04	1.3E+04	1.9E+03	7.5E+00	9.63
		Cut	Mean	51.01	0.37	1.50	1.4E+07	2.83	0.14	1.8E+03	1.1E+03	1.1E+01	14.00
			Std. Dev.	27.06	0.20	0.00	1.7E+06	0.34	0.07	1.6E+03	4.6E+02	1.6E+01	10.03
Wood Fiber ECB (WFB)	Event 1 - Fall 1998	Fill	Mean	28.60	0.70	2.75	2.2E+07	4.40	0.28	3.3E+03	1.4E+03	2.4E+01	24.94
			Std. Dev.	20.23	0.52	0.25	1.1E+07	2.29	0.32	1.7E+03	7.7E+00	6.9E+00	12.41
		Cut	Mean	9.36	0.19	2.50	1.0E+07	2.06	0.07	2.3E+03	2.0E+03	1.8E+02	14.15
			Std. Dev.	13.24	0.27	N/A	2.4E+06	0.48	0.10	1.8E+03	1.9E+03	2.1E+02	8.95
	Event 2 - Spring 1999	Fill	Mean	91.73	0.65	1.33	3.3E+07	6.67	0.08	4.9E+03	3.8E+03	3.9E+01	32.00
			Std. Dev.	99.42	0.73	0.24	1.2E+07	2.37	0.07	2.9E+03	2.3E+03	3.6E+01	6.68
		Cut	Mean	96.97	1.11	1.83	3.2E+07	6.40	0.19	1.7E+04	5.8E+03	8.4E+01	26.33
			Std. Dev.	25.31	0.48	0.24	5.4E+06	1.07	0.12	2.2E+04	6.2E+03	4.5E+01	11.90
	Event 3 - Spring 2000	Fill	Mean	128.26	0.93	1.50	1.9E+07	3.74	0.25	1.0E+04	3.4E+03	3.1E+01	12.33
			Std. Dev.	26.98	0.20	0.00	3.9E+05	0.08	0.06	8.9E+03	7.3E+02	4.0E+01	2.05
		Cut	Mean	62.75	0.45	1.50	1.5E+07	3.10	0.14	9.7E+02	1.1E+03	1.6E+01	22.67
			Std. Dev.	48.81	0.35	0.00	1.7E+06	0.33	0.10	8.2E+02	6.1E+02	1.3E+01	1.25

Table 6-2A (Continued)
SOIL MICROBIAL DATA - IRRIGATED PLANT ESTABLISHMENT TEST PLOTS
ALL SAMPLING EVENTS

Treatment	Monitoring Event	Slope Type	Statistic	FUNGI Length, Active (cm per g soil)	FUNGI Biomass, Active (µg per g soil)	FUNGI Hyphal Diameter (µm)	BACTERIA Number, Active (count per g soil)	BACTERIA Biomass, Active (µg per g soil)	FUNGI/ BACTERIA RATIO	PROTOZOA Flagellates (count per g soil)	PROTOZOA Amoebae (count per g soil)	PROTOZOA Ciliates (count per g soil)	VAM(2) % Root
Wood Mulch and Psyllium Tackifier (WMG)	Event 1 - Fall 1998	Fill	Mean	47.21	0.95	2.50	2.1E+07	4.11	0.43	2.5E+03	2.4E+03	2.4E+01	21.10
			Std. Dev.	66.77	1.34	N/A	9.1E+06	1.82	0.61	2.4E+03	1.7E+03	1.8E+01	17.75
		Cut	Mean	42.40	0.85	2.50	1.4E+07	2.84	0.36	3.7E+03	2.2E+03	3.5E+01	9.23
			Std. Dev.	19.69	0.40	N/A	3.2E+06	0.65	0.26	2.2E+03	1.8E+03	8.4E+00	3.47
	Event 2 - Spring 1999	Fill	Mean	106.35	1.10	1.17	2.6E+07	5.30	0.15	5.7E+03	5.5E+03	6.3E+01	22.67
			Std. Dev.	76.10	0.92	0.85	1.2E+07	2.46	0.12	7.2E+03	2.4E+03	5.8E+01	12.97
		Cut	Mean	154.69	2.56	2.17	2.7E+07	5.33	0.49	1.6E+03	3.0E+03	3.1E+01	16.33
			Std. Dev.	56.10	1.52	0.24	2.6E+06	0.54	0.32	2.0E+03	1.4E+03	1.4E+01	1.25
	Event 3 - Spring 2000	Fill	Mean	100.94	0.73	1.50	1.9E+07	3.80	0.20	2.4E+03	5.6E+03	3.0E+01	10.00
			Std. Dev.	23.82	0.17	0.00	4.7E+06	0.95	0.06	6.9E+02	1.2E+03	2.3E+01	4.24
		Cut	Mean	127.95	1.39	1.67	1.7E+07	3.39	0.38	2.5E+03	3.0E+03	2.6E+01	13.33
			Std. Dev.	83.59	1.26	0.24	2.7E+06	0.55	0.32	1.8E+03	2.2E+03	2.0E+01	9.98
Wood Mulch and Polymer Tackifier (WMP)	Event 1 - Fall 1998	Fill	Mean	0.00	0.00	N/A	1.4E+07	2.79	0.00	5.5E+03	5.3E+03	4.4E+01	11.11
			Std. Dev.	0.00	0.00	N/A	6.9E+06	1.37	0.00	2.6E+03	6.3E+03	3.5E+01	7.86
		Cut	Mean	28.87	0.58	2.50	2.1E+07	4.22	0.09	3.4E+03	2.1E+03	4.4E+01	18.59
			Std. Dev.	40.82	0.82	N/A	9.1E+06	1.83	0.13	1.8E+03	1.1E+03	2.7E+01	7.49
	Event 2 - Spring 1999	Fill	Mean	135.47	1.48	1.17	2.2E+07	4.47	0.23	1.7E+03	4.2E+03	1.3E+02	14.00
			Std. Dev.	107.17	1.41	0.85	1.2E+07	2.43	0.19	9.5E+02	9.0E+02	1.2E+02	8.16
		Cut	Mean	112.21	1.36	1.83	2.4E+07	4.77	0.30	3.2E+03	2.1E+03	8.4E+01	42.33
			Std. Dev.	107.99	1.45	0.24	3.9E+06	0.76	0.33	1.8E+03	9.1E+02	4.5E+01	9.74
	Event 3 - Spring 2000	Fill	Mean	89.25	0.65	1.50	1.7E+07	3.30	0.20	3.5E+03	3.4E+03	4.6E+01	12.33
			Std. Dev.	15.36	0.11	0.00	2.0E+06	0.41	0.06	1.8E+03	1.9E+03	2.7E+01	8.18
		Cut	Mean	62.53	0.45	1.50	1.6E+07	3.29	0.14	7.4E+02	7.4E+02	4.1E+00	20.00
			Std. Dev.	46.04	0.33	0.00	2.3E+06	0.46	0.10	5.2E+02	5.1E+02	2.9E+00	4.08

Table 6-2B
SOIL MICROBIAL DATA - NON-IRRIGATED PLANT ESTABLISHMENT TEST PLOTS
ALL SAMPLING EVENTS

Treatment	Monitoring Event	Statistic	Slope Type	FUNGI Length, Active (cm per g soil)	FUNGI Biomass, Active (µg per g soil)	FUNGI Hyphal Diameter (µm)	BACTERIA Number, Active (count per g soil)	BACTERIA Biomass, Active (µg per g soil)	FUNGI/ BACTERIA RATIO	PROTOZOA Flagellates (count per g soil)	PROTOZOA Amoebae (count per g soil)	PROTOZOA Ciliates (count per g soil)	VAM(2) % ROOT
No Treatment (Bare)	Event 1 - Fall 1998	Fill	Mean	7.51	0.22	3.00	1.2E+07	2.40	0.07	2.9E+04	1.8E+03	0.0E+00	8.33
			Std. Dev.	10.62	0.31	N/A	2.3E+06	0.46	0.10	2.3E+04	2.0E+03	0.0E+00	11.79
		Cut	Mean	14.21	0.23	2.00	1.4E+07	2.89	0.07	5.0E+02	4.7E+03	3.9E+01	20.09
			Std. Dev.	11.61	0.25	0.50	2.3E+06	0.46	0.07	3.4E+02	6.7E+03	5.6E+01	5.64
	Event 2 - Spring 1999	Fill	Mean	108.12	0.85	1.50	3.0E+07	6.00	0.20	4.6E+03	2.6E+03	3.1E+01	4.33
			Std. Dev.	13.66	0.66	0.71	8.3E+06	1.67	0.21	1.3E+03	1.6E+03	1.4E+01	3.30
		Cut	Mean	41.99	0.39	1.67	1.1E+07	2.20	0.17	4.0E+03	3.9E+03	3.7E+01	22.67
			Std. Dev.	14.61	0.16	0.24	1.3E+06	0.29	0.07	1.8E+03	2.2E+03	2.3E+01	12.66
	Event 3 - Spring 2000	Fill	Mean	123.68	0.90	1.50	1.6E+07	3.28	0.28	5.2E+03	4.6E+03	3.0E+01	3.33
			Std. Dev.	10.50	0.08	0.00	9.7E+05	0.19	0.04	5.5E+02	1.7E+02	1.7E+01	2.62
		Cut	Mean	75.65	1.40	1.50	1.7E+07	3.31	0.37	8.2E+03	1.3E+04	2.9E+01	24.67
			Std. Dev.	74.47	1.55	1.08	5.3E+06	1.06	0.32	4.6E+03	1.1E+04	2.1E+01	7.59
Bonded Fiber Matrix (BFM)	Event 1 - Fal 1998	Fill	Mean	0.00	0.00	N/A	1.2E+07	2.33	0.00	1.6E+05	1.5E+03	0.0E+00	24.21
			Std. Dev.	0.00	0.00	N/A	1.2E+06	0.24	0.00	2.2E+05	1.0E+03	0.0E+00	17.16
		Cut	Mean	4.77	0.06	2.00	1.8E+07	3.51	0.02	5.1E+02	9.6E+02	2.2E+01	13.30
			Std. Dev.	6.74	0.09	N/A	3.6E+06	0.72	0.02	5.4E+01	1.3E+03	1.5E+01	15.33
	Event 2 - Spring 1999	Fill	Mean	184.88	2.66	1.83	4.8E+07	9.60	0.35	3.1E+03	6.7E+03	1.8E+02	10.00
			Std. Dev.	141.98	1.95	0.62	1.9E+07	3.85	0.28	2.4E+03	6.2E+03	2.2E+02	10.20
		Cut	Mean	64.58	0.66	1.67	1.5E+07	2.93	0.20	1.7E+04	2.9E+03	3.4E+01	21.67
			Std. Dev.	41.09	0.52	0.24	1.1E+07	2.13	0.10	2.2E+04	1.2E+03	1.9E+01	10.53
	Event 3 - Spring 2000	Fill	Mean	107.70	0.78	1.50	2.3E+07	4.69	0.17	6.7E+03	8.0E+03	2.2E+01	6.67
			Std. Dev.	31.93	0.23	0.00	1.7E+06	0.33	0.06	5.9E+03	5.7E+03	1.1E+01	2.87
		Cut	Mean	86.35	1.00	1.83	1.7E+07	3.30	0.31	1.7E+03	2.8E+03	7.0E+00	19.00
			Std. Dev.	2.79	0.54	0.47	1.8E+06	0.36	0.18	9.6E+02	1.8E+03	6.1E+00	4.90

Table 6-2B (Continued)
SOIL MICROBIAL DATA - IRRIGATED PLANT ESTABLISHMENT TEST PLOTS
ALL SAMPLING EVENTS

Treatment	Monitoring Event	Statistic	Slope Type	FUNGI Length, Active (cm per g soil)	FUNGI Biomass, Active (µg per g soil)	FUNGI Hyphal Diameter (µm)	BACTERIA Number, Active (count per g soil)	BACTERIA Biomass, Active (µg per g soil)	FUNGI/ BACTERIA RATIO	PROTOZOA Flagellates (count per g soil)	PROTOZOA Amoebae (count per g soil)	PROTOZOA Ciliates (count per g soil)	VAM(2) % ROOT
Coconut ECB (CB)	Event 1 - Fall 1998	Fill	Mean	0.00	0.00	N/A	9.5E+06	1.89	0.00	5.8E+04	1.6E+04	0.0E+00	4.24
			Std. Dev.	0.00	0.00	N/A	2.3E+06	0.46	0.00	6.3E+04	2.3E+04	0.0E+00	3.01
		Cut	Mean	66.50	1.68	2.67	1.4E+07	2.85	0.85	1.8E+03	2.1E+03	5.5E+01	18.46
			Std. Dev.	40.86	1.24	0.24	5.6E+06	1.13	0.89	1.0E+03	1.9E+03	6.3E+01	11.74
	Event 2 - Spring 1999	Fill	Mean	116.70	0.67	1.67	3.6E+07	7.10	0.10	8.7E+02	3.6E+03	2.2E+01	26.00
			Std. Dev.	75.41	0.17	0.62	1.4E+07	2.77	0.03	4.4E+02	1.9E+03	2.1E+01	21.23
		Cut	Mean	43.22	0.31	1.50	1.7E+07	3.30	0.09	2.3E+03	2.3E+04	1.2E+02	15.33
			Std. Dev.	34.35	0.25	N/A	9.6E+06	1.90	0.02	1.8E+03	2.6E+04	1.3E+02	10.87
	Event 3 - Spring 2000	Fill	Mean	74.32	0.54	1.50	2.1E+07	4.28	0.12	2.1E+03	8.6E+03	2.0E+01	10.33
			Std. Dev.	30.50	0.22	0.00	5.1E+06	1.02	0.02	1.7E+03	5.3E+03	1.4E+01	1.70
		Cut	Mean	84.04	1.27	1.83	1.9E+07	3.73	0.27	2.6E+03	5.2E+03	4.2E+01	17.00
			Std. Dev.	51.45	1.29	0.47	6.5E+06	1.30	0.21	1.6E+03	6.5E+02	1.4E+01	5.72
Coir Netting (COIR)	Event 1 - Fall 1998	Fill	Mean	0.00	0.00	N/A	8.4E+06	1.68	0.00	2.7E+05	1.7E+04	0.0E+00	1.23
			Std. Dev.	0.00	0.00	N/A	3.9E+06	0.78	0.00	1.8E+05	1.5E+04	0.0E+00	1.75
		Cut	Mean	62.32	0.94	2.25	1.2E+07	2.43	0.38	4.4E+02	3.6E+02	1.3E+01	30.18
			Std. Dev.	52.96	0.70	0.25	3.2E+06	0.64	0.32	1.2E+02	2.6E+02	1.4E+01	9.56
	Event 2 - Spring 1999	Fill	Mean	114.02	1.94	2.33	3.0E+07	6.00	0.31	5.5E+04	2.1E+05	2.1E+00	20.67
			Std. Dev.	71.20	1.34	0.24	1.5E+07	3.06	0.21	7.5E+04	2.9E+05	2.9E+00	18.21
		Cut	Mean	116.79	1.37	1.83	1.8E+07	3.53	0.56	2.7E+03	4.6E+03	3.6E+01	28.67
			Std. Dev.	43.91	0.72	0.24	9.5E+06	1.89	0.37	1.8E+03	3.4E+03	1.5E+01	9.74
	Event 3 - Spring 2000	Fill	Mean	169.10	1.23	1.50	1.2E+07	2.45	0.46	2.3E+03	4.6E+03	7.0E+00	12.67
			Std. Dev.	108.86	0.79	0.00	4.3E+06	0.87	0.18	1.8E+03	1.4E+03	6.2E+00	6.60
		Cut	Mean	79.52	0.67	1.67	1.5E+07	3.09	0.22	1.6E+04	1.1E+04	9.1E+00	19.67
			Std. Dev.	36.04	0.21	0.24	2.9E+06	0.57	0.09	20819.47	13334.00	4.10	5.19

Table 6-2B (Continued)
SOIL MICROBIAL DATA - IRRIGATED PLANT ESTABLISHMENT TEST PLOTS
ALL SAMPLING EVENTS

Treatment	Monitoring Event	Statistic	Slope Type	FUNGI Length, Active (cm per g soil)	FUNGI Biomass, Active (µg per g soil)	FUNGI Hyphal Diameter (µm)	BACTERIA Number, Active (count per g soil)	BACTERIA Biomass, Active (µg per g soil)	FUNGI/ BACTERIA RATIO	PROTOZOA Flagellates (count per g soil)	PROTOZOA Amoebae (count per g soil)	PROTOZOA Ciliates (count per g soil)	VAM(2) % ROOT
Compost (COMP)	Event 1 - Fall 1998	Fill	Mean	0.00	0.00	N/A	1.1E+07	2.29	0.00	1.7E+05	9.9E+02	1.1E+01	3.70
			Std. Dev.	0.00	0.00	N/A	3.3E+06	0.66	0.00	2.1E+05	8.9E+02	1.6E+01	5.24
		Cut	Mean	38.36	0.77	2.50	1.6E+07	3.13	0.14	6.9E+02	1.1E+03	5.8E+01	8.51
			Std. Dev.	54.25	1.09	N/A	9.1E+06	1.82	0.19	5.7E+02	1.3E+03	1.5E+01	6.02
	Event 2 - Spring 1999	Fill	Mean	165.07	1.81	1.83	3.6E+07	7.20	0.27	7.0E+03	3.2E+03	1.6E+01	16.67
			Std. Dev.	112.62	1.61	0.62	1.2E+07	2.38	0.20	5.6E+03	1.5E+03	2.3E+01	21.48
		Cut	Mean	61.70	0.45	1.50	1.8E+07	3.70	0.12	1.7E+03	4.1E+03	3.7E+01	24.33
			Std. Dev.	23.20	0.17	N/A	7.2E+06	1.42	0.02	8.8E+02	1.8E+03	2.6E+01	11.84
	Event 3 - Spring 2000	Fill	Mean	154.59	1.12	1.50	1.9E+07	3.79	0.29	1.5E+04	1.2E+04	1.8E+01	13.00
			Std. Dev.	50.10	0.36	0.00	1.9E+06	0.38	0.08	2.1E+04	4.1E+03	2.2E+01	9.20
		Cut	Mean	88.14	0.64	1.50	1.7E+07	3.39	0.20	2.2E+03	1.6E+04	1.7E+01	18.33
			Std. Dev.	4.21	0.03	0.00	3.9E+06	0.78	0.06	1.7E+03	2.1E+04	9.5E+00	10.34
Curled Wood Fiber (CWFB)	Event 1 - Fal 1998	Fill	Mean	0.00	0.00	N/A	1.0E+07	2.01	0.00	1.7E+05	7.8E+02	9.5E+00	16.85
			Std. Dev.	0.00	0.00	N/A	2.7E+06	0.55	0.00	2.1E+05	4.4E+02	6.8E+00	4.97
		Cut	Mean	47.36	0.61	2.00	1.5E+07	3.09	0.15	5.4E+02	1.1E+02	4.8E+00	32.56
			Std. Dev.	66.97	0.86	N/A	4.1E+06	0.82	0.21	6.0E+02	1.2E+02	6.8E+00	11.25
	Event 2 - Spring 1999	Fill	Mean	103.89	0.94	1.67	4.1E+07	8.23	0.21	4.1E+03	3.7E+03	2.7E+01	16.00
			Std. Dev.	69.45	0.56	0.62	2.1E+07	4.29	0.20	2.0E+03	2.4E+03	9.8E+00	19.87
		Cut	Mean	116.69	1.25	1.83	2.5E+07	4.93	0.46	1.2E+03	2.9E+03	4.4E+01	21.33
			Std. Dev.	13.97	0.19	0.24	1.5E+07	3.00	0.37	1.3E+03	1.9E+03	6.9E+00	7.93
	Event 3 - Spring 2000	Fill	Mean	97.27	0.70	1.50	2.1E+07	4.26	0.17	3.1E+03	1.1E+04	9.0E+00	5.33
			Std. Dev.	24.14	0.17	0.00	3.4E+06	0.69	0.04	2.2E+03	1.3E+04	4.1E+00	3.86
		Cut	Mean	79.88	1.35	2.50	2.0E+07	3.98	0.36	1.7E+04	4.1E+03	2.2E+01	17.33
			Std. Dev.	45.65	0.56	0.41	4.3E+06	0.85	0.18	2.0E+04	1.9E+03	1.7E+01	8.65

Table 6-2B (Continued)
SOIL MICROBIAL DATA - IRRIGATED PLANT ESTABLISHMENT TEST PLOTS
ALL SAMPLING EVENTS

Treatment	Monitoring Event	Statistic	Slope Type	FUNGI Length, Active (cm per g soil)	FUNGI Biomass, Active (µg per g soil)	FUNGI Hyphal Diameter (µm)	BACTERIA Number, Active (count per g soil)	BACTERIA Biomass, Active (µg per g soil)	FUNGI/ BACTERIA RATIO	PROTOZOA Flagellates (count per g soil)	PROTOZOA Amoebae (count per g soil)	PROTOZOA Ciliates (count per g soil)	VAM(2) % ROOT
Gypsum, Rate 1 (GYP1)	Event 1 - Fall 1998	Fill	Mean	0.00	0.00	N/A	1.1E+07	2.16	0.00	3.1E+04	9.8E+02	0.0E+00	11.90
			Std. Dev.	0.00	0.00	N/A	3.0E+06	0.60	0.00	2.2E+04	6.1E+02	0.0E+00	16.84
		Cut	Mean	154.24	3.03	2.33	1.9E+07	3.86	0.72	3.4E+03	1.4E+03	4.4E+01	11.27
			Std. Dev.	157.56	3.23	0.24	1.9E+06	0.39	0.72	3.7E+03	1.2E+03	3.0E+01	2.14
	Event 2 - Spring 1999	Fill	Mean	237.44	3.89	2.17	4.4E+07	8.77	0.49	2.2E+03	3.1E+03	3.4E+01	18.33
			Std. Dev.	91.46	2.46	0.47	9.8E+06	1.98	0.33	1.8E+03	1.5E+03	2.0E+01	25.93
		Cut	Mean	66.64	0.76	1.83	1.3E+07	2.63	0.30	1.8E+03	5.6E+03	3.0E+01	26.33
			Std. Dev.	13.82	0.29	0.24	6.6E+06	1.33	0.04	9.6E+02	6.2E+03	4.2E+01	10.66
	Event 3 - Spring 2000	Fill	Mean	138.28	1.00	1.50	2.0E+07	3.92	0.26	6.0E+02	3.8E+03	0.0E+00	12.33
			Std. Dev.	92.24	0.67	0.00	9.7E+05	0.19	0.19	1.7E+01	1.7E+03	0.0E+00	4.50
		Cut	Mean	96.43	0.89	1.83	1.4E+07	2.73	0.40	2.0E+03	2.3E+03	0.0E+00	29.00
			Std. Dev.	36.82	0.04	0.47	6.1E+06	1.21	0.16	7.2E+02	1.6E+03	0.0E+00	15.58
Gypsum, Rate 2 (GYP2)	Event 1 - Fall 1998	Fill	Mean	27.86	0.56	#REF!	9.4E+06	1.88	0.32	3.7E+04	2.6E+03	2.0E+00	0.00
			Std. Dev.	29.54	0.59	N/A	2.6E+06	0.52	0.30	2.5E+04	2.6E+03	2.8E+00	0.00
		Cut	Mean	43.10	0.80	2.33	1.5E+07	2.95	0.25	2.0E+03	1.9E+03	4.7E+02	15.47
			Std. Dev.	20.59	0.47	0.24	4.7E+06	0.93	0.07	2.0E+03	2.1E+03	6.6E+02	9.36
	Event 2 - Spring 1999	Fill	Mean	105.70	1.28	1.67	2.4E+07	4.77	0.44	3.0E+03	2.8E+03	0.0E+00	10.33
			Std. Dev.	68.25	0.99	0.62	1.3E+07	2.51	0.37	1.7E+03	2.0E+03	0.0E+00	3.30
		Cut	Mean	79.04	1.01	1.83	1.9E+07	3.80	0.22	5.5E+03	4.2E+03	1.0E+01	19.00
			Std. Dev.	56.19	0.74	0.24	7.1E+06	1.44	0.16	6.4E+03	1.0E+03	1.5E+01	9.90
	Event 3 - Spring 2000	Fill	Mean	132.84	1.25	1.67	1.4E+07	2.76	0.51	4.2E+03	5.3E+03	4.9E+00	17.67
			Std. Dev.	14.30	0.50	0.24	2.8E+06	0.56	0.30	1.9E+03	5.4E+02	7.0E+00	5.19
		Cut	Mean	74.97	0.83	1.67	1.4E+07	2.86	0.41	2.3E+03	1.7E+03	3.2E+01	21.33
			Std. Dev.	54.46	0.79	0.24	3.7E+06	0.74	0.47	1.9E+03	2.2E+02	4.1E+01	8.50

Table 6-2B (Continued)
SOIL MICROBIAL DATA - IRRIGATED PLANT ESTABLISHMENT TEST PLOTS
ALL SAMPLING EVENTS

Treatment	Monitoring Event	Statistic	Slope Type	FUNGI Length, Active (cm per g soil)	FUNGI Biomass, Active (µg per g soil)	FUNGI Hyphal Diameter (µm)	BACTERIA Number, Active (count per g soil)	BACTERIA Biomass, Active (µg per g soil)	FUNGI/ BACTERIA RATIO	PROTOZOA Flagellates (count per g soil)	PROTOZOA Amoebae (count per g soil)	PROTOZOA Ciliates (count per g soil)	VAM(2) % ROOT
Paper Mulch and Psyllium Tackifier (PMG)	Event 1 - Fall 1998	Fill	Mean	0.00	0.00	N/A	7.9E+06	1.58	0.00	1.6E+05	1.3E+04	4.7E+00	0.00
			Std. Dev.	0.00	0.00	N/A	5.7E+05	0.11	0.00	2.2E+05	1.6E+04	6.7E+00	0.00
		Cut	Mean	61.84	1.24	2.50	1.5E+07	3.02	0.55	1.8E+03	1.8E+03	1.2E+01	9.22
			Std. Dev.	24.31	0.49	N/A	5.3E+06	1.05	0.40	2.1E+03	2.1E+03	1.2E+01	7.23
	Event 2 - Spring 1999	Fill	Mean	261.68	4.65	2.33	3.2E+07	6.30	0.74	1.7E+05	3.5E+03	1.1E+01	19.00
			Std. Dev.	29.06	1.13	0.24	7.4E+05	0.14	0.18	2.3E+05	2.0E+03	1.6E+01	21.46
		Cut	Mean	43.73	0.32	1.50	1.4E+07	2.80	0.09	2.5E+03	4.4E+03	2.9E+01	29.33
			Std. Dev.	50.64	0.37	N/A	3.9E+06	0.80	0.09	1.4E+03	2.3E+03	1.0E+01	12.66
	Event 3 - Spring 2000	Fill	Mean	73.90	0.54	1.50	1.8E+07	3.55	0.14	2.6E+03	1.8E+04	7.0E+00	10.33
			Std. Dev.	46.00	0.33	0.00	4.8E+06	0.95	0.05	1.6E+03	2.2E+04	6.1E+00	7.93
		Cut	Mean	137.71	1.88	2.00	1.6E+07	3.29	0.74	2.8E+03	4.4E+03	4.7E+01	18.33
			Std. Dev.	28.79	0.78	0.41	8.2E+06	1.64	0.54	1.7E+03	3.2E+03	3.1E+01	10.34
Paper Mulch and Polymer Tackifier (PMP)	Event 1 - Fall 1998	Fill	Mean	0.00	0.00	N/A	1.3E+07	2.52	0.00	5.6E+04	6.8E+02	2.0E+02	0.00
			Std. Dev.	0.00	0.00	N/A	6.1E+06	1.22	0.00	6.1E+04	6.5E+02	2.7E+02	0.00
		Cut	Mean	66.40	1.27	2.25	1.6E+07	3.20	0.38	6.8E+02	4.0E+02	0.0E+00	19.58
			Std. Dev.	74.68	1.54	0.25	5.4E+06	1.08	0.40	5.4E+02	2.6E+02	0.0E+00	1.17
	Event 2 - Spring 1999	Fill	Mean	236.30	4.16	2.33	4.6E+07	9.17	0.49	1.8E+04	1.2E+04	7.4E+01	0.00
			Std. Dev.	48.11	1.19	0.24	9.6E+06	1.90	0.22	2.1E+04	1.2E+04	5.1E+01	0.00
		Cut	Mean	150.24	2.10	2.00	2.3E+07	4.60	0.46	2.7E+03	1.8E+04	7.1E+01	17.00
			Std. Dev.	19.06	1.07	0.41	3.2E+06	0.65	0.26	3.0E+03	1.5E+04	5.8E+01	0.82
	Event 3 - Spring 2000	Fill	Mean	69.43	0.70	1.67	1.8E+07	3.68	0.21	1.7E+04	6.7E+03	1.3E+01	2.00
			Std. Dev.	24.12	0.45	0.24	4.2E+06	0.83	0.16	2.2E+04	5.5E+03	1.5E+01	2.83
		Cut	Mean	55.21	0.49	1.67	1.7E+07	3.37	0.15	5.2E+03	3.3E+03	7.6E+01	17.33
			Std. Dev.	33.74	0.26	0.24	1.5E+06	0.30	0.08	6.7E+03	1.9E+03	5.0E+01	8.06

Table 6-2B (Continued)
SOIL MICROBIAL DATA - IRRIGATED PLANT ESTABLISHMENT TEST PLOTS
ALL SAMPLING EVENTS

Treatment	Monitoring Event	Statistic	Slope Type	FUNGI Length, Active (cm per g soil)	FUNGI Biomass, Active (µg per g soil)	FUNGI Hyphal Diameter (µm)	BACTERIA Number, Active (count per g soil)	BACTERIA Biomass, Active (µg per g soil)	FUNGI/ BACTERIA RATIO	PROTOZOA Flagellates (count per g soil)	PROTOZOA Amoebae (count per g soil)	PROTOZOA Ciliates (count per g soil)	VAM[2] % ROOT
Wheat Straw	Event 1 - Fall 1998	Fill	Mean	22.63	0.46	2.50	1.2E+07	2.32	0.18	6.0E+04	1.2E+03	2.0E+02	11.67
			Std. Dev.	18.34	0.37	N/A	3.0E+06	0.60	0.13	6.5E+04	1.2E+03	2.8E+02	16.50
		Cut	Mean	195.05	3.89	2.33	1.2E+07	2.47	1.53	6.6E+02	4.9E+02	1.4E+01	36.60
			Std. Dev.	188.61	3.83	0.24	4.8E+06	0.97	1.07	5.5E+02	5.0E+02	1.6E+01	7.29
	Event 2 - Spring 1999	Fill	Mean	132.92	2.29	2.33	2.2E+07	4.37	0.48	2.3E+03	9.1E+02	3.0E+01	22.33
			Std. Dev.	74.23	1.45	0.24	6.7E+06	1.37	0.21	1.8E+03	4.0E+02	2.5E+01	11.90
		Cut	Mean	31.61	0.23	1.00	1.6E+07	3.27	0.08	4.6E+03	5.3E+03	1.7E+01	17.33
			Std. Dev.	29.80	0.22	0.71	5.0E+06	0.97	0.06	1.2E+03	1.3E+03	2.4E+01	4.11
	Event 3 - Spring 2000	Fill	Mean	103.30	0.75	1.50	2.0E+07	3.91	0.24	1.0E+04	2.3E+04	4.4E+01	27.00
			Std. Dev.	38.70	0.28	0.00	6.5E+06	1.31	0.14	7.1E+03	2.7E+04	2.8E+01	5.89
		Cut	Mean	60.94	0.55	1.83	1.2E+07	2.30	0.26	6.2E+03	1.3E+04	1.9E+01	19.00
			Std. Dev.	26.26	0.06	0.47	3.0E+06	0.60	0.07	1.2E+03	1.4E+04	1.9E+01	12.68
Straw ECB (SB)	Event 1 - Fall 1998	Fill	Mean	0.00	0.00	N/A	9.2E+06	1.85	0.00	5.6E+04	3.0E+02	2.0E+00	8.75
			Std. Dev.	0.00	0.00	N/A	1.3E+06	0.26	0.00	6.0E+04	1.1E+02	2.8E+00	8.35
		Cut	Mean	47.51	0.96	2.50	1.7E+07	3.43	0.29	3.7E+03	2.8E+02	2.7E+01	26.54
			Std. Dev.	67.19	1.35	N/A	6.9E+06	1.37	0.41	2.3E+03	2.2E+02	2.3E+01	7.92
	Event 2 - Spring 1999	Fill	Mean	127.55	1.08	1.50	3.4E+07	6.80	0.41	1.2E+04	1.8E+04	4.3E+01	17.67
			Std. Dev.	60.35	0.94	0.71	1.8E+07	3.58	0.53	1.2E+04	2.2E+04	3.3E+00	13.72
		Cut	Mean	135.90	1.34	1.67	1.9E+07	3.80	0.43	2.0E+03	7.0E+03	3.1E+01	26.00
			Std. Dev.	37.26	0.77	0.24	4.3E+06	0.85	0.35	2.0E+03	5.7E+03	1.1E+01	9.93
	Event 3 - Spring 2000	Fill	Mean	92.83	0.67	1.50	1.7E+07	3.47	0.19	3.6E+03	1.3E+04	1.5E+01	13.00
			Std. Dev.	9.75	0.07	0.00	1.7E+06	0.34	0.01	1.5E+03	1.1E+04	6.9E+00	9.90
		Cut	Mean	42.95	0.35	1.83	1.6E+07	3.28	0.11	4.2E+03	1.9E+03	1.2E+01	15.33
			Std. Dev.	36.86	0.23	0.47	2.6E+06	0.52	0.06	9.1E+02	1.9E+03	1.3E+01	3.86

Table 6-2B (Continued)
SOIL MICROBIAL DATA - IRRIGATED PLANT ESTABLISHMENT TEST PLOTS
ALL SAMPLING EVENTS

Treatment	Monitoring Event	Slope Type	Statistic	FUNGI Length, Active (cm per g soil)	FUNGI Biomass, Active (µg per g soil)	FUNGI Hyphal Diameter (µm)	BACTERIA Number, Active (count per g soil)	BACTERIA Biomass, Active (µg per g soil)	FUNGI/ BACTERIA RATIO	PROTOZOA Flagellates (count per g soil)	PROTOZOA Amoebae (count per g soil)	PROTOZOA Ciliates (count per g soil)	VAM(2) % ROOT
Straw/Coconut ECB (SCB)	Event 1 - Fall 1998	Fill	Mean	0.00	0.00	N/A	7.8E+06	1.57	0.00	3.5E+04	1.1E+03	1.1E+01	37.15
			Std. Dev.	0.00	0.00	N/A	2.5E+06	0.50	0.00	2.5E+04	4.4E+02	1.5E+01	33.33
		Cut	Mean	89.90	1.77	2.25	1.6E+07	3.12	0.47	1.8E+04	1.0E+04	9.6E+01	23.41
			Std. Dev.	117.10	2.38	0.25	2.9E+06	0.58	0.63	2.1E+04	1.3E+04	1.3E+02	30.62
	Event 2 - Spring 1999	Fill	Mean	154.93	1.23	1.50	3.3E+07	6.50	0.22	1.3E+04	1.9E+03	8.7E+01	2.33
			Std. Dev.	79.90	1.00	0.71	5.4E+06	1.08	0.21	1.2E+04	6.9E+02	4.7E+01	3.30
		Cut	Mean	86.43	0.79	1.67	1.4E+07	2.87	0.28	3.1E+03	2.7E+03	3.5E+01	18.33
			Std. Dev.	11.15	0.25	0.24	5.3E+06	1.08	0.02	2.1E+03	2.4E+03	2.2E+01	6.60
	Event 3 - Spring 2000	Fill	Mean	92.65	0.67	1.50	2.2E+07	4.41	0.15	1.4E+04	3.7E+03	3.5E+01	10.00
			Std. Dev.	24.96	0.18	0.00	2.4E+06	0.48	0.02	8.0E+00	1.6E+03	1.4E+01	7.87
		Cut	Mean	84.55	0.95	1.83	1.5E+07	2.98	0.34	1.0E+04	2.2E+04	4.0E+01	14.67
			Std. Dev.	15.72	0.46	0.47	1.4E+06	0.28	0.19	6.7E+03	1.9E+04	2.1E+01	3.30
Wood Fiber ECB (WFB)	Event 1 - Fall 1998	Fill	Mean	0.00	0.00	N/A	8.5E+06	1.69	0.00	1.9E+04	8.0E+02	0.0E+00	4.17
			Std. Dev.	0.00	0.00	N/A	2.3E+06	0.46	0.00	1.8E+04	4.7E+02	0.0E+00	5.89
		Cut	Mean	183.53	3.69	2.50	2.0E+07	4.06	0.88	6.1E+04	3.6E+02	2.2E+01	29.23
			Std. Dev.	130.67	2.63	N/A	3.2E+06	0.64	0.63	8.4E+04	2.6E+02	1.5E+01	24.39
	Event 2 - Spring 1999	Fill	Mean	166.03	2.25	1.67	3.9E+07	7.70	0.29	2.8E+03	4.6E+03	7.5E+01	10.67
			Std. Dev.	89.56	2.15	0.62	6.1E+06	1.23	0.29	1.7E+03	1.2E+03	7.4E+01	9.98
		Cut	Mean	91.79	0.88	1.67	1.9E+07	3.80	0.29	5.9E+02	2.7E+03	1.7E+01	15.00
			Std. Dev.	24.37	0.44	0.24	8.2E+06	1.63	0.17	6.1E+02	1.7E+03	2.0E+01	9.20
	Event 3 - Spring 2000	Fill	Mean	116.65	0.85	1.50	1.8E+07	3.60	0.22	2.2E+04	8.8E+03	3.4E+01	9.00
			Std. Dev.	68.53	0.50	0.00	4.0E+06	0.81	0.08	2.7E+04	5.1E+03	3.4E+00	4.55
		Cut	Mean	66.44	0.61	1.83	1.8E+07	3.61	0.19	4.0E+03	7.2E+03	4.7E+01	19.00
			Std. Dev.	28.42	0.08	0.47	5.2E+06	1.03	0.07	2.2E+03	5.8E+03	1.1E+01	13.64

Table 6-2B (Continued)
SOIL MICROBIAL DATA - IRRIGATED PLANT ESTABLISHMENT TEST PLOTS
ALL SAMPLING EVENTS

Treatment	Monitoring Event	Slope Type	Statistic	FUNGI Length, Active (cm per g soil)	FUNGI Biomass, Active (µg per g soil)	FUNGI Hyphal Diameter (µm)	BACTERIA Number, Active (count per g soil)	BACTERIA Biomass, Active (µg per g soil)	FUNGI/ BACTERIA RATIO	PROTOZOA Flagellates (count per g soil)	PROTOZOA Amoebae (count per g soil)	PROTOZOA Ciliates (count per g soil)	VAM(2) % ROOT
Wood Mulch and Psyllium Tackifier (WMG)	Event 1 - Fall 1998	Fill	Mean	18.89	0.38	2.50	1.1E+07	2.24	0.11	1.1E+05	8.3E+02	4.8E+00	7.65
			Std. Dev.	26.71	0.54	N/A	4.7E+06	0.95	0.15	1.2E+05	4.2E+02	6.8E+00	7.70
		Cut	Mean	142.78	3.98	2.50	2.3E+07	4.67	0.72	7.7E+02	1.2E+03	2.1E+01	16.30
			Std. Dev.	181.94	5.37	0.50	4.5E+06	0.89	0.97	4.9E+02	1.2E+03	1.1E+01	14.20
	Event 2 - Spring 1999	Fill	Mean	92.70	0.95	1.50	3.8E+07	7.57	0.12	1.3E+05	1.6E+06	3.9E+01	16.67
			Std. Dev.	56.50	1.00	0.71	8.0E+06	1.59	0.13	1.7E+05	2.3E+06	3.6E+01	17.00
		Cut	Mean	138.98	1.48	1.67	1.9E+07	3.83	0.41	2.1E+03	3.4E+03	3.9E+01	24.67
			Std. Dev.	90.32	1.27	0.24	6.8E+06	1.37	0.27	5.9E+02	1.9E+03	1.7E+01	9.39
	Event 3 - Spring 2000	Fill	Mean	90.03	0.65	1.50	1.8E+07	3.63	0.24	3.3E+03	7.5E+03	6.1E+01	1.00
			Std. Dev.	22.36	0.16	0.00	8.2E+06	1.64	0.14	2.0E+03	5.1E+03	7.2E+01	1.41
		Cut	Mean	68.12	0.69	1.17	1.5E+07	2.96	0.22	3.6E+03	1.6E+04	1.6E+01	30.67
			Std. Dev.	48.24	0.55	0.85	1.1E+06	0.22	0.18	9.5E+02	2.1E+04	1.4E+01	8.50
Wood Mulch and Polymer Tackifier (WMP)	Event 1 - Fall 1998	Fill	Mean	0.00	0.00	N/A	1.1E+07	2.22	0.00	2.5E+03	1.3E+03	1.1E+01	4.55
			Std. Dev.	0.00	0.00	N/A	5.3E+06	1.05	0.00	1.8E+03	1.2E+03	1.5E+01	6.43
		Cut	Mean	9.62	0.12	2.00	1.5E+07	3.08	0.07	1.8E+04	7.3E+02	1.8E+01	20.95
			Std. Dev.	13.60	0.18	N/A	4.6E+06	0.92	0.09	2.1E+04	5.2E+02	1.1E+01	2.99
	Event 2 - Spring 1999	Fill	Mean	95.24	1.51	2.00	3.1E+07	6.27	0.35	4.9E+03	4.1E+03	0.0E+00	28.67
			Std. Dev.	19.73	0.93	0.71	1.4E+07	2.85	0.24	2.5E+02	1.6E+03	0.0E+00	18.70
		Cut	Mean	117.14	1.29	1.83	1.8E+07	3.63	0.34	2.2E+03	4.8E+03	2.6E+01	17.00
			Std. Dev.	48.18	0.69	0.24	2.1E+06	0.42	0.14	1.9E+03	1.3E+03	2.0E+01	3.27
	Event 3 - Spring 2000	Fill	Mean	119.33	0.86	1.50	2.2E+07	4.45	0.21	4.0E+03	8.1E+03	3.5E+01	10.33
			Std. Dev.	31.12	0.23	0.00	8.9E+06	1.78	0.07	1.9E+03	4.8E+03	1.9E+01	6.85
		Cut	Mean	51.26	0.62	2.00	1.4E+07	2.87	0.23	2.3E+03	3.5E+03	2.0E+01	10.33
			Std. Dev.	14.57	0.27	0.71	3.2E+06	0.63	0.12	1.8E+03	2.0E+03	2.9E+01	4.64

Table 6-3
ANALYSIS OF VARIANCE P-VALUES FOR SOIL CHEMISTRY DATA

	Site	Irrigation	Treatment	Site* Irrigation	Site* Treatment	Irrigation* Treatment	Site* Irrigation* Treatment
Saturation	0	0.75	0.758	0.004	0.93	0.722	0.833
pH	0	0.197	0.17	0.946	0.523	0.229	0.245
Ece	0.325	0.053	0.665	0	0.591	0.582	0.438
Ca	0.274	0.006	0.54	0	0.716	0.416	0.494
Mg	0	0.003	0.636	0.004	0.351	0.244	0.294
Na	0.173	0.649	0.63	0.012	0.255	0.574	0.244
Cl	0	0	0.062	0	0.141	0.556	0.768
B	0	0	0.097	0.001	0.578	0.26	0.11
N	0	0.028	0.967	0.026	0.489	0.335	0.589
P	0.006	0.542	0.594	0.099	0.899	0.695	0.899
K	0	0.269	0.951	0.025	0.615	0.668	0.809
Ca (ppm)	0	0	0.231	0.123	0.588	0.174	0.637
Mg (ppm)	0	0.867	0.975	0	0.148	0.418	0.73
Na (ppm)	0	0.542	0.355	0.08	0.672	0.943	0.993
Zn	0	0	0.813	0	0.871	0.885	0.706
Mn	0	0.313	0.251	0.179	0.171	0.19	0.646
Fe	0	0.015	0.198	0	0.212	0.127	0.189
Cu	0	0	0.875	0.93	0.864	0.249	0.396
Dryweight	0.452	0.258	0.554	0.298	0.965	0.69	0.603

Note: Entries less than 0.05 represent statistically significant differences in the variable listed in the left-hand-column for the factor listed in the column heading. Note that none of the three-way interactions are significant, and that none of the Irrigated * Treatment and Site * Treatment interactions are significant. These analyses were performed on the Event 3 data, using the Event 1 data as covariates.

Table 6-4
ANALYSIS OF VARIANCE (P-VALUES) FOR SOIL MICROBIAL DATA

	Site	Irrigation	Treatment	Site* Irrigation	Site* Treatment	Irrigation * Treatment	Site* Irrigation* Treatment
Fungi Biomass	0.06	0.216	0.729	0.809	0.623	0.536	0.608
Bacteria Biomass	0.182	0	0.691	0	0.426	0.943	0.31
Flagellates	0	0	0.912	0	0.575	0.829	0.712
Amoebae	0.263	0.497	0.592	0.159	0.24	0.317	0.297
Ciliates	0.708	0.046	0.661	0.14	0.302	0.482	0.35
VAM Percent Root	0.001	0.851	0.589	0.174	0.677	0.421	0.58

Note: Entries less than 0.05 represent statistically significant differences in the variable listed in the left-hand-column for the factor listed in the column heading. Note that none of the three-way interactions are significant, and that none of the Irrigated * Treatment and Site * Treatment interactions are significant. These analyses were performed on the Event 3 data, using the Event 1 data as covariates.

was 57 percent below the historical average of 358 mm (14 in.). The 1999-2000 rainfall amounts (Table 8-5B) for Sites 10-2 and 57-4 were 258 mm (10.1 in.) and 263 mm (10.3 in.), respectively. These rainfall amounts were 41 and 27 percent below the historical annual averages of 439 mm (17.1 in.) and 358 mm (14 in.), respectively, reported for the closest rain gauge stations.

6.3 EFFECT OF IRRIGATION ON PLANT ESTABLISHMENT

Irrigation was conducted only for the initial planting in Fall 1998 through February 11, 1999. In order to determine if the irrigation period was effective in establishing native vegetation, the data were analyzed for seedling densities in the first spring. Plant densities from the spring sampling events for 1999 and 2000 were then compared to seedling density data. Additionally, total density for the CSS species for the final monitoring was analyzed to determine if there was an effect on final native plant density from initial irrigation.

To determine if the irrigation affected seedling germination, total density for the CSS species across erosion control treatments for the irrigated and non-irrigated plots at Monitoring Events 2 (March 1999) and 3 (May 1999) at each site was analyzed. The density of native plants for both irrigated and non-irrigated plots increased between Monitoring Event 1 (December 1998) and Monitoring Event 2 (March 1999), with the density approximately 2½ times greater in the irrigated plots. By Event 3, however, this difference had been reduced between the irrigated and non-irrigated plots. The analysis of variance for Monitoring Events 2 and 3 is presented in Table 6-5. Irrigation is significant for Monitoring Event 2, but irrigation is not significant for Event 3. Irrigation had some beneficial effects related to earlier germination of native species compared to 'natural' germination in a year with late fall and winter rains, as occurred in 1999. However, the effect of higher plant densities disappears as natural rainfall begins and the seeds in the non-irrigated plots began to germinate. The effect of irrigation is strongly dependent on the site (cut or fill slope) in these experiments. Table 6-6 shows the mean and standard deviation of the total density of CSS seed mix by site and irrigation, pooled across all erosion control treatments. Note that the difference in density between the irrigated and non-irrigated plots is most apparent on the cut slope at the 57-4 site.

To determine if irrigation was effective in establishing vegetation over the length of the study, the density data from the irrigated and non-irrigated plots for the cut and fill slopes were analyzed using the spring sampling events for 1999 and 2000 (Events 3 and 7). These two sampling events were examined because the early spring season is when the greatest number of plants are present including annuals and shrubs of both native and non-native species. Tables 6-7 through 6-14 show the average plant densities and standard deviations of native and non-native species for the different erosion control treatments in irrigated and non-irrigated plots on both cut and fill slope sites.

Multivariate analysis of variance of plant densities for individual native species, all non-native grasses (TGR), and all broadleaf non-native species (TBR) show that all main effects (i.e., site, irrigation treatment, erosion control treatment, and sampling event) are statistically significant when analyzing the two spring sampling events. However, only the interaction between irrigation treatment and site is significant for the interaction of the main effects. Table 6-15 presents the p-values from the analysis of variance of the plant density data, from plant establishment plots for Monitoring Events 3 and 7. These are p-values from univariate analyses of variance performed automatically by SYSTAT following the multivariate analysis of variance.

Table 6-5
ANALYSIS OF VARIANCE
MONITORING EVENTS 2 AND 3

EVENT 2 – MARCH 1999				
Source	**DOF(1)**	**Mean-Square**	**F-Ratio**	**p-Value**
Slope Type	1		21.539	0.000
Irrigation	1		41.885	0.000
Treatment	15		3.641	0.000
Slope Type * Irrigation	1		88.345	0.000
Slope Type * Treatment	15		3.016	0.000
Irrigation * Treatment	15		3.493	0.000
Slope Type * Irrigation * Treatment	15		1.524	0.106
Error	128	1752.380		
EVENT 3 – MAY 1999				
Source	**DOF(1)**	**Mean-Square**	**F-Ratio**	**p-Value**
Slope Type	1		10.695	0.001
Irrigation	1		1.183	0.279
Treatment	15		1.843	0.035
Slope Type * Irrigation	1		26.599	0.000
Slope Type * Treatment	15		1.160	0.311
Irrigation * Treatment	15		1.543	0.099
Slope Type Irrigation * Treatment	15		1.333	0.192
Error	128	362.703		

(1) DOF = Degrees of Freedom.

Note: "*" indicates interaction between the variables indicated.

Table 6-6
MEAN AND STANDARD DEVIATION OF
TOTAL DENSITY OF CSS SEED MIX SPECIES

Irrigated	Statistic	Total Density	
		Fill Slope	**Cut Slope**
No	Mean	11.86	4.02
	Std. Dev.	*23.88*	*7.89*
Yes	Mean	8.19	24.57
	Std. Dev.	*15.58*	*52.52*

Table 6-7
NATIVE PLANT DENSITY
IRRIGATED FILL SLOPE

Treatment	Statistic	Plant Density[(1)]	
		Event 3 (May 1999)	Event 7 (April 2000)
Bare (BARE)	Mean	4	3
	Std. Dev.	*3*	*3*
Bonded Fiber Matrix (BFM)	Mean	16	29
	Std. Dev.	*11*	*21*
Coconut Blanket (CB)	Mean	21	0
	Std. Dev.	*18*	*0*
Coir (COIR)	Mean	10	4
	Std. Dev.	*4*	*3*
Compost (COMP)	Mean	3	6
	Std. Dev.	*2*	*4*
Curled Wood Fiber Blanket (CWFB)	Mean	25	0
	Std. Dev.	*19*	*0*
Gypsum, Rate 1 (GYP1)	Mean	4	2
	Std. Dev.	*5*	*1*
Gypsum, Rate 2 (GYP2)	Mean	1	3
	Std. Dev.	*1*	*2*
Paper Mulch with Psyllium Tackifier (PMG)	Mean	27	1
	Std. Dev.	*32*	*1*
Paper Mulch with Polymer Tackifier (PMP)	Mean	8	3
	Std. Dev.	*2*	*1*
Wheat Straw (RS)	Mean	20	10
	Std. Dev.	*9*	*9*
Straw Blanket (SB)	Mean	21	0
	Std. Dev.	*12*	*0*
Straw-Coconut Blanket (SB)	Mean	29	4
	Std. Dev.	*13*	*3*
Wood Fiber Blanket (WFB)	Mean	26	9
	Std. Dev.	*28*	*8*
Wood Mulch with Psyllium Tackifier (WMG)	Mean	9	28
	Std. Dev.	*3*	*27*
Wood Mulch with Polymer Tackifier (WMP)	Mean	29	28
	Std. Dev.	*20*	*29*

(1) Density is defined as the number of plants per $1m^2$ quadrat monitoring area.

Table 6-8
NATIVE PLANT DENSITY
IRRIGATED CUT SLOPE

Treatment	Statistic	Plant Density[1] Event 3 (May 1999)	Plant Density[1] Event 7 (April 2000)
Bare (BARE)	Mean	10	5
	Std. Dev.	*3*	*3*
Bonded Fiber Matrix (BFM)	Mean	38	33
	Std. Dev.	*30*	*24*
Coconut Blanket (CB)	Mean	13	4
	Std. Dev.	*8*	*4*
Coir (COIR)	Mean	14	1
	Std. Dev.	*15*	*1*
Compost (COMP)	Mean	22	18
	Std. Dev.	*7*	*10*
Curled Wood Fiber Blanket (CWFB)	Mean	2	0
	Std. Dev.	*3*	*0*
Gypsum, Rate 1 (GYP1)	Mean	24	10
	Std. Dev.	*31*	*11*
Gypsum, Rate 2 (GYP2)	Mean	20	7
	Std. Dev.	*11*	*2*
Paper Mulch with Psyllium (PMG)	Mean	5	2
	Std. Dev.	*6*	*1*
Paper Mulch with Polymer (PMP)	Mean	4	5
	Std. Dev.	*4*	*2*
Wheat Straw (RS)	Mean	11	3
	Std. Dev.	*6*	*3*
Straw Blanket (SB)	Mean	31	1
	Std. Dev.	*30*	*1*
Straw-Coconut Blanket (SCB)	Mean	5	0
	Std. Dev.	*4*	*0*
Wood Fiber Blanket (WFB)	Mean	67	14
	Std. Dev.	*39*	*11*
Wood Mulch with Psyllium (WMG)	Mean	10	4
	Std. Dev.	*7*	*4*
Wood Mulch with Polymer (WMP)	Mean	59	8
	Std. Dev.	*31*	*4*

(1) Density is defined as the number of plants per $1 m^2$ quadrat monitoring area.

Table 6-9
NATIVE PLANT DENSITY
NON-IRRIGATED FILL SLOPE

Treatment	Statistic	Plant Density(1)	
		Event 3 (May 1999)	Event 7 (April 2000)
Bare (BARE)	Mean	48	13
	Std. Dev.	*24*	*2*
Bonded Fiber Matrix (BFM)	Mean	3	1
	Std. Dev.	*3*	*1*
Coconut Blanket (CB)	Mean	40	2
	Std. Dev.	*25*	*3*
Coir (COIR)	Mean	27	1
	Std. Dev.	*13*	*1*
Compost (COMP)	Mean	43	37
	Std. Dev.	*42*	*32*
Curled Wood Fiber Blanket (CWFB)	Mean	9	0
	Std. Dev.	*10*	*0*
Gypsum, Rate 1 (GYP1)	Mean	11	11
	Std. Dev.	*4*	*13*
Gypsum, Rate 2 (GYP2)	Mean	48	22
	Std. Dev.	*16*	*23*
Paper Mulch with Psyllium (PMG)	Mean	21	10
	Std. Dev.	*5*	*11*
Paper Mulch with Polymer (PMP)	Mean	16	2
	Std. Dev.	*16*	*2*
Wheat Straw (RS)	Mean	36	2
	Std. Dev.	*14*	*2*
Straw Blanket (SB)	Mean	28	2
	Std. Dev.	*24*	*1*
Straw-Coconut Blanket (SCB)	Mean	29	6
	Std. Dev.	*19*	*3*
Wood Fiber Blanket (WFB)	Mean	44	32
	Std. Dev.	*30*	*26*
Wood Mulch with Psyllium (WMG)	Mean	10	10
	Std. Dev.	*10*	*3*
Wood Mulch with Polymer (WMP)	Mean	20	6
	Std. Dev.	*7*	*8*

(1) Density is defined as the number of plants per 1m^2 quadrat monitoring area.

Table 6-10
NATIVE PLANT DENSITY
NON-IRRIGATED CUT SLOPE

Treatment	Statistic	Plant Density[1] Event 3 (May 1999)	Plant Density[1] Event 7 (April 2000)
Bare (BARE)	Mean	3	2
	Std. Dev.	*1*	*1*
Bonded Fiber Matrix (BFM)	Mean	2	13
	Std. Dev.	*1*	*15*
Coconut Blanket (CB)	Mean	6	0
	Std. Dev.	*5*	*0*
Coir (COIR)	Mean	2	0
	Std. Dev.	*2*	*0*
Compost (COMP)	Mean	10	17
	Std. Dev.	*7*	*9*
Curled Wood Fiber Blanket (CWFB)	Mean	2	0
	Std. Dev.	*2*	*0*
Gypsum, Rate 1 (GYP1)	Mean	5	2
	Std. Dev.	*3*	*2*
Gypsum, Rate 2 (GYP2)	Mean	1	6
	Std. Dev.	*1*	*2*
Paper Mulch with Psyllium (PMG)	Mean	1	3
	Std. Dev.	*1*	*2*
Paper Mulch with Polymer (PMP)	Mean	1	4
	Std. Dev.	*1*	*3*
Wheat Straw (RS)	Mean	2	3
	Std. Dev.	*0*	*2*
Straw Blanket (SB)	Mean	4	0
	Std. Dev.	*2*	*0*
Straw-Coconut Blanket (SCB)	Mean	2	0
	Std. Dev.	*1*	*0*
Wood Fiber Blanket (WFB)	Mean	2	2
	Std. Dev.	*1*	*3*
Wood Mulch with Psyllium (WMG)	Mean	4	14
	Std. Dev.	*5*	*12*
Wood Mulch with Polymer (WMP)	Mean	14	11
	Std. Dev.	*1*	*8*

(1) Density is defined as the number of plants per 1m^2 quadrat monitoring area.

Table 6-11
NON-NATIVE PLANT DENSITY
IRRIGATED FILL SLOPE

Treatment	Statistic	Plant Density(1)	
		Event 3 (May 1999)	Event 7 (April 2000)
Bare (BARE)	Mean	224	191
	Std. Dev.	*15*	*59*
Bonded Fiber Matrix (BFM)	Mean	111	313
	Std. Dev.	*31*	*103*
Coconut Blanket (CB)	Mean	253	244
	Std. Dev.	*66*	*72*
Coir (COIR)	Mean	143	207
	Std. Dev.	*31*	*16*
Compost (COMP)	Mean	151	195
	Std. Dev.	*65*	*52*
Curled Wood Fiber Blanket (CWFB)	Mean	201	204
	Std. Dev.	*54*	*72*
Gypsum, Rate 1 (GYP1)	Mean	138	268
	Std. Dev.	*40*	*146*
Gypsum, Rate 2 (GYP2)	Mean	76	179
	Std. Dev.	*31*	*105*
Paper Mulch with Psyllium (PMG)	Mean	124	352
	Std. Dev.	*43*	*196*
Paper Mulch with Polymer (PMP)	Mean	156	282
	Std. Dev.	*51*	*92*
Wheat Straw (RS)	Mean	143	196
	Std. Dev.	*7*	*32*
Straw Blanket (SB)	Mean	261	367
	Std. Dev.	*92*	*63*
Straw-Coconut Blanket (SCB)	Mean	203	284
	Std. Dev.	*17*	*95*
Wood Fiber Blanket (WFB)	Mean	218	412
	Std. Dev.	*49*	*141*
Wood Mulch with Psyllium (WMG)	Mean	153	342
	Std. Dev.	*51*	*142*
Wood Mulch with Polymer (WMP)	Mean	196	294
	Std. Dev.	*70*	*87*

(1) Density is defined as the number of plants per 1m^2 quadrat monitoring area.

Table 6-12
NON-NATIVE PLANT DENSITY
IRRIGATED CUT SLOPE

Treatment	Statistic	Plant Density[(1)]	
		Event 3 (May 1999)	Event 7 (April 2000)
Bare (BARE)	Mean	655	1239
	Std. Dev.	*349*	*376*
Bonded Fiber Matrix (BFM)	Mean	355	587
	Std. Dev.	*11*	*116*
Coconut Blanket (CB)	Mean	373	1056
	Std. Dev.	*180*	*372*
Coir (COIR)	Mean	365	707
	Std. Dev.	*137*	*161*
Compost (COMP)	Mean	354	999
	Std. Dev.	*36*	*140*
Curled Wood Fiber Blanket (CWFB)	Mean	452	570
	Std. Dev.	*106*	*181*
Gypsum, Rate 1 (GYP1)	Mean	575	1365
	Std. Dev.	*329*	*499*
Gypsum, Rate 2 (GYP2)	Mean	206	990
	Std. Dev.	*32*	*245*
Paper Mulch with Psyllium (PMG)	Mean	319	647
	Std. Dev.	*14*	*136*
Paper Mulch with Polymer (PMP)	Mean	320	1204
	Std. Dev.	*84*	*153*
Wheat Straw (RS)	Mean	304	824
	Std. Dev.	*123*	*181*
Straw Blanket (SB)	Mean	478	1035
	Std. Dev.	*237*	*267*
Straw-Coconut Blanket (SCB)	Mean	450	800
	Std. Dev.	*102*	*38*
Wood Fiber Blanket (WFB)	Mean	341	1006
	Std. Dev.	*116*	*319*
Wood Mulch with Psyllium (WMG)	Mean	299	875
	Std. Dev.	*81*	*113*
Wood Mulch with Polymer (WMP)	Mean	381	785
	Std. Dev.	*57*	*188*

[(1)] Density is defined as the number of plants per 1m^2 quadrat monitoring area.

Table 6-13
NON-NATIVE PLANT DENSITY
NON-IRRIGATED FILL SLOPE

Treatment	Statistic	Plant Density[(1)] Event 3 (May 1999)	Plant Density[(1)] Event 7 (April 2000)
Bare (BARE)	Mean	122	318
	Std. Dev.	*15*	*100*
Bonded Fiber Matrix (BFM)	Mean	98	443
	Std. Dev.	*24*	*58*
Coconut Blanket (CB)	Mean	143	356
	Std. Dev.	*56*	*38*
Coir (COIR)	Mean	175	367
	Std. Dev.	*60*	*21*
Compost (COMP)	Mean	155	409
	Std. Dev.	*47*	*168*
Curled Wood Fiber Blanket (CWFB)	Mean	123	203
	Std. Dev.	*28*	*15*
Gypsum, Rate 1 (GYP1)	Mean	60	536
	Std. Dev.	*11*	*54*
Gypsum, Rate 2 (GYP2)	Mean	68	467
	Std. Dev.	*34*	*207*
Paper Mulch with Psyllium (PMG)	Mean	77	481
	Std. Dev.	*36*	*76*
Paper Mulch with Polymer (PMP)	Mean	90	306
	Std. Dev.	*8*	*65*
Wheat Straw (RS)	Mean	96	469
	Std. Dev.	*12*	*188*
Straw Blanket (SB)	Mean	107	349
	Std. Dev.	*38*	*76*
Straw-Coconut Blanket (SCB)	Mean	91	317
	Std. Dev.	*14*	*20*
Wood Fiber Blanket (WFB)	Mean	125	536
	Std. Dev.	*43*	*182*
Wood Mulch with Psyllium (WMG)	Mean	48	301
	Std. Dev.	*35*	*164*
Wood Mulch with Polymer (WMP)	Mean	82	431
	Std. Dev.	*14*	*208*

(1) Density is defined as the number of plants per 1m^2 quadrat monitoring area.

Table 6-14
NON-NATIVE PLANT DENSITY
NON-IRRIGATED CUT SLOPE

Treatment	Statistic	Plant Density[1] Event 3 (May 1999)	Plant Density[1] Event 7 (April 2000)
Bare (BARE)	Mean	395	1170
	Std. Dev.	*59*	*250*
Bonded Fiber Matrix (BFM)	Mean	289	783
	Std. Dev.	*116*	*377*
Coconut Blanket (CB)	Mean	278	738
	Std. Dev.	*36*	*177*
Coir (COIR)	Mean	357	1315
	Std. Dev.	*66*	*219*
Compost (COMP)	Mean	341	1283
	Std. Dev.	*11*	*196*
Curled Wood Fiber Blanket (CWFB)	Mean	275	673
	Std. Dev.	*92*	*134*
Gypsum, Rate 1 (GYP1)	Mean	297	1568
	Std. Dev.	*50*	*111*
Gypsum, Rate 2 (GYP2)	Mean	261	1218
	Std. Dev.	*93*	*498*
Paper Mulch with Psyllium (PMG)	Mean	276	920
	Std. Dev.	*53*	*345*
Paper Mulch with Polymer (PMP)	Mean	246	879
	Std. Dev.	*36*	*135*
Wheat Straw (RS)	Mean	348	1006
	Std. Dev.	*44*	*162*
Straw Blanket (SB)	Mean	423	1027
	Std. Dev.	*126*	*166*
Straw-Coconut Blanket (SCB)	Mean	419	867
	Std. Dev.	*75*	*242*
Wood Fiber Blanket (WFB)	Mean	386	674
	Std. Dev.	*60*	*104*
Wood Mulch with Psyllium (WMG)	Mean	242	773
	Std. Dev.	*22*	*192*
Wood Mulch with Polymer (WMP)	Mean	427	1025
	Std. Dev.	*22*	*242*

(1) Density is defined as the number of plants per $1m^2$ quadrat monitoring area.

Table 6-15
PLANT DENSITY[1] P-VALUES FROM ANALYSIS OF VARIANCE
MONITORING EVENTS 3 AND 7 (MAY 1999 AND APRIL 2000)

Response	Slope Type	Irrigation	Treatment	Event	Irrigation * Slope Type	Treatment * Slope Type	Treatment * Irrigation	Treatment * Irrigation* Slope Type
California Sagebrush *(Artemisa californica)*	0.532	0.008	0	0	0.005	0.842	0.004	0.832
Bush Sunflower *(Encelia californica)*	0.002	0.921	0	0.542	0.009	0.004	0.668	0.007
California Buckwheat *(Erigonum fasciculatum)*	0	0.001	0	0	0	0.012	0.162	0.083
Golden Bush *(Isocoma menziesii)*	0.565	0.565	0.607	1	0.565	0.795	0.794	0.146
Deerweed *(Lotus scoparius* var. *scoprius)*	0	0.782	0.959	0.019	0.221	0.165	0.842	0.144
Black Sage *(Salvia mellifera)*	0	0	0.028	0.819	0.002	0.059	0.132	0.163
California Barley *(Hordeum californicum)*	0.865	0.865	0.562	0.865	0.063	0.328	0.329	0.561
Purple Needlegrass *(Nasella pulchra)*	0.49	0.215	0.868	0.215	0.216	0.542	0.356	0.528
Goldfields *(Lasthenia californica)*	0.004	0.366	0.003	0	0	0.748	0.254	0.371
Lupine *(lupinus bicolor)*	0	0.001	0.7	0	0	0.515	0.865	0.754
Six-week Fescue *(Vulpia octoflora)*	0.002	0.079	0.511	0	0.131	0.459	0.394	0.284
Non-native grasses	0	0.004	0.357	0	0.287	0.9	0.851	0.975
Non-native broadleaves	0.827	0.836	0.09	0	0.016	0.419	0.563	0.714

(1) Density is defined as the number of plants 1m^2 quadrat monitoring area.
Note: "*" indicates an interaction between the variables indicated.

A p-value less than 0.05 indicates a significant effect of the factor corresponding to the column in the table on the variable corresponding to the row in the table. There are significant differences with irrigation for some but not all native species and for non-native grass species.

To further refine the analysis of the effect of irrigation on the overall establishment of native species for different erosion control treatments, only the total density of the coastal sage scrub (CSS) seed mix was analyzed for the final sampling event in Spring 2000. Table 6-16 presents the mean densities and standard deviations for the total CSS seed mix are presented for the different erosion control treatments in irrigated and non-irrigated plots on both cut and fill slope sites. A factorial analysis of variance with site, irrigation and erosion control treatment as factors was used in the analysis of the final spring monitoring event. The analysis of variance is presented in Table 6-17. In this analysis, irrigation is not a significant effect. However, slope type (cut and fill) and erosion control treatments as well as the interaction between the two effects are significant. Therefore, after an initial effect on germination, irrigation is not a factor in the second year for overall establishment of the CSS seed mix.

6.4 COMPARISON OF TREATMENT SUCCESS

To determine if erosion control treatment affected success of plant growth the data on vegetation cover and plant density from the last monitoring event (April 2000) were analyzed.

6.4.1 Vegetation Cover – Treatment Comparisons

Data were collected on percent vegetation cover for each treatment test plot. Because native plants did not contribute enough vegetation cover in the plots to distinguish among treatments, the total plant cover was measured using both native and non-native plant species for the final monitoring event. Monitoring data were analyzed to determine any plant cover differences between erosion control treatments. Tables 6-18a and 6-18b show the mean total plant cover and standard deviation for the erosion control treatments for irrigated and non-irrigated plots at each slope type (cut or fill) for Events 3 (April 1999) and 7 (May 2000), respectively. The total plant cover for Event 7 was analyzed using a factorial analysis of variance with slope type, irrigation and erosion control treatment as factors.

The analysis of variance for total plant cover is shown in Table 6-19. The data indicate that the main effects for slope type, irrigation, and erosion control treatment are significant. The interactions of slope type by irrigation treatment and irrigation treatment by erosion control treatment are also significant. These significant interactions of the main effects imply that relative to percent cover the effects of the irrigation are different on the two slope types, and for the different erosion control treatments. In other words, there is no single best erosion control treatment across all slope conditions.

6.4.2 Plant Density – Treatment Comparisons

Plant density was also analyzed to determine any differences between erosion control treatments. Table 6-16 presents the means and standard deviations for total CSS seed mix plant density for the different erosion control treatments on irrigated and non-irrigated plots for both cut and fill slopes. Three erosion control treatments (bonded fiber matrix, compost, and wood fiber blanket)

Table 6-16
MEAN AND STANDARD DEVIATION OF DENSITY(1) OF
CSS SEED MIX SPECIES MONITORING EVENT 7 (APRIL 2000)

Treatment	Statistics	Plant Density(1)			
		Fill Slope		Cut Slope	
		Non-irrigated	Irrigated	Non-irrigated	Irrigated
Bare (BARE)	Mean	2.33	0.33	0.67	1.67
	Std. Dev.	*0.94*	*0.47*	*0.94*	*1.25*
Bonded Fiber Matrix (BFM)	Mean	0.00	0.67	5.67	13.00
	Std. Dev.	*0.00*	*0.94*	*6.02*	*12.36*
Coconut Blanket (CB)	Mean	2.33	0.00	0.00	3.67
	Std. Dev.	*3.30*	*0.00*	*0.00*	*3.77*
Coir (COIR)	Mean	0.33	2.67	0.33	0.33
	Std. Dev.	*0.47*	*0.94*	*0.47*	*0.47*
Compost (COMP)	Mean	4.33	0.33	4.67	10.67
	Std. Dev.	*3.68*	*0.47*	*3.77*	*9.46*
Curled Wood Fiber Blanket (CWFB)	Mean	0.33	0.00	0.33	0.00
	Std. Dev.	*0.47*	*0.00*	*0.47*	*0.00*
Gypsum Rate 1(GYP1)	Mean	2.33	1.33	0.33	1.67
	Std. Dev.	*1.89*	*1.89*	*0.47*	*2.36*
Gypsum Rate 2 (GYP2)	Mean	5.33	1.33	2.67	3.67
	Std. Dev.	*5.44*	*0.94*	*2.49*	*0.47*
Paper Mulch With Psyllium (PMG)	Mean	1.00	0.67	2.00	1.67
	Std. Dev.	*1.41*	*0.94*	*2.16*	*1.25*
Paper Mulch With Polymer (PMP)	Mean	0.67	0.67	3.67	2.33
	Std. Dev.	*0.47*	*0.47*	*2.87*	*1.70*
Wheat Straw (RS)	Mean	2.00	2.67	1.67	1.33
	Std. Dev.	*1.63*	*1.25*	*1.70*	*1.25*
Straw Blanket (SB)	Mean	1.00	0.00	0.00	0.33
	Std. Dev.	*1.41*	*0.00*	*0.00*	*0.47*
Straw-Coconut Blanket (SCB)	Mean	1.33	3.33	0.00	0.33
	Std. Dev.	*1.25*	*2.62*	*0.00*	*0.47*
Wood Fiber Blanket (WFB)	Mean	3.67	3.67	0.67	10.00
	Std. Dev.	*3.09*	*3.86*	*0.94*	*6.98*
Wood Mulch With Psyllium (WMG)	Mean	0.67	1.67	5.33	1.33
	Std. Dev.	*0.94*	*0.47*	*6.18*	*1.25*
Wood Mulch With Polymer (WMP)	Mean	0.33	1.33	5.00	3.33
	Std. Dev.	*0.47*	*1.89*	*4.32*	*2.49*

(1) Density is defined as the number of plants per 1m^2 quadrat monitoring area.

Table 6-17
ANALYSIS OF VARIANCE FOR PLANT DENSITY
MONITORING EVENT 7 (APRIL 2000)

SOURCE	DOF[1]	F-ratio	p-value
Slope type	1	5.506	0.02
Irrigation	1	0.787	0.377
Treatment	15	2.051	0.016
Slope type * Irrigation	1	3.080	0.082
Slope type * Irrigation * Treatment	15	1.761	0.047
Slope type * Irrigation * Treatment	15	1.108	0.356

[1]DOF = Degrees of Freedom
Note: "*"indicates an interaction between the variables indicated.

have significantly higher native plant densities than the bare treatment as determined by the factorial analysis of variance with slope type, irrigation and erosion control treatment as factors. The p-values for the analysis of variance are presented in Table 6-17. As previously discussed in Section 6.2, there was a significant interaction between slope type and erosion control treatment for native plant densities. Therefore, the effects of erosion control treatments on native plant density were not the same for cut and fill slopes. Of the three erosion control treatments identified as significantly different from the bare treatment, bonded fiber matrix had significantly different densities for native plants on the cut-slope site compared to the fill-slope site. Compost and wood fiber blanket plant densities were not significantly different between cut and fill slopes. As with the comparisons of plant cover, the density results indicate that different erosion control treatments may be required for optimum establishment of native species depending on whether a slope is a cut or a fill.

6.4.3 Plant Vigor and Phenology

The vigor and phenology data were collected to provide information on whether the different treatments affected plant growth differently. However, the quantities of data that were obtained in the course of the study were not sufficient to allow analyses that would lead to firm conclusions. In addition, analyses of the mortality data lead to conclusions about the effects of the treatments on plant growth. Therefore, analyses of the vigor and phenology data are not presented here.

6.5 SEASONAL VARIATIONS IN GROWTH RATES OF SHRUB SPECIES

To determine the growth rates of shrub species, the height data from the spring sampling events for May 1999 and April 2000 (Events 3 and 7), from irrigated and non-irrigated plots were analyzed. Because there were few shrubs to measure, the data for the cut and fill slopes were pooled. Tables 6-20 and 6-21 show the average shrub species for irrigated and non-irrigated plots height at Events 3 and 7. Generally, shrub height increased more on the irrigated plots; however, all heights of surviving shrubs increased over the study period.

Table 6-18a
MEAN AND STANDARD DEVIATION FOR TOTAL PLANT COVER MONITORING EVENT 3 (APRIL 1999)

Treatment	Statistic	Total Cover(1)			
		Fill Slope		Cut Slope	
		Non-irrigated	Irrigated	Non-irrigated	Irrigated
Bare (BARE)	Mean	4.00	3.33	4.33	4.33
	Std. Dev.	*0.00*	*0.47*	*0.47*	*0.47*
Bonded Fiber Matrix (BFM)	Mean	3.00	3.67	4.00	4.00
	Std. Dev.	*0.82*	*0.47*	*0.00*	*0.00*
Coconut Blanket (CB)	Mean	4.33	4.00	4.33	4.00
	Std. Dev.	*0.47*	*0.00*	*0.47*	*0.82*
Coir (COIR)	Mean	4.00	3.67	4.00	4.33
	Std. Dev.	*0.00*	*0.47*	*0.00*	*0.47*
Compost (COMP)	Mean	3.33	3.67	4.33	4.33
	Std. Dev.	*0.94*	*0.47*	*0.47*	*0.47*
Curled Wood Fiber Blanket (CWFB)	Mean	3.33	4.00	4.67	4.67
	Std. Dev.	*0.47*	*0.00*	*0.47*	*0.47*
Gypsum Rate 1(GYP1)	Mean	3.33	3.67	5.00	4.33
	Std. Dev.	*0.47*	*0.47*	*0.82*	*0.47*
Gypsum Rate 2 (GYP2)	Mean	4.00	3.33	4.67	4.67
	Std. Dev.	*0.00*	*0.47*	*0.47*	*0.47*
Paper Mulch With Psyllium (PMG)	Mean	4.00	4.00	4.33	4.33
	Std. Dev.	*0.00*	*0.00*	*0.47*	*0.47*
Paper Mulch With Polymer (PMP)	Mean	4.00	4.00	4.67	4.33
	Std. Dev.	*0.00*	*0.00*	*0.47*	*0.47*
Wheat Straw (RS)	Mean	5.00	3.33	5.00	4.33
	Std. Dev.	*0.82*	*0.47*	*0.00*	*0.47*
Straw Blanket (SB)	Mean	4.00	4.00	4.33	4.67
	Std. Dev.	*0.00*	*0.00*	*0.47*	*0.47*
Straw-Coconut Blanket (SCB)	Mean	3.67	3.67	4.33	4.00
	Std. Dev.	*0.47*	*0.47*	*0.94*	*0.00*
Wood Fiber Blanket (WFB)	Mean	3.67	3.33	3.33	4.00
	Std. Dev.	*0.47*	*0.47*	*0.47*	*0.00*
Wood Mulch With Psyllium (WMG)	Mean	2.33	4.00	3.33	4.33
	Std. Dev.	*1.70*	*0.00*	*0.47*	*0.47*
Wood Mulch With Polymer (WMP)	Mean	4.33	4.00	4.33	4.67
	Std. Dev.	*0.94*	*0.00*	*0.47*	*0.47*

(1) Cover based on Daubenmire cover estimation method (Table 3-2).

Table 6-18b
MEAN AND STANDARD DEVIATION FOR TOTAL PLANT COVER
MONITORING EVENT 7 (MAY 2000)

Treatment	Statistic	Total Cover(1)			
		Fill Slope		Cut Slope	
		Non-irrigated	Irrigated	Non-irrigated	Irrigated
Bare (BARE)	Mean	3.19	3.52	3.57	4.10
	Std. Dev.	*1.05*	*0.79*	*0.95*	*0.87*
Bonded Fiber Matrix (BFM)	Mean	2.81	3.62	3.48	3.95
	Std. Dev.	*1.18*	*0.84*	*0.79*	*0.72*
Coconut Blanket (CB)	Mean	3.48	3.62	3.62	3.76
	Std. Dev.	*1.18*	*0.65*	*0.90*	*1.06*
Coir (COIR)	Mean	3.14	3.43	3.38	3.48
	Std. Dev.	*1.08*	*0.73*	*0.90*	*1.01*
Compost (COMP)	Mean	2.90	3.67	3.48	4.10
	Std. Dev.	*1.19*	*0.71*	*0.85*	*0.81*
Curled Wood Fiber Blanket (CWFB)	Mean	2.90	3.57	3.76	4.14
	Std. Dev.	*0.92*	*0.66*	*1.02*	*0.56*
Gypsum Rate 1(GYP1)	Mean	3.10	3.43	4.14	4.19
	Std. Dev.	*1.11*	*0.73*	*1.04*	*0.66*
Gypsum Rate 2 (GYP2)	Mean	3.33	3.00	3.90	4.10
	Std. Dev.	*1.17*	*0.82*	*0.87*	*0.97*
Paper Mulch With Psyllium (PMG)	Mean	3.33	3.62	3.67	3.81
	Std. Dev.	*1.08*	*0.58*	*0.99*	*0.66*
Paper Mulch With Polymer (PMP)	Mean	3.24	3.86	3.95	3.90
	Std. Dev.	*1.15*	*0.77*	*1.17*	*0.61*
Wheat Straw (RS)	Mean	3.57	3.48	4.33	3.95
	Std. Dev.	*1.40*	*0.79*	*1.08*	*0.72*
Straw Blanket (SB)	Mean	3.10	4.14	3.85	4.19
	Std. Dev.	*1.06*	*0.56*	*0.85*	*0.73*
Straw-Coconut Blanket (SCB)	Mean	3.24	3.57	3.62	3.86
	Std. Dev.	*1.02*	*0.49*	*1.05*	*0.56*
Wood Fiber Blanket (WFB)	Mean	3.00	3.48	3.10	3.95
	Std. Dev.	*1.05*	*0.73*	*0.87*	*0.49*
Wood Mulch With Psyllium (WMG)	Mean	2.19	4.05	3.23	3.81
	Std. Dev.	*1.47*	*0.72*	*0.79*	*0.85*
Wood Mulch With Polymer (WMP)	Mean	3.33	3.71	3.80	4.52
	Std. Dev.	*1.17*	*0.55*	*0.75*	*0.73*

(1) Cover based on Daubenmire cover estimation method (Table 3-2).

Table 6-19
ANALYSIS OF VARIANCE FOR TOTAL PLANT COVER
MONITORING EVENT 7 (APRIL 2000)

Source	DOF(1)	Mean - Square	F-ratio	p-value
Slope Type	1		102.672	0.000
Irrigation	1		73.836	0.000
Treatment	15		3.168	0.000
Slope Type * Irrigation	1		4.001	0.046
Slope Type * Treatment	15		1.488	0.102
Irrigation * Treatment	15		3.601	0.000
Slope Type * Irrigation * Treatment	15		1.456	0.114
Event	1		244.557	0.000
Error	1277	0.725		

"*" indicates an interaction between the variables indicated.

Note: (1) DOF = Degrees of Freedom

6.6 ROOT DEPTHS

Because there were fewer than expected shrub species available for measurements, grass and broadleaf species were also sampled to allow for comparisons of their root depths to the shrub species. Species measured other than those found in the CSS seed mix include native arroyo lupine and non-native clover, sunflower, black mustard, yellow star thistle, filaree, wild radish, California chicory and annual grasses. Figures 1(a) through (z) show root depth measurements of native and non-native plants for Site 10-2, irrigated and non-irrigated and Site 57-4, irrigated. Table 6-22 shows the number of plants sampled and the average root depth for each species measured. As shown, deerweed (Lotus *scoparius* var. *scoparius*) had the deepest roots (50.6 cm) and goldfields (*Lastheria californica*) had the most shallow roots (6.0 cm). Non-native species (clover, black mustard, yellow star thistle, filaree, wild radish, and grass) root depths varied widely (41 cm [radish] to 13 cm [grass]). The grass, which was the dominant species on most plots, is shallow rooted.

6.7 EFFECTS OF EROSION CONTROL TREATMENTS ON SHRUB SEEDLING MORTALITY

To determine if erosion control treatments had an effect on shrub seedling survival, the data were examined for mortality of shrub seedlings from all plant establishment plots for both spring sampling events (Events 3 and 7). The density of each shrub species at Monitoring Event 7 was subtracted from the corresponding species density at Monitoring Event 3. These two sampling events were examined to include the early spring season of 1999 to capture the shrub seedlings that could have germinated under irrigation, and the final monitoring period to ascertain the final number of surviving shrubs. Tables 6-23 and 6-24 show the average plant mortality (and standard deviations) for shrub species for the different erosion control treatments at all plots. Negative values indicate germination of new individuals during the study period.

Table 6-20
AVERAGE HEIGHT(1) OF TAGGED SHRUBS AT IRRIGATED PLOTS MONITORING EVENTS 3 AND 7 (MAY 1999 AND APRIL 2000)

Shrub Species	California Sagebrush		Bush Sunflower		California Buckwheat		Golden Bush		Deerweed		Black Sage	
Treatment	Event		Event		Event		Event		Event		Event	
	3	7	3	7	3	7	3	7	3	7	3	7
Bare (BARE)	0.3	--(2)	2.5	--	2.2	42.0	--	--	--	--	0.4	--
Bonded Fiber Matrix (BFM)	1.9	--	--	--	2.7	30.5	--	--	--	--	2.2	--
Coconut Blanket (CB)	3.2	--	17.2	--	3.7	--	--	--	8.3	--	2.4	--
Coir (COIR)	5.3	27.0	6.6	30.0	2.3	--	--	--	11.4	39.3	--	--
Compost (COMP)	3.3	--	2.3	--	1.6	--	--	--	6.1	--	--	--
Curled Wood Fiber Blanket (CWFB)	1.5	--	8.3	--	2.0	--	--	--	14.0	--	--	--
Gypsum, Rate 1 (GYP1)	1.4	--	2.6	--	1.5	--	--	--	6.4	55.9	1.0	--
Gypsum, Rate 2 (GYP2)	1.6	--	9.0	--	2.7	30.5	--	--	--	--	1.0	--
Paper Mulch with Psyllium (PMG)	7.4	37.0	2.8	--	4.2	--	--	--	13.7	--	3.5	--
Paper Mulch with Polymer (PMP)	--	--	--	--	4.8	--	--	--	15.1	50.8	--	--
Wheat Straw (RS)	3.8	38.0	4.1	26.7	6.1	52.5	--	--	7.6	31.5	2.1	--
Straw Blanket (SB)	2.0	--	3.5	--	3.1	--	0.3	--	5.9	--	0.4	--
Straw-Coconut Blanket (SCB)	4.5	34.6	9.0	41.3	4.1	--	--	--	11.2	6.5	--	--
Wood Fiber Blanket (WFB)	3.0	--	3.9	14.0	2.7	19.9	2.0	--	5.2	--	1.2	--
Wood Mulch with Psyllium (WMG)	1.5	--	--	--	1.9	--	9.0	--	23.1	59.0	--	--
Wood Mulch with Polymer (WMP)	3.0	27.9	3.5	--	2.1	26.3	--	--	6.3	--	0.9	--

Note:

(1) Height value is the average height (cm) of living tagged plants in all subplots with the treatment.

(2 slope types x 3 subplots per slope type x 3 tagged plants per subplot) = 18 possible plants included in the calculation.

(2) Dashes indicate no live plants were available in any of the subplots.

Table 6-21
AVERAGE HEIGHT[1] OF TAGGED SHRUBS AT NON-IRRIGATED PLOTS MONITORING EVENTS 3 AND 7 (MAY 1999 AND APRIL 2000)

Shrub Species	California Sagebrush		Bush Sunflower		California Buckwheat		Golden Bush		Deerweed		Black Sage	
Treatment	Event		Event		Event		Event		Event		Event	
	3	7	3	7	3	7	3	7	3	7	3	7
Bare (BARE)	2.0	-- [2]	--	--	3.2	--	--	--	5.3	27.8	--	--
Bonded Fiber Matrix (BFM)	--	--	--	--	2.8	--	1.8	--	--	--	--	--
Coconut Blanket (CB)	4.1	16.0	7.6	--	6.7	--	--	--	14.5	69.2	1.9	--
Coir (COIR)	2.0	--	3.2	--	4.9	--	--	--	4.4	--	--	--
Compost (COMP)	1.8	--	2.8	--	4.0	--	--	--	5.2	33.0	--	--
Curled Wood Fiber Blanket (CWFB)	--	--	6.3	--	1.1	--	--	--	7.9	--	--	--
Gypsum, Rate 1 (GYP1)	2.1	--	4.2	--	3.1	--	--	--	2.4	--	--	--
Gypsum, Rate 2 (GYP2)	4.2	12.5	--	--	4.4	--	--	--	8.6	66.1	--	--
Paper Mulch with Psyllium (PMG)	3.1	--	--	--	3.1	--	--	--	6.9	67.3	--	--
Paper Mulch with Polymer (PMP)	2.5	--	2.0	--	1.8	--	--	--	3.1	--	--	--
Wheat Straw (RS)	2.6	--	5.8	8.5	3.8	--	--	--	8.7	--	2.0	--
Straw Blanket (SB)	--	--	2.6	--	1.8	--	8.4	--	6.3	--	--	--
Straw-Coconut Blanket (SCB)	3.0	--	2.5	--	2.2	--	--	--	8.1	--	--	--
Wood Fiber Blanket (WFB)	3.8	19.7	4.7	33.0	2.1	--	--	--	8.1	63.5	--	--
Wood Mulch with Psyllium (WMG)	--	--	4.5	--	1.7	--	--	--	3.9	--	--	--
Wood Mulch with Polymer (WMP)	4.0	--	--	--	3.3	--	--	--	4.5	--	--	--

Note:

(1) Height value is the average height (cm) of living tagged plants in all subplots with the treatment.

(2 slope types x 3 subplots per slope type x 3 tagged plants per subplot) = 18 possible plants included in the calculation.

(2) Dashes indicate no live plants were available in any of the subplots.

Table 6-22
AVERAGE ROOT DEPTH OF SELECTED SPECIES

Species	Total Number Measured	Average Root Depth (cm)
California Sagebrush	21	44.3
Chickory	13	40.9
Clover	49	15.0
Bush Sunflower	8	49.0
California Buckwheat	37	47.2
Filaree	87	23.1
Non-native Grass	123	13.2
Goldfields	37	6.0
Deerweed	30	50.6
Lupine	21	24.6
Arroyo Lupine	33	29.1
Mustard	30	34.5
Radish	2	41.0
Star Thistle	68	18.4
Sunflower	7	39.0

Table 6-23
MEAN MORTALITIES IRRIGATED PLOTS

VEGETATION TYPES	Bare (BARE)			Bonded Fiber Matrix (BFM)			Coconut Blanket (CB)			Coir (COIR)			Compost (COMP)			Curled Wood Fiber Blanket (CWFB)			Gypsum Rate 1 (GYP1)			Gypsum Rate 2 (GYP2)			Paper Mulch with Psyllium (PMG)			Paper Mulch with Polymer (PMP)			Wheat Straw (RS)			Straw Blanket (SB)			Straw-Coconut Blanket (SCB)			Wood Fiber Blanket (WFB)			Wood Mulch with Psyllium (WMG)			Wood Mulch with Polymer (WMP)		
	Fill	Cut	Both	Fill	Cut	Both	Fill	Cut	Both	Fill	Cut	Both	Fill	Cut	Both	Fill	Cut	Both	Fill	Cut	Both	Fill	Cut	Both	Fill	Cut	Both	Fill	Cut	Both	Fill	Cut	Both	Fill	Cut	Both	Fill	Cut	Both	Fill	Cut	Both	Fill	Cut	Both	Fill	Cut	Both
California Sage Brush *(Artemisia californica)*	0	0	0	0	0	0	1.33	0.33	0.83	1.67	1.00	1.33	0.33	-2.00	-0.83	0.67	0	0.33	0	-0.33	-0.17	0	0.33	0.17	0.33	0	0.17	0	-0.33	-0.17	-0.33	0	-0.17	1.67	0.33	1.00	2.00	0	1.00	4.00	2.33	3.17	0	-0.33	-0.17	1.33	0.33	0.83
Bush Sunflower *(Encelia californica)*	0	0	0	0	-1.33	-0.67	0	-0.33	-0.17	0.33	0	0.17	0	-2.00	-1.00	0.33	0	0.17	0	0.33	0.17	-0.33	-0.33	-0.33	0	0	0	0	-1.00	-0.50	0.00	-0.33	-0.17	0.33	0	0.17	0	0	0	0	0.33	0.17	-0.67	0	-0.33	0	1.00	0.50
California Buckwheat *(Eriogonum fasciculatum)*	0.33	1.33	0.83	-0.33	3.67	1.67	1.33	0.33	0.83	-0.33	2.67	1.17	0.33	0	0.17	1.00	0	0.50	0	3.00	1.50	-0.33	1.33	0.50	0.67	0.67	0.67	0	0.67	0.33	0.67	1.67	1.17	1.00	3.00	2.00	0.33	0	0.17	0.67	0.67	0.67	0.33	0.67	0.50	1.00	-0.67	0.17
Golden Bush *(Isocoma menziesii)*	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	-0.33	0	-0.17	0	0	0	0	0	0	0	0.33	0.17	0	0	0	0	0	0
Deerwood *(Lotus scoparius* var. *scoparius)*	-0.33	-1.00	-0.67	0	-3.33	-1.67	1.00	-0.33	0.33	0.33	-0.33	0	0.33	3.33	-1.50	2.00	0	1.00	-0.33	-0.67	-0.50	-0.67	-2.00	-1.33	0.67	0.33	0.50	0.67	-0.33	0.17	0	-0.33	-0.17	4.00	-0.33	1.83	0	0	0	0.33	-2.33	-1.00	0.67	0	0.33	0	0.33	0.17
Black Sage *(Salvia mellifera)*	0	-0.33	-0.17	0	-3.67	-1.83	1.00	0.33	0.17	0	0	0	0	-1.67	-0.83	0	0	0	0	-0.33	-0.17	0	0.33	0.17	0.33	-1.33	-0.50	0	-0.67	-0.33	0	-0.33	-0.17	0	0	0	0	0	0	0	-1.33	-0.67	0	0	0	0	-0.33	-0.17
California Barley *(Hordeum californicum)*	0	0	0	0	0	0	0	-1.67	-0.83	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Purple Needlegrass *(Nasella pulchra)*	0	0	0	0	-0.33	-0.17	0.00	-1.33	-0.67	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	-0.33	-0.17	0.00	-0.33	-0.17	0	0	0

Table 6-24
MEAN MORTALITIES NON-IRRIGATED PLOTS

VEGETATION TYPES	Bare (BARE)			Bonded Fiber Matrix (BFM)			Coconut Blanket (CB)			Coir (COIR)			Compost (COMP)			Curled Wood fiber Blanket (CWFB)			Gypsum Rate 1 (GYP1)			Gypsum Rate 2 (GYP2)			Paper Mulch withPsyllium (PMG)			Paper Mulch with Polymer (PMP)			Wheat Straw (RS)			Straw Blanket (SB)			Straw-Coconut (SCB)			Wood Fiber Blanket (WFB)			Wood Mulch with Psyllium (WMG)			Wood Mulch with Polymer (WMP)		
	Fill	Cut	Both	Fill	Cut	Both	Fill	Cut	Both	Fill	Cut	Both	Fill	Cut	Both	Fill	Cut	Both	Fill	Cut	Both	Fill	Cut	Both	Fill	Cut	Both	Fill	Cut	Both	Fill	Cut	Both	Fill	Cut	Both	Fill	Cut	Both	Fill	Cut	Both	Fill	Cut	Both	Fill	Cut	Both
California Sage Brush *(Artemisia californica)*	0	0	0	0	0	0	1.33	0.33	0.83	1.67	1.00	1.33	0.33	-2.00	-0.83	0.67	0	0.33	0	-0.33	-0.17	0	0.33	0.17	0.33	0	0.17	0	-0.33	-0.17	-0.33	0	-0.17	1.67	0.33	1.00	2.00	0	1.00	4.00	2.33	3.17	0	-0.33	-0.17	1.33	0.33	0.83
Bush Sunflower *(Encelia californica)*	0	0	0	0	-1.33	-0.67	0	-0.33	-0.17	0.33	0	0.17	0	-2.00	-1.00	0.33	0	0.17	0	0.33	0.17	-0.33	-0.33	-0.33	0	0	0	0	-1.00	-0.50	0.00	-0.33	-0.17	0.33	0	0.17	0	0	0	0	0.33	0.17	-0.67	0	-0.33	0	1.00	0.50
California Buckwheat *(Eriogonum fasciculatum)*	0.33	1.33	0.83	-0.33	3.67	1.67	1.33	0.33	0.83	-0.33	2.67	1.17	0.33	0	0.17	1.00	0	0.50	0	3.00	1.50	-0.33	1.33	0.50	0.67	0.67	0.67	0	0.67	0.33	0.67	1.67	1.17	1.00	3.00	2.00	0.33	0	0.17	0.67	0.67	0.67	0.33	0.67	0.50	1.00	-0.67	0.17
Golden Bush *(Isocoma menziesii)*	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	-0.33	0	-0.17	0	0	0	0	0	0	0	0.33	0.17	0	0	0	0	0	0
Deerwood *(Lotus scoparius var. scoparius)*	-0.33	-1.00	-0.67	0	-3.33	-1.67	1.00	-0.33	0.33	0.33	-0.33	0	0.33	3.33	-1.50	2.00	0	1.00	-0.33	-0.67	-0.50	-0.67	-2.00	-1.33	0.67	0.33	0.50	0.67	-0.33	0.17	0	-0.33	-0.17	4.00	-0.33	1.83	0	0	0	0.33	-2.33	-1.00	0.67	0	0.33	0	0.33	0.17
Black Sage *(Salvia mellifera)*	0	-0.33	-0.17	0	-3.67	-1.83	1.00	0.33	0.17	0	0	0	0	-1.67	-0.83	0	0	0	0	-0.33	-0.17	0	0.33	0.17	0.33	-1.33	-0.50	0	-0.67	-0.33	0	-0.33	-0.17	0	0	0	0	0	0	0	-1.33	-0.67	0	0	0	0	-0.33	-0.17
California Barley *(Hordeum californicum)*	0	0	0	0	0	0	0	-1.67	-0.83	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Purple Needlegrass *(Nasella pulchra)*	0	0	0	0	-0.33	-0.17	0.00	-1.33	-0.67	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	-0.33	-0.17	0.00	-0.33	-0.17	0	0	0

Multivariate analysis of variance of plant mortality for native shrub species show that all main effects (slope type, irrigation, and erosion control treatment) are statistically significant for plant mortality. The results of univariate analysis of variance are presented in Table 6-25. There are significant interactions between irrigation and slope type, and between irrigation and erosion control treatment and slope type.

6.8 OTHER FACTORS

6.8.1 Detailed Plot Observations

The purpose of the plant establishment test plot program was to obtain data on the effectiveness of selected temporary soil stabilization/erosion control methods on the establishment of vegetation on cut and fill slopes. However, during the course of constructing the plant establishment test plots and in the initial weeks of maintenance, it appeared that other factors may have at least as great as or greater effect than the alternative stabilization treatments on plant establishment. Such factors included gopher activity and animals trespassing across the test plots. At the 10-2 site, the factors also included debris ("projectiles") from the roadway at the top of the slope. In addition, significant variations in the durability of the different treatments under local weather conditions were observed; some of the treatments weathered and eroded relatively quickly, thereby exposing a relatively large percentage of bare ground in a "treated" subplot, while others were nearly completely intact at the end of the study. Finally, it was observed that some of the erosion control blankets used in the study formed a physical barrier to plant growth.

It was acknowledged by the project team that the interpretation of the measurements being made at the plant establishment test plots would not take into account changes in the condition of the plots due to uncontrolled site factors and weathering. For instance, if the treatment used is severely disturbed or deteriorated, correlations between the treatment type and plant growth may not be completely valid. Therefore, as part of each plant monitoring event, observations of the disturbance to, and general condition of, each subplot were recorded on sketches of each subplot. An example of a completed plot plan with supplemental comments is provided as Figure 6-2(a) and (b). There were seven monitoring events in a 16-month period, namely: December 1998/January 1999, March 1999, June 1999, November 1999/December 1999, March 2000, and May 2000.

Interpretation Methodology

It is important to understand that a change in the physical integrity (i.e., degradation) of soil stabilization/erosion control methods is not always detrimental to plant establishment. Biodegradation of a rolled erosion control product (RECP) is sometimes necessary for plant growth through the material. In a similar manner, hydraulic soil stabilizers (i.e., acrylic copolymers) which bind soil particles together may loose bonding strength over time, but this degradation also promotes vegetation establishment. The key to success of any soil stabilization/erosion control method is that it degrades at a rate compatible with the establishment of permanent, stabilizing vegetation.

Table 6-25
PLANT DENSITY P-VALUES FROM ANALYSES OF VARIANCE

Species	Slope Type	Irrigation	Treatment	Irrigation * Slope Type	Treatment * Slope Type
California sage brush	0.001	0.051	0.021	0.512	0.892
Bush sunflower	0.078	0.354	0.005	0.933	0.878
California buckwheat	0.030	0.008	0.333	0.159	0.432
Golden bush	0.739	0.319	0.253	0.319	0.651
Deerwood	0	0.589	0.155	0.480	0.643
Black sage	0.002	0.112	0.031	0.020	0.050
California barley	0.319	0.319	0.459	0.319	0.459
Purple needlegrass	0.038	0.889	0.717	0.889	0.614

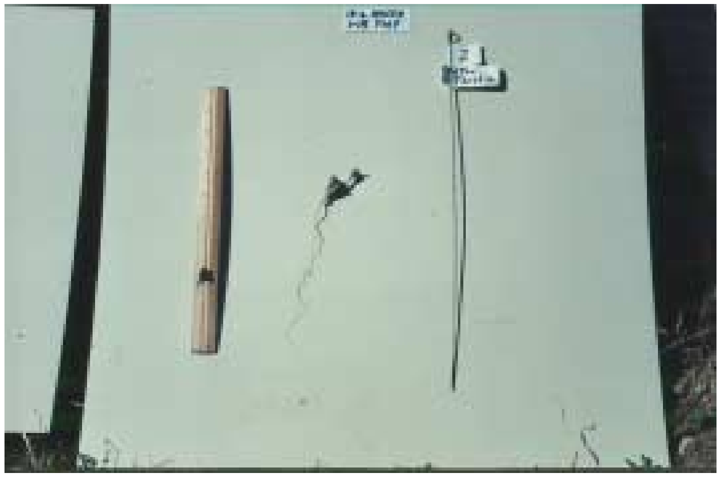
Note: These are p-values from univariate analyses of variance performed automatically by SYSTAT following multivariate analysis of variance. A p-value less than 0.05 indicates a significant effect of the factor corresponding to the column in the table on the variable corresponding to the row in the table.

"*" indicates an interaction between the variables indicated.

(a) Clover and California sage brush (Site 10-2 Non-irrigated, Plot 1-1 gypsum, rate 2).

(b) California buckwheat (Site 10-2 Non-irrigated, Plot 1-6 compost).

(c) Lupine (Site 10-2 Non-irrigated, Plot 1-10 Bare).



(d) Star Thistle (Site 10-2 Non-irrigated, Plot 1-15 paper mulch with polymer tackifier).

(e) Sunflower, Site 10-2 Non-irrigated, Plot 2-13 GYP1.

(f) Deerweed (Site 10-2 Non-irrigated, Plot 3-3 paper mulch with psyllium tackifier).

(g) Grass (Site 10-2 Non-irrigated, Plot 3-5 Coconut blanket).

(h) Bush sunflower (Site 10-2 Non-irrigated, Plot 3-6 wood fiber blanket).

(i) Filaree (Site 10-2 Non-irrigated, Plot 3-13 Incorporated wheat straw).

(j) California sage brush, California buckwheat, Filaree (Site 10-2 Irrigated, Plot 1-1 wood fiber blanket).

(k) Deerweed (Site 10-2 Irrigated, Plot 1-8 wood mulch with psyllium tackifier).

(l) Star thistle and Mustard (Site 10-2 Irrigated, Plot 1-9 Paper mulch with polymer tackifier).

(m) Lupine (Site 10-2 Irrigated, Plot 1-12 straw-cocomut blanket).

(n) Grass and California sage brush (Site 10-2 Irrigated, Plot 1-13 wwood mulch with polymer tackifier).

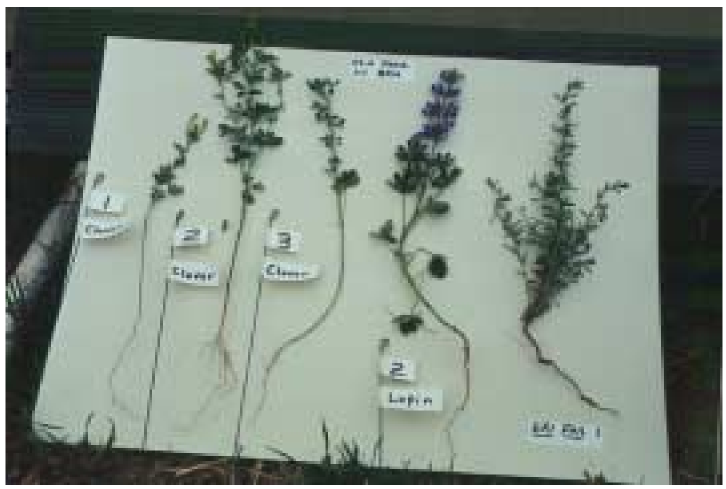
(o) Mustard and Star thistle (Site 10-2 Irrigated, 1-14 Incorporated wheat straw).

(p) Lupine (Site 10-2 Irrigated, Plot 1-15 Coir netting).

(q) Goldfields and Filaree (Site 10-2 Irrigated, Plot 2-1 paper mulch with psyllium tackifier).

(r) Sunflower (Site 10-2 Irrigated, Plot 3-5 gypsum, rate 1).

(s) Grass (Site 10-2 Irrigated, Plot 3-15 bonded fiber matrix).



(t) Clover, Lupin, and California buckwheat (Site 57-4 Irrigated, Plot 1-1 bonded fiber matrix).

(u) Lupin and Grass (Site 57-4 Irrigated, Plot 1-2 gypsum, rate 2).

(v) Lupin and Chickory (Site 57-4 Irrigated, Plot 1-11 Straw-coconut blanket).

(w) California sage brush, Chickory, Grass, and Clover (Site 57-4 Irrigated, Plot 1-14 wood fiber blanket).

(x) Mustard and Clover (Site 57-4 Irrigated, Plot 2-13 wood mulch with polymer tackifier).

(y) Clover, Grass, and Lupin (Site 57-4 Irrigated, Plot 2-15 wheat straw with psyllium tackifier).

(z) California buckwheat (Site 57-4 Irrigated, Plot 3-16 Bare).

Based on a review of the sketches and observation notes for each subplot, environmental factors in the subplots were generally classified as follows:

Gopher/Rodent activity:

Holes in the seeded ground surface and treatment, and burrow debris covering the seeded ground surface.

Animal Footprints:

Holes in the treatment, exposing bare ground.

Debris from Roadway at Top of Slope (Site 10-2 only):

Holes in the seeded ground surface and treatment.

Blanket Lifting:

Cases where the blankets were considered to be a physical barrier to plant growth as measured in the study.

Deterioration:

Subjective observations of the deterioration of erosion control measures due to weather conditions was noted in terms of cracks, fragility, thinness (relative to initial application), and downslope drift.

Exposed Soils:

Soil exposed as a result of disturbance and/or deterioration.

Statistical analysis of the gopher data revealed the following:

1) Total cover and native shrub density (or the log of native shrub density) are used as covariates in an analysis of covariance on gopher density. There is not enough variability in the other vegetation measures (native grass and forb densities, non-native grass and broadleaf densities) to justify including them as covariates.
2) There is a possibility that unequal variances across treatments in the gopher damage data might lead to significant violations of the assumptions of the analysis of covariance. Therefore, Levene's test for equal variances was run to assess the extent of unequal variances. The test showed significant differences in the variances among treatments. Thus, the analysis results for differences between treatments may be unreliable. In particular, unless the treatment effect is highly significant, with a very small p-value, it may be only spuriously significant.
3) Statistical analyses showed that treatment has no effect on gopher disturbance. Descriptive statistics for percent gopher disturbance are shown in Table 6-26. Model diagnostic plots showed that the assumptions of the analysis of variance were met.

Additional analysis of the data was performed, using the log of percent gopher damages as the dependent variable, total plant cover and the log of native shrub density as covariates, and treatment and irrigation as experimental factors. This analysis revealed the following:

1) As with the previous analysis of these data, the treatments have no effect no gopher damage, while irrigation does influence gopher damage.

Table 6-26
DESCRIPTIVE STATISTICS FOR PERCENT GOPHER DISTURBANCE

Statistic	Irrigated (%)	Non-irrigated (%)
Mean	0.913	1.466
Standard error	0.136	0.149
Standard deviation	1.330	1.456
Coefficient of variation	1.457	0.993

2) Of the two covariates included in the analysis, total cover was not significant, but the log of native shrub density was. Figure 6-3 shows that gopher damage decreases (weakly) with increasing native shrub density on non-irrigated sites, but remains relatively constant across all values of native shrub density on irrigated sites.

3) Several diagnostic tests were run on the results of the analysis of covariance of the gopher data. These tests were intended to provide an indication of any significant departures from the assumptions of the analysis. The diagnostics indicated no problems.

From these analyses, the conclusion is that there is no consistent or detectable relationship between gopher damage and total cover, or between gopher damage and the treatments. Gopher damage tends to be higher in non-irrigated plots than in irrigated plots, and there is a weak negative relationship between gopher damage and native shrub density that appears only in non-irrigated plots. With the available data, it is not possible to draw conclusions about causation in the relationship between gopher disturbance and native shrub density in non-irrigated plots.

6.8.2 Findings

Tables 6-27 through 6-30 summarize the observations of the conditions of the subplots at each test site. General conclusions from the observations are as follows:

- The most significant physical disturbance to the subplots was due to gopher/rodent activity.
- Disturbance to the subplots due to gopher/rodent activity was more severe at the 57-4 (cut) site than the 10-2 (fill) site. At the 57-4 site, the percent of the subplot area disturbed by gopher/rodent activity ranged from less than 5 percent to 80 percent, with the average extent of the gopher/rodent damage being 24 percent of the subplot area. At the 10-2 site, the percent of the subplot area disturbed by gopher/rodent activity ranged from less than 1 percent to 25 percent, with the average extent of the gopher/rodent damage being about 4 percent of the subplot area. At both sites, the distribution of the gopher/rodent disturbance appeared to be random (i.e., independent of treatment type).
- Animal tracks were more prevalent at the 10-2 site than the 57-4 site. While several subplots at the 10-2 site had over 5 percent disturbance due to animal tracks, physical disturbance due to animal tracks generally amounted to less than 1 percent of the total area of the test plots. The distribution of animal tracks at the test sites appeared to be random (i.e., independent of treatment type).

Table 6-27
ENVIRONMENTAL AND WEATHERING EFFECTS ON EROSION CONTROL TREATMENTS
SITE 10-2, NON-IRRIGATED

Plot No.	Treatment	Environmental Factors				Durability Comments(2)	Exposed Soil (%)	Overall Effect (3)
		Gopher (%) (1)	Animal Track (%)	Debris (%)	Blanket Lifting (%)			
1-1	Gypsum, Rate 2 (GYP2)	10	≤ 1	-	-	1. Cracks occur 2. GYP2 very thin, and not visible in most areas	Rock extended above surface	10
1-2	Wheat-straw Incorporated (RS)	20	-	-	-	straw thinning for about 5% of area	-	20
1-3	Coconut Blanket (CB)	10	-	-	≤ 1	CB is still visible and mostly intact, but more weathered from exposure.		11
1-4	Bonded Fiber Mix (BFM)	10	≤ 1	-	-	BFM is still intact.	≤ 1	1
1-5	Wood Mulch with Polymer (WMP)	25	≤ 1	-	-	WMP is still visible between disturbance.	Many rocks and gravels exposed	25
1-6	Compost (COMP)	10	-	-	-	COMP is not visible.	Rocks and gravels exposed on surface	10
1-7	Coir (COIR)	5	-	-	5	Some wrinkles, some loose soil over the blanket. But the COIR blanket is still intact and in a good condition.	-	10
1-8	Straw Blanket (SB)	-	≤ 1	-	5	straw thinning for about 5% of area.	5	10
1-9	Curled Wood Fiber Blanket (CWFB)	-	-	-	5	CWFB is still visible, intact and in a good condition.	≤ 1	6
1-10	Bare (BARE)	5	≤ 1	-	-		Rocks and gravels exposed on surface	5
1-11	Gypsum, Rate 1 (GYP1)	-	≤ 1	-	-	GYP1 not visible.	Rocks and gravels exposed on surface	0
1-12	Paper Mulch with Psyllium (PMG)	-	-	-	-	PMG has a honeycomb appearance with many bare spots exposing soil and washed clean rocks. There are also many cracks, some are as wide as 1/2".	Exposed Soil from many bare spots	0
1-13	Straw-Coconut Blanket (SCB)	-	≤ 1	-	≤ 1	The straw coconut blanket is still intact and becoming very weathered and fragile to touch.	15	16

Table 6-27 (Continued)
ENVIRONMENTAL AND WEATHERING EFFECTS ON EROSION CONTROL TREATMENTS
SITE 10-2, NON-IRRIGATED

Plot No.	Treatment	Environmental Factors				Durability Comments[(2)]	Exposed Soil (%)	Overall Effect [(3)]
		Gopher (%) [(1)]	Animal Track (%)	Debris (%)	Blanket Lifting (%)			
1-14	Wood Fiber Blanket (WFB)	20	≤ 1	-	-	Over 50% of the WFB are missing, exposing soil and cleaned rocks and gravels.	50	70
1-15	Paper Mulch with Polymer (PMP)	5	-	-	-	1. Cracks occur 2. Many bare spots exposed	Surface is rough with many rocks exposed	5
1-16	Wood Mulch with Psyllium (WMG)	10	≤ 1	-	-	WMG is still visible, intact but thinning out.	5	15
2-1	Wood Mulch with Polymer (WMP)	15	-	≤ 1	-	WMP treatment thinning mostly on the left side. Some cracks are as deep as 1/2".	Rocks and gravels exposed on surface	15
2-2	Paper Mulch with Psyllium (PMG)	15	-	≤ 1	-	Many cracks, some are as wide as 1/2".	Rocks and gravels exposed on surface	15
2-3	Coir (COIR)	5	-	-	≤ 1	About 5% blanket bulged upward. The blanket is still intact and becoming weathered in appearance and more fragile to touch.	-	6
2-4	Wheat-straw Incorporated (RS)	20	-	-	-	Straw is visible, but continue to drift downslope and expose soil in many areas.	5	25
2-5	Gypsum, Rate 2 (GYP2)	15	≤ 1	-	-	GYP2 is not visible.	Surface rough with rocks and gravels exposed	15
2-6	Wood Mulch with Psyllium (WMG)	≤ 1	≤ 1	-	-	WMG is still visible, intact but thinning out.	Surface rough with rocks and gravels exposed	≤ 1
2-7	Wood Fiber Blanket (WFB)	≤ 1	≤ 1	-	-	The WFB surface are still visible over about 50% of plot.	5	6
2-8	Coconut Blanket (CB)	-	≤ 1	-	≤ 1	The CB is intact, but weathered and fragile to touch.	-	≤ 1
2-9	Bare (BARE)	-	5	-	-		Rocks and gravels exposed on surface	0
2-10	Compost (COMP)	≤ 1	≤ 1	-	-		Rocks and gravels exposed on surface	≤ 1

Table 6-27 (Continued)
ENVIRONMENTAL AND WEATHERING EFFECTS ON EROSION CONTROL TREATMENTS
SITE 10-2, NON-IRRIGATED

Plot No.	Treatment	Environmental Factors				Durability Comments(2)	Exposed Soil (%)	Overall Effect (3)
		Gopher (%) (1)	Animal Track (%)	Debris (%)	Blanket Lifting (%)			
2-11	Straw-Coconut Blanket (SCB)	-	≤ 1	-	-	SCB is still intact, but very weathered from sun exposure and fragile to touch.	5	5
2-12	Straw Blanket (SB)	-	≤ 1	-	≤ 1	SB is weathered in appearance and fragile to touch.	15	16
2-13	Gypsum, Rate 1 (GYP1)	-	5	-	-	The GYP1 is not visible. The surface is rough and weathered in appearance.	Rocks and gravels exposed over entire plot	0
2-14	Curled Wood Fiber Blanket (CWFB)	-	-	-	5	CWFB is intact, but weathered in appearance.	≤1	6
2-15	Paper Mulch with Polymer (PMP)	5	5	-	-	PMP is still intact, cracks occur.	5	10
2-16	Bonded Fiber Matrix (BFM)	-	5	-	-	BFM is still visible in many areas.	20	20
3-1	Coir (COIR)	25	-	-	5	COIR is still intact, but weathered from sun exposure and fragile to touch.	-	30
3-2	Gypsum, Rate 1 (GYP1)	≤ 5	-	-	-	GYP1 is still visible but thinning out.	Soil exposed in many areas	≤ 5
3-3	Paper Mulch with Psyllium (PMG)	-	≤ 1	-	-	Many cracks. Some are as wide as ¾".	Rocks shows in many areas	0
3-4	Compost (COMP)	10	-	-	-	COMP is still slightly visible between disturbances, a few cracks.	Loose rocks and gravels on surface	10
3-5	Coconut Blanket (CB)	5	-	-	5	CB is still intact.	-	10
3-6	Wood Fiber Blanket (WFB)	-	≤ 1	-	-	Green plastic mesh of the WFB has been deteriorated completely.	10	10
3-7	Wood Mulch with Psyllium (WMG)	-	-	-	-	WMG thinning, rocks and gravels exposed in most areas.	10	10
3-8	Bare (BARE)	-	-	-	-	The BARE surface is very rough and weathered appearance.	Rocks and gravels exposed on surface	0

Table 6-27 (Continued)
ENVIRONMENTAL AND WEATHERING EFFECTS ON EROSION CONTROL TREATMENTS
SITE 10-2, NON-IRRIGATED

Plot No.	Treatment	Environmental Factors				Durability Comments(2)	Exposed Soil (%)	Overall Effect (3)
		Gopher (%) (1)	Animal Track (%)	Debris (%)	Blanket Lifting (%)			
3-9	Gypsum, Rate 2 (GYP2)	-	≤ 1	≤ 1	-	The GYP2 is slightly visible, a few cracks.	Loose rocks and gravels on surface	≤ 1
3-10	Straw Blanket (SB)	-	-	-	-	The SB is still intact, but becoming very weathered and thin. The straw blanket is very fragile and can been torn easily by hand.	Rocks and soils show from below subground	0
3-11	Straw Coconut Blanket (SCB)	-	-	-	-	The SCB is thin and weathered in appearance and soil showing through in many areas.	5	5
3-12	Wood Mulch with Polymer (WMP	≤ 1	≤ 1	-	-	The WMP is still intact and visible.	5	6
3-13	Wheat-straw Incorporated (RS)	≤1	-	-	-	The RSI is still mostly intact, but many bare spots observed exposing soil.	10	11
3-14	Paper Mulch with Polymer (PMP)	5	-	-	-	The PMP is still intact and visible, many cracks.	Rocks exposed in many areas	5
3-15	Curled Wood Fiber Blanket (CWFB)	5	-	-	5	The CWFB blanket remains intact and in good condition.	-	10
3-16	Bonded Fiber Matrix (BFM)	≤ 1	≤1	-	-	The BFM is still visible and continues to thin.	10	11

(1) The disturbed area caused by gopher activity is rounded up to nearest 5%.

(2) Description about the treatment is based on the observation in the last monitoring event.

(3) Define overall effect as a summation of affected areas from gopher activity, plants pushing up blankets, and that indicated by "Exposed soil".

Deterioration of treatment due to all factors at the end of study is described in terms of the four classes (Slight, Medium, Rather Severe, and Severe), which is mainly based on the following classification:

if overall effect <=20 disturbance is slight
if 20<overall effect <=35 disturbance is medium
if 35<overall effect <=50 disturbance is rather severe
if 50<overall effect disturbance is severe

Meanwhile, the description about the treatment is taken into account to determine the severity of the deterioration.
Note: (-) means no effect was observed

Table 6-28
ENVIRONMENTAL AND WEATHERING EFFECTS ON TEST TREATMENTS SITE 10-2, IRRIGATED CONDITION

Plot No.	Treatment	Environmental Factors				Durability Comments(2)	Exposed Soil (%)	Overall Effect (3)
		Gopher (%) (1)	Animal Track (%)	Debris (%)	Blanket Lifting (%)			
1-1	Wood Fiber Blanket (WFB)	10	-	-	-	Green plastic mesh completely deteriorated, wood fibers in tact but showing signs of thinning		10
1-2	Paper Mulch with Psyllium (PMG)	≤ 1	≤ 1	-	-	Treatment cracked over much of site, surface is rough and weathered, but mostly still intact	≤ 1	2
1-3	Curled Wood Fiber Blanket (CWFB)	10	-	-	5	Weathered in appearance, intact and in good condition.		15
1-4	Bonded Fiber Mix (BFM)	≤ 10	1	-	-	Very thin and missing in some areas, intact between disturbances	Many scattered spots over entire subplot	10
1-5	Gypsum, Rate 2 (GYP2)	5	-	-	-	Very thin but still visible	Generally over entire subplot	5
1-6	Gypsum, Rate 1 (GYP1)	≤ 10	≤ 5	-	-	Treatment not visible, surface appears weathered and rough	SSG Exposed throughout	10
1-7	Coconut Blanket (CB)	-	-	-	≤ 5	Very fragile from sun exposure, still intact		5
1-8	Wood Mulch with Psyllium (WMG)	-	≤ 1	-	-	Still visible and intact	Rocks and gravels exposed at surface over subplot area	0
1-9	Paper Mulch with Polymer (PMP)	5	≤ 1	-	-	Treatment cracked, visible and intact with a washed out look	Rocks and gravels exposed	5
1-10	Straw Blanket (SB)	≤ 1	1	-	≤ 1	Intact, weathered in appearance and fragile to the touch		≤ 1
1-11	Compost (COMP)	-	1	-	-	Slightly visible but missing in more eroded areas	10	10
1-12	Straw-Coconut Blanket (SCB)	1	-	-	≤ 1	Intact	-	≤ 1
1-13	Wood Mulch with Polymer (WMP)	<1	-	-	-	Visible and intact, thinned-out	30	31
1-14	Wheat-Straw Incorporated (RS)	<5	-	-	-	Bare spots caused by shifting straw, intact.	≤ 5	10

Table 6-28 (Continued)
ENVIRONMENTAL AND WEATHERING EFFECTS ON TEST TREATMENTS SITE 10-2, IRRIGATED CONDITION

		Environmental Factors						
Plot No.	Treatment	Gopher (%) [1]	Animal Track (%)	Debris (%)	Blanket Lifting (%)	Durability Comments[2]	Exposed Soil (%)	Overall Effect [3]
1-15	Coir (COIR)	-	-	-	≤ 15	Blanket drifted downslope		15
1-16	Bare (BARE)	-	-	-	-	Washed appearance, but basically little change from beginning	Rocks and gravels exposed	0
2-1	Paper Mulch with Psyllium (PMG)	≤ 5	-	-	-	Cracks in treatment widened due to erosion of soil exposed by cracks		5
2-2	Curled Wood Fiber Blanket (CWFB)	-	≤ 5	-	5	Weathered in appearance, gray in color, intact and in good condition	-	5
2-3	Coir (COIR)	-	-	-	-	Intact and in good condition	-	0
2-4	Straw Blanket (SB)	-	-	-	-	Intact, weathered in appearance and fragile to the touch.	≤ 5	5
2-5	Straw-Coconut Blanket (SCB)	-	-	-	-	Intact, weathered in appearance, light gray in color, straw below blanket is very thin.	<5	5
2-6	Coconut Blanket (CB)	10	-	-	≤ 5	Intact, weathered in appearance, fragile to the touch.		≤ 15
2-7	Gypsum, Rate 1 (GYP1)	-	≤ 1	-	-	Treatment not visible, surface has a rough weathered appearance.	Over much of the site.	0
2-8	Bare (BARE)	-	5	-	-	Treatment cracked, rocks and gravels exposed and surface has a rough and washed out appearance.		0
2-9	Wood Fiber Blanket (WFB)	-	≤ 10	-	-	Treatment is "spotty" and thin with loose rocks and gravels on the surface.	50	50
2-10	Gypsum, Rate 2 (GYP2)	≤ 5	-	-	-	Visible and intact, thinned out considerably.	5	10
2-11	Paper Mulch with Polymer (PMP)	-	≤ 1	-	-	Treatment cracked over much of subplot, rough in appearance and intact.		0
2-12	Wood Mulch with Polymer (WMP)	-	-	-	-	Treatment has hairline cracks in area of quadrat, visible, intact and covers almost 100% of subplot.	40	40
2-13	Wheat-Straw Incorporated (RS)	-	-	-	-	Straw drifted downslope and shifted exposing SSG.	>5	5

Table 6-28 (Continued)
ENVIRONMENTAL AND WEATHERING EFFECTS ON TEST TREATMENTS SITE 10-2, IRRIGATED CONDITION

Plot No.	Treatment	Environmental Factors				Durability Comments[(2)]	Exposed Soil (%)	Overall Effect [(3)]
		Gopher (%) [(1)]	Animal Track (%)	Debris (%)	Blanket Lifting (%)			
2-14	Wood Mulch with Psyllium (WMG)	-	-	≤ 1	-	Visible, slightly thinner.	Much of the SSG in the lower half of subplot exposed due to thinning treatment.	0
2-15	Bonded Fiber Matrix (BFM)	-	-	≤ 1	-	Thinning causing numerous bare spots	≤ 5	5
2-16	Compost (COMP)	-	-	-	-	Compost fragments not visible in most areas of subplot	SSG appears loose mostly in right half of subplot.	0
3-1	Wood Mulch with Polymer (WMP)	5	-	-	-	Visible and intact, very thin over most of quadrat.	15	20
3-2	Straw Blanket (SB)	≤ 1	-	-	≤ 5	Visible, intact, very weathered in appearance and fragile to the touch.	≤ 1	7
3-3	Wood Mulch with Psyllium (WMG)	5	≤ 1	-	-	Treatment thinning overall, with a rough, washed out appearance. Slightly visible between disturbances.	SSG exposed throughout entire subplot.	5
3-4	Wheat-Straw Incorporated (RS)	<5	-	-	-	Straw thinned, exposing subgrade in several locations, intact.	5	10
3-5	Gypsum, Rate 1 (GYP1)	-	-	-	-	Slightly visible in some areas.	SSG appears eroded and spread over entire site.	0
3-6	Wood Fiber Blanket (WFB)	≤ 1	≤ 5	-	-	Very patchy , green plastic mesh fragments not visible.	SSG exposed throughout entire subplot, patchy.	≤ 1
3-7	Paper Mulch with Psyllium (PMG)	≤ 1	-	-	-	Treatment cracked over much of the sunplot, surface rough but mostly intact.	1	2
3-8	Coconut Blanket (CB)	≤ 1	-	-	≤ 5	Weathered in appearance and webbing very fragile and easy to tear.	< 5	11
3-9	Straw Coconut Blanket (SCB)	≤ 1	-	-	≤ 1	Visible and intact , appears weathered.	<1	3
3-10	Compost (COMP)	1	-	-	-	Surface appears rough and has washed look, treatment not visible.	SSG exposed throughout entire subplot.	1

Table 6-28 (Continued)
ENVIRONMENTAL AND WEATHERING EFFECTS ON TEST TREATMENTS SITE 10-2, IRRIGATED CONDITION

Plot No.	Treatment	Environmental Factors				Durability Comments(2)	Exposed Soil (%)	Overall Effect (3)
		Gopher (%) (1)	Animal Track (%)	Debris (%)	Blanket Lifting (%)			
3-11	Curled Wood Fiber Blanket (CWFB)	-	≤ 5	-	≤ 5		1	6
3-12	Gypsum, Rate 2 (GYP2)	≤ 1	-	-	-	Very thin but still visible and mostly intact.	≤ 10	11
3-13	Coir (COIR)	-	-	-	≤ 5	Treatment still intact and in good condition.		5
3-14	Bare (BARE)	1	1	-	-	More weathered, rocks and gravels exposed, plant growth is patchy		1
3-15	Bonded Fiber Matrix (BFM)	≤ 5	≤ 5	-	-	Considerably thin with many bare spots. Barely visible in lower portion.	20	25
3-16	Paper Mulch with Polymer (PMP)	≤ 5	≤ 5	-	-	Treatment cracked over much of site, erosion rill present. Treatment deteriorated, only fragments visible. Surface hard to see because of heavy plant growth.	≤ 1	6

(1) The disturbed area caused by gopher activity is rounded up to nearest 5%.

(2) Description about the treatment is based on the observation in the last monitoring event.

(3) Define overall effect as a summation of affected areas from gopher activity, plants pushing up blankets, and that indicated by "Exposed soil".

Deterioration of treatment due to all factors at the end of study is described in terms of the four classes (Slight, Medium, Rather Severe, and Severe), which is mainly based on the following classification:

- if overall effect ≤20 disturbance is slight
- if 20<overall effect ≤35 disturbance is medium
- if 35<overall effect ≤50 disturbance is rather severe
- if 50<overall effect disturbance is severe

Meanwhile, the description about the treatment is taken into account to determine the severity of the deterioration.
Note: (-) means no effect was observed

Table 6-29
ENVIRONMENTAL AND WEATHERING EFFECTS ON TEST TREATMENTS SITE 57-4, NON-IRRIGATED

Plot No.	Treatment	Environmental Factors: Gopher (%) (1)	Environmental Factors: Animal Track (%)	Environmental Factors: Debris (%)	Environmental Factors: Blanket Lifting (%)	Durability Comments(2)	Exposed Soil (%)	Overall Effect (3)
1-1	Paper Mulch with Polymer (PMP)	55	0	-	-	Many cracks developed in PMP layer. PMP is more or less still intact and has a washout, weathered look. Rocks washed clean.	-	55
1-2	Curled Wood Fiber Blanket (CWFB)	0	0	-	20	The CWFB is intact with no bare spots.	-	20
1-3	Bare (BARE)	30	0	-	-	1. Only one crack, caused by growth of mustard plants 2. Soil surface has a washed appearance.	-	30
1-4	Bonded Fiber Mix (BFM)	30	≤ 1	-	-	Rocks washed clean. BFM is visible and more or less intact, but becoming thinner.	-	30
1-5	Wood Mulch with Polymer (WMP)	55	0	-	-	The WMP is still visible but very thin.	-	55
1-6	Straw Blanket (SB)	25	0	-	-	The WMP is very thin.	-	25
1-7	Straw-Coconut Blanket (SCB)	25	0	-	3	The SB very weathered, but still intact between the disturbance.	-	28
1-8	Wood Fiber Blanket (WFB)	35	0	-	4	The SCB is very weathered in appearance, and has been torn and pushed around from rodent activity, but is more or less still intact between disturbances. The blanket is very fragile to the touch.	-	39
1-9	Coconut Blanket (CB)	20	0	-	1	Soil is exposed in many areas. The CB blanket is very weathered, thin and torn in many areas, but is still more or less intact.	Soil exposed in many areas	21
1-10	Coir (COIR)	10	0	-	2	The COIR appears weathered, but is still intact and relatively in good condition.	-	12
1-11	Gypsum, Rate 1 (GYP1)	15	0	-	-	Large rocks on blanket from burrow activity GYP1 not visible, surface rough with many rocks and gravels exposed	Many rocks and gravels exposed	15
1-12	Wood Mulch with Psyllium (WMG)	15	0	-	-	WMG becomes very thin. The surface appears more weathered on upper half plot, with loose rocks and gravels exposed on surface.	Loose rocks and gravels exposed.	15
1-13	Wheat-Straw Incorporated (RS)	20	0	-	-	RSG has weathered appearance and is thinning, but generally still intact.	-	20
1-14	Compost (COMP)	15	≤ 1	-	-	COMP still slightly visible, but very washout looking, rocks and gravels exposed	Rocks and gravels exposed	15

Table 6-29 (Continued)
ENVIRONMENTAL AND WEATHERING EFFECTS ON TEST TREATMENTS SITE 57-4, NON-IRRIGATED

Plot No.	Treatment	Environmental Factors: Gopher (%) (1)	Animal Track (%)	Debris (%)	Blanket Lifting (%)	Durability Comments(2)	Exposed Soil (%)	Overall Effect (3)
1-15	Gypsum, Rate 2 (GYP2)	20	0	-	-	The plot surface is weathered from erosion, with many washed appearing rocks on the surface.	-	20
1-16	Paper Mulch with Psyllium (PMG)	20	0	-	-	1. Many cracks. 2. Treatment is rough in appearance, but mostly intact between gopher holes. Rocks exposed in the PMG have been washed clean.	Rocks exposed	20
2-1	Coir (COIR)	15	0	-	4	1. Upward wrinkles about 2% 2. The COIR is weathered in appearance, but still intact and in relatively good condition.	-	19
2-2	Compost (COMP)	35	0	-	-	Entire plot has a washed out appearance.	10	45
2-3	Bare (BARE)	25	0	-	-	The surface looks weathered with rocks washed out.	6	31
2-4	Gypsum, Rate 1 (GYP1)	25	0	-	-	The plot surface is rough, weathered, and has a washed out appearance.	-	25
2-5	Wheat-Straw Incorporated (RS)	25	0	-	-	The RSG is very thin, but is more or less still intact. Exposed rocks are washed clean.	Rocks exposed	25
2-6	Wood Mulch with Psyllium (WMG)	20	0	-	-	1. Many cracks 2. Rocks and gravels are showing through the treatment. The rocks are washed clean.	Rocks and gravels exposed	20
2-7	Wood Fiber Blanket (WFB)	25	0	-	-	WMG appears to be thinning, with rocks and gravels exposed.	Rock and gravels exposed	25
2-8	Curled Wood Fiber Blanket (CWFB)	10	0	-	-	The CWF blanket appears weathered, but still intact and in relatively good condition. No bare spot observed except areas around gopher activity.	-	10
2-9	Wood Fiber Blanket (WFB)	45	0	-	4	The WFB is still visible and intact. Rocks and gravels are washed clean.	-	49
2-10	Paper Mulch with Polymer (PMP)	40	0	-	-	1. One crack in PMP 2. The PMP has a very rough and weathered appearance.	-	40
2-11	Gypsum, Rate 2 (GYP2)	25	0	-	-	The GYP2 is still visible, but thinning with more S.G. exposed. Rocks are washed clean.	soil exposed	25
2-12	Bonded Fiber Matrix (BFM)	25	0	-	-	The BFM is still visible, but thinning with more S.G. exposed. Rocks are washed clean.	soil exposed	25

Table 6-29 (Continued)
ENVIRONMENTAL AND WEATHERING EFFECTS ON TEST TREATMENTS SITE 57-4, NON-IRRIGATED

Plot No.	Treatment	Environmental Factors				Durability Comments(2)	Exposed Soil (%)	Overall Effect (3)
		Gopher (%) (1)	Animal Track (%)	Debris (%)	Blanket Lifting (%)			
2-13	Wood Mulch with Polymer (WMP)	15	0	-	-	The WMP is thin, but still visible and more or less intact. Exposed surface areas appear weathered and surface rocks are washed clean.	surface exposed	15
2-14	Straw Blanket (SB)	15	0	-	-	The straw is thinning, but is still intact.	-	15
2-15	Coconut Blanket (CB)	25	0	-	-	The CB appears weathered and fragile to the touch, but still intact.	-	25
2-16	Straw Coconut Blanket (SCB)	25	0	-	-	The SCB is weathered and has been torn and pushed around rodent activity, but still more or less intact.	-	25
3-1	Paper Mulch with Polymer (PMP)	40	0	-	-	The PMP is weathered looking and thinning, but still visible and intact. Rocks and gravels are washed clean.	-	40
3-2	Straw Blanket (SB)	10	0	-	1	The SB blanket is weathered, webbing starting to stretch and tear in some areas.	-	11
3-3	Wood Mulch with Polymer (WMP)	25	0	-	-	The WMP is thin, but still visible and intact and relatively good condition. Exposed rocks have a washed appearance.	rocks exposed	25
3-4	Compost (COMP)	35	0	-	-	1. Only one crack shows up on plot 2. Subplot has a washed out appearance. The COMP is not visible in the last monitoring.	-	35
3-5	Gypsum, Rate 1 (GYP1)	10	0	-	-	Treatment has washed-out looking. Rocks and gravels are washed clean.	-	10
3-6	Coir (COIR)	5	0	-	4	1. Wrinkles about 1% 2. The COIR is weathered in appearance, but intact and still in good condition.	-	9
3-7	Wood Mulch with Psyllium (WMG)	30	0	-	-	The WMG is still visible but is thinning. Rocks are washed clean.	-	30
3-8	Gypsum, Rate 2 (GYP2)	20	≤ 1	-	-	Treatment has washed-out looking. Rocks and gravels are washed clean.	-	20
3-9	Wood Fiber Blanket (WFB)	15	0	-	3	The WFB is still intact but continue to thin with soil exposed in many areas.	soil exposed in many areas	18

Table 6-29 (Continued)
ENVIRONMENTAL AND WEATHERING EFFECTS ON TEST TREATMENTS SITE 57-4, NON-IRRIGATED

Plot No.	Treatment	Environmental Factors				Durability Comments(2)	Exposed Soil (%)	Overall Effect (3)
		Gopher (%) (1)	Animal Track (%)	Debris (%)	Blanket Lifting (%)			
3-10	Paper Mulch with Psyllium (PMG)	20	≤ 1	-	-	1. Many cracks 2. The PMG is weathered with rocks exposed.	rocks exposed	20
3-11	Straw Coconut Blanket (SCB)	40	≤ 1	-	-	The SCB is weathered but still intact.	-	40
3-12	Bare (BARE)	45	≤ 1	-	-	Surface has a washed out appearance.	-	45
3-13	Wheat-straw Incorporated (RS)	25	0	-	-	The RS is still visible and more or less still intact.	-	25
3-14	Coconut Blanket (CB)	35	0	-	10	The CB is very weathered, but still more or less intact.	-	45
3-15	Bonded Fiber Matrix (BFM)	50	0	-	-	The BFM is still visible and intact. Exposed rocks are washed clean.	rocks exposed	50
3-16	Curled Wood Fiber Blanket (CWFB)	30	0	-	-	The CWFB is weathered, but still intact.	-	30

(1) The disturbed area caused by gopher activity is rounded up to nearest 5%.

(2) Description about the treatment is based on the observation in the last monitoring event.

(3) Define overall effect as a summation of affected areas from gopher activity, plants pushing up blankets, and that indicated by "Exposed soil".

Deterioration of treatment due to all factors at the end of study is described in terms of the four classes (Slight, Medium, Rather Severe, and Severe), which is mainly based on the following classification:

- if overall effect ≤20 disturbance is slight
- if 20<overall effect ≤35 disturbance is medium
- if 35<overall effect ≤50 disturbance is rather severe
- if 50<overall effect disturbance is severe

Meanwhile, the description about the treatment is taken into account to determine the severity of the deterioration.
Note: (-) means no effect was observed

Table 6-30
ENVIRONMENTAL AND WEATHERING EFFECTS ON TEST TREATMENTS SITE 57-4, IRRIGATED CONDITION

Plot No.	Treatment	Environmental Factors				Durability Comments[2]	Exposed Soil (%)	Overall Effect [3]
		Gopher (%) [1]	Animal Track (%)	Debris (%)	Blanket Lifting (%)			
1-1	Bonded Fiber Matrix (BFM)	25	-	-	-	Thin , visible between bare spots. Numerous bare patches up to 3" in diameter mostly at bottom half of subplot.	Numerous bare patches	25
1-2	Gypsum, Rate 2 (GYP2)	50	-	-	-	Thin, and visible in areas not covered by soil created by gopher disturbance	-	50
1-3	Curled Wood Fiber Blanket (CWFB)	10	-	-	-	Visible and intact	-	10
1-4	Bare (BARE)	20	-	-	-	Surface weathered with a rough appearance	-	20
1-5	Straw Blanket (SB)	15	-	-	10	Intact between disturbances , very weathered and torn in some areas.	-	25
1-6	Wood Mulch with Polymer (WMP)	10	≤ 5	-	-	WMP is visible but very thin, having washed appearance.	Soil exposed in some areas	10
1-7	Gypsum, Rate 1 (GYP1)	≤ 5	-	-	-	GYP1 is slightly visible. Rocks have a washed appearance.	-	5
1-8	Coconut Blanket (CB)	≤ 5	-	-	30	CB is weathered, but still visible and intact	-	35
1-9	Paper Mulch with Polymer (PMP)	30	≤ 5	-	-	1.A few cracks. 2. PMP is intact and visible. Rocks have been washed clean.	-	30
1-10	Wood Mulch with Psyllium (WMG)	30	≤ 5	-	-	Treatment visible and thin. Many rocks showing through with a washed clean appearance.	5	35
1-11	Straw-Coconut Blanket (SCB)	40	≤ 5	-	-	SCB is intact.	5	45
1-12	Compost (COMP)	15	≤ 5	-	-	COMP is not visible.	-	15
1-13	Paper Mulch with Psyllium (PMG)	30	≤ 5	-	-	1. Many cracks. 2. PMG still visible	-	30
1-14	Wood Fiber Blanket (WFB)	20	≤ 5	-	-	The green plastic mesh of the blanket has completely deteriorated. WFB is still visible and intact.	≤ 1	21

Table 6-30 (Continued)
ENVIRONMENTAL AND WEATHERING EFFECTS ON TEST TREATMENTS SITE 57-4, IRRIGATED CONDITION

Plot No.	Treatment	Environmental Factors				Durability Comments(2)	Exposed Soil (%)	Overall Effect (3)
		Gopher (%) (1)	Animal Track (%)	Debris (%)	Blanket Lifting (%)			
1-15	Wheat Straw Incorporated (RS)	10	-	-	-	RS is still intact but start to thin.	≤ 1	11
1-16	Coir (COIR)	20	-	-	≤ 5	Less the 5% of areas has some wrinkle in blanket, not due to plant growing. COIR blanket is intact.	-	25
2-1	Wood Mulch with Psyllium (WMG)	15	-	-	-	WMG visible and intact	-	15
2-2	Gypsum, Rate 2 (GYP2)	80	-	-	-	GYP2 is slightly visible.	-	80
2-3	Straw Blanket (SB)	25	-	-	-	SB is very thin, but still slightly visible and intact.	-	25
2-4	Paper Mulch with Polymer (PMP)	20	-	-	-	1. Many cracks. 2. PMP is intact and visible, but very rough at the surface.	-	20
2-5	Bonded Fiber Matrix (BFM)	30	≤ 5	-	-	1. A few cracks. 2. BFM visible but very rough appearance with many bare spots begin to show.	≤ 1	31
2-6	Gypsum, Rate 1 (GYP1)	≤ 5	≤ 5	-	-	GYP1 is slightly visible in some areas. Soil is exposed in.	Soil exposed in some areas	5
2-7	Curled Wood Fiber Blanket (CWFB)	≤ 5	-	-	-	CWFB intact.	≤ 1	6
2-8	Compost (COMP)	<5	0	-	-	The COMP is not visible.	-	5
2-9	Straw Coconut Blanket (SCB)	20	2	-	0	The SCB is intact and very weathered.	-	20
2-10	Coconut Blanket (CB)	45	0	-	35	The CB is very weathered.	-	80
2-11	Bare (BARE)	50	2	-	-	Surface has uneven, washed looking.	-	50
2-12	Paper Mulch with Psyllium (PMG)	35	0	-	-	PMG is very thin and weathered.	-	35

Table 6-30 (Continued)
ENVIRONMENTAL AND WEATHERING EFFECTS ON TEST TREATMENTS SITE 57-4, IRRIGATED CONDITION

Plot No.	Treatment	Environmental Factors				Durability Comments(2)	Exposed Soil (%)	Overall Effect (3)
		Gopher (%) (1)	Animal Track (%)	Debris (%)	Blanket Lifting (%)			
2-13	Wood Mulch with Polymer (WMP)	60	0	-	-	WMP has a washed appearance.	-	60
2-14	Coir (COIR)	20	0	-	≤ 1	The COIR blanket is intact but very weathered.	-	21
2-15	Wheat Straw Incorporated (RS)	20	0	-	-	RSG is mostly intact.	2	22
2-16	Wood Fiber Blanket (WFB)	20	0	-	≤ 1	Exposed soil has a weathered appearance with rocks washed clean.	Soil exposed in some areas	21
3-1	Curled Wood Fiber Blanket (CWFB)	10	0	-	0	The CWF blanket is intact.	-	10
3-2	Paper Mulch with Polymer (PMP)	20	0	-	-	1. A lot cracks. 2. The PMP is intact but thinning. Rocks through the PMP are washed clean.	-	20
3-3	Wood Mulch with Psyllium (WMG)	20	0	-	-	Treatment looks weathered and washed out.	4	24
3-4	Gypsum, Rate 1 (GYP1)	10	0	-	-	The GYP1 is very thin but still visible. Rocks and gravels are washed clean.	-	10
3-5	Coconut Blanket (CB)	20	0	-	20	The CB is very weathered.	-	40
3-6	Straw Blanket (SB)	20	0	-	≤ 1	The SB is intact and very weathered.	2	23
3-7	Straw Coconut Blanket (SCB)	20	2	-	≤ 1	The SCB is intact and very weathered.	-	21
3-8	Wood Fiber Blanket (WFB)	5	0	-	10	The WFB is visible and intact between disturbance. Rocks showing are washed clean.	-	15
3-9	Compost (COMP)	10	0	-	-	Rocks have a washed appearance.	<1	11
3-10	Gypsum, Rate 2 (GYP2)	15	0	-	-	The GYP2 is visible and more or less intact. Rocks and gravels are washed clean.	-	15

Table 6-30 (Continued)
ENVIRONMENTAL AND WEATHERING EFFECTS ON TEST TREATMENTS SITE 57-4, IRRIGATED CONDITION

Plot No.	Treatment	Environmental Factors				Durability Comments(2)	Exposed Soil (%)	Overall Effect (3)
		Gopher (%) (1)	Animal Track (%)	Debris (%)	Blanket Lifting (%)			
3-11	Wood Mulch with Polymer (WMP)	10	0	-	-	The WMP is visible but continues to thin.	-	10
3-12	Wheat-straw Incorporated (RS)	5	0	-	-	RSG is visible and more or less intact.	5	10
3-13	Paper Mulch with Psyllium (PMG)	25	0	-	-	1. A few cracks. 2. The PMG is weathered and more or less intact. Rocks are washed clean.	-	25
3-14	Coir (COIR)	10	0	-	4	The COIR is weathered but still intact between disturbance.	-	14
3-15	Bonded Fiber Matrix (BFM)	10	0	-	-	The BFM is visible and still intact between disturbance.	-	10
3-16	Bare (BARE)	15	0	-	-	Surface has washed-out looking.	-	15

(1) The disturbed area caused by gopher activity is rounded up to nearest 5%.

(2) Description about the treatment is based on the observation in the last monitoring event.

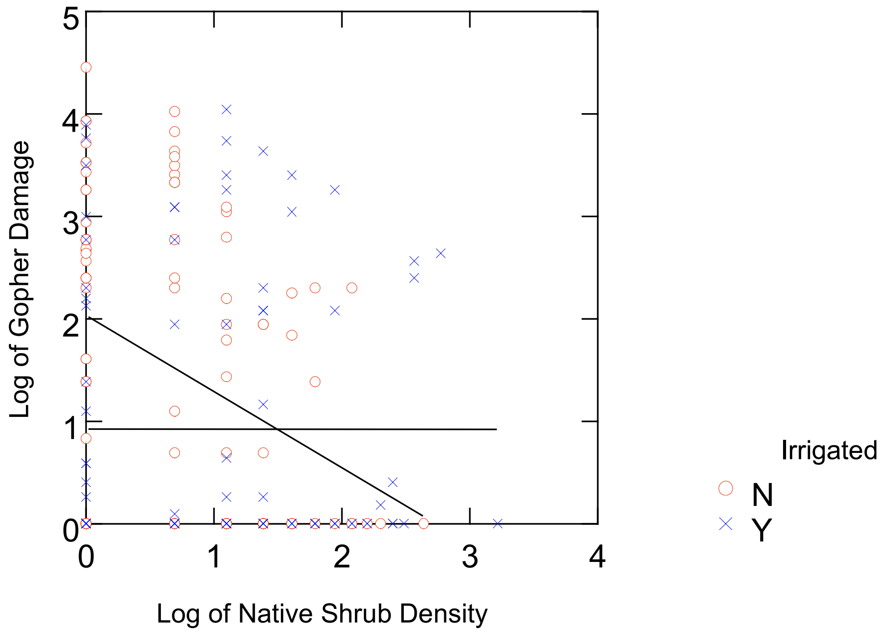
(3) Define overall effect as a summation of affected areas from gopher activity, plants pushing up blankets, and that indicated by "Exposed soil".

Deterioration of treatment due to all factors at the end of study is described in terms of the four classes (Slight, Medium, Rather Severe, and Severe), which is mainly based on the following classification:

- if overall effect ≤20 disturbance is slight
- if 20<overall effect ≤35 disturbance is medium
- if 35<overall effect ≤50 disturbance is rather severe
- if 50<overall effect disturbance is severe

Meanwhile, the description about the treatment is taken into account to determine the severity of the deterioration.
Note: (-) means no effect was observed

Figure 6-3
LOG-LOG SCATTER PLOT OF GOPHER DAMAGE AS A FUNCTION OF NATIVE SHRUB DENSITY, FOR IRRIGATED VS. NON-IRRIGATED PLOTS



- Physical disturbance to the subplots at the 10-2 site due to debris from the roadway at the top of the slope occurred at five subplots. The distribution of the debris damage at the test sites appeared to be random (i.e., independent of treatment type).
- Blanket treatments that appeared to form the most significant physical barrier to plant growth are coir, straw blanket, curled wood fiber blanket, coconut blanket, and wood fiber blanket. In most cases, from 1 to 10 percent of the blanket may be lifted due to underlying growth. However, in two cases, namely, subplots 1-8 and 2-10 in the irrigated plot at the 57-4 site, both treated with coconut blanket, over 30 percent of the blanket was lifted.
- Deterioration of the erosion control treatment was most severe for subplots treated with gypsum rate 1, gypsum rate 2, compost, paper mulch with polymer, and paper mulch with psyllium, and of limited severity for some subplots treated with bonded fiber matrix and wood fiber blanket. The gypsum rate 1, gypsum rate 2, compost, bonded fiber matrix, and wood fiber blanket subplots typically became discolored and "washed out" in appearance early in the study, then only "slightly visible" to "not visible" by the end of the study. This particular characteristic is due to photo degradation of the vegetable dye in the mulch material itself and is therefore not related to overall degradation of the practice.
- The paper mulch with polymer and paper mulch with psyllium treatments were prone to cracking and subsequent deterioration. In most cases, the deterioration was relatively severe and the paper mulch with polymer and paper mulch with psyllium were noted as being "not visible." Some of the subplots treated with compost, wood mulch with polymer, gypsum rate 2, bonded fiber matrix, and straw-coconut blanket, as well as the bare subplots, also showed cracking, but less consistently than the paper mulch with polymer and paper mulch with psyllium subplots. No cracks were noted for the subplots treated with other materials and whether or not this cracking of application materials is related to soil conditions is not known; i.e., a high clayey soil when dried out will exhibit "cracking" which is then transferred to the material (paper mulch with polymer, paper mulch with psyllium) adhering to the surface.

6.9 SUMMARY AND CONCLUSIONS

The rainfall amounts at both sites over the course of the two-year study were considerably lower than the long-term historical average for the area.

Irrigation influenced the germination of non-native species and native annuals early in the fall and winter of 1999 before the natural rainfall began. Irrigation had some beneficial effects related to earlier germination of native species compared to 'natural' germination in a year with late fall and winter rains as occurred in 1999. However, the effect of higher plant densities disappears as natural rainfall begins and the seeds in the non-irrigated plots began to germinate. The effect of irrigation was strongly dependent on the site in these experiments with the difference in densities between irrigated and non-irrigated plots most apparent at the cut slope (Site 57-4).

As the statistical data indicates for the final spring monitoring event, irrigation did not have a significant effect on the overall establishment of the CSS seed mix. However, slope type (cut and fill), erosion control treatments, as well as the interaction between them did have a significant effect. Therefore, after an initial effect, irrigation is not a factor in the second year for overall plant establishment. Plant densities for non-native species were greater at the cut slope for both irrigated and non-irrigated plots possibly due to a more extensive weed-seed bank in the soil.

There was no single best erosion control treatment across all slope conditions because of interactions of site by irrigation treatment and irrigation treatment by erosion control treatment. These significant interactions of the main effects imply that the effects of the irrigation are different on the two slope types, and for the different erosion control treatments.

The effects of erosion control treatments on native plant density was not the same for cut and fill slopes. As with the comparisons of plant cover, the density results imply that different erosion control treatments may be required for optimum establishment of native species depending on whether a slope is a cut or a fill.

Generally, shrub height increased more on the irrigated plots, however, heights of all surviving shrubs increased significantly during the monitoring period.

Shrubs had the deepest roots and the shortest height. This indicates that native shrubs develop an extensive root system before providing much growth above ground.

The survival of shrub species depended on slope type (cut or fill) and whether irrigation was applied. As with previous conclusions, there is no single best erosion control treatment across all conditions.

The most significant physical disturbance to the subplots was due to gopher and rodent activity. At both the cut and fill slopes, the distribution of the gopher/rodent damage appeared to be random. Some blanket treatments inhibited plant growth; others were lifted due to underlying plant growth. A number of the treatments were observed to degrade over the course of the two-year study.

This section presents the results and analysis of outdoor testing of the myoporum test plots using simulated rainfall. The purpose of the outdoor laboratory testing was to demonstrate and quantify the inverse relationship between vegetative cover and rate of erosion; that is, as vegetation coverage increases, soil erosion rate decreases. As described above, two myoporum test locations (fill slope at the 10-2 site and cut slope at the 57-4 site) were used to perform the testing. The study evaluated the effect of percent cover on erosion rate and runoff volume under one test storm type (the 10-year (2) storm for the Los Angeles area). Myoporum testing was conducted by taking the portable rainfall simulators from the Soil Erosion Research Laboratory out to the field test sites. Testing was conducted on the myoporum test plots at vegetation cover (measured as percent cover) of 35, 50, 65, 80, and 95 percent between August 1999 and May 2000. Figures 7-1(a) through 7-10(b) show myoporum test plots by percent cover at both test sites. The tests conducted at 35 percent cover were conducted when the plants had grown naturally to that percent cover. Subsequently, plants were allowed to grow to 100 percent coverage and were cut back manually to the other cover percentages.

Data collected over the course of the study were evaluated in order to address the following questions:

1. How does myoporum plant density relate to erosion rate on cut and fill slopes?
2. How do the myoporum laboratory results compare with field myoporum results?

7.1 RELATIONSHIP OF PLANT DENSITY TO EROSION RATE

7.1.1 Erosion Rate Testing Evaluation

Means and standard deviations of normalized erosion rate in $kg/m^2/mm$ and runoff for the outdoor myoporum tests are presented in Table 7-1. The total weight of sediment recovered from each test was measured in the Soil Erosion Research Laboratory. Sediment results were normalized by plot size and rainfall depth. Figure 7-1 presents normalized erosion rates at the 5 plant densities that were tested for both cut and fill slopes. For the cut slopes, the data indicates a trend of decreasing erosion rate with increased percent cover. The data for the fill slope show less of a trend, decreasing at first (between 35 and 50 percent cover), then exhibiting a slight increase in erosion rate with increasing cover. The reason for this difference is not known, but may have to do with greater variation in, or lower compaction of, fill slope soils and/or effects of gopher activity on the fill slopes.

The relationship of percent runoff vs. percent plant cover is shown in Figure 7-2. Again, the data from the cut slope shows a decrease in the percent runoff as cover percentage increases. Similarly, the fill slope data did not indicate a clear trend.

7.1.2 Statistical Evaluation of the Data

The means and standard errors were calculated for runoff volumes compared to slope type (Figure 7-3) and percent vegetation cover (Figure 7-4). The means and standard errors were calculated for sediment weight compared to slope type (Figure 7-5) and percent plant cover (Figure 7-6).

Table 7-1
RESULTS OF RAINFALL SIMULATION TESTING ON MYOPORUM TEST PLOTS

Percent Cover	Measurement	Statistic	Cut Slope	Fill Slope
35	Normalized Erosion Rate (kg/m²/mm)	Mean	0.015	0.0078
		Std. Dev.	*0.0019*	*0.0079*
	Runoff (L)	Mean	303.7	96.9
		Std. Dev.	*80.7*	*6.0*
		As % of Rainfall Volume	44%	14%
50	Normalized Erosion Rate (kg/m²/mm)	Mean	0.0049	0.0026
		Std. Dev.	*0.0019*	*0.0019*
	Runoff (L)	Mean	195.8	144.1
		Std. Dev.	*11.6*	*15.5*
		As % of Rainfall Volume	28%	21%
65	Normalized Erosion Rate (kg/m²/mm)	Mean	0.0019	0.0007
		Std. Dev.	*0.0008*	*0.0003*
	Runoff (L)	Mean	144.3	105.7
		Std. Dev.	*40.2*	*19.8*
		As % of Rainfall Volume	21%	15%
80	Normalized Erosion Rate (kg/m²/mm)	Mean	0.0029	0.0012
		Std. Dev.	*0.0024*	*0.0006*
	Runoff (L)	Mean	122.7	149.6
		Std. Dev.	*19.9*	*15.0*
		As % of Rainfall Volume	18%	21%
90	Normalized Erosion Rate (kg/m²/mm)	Mean	0.0003	0.0024
		Std. Dev.	*0.0002*	*0.0015*
	Runoff (L)	Mean	40.4	104.4
		Std. Dev.	*14.8*	*8.8*
		As % of Rainfall Volume	6%	21%

Runoff amounts and sediment weights were subjected to analyses of variance using slope type (site) and percent cover as treatment factors. Percent cover significantly influenced runoff, but slope type did not. Both percent cover and slope type significantly influenced sediment weight. The interaction between the two factors also significantly influenced sediment.

7.1.3 Conclusions

Low percent cover (less than 50%) of myoporum leads to large amounts of runoff (Figure 4). Higher values of percent cover (greater than 50%) lead to lower amounts of runoff; however, values of percent cover (65% or more) do not differ appreciably in their ability to reduce runoff (Figure 7-4). The pattern is different for sediment loss. High values of percent cover (90% or greater) lead to low sediment losses, intermediate values of percent cover (65% to 85%) lead to intermediate sediment losses, and low values of percent cover (50% or less) lead to high sediment losses (Figure 7-6).

Figure 7-1
NORMALIZED EROSION RATE FROM MYOPORUM PLOTS BY PERCENT PLANT COVER

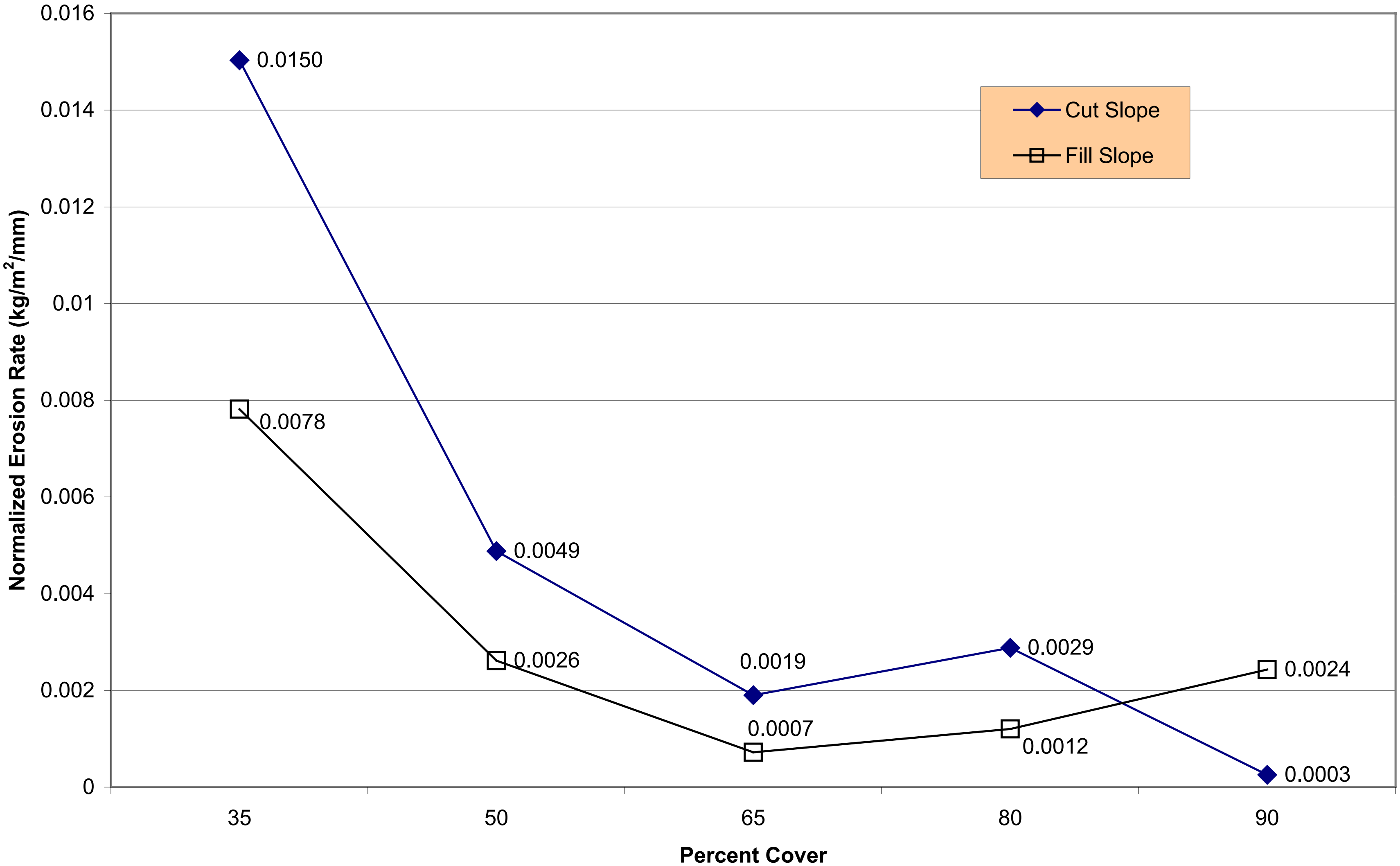


Figure 7-2
PERCENT RUNOFF FROM MYOPORUM PLOTS BY PERCENT PLANT COVER

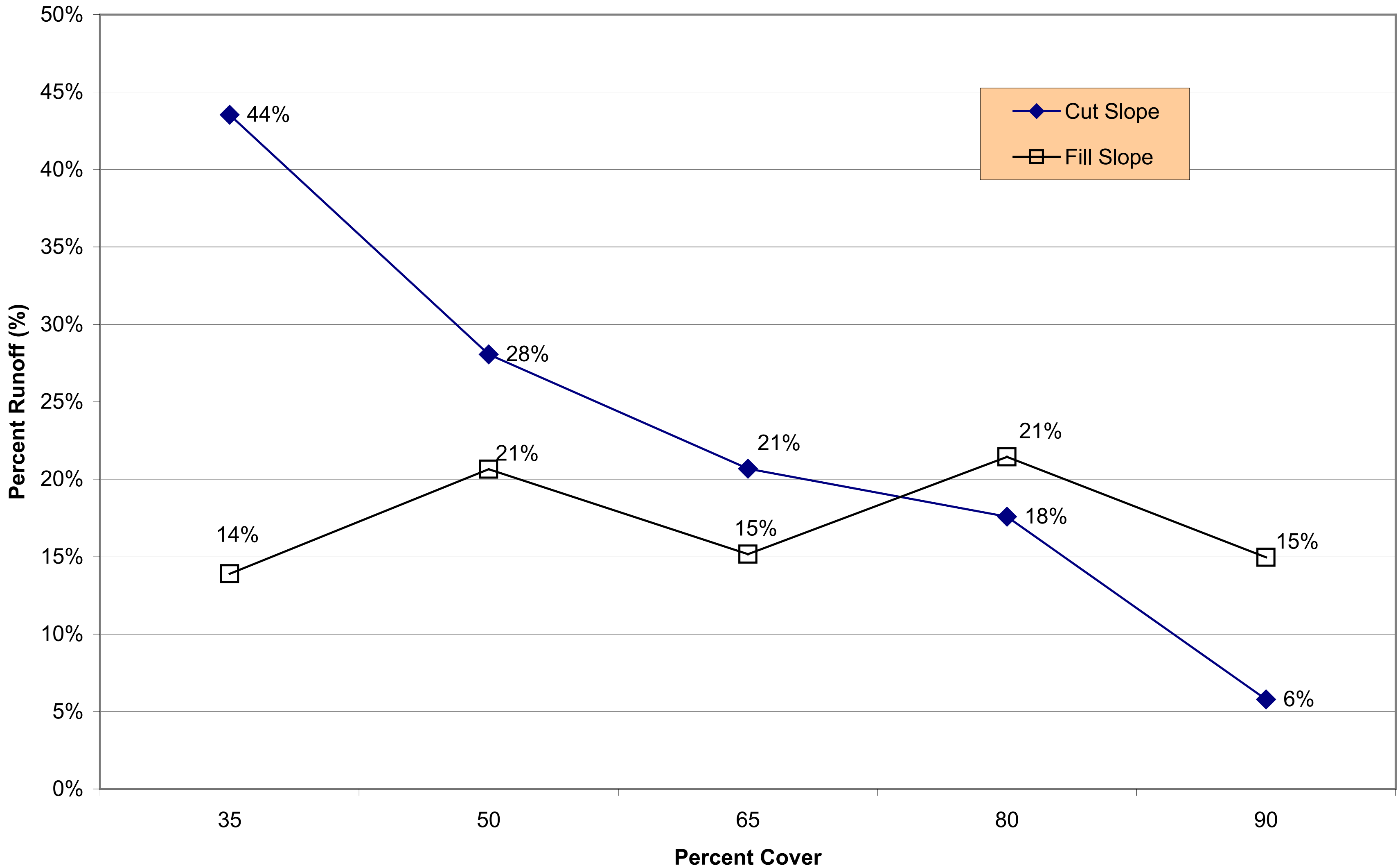


Figure 7-3
MEANS AND STANDARD ERRORS OF RUNOFF VOLUMES BY SLOPE TYPE MYPORUM TEST PLOTS

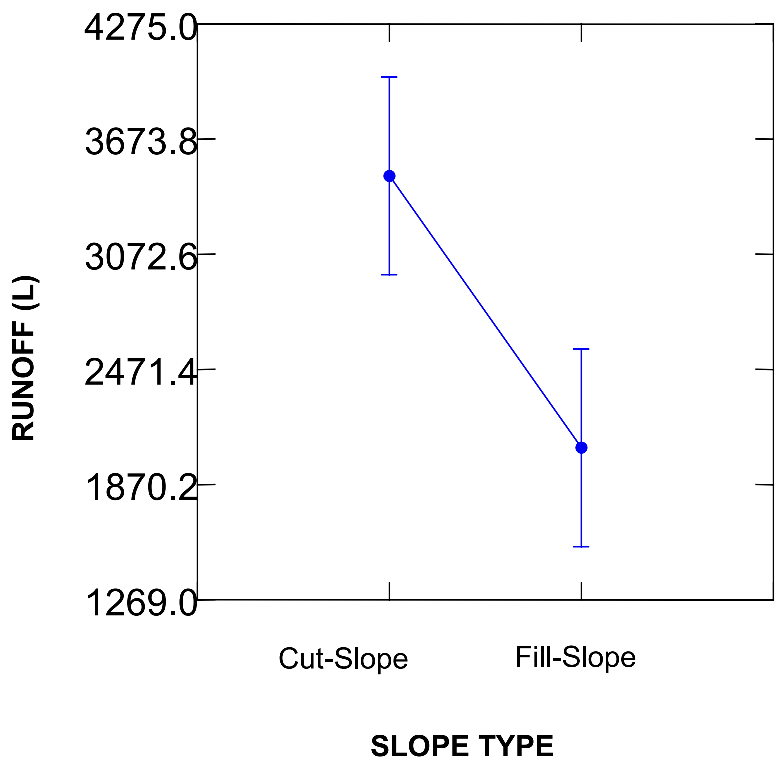


Figure 7-4
MEANS AND STANDARD ERRORS OF RUNOFF VOLUME BY PERCENT PLANT COVER MYPORUM TEST PLOTS

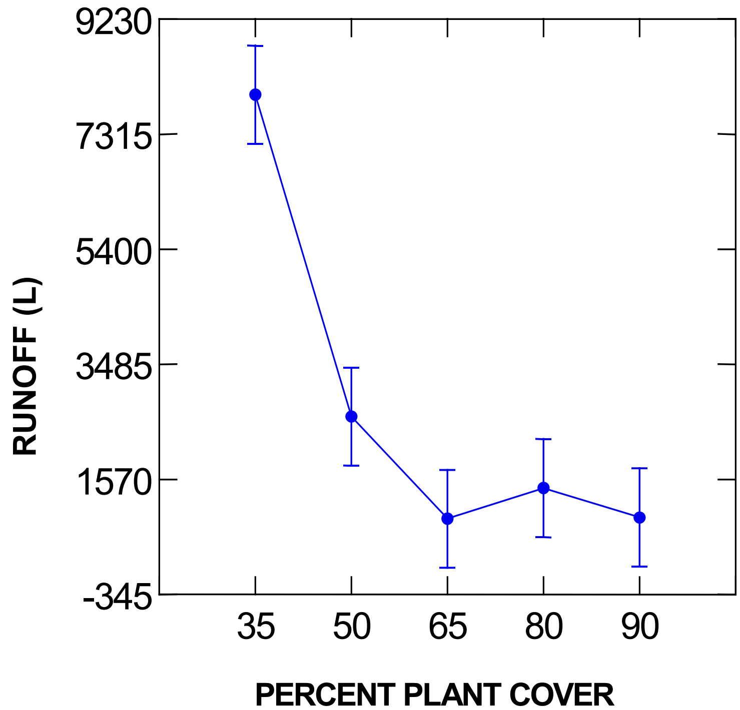


Figure 7-5
MEANS AND STANDARD ERRORS OF SEDIMENT WEIGHT BY SLOPE TYPE
MYOPORUM TEST PLOTS

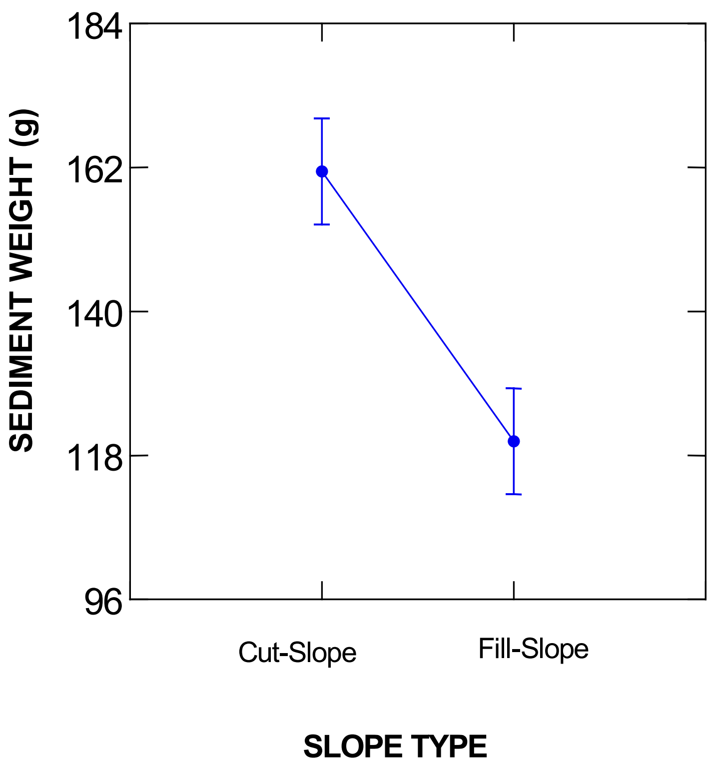
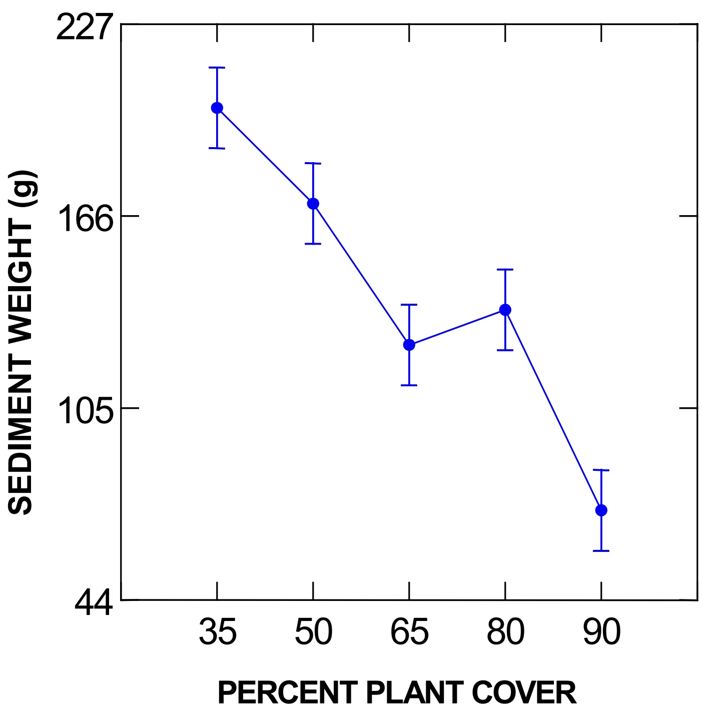


Figure 7-6
MEANS AND STANDARD ERRORS OF SEDIMENT WEIGHT BY PERCENT PLANT COVER MYOPORUM TEST PLOTS



7.2 COMPARISON BETWEEN MYOPORUM FIELD AND LABORATORY DATA

Because the erosion rate testing on the myoporum test plots was conducted under both natural field (Section 8) and simulated rainfall conditions, it was possible to generally compare the results from the two testing efforts. Since the types of rainfall conditions varied considerably between the efforts (natural rainfall vs. simulated 10-year storm event), the data are not directly comparable, but may be compared qualitatively.

The myoporum plots that were evaluated with simulated rainfall were tested at five cover percentages (35%, 50%, 65% 80%, and 90%), while the myoporum plots that were evaluated under natural rainfall conditions had 100% cover.

Table 7-2 presents comparisons of normalized erosion rates from the myoporum plots under natural and simulated rainfall conditions for the various cover percentages tested. The comparison shows that although the natural rainfall events were much smaller than the simulated 10-yr (2) event, the range of normalized erosion rates for 100% cover brackets the value for 90% cover on cut slopes, and brackets the values for 65 to 90% cover for fill slopes.

Table 7-2
COMPARISON OF NORMALIZED EROSION RATES FROM MYOPORUM PLOTS UNDER NATURAL AND SIMULATED RAINFALL

Percent Cover	Normalized Erosion Rates ($g/m^2/mm$)			
	10-YR (2) Storm		Natural Rainfall	
	Cut Slope	Fill Slope	Cut Slope	Fill Slope
35	15	7.8		
50	4.9	2.6		
65	1.9	0.7		
80	2.9	1.2		
90	0.3	2.4		
100			0.03 - 0.44	0.01 - 1.79

(a) Outdoor laboratory myoporum test plots at 35 percent cover (Site 10-2).

(b) Individual myoporum test plot at 35 percent cover (Site 10-2).

(a) Outdoor laboratory myoporum test plots at 50 percent cover (Site 10-2).

(b) Individual myoporum test plot at 50 percent cover (Site 10-2).

(a) Outdoor laboratory myoporum test plots at 65 percent cover (Site 10-2).

(b) Individual myoporum test plot at 65 percent cover (Site 10-2).

(a) Outdoor laboratory myoporum test plots at 80 percent cover (Site 10-2).

(b) Individual myoporum test plot at 80 percent cover (Site 10-2).

(a) Outdoor laboratory myoporum test plots at 95 percent cover (Site 10-2).

(b) Individual myoporum test plot at 95 percent cover (Site 10-2).

(a) Outdoor laboratory myoporum test plots at 35 percent cover (Site 57-4).

(b) Individual myoporum test plot at 35 percent cover (Site 57-4).

Individual myoporum test plot at 50 percent cover (Site 57-4).

(a) Outdoor laboratory myoporum test plots at 65 percent cover (Site 57-4).

(b) Individual myoporum test plot at 65 percent cover (Site 57-4).

(a) Outdoor laboratory myoporum test plots at 80 percent cover (Site 57-4).

(b) Individual myoporum test plot at 80 percent cover (Site 57-4).

(a) Outdoor laboratory myoporum test plots at 95 percent cover (Site 57-4).

(b) Individual myoporum test plot at 95 percent cover (Site 57-4).

This section presents a discussion of the data obtained from the erosion rate test plots collected over the two year ECPS monitoring period. This data describes what can be anticipated in terms of runoff and erosion rate from established vegetated slopes under rainfall conditions similar to those of the 1998-1999 and 1999-2000 study period. As introduced in the previous sections, the erosion rate test plot study was designed to assess the effectiveness of four selected vegetation types (iceplant, myoporum, grass/forb complex, and coastal sage scrub) on runoff and erosion control on cut and fill slopes with inclinations of at least 1V:2H under natural precipitation conditions. Iceplant and myoporum are non-native, ornamental ground covers commonly used in the study area. A grass/forb plant association is a broad term. However, for the specific purposes of this study, it can be described as an assemblage of non-native, annual grass and broadleaf (forb) species, with the grasses usually being dominant. Because the plants are annuals, the vegetation is dry and brown for much of the year. At the beginning of the rainy season germination of these species occurs. They usually remain green for a few months until hot, dry weather begins. Coastal sage scrub is the dominant native plant community found in the study area. It is composed primarily of summer drought-deciduous shrubs and subshrubs. This community is usually dominated by only a few species of shrubs. The more common are California sagebrush (*Artemisia californica*), California buckwheat (*Eriogonum fasciculatum*), black sage (*Salvia mellifera*) and bush sunflower (*Encelia californica*). Unvegetated (bare) test plots on cut and fill slopes and an undisturbed slope vegetated with coastal sage scrub were also included in the erosion rate test plot study to provide control and reference data.

The coastal sage scrub vegetation at the two highway reference slopes on the I-210 freeway was seeded by Caltrans using specifications for erosion control "Type C" on the fill slope and erosion control "Type D" on the cut slope. These specifications call for hydroseeding with straw mulch. The straw was incorporated on the fill slope and tacked on the cut slope. The coastal sage scrub species were successful at achieving more than 90 percent plant cover on both slopes.

The grass/forb vegetation at the two highway reference slopes (on the I-10 and Highway 57 freeways) was also seeded by Caltrans using erosion control "Type C" on the fill slope and "Type D" on the cut slope. The original species that were seeded were not all successful, and the dominant species present today are likely due to seeds blown into the site and/or encroaching from adjacent areas. However, since grassed slopes are represented in District 7 this vegetation complex was included in the study to evaluate their relative performance for permanent erosion control.

The data collected at each test plot included soil characteristics and precipitation amounts for each storm event; and, sediment discharge and runoff volumes for each sampled storm event (6 mm [0.25 in.] or more of rainfall within 24-hours). Vegetation cover, density, and diversity data were also collected from all but the bare test plot.

The data were analyzed to address the following questions:

- How did soil characteristics change over the study period?
- How did the two seasons of monitoring rainfall compare to the long-term average rainfall for the study area?
- How did the four vegetation types at the on-highway (reference) slopes rank in runoff production on cut and fill slopes? What were the values of runoff production for the

undisturbed (research) coastal sage scrub, and how did they compare to the on-highway (reference) cut and fill slopes planted with the four vegetation types?

- How did the four vegetation types at the on-highway (reference) slopes rank in erosion control effectiveness on cut and fill slopes? What were the values of erosion rate for undisturbed (research) coastal sage scrub, and how did they compare to highway (reference) cut and fill slopes planted with the four vegetation types?
- How did the soils and vegetation compare between the coastal sage scrub reference and research sites?
- To what extent was soil loss impacted by gopher activity and was gopher activity correlative with vegetation type or slope type (cut or fill)?
- Were the native species more or less effective than the non-native species?

8.1 SOIL CHARACTERISTICS

8.1.1 Soil Testing Data

During the site selection process and on two occasions during the test period, soil samples were collected from all of the erosion rate test plots and analyzed for attributes relevant to plant growth and the data for each test plot were compared to evaluate for changes over time. The chemical constituents also provided another method of comparing the soils in the different test plots. Sampling was conducted three times: in Fall 1998 during setup of the test plots, in Spring 1999, and in Spring 2000.

8.1.1.1 Chemical Soil Analysis

During each of the three soil sampling events, the following chemical parameters were analyzed: pH, sodium adsorption ratio (SAR), electrical conductivity (EC_e), boron (B), nitrogen (N), phosphorus (P), potassium (K), calcium (Ca), magnesium (Mg), chlorine (Cl), zinc (Zn), copper (Cu), iron (Fe), manganese (Mn), sodium (Na), and organic matter (OM). Due to analytical suite groupings, analyses for Ca, Mg, and Na were performed by two methods: atomic absorption (S 1.60), which yields results in milliequivalents per L (me/L), and ammonium acetate (S 5.10), which yields results in parts per million (ppm) (Western States Laboratory, 1998). The means and standard deviations of soil chemistry data for each of the erosion rate test plots are shown in Table 8-1. A comparison of the chemical data for the three soil sampling events indicates that each of the analyzed parameters stayed generally consistent over the course of the study period at each erosion rate test plot.

8.1.1.2 Microbial Soil Analysis

During each of the three soil sampling events, the soils were analyzed for certain microbial parameters, including bacteria (number and biomass), fungi, protozoa (flagellates, amoebae, ciliates), and vesicular arbuscular mycorrhiza (VAM) colonization. For fungi, details regarding the length, active biomass, and hyphal diameter were also measured and recorded. The means and standard deviations of the microbial soil analysis data for each type of erosion rate test plots by vegetation and sampling event are included in Table 8-2. A comparison of the microbial soil analysis data for the three sampling events indicates that with the exception of the protozoa data, the analyzed parameters stayed generally consistent over the course of the study period at each erosion rate test plot.

8.1.2 Statistical Data Analysis

No indications of trends over time were observed in the soil chemistry or microbial data. Therefore, variability in the soil data versus the plant type became the primary interest. Since the data of all three sampling events was correlated, the analysis of variance was only conducted on the data collected during Monitoring Event 3. Tables 8-3 and 8-4 show analysis of variance results for Monitoring Event 3 for the soil data from the erosion rate plots. Table 8-3 shows that percent saturation, pH, electrical conductivity, Na, Cl, B, N, P, Ca (ppm), Mg (ppm), Na (ppm), Zn, Mn, and Fe all differ significantly between vegetation types. Table 8-4 shows that dry weight, fungal hyphal diameter, bacterial numbers, bacterial biomass, and flagellates all differ significantly between vegetation types.

Table 8-1
SOIL COMPOSITION AND CHEMICAL DATA – EROSION RATE TEST PLOTS
THREE SAMPLING EVENTS (FALL 1998, SPRING 1999, AND SPRING 2000)

Vegetation	Monitoring Event	Statistic	Loss on Ignition	Saturation Paste Extract								Potassium Chloride Extract	Olsen Extract	Ammonium Acetate Extract				DPTA Extract			
			OM	Saturation	pH	ECe	Ca	Mg	Na	Cl	B	N	P	K	Ca	Mg	Na	Zn	Mn	Fe	Cu
			%	%		dS m-1(1)	me/L(2)	me/L	me/L	me/L	me/L	ppm(3)	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm
Grass/Forb Complex	Event 1 - Fall 1998	Mean	0.28	48.00	7.35	0.77	3.40	2.43	0.73	2.05	0.28	16.50	13.50	189.83	4883.67	910.67	31.00	1.08	0.78	1.62	0.73
		Std. Dev.	*0.12*	*7.42*	*0.07*	*0.32*	*1.14*	*1.26*	*0.17*	*0.61*	*0.07*	*9.39*	*9.09*	*14.86*	*1130.57*	*244.71*	*14.45*	*0.41*	*0.12*	*0.12*	*0.16*
	Event 2 - Spring 1999	Mean	0.88	50.83	7.32	0.68	4.50	1.58	0.62	1.48	0.47	11.83	8.00	244.17	6070.17	775.33	60.83	2.88	3.10	4.80	2.25
		Std. Dev.	*0.40*	*5.46*	*0.07*	*0.17*	*1.02*	*0.68*	*0.09*	*0.43*	*0.12*	*7.20*	*7.19*	*31.79*	*1337.99*	*204.83*	*29.57*	*0.67*	*0.40*	*0.31*	*0.30*
	Event 3 - Spring 2000	Mean	NA(4)	44.83	7.71	0.46	3.78	1.33	0.58	0.50	0.06	2.00	5.33	179.20	4849.68	585.35	22.99	2.95	3.68	8.55	1.25
		Std. Dev.	*NA*	*6.41*	*0.05*	*0.04*	*0.43*	*0.30*	*0.10*	*0.23*	*0.01*	*0.44*	*2.62*	*17.98*	*802.02*	*105.81*	*2.65*	*0.66*	*0.25*	*2.03*	*0.10*
Iceplant	Event 1 - Fall 1998	Mean	0.93	30.00	7.35	0.93	2.30	2.33	4.55	3.68	0.53	3.67	17.17	81.67	1775.00	272.67	140.67	1.26	0.92	10.75	0.91
		Std. Dev.	*0.31*	*3.46*	*0.26*	*0.30*	*0.49*	*0.57*	*0.71*	*1.76*	*0.20*	*1.25*	*6.09*	*40.14*	*864.98*	*24.95*	*20.30*	*0.42*	*0.18*	*4.86*	*0.20*
	Event 2 - Spring 1999	Mean	0.12	34.17	7.23	0.88	2.30	0.92	5.43	3.23	0.63	8.67	7.50	75.83	2429.67	194.67	217.00	1.74	2.65	18.35	1.24
		Std. Dev.	*0.03*	*1.67*	*0.33*	*0.16*	*0.38*	*0.25*	*1.29*	*1.67*	*0.16*	*5.12*	*9.46*	*40.34*	*955.63*	*21.39*	*43.23*	*0.95*	*0.63*	*6.92*	*0.38*
	Event 3 - Spring 2000	Mean	NA	21.80	7.81	1.36	3.67	1.83	11.57	1.29	0.42	2.23	11.33	32.58	1035.40	99.25	28.69	1.73	3.35	14.48	0.80
		Std. Dev.	*NA*	*3.14*	*0.43*	*0.48*	*2.52*	*1.37*	*2.59*	*1.28*	*0.27*	*1.65*	*1.37*	*17.87*	*521.38*	*10.91*	*13.29*	*0.55*	*2.08*	*2.91*	*0.31*
Myoporum	Event 1 - Fall 1998	Mean	1.06	31.67	7.64	1.20	3.23	2.42	4.60	5.40	0.55	3.83	14.00	165.50	3353.17	452.83	165.17	1.92	1.63	6.15	2.10
		Std. Dev.	*1.45*	*1.60*	*0.13*	*0.50*	*0.95*	*0.68*	*2.97*	*2.33*	*0.10*	*1.07*	*8.94*	*29.28*	*546.39*	*188.90*	*86.97*	*0.78*	*0.21*	*2.40*	*0.42*
	Event 2 - Spring 1999	Mean	0.34	38.67	7.62	0.87	3.45	0.98	4.03	3.20	0.55	3.17	8.67	149.33	4901.00	348.83	191.67	2.70	5.20	14.60	2.74
		Std. Dev.	*0.18*	*3.40*	*0.19*	*0.24*	*0.62*	*0.30*	*2.50*	*1.72*	*0.26*	*1.07*	*8.10*	*18.31*	*621.50*	*124.18*	*87.97*	*1.20*	*1.10*	*4.20*	*0.66*
	Event 3 - Spring 2000	*Mean*	NA	32.62	7.69	0.96	4.38	1.60	5.76	1.77	0.51	0.09	16.50	74.29	2324.64	176.21	17.14	1.64	5.20	10.85	1.04
		Std. Dev.	*NA*	*1.98*	*0.19*	*0.23*	*1.29*	*0.51*	*3.58*	*1.02*	*0.31*	*0.00*	*10.21*	*6.77*	*503.66*	*23.00*	*11.22*	*0.79*	*3.91*	*7.30*	*0.84*
Coastal Sage Scrub	Event 1 - Fall 1998	Mean	0.21	45.17	6.97	0.43	2.18	1.43	0.38	1.42	0.50	2.50	28.33	257.00	4676.33	869.50	19.33	1.52	0.68	5.75	0.88
		Std. Dev.	*0.09*	*10.11*	*0.63*	*0.19*	*1.04*	*0.57*	*0.07*	*0.21*	*0.13*	*1.26*	*18.83*	*81.14*	*2434.78*	*324.29*	*16.99*	*1.21*	*0.16*	*4.58*	*0.13*
	Event 2 - Spring 1999	Mean	0.81	48.00	6.22	0.48	3.43	1.03	0.47	1.42	0.42	7.67	14.00	260.50	5324.67	615.00	41.17	3.87	3.42	23.42	2.83
		Std. Dev.	*0.53*	*15.14*	*0.72*	*0.24*	*1.81*	*0.43*	*0.12*	*0.43*	*0.13*	*5.85*	*14.65*	*99.66*	*2632.27*	*220.89*	*18.65*	*2.17*	*0.72*	*16.81*	*0.53*
	Event 3 - Spring 2000	Mean	NA	41.47	7.06	0.83	7.85	2.60	0.54	0.23	0.13	1.68	14.83	182.46	4241.80	538.76	8.61	3.88	3.32	19.15	1.37
		Std. Dev.	*NA*	*12.31*	*0.32*	*0.63*	*6.10*	*2.11*	*0.23*	*0.13*	*0.04*	*0.28*	*5.64*	*56.78*	*1843.09*	*219.72*	*9.38*	*2.09*	*0.98*	*7.00*	*0.16*
Undisturbed Coastal Sage Scrub	Event 1 - Fall 1998	Mean	0.17	35.67	5.92	0.33	1.37	1.13	0.63	1.97	0.47	1.33	38.00	303.67	2794.00	874.00	38.67	1.21	2.50	9.70	0.97
		Std. Dev.	*0.02*	*2.05*	*0.21*	*0.03*	*0.19*	*0.09*	*0.05*	*0.34*	*0.09*	*0.47*	*17.72*	*35.65*	*224.13*	*56.86*	*11.47*	*0.33*	*0.37*	*3.14*	*0.01*
	Event 2 - Spring 1999	Mean	1.36	43.33	5.43	0.33	2.07	0.67	0.73	1.23	0.43	7.67	15.67	291.67	3266.00	687.33	64.00	2.69	10.50	27.47	2.85
		Std. Dev.	*0.03*	*1.89*	*0.05*	*0.05*	*0.45*	*0.12*	*0.12*	*0.21*	*0.05*	*2.49*	*10.87*	*47.20*	*240.61*	*129.07*	*14.35*	*1.13*	*3.55*	*9.85*	*0.13*
	Event 3 - Spring 2000	Mean	NA	*40.27*	*6.33*	*0.41*	*3.20*	*1.47*	*0.68*	*0.36*	*0.14*	*3.00*	*16.00*	*217.65*	*2792.24*	*530.66*	*22.99*	*2.23*	*10.00*	*24.50*	*1.73*
		Std. Dev.	*NA*	*1.08*	*0.16*	*0.04*	*0.08*	*0.05*	*0.06*	*0.15*	*0.05*	*1.26*	*4.55*	*38.09*	*9.45*	*24.97*	*1.88*	*0.54*	*1.56*	*3.88*	*0.05*

(1) dSm-1

(2) me/L: milliequivalents per liter

(3) ppm: parts per million

(4) NA: Data not available. Due to a change in laboratories used for soil chemical analyses, organic matter was no longer included in the analytical suite in Event 3.

Table 8-2
SOIL MICROBIAL DATA - EROSION RATE TEST PLOTS
THREE SOIL SAMPLING EVENTS (FALL 1998, SPRING 1999 AND SPRING 2000)

Vegetation	Monitoring Event	Statistic	FUNGI Length Active (cm per g soil)	FUNGI Biomass Active (µg per g soil)	FUNGI Hyphal Diameter (µm)	BACTERIA Number Active (count per g soil)	BACTERIA Biomass Active (µg per g soil)	FUNGI/ BACTERIA RATIO	PROTOZOA Flagellates (count per g soil)	PROTOZOA Amoebae (count per g soil)	PROTOZOA Ciliates (Count per g soil)	VAM[2] % Root
Grass/Forb Complex	Event 1 - Fall 1998	Mean	42.81	1.14	2.50	1.8E+07	3.68	0.25	1.4E+04	7.3E+03	8.3E+01	17.67
		Std. Dev.	*75.98*	*2.23*	*0.41*	*4.3E+06*	*0.84*	*0.47*	*1.7E+04*	*1.1E+04*	*6.3E+01*	*16.65*
Grass/Forb Complex	Event 2 - Spring 1999	Mean	138.79	1.15	1.58	2.8E+07	5.62	0.21	2.9E+03	5.6E+03	7.5E+01	4.67
		Std. Dev.	*26.13*	*0.40*	*0.19*	*6.6E+06*	*1.32*	*0.08*	*2.1E+03*	*4.6E+03*	*6.9E+01*	*3.35*
Grass/Forb Complex	Event 3 - Spring 2000	*Mean*	95.19	0.64	1.42	2.1E+07	4.29	0.15	2.9E+03	4.8E+03	2.6E+01	11.27
		Std. Dev.	*42.23*	*0.35*	*0.19*	*3.8E+06*	*0.76*	*0.08*	*1.9E+03*	*2.0E+03*	*2.0E+01*	*6.54*
Iceplant	Event 1 - Fall 1998	Mean	132.09	2.49	2.20	3.2E+07	6.32	0.43	2.4E+03	1.6E+03	5.8E+01	2.33
		Std. Dev.	*128.28*	*2.65*	*0.40*	*8.0E+06*	*1.59*	*0.47*	*1.9E+03*	*1.7E+03*	*4.8E+01*	*2.92*
Iceplant	Event 2 - Spring 1999	Mean	172.61	3.47	2.50	4.9E+07	9.72	0.38	5.0E+03	3.6E+03	9.8E+01	14.67
		Std. Dev.	*69.75*	*1.40*	*0.00*	*7.0E+06*	*1.40*	*0.17*	*5.2E+03*	*5.1E+03*	*9.1E+01*	*14.08*
Iceplant	Event 3 - Spring 2000	*Mean*	65.62	0.78	1.75	2.8E+07	5.66	0.13	1.2E+04	2.2E+03	3.2E+01	1.27
		Std. Dev.	*46.42*	*0.63*	*0.25*	*3.6E+06*	*0.73*	*0.10*	*1.2E+04*	*2.3E+03*	*1.4E+01*	*2.07*
Myoporum	Event 1 - Fall 1998	Mean	96.01	1.59	2.33	2.9E+07	5.75	0.34	7.1E+03	1.2E+04	1.3E+03	47.67
		Std. Dev.	*74.23*	*0.93*	*0.24*	*1.0E+07*	*2.08*	*0.27*	*6.0E+03*	*2.2E+04*	*2.3E+03*	*33.16*
Myoporum	Event 2 - Spring 1999	Mean	132.97	2.68	2.50	5.3E+07	10.50	0.25	3.6E+03	1.1E+04	4.7E+01	31.50
		Std. Dev.	*64.90*	*1.30*	*0.00*	*1.4E+07*	*2.81*	*0.11*	*1.3E+03*	*1.7E+04*	*5.0E+01*	*25.97*
Myoporum	Event 3 - Spring 2000	*Mean*	53.10	0.57	1.33	1.8E+07	3.64	0.17	2.0E+04	2.0E+03	3.7E+01	56.68
		Std. Dev.	*39.95*	*0.53*	*0.69*	*5.4E+06*	*1.08*	*0.18*	*1.7E+04*	*1.7E+03*	*4.0E+01*	*11.80*
Coastal Sage Scrub	Event 1 - Fall 1998	Mean	11.65	0.12	1.83	1.6E+07	3.13	0.04	2.0E+03	1.0E+03	9.8E+01	6.40
		Std. Dev.	*12.84*	*0.12*	*0.47*	*8.5E+06*	*1.71*	*0.04*	*2.0E+03*	*9.1E+02*	*1.0E+02*	*6.34*
Coastal Sage Scrub	Event 2 - Spring 1999	Mean	76.63	0.66	1.58	2.1E+07	4.17	0.15	1.5E+03	4.0E+02	2.8E+01	1.83
		Std. Dev.	*59.88*	*0.53*	*0.19*	*7.9E+06*	*1.58*	*0.13*	*9.4E+02*	*1.9E+02*	*3.3E+01*	*2.97*
Coastal Sage Scrub	Event 3 - Spring 2000	*Mean*	72.91	0.53	1.50	9.7E+06	1.95	0.34	3.3E+03	2.1E+03	5.2E+01	0.48
		Std. Dev.	*42.53*	*0.31*	*0.00*	*4.5E+06*	*0.90*	*0.27*	*2.4E+03*	*1.7E+03*	*6.2E+01*	*1.08*
Undisturbed Coastal Sage Scrub	Event 1 - Fall 1998	Mean	16.94	0.19	2.00	2.1E+07	4.13	0.05	2.2E+03	5.4E+02	3.1E+01	13.00
		Std. Dev.	*14.74*	*0.13*	*0.50*	*3.7E+06*	*0.74*	*0.04*	*1.2E+03*	*5.9E+01*	*2.6E+01*	*9.20*
Undisturbed Coastal Sage Scrub	Event 2 - Spring 1999	Mean	288.35	2.09	1.50	2.5E+07	5.00	0.38	1.0E+03	1.0E+03	4.2E+00	3.00
		Std. Dev.	*198.19*	*1.43*	*0.00*	*4.7E+06*	*0.94*	*0.20*	*6.8E+02*	*9.3E+02*	*3.0E+00*	*4.24*
Undisturbed Coastal Sage Scrub	Event 3 - Spring 2000	*Mean*	103.75	0.75	1.50	1.5E+07	3.02	0.25	5.3E+02	1.3E+03	2.0E+01	0.00
		Std. Dev.	*21.86*	*0.16*	*0.00*	*2.9E+06*	*0.57*	*0.05*	*5.9E+01*	*1.2E+03*	*1.4E+01*	*0.00*

Table 8-3
ANALYSIS OF VARIANCE FOR SOIL COMPOSITION AND CHEMICAL DATA EROSION RATE TEST PLOTS

Soil Response Variable	Vegetation
	p-value
% Saturation	0
PH	0
ECe	0.009
Ca(1)	0.216
Mg(1)	0.573
Na(1)	0
Cl	0.021
B	0.001
N	0
P	0.005
K	0.327
Ca(2)	0
Mg(2)	0
Na(2)	0.001
Zn	0.011
Mn	0.001
Fe	0
Cu	0.078

(1) Analysis by atomic absorption reported in me/L.

(2) Analysis by ammonium acetate reported in ppm.

Note: Factorial analysis of variance with vegetation as the factor and soil constituents as the response variables. These analyses were univariate tests performed using the Event 3 monitoring data.

p-values less than 0.05 represent statistically significant differences in the variable listed in the left hand column.

Table 8-4
ANALYSIS OF VARIANCE FOR SOIL MICROBIAL DATA
EROSION RATE TEST PLOTS

Soil Response Variable	Vegetation
	p-value
Dry Weight	0
Fungi Length Active	0.206
Fungi Biomass Active	0.222
Fungi Hyphal Diameter	0.034
Bacteria Number Active	0
Bacteria biomass Active	0
Fungi Bacteria Ratio	0.092
Flagellates	0.029
Amoebae	0.157
Ciliates	0.694

Note: Factorial analysis of variance with vegetation as the factor and soil constituents as the response variables. These analyses were univariate tests performed using the Event 3 monitoring data.

p-values less than 0.05 represent statistically significant differences in the variable listed in the left hand column.

8.2 RAINFALL DATA

8.2.1 Rainfall Data - All Storm Events

Rainfall was measured with onsite rain gauges for each erosion rate test plot during the wet seasons (November through April) of the two-year monitoring periods, as described in Section 3.3. During the 1998-1999 monitoring season, one precipitation event was recorded on June 2, 1999, that was outside of the wet season monitoring period. Due to the geographic separation of the test sites throughout Los Angeles County, the test sites received a range of precipitation rates over the course of the study.

Rainfall measurements collected from the test sites were compared to historical average annual rainfall data from the study area. The rainfall data were used to determine which rainfall events would be sampled for runoff analysis. The rainfall data was compared to runoff data, and sediment discharge data, and was used to calculate normalized erosion rates.

As presented in Table 8-5A, the cumulative rainfall for all storm events (including the June 2, 1999 storm event) measured during the 1998-1999 monitoring season ranged from 153 mm (6.0 in.) at the grass/forb complex cut-slope test plot (Site 57-4) to 231 mm (9.1 in.) at the coastal sage scrub undisturbed-slope research test plot (Site R1). As presented in Table 8-5B, the cumulative rainfall for all storm events measured during the 1999-2000 monitoring season ranged from 177 mm (7.0 in.) at the iceplant fill-slope test plot (Site 405-6) to 313 mm (12.3 in.) at the coastal sage scrub cut-slope test plot (Site 210-1).

Precipitation measured during each of the two monitoring seasons was compared to historical average annual rainfall measurements recorded at rain gauge stations located closest to each of the test plots (Table 8-6). The historical annual rainfall data were obtained from the Western Regional Climatic Center. The average annual rainfall measurements recorded at the four closest rain gauge stations; Pomona Cal Poly, Yorba Linda, Long Beach and San Fernando; are 439 mm, 358 mm, 313 mm, and 411 mm, respectively. As presented in Table 8-6 and Figure 8-1A, precipitation recorded at the erosion rate test sites during the 1998-1999 monitoring season ranged from 42 to 64 percent below the historical annual averages. As presented in Table 8-6 and Figure 8-1B, precipitation recorded at the erosion rate test sites during the 1999-2000 monitoring season ranged from 27 to 44 percent below the historical annual averages. It should be noted that since the monitored period was only for the "wet season," and not the entire year, the calculated percent below historical annual averages may be slightly over estimated.

Historical climatic data dating back to 1914 and 1939 is available for the Los Angeles Civic Center (Figure 8-2A) and Burbank (Figure 8-2B) weather stations, respectively. These historical data include multiple day (2 to 4 days) precipitation intensities for 2-year, 5-year, 10-year, and 25-year frequency storm events. The duration of each storm event measured at the test sites during the two monitoring seasons is included on Tables 8-5A and 8-5B. These data were compared to historical storm data collected from the Los Angeles Civic Center and the Burbank weather stations.

The highest rainfall volume storm events that lasted a duration of two or more days during the course of the study are presented in Table 8-7. The greatest precipitation amounts recorded over a two-day period at the erosion rate test sites during the 1998-1999 monitoring season occurred between January 25 and 27, 1999 and ranged from 21 mm (0.8 in.) to 38 mm (1.5 in.). The

Table 8-5A
RAINFALL AMOUNTS (mm) – ALL STORMS 1998-1999

Site	Vegetation	Slope Type	11/28/98 to 11/29/98	12/1/98 to 12/2/98	12/4/98 to 12/6/98	12/19/98 to 12/21/98	1/20/99 to 1/21/99	1/25/99 to 1/27/99	1/31/99	2/4/99 to 2/5/99	2/7/99 to 2/9/99	3/3/99 to 3/4/99	3/9/99	3/11/99	3/15/99 to 3/16/99	3/20/99	3/25/99	4/1/99	4/6/99 to 4/7/99(1)	4/8/99	4/11/99 to 4/12/99	4/30/99	6/2/99(2)	Total Rainfall, All Storms 1998-1999
10-2	Bare	Fill	8	Trace	6	4	5	36	5	14	8	1	1	Trace	10	1	5	3	26	Trace	15	Trace	12	159
57-4	Bare	Cut	8	3	11	4	7	33	6	9	10	Trace	1	Trace	13	1	3	0	21	Trace	18	Trace	6	154
10-2	Grass/Forb Complex	Fill	8	Trace	7	4	6	34	5	13	8	1	1	Trace	10	1	5	4	26	Trace	15	Trace	12	160
57-4	Grass/Forb Complex	Cut	8	2	10	4	7	35	6	10	10	Trace	1	Trace	13	1	3	Trace	20	Trace	18	Trace	6	153
405-6	Iceplant	Fill	7	5	5	4	7	21	11	8	3	Trace	1	2	14	3	13	Trace	17	1	45	Trace	7	172
105-6	Iceplant	Cut	12	8	9	3	6	22	6	4	7	Trace	0	Trace	13	2	12	Trace	17	Trace	38	Trace	13	171
105-3	Myoporum	Fill	8	5	11	2	9	23	4	3	9	Trace	1	Trace	14	4	13	Trace	25	Trace	36	Trace	14	182
105-8	Myoporum	Cut	9	5	13	2	9	26	4	3	7	Trace	1	Trace	12	4	12	Trace	20	Trace	37	Trace	16	182
210-10	Coastal Sage Scrub	Fill	14	5	4	Trace	6	37	14	1	14	Trace	4	Trace	17	12	13	1	31	Trace	24	Trace	22	220
210-1	Coastal Sage Scrub	Cut	13	Trace	9	4	6	38	5	18	15	Trace	1	Trace	12	2	6	Trace	26	2	15	1	14	188
R1	Coastal Sage Scrub	Undisturbed	25	6	4	Trace	6	37	14	1	14	Trace	4	Trace	17	12	13	1	31	Trace	24	Trace	21	231

Notes:

Rainfall dates indicate start and end date of the precipitation event, unless indicated otherwise.
(1)Rainfall event ended on 4/8/99 for Site 10-2 Baseline and Grass/Forb and 57-4 Baseline and Grass/Forb.
(2)Rainfall event on 6/2/99 occurred outside the wet season monitoring period and was not sampled.
Rain gauge data for Sites 10-2 and 57-4 Bare erosion control plots were also used for Plant Establishment Test Plot rainfall amounts.

Table 8-5B
RAINFALL AMOUNTS (mm) – ALL STORMS 1999 - 2000

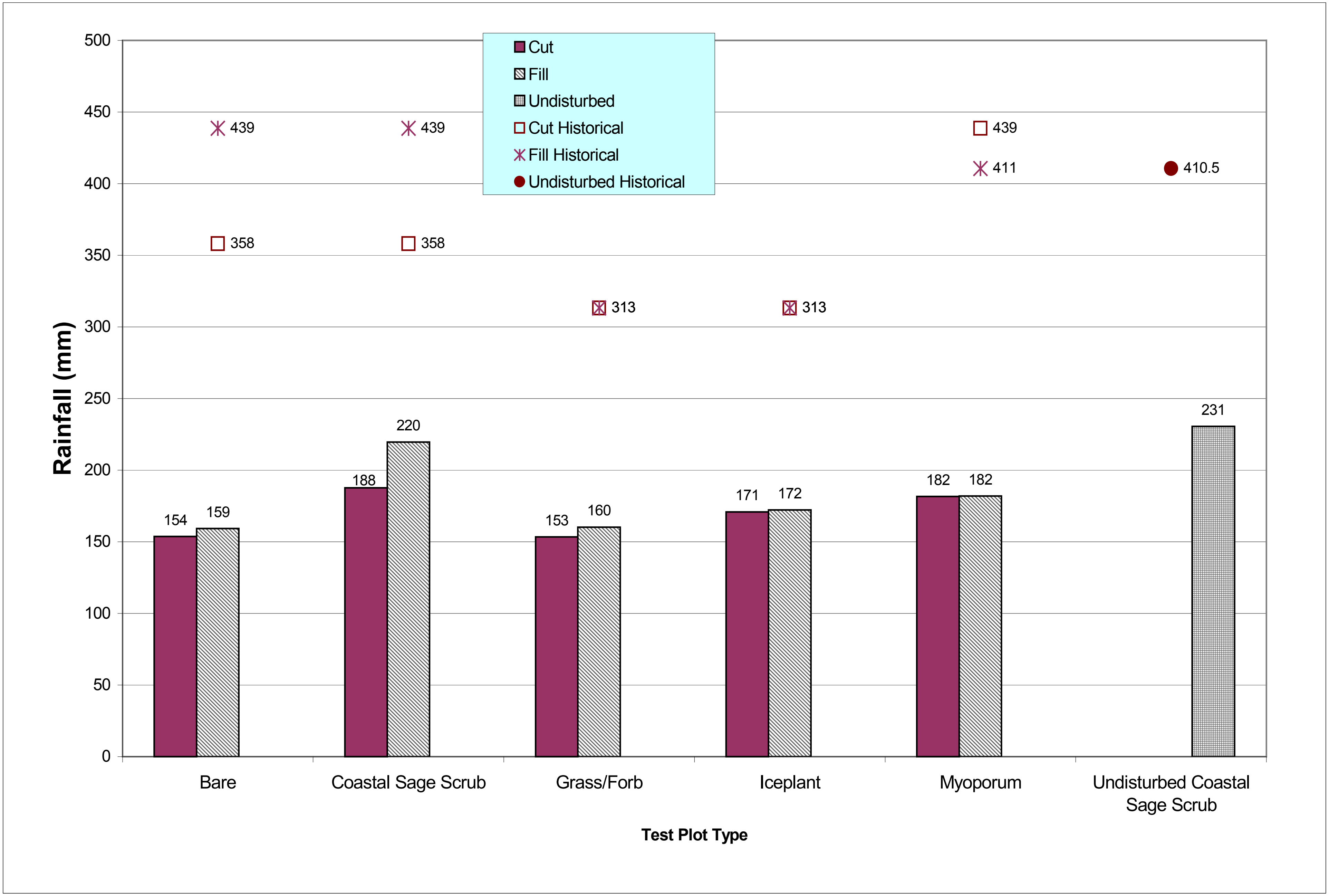
Site	Vegetation	Slope Type	12/31/99 to 1/2/00(1)	1/25/00 to 1/26/00	1/31/00	2/10/00 to 2/13/00(2)	2/16/00	2/20/00 to 2/23/00	2/27/00	3/3/00 to 3/5/00	3/7/00 to 3/8/00	Total Rainfall 1999-2000	Cumulative Rainfall, All Storms 1998-2000
10-2	Bare	Fill	8	19	6	51	3	105	8	38	20	258	417
57-4	Bare	Cut	9	18	8	55	12	93	6	42	20	263	417
10-2	Grass/Forb Complex	Fill	8	18	6	48	3	105	8	38	19	253	413
57-4	Grass/Forb Complex	Cut	8	18	8	55	12	94	6	42	19	262	416
405-6	Iceplant	Fill	0	11	4	39	3	60	4	42	10	177	349
105-6	Iceplant	Cut	1	12	6	36	6	67	4	37	21	193	363
105-3	Myoporum	Fill	1	13	5	33	13	82	5	48	20	224	406
105-8	Myoporum	Cut	1	14	5	39	9	72	5	41	22	213	395
210-10	Coastal Sage Scrub	Fill	0	18	6	38	25	99	11	41	8	250	470
210-1	Coastal Sage Scrub	Cut	13	23	8	71	11	107	10	42	25	313	501
R1	Coastal Sage Scrub	Undisturbed	0	18	5	36	25	92	9	41	7	237	468

Notes:
Rainfall dates indicate start and end date of the precipitation event, unless indicated otherwise.
(1) Rainfall event ended on 1/3/00 for Sites 105-6 Iceplant and 105-8 Myoporum.
(2) Rainfall event ended on 2/15/00 for Site 57-4 Bare.
Rain gauge data for Sites 10-2 and 57-4 Bare erosion Control Test Plots were also used for Plant Establishment Test Plot rainfall amounts.

Table 8-6
COMPARISON OF ANNUAL PRECIPITATION RATES AT TEST PLOTS WITH RAIN GAUGE STATION DATA

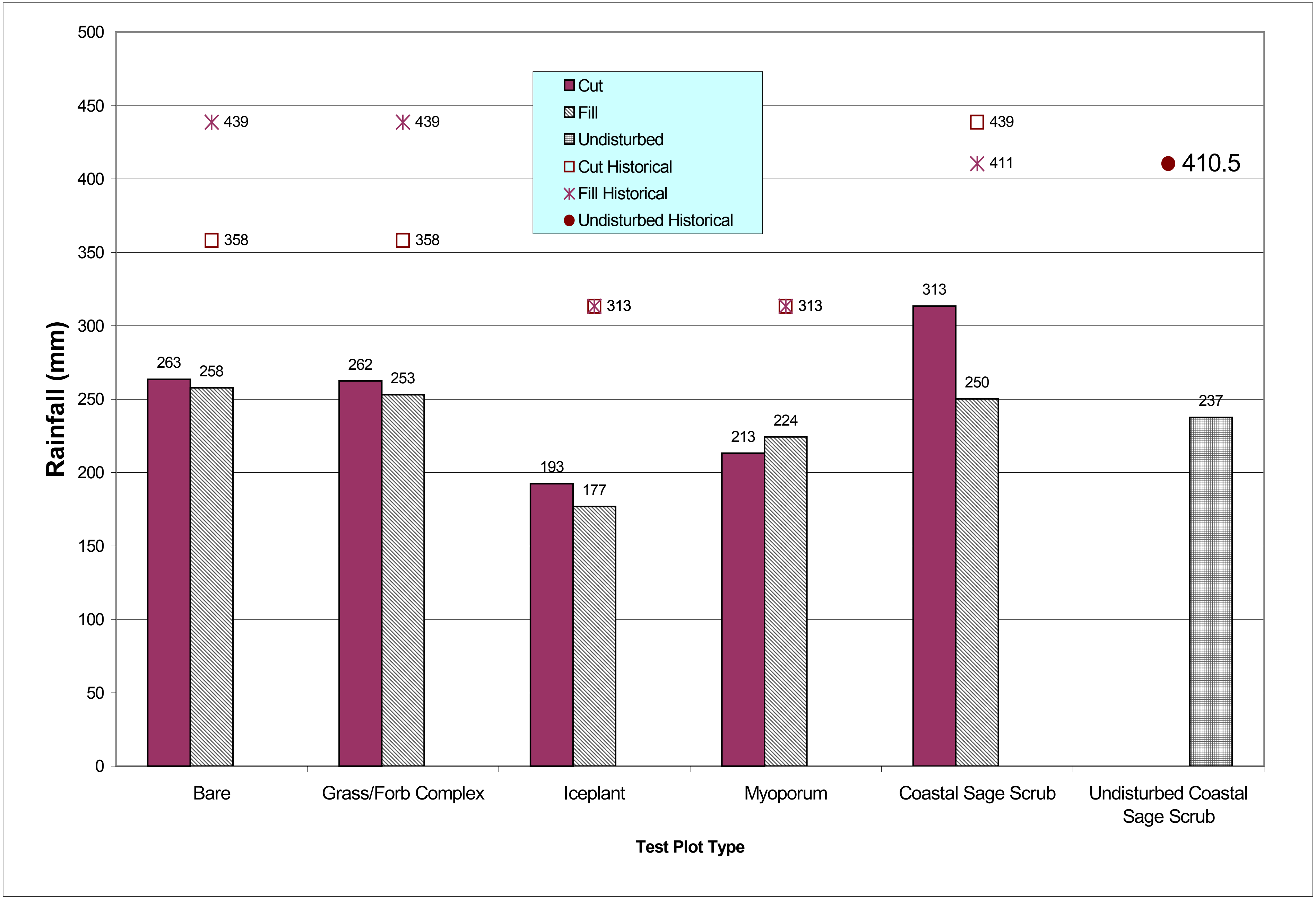
Site	Vegetation	Slope Type	Total Rainfall 1998-1999 (mm)	Total Rainfall 1999-2000 (mm)	Closest Rain Gauge Station (WRCC Site number)(1)	Historic Average Annual Rainfall (mm)	Years in Average	Percent Below Average	
								1998-1999	1999-2000
10-2	Bare	Fill	159	258	Pomona Cal Poly (17)	438.7	1927-95	64	41
57-4	Bare	Cut	154	263	Yorba Linda (19)	358.1	1948-82	57	27
10-2	Grass/Forb Complex	Fill	160	253	Pomona Cal Poly (17)	438.7	1927-95	63	42
57-4	Grass/Forb Complex	Cut	153	262	Yorba Linda (19)	358.1	1948-82	57	27
405-6	Iceplant	Fill	172	177	Long Beach (11)	313.2	1958-99	45	43
105-6	Iceplant	Cut	171	193	Long Beach (11)	313.2	1958-99	45	38
105-3	Myoporum	Fill	182	224	Long Beach (11)	313.2	1958-99	42	28
105-8	Myoporum	Cut	182	213	Long Beach (11)	313.2	1958-99	42	32
210-10	Coastal Sage Scrub	Fill	220	250	San Fernando (1)	410.5	1927-74	46	39
210-1	Coastal Sage Scrub	Cut	188	313	Pomona Cal Poly (17)	438.7	1927-95	57	29
R1	Coastal Sage Scrub	Undisturbed	231	237	San Fernando (1)	410.5	1927-74	44	42

1)WRCC – Western Regional Climatic Center



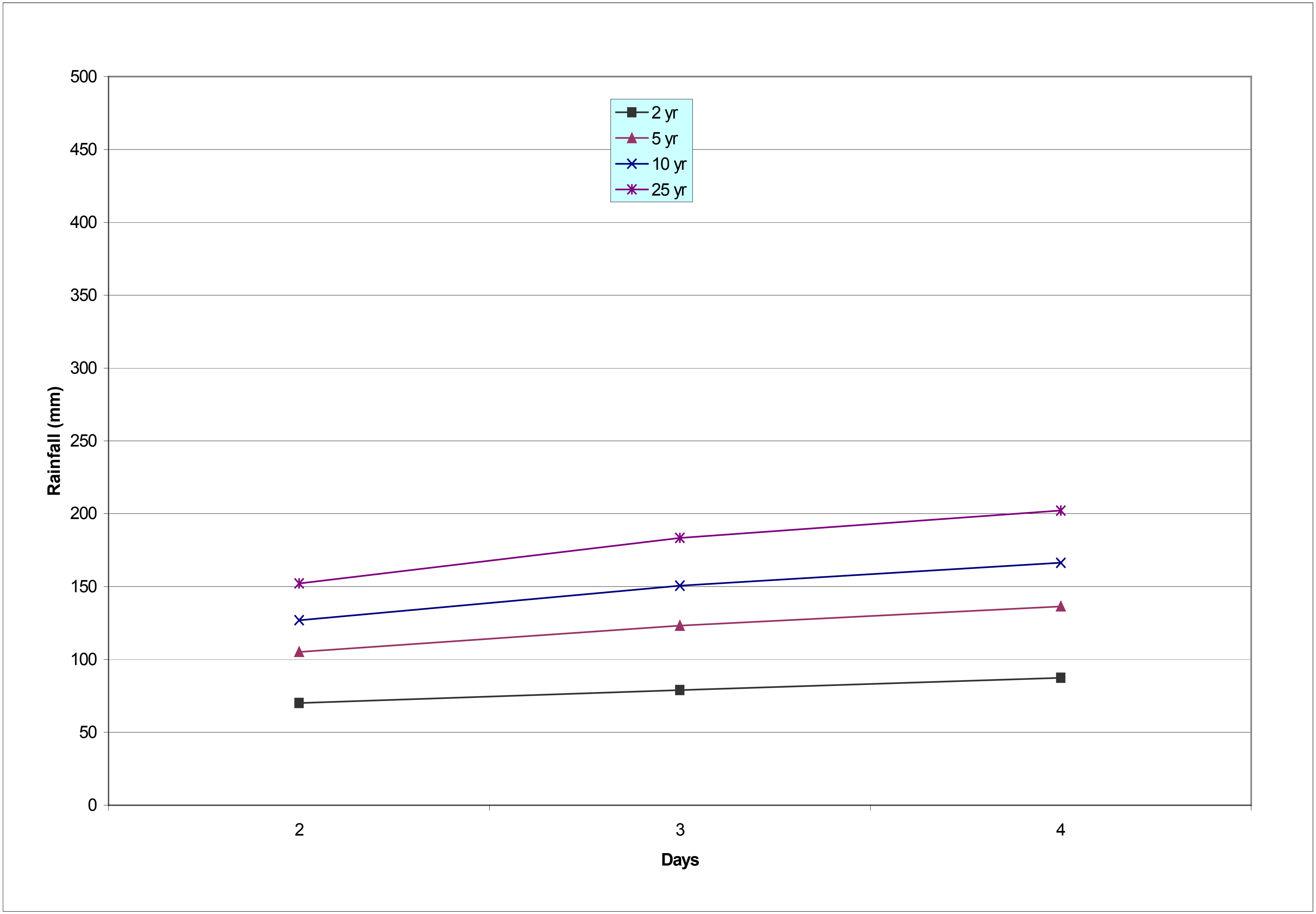
TOTAL RAINFALL (mm) 1998-1999 STORMS COMPARED TO HISTORICAL AVERAGE ANNUAL RAINFALL AT AREA RAIN GAUGES

Project No.: 57-977001NM.00	Date: JUNE 2000	Project: CALTRANS EROSION CONTROL PILOT STUDY	Fig.: 8-1A



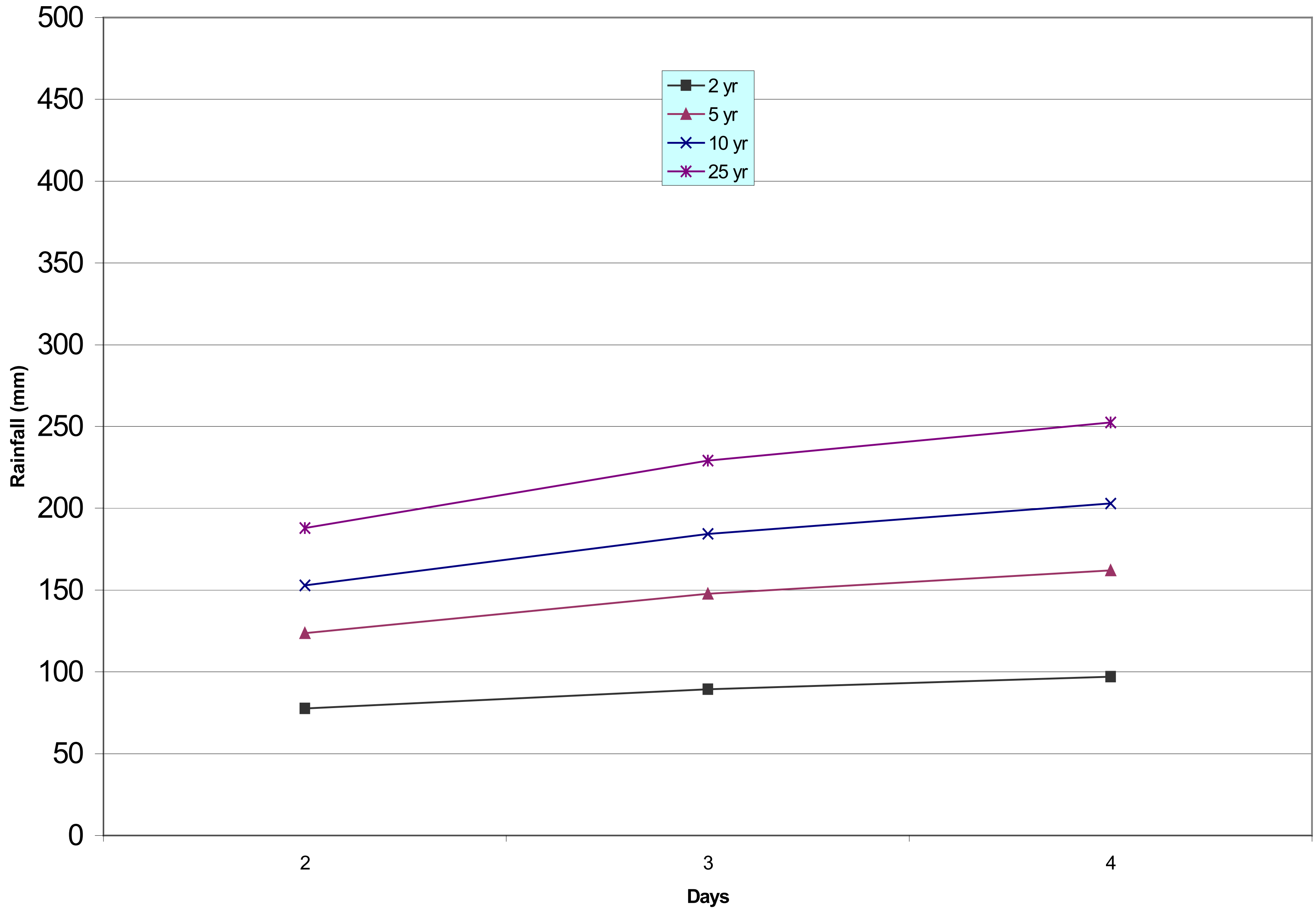
TOTAL RAINFALL (mm) 1999-2000 STORMS COMPARED TO HISTORICAL AVERAGE ANNUAL RAINFALL AT AREA RAIN GAUGES

Project No.: 57-977001NM.00	Date: JUNE 2000	Project: CALTRANS EROSION CONTROL PILOT STUDY	Fig.: 8-1B



PRECIPITATION FREQUENCY OVER EXTENDED DURATIONS FOR LOS ANGELES CIVIC CENTER STATION

Project No.: 57-977001NM.00	Date: JUNE 2000	Project: CALTRANS EROSION CONTROL PILOT STUDY	Fig.: 8-2A



PRECIPITATION FREQUENCY OVER EXTENDED DURATIONS FOR BURBANK STATION

Project No.: 57-977001NM.00	Date: JUNE 2000	Project: CALTRANS EROSION CONTROL PILOT STUDY	Fig.: 8-2B

Table 8-7
RAINFALL FOR HIGHEST RAINFALL VOLUME STORM EVENTS LASTING A DURATION OF TWO DAYS OR MORE RECORDED DURING THE TWO YEAR MONITORING PERIOD

Site	Vegetation	Slope Type	1/25/99-1/27/99 (2 days) (mm)	2/20/00-2/23/00 (4 days) (mm)	3/3/00-3/5/00 (2 days) (mm)	Reference Station [1]
10-2	Bare	Fill	35.6	105.2	38.1	LA
57-4	Bare	Cut	33.0	92.7	41.7	LA
10-2	Grass/Forb Complex	Fill	34.3	104.6	38.1	LA
57-4	Grass/Forb Complex	Cut	34.8	94.0	41.7	LA
405-6	Iceplant	Fill	21.3	59.9	41.9	LA
105-6	Iceplant	Cut	22.4	66.8	36.8	LA
105-3	Myoporum	Fill	23.4	81.8	47.8	LA
105-8	Myoporum	Cut	26.4	71.6	40.6	LA
210-10	Coastal Sage Scrub	Fill	37.1	98.8	41.2	B
210-1	Coastal Sage Scrub	Cut	37.9	106.9	42.2	LA
R1	Coastal Sage Scrub	Undisturbed	37.1	91.7	40.6	B

(1) Reference Stations are Los Angeles Civic Center Station (LA) with a database back to 1914 and Burbank Station (B) with a database back to 1939.

greatest precipitation amounts recorded over a two-day period during the 1999-2000 monitoring season occurred between March 3 and 5, 2000 and ranged from 38 mm (1.5 in.) to 48 mm (1.9 in). The measured rainfall over these two highest rainfall volumes measured during two-day storm events were less then the 70 mm (2.8 in.) and 75 mm (3.0 in.) historic rainfall averages recorded for a two-day, 2-year frequency storm event at the Los Angeles Civic Center and Burbank weather stations, respectively.

A three-day storm event was also recorded at the erosion rate test sites during the 1999-2000 monitoring season. This event occurred between February 20 and 23, 2000 and ranged from 60 mm (2.4 in.) to 107 mm (4.2 in.) (Table 8-5B). Precipitation amounts recorded at all but three of the test plots were greater than the 78 mm (3.1 in.) and 68 mm (2.7 in.) historic rainfall averages recorded for a three-day, 2-year frequency storm event at the Los Angeles Civic Center and Burbank weather stations, respectively. Measured rainfall for these events was less than the 123 mm (4.8 in.) and 147 mm (5.8 in.) historic rainfall averages recorded for a three-day, 5-year frequency storm event for the Los Angeles Civic Center and Burbank weather stations, respectively. The February 20, 2000 storm event appears to be most similar to a two-day, 2-year frequency storm event.

8.2.2 Statistical Interpretation of Monthly Rainfall Data

A statistical comparison was developed based on average monthly rainfall recorded at the erosion rate test plots and the historical average monthly rainfall amounts recorded at two of the Western Regional Climate Center rain gauges.

Table 8-8 shows historical average monthly rainfall data for Long Beach. Table 8-9 shows historical average monthly rainfall data for Pomona. Table 8-10 shows monthly average rainfall amounts measured at the erosion rate test plots. The tables show that observed rainfall amounts on the erosion rate study plots during the test period are often outside the 95 percent confidence limits for long-term mean monthly precipitation. However, the observed rainfall amounts are well within the observed range of variation of monthly rainfall. Therefore, while rainfall during the study period may not have been average, it was not atypical.

8.2.3 Rainfall Data From Sampled Storm Events

Rainfall measured during the 1998-1999 and 1999-2000 sampled storm events are presented on Tables 8-11A and 8-11B, respectively. Rainfall for individual storm events sampled during the 1998-1999 monitoring season ranged from 6 mm (0.25 in.) to 45 mm (1.8 in.). Rainfall for individual storm events sampled during the 1999-2000 monitoring season ranged from 8 mm (0.3 in.) to 107 mm (4.2 in.). Total rainfall for all sampled storms during the 1998-1999 monitoring season ranged from 121 mm (4.8 in.) at the grass/forb fill-slope test plot (Site 10-2), which had eight sampled storms, to 188 mm (7.4 in.) at the coastal sage scrub, undisturbed-slope research test plot (Site R1), which had nine sampled storm events. Total rainfall for all sampled storms during the 1999-2000 monitoring season ranged from 163 mm (6.4 in.) at the iceplant fill-slope test plot (Site 405-6) which had five sampled storms to 310 mm (12.2 in.) at the coastal sage scrub cut-slope test plot (Site 210-1) which had nine sampled storms. Figures 8-3A and 8-3B graphically illustrate cumulative rainfall for the 1998-1999 and 1999-2000 sampled storm events, respectfully.

Table 8-8
MEANS, STANDARD DEVIATIONS, AND UPPER AND LOWER 95% CONFIDENCE LIMITS FOR LONG BEACH MONTHLY RAINFALL DATA (1)

Month	Mean(2)	95% CL(3) Upper	95% CL(3) Lower	Standard Deviation
JAN	1.902	2.629	1.320	0.117
FEB	1.902	2.692	1.281	0.126
MAR	1.540	2.098	1.083	0.103
APR	0.514	0.730	0.324	0.068
MAY	0.126	0.226	0.035	0.043
JUN	0.063	0.111	0.016	0.022
JUL	0.016	0.028	0.004	0.006
AUG	0.057	0.122	-0.004	0.207
SEP	0.172	0.280	0.073	0.045
OCT	0.212	0.315	0.117	0.041
NOV	1.044	1.452	0.703	0.094
DEC	1.293	1.769	0.899	0.098
Annual average	11.052	12.955	9.408	0.075

(1) Rainfall data presented in mm.
(2) Means are based on 41 years of data.
(3)CL: Confidence Limit.

Table 8-9
MEANS, STANDARD DEVIATIONS, AND UPPER AND LOWER 95% CONFIDENCE LIMITS FOR POMONA MONTHLY RAINFALL DATA (1)

Month	Mean(2)	95% CL(3) Upper	95% CL Lower	Standard Deviation
JAN	2.561	3.287	1.957	0.097
FEB	2.557	3.287	1.951	0.098
MAR	2.135	2.744	1.625	0.093
APR	0.952	1.235	0.704	0.070
MAY	0.192	0.281	0.109	0.037
JUN	0.059	0.091	0.028	0.015
JUL	0.013	0.027	-0.001	0.007
AUG	0.068	0.122	0.017	0.025
SEP	0.196	0.305	0.096	0.045
OCT	0.468	0.625	0.326	0.052
NOV	1.132	1.487	0.827	0.080
DEC	1.985	2.565	1.499	0.093
Annual average	15.701	17.627	13.974	0.056

(1) Rainfall data presented in mm.
(2) Means are based on 63 to 65 years of data.
(3) CL: Confidence Limit

Table 8-10
MEANS AND STANDARD DEVIATIONS OF EROSION RATE TEST PLOTS MONTHLY RAINFALL AMOUNTS[(1)]

Month	Mean	Standard Deviation	Long Beach Station	Pomona Station
DEC 98	0.56	0.11	Low	Low
JAN 99	1.76	0.11	OK	Low
FEB 99	0.65	0.17	Low	Low
MAR 99	1.05	0.22	Low	Low
APR 99	1.99	0.12	High	High
MAY 99	0.00	0.00	Low	Low
JUN 99	0.51	0.15	High	High
JUL 99	0.00	0.00	OK	OK
AUG 99	0.00	0.00	OK	Low
SEP 99	0.00	0.00	Low	Low
OCT 99	0.00	0.00	Low	Low
NOV 99	0.13	0.07	Low	Low
DEC 99	0.16	0.16	Low	Low
JAN 00	0.87	0.10	Low	Low
FEB 00	5.90	0.18	High	High
MAR 00	2.28	0.09	High	OK

(1) Rainfall data presented in mm.

Note: The two right-hand columns in the table indicate whether the observed monthly mean is within ('OK'), above ('High'), or below ('Low') the calculated 95% confidence limits for Long Beach and Pomona Stations, respectively.

Table 8-11A
RAINFALL AMOUNTS (mm) – SAMPLED STORMS(1) 1998-1999

Site	Vegetation	Slope Type	11/28/98 to 11/29/98	12/1/98 to 12/2/98	12/4/98 to 12/6/98	1/20/99 to 1/21/99	1/25/99 to 1/27/99	1/31/99	2/4/99 to 2/5/99	2/7/99 to 2/9/99	3/15/99 to 3/16/99	3/20/99	3/25/99	4/6/99 to 4/7/99(1)	4/11/99 to 4/12/99	Total Rainfall Sampled Storms 1998-1999
10-2	Bare	Fill	8	NS(2)	6	NS	36	NS	14	8	10	NS	NS	26	16	123
57-4	Bare	Cut	8	NS	11	7	33	NS	9	10	13	NS	NS	21	18	131
10-2	Grass/Forb Complex	Fill	8	NS	7	NS	34	NS	13	8	10	NS	NS	26	15	121
57-4	Grass/Forb Complex	Cut	8	NS	10	7	35	NS	10	10	13	NS	NS	20	18	132
405-6	Iceplant	Fill	7	NS	NS	7	21	11	8	NS	14	NS	13	17	45	142
105-6	Iceplant	Cut	12	8	9	NS	22	NS	NS	7	13	NS	12	17	38	138
105-3	Myoporum	Fill	8	NS	11	9	23	NS	NS	9	14	NS	14	25	36	149
105-8	Myoporum	Cut	9	NS	13	9	26	NS	NS	7	12	NS	12	20	37	147
210-10	Coastal Sage Scrub	Fill	14	NS	NS	NS	37	15	NS	14	17	12	13	31	24	177
210-1	Coastal Sage Scrub	Cut	13	NS	9	NS	38	NS	18	15	12	NS	NS	26	15	147
R1	Coastal Sage Scrub	Undisturbed	25	NS	NS	NS	37	15	NS	14	17	12	13	31	24	188

Notes:

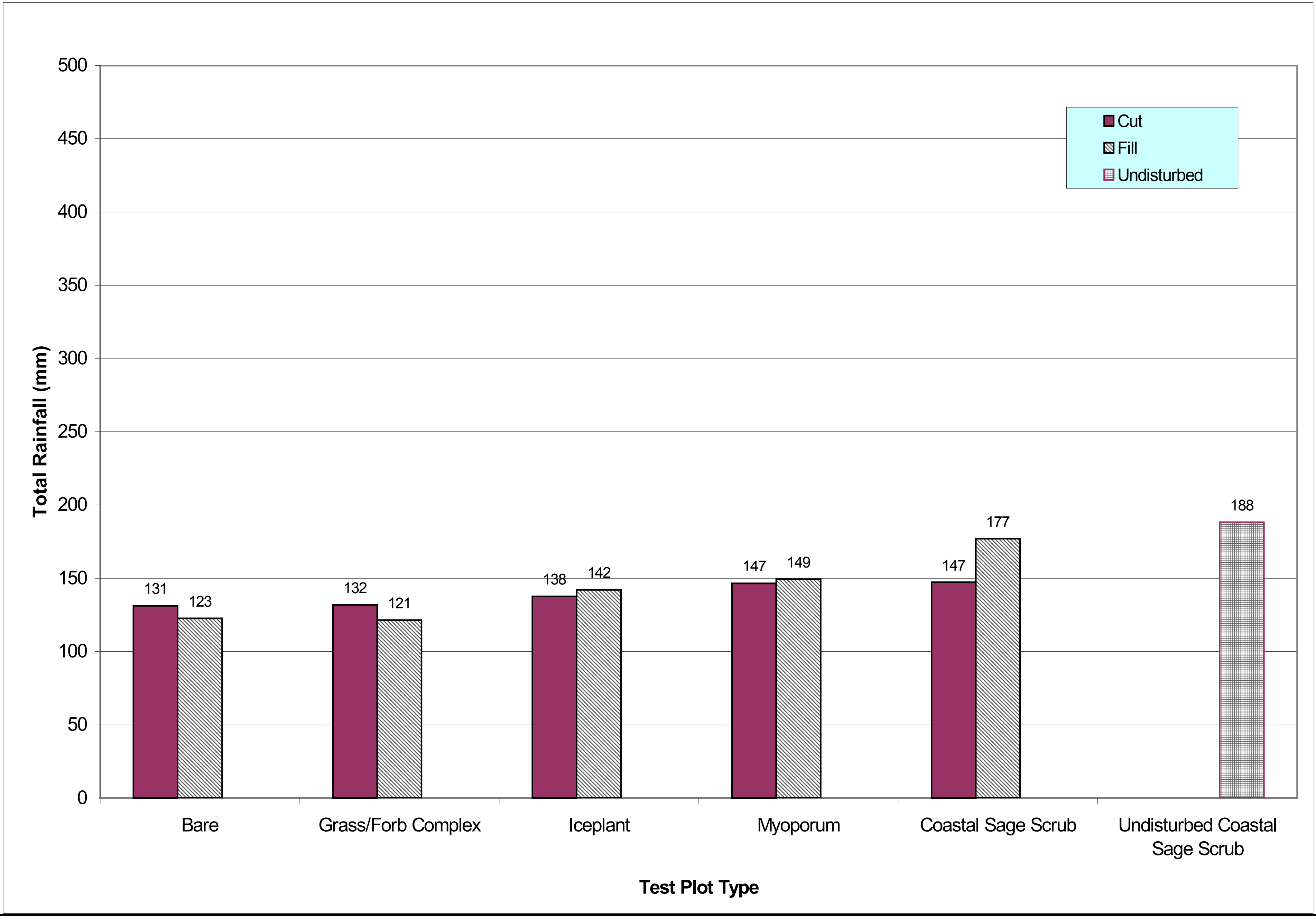
(1) Sampled storms include all storm events of 6 mm (0-25in.) or more of rainfall in a 24-hr. period.
(2) NS = Not Sampled
Rainfall dates indicate start and end date of precipitation event except where indicated.
(3) Rainfall event ended on 4/8/99 for Sites 10-2 Bare and Grass/Forb and 57-4 Bare and Grass/Forb

Table 8-11B
RAINFALL AMOUNTS (mm) – SAMPLED STORMS(1) 1999-2000

Site	Vegetation	Slope Type	12/31/99 to 1/2/00	1/25/00 to 1/26/00	1/31/00	2/10/00 to 2/13/00(3)	2/16/00	2/20/00 to 2/23/00	2/27/00	3/3/00 to 3/5/00	3/7/00 to 3/8/00	Total Rainfall Sampled Storms 1999-2000	Cumulative Rainfall, Sampled Storms 1998-2000
10-2	Bare	Fill	8	19	NS(2)	51	NS	105	8	38	20	248	371
57-4	Bare	Cut	9	18	8	55	12	93	NS	42	20	255	387
10-2	Grass/Forb Complex	Fill	8	18	NS	48	NS	105	8	38	19	244	366
57-4	Grass/Forb Complex	Cut	8	18	8	55	12	94	NS	42	19	255	386
405-6	Iceplant	Fill	NS	11	NS	39	NS	60	NS	42	10	163	305
105-6	Iceplant	Cut	NS	12	NS	36	NS	67	NS	37	21	173	311
105-3	Myoporum	Fill	NS	13	NS	33	13	82	NS	48	20	209	358
105-8	Myoporum	Cut	NS	14	NS	39	9	72	NS	41	22	197	343
210-10	Coastal Sage Scrub	Fill	NS	18	NS	38	25	99	11	41	8	239	416
210-1	Coastal Sage Scrub	Cut	13	23	8	71	11	107	10	42	25	310	458
R1	Coastal Sage Scrub	Undisturbed	NS	18	NS	36	25	92	9	41	7	226	415

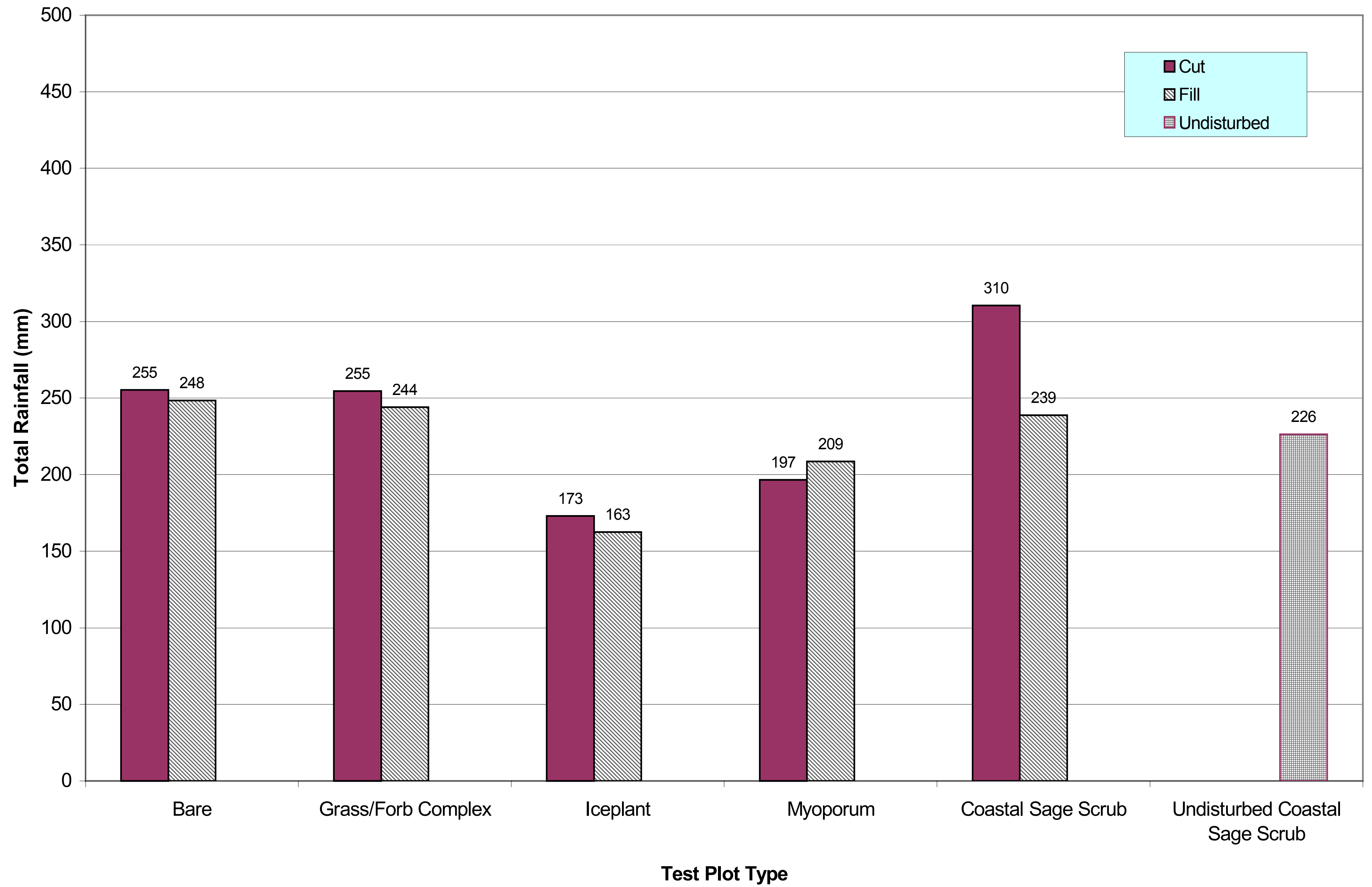
Notes:

(1) Sampled storms include all storm events of 6 mm (0-25in.) or more of rainfall in a 24-hr. period.
(2) NS = Not Sampled
Rainfall dates indicate start and end date of precipitation event except where indicated.
(3) Rainfall event ended on 2/15/00 for Site 57-4 Bare.



TOTAL RAINFALL (mm) 1998-1999 SAMPLED STORMS

Project No.: 57-977001NM.00	Date: JUNE 2000	Project: CALTRANS EROSION CONTROL PILOT STUDY	Fig.: 8-3A



TOTAL RAINFALL (mm) 1999-2000 SAMPLED STORMS

Project No.: 57-977001NM.00	Date: JUNE 2000	Project: CALTRANS EROSION CONTROL PILOT STUDY	Fig.: 8-3B

8.3 RUNOFF DATA-FROM SAMPLED STORM EVENTS

Total runoff was measured for sampled storms only. Total runoff volumes for the 1998-1999 sampled storms are presented in Table 8-12A. Total runoff volumes for the 1999-2000 sampled storms and cumulative runoff volumes for both monitored years are presented in Table 8-12B. Table 8-13 shows the means and standard deviations of runoff data from the erosion rate test plots for the two-year study period. The mean total runoff volumes from the erosion rate test plots for the two-year storm period ranged from 341 L (90.2 gal.) at the iceplant fill-slope test plots to 1639 L (433.6 gal.) at the bare fill-slope test plot.

Total runoff data is graphically presented on Figure 8-4A for the 1998-1999 data and Figure 8-4B for the 1999-2000 data. As presented in Table 8-12A, total runoff volumes for individual sampled storms in 1998-1999 ranged from 7 L (1.8 gal.) to 126 L (33 gal.) at the bare fill-slope test plot (Site 10-2). The January 25, 1999 storm event produced the highest runoff values at the most test plots during the 1998-1999 monitoring year. Total runoff for all sampled 1998-1999 storms ranged from 161 L (43 gal.) at the iceplant fill-slope test plot to 351 L (93 gal.) at the coastal sage undisturbed-slope research test plot.

As presented in Table 8-12B and Figure 8-4B, total runoff volumes for individual sampled storms in 1999-2000 ranged from 7.5 L (2 gal.) at the coastal sage scrub undisturbed-slope test plot (Site R-1) to 632 L (167 gal.) at the bare fill-slope test plot (Site 10-2). The February 20, 2000 storm event produced the highest runoff values at the most test plots during the 1999-2000 monitoring year. Total runoff for all 1999-2000 storms ranged from 180 L (48 gal.) at the iceplant fill-slope test plot (Site 405-6) to 1,304 L (344 gal.) at the bare fill-slope test plot (Site 10-2).

8.3.1 Runoff Coefficients

The runoff coefficient was calculated for each test plot. The runoff coefficient normalizes runoff based on rainfall volume over the sample area. The lower the runoff coefficient value, the less runoff. Runoff coefficients for the 1998-1999 sampled storms are presented in Figure 8-5A and ranged from 0.17 at the bare fill-slope test plot (Site 10-2) to 0.07 at the iceplant fill-slope test plot (Site 405-6). This normalized data indicates that runoff coefficients for grass/forb complex, iceplant, myoporum, and coastal sage scrub vegetation on the cut- and fill-slope test plots were generally similar (0.07 to 0.09). The runoff coefficient for the coastal sage scrub undisturbed slope was 0.12. The runoff coefficients calculated for the bare cut-slope and fill-slope control test plots were 0.14 and 0.17, respectively.

Runoff coefficients for the 1999-2000 sampled storms are presented in Figure 8-5B and ranged from 0.33 at the bare fill-slope test plot (Site 10-2) to 0.07 at the iceplant cut-slope (Site 105-6) and fill-slope test plots (Site 210-10). The second year runoff coefficients for the grass/forb complex, iceplant, myoporum, and coastal sage scrub reference test plots were similar to the runoff coefficients calculated during the first monitoring year, even though rainfall measurements were greater the second year, indicating these vegetation types have similar runoff control capabilities under the range of rainfall volumes experienced during the two-year monitoring period. The runoff coefficients calculated for the bare cut-slope (0.22) and fill-slope (0.33) test plots were almost twice the coefficient values calculated during the previous monitoring year. These increased runoff coefficients correspond to the increase rainfall amounts (approximately double) measured during the second year of monitoring at the bare slopes.

Table 8-12A
RUNOFF AMOUNTS (L) – SAMPLED STORMS(1) 1998-1999

Site	Vegetation	Slope Type	11/28/98 to 11/29/98	12/1/98 to 12/2/98	12/4/98 to 12/6/98	1/20/99 to 1/21/99	1/25/99 to 1/27/99	1/31/99	2/4/99 to 2/5/99	2/7/99 to 2/9/99	3/15/99 to 3/16/99	3/20/99	3/25/99	4/6/99 to 4/7/99(3)	4/11/99 to 4/12/99	Total Runoff, Sampled Storms 1998-1999
10-2	Bare	Fill	7.0	NS	7.6	NS	100.4	NS	19.8	21.2	21.2	NS	NS	126.1	31.5	334.8
57-4	Bare	Cut	10.7	NS	24.1	8.7	76.6	NS	17.0	26.2	21.2	NS	NS	62.1	43.3	289.9
10-2	Grass/Forb Complex	Fill	7.7	NS	7.0	NS	37.2	NS	19.6	13.1	18.3	NS	NS	30.9	18.9	152.7
57-4	Grass/Forb Complex	Cut	8.5	NS	12.2	8.9	46.1	NS	13.3	14.4	26.5	NS	NS	29.5	25.3	184.6
405-6	Iceplant	Fill	9.5	NS	NS	7.6	27.8	13.1	7.9	NS	15.8	NS	14.3	19.0	46.4	161.4
105-6	Iceplant	Cut	14.1	10.3	12.2	NS	29.9	NS	NS	8.9	16.4	NS	14.1	21.3	45.1	172.3
105-3	Myoporum	Fill	9.8	NS	17.7	9.4	27.3	NS	NS	12.1	18.3	NS	27.7	33.9	46.7	203.0
105-8	Myoporum	Cut	10.9	NS	22.7	11.0	37.5	NS	NS	11.1	21.3	NS	17.3	25.9	49.7	207.5
210-10	Coastal Sage Scrub	Fill	15.4	NS	NS	NS	43.8	24.3	NS	19.0	18.4	13.4	31.9	35.7	25.2	227.2
210-1	Coastal Sage Scrub	Cut	15.8	NS	15.1	NS	53.9	NS	22.6	17.4	16.4	NS	NS	34.6	19.7	195.6
R1	Coastal Sage Scrub	Undisturbed	42.0	NS	NS	NS	83.3	36.4	NS	22.3	33.6	19.6	33.7	46.9	33.7	351.4

Notes:

(1) Sampled storms include all storm events of 6 mm (0-25in.) or more of rainfall in a 24-hr. period.
Refer to Table 8-5A for details of storm events.

(2) NS = Not Sampled
Rainfall dates indicate start and end date of precipitation event except where indicated.

(3) Rainfall event ended on 4/8/99 for Sites 10-2 Bare and Grass/Forb and 57-4 Bare and Grass/Forb

.

Table 8-12B
RUNOFF AMOUNTS (L) – SAMPLED STORMS(1) 1999-2000

Site	Vegetation	Slope Type	12/31/99 to 1/2/00	1/25/00 to 1/26/00	1/31/00	2/10/00 to 2/13/00(3)	2/16/00	2/20/00 to 2/23/00	2/27/00	3/3/00 to 3/5/00	3/7/00 to 3/8/00	Total Runoff, Sampled Storms 1999-2000	Cumulative Runoff, Sampled Storms 1998-2000
10-2	Bare	Fill	15.3	34.2	NS	255.5	NS	632.0	32.8	184.2	150.0	1304.0	1638.8
57-4	Bare	Cut	13.8	32.2	14.0	199.5	28.3	426.2	NS	120.3	55.7	890.0	1179.9
10-2	Grass/Forb Complex	Fill	8.0	26.4	NS	57.8	NS	148.7	9.7	47.8	21.5	319.9	472.6
57-4	Grass/Forb Complex	Cut	8.2	23.2	10.4	80.7	19.0	147.0	NS	60.3	25.0	373.8	558.4
405-6	Iceplant	Fill	NS	12.5	NS	43.0	NS	68.2	NS	45.0	11.0	179.7	341.1
105-6	Iceplant	Cut	NS	13.2	NS	41.0	NS	79.7	NS	37.3	19.5	190.7	363.0
105-3	Myoporum	Fill	NS	16.0	NS	47.7	14.3	105.5	NS	68.8	32.8	285.2	488.2
105-8	Myoporum	Cut	NS	15.7	NS	43.3	10.7	100.8	NS	59.2	30.8	260.5	468.0
210-10	Coastal Sage Scrub	Fill	NS	19.1	NS	46.2	30.3	104.2	14.2	41.8	10.2	265.9	493.1
210-1	Coastal Sage Scrub	Cut	16.5	31.8	14.3	99.5	15.0	146.7	12.5	53.8	26.0	416.2	611.7
R1	Coastal Sage Scrub	Undisturbed	NS	28.3	NS	67.2	44.0	146.3	15.3	61.0	7.5	369.7	721.0

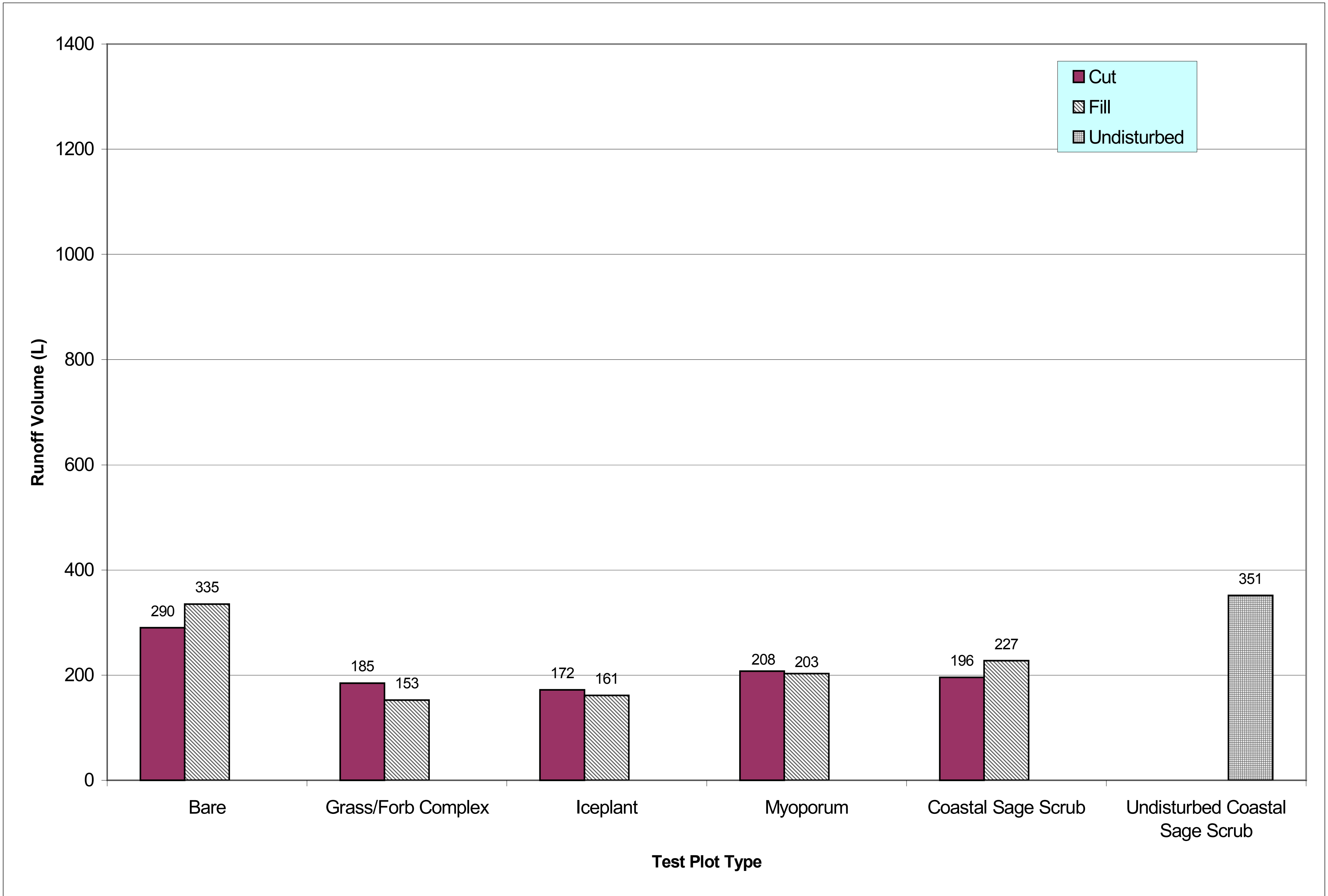
Notes:
(1) Sampled storms include all storm events of 6 mm (0-25in.) or more of rainfall in a 24-hr. period.
Refer to Table 8-5B for details of storm events.
(2) NS = Not Sampled
Rainfall dates indicate start and end date of precipitation event except where indicated.
(3) Rainfall event ended on 2/15/00 for Site 57-4 Bare.

Table 8-13
RUNOFF DATA (L) STATISTICS

Vegetation	Statistic[(1)]	SLOPE TYPE Total Runoff (L)		
		Cut	Fill	Undisturbed
Bare	Mean	1180	1639	
	Std. Dev	*201*	*57*	
Grass/Forb Complex	Mean	558	473	
	Std. Dev	*23*	*29*	
Iceplant	Mean	363	341	
	Std. Dev	*8*	*12*	
Myoporum	Mean	468	488	
	Std. Dev	*13*	*20*	
Coastal Sage Scrub	Mean	612	493	
	Std. Dev	*7*	*28*	
Undisturbed Coastal Sage Scrub	Mean			721
	Std. Dev			*132*

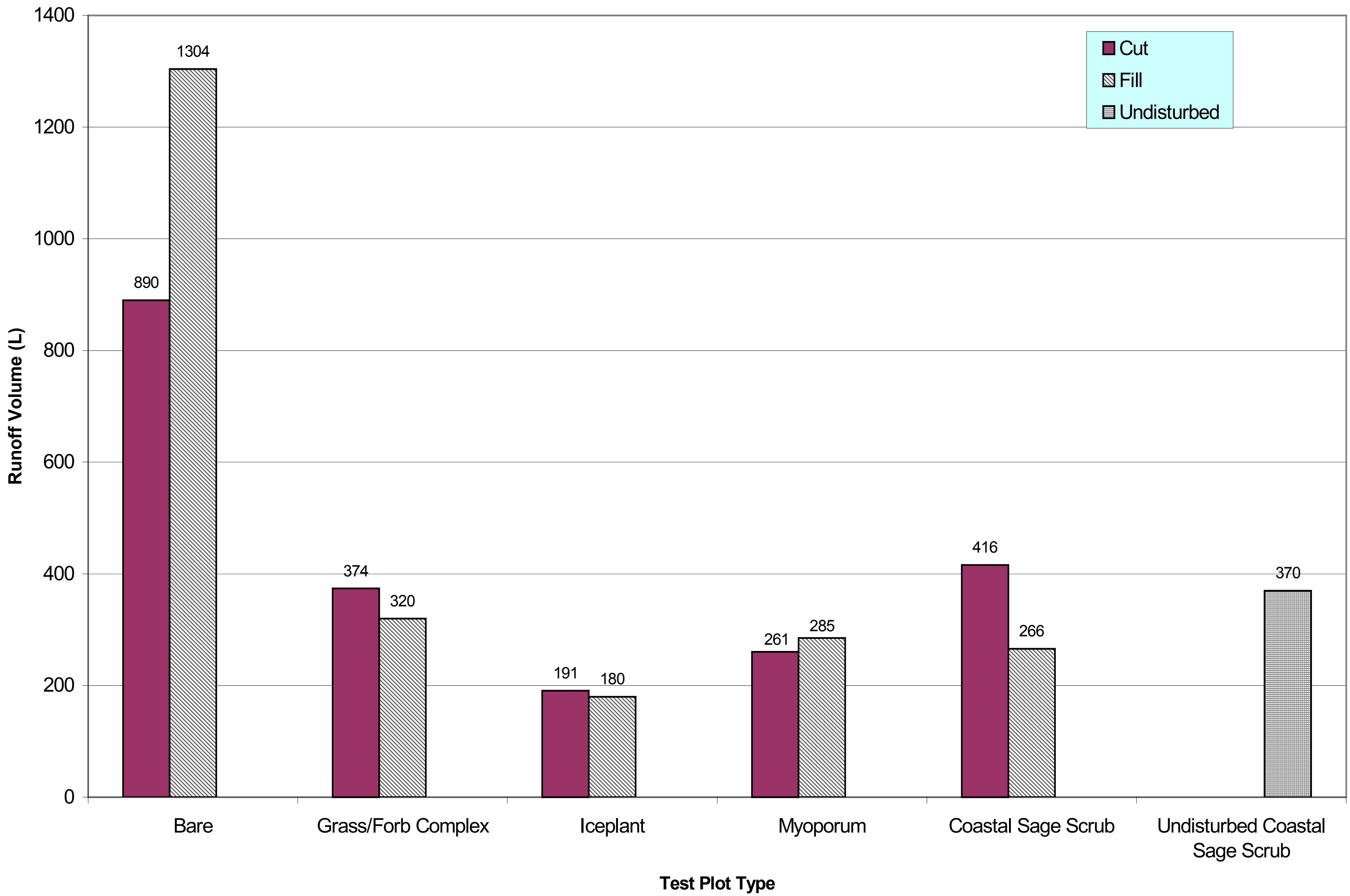
Sampled storms include all storms with 6 mm (0.25 in.) or more of rainfall in a 24-hour period at each plot type. Refer to Tables 8-11A and 8-11B for details of sampled storm events.

(1) Mean and standard deviation calculated from runoff data of sampled storm events.



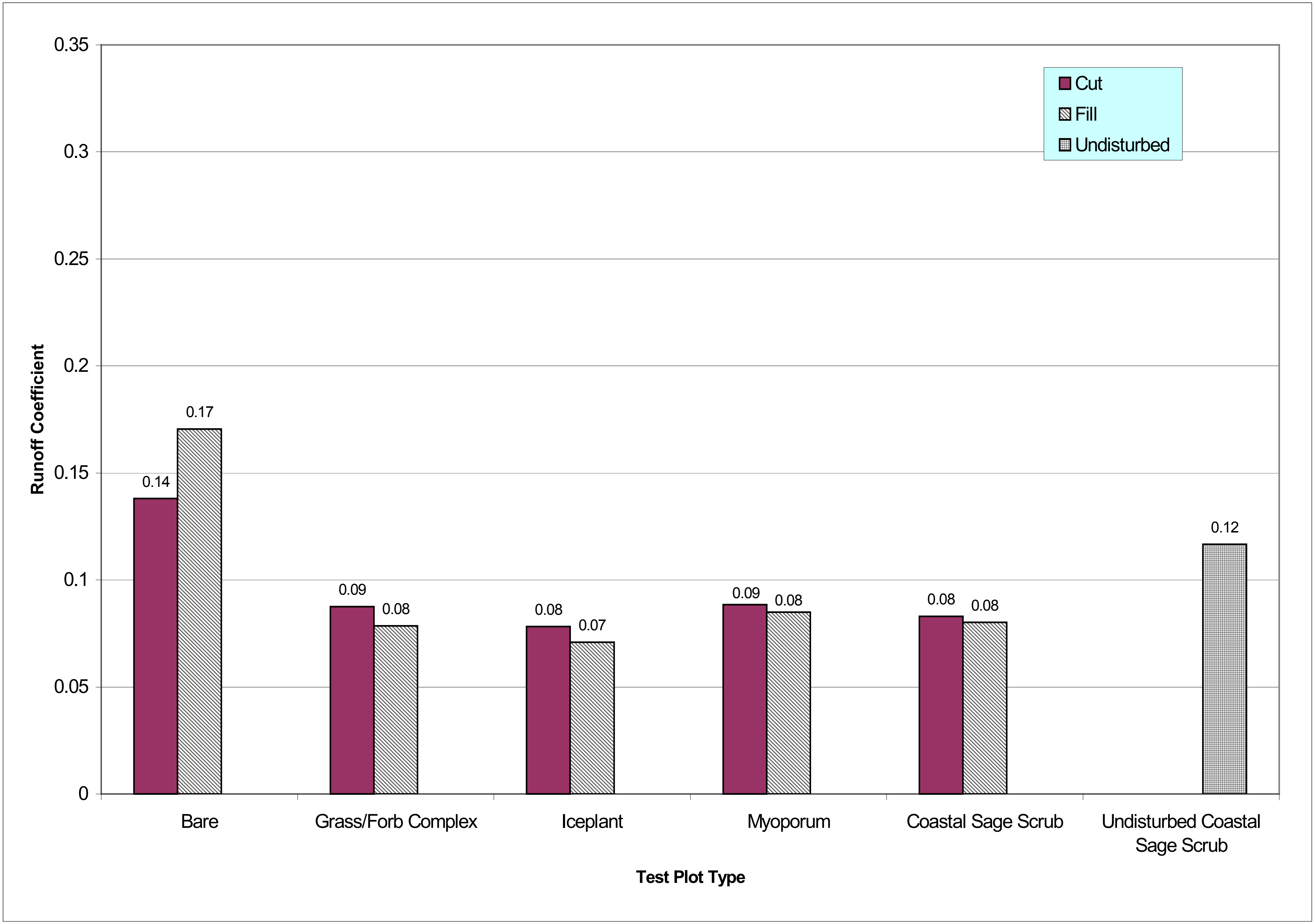
TOTAL RUNOFF VOLUMES (L) 1998-1999 SAMPLED STORMS

Project No.: 57-977001NM.00	Date: JUNE 2000	Project: CALTRANS EROSION CONTROL PILOT STUDY	Fig.: 8-4A



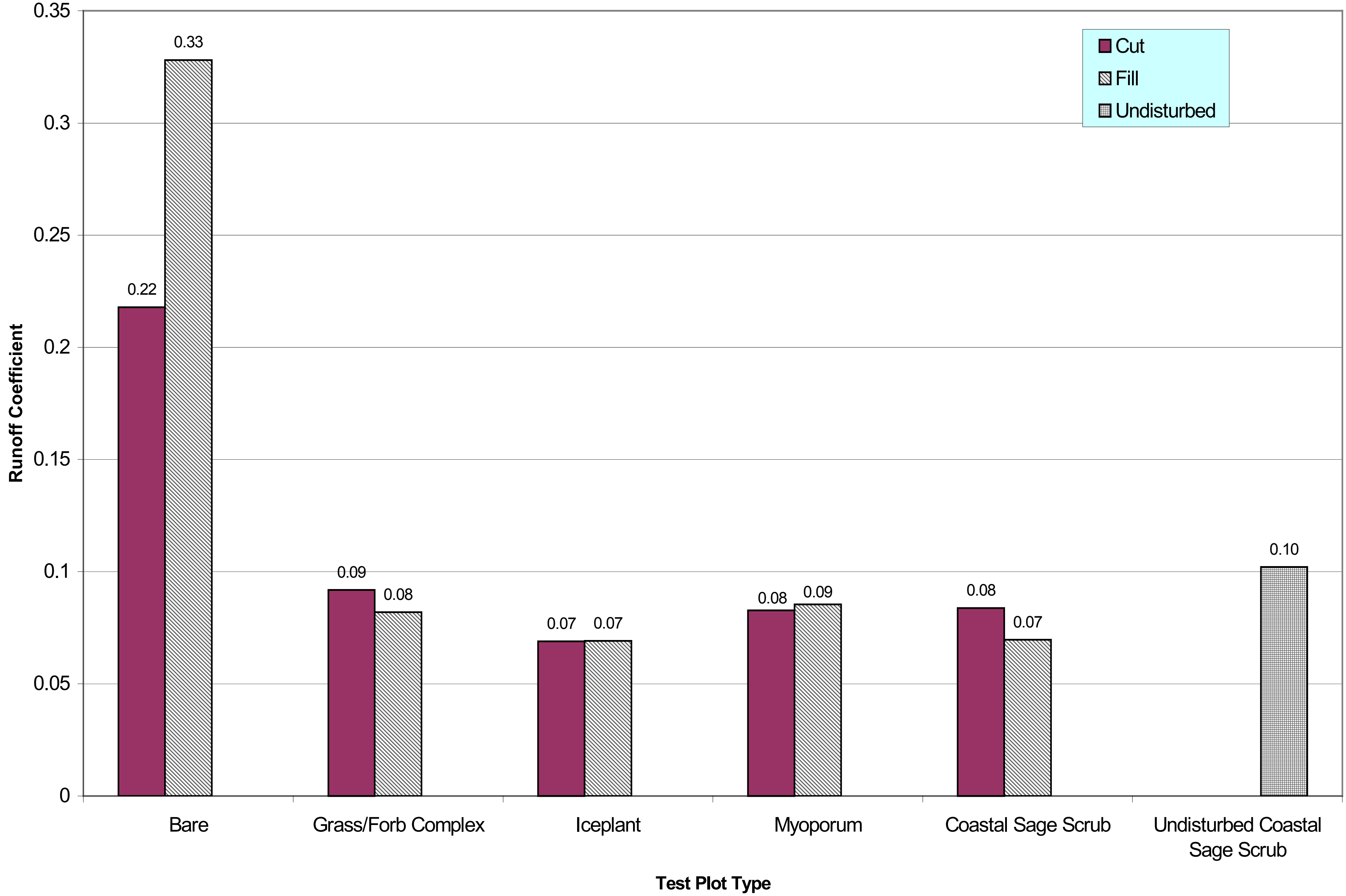
TOTAL RUNOFF VOLUMES (L) 1999-2000 SAMPLED STORMS

Project No.: 57-977001NM.00	Date: JUNE 2000	Project: CALTRANS EROSION CONTROL PILOT STUDY	Fig.: 8-4B



RUNOFF COEFFICIENTS 1998-1999 SAMPLED STORMS

Project No.: 57-977001NM.00	Date: JUNE 2000	Project: CALTRANS EROSION CONTROL PILOT STUDY	Fig.: 8-5A



RUNOFF COEFFICIENTS 1999-2000 SAMPLED STORMS

Project No.: 57-977001NM.00	Date: JUNE 2000	Project: CALTRANS EROSION CONTROL PILOT STUDY	Fig.: 8-5B

8.3.1.1 Cut Slopes

Runoff coefficients for the two monitoring seasons for the vegetated cut-slope tests plots were compared to the runoff coefficients calculated for the bare (control) cut-slope test plot. Runoff coefficients for the vegetated cut-slopes ranged from about 57 percent (iceplant and coastal sage scrub) to 64 percent (grass/forb complex, myoproum) of the bare cut-slope runoff coefficient value calculated from the 1998-1999 data. Runoff coefficients for the vegetated cut-slope test plots ranged from about 32 percent (iceplant), to 36 percent (myoporum and coastal sage scrub) to 41 percent (grass/forb complex) of the bare cut-slope runoff coefficient value calculated from the 1999-2000 data. During both monitoring periods, the runoff coefficient values for the grass/forb complex and coastal sage scrub test plots were similar even though rainfall increased 48 and 53 percent, respectively, during the second monitoring season. Runoff coefficient values for the iceplant and myoporum vegetation cut-slope plots decreased slightly from the first to second monitoring periods, while rainfall recorded at the iceplant and myoporum test plots increased 20 to 25 percent, respectively, the second year.

8.3.1.2 Fill Slopes

Runoff coefficients for the two monitoring seasons for the vegetated fill-slope test plots were compared to the runoff coefficients calculated for the bare (control) fill-slope test plots. Runoff coefficients for the vegetated fill slopes ranged from about 41 percent (iceplant) to 47 percent (grass/forb complex, myoporum, and coastal sage scrub) of the bare fill slope runoff coefficient value calculated from the 1998-1999 data. Runoff coefficients for the vegetated fill-slope test plots ranged from about 21 percent (iceplant, coastal sage scrub) to 24 percent (grass/forb complex), to 27 percent (myoporum) of the bare fill slope runoff coefficient value calculated from the 1999-2000 data. During both monitoring periods, the runoff coefficient values for the grass/forb complex and iceplant vegetation fill-slope test plots were similar, even though rainfall increased 50 and 13 percent, respectively at these two test plots the second year. Runoff coefficient values for the myoporum fill-slope test plot increased slightly between the first and second monitoring years. Rainfall was 31 percent greater at the myoporum test plot during the second monitoring year. The runoff coefficient at the coastal sage scrub fill-slope test plot decreased slightly during the second year, while the measured rainfall was 26 percent greater.

8.3.1.3 Undisturbed Slope

Runoff coefficients for the two monitoring years calculated for the off-highway coastal sage scrub undisturbed slope (research) test plot were compared with the vegetated highway (reference) test plots. The runoff coefficient calculated for the undisturbed test plot was 25 to 42 percent greater than the reference sites, during the 1998-1999 monitoring season, and was 10 to 30 percent greater than the reference sites during the 1999-2000 monitoring season. Rainfall measured during the 1998-1999 monitoring period at the undisturbed research test plot was 6 to 36 percent greater than rainfall measured at the reference sites. Rainfall measured at the undisturbed research test plot during the 1999-2000 monitoring period was 8 to 28 percent greater than the iceplant and myoporum reference test plots, and 5 to 27 percent less than the grass/forb complex and coastal sage scrub reference test plots. The increased runoff coefficients at the coastal sage scrub undisturbed test plot may in part be due to a slight variation in slope steepness compared to the other test plots.

8.4 EROSION DATA

8.4.1 Normalized Erosion Rate Data

As discussed in previous sections, runoff and sediment were captured in the flume and drum collection system installed at the base of each test plot. The water was evaporated, and the dry weight of the sediment was calculated. Erosion rate was then calculated as the total dry weight of sediment discharged per unit area of the test plot and was normalized based on measured rainfall data. Tables 8-14A and 8-14B present normalized erosion rate data for the 1998-1999 and 1999-2000 sampled storms, respectively. Figures 8-6 through 8-10 present erosion rate data for each type of erosion rate test plot per storm event. The normalized erosion rates are expressed as $g/m^2/mm$. Normalized erosion rates from individual sampled storms ranged from 0.004 $g/m^2/mm$ at the bare cut-slope test plot during the November 28, 1998 storm and at the iceplant fill-slope test plot during the April 11, 1999 storm to 27.53 $g/m^2/mm$ at the grass/forb cut-slope test plot during the March 15, 1999 storm. Table 8-15 shows the means and standard deviations of normalized erosion rate data for the two year study period, and Figure 8-11A illustrates the means graphically. The average normalized erosion rates for the two year study period ranged from 0.03 $g/m^2/mm$ at the coastal sage scrub cut-slope test plot to 6.44 $g/m^2/mm$ at the bare fill-slope test plot. The coastal sage scrub fill-slope test plot and the iceplant cut- and fill-slope test plots had an erosion rate of 0.05 $g/m^2/mm$. The undisturbed coastal sage scrub test plot and the myoporum cut-slope test plot had an erosion rate of 0.13 $g/m^2/mm$. The myoporum fill-slope test plot had an erosion rate of 0.25 $g/m^2/mm$. The erosion rates for the grass/forb complex cut- and fill-slope test plots were the highest of the vegetation types and were 1.65 $g/m^2/mm$ and 0.89 $g/m^2/mm$, respectively. The erosion rates for the bare (control) cut- and fill-slope test plots were 1.32 $g/m^2/mm$ and 6.44 $g/m^2/mm$, respectively. The normalized erosion rate of the grass/forb cut slope was greater than the normalized erosion rate measured on the bare cut-slope test plot.

The data for the grass/forb cut-slope test plot and the bare cut-slope test plot were further evaluated to gain insight into the higher normalized erosion rates measured at the grass/forb vegetated slope compared to the bare slope. An anonymously high amount of sediment was discharged from the grass/forb cut-slope during the March 15, 1999 storm event. Rainfall during this storm event was similar (13 mm) at both the grass/forb and bare test plot sites. A slightly higher runoff volume was measured at the grass/forb test plot (26.5 L) compared to the bare test plot (21.2 L) during this storm event. This difference may be accounted for by rainfall intensity. However, in general, the rainfall and runoff data for the March 15, 1999 storm event did not indicate unusual conditions that would account for the anonymously high erosion rates observed at the grass/forb test plot. As shown on Figures 8-12 and 8-14, the majority of the sediment collected at the grass/forb test plot during this storm event was collected directly from the flume, and is believed to be the result of gopher activity, and not necessarily representative of the actual erosion control effectiveness of grass/forb vegetation at 90 to 100 percent cover. A more detailed discussion of gopher activity is presented below in Section 8.4.1.1.

Since the sediment discharged during the March 15, 1999 storm event is believed to be anonymously high due to gopher activity, the normalized erosion rate for the grass/forb cut slope test plot was recalculated without the March 15, 1999 storm event data. As shown on Figure 8-11B, the recalculated normalized erosion rate for the grass/forb cut-slope was 0.73 $g/m^2/mm$.

8.4.1.1 Sediment Due to Gopher Activity

Soil disturbance due to gopher activity was observed at several of the erosion rate test plots during the course of the study. The greatest soil disturbance due to gopher activity was observed at the grass/forb cut slope, and to a lesser extent at the grass/forb fill slope, and bare cut and fill slopes. The grass/forb and bare cut slopes test plots were both located at Site 57-4. The grass/forb and bare fill slope test plots were both located at Site 10-2. The 57-4 cut slope site is bounded to the west, north, and south by undeveloped land, and is used for cattle grazing to the west. The 10-2 fill slope site is bounded by roadways, parking lots, and business development on all sides. Consequently, gopher access to the cut slope was less restricted at the cut slope site than the fill slope site. Notable gopher activity was not noted at the myoporum, iceplant, or coastal sage scrub erosion rate test plots.

As introduced above, sediment collected in the flume that was suspected to have originated from gopher activity was segregated from sediment that originated from runoff during the 1998-1999 monitoring season. Figure 8-12 illustrates the non-normalized discharged sediment from suspected gopher activity at the grass/forb complex cut-slope test plots.

As shown on Figure 8-13, the 1998-1999 non-normalized sediment data for the bare fill-slope test plots showed that the majority of sediment collected from the flume (suspected gopher activity soil), was collected during a single storm event (January 25, 1999). The majority of the suspected gopher activity soil for the grass/forb fill-slope test plots (Figure 8-14) was collected during two storm events (December 4, 1998 and January 25, 1999). For the grass/forb cut-slope test plots, the majority of suspected gopher activity soil was also collected during two storm events (December 4, 1998 and March 15, 1999).

A comparison between cut and fill normalized erosion data indicated a trend of lower or similar normalized erosion rates on cut slopes than on fill slopes. The greater difference was observed on the bare slopes where the normalized erosion rates on the bare and myoporum fill-slope test plots were greater than their respective cut-slope test plots. The normalized erosion rate for the bare fill-slope test plot was almost five times the normalized erosion rate for the bare cut-slope test plot.

Table 8-14A
NORMALIZED EROSION RATE ($g/m^2/mm$) - SAMPLED STORMS(1) 1998-1999

Site	Vegetation	Slope Type	11/28/98 to 11/29/98	12/1/98 to 12/2/98	12/4/98 to 12/6/98	1/20/99 to 1/21/99	1/25/99 to 1/27/99	1/31/99	2/4/99 to 2/5/99	2/7/99 to 2/9/99	3/15/99 to 3/16/99	3/20/99	3/25/99	4/6/99 to 4/7/99(3)	4/11/99 to 4/12/99
10-2	Baseline (Bare)	Fill	0.018	NS(2)	1.101	NS	12.137	NS	0.239	0.735	0.505	NS	NS	7.498	0.541
57-4	Baseline (Bare)	Cut	0.004	NS	0.390	2.302	0.567	NS	0.360	0.937	1.876	NS	NS	1.003	0.252
10-2	Grass/Forb Complex	Fill	0.038	NS	9.749	NS	5.960	NS	0.072	0.101	0.295	NS	NS	0.341	0.163
57-4	Grass/Forb Complex	Cut	0.053	NS	11.426	8.748	0.295	NS	0.617	1.329	27.526	NS	NS	1.214	0.156
405-6	Iceplant	Fill	0.184	NS	NS	0.093	0.023	0.016	0.019	NS	0.033	NS	0.035	0.014	0.004
105-6	Iceplant	Cut	0.157	0.085	0.142	NS	0.058	NS	NS	0.054	0.093	NS	0.046	0.022	0.065
105-3	Myoporum	Fill	0.136	NS	0.081	0.107	0.033	NS	NS	0.044	0.049	NS	0.076	0.027	0.013
105-8	Myoporum	Cut	0.106	NS	0.265	0.305	0.121	NS	NS	0.217	0.439	NS	0.187	0.122	0.066
210-10	Coastal Sage Scrub	Fill	0.076	NS	NS	NS	0.069	0.043	NS	0.019	0.082	0.029	0.052	0.024	0.033
210-1	Coastal Sage Scrub	Cut	0.061	NS	0.176	NS	0.030	NS	0.023	0.020	0.137	NS	NS	0.050	0.021
R1	Coastal Sage Scrub	Undisturbed	0.262	NS	NS	NS	0.149	0.277	NS	0.053	0.171	0.066	0.272	0.123	0.125

Notes:

(1) Sampled Storms includes all storms with greater than 6.3 mm (0.25 in.) of rain in a 24-hour period.
Refer to Table 8-5A for details of all storm events
(2) NS = Not Sampled.
Rainfall dates indicate start and end date of precipitation event except where indicated.
(3) Rainfall event ended on 4/8/99 for Sites 10-2 Bare and Grass/Forb and 57-4 Bare and Grass/Forb.

Table 8-14B
NORMALIZED EROSION RATE ($g/m^2/mm$) - SAMPLED STORMS[1] 1999-2000

Site	Vegetation	Slope Type	12/31/99 to 1/2/00	1/25/00 to 1/26/00	1/31/00	2/10/00 to 2/13/00[3]	2/16/00	2/20/00 to 2/23/00	2/27/00	3/3/00 to 3/5/00	3/7/00 to 3/8/00
10-2	Baseline (Bare)	Fill	2.374	6.742	NS[2]	5.855	NS	11.223	1.538	1.324	2.545
57-4	Baseline (Bare)	Cut	1.126	0.137	0.136	1.181	0.184	3.255	NS	0.367	0.473
10-2	Grass/Forb Complex	Fill	1.092	0.089	NS	0.346	NS	0.085	0.116	0.053	0.098
57-4	Grass/Forb Complex	Cut	0.961	0.178	0.110	0.135	0.071	0.134	NS	0.080	0.079
405-6	Iceplant	Fill	NS	0.497	NS	0.089	NS	0.011	NS	0.011	0.022
105-6	Iceplant	Cut	NS	0.092	NS	0.087	NS	0.009	NS	0.011	0.015
105-3	Myoporum	Fill	NS	1.786	NS	0.338	0.276	0.412	NS	0.233	0.079
105-8	Myoporum	Cut	NS	0.361	NS	0.121	0.300	0.031	NS	0.075	0.058
210-10	Coastal Sage Scrub	Fill	NS	0.232	NS	0.051	0.028	0.019	0.030	0.023	0.052
210-1	Coastal Sage Scrub	Cut	0.182	0.039	0.057	0.019	0.038	0.009	0.027	0.013	0.013
R1	Coastal Sage Scrub	Undisturbed	NS	0.439	NS	0.103	0.034	0.076	0.079	0.046	0.048

Notes:

(1) Sampled Storms includes all storms with greater than 6.3 mm (0.25 in.) of rain in a 24-hour period.
Refer to Table 8-5A for details of all storm events
(2) NS = Not Sampled.
Rainfall dates indicate start and end date of precipitation event except where indicated.
(3) Rainfall event ended on 4/8/99 for Sites 10-2 Bare and Grass/Forb and 57-4 Bare and Grass/Forb.

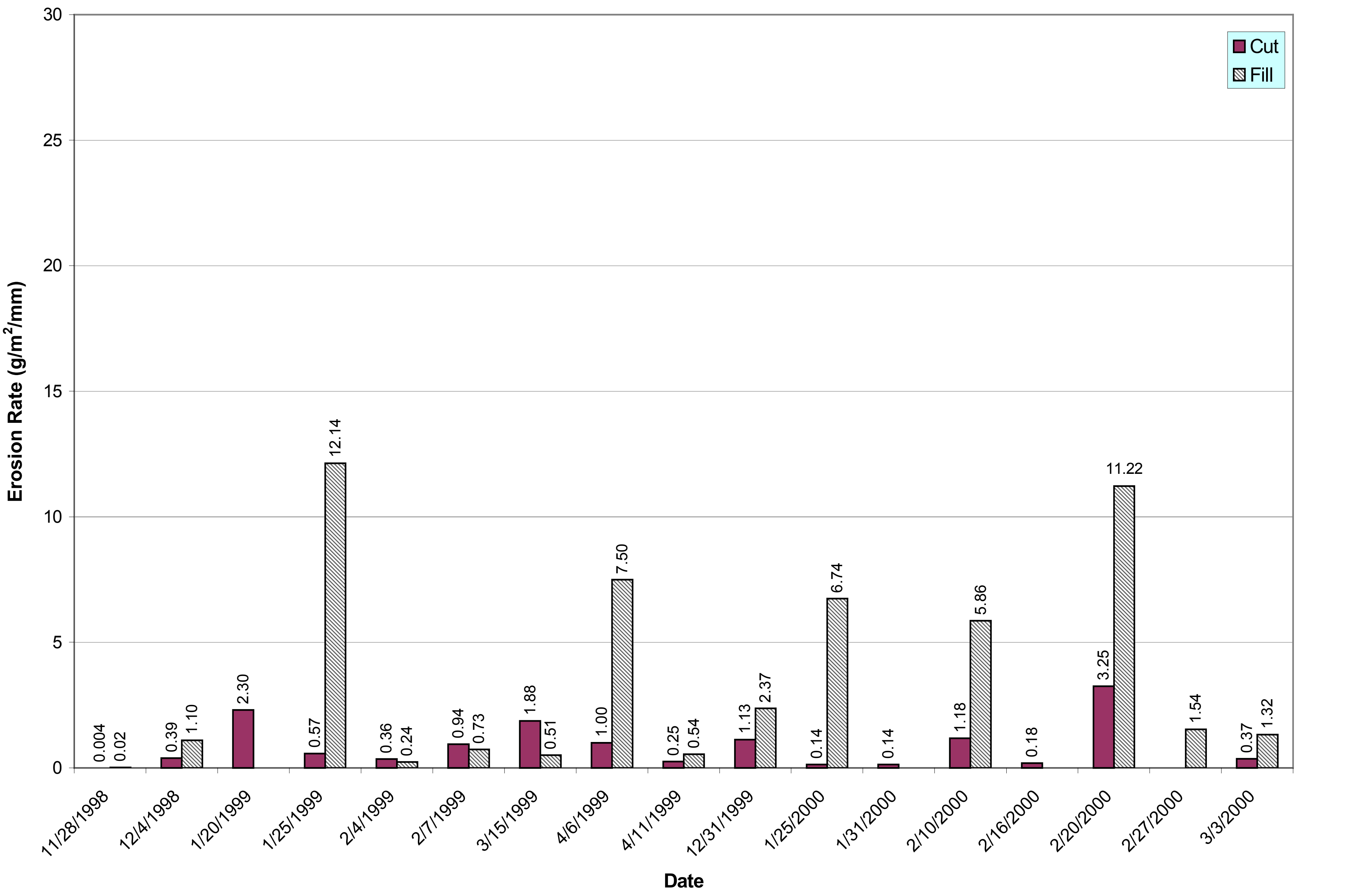
Table 8-15
NORMALIZED EROSION RATE (g/m²/mm) STATISTICS

Vegetation	Statistic[1]	SLOPE TYPE Normalized Erosion Rate (g/m²/mm)		
		Cut	Fill	Undisturbed
Bare	Mean	1.32	6.44	
	Std. Dev	*0.52*	*0.38*	
Grass/Forb Complex	Mean	0.73[2]	0.89	
	Std. Dev	*0.252*[2]	*0.57*	
Iceplant	Mean	0.05	0.05	
	Std. Dev	*0.004*	*0.001*	
Myoporum	Mean	0.13	0.25	
	Std. Dev	*0.02*	*0.07*	
Coastal Sage Scrub	Mean	0.03	0.05	
	Std. Dev	*0.003*	*0.007*	
Undisturbed Coastal Sage Scrub	Mean			0.13
	Std. Dev			*0.06*

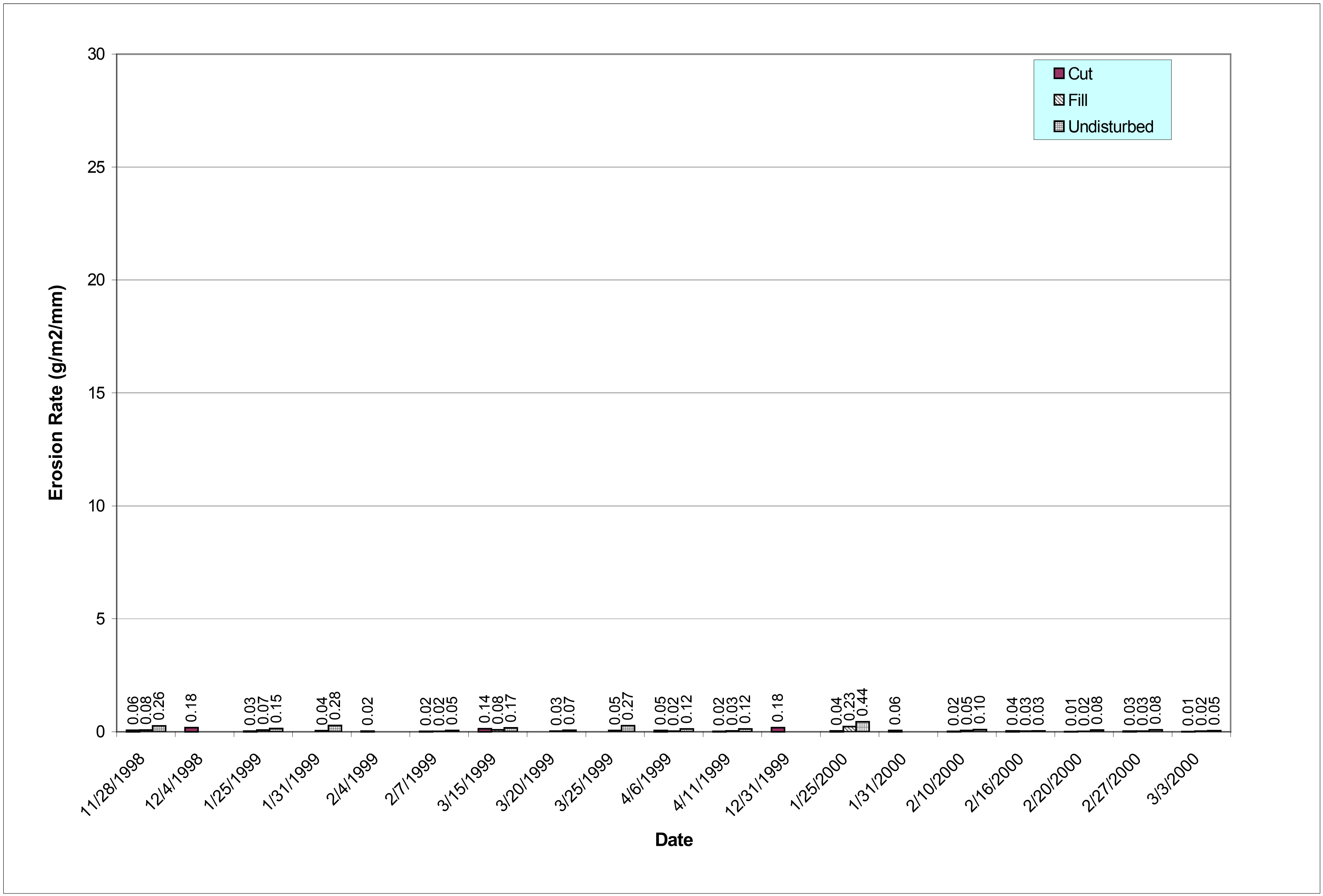
Sampled storms include all storm events with 6 mm (0.25 in.) or more of rainfall in a 24-hour period at each plot type. Refer to Tables 8-11A and 8-11B for details of sampled storm events and Tables 8-13A and 8-13B for details of sediment discharge data.

(1) Mean and standard deviation calculated from normalized erosion rate based on dry sediment weight collected in runoff during sampled storm events and rainfall from sampled storm events.

(2) Mean and standard deviations do not include March 15, 1999 storm event data due to anonymously high sediment discharge measured at the grass/forb cut-slope during this storm event.

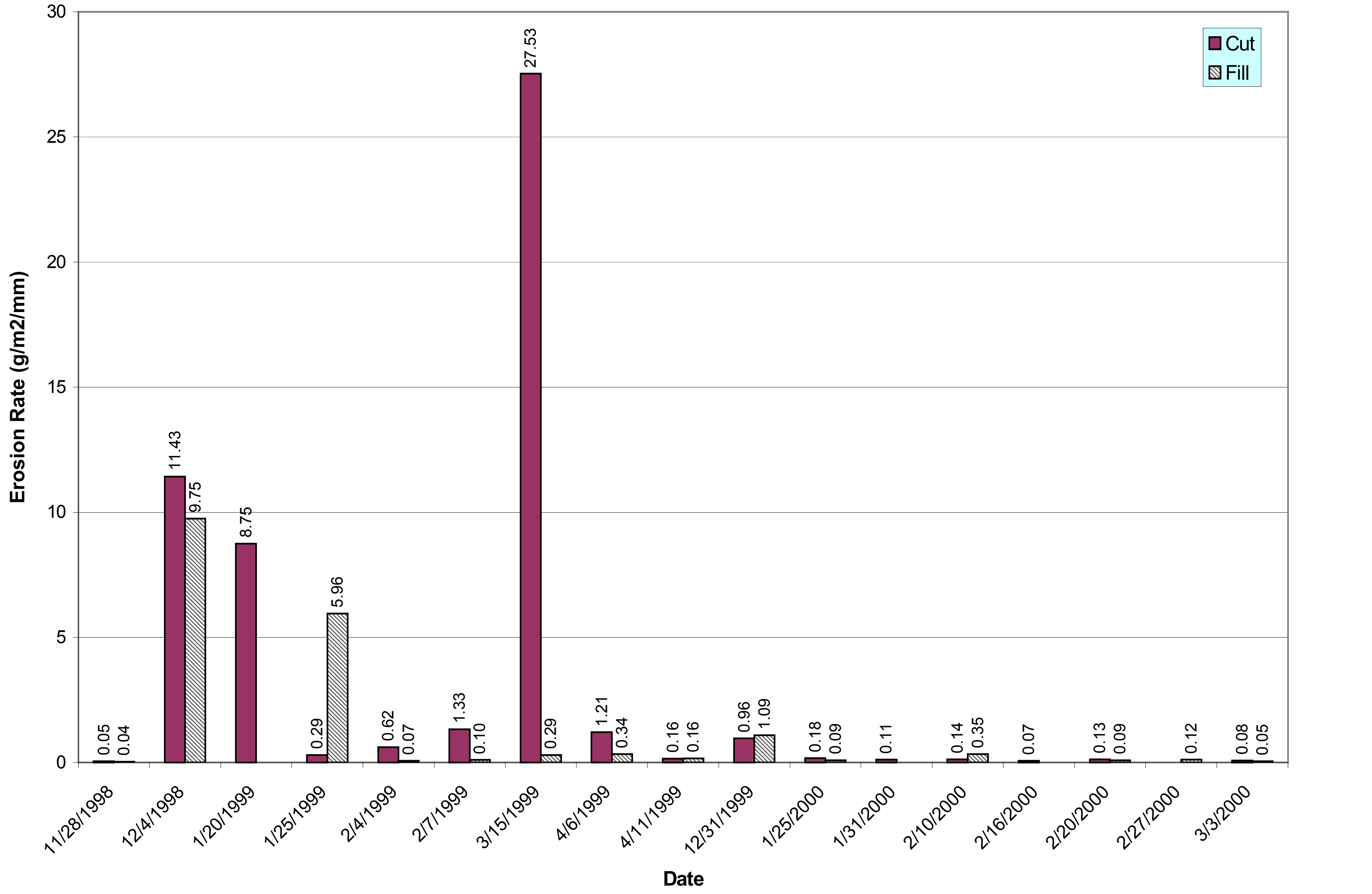


NORMALIZED EROSION RATE (g/m²/mm) - BARE SLOPES			
Project No.: 57-977001NM.00	Date: JUNE 2000	Project: CALTRANS EROSION CONTROL PILOT STUDY	Fig.: 8-6



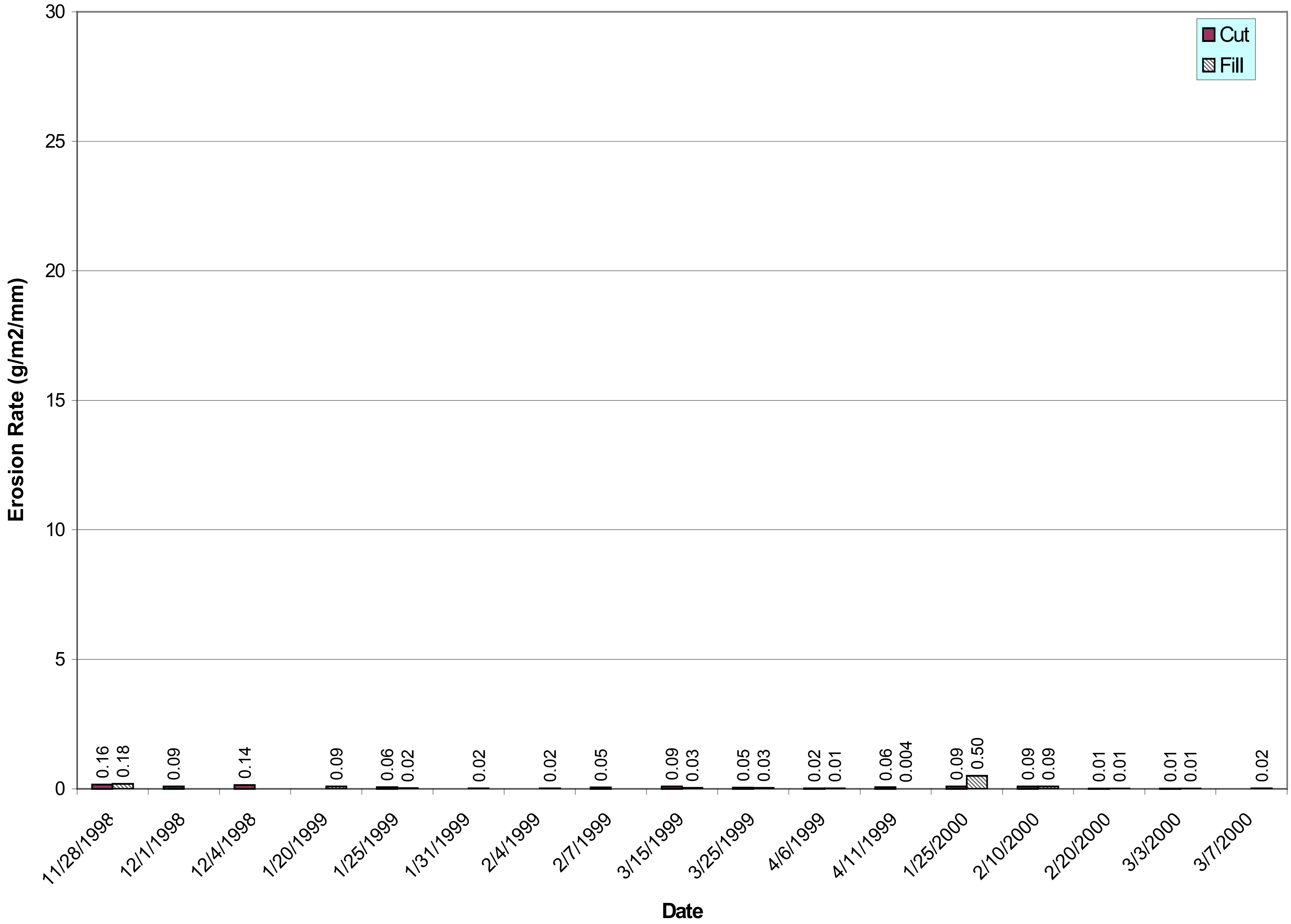
NORMALIZED EROSION RATE ($g/m^2/mm$) - COASTAL SAGE SCRUB SLOPES

Project No.: 57-977001NM.00	Date: JUNE 2000	Project: CALTRANS EROSION CONTROL PILOT STUDY	Fig.: 8-7



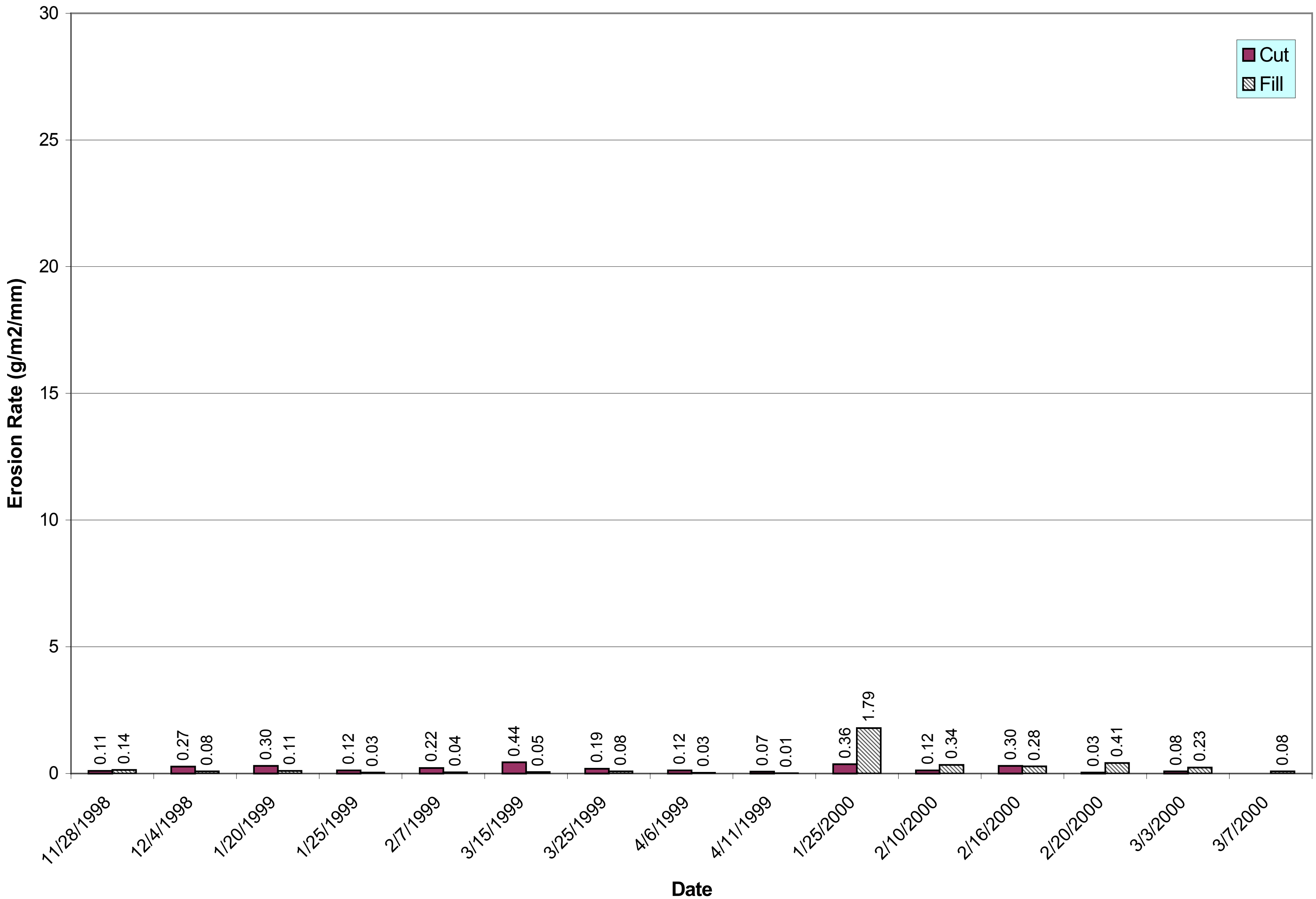
NORMALIZED EROSION RATE (g/m^2/mm) - GRASS/FORB SLOPES

Project No.: 57-977001NM.00	Date: JUNE 2000	Project: CALTRANS EROSION CONTROL PILOT STUDY	Fig.: 8-8



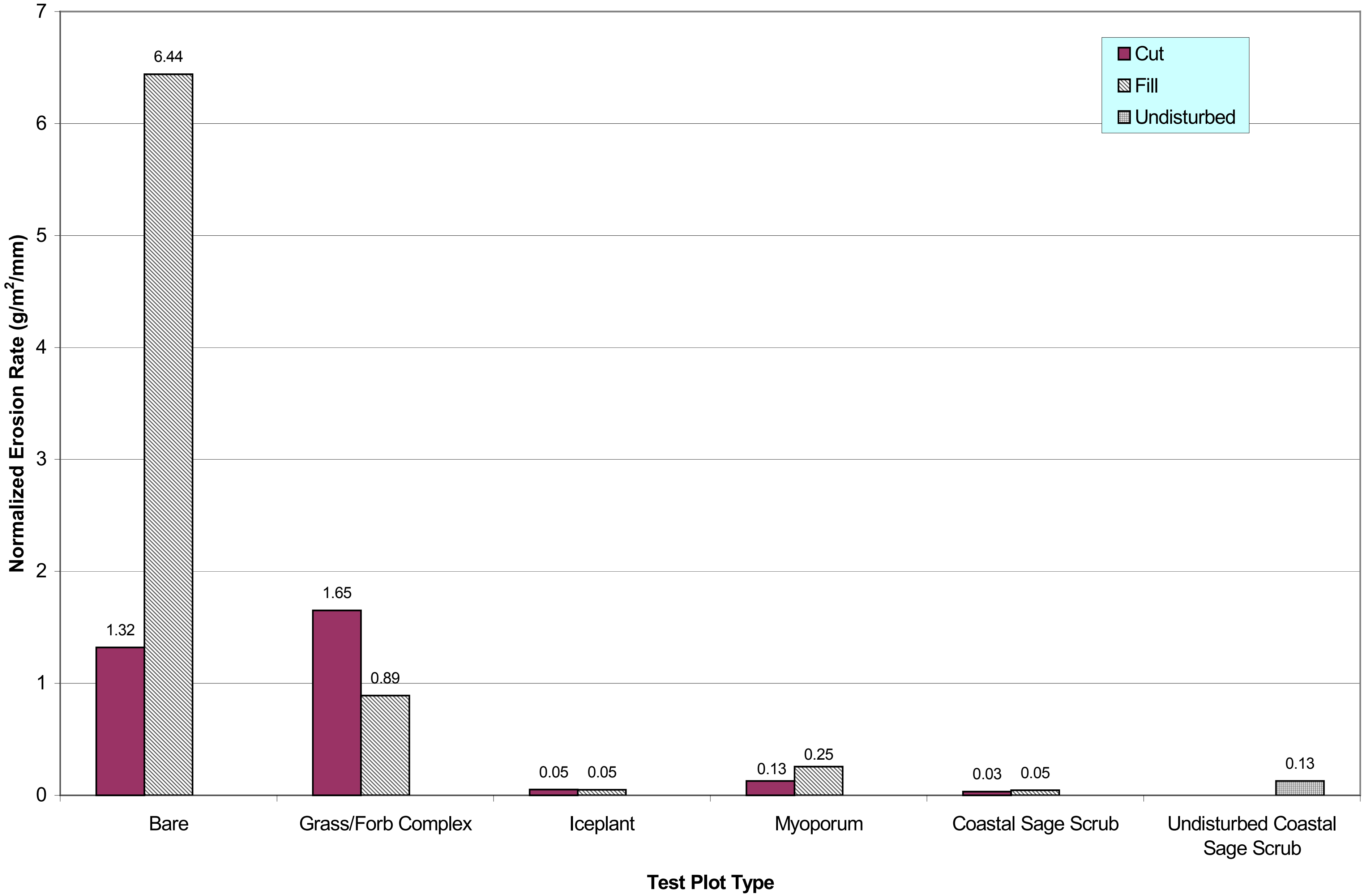
NORMALIZED EROSION RATE (g/m^2/mm) - ICEPLANT SLOPES

Project No.: 57-977001NM.00	Date: JUNE 2000	Project: CALTRANS EROSION CONTROL PILOT STUDY	Fig.: 8-9



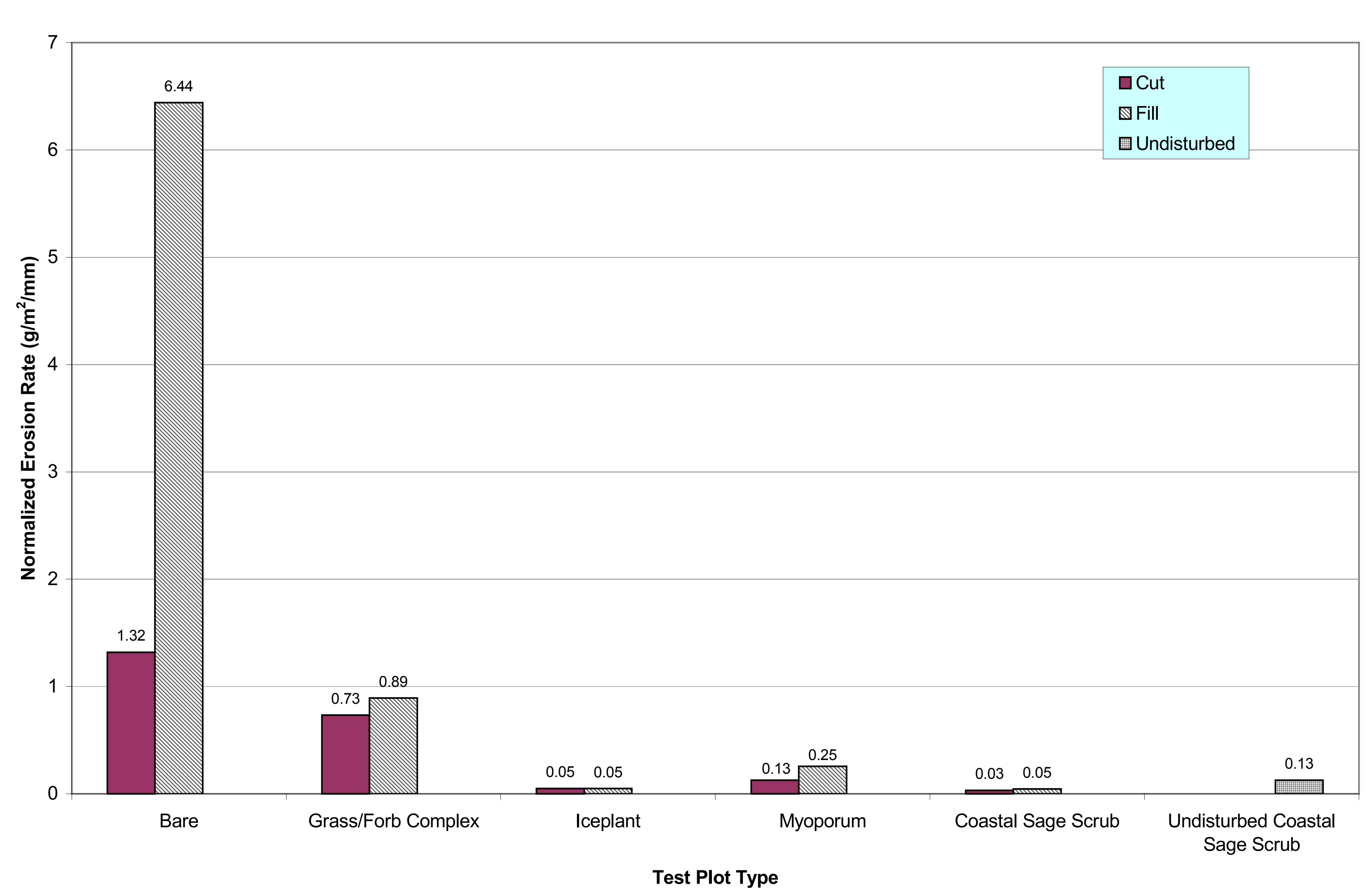
NORMALIZED EROSION RATE (g/m^2/mm) - MYOPORUM SLOPES

Project No.: 57-977001NM.00	Date: JUNE 2000	Project: CALTRANS EROSION CONTROL PILOT STUDY	Fig.: 8-10



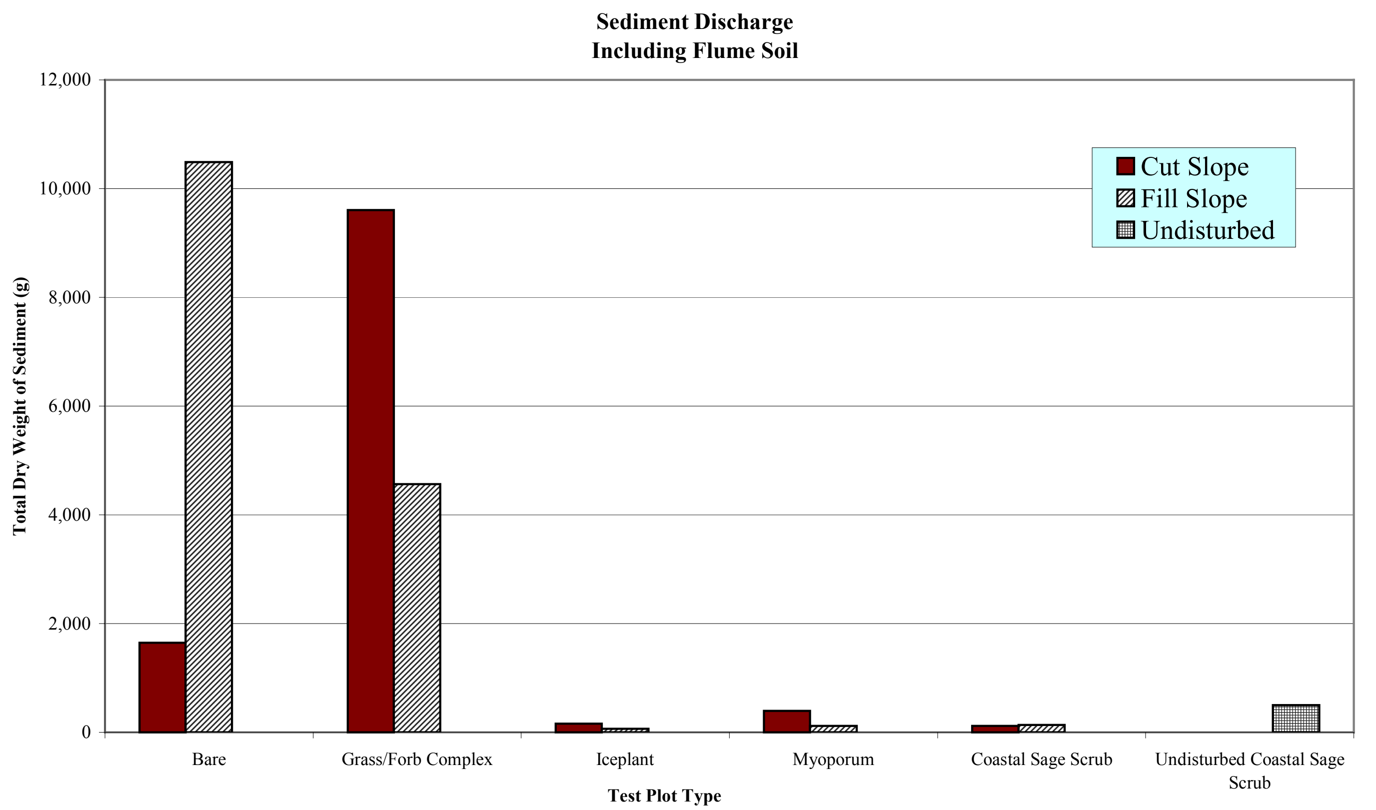
NORMALIZED EROSION RATE (g/m^2/mm) AT EROSION RATE TEST PLOTS (CUMULATIVE 1998-2000) SAMPLED STORMS

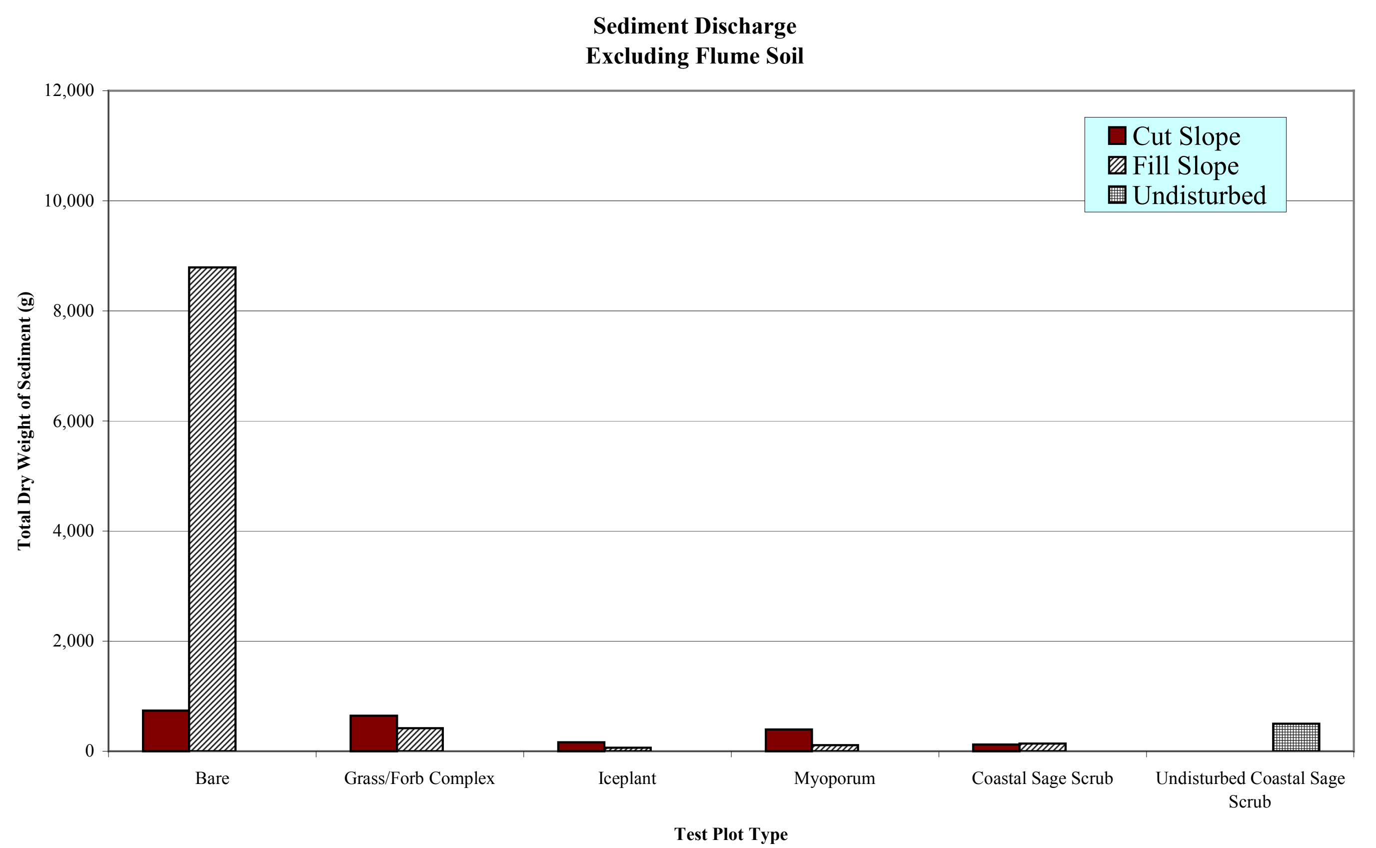
Project No.: 57-977001NM.00	Date: JUNE 2000	Project: CALTRANS EROSION CONTROL PILOT STUDY	Fig.: 8-11A



NORMALIZED EROSION RATE (g/m^2/mm) AT EROSION RATE TEST PLOTS (CUMULATIVE 1998-2000) SAMPLED STORMS

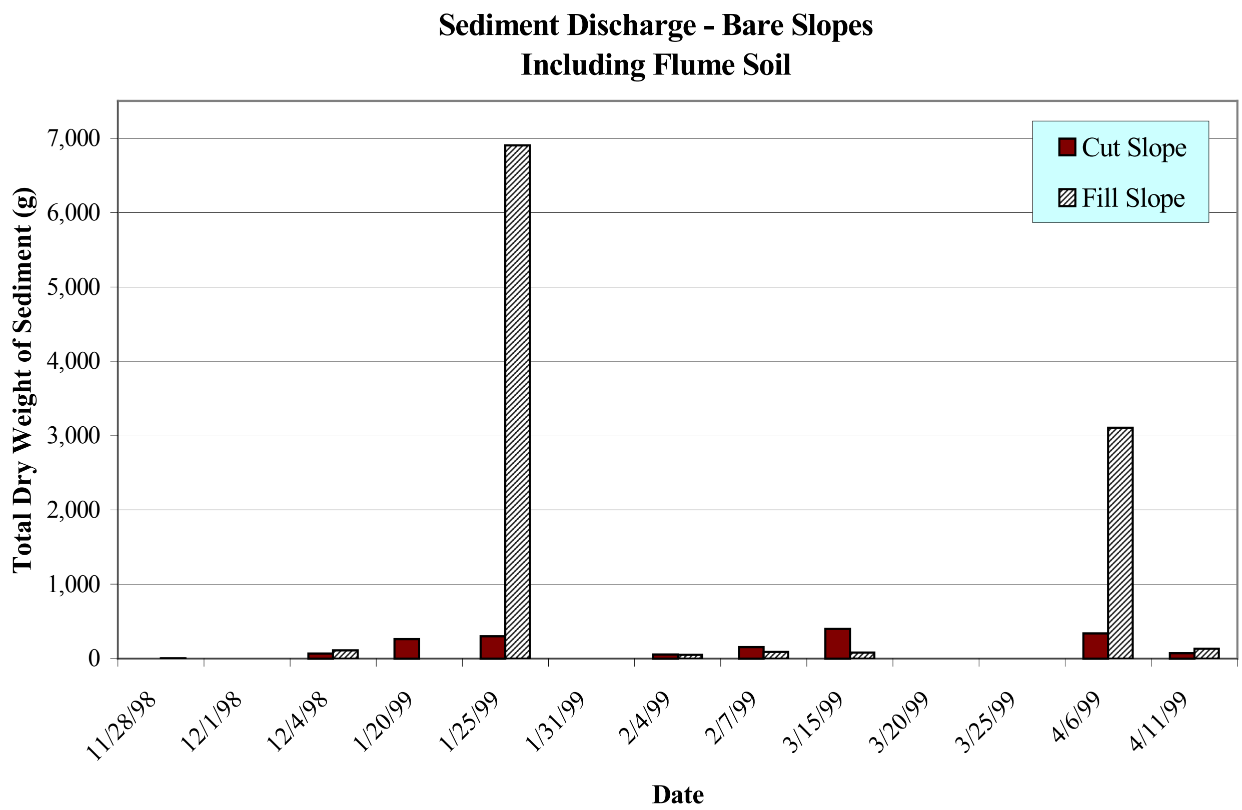
Project No.: 57-977001NM.00	Date: JUNE 2000	Project: CALTRANS EROSION CONTROL PILOT STUDY	Fig.: 8-11B

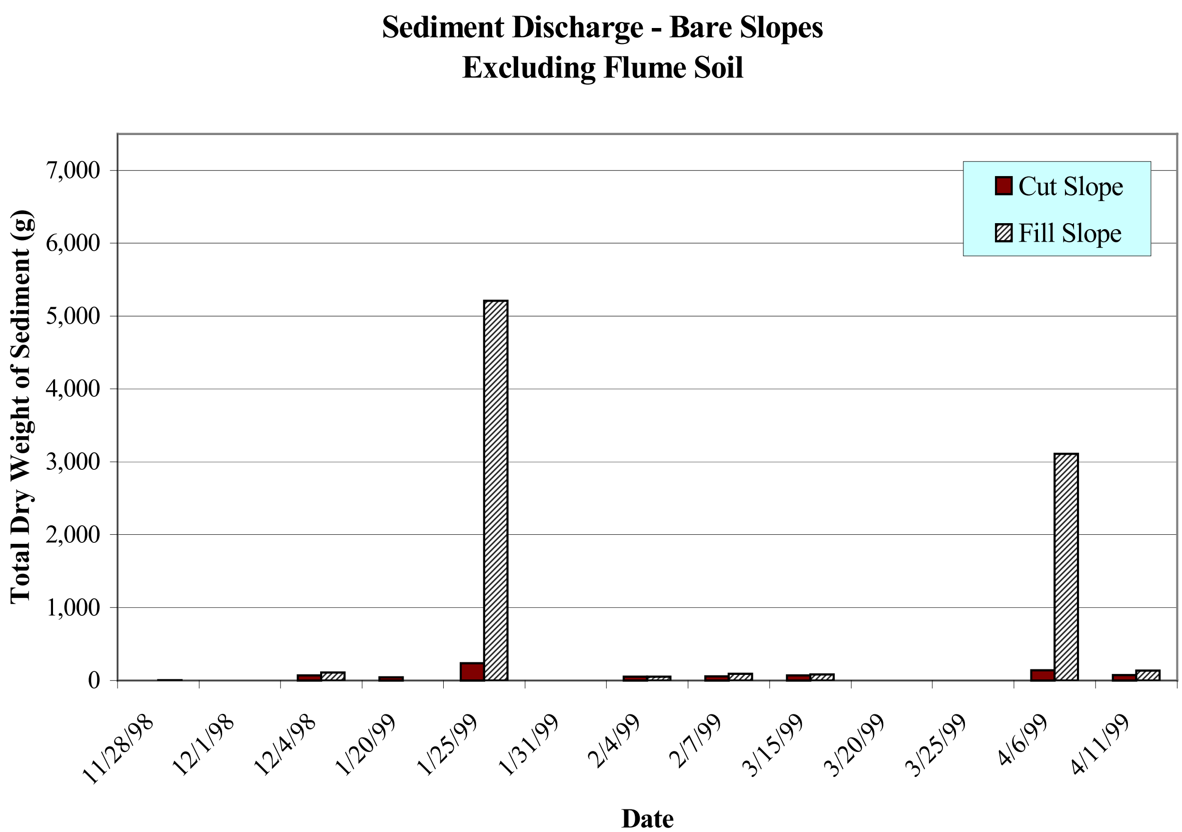




TOTAL DRY WEIGHT OF SEDIMENT (FLUME VERSUS NON-FLUME) RECOVERED FROM EROSION RATE TEST PLOTS 1998-1999 SAMPLED STORMS

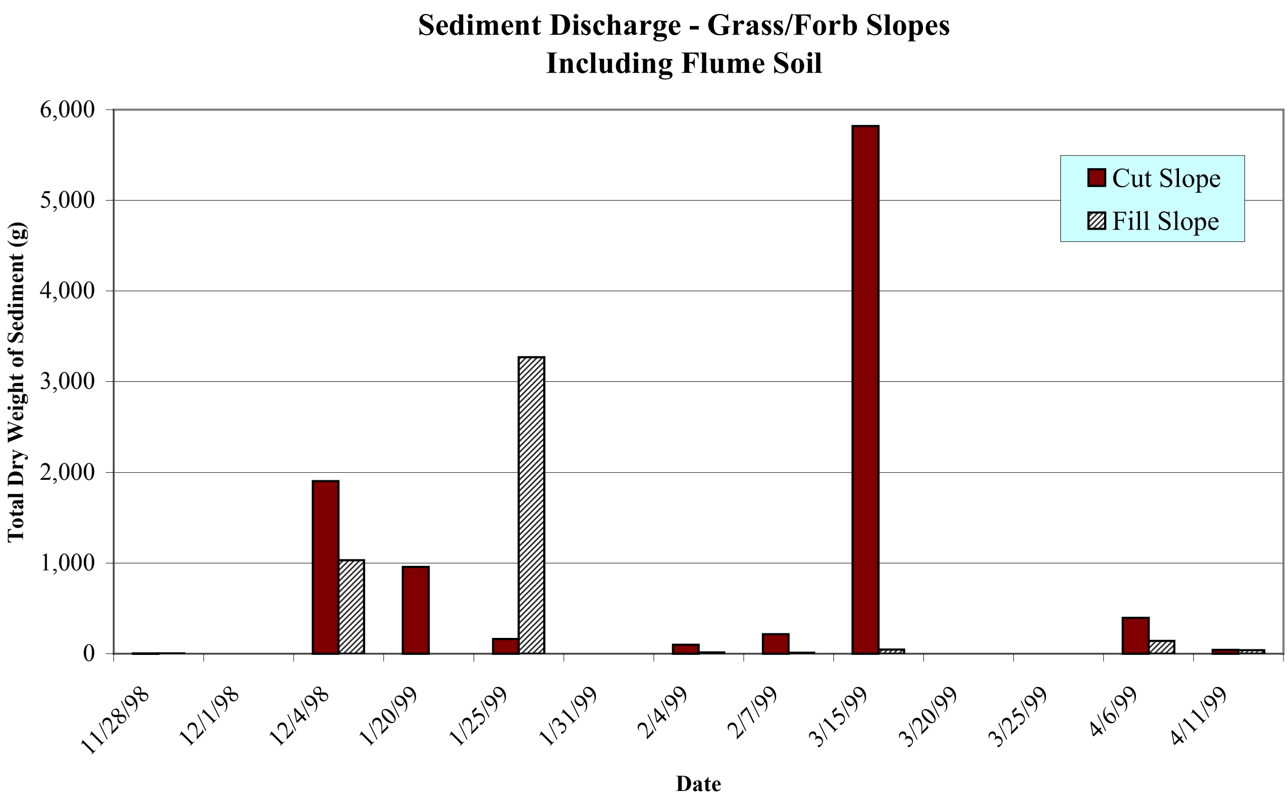
Project No.: 57-977001NM.00	Date: JUNE 2000	Project: CALTRANS EROSION CONTROL PILOT STUDY	Fig.: 8-12

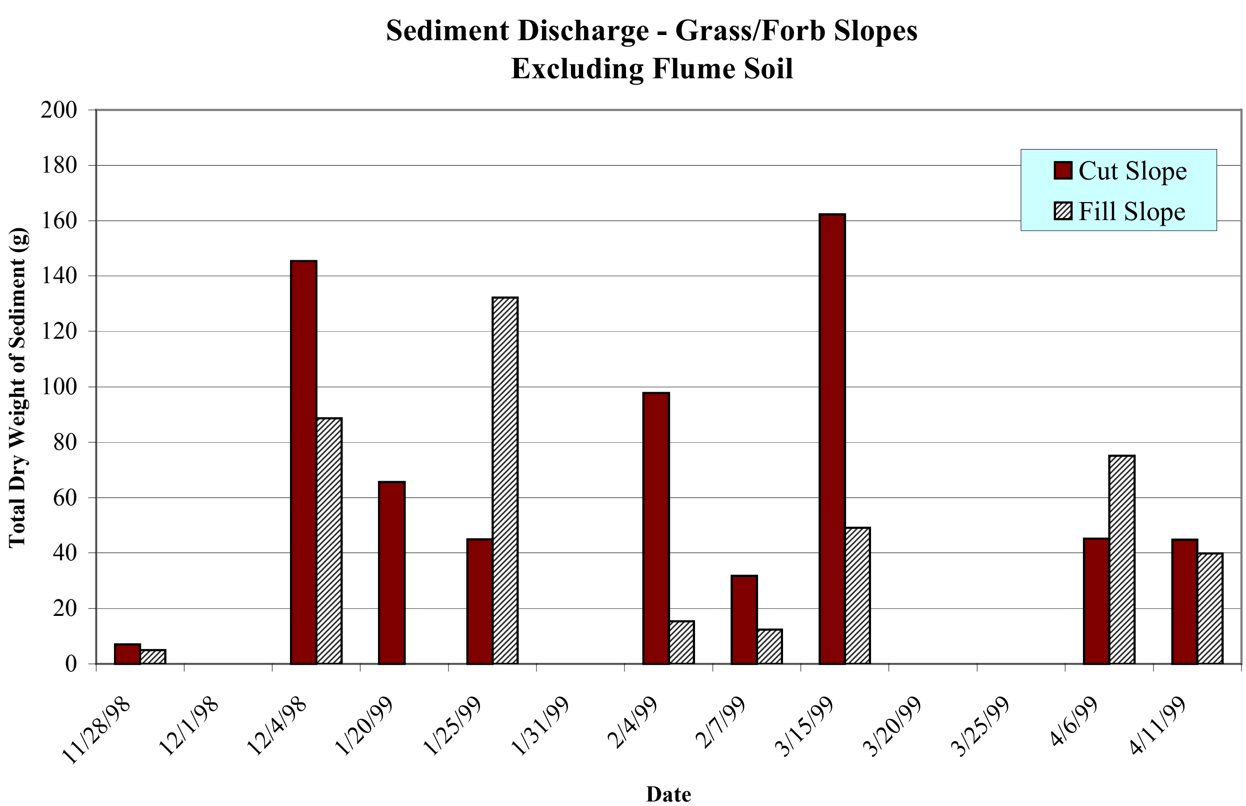




(FLUME VERSUS NON-FLUME) SEDIMENT DISCHARGE FROM BARE SLOPES
1998-1999 SAMPLED STORMS

Project No.: 57-977001NM.00	Date: JUNE 2000	Project: CALTRANS EROSION CONTROL PILOT STUDY	Fig.: 8-13





(FLUME VERSUS NON-FLUME) SEDIMENT DISCHARGE FROM GRASS/FORB SLOPES
1998-1999 SAMPLED STORMS

Project No.: 57-977001NM.00	Date: JUNE 2000	Project: CALTRANS EROSION CONTROL PILOT STUDY	Fig.: 8-14

During the 1998-1999 monitoring year, the January 25, 1999 storm event produced the most runoff than other sampled events, and a large percentage of the total soil loss from the bare and grass/forb fill-slope test plots occurred during this event. Figures 8-15 and 8-16 present plots of cumulative rainfall and non-normalized sediment discharge for the bare cut- and fill-slope test plots, respectively. These figures illustrate the correspondence between the rainfall amounts and dry weight of sediment eroded (including flume soil) during the January 25 event. Figures 8-17 and 8-18 present plots of cumulative runoff and non-normalized sediment discharge for the grass/forb cut and fill slope plots, respectively. These figures illustrate the correspondence between the high rainfall amounts and dry weight of sediment eroded (including flume soil) during the December 4 and January 25 events (cut slope) and December 4 and March 15 events (fill slope).

The data for the grass/forb cut-slope test plot and the bare cut-slope test plot were further evaluated to gain insight into the higher normalized erosion rates measured at the grass/forb vegetated slope compared to the bare slope. As previously discussed, the majority of sediment discharged from the grass/forb cut –slope occurred during the March 15, 1999 storm event. Rainfall during this storm event was similar (13 mm) at both the grass/forb and bare test plot sites. A slightly higher runoff volume was measured at the grass/forb test plot (26.5 L) compared to the bare test plot (21.2 L) during this storm event. This difference may be accounted for by rainfall intensity. However, in general, the rainfall and runoff data for the March 15, 1999 storm event did not indicate unusual conditions that would account for the high erosion rates observed at the grass/forb cut-slop test plot. The majority of the sediment collected during this storm event at the grass/forb test plot was collected from the flume and is believed to be the result of gopher activity, and not necessarily representative of the actual erosion control effectiveness of grass/forb vegetation at 90 to 100 percent cover. Less gopher activity was observed at the grass/forb fill slope, and therefore, the erosion rates measured at the grass/forb fill site are likely more representative for this vegetation type.

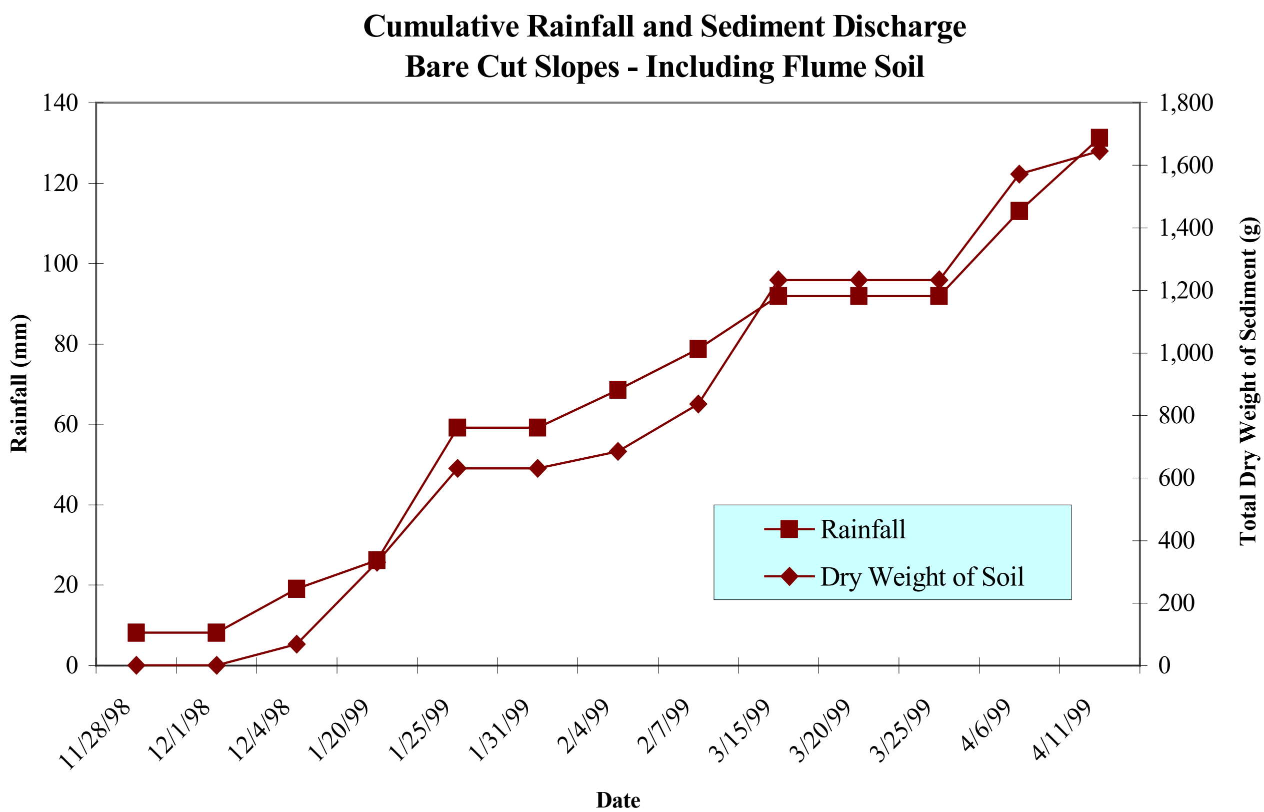
8.4.2 Statistical Interpretation of Normalized Erosion Rate Data

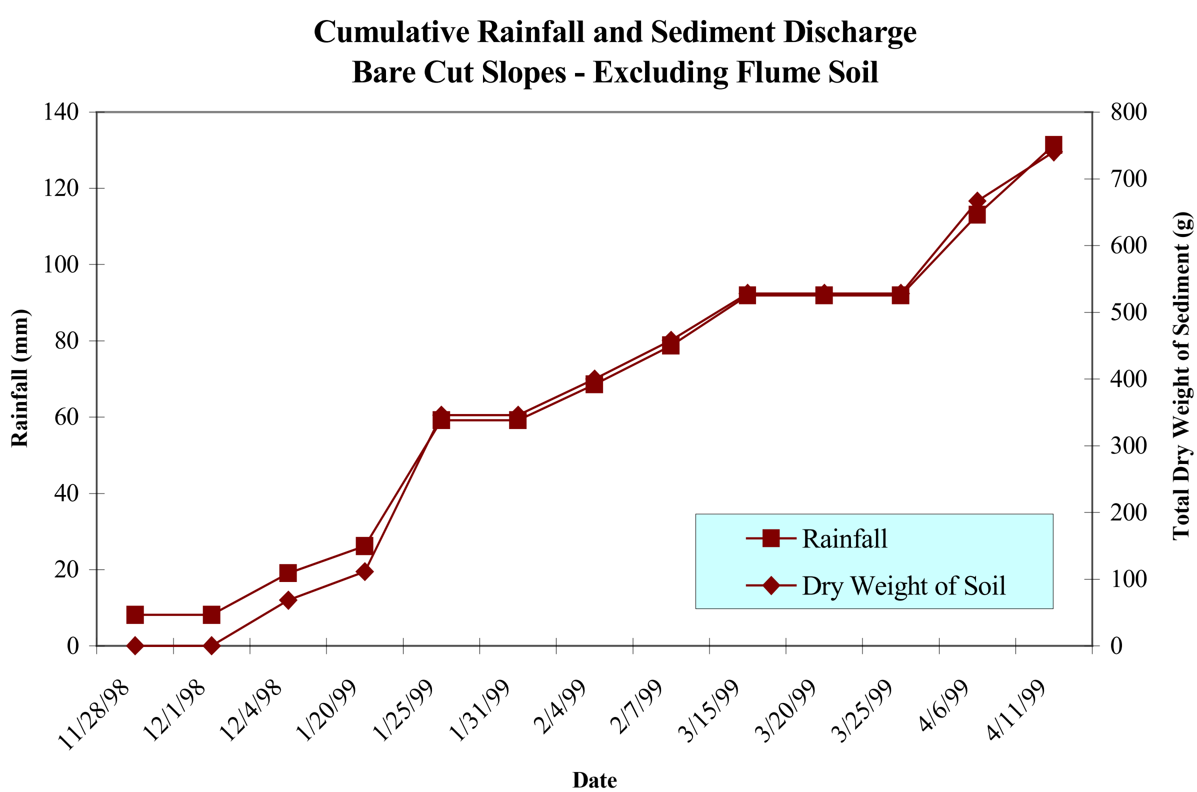
As shown in Section 8.4.1, Table 8-15 shows the means and standard deviations of normalized erosion rate data. Figure 8-11B illustrates the means graphically (without the March 15, 1999 storm data for the grass/forb cut slope). These data suggest that overall, the lowest erosion rates occurred on cut- and fill-slope plots that were vegetated with coastal sage scrub or iceplant followed by myoporum, then grass/forb vegetation. All vegetation types tested had erosion rates below those observed on the bare test plots.

8.4.2.1 Analysis of Covariance

For the erosion rate testing, the purpose of the analyses of variance is to establish relationships between rainfall volumes and amounts of sediment eroded, and to determine whether these relationships vary for different vegetation/slope combinations. To conduct the analyses, combinations of slope and vegetation type were combined into a single classification, since the "undisturbed" slope type only occurs with the "coastal sage scrub" vegetation type. The covariate (rainfall) and three non-normalized response variables (total dry weight excluding flume sediment, total dry weight including flume sediment, and total runoff volume) make for three possible analyses.

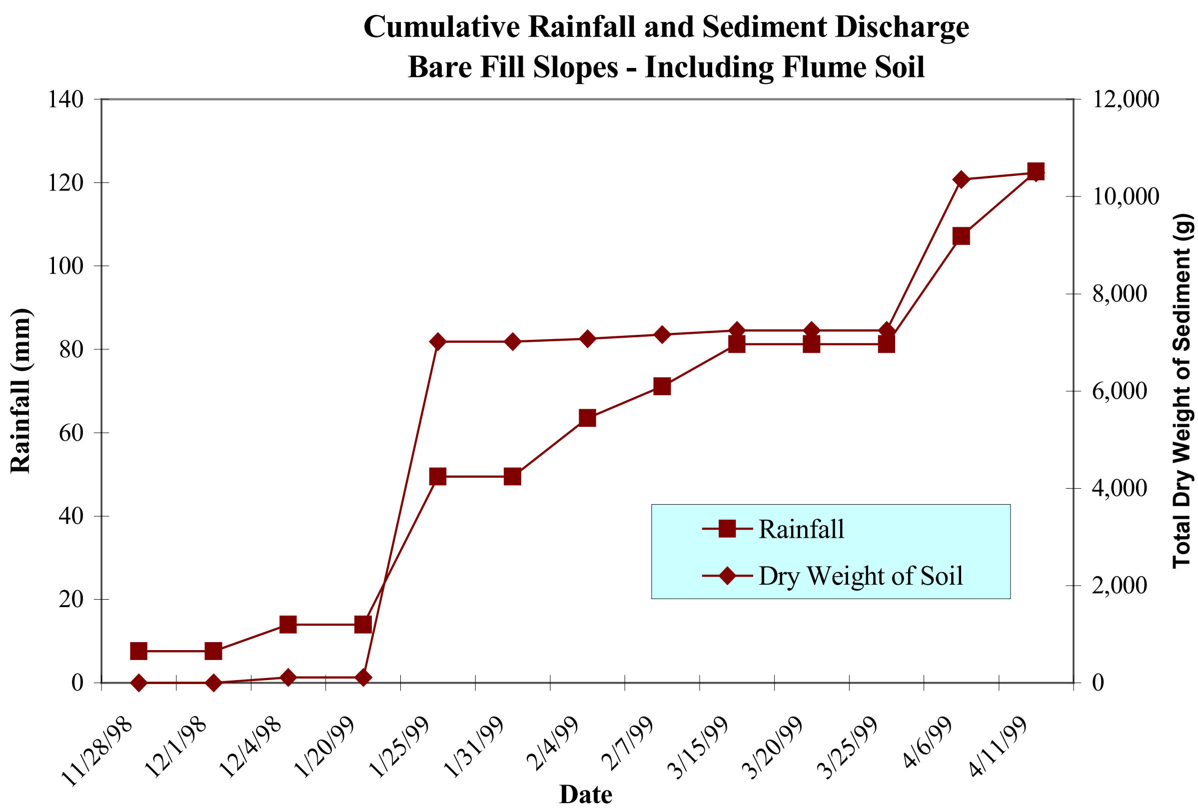
Table 8-16 shows results of analyses of covariance on non-normalized sediment, runoff, and rain data from the erosion rate test plots. This analysis is a one-way analysis of covariance with vegetation/slope combination as the treatment factor, and total rainfall as the covariate. The runoff and dry weight of soil, including flume soil statistics were based on data from both monitored years. The total dry weight of soil excluding flume soil statistical analysis was based on data collected from the first year of monitoring. All response variables tested are strongly influenced by the treatments, but only weakly affected by total rainfall, except for total sediment dry weight excluding flume soil. This is not unexpected since the flume soil is assumed to be present as the result of gopher activity on the plots. Table 8-17 shows means and standard errors of the response variables for each of the vegetation/slope type combinations. Both total runoff volumes and total dry weight of soil, including flume soil, statistical analysis are based on data collected from both monitoring years. The total dry weight of soil excluding flume soil statistical analysis was based on data from the first year of monitoring. Coastal sage scrub and iceplant consistently produce low amounts of sediment and runoff, with coastal sage scrub frequently outperforming myoporum. There is no consistent pattern to show whether cut or fill slopes produce less runoff and sediment.

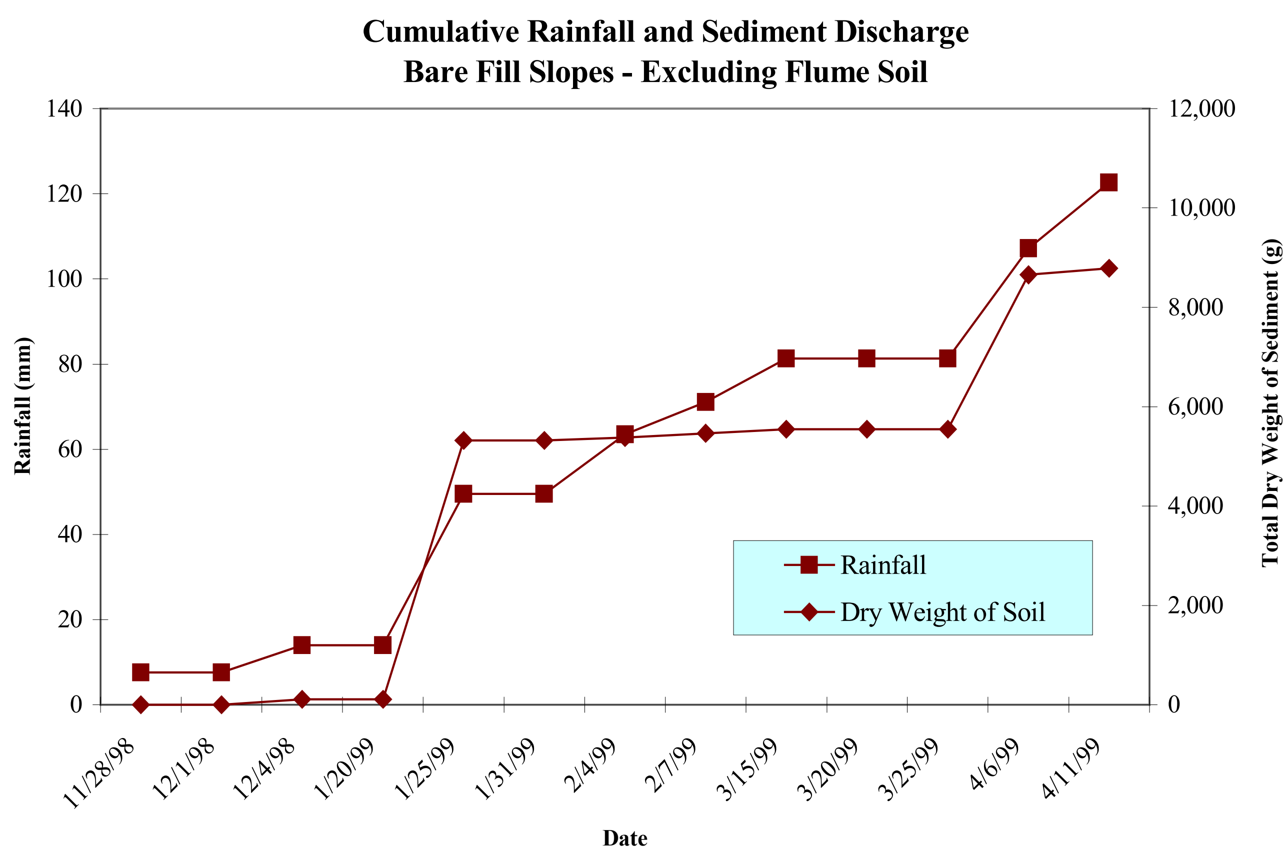




CUMULATIVE RAINFALL AND SEDIMENT DISCHARGE (FLUME VERSUS NON-FLUME)
FROM BARE CUT SLOPES 1998-1999 SAMPLED STORMS

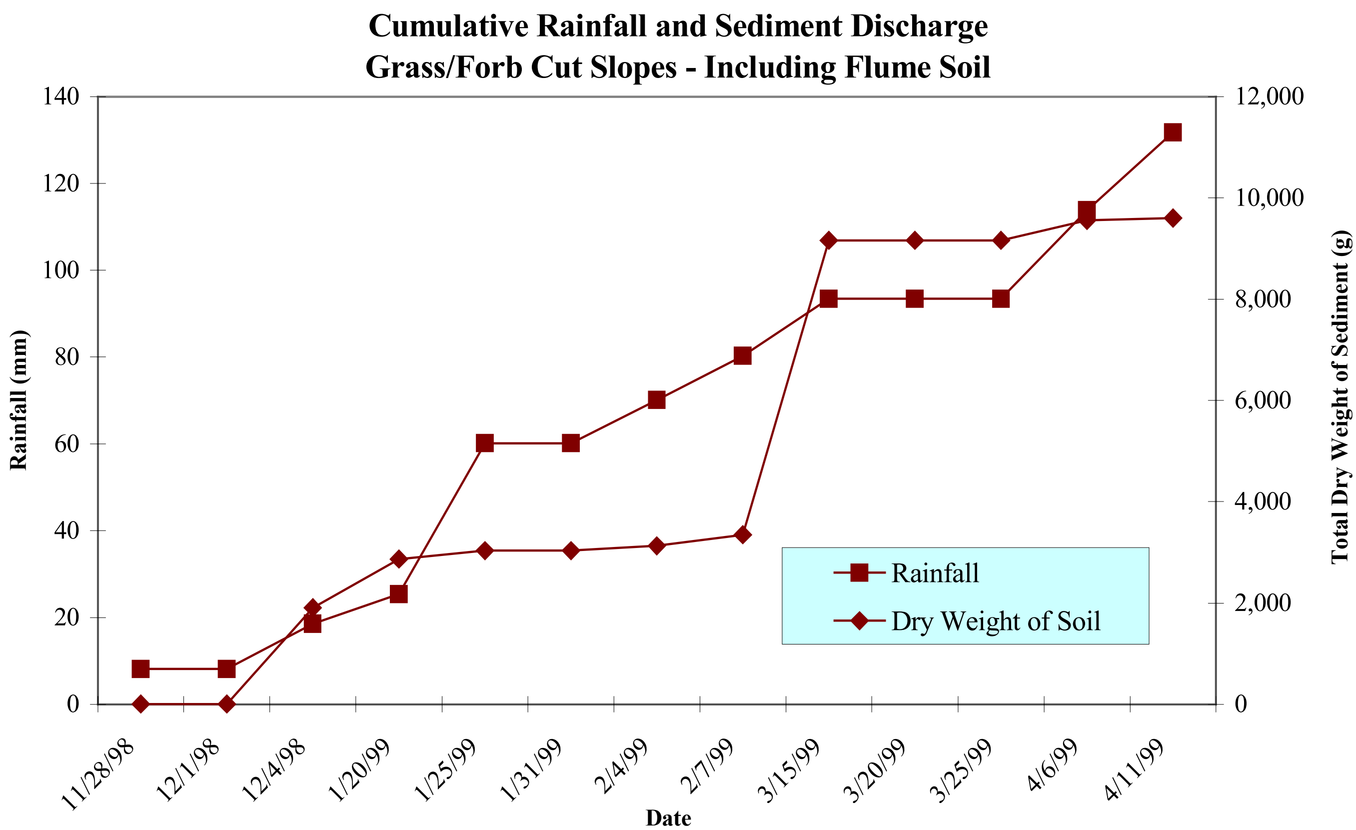
Project No.: 57-977001NM.00	Date: JUNE 2000	Project: CALTRANS EROSION CONTROL PILOT STUDY	Fig.: 8-1

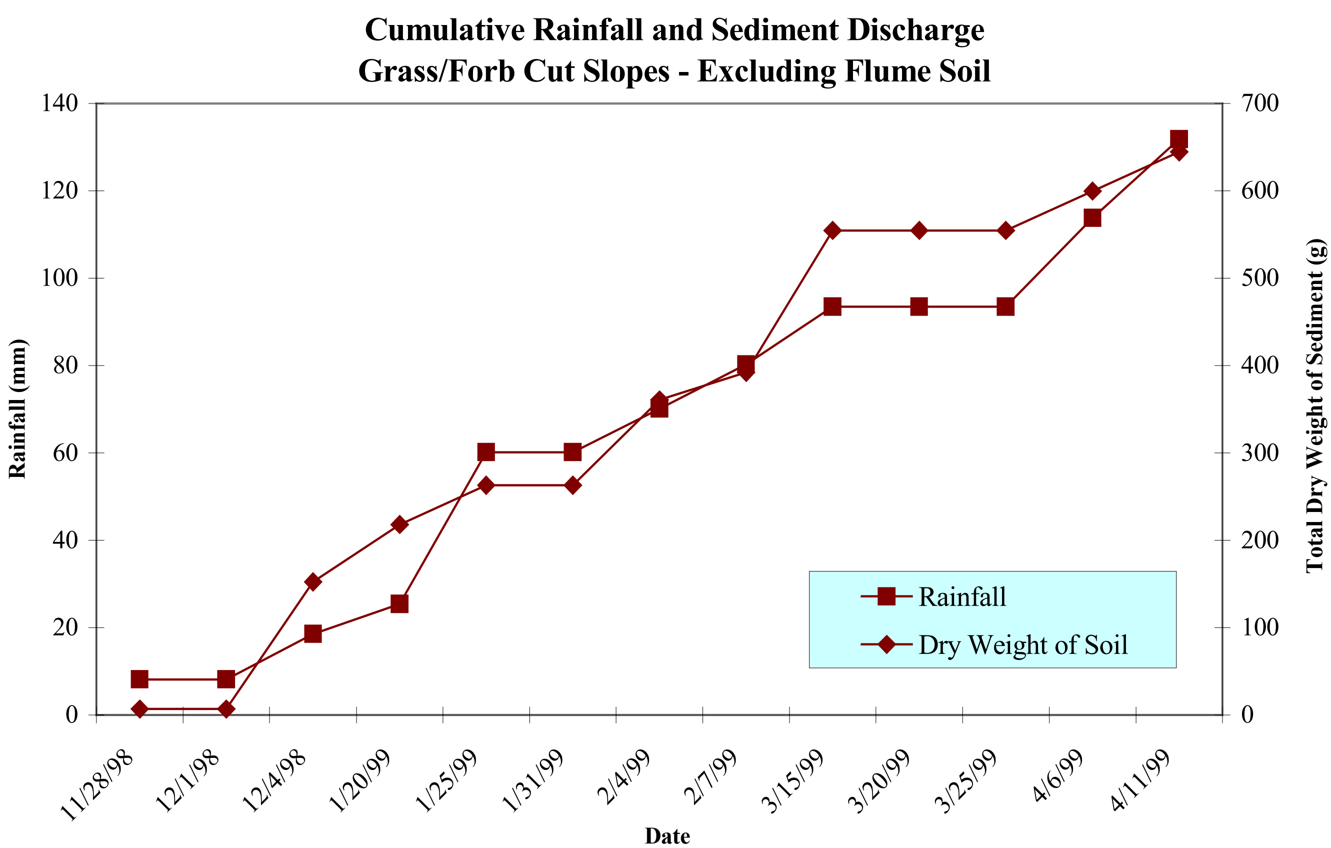




CUMULATIVE RAINFALL AND SEDIMENT DISCHARGE (FLUME VERSUS NON-FLUME)
FROM BARE FILL SLOPES 1998-1999 SAMPLED STORMS

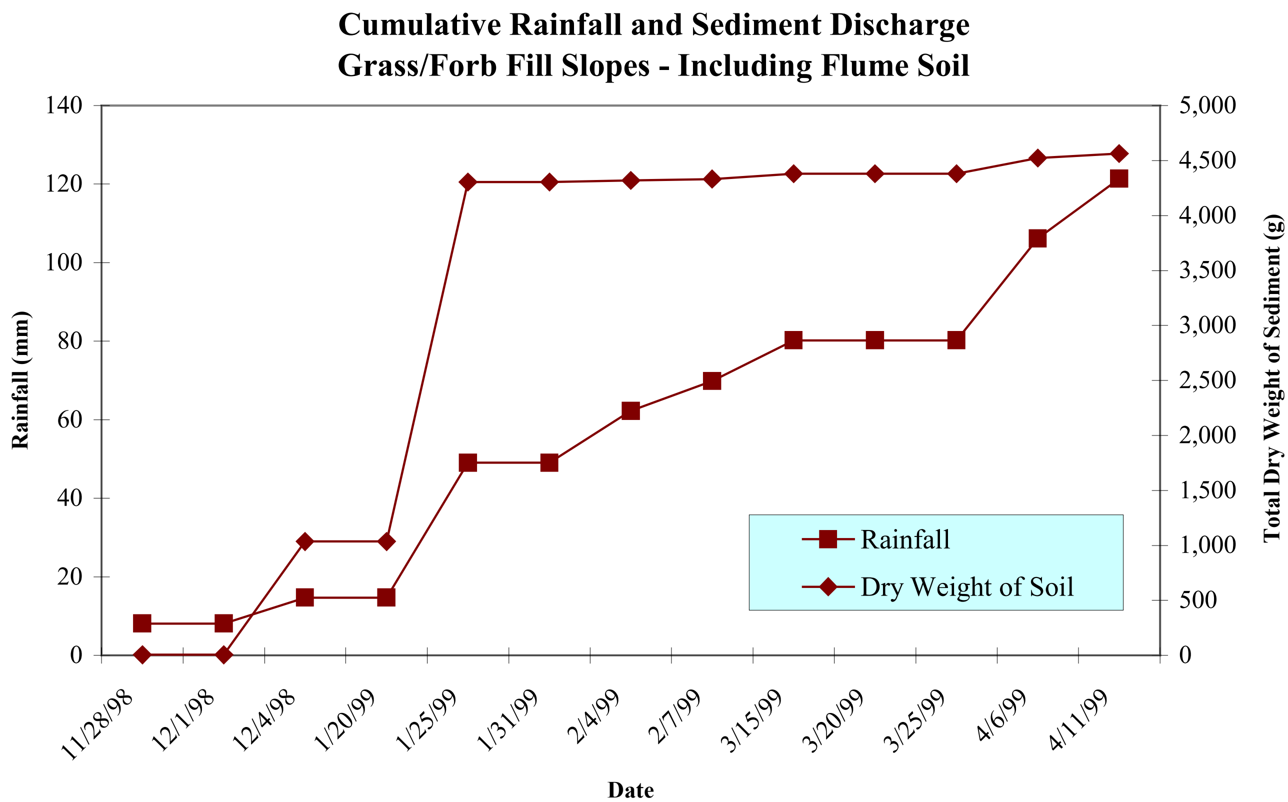
Project No.: 57-977001NM.00	Date: NOV. 1999	Project: CALTRANS EROSION CONTROL PILOT STUDY	Fig.: 8-16

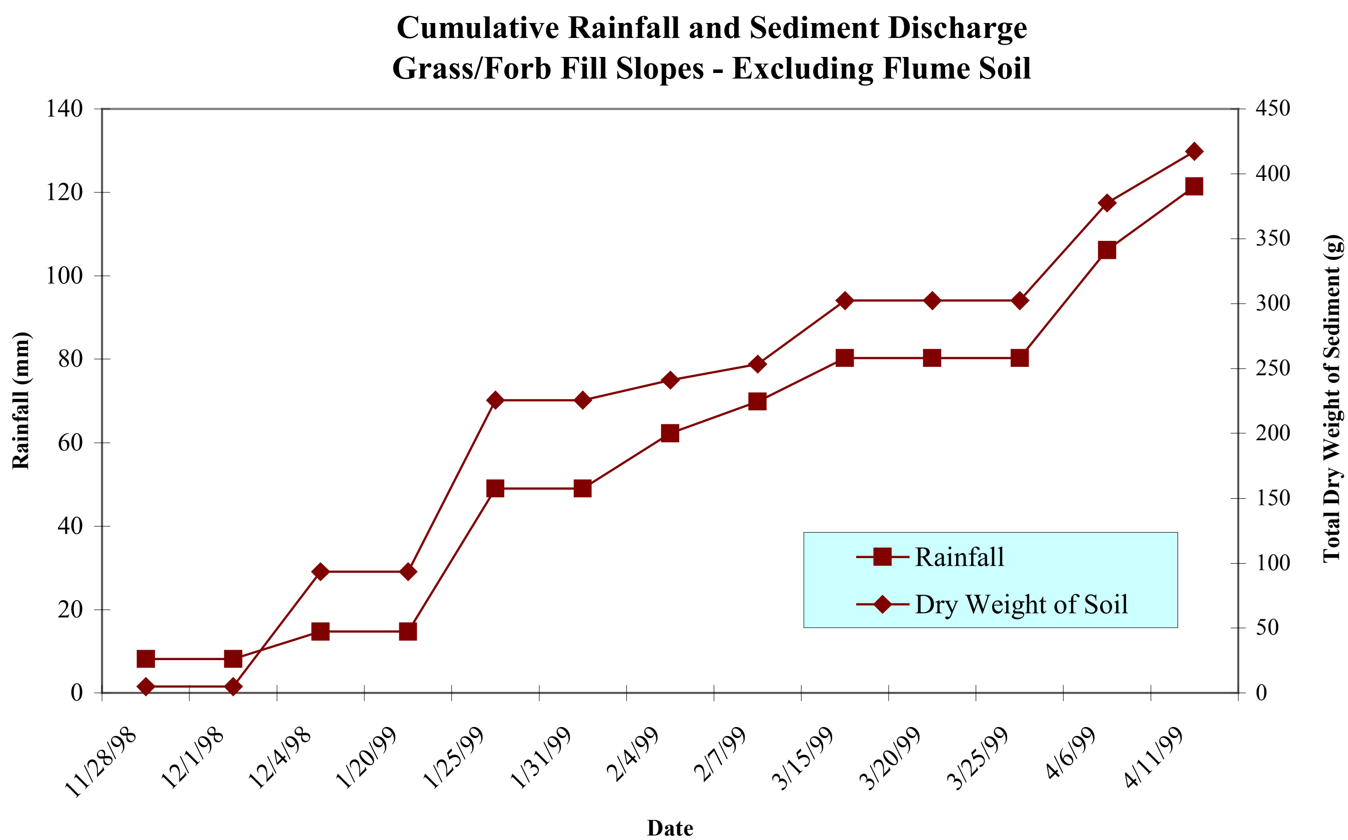




CUMULATIVE RAINFALL AND SEDIMENT DISCHARGE (FLUME VERSUS NON-FLUME)
FROM GRASS/FORB CUT SLOPES 1998-1999 SAMPLED STORMS

Project No.: 57-977001NM.00	Date: JUNE 2000	Project: CALTRANS EROSION CONTROL PILOT STUDY	Fig.: 8-17





CUMULATIVE RAINFALL AND SEDIMENT DISCHARGE (FLUME VERSUS NON-FLUME)
FROM GRASS/FORB FILL SLOPES 1998-1999 SAMPLED STORMS

Project No.: 57-977001NM.00	Date: JUNE 2000	Project: CALTRANS EROSION CONTROL PILOT STUDY	Fig.: 8-18

Table 8-16
ANALYSIS OF COVARIANCE FOR SEDIMENT/RUNOFF DATA EROSION RATE TEST PLOTS (1)

Response	Treatment Effect			Covariate Effect(1)		
	p-value	F-value	DOF(2)	p-value	F-value	DOF(2)
Total runoff volume(3)	< 0.001	57.415	9,22	0.295	1.149	1,22
Total dry weight of soil, including flume soil(3)	< 0.001	95.259	9,22	0.510	0.448	1,22
Total dry weight of soil, excluding flume soil(4)	< 0.001	358.578	9,22	<0.001	47.549	1,22

(1) One-way analysis of covariance with vegetation/slope combination as the factor, and the covariant and response variable as indicated.
(2) DOF - degrees of freedom.
(3) Represents data collected from both monitoring years (1998-2000).
(4) Represents data collected from first monitoring year (1998-1999).
Note: Variation in the denominator degrees of freedom reflects the presence of missing values for some of the response variables.

Table 8-17
MEANS AND STANDARD ERRORS FOR EACH RESPONSE VARIABLE FROM THE ANALYSES OF COVARIANCE REPORTED IN TABLE 8-16

Treatment	Slope Type	Total Runoff Volume(1) (L)		Total Dry Weight Of Soil, Including Flume Soil(1) (g)		Total Dry Weight Of Soil, Excluding Flume Soil(2) (g)	
		Mean	Standard Error	Mean	Standard Error	Mean	Standard Error
Bare	Cut	1178.20	53.84	8157.84	2287.24	8787.91	290.87
	Fill	1637.05	53.84	38243.14	1596.89	740.32	171.57
Coastal Sage Scrub	Cut	666.90	16.27	242.89	17.23	121.36	17.00
	Fill	527.13	65.16	301.56	34.94	136.53	15.01
Grass Forb	Cut	555.85	53.79	10196.20	1659.45	644.63	196.92
	Fill	468.33	53.73	5209.447	2362.57	417.40	191.25
Iceplant	Cut	324.99	61.67	250.50	12.85	160.64	29.69
	Fill	293.29	66.63	231.37	2.59	65.64	7.97
Myoporum	Cut	451.19	54.75	696.24	70.79	393.54	72.50
	Fill	479.09	53.82	1459.83	278.12	112.39	17.13
	Undisturbed	753.86	64.53	850.96	263.82	495.79	164.44

(1) Represents data collected from both monitoring years (1998-2000).
(2) Represents data collected from first monitoring year (1998-1999).

8.5 EROSION CONTROL EFFECTIVENESS AND RUNOFF PRODUCTION: RANKING OF VEGETATION TYPE

Table 8-18 shows average values of total cover (based on the Daubenmire scale) from the erosion rate test plots. Total cover is lowest for the grass/forb vegetation, but roughly comparable for all other vegetation types on cut or fill slopes. The highest total cover was provided by the iceplant. As expected, in terms of dominant species, iceplant dominates the iceplant plots and myoporum dominates the myoporum plots. California buckwheat *(Eriogonum fasciculatum)* dominates coastal sage scrub on cut and fill slopes, but black sage *(Salvia mellifera)* dominates coastal sage scrub on undisturbed slopes. Ripgut brome *(Bromus diandrus)* and California chickory *(Cichorium intybus)* dominate the grass/forb vegetation on cut slopes, while black mustard *(Brassica nigra)*, ripgut brome *(Bromus diandrus)*, and milk thistle *(Silybum marianum)* dominate the grass/forb vegetation on fill slopes. There were strong statistically significant differences in total cover among the vegetation/slope type combinations. Not all possible combinations of vegetation/slope type occur (i.e., coastal sage scrub is the only vegetation type that occurs on the undisturbed slope type), therefore, it was necessary to conduct one-way repeated measures analysis using slope/vegetation type as the treatment factor. The analysis included measurements from all monitoring events, but because the data from all monitoring events were not independent, the data had to be treated not as a replicate, but as repeated measures.

In order to rank the effectiveness of the different types of vegetation for erosion control, the normalized erosion rate was evaluated by vegetation/slope type combinations (Figure 8-16).

On cut slopes, coastal sage scrub and iceplant performed almost the same and provided the best erosion control. Myoporum performed next in erosion control effectiveness on cut slopes. The erosion control effectiveness of coastal sage scrub on undisturbed slopes ranked similar to the myoporum vegetation on cut slopes. Grass/forb vegetation was the least effective at controlling erosion on cut slopes.

On fill slopes, coastal sage scrub and iceplant performed the same and provided the best erosion control. Coastal sage scrub on undisturbed slopes and myoporum on fill slopes performed next respectively, in erosion control effectiveness. Grass/forb vegetation provided the least erosion control on fill slopes.

Table 8-18
AVERAGE VALUES OF TOTAL PLANT COVER

Vegetation	Event	Average Of Total Cover(1) Cut	Fill	Undisturbed
Coastal Sage Scrub	1	4.00	5.67	
	2	3.67	5.67	
	3	6.00	6.00	
	4	4.33	5.33	
Coastal Sage Scrub Total		4.50	5.67	
Grass/Forb Complex	1	1.33	2.00	
	2	2.33	3.00	
	3	4.67	4.33	
	4	5.00	6.00	
Grass/Forb Complex Total		3.33	3.83	
Iceplant	1	6.00	6.00	
	2	6.00	5.33	
	3	6.00	5.33	
	4	6.00	4.00	
Iceplant Total		6.00	5.17	
Myoporum	1	5.33	5.67	
	2	6.00	6.00	
	3	6.00	5.33	
	4	6.00	5.33	
Myoporum Total		5.83	5.58	
Undisturbed Coastal Sage Scrub	1			4.67
	2			4.00
	3			5.00
	4			5.67
Undisturbed Coastal Sage Scrub Total				4.83

(1) Based on Daubenmire scale for all plants in plots (see Table 3-2).

Note: Shaded fields indicate no data

8.6 COMPARISON OF RELATIVE EFFECTIVENESS OF NATIVE VS. NON-NATIVE PLANT SPECIES

As described in Section 8.4, the coastal sage scrub and iceplant on both cut and fill slopes provided the best erosion control. Iceplant is non-native and requires permanent irrigation for survival in southern California. The coastal sage scrub is native and does not need irrigation for survival.

8.7 COMPARISON OF EROSION RATE FROM THE COASTAL SAGE SCRUB AND GRASS/FORB PLOTS

The test locations for the erosion rate field testing were selected based on a set of field conditions that met the study design criteria. A discussion of the original site selection procedure is presented in the *Detailed Study Plan* (URS Greiner Woodward Clyde, 1998). Subsequent to conducting the field tests, the physical conditions of the slopes and their histories were evaluated to determine the real world factors that may have influenced the results that were observed in the field tests. In particular, this effort was conducted in order to evaluate what factors may have resulted in the establishment of the mature coastal sage scrub that had a lower erosion rate than the grass/forb vegetation. The factors that were evaluated included:

- Age
- Slope inclination
- Slope aspect
- Soil type
- Underlying geology
- Elevation and topography
- Initial seeding, maintenance, and irrigation
- Initial seed mix
- Surrounding vegetation and land uses

A summary of the available data is provided in Table 8-19. Sites 10-2 and 57-4 are the grass/forb fill and cut slopes, respectively, and Sites 210-10 and 210-1 are the coastal sage scrub fill and cut slopes, respectively. Some of the physical information about the sites (e.g., slope inclination, slope aspect, geology, soil type, and surrounding conditions) were gathered as part of the initial site selection process. Information regarding the initial construction and maintenance of the slopes was obtained through interviews with District 7 personnel.

All of the slopes were constructed as part of the original freeway construction activities, were seeded for erosion control, and did not receive supplemental irrigation or maintenance since construction. The age of the mature coastal sage scrub was estimated to be at least ten years (District 7, personal communication). The age of the grass/forb vegetation could not be determined because these annual plants die back and self-seed annually; although the slopes were reportedly constructed at least ten years ago (District 7, personal communication). All slopes had a similar steepness of approximately 1:2 (V:H). The soil types on the 10-2, 57-4, and 210-10 sites were similar (silty to clayey sand, or sandy to sandy clay loam), whereas the soils on the 210-1 site were finer (sandy clay or loam). Both cut slopes were constructed in Puente Formation (sandstone to siltstone) materials. The historical average annual rainfall was similar among the 10-2, 210-10, and 210-1 sites (approximately 400 mm/yr). Historical rainfall was about 12 percent lower (approximately

Table 8-19
TEST SITE CHARACTERISTICS

Site Number	Vegetation	Slope Type	Slope Angle (V:H)	Elevation (m)	Slope Aspect	Soil Type		Average Annual Rainfall (mm)	Geology
						USCS	USDA		
10-2	Grass/Forb Complex	Fill	1:2	234	S/SE 160°	Clayey sand	Sandy clay loam	438.7	Fill slope
57-4	Grass/Forb Complex	Cut	1:2	172	E/SE 121°	Silty sand with gravel	Sandy loam	358.1	Puente Formation
210-10	Coastal Sage Scrub	Fill	1:2	356	S/SW 211°	Clayey sand	Sandy loam	410.5	Fill Slope
210-1	Coastal Sage Scrub	Cut	1:2	368	W/SW 241°	Sandy clay with gravel	Loam	438.7	Puente Formation

Notes:

USCS = Unified Soil Classification System soil description

USDA = United States Department of Agriculture soil description

350 mm) for the 57-4 site. The aspects of all four slopes were generally toward the south, with Site 57-4 facing more toward the southeast, Site 10-2 facing more toward due south, and Sites 210-10 and 210-1 facing more toward the southwest. The slopes range in elevation between 172 m (Site 10-2) to 369 m (Site 210-1).

It was not possible to obtain specific information about some of the factors. For example, the exact age of the slopes and specific seed mixes that were originally applied could not be determined. In addition, the original source of the fill material for the two fill slopes is unknown. The composition of plant types on the coastal sage scrub plots appears to represent a typical coastal sage scrub assemblage. The composition of the species growing on the grass/forb sites include a large proportion of non-native weeds. The slopes surrounding the coastal sage scrub test plots are vegetated with coastal sage scrub vegetation and the slopes surrounding the grass/forb vegetation test plots are vegetated with grass/forb vegetation.

The success of plant establishment is highly dependent on site-specific conditions. However, the typical factors influencing plant establishment of CSS may be considered. In general, CSS is well adapted to the semi-arid climatic conditions found in southern California, up to an elevation of about 923 m. Although slower growing than some plants, once CSS is established, it is less likely to convert to other plant assemblages than grass/forb. Aspect influences the specific mix of species in the CSS assemblage. In inland areas, slopes that face toward the south and west may tend to take slightly longer to become established, and may have greater spacing between individual plants (as compared to north- and east-facing slopes). Finer grained soils (e.g., clayey soils) may promote denser growth of CSS, but site-specific conditions are likely to have a greater influence on plant establishment.

In summary, the CSS plots and grass/forb plots evaluated for field erosion rate testing in the ECPS appear to be relatively similar. All sites are located in the Los Angeles Basin, with similar semi-arid growing conditions. They were constructed at approximately the same time, were stabilized by seeding following construction, and received no irrigation or specialized maintenance. The soil type, underlying geology (of the cut slope), aspect, and rainfall are generally consistent. All the sites are below the elevation of 923 m. The difference in their erosion rate effectiveness, therefore, appears to be a result of vegetation type. This is supported by the statistical analysis. Because the CSS vegetation is well established, it appears to be providing good erosion control effectiveness through a canopy effect as well as a deep root system. In contrast, the grass/forb sites are weedy, with a less-well developed canopy and more variable root network.

8.8 SUMMARY AND CONCLUSIONS

The value of the field erosion rate tests is in comparing non-irrigated grass/forb, irrigated myoporum, irrigated iceplant, and non-irrigated coastal sage scrub vegetation types in terms of their relative erosion control effectiveness at 90 to 100 percent density on highway cut and fill slopes. The results of the evaluation showed that the coastal sage scrub and iceplant performed similarly, and were the most effective at controlling erosion on cut- and fill-slopes. Myoporum performed next in erosive control effectiveness, and did better on cut slopes than on fill slopes. Grass/forb complex vegetation was the least effective at controlling erosion of the vegetation types tested in this study, and was the most susceptible to gopher activity which resulted in higher calculated erosion rates.

Highway cut and fill slopes vegetated with coastal sage scrub and iceplant exhibited less erosion than off-highway, undisturbed slopes vegetated with coastal sage scrub.

9.1 INTRODUCTION

The objective of the Erosion Control Pilot Study (ECPS) was to evaluate alternative permanent soil stabilization methods designed to minimize the transport of sediment from cut and fill slopes within Caltrans District 7 rights-of-way to storm drain inlets in District 7. The basic assumption of the pilot study was that erosion of slopes can be reduced by increasing the percentage of vegetative cover on cut and fill slopes to provide soil protection from wind and water.

The identification of potentially effective erosion control measures and practices took into account previous and ongoing studies by Caltrans and others. Through this process, recommendations were developed regarding measures and practices to be evaluated by Caltrans in this pilot study.

The purpose of this final report is to provide an assessment of the effectiveness of the alternative permanent soil stabilization methods for geographic and climatic conditions encountered in Caltrans District 7, plus their associated costs. The soil stabilization measures evaluated herein may be used to stabilize temporary construction slopes. However, since the focus of the study is on permanent slope stabilization, the products and techniques were evaluated in the context of their use for permanent soil stabilization. Their role, as such, is twofold: (1) to provide interim soil stabilization until the permanent vegetation is established and controlling erosion effectively; and (2) to enhance the successful establishment of the permanent vegetation.

9.2 EVALUATION OF SLOPE ROUGHNESS

Soil roughening is the creation of a soil surface roughness by mechanical means. Typically, the roughening is performed parallel to the slope contours and perpendicular to the direction of runoff. The benefits provided by soil roughening are to slow runoff, enhance infiltration, moderate soil temperature, trap moisture, and enhance seed germination and root penetration. The slope roughness is complementary to most soil stabilization techniques, such as the hydraulic mulches evaluated herein, which can be applied over the surface roughness treatment. The surface roughness provides a permanent slope surface configuration that works in conjunction with the short-term soil stabilization and permanent vegetation to provide an effective erosion control system.

Five surface roughness techniques were evaluated as part of this study: smooth-rolled, sheepsfoot-rolled, ripped, trackwalked, and imprinted as presented in Section 4. The five soil roughness techniques were evaluated against one criterion, erosion rate. The five techniques were rated with respect to how they performed during the erosion rate testing, and ranked based on the given ratings. The ranking of the slope roughness techniques is provided in Table 9-1 with estimated cost per hectare.

9.3 EVALUATION OF TEMPORARY IRRIGATION

From examination of the study data, irrigation has an initial positive effect on CSS seed germination. This trend also applies to non-native vegetation. By spring of the first year, the effect of higher plant densities is no longer discernable between the irrigated and non-irrigated plots. In the long term, initial irrigation has no benefit to plant density (Tables 6-7 to 6-14).

It appeared that irrigation had no discernable effect on total plant cover by Event 3 (May 1999), as shown on Tables 6-18A and 6-18B. This is when we would expect to see any difference. Therefore, there appears to be limited short-term cover benefit to applying temporary irrigation.

There is no substantial difference between irrigated and non-irrigated field plots with respect to density and cover. It is widely accepted that plant cover is a measure of erosion control effectiveness. Therefore, it appears there is no short-term or long-term benefit to the application of temporary irrigation for the purpose of improving erosion control effectiveness.

9.4 COLLECTIVE EVALUATION OF 15 SOIL STABILIZATION MEASURES

The 15 soil stabilization measures evaluated herein are of value in the early stages of slope stabilization. Since vegetation takes time to grow and may not provide effective erosion control for several months to years, the soils stabilization measures provide interim erosion control, and provide a nurturing environment for seeds and plants to become established. They keep the seed from being washed off the slope, they hold the soil in place, and to varying degrees, they provide moisture retention, temperature moderation, and texture to assist in germination, growth, and root penetration.

The 15 soil stabilization measures were evaluated for their initial effectiveness at reducing erosion, their impacts on water quality, and their effects on establishing vegetation. The results of the erosion rate and water quality, and plant establishment tests for the 15 soil stabilization measures are presented separately in Sections 5 and 6, respectively. In order to compare the 15 soil stabilization treatments, a rating system was developed for each of the parameters that were evaluated in this study. The rating scale for erosion rate is shown in Table 9-2. The rating system correlates percent erosion rate reduction compared to bare soil with a scale from 0 through 10.

The rating scale for plant establishment effectiveness is shown in Table 9-3. The results of the evaluation of total plant cover for the final monitoring event (Event 7, April 2000) for all plants (natives and non-natives) were used to rate the treatments on a scale of 0 to 10. By Event 7 (for slope types and irrigation treatments considered together), compost and bonded fiber matrix performed the best in terms of total plant cover. Wood fiber blanket, wood mulch with psyllium, and wood mulch with polymer also performed well.

The total plant cover and erosion rate criteria were given equal weighting. Each alternative was evaluated with respect to how it performed during the testing for each evaluation criteria, and given a numerical rating. The ratings were then totaled for each alternative, resulting in a total numerical rating value for each alternative. This was done for each of the four types of plant establishment plots: non-irrigated fill, irrigated fill, cut, and irrigated cut slopes (Tables 9-4 through 9-7).

Table 9-1
RANKING OF SOIL ROUGHNESS TECHNIQUES

Roughness	Erosion Control Rating	Overall Ranking	Cost Per Ha
Smooth-rolled	0	5	$3,000
Imprinted	7	1	$1,235
Trackwalked	5	3	$3,200
Sheepsfoot-rolled	5.5	2	$3,300
Ripped	1	4	$3,200

Note: Costs include on-site operational costs only.

In the plots treated with curled wood fiber mulch, complete mortality of the native plant species resulted by the end of the second year under all four slope conditions. Low treatment effectiveness was also observed in the coconut blanket, coir, straw blanket, and straw-coconut blanket plots.

In order to develop a method to evaluate which of the treatments resulted in notable impacts to water quality and which ones did not, a comparative water quality evaluation process was developed. The water quality results from runoff from each of the 15 erosion control treatments as well as the control plot (bare soil) were compared to Caltrans statewide water quality ranges, and typical urban runoff concentrations from Los Angeles County storm water monitoring for transportation land use. These data are summarized in Tables 5-3 and 5-4. For several of the constituents analyzed in this study, there were no outside data with which to make a comparison.

The data from the SDSU laboratory testing were compared to Caltrans statewide ranges, in order to qualitatively compare the data to determine whether the water quality of runoff from the treatments caused a significant increase in pollutant concentrations, posed a moderate increase in some pollutants, or posed virtually no increase in pollutants. The range of values for this analysis are shown in Table 9-8.

The overall result of this analysis was that none of the products used for treatment caused a significant increase in pollutant concentrations. Runoff from five of the products (wood fiber blanket, bonded fiber matrix, straw-coconut blanket, and wheat straw incorporated) contained elevated levels of organic indicators (TOC, BOD5, and COD), suggesting that they are releasing organic materials that have an elevated oxygen demand (i.e., undergoing biodegradation). Because these particular constituents are not specifically “pollutants” they were not considered to be significant discriminators. Therefore, in lieu of a specific “ranking” scheme for water quality, these five products were qualified to note their propensity to release oxygen-demanding organics.

Table 9-2
EROSION RATE RATING SCALE

Erosion Rate Reduction (Compared to Bare Soil)	Rating
91 – 100%	10
81 - 90%	9
71 - 80%	8
61 - 70%	7
51 - 60%	6
41 - 50%	5
31 - 40%	4
21 - 30%	3
11 - 20%	2
1 - 10%	1
0%	0

Table 9-3
TOTAL COVER RATING SCALE

Cover Class(1)	Rating(2)
6	10
5	8.33
4	6.67
3	5.0
2	3.33
1	1.67
0	0

(1)Daubenmire cover class.

(2)Based on mean total cover estimation for all plants (natives and non-natives).

Table 9-4
TREATMENT RANKINGS NON-IRRIGATED FILL SLOPE

Treatment	Rating (1 – 10)				Other Criteria			
	Erosion Rate	Total Cover After 2 Years	Total Rating	Ranking	Water Quality	Number of Native Plants After 2 Years	Native Plant Rating	Installed Cost per Ha
Bonded Fiber Matrix (BFM)	10	4.7	14.7	7	*	1	Low	$13,600
Coconut Blanket (CB)	10	5.8	15.8	2		2	Low	$32,000
Coir (COIR)	10	5.2	15.2	4		1	Low	$77,000
Compost (COMP)	4	4.8	8.8	14		37	High	$ 1,200
Curled Wood Fiber Blanket (CWFB)	10	4.8	14.8	6		0	Low	$26,000
Gypsum, Rate 1 (GYP1)	8	5.2	13.2	10		11	Medium	$ 2,000
Gypsum, Rate 2 (GYP2)	8	5.6	13.6	8		22	High	$ 2,400
Paper Mulch wth Psyllium (PMG)	7	5.6	12.6	12		10	Medium	$ 2,400
Paper Mulch with Polymer (PMP)	8	5.4	13.4	9		2	Low	$ 2,800
Wheat Straw Incorporated (RS)	10	6.0	16.0	1	*	2	Low	$ 5,200
Straw Blanket (SB)	10	5.2	15.2	4	*	2	Low	$22,000
Straw Coconut Blanket (SCB)	10	5.4	15.4	3	*	6	Low	$27,000
Wood Fiber Blanket (WFB)	10	5.0	15.0	5	*	32	High	$22,000
Wood Mulch with Psyllium (WMG)	9	3.7	12.7	11		10	Medium	$ 2,500
Wood Mulch with Polymer (WMP)	6	5.6	11.6	13		6	Low	$ 2,900

Notes: Cover ratings have been normalized from Daubenmire scale values to a scale of 1 to 10.
(*) Indicates that runoff from treatments may contain elevated level of oxygen-demanding organics and/or nutrients in runoff.
For Native Plant Rating: >25 = High
10 – 25 = Medium
<10 = Low

Table 9-5
TREATMENT RANKINGS IRRIGATED FILL SLOPE

Treatment	Rating (1 – 10)		Total Rating	Ranking	Other Criteria			
	Erosion Rate	Total Cover After 2 Years			Water Quality	Number of Native Plants After 2 Years	Native Plant Rating	Installed Cost per Ha
Bonded Fiber Matrix (BFM)	10	6.0	16.0	5	*	13	Medium	$13,600
Coconut Blanket (CB)	10	6.0	16.0	4		0	Low	$32,000
Coir (COIR)	10	5.7	15.7	6		0	Low	$77,000
Compost (COMP)	4	6.1	10.1	14		17	Medium	$ 1,200
Curled Wood Fiber Blanket (CWFB)	10	6.0	16.0	3		0	Low	$26,000
Gypsum, Rate 1 (GYP1)	8	5.7	13.7	8		2	Low	$ 2,000
Gypsum, Rate 2 (GYP2)	8	5.0	13.0	10		6	Low	$ 2,400
Paper Mulch wth Psyllium (PMG)	7	6.0	13.0	12		3	Low	$ 2,400
Paper Mulch with Polymer (PMP)	8	6.4	14.4	9		4	Low	$ 2,800
Wheat Straw Incorporated (RS)	10	5.8	15.8	1	*	3	Low	$ 5,200
Straw Blanket (SB)	10	6.9	16.9	2	*	0	Low	$22,000
Straw Coconut Blanket (SCB)	10	6.0	16.0	4	*	0	Low	$27,000
Wood Fiber Blanket (WFB)	10	5.8	15.8	7	*	2	Low	$22,000
Wood Mulch with Psyllium (WMG)	9	6.8	15.8	11		14	Medium	$ 2,500
Wood Mulch with Polymer (WMP)	6	6.2	12.2	13		11	Medium	$ 2,900

Notes: Cover ratings have been normalized from Daubenmire scale values to a scale of 1 to 10.
(*) Indicates that runoff from treatments may contain elevated level of oxygen-demanding organics and/or nutrients in runoff.
For Native Plant Rating: >25 = High
10 – 25 = Medium
<10 = Low

Table 9-6
TREATMENT RANKINGS NON-IRRIGATED CUT SLOPE

Treatment	Rating (1 – 10)		Total Rating	Ranking	Other Criteria			
	Erosion Rate	Total Cover After 2 Years			Water Quality	Number of Native Plants After 2 Years	Native Plant Rating	Installed Cost per Ha
Bonded Fiber Matrix (BFM)	10	5.8	15.8	2	*	29	High	$13,600
Coconut Blanket (CB)	10	6.0	16.0	2		0	Low	$32,000
Coir (COIR)	10	5.6	15.6	4		4	Low	$77,000
Compost (COMP)	4	5.8	9.8	9		6	Low	$ 1,200
Curled Wood Fiber Blanket (CWFB)	10	6.3	16.3	2		0	Low	$26,000
Gypsum, Rate 1 (GYP1)	8	6.9	14.9	6		2	Low	$ 2,000
Gypsum, Rate 2 (GYP2)	8	6.5	14.5	7		3	Low	$ 2,400
Paper Mulch wth Psyllium (PMG)	7	6.1	13.1	7		1	Low	$ 2,400
Paper Mulch with Polymer (PMP)	8	6.6	14.6	5		3	Low	$ 2,800
Wheat Straw Incorporated (RS)	10	7.2	17.2	3	*	10	Medium	$ 5,200
Straw Blanket (SB)	10	6.4	16.4	1	*	0	Low	$22,000
Straw Coconut Blanket (SCB)	10	6.0	16.0	2	*	4	Low	$27,000
Wood Fiber Blanket (WFB)	10	5.2	15.2	3	*	9	Low	$22,000
Wood Mulch with Psyllium (WMG)	9	5.4	14.4	3		28	High	$ 2,500
Wood Mulch with Polymer (WMP)	6	6.3	12.3	8		28	High	$ 2,900

Notes: Cover ratings have been normalized from Daubenmire scale values to a scale of 1 to 10.
(*) Indicates that runoff from treatments may contain elevated level of oxygen-demanding organics and/or nutrients in runoff.
For Native Plant Rating: >25 = High
10 – 25 = Medium
<10 = Low

Table 9-7
TREATMENT RANKINGS IRRIGATED CUT SLOPE

Treatment	Rating (1 – 10)		Total Rating	Ranking	Other Criteria			
	Erosion Rate	Total Cover After 2 Years			Water Quality	Number of Native Plants After 2 Years	Native Plant Rating	Installed Cost per Ha
Bonded Fiber Matrix (BFM)	10	6.6	16.6	3	*	33	High	$13,600
Coconut Blanket (CB)	10	6.3	16.3	5		4	Low	$32,000
Coir (COIR)	10	5.8	15.8	6		1	Low	$77,000
Compost (COMP)	4	6.8	10.8	13		18	Medium	$ 1,200
Curled Wood Fiber Blanket (CWFB)	10	6.9	16.9	2		0	Low	$26,000
Gypsum, Rate 1 (GYP1)	8	7.0	15.0	8		10	Medium	$ 2,000
Gypsum, Rate 2 (GYP2)	8	6.8	14.8	9		7	Low	$ 2,400
Paper Mulch wth Psyllium (PMG)	7	6.4	13.4	12		2	Low	$ 2,400
Paper Mulch with Polymer (PMP)	8	6.5	14.5	10		5	Low	$ 2,800
Wheat Straw Incorporated (RS)	10	6.6	16.6	3	*	3	Low	$ 5,200
Straw Blanket (SB)	10	7.0	17.0	1	*	1	Low	$22,000
Straw Coconut Blanket (SCB)	10	6.4	16.4	4	*	0	Low	$27,000
Wood Fiber Blanket (WFB)	10	6.6	16.6	3	*	14	Medium	$22,000
Wood Mulch with Psyllium (WMG)	9	6.4	15.4	7		4	Low	$ 2,500
Wood Mulch with Polymer (WMP)	6	7.5	13.5	11		8	Low	$ 2,900

Notes: Cover ratings have been normalized from Daubenmire scale values to a scale of 1 to 10.
(*) Indicates that runoff from treatments may contain elevated level of oxygen-demanding organics and/or nutrients in runoff.
For Native Plant Rating: >25 = High
10 – 25 = Medium
<10 = Low

Table 9-8
VALUES USED FOR WATER QUALITY EVALUATION

Constituent	Caltrans Statewide Range
pH	6.6 – 17.3 mg/L
COD	10 – 480 mg/L
BOD5	3 – 37 mg/L
Nitrite	0.2 – 8.3 mg N/L
Nitrate	0.1 – 1.7 mg N/L
TKN	1 – 57 mg N/L
Phosphorus	0.05 – 3.3 mg P/L
Al	25 – 200 μg/L
As	1 - 15 μg/L
Cd	05 –6.1 μg/L
Cu	2 - 140 μg/L
Cr	2 - 50 μg/L
Fe	100 - 7500 μg/L
Hg	0.2 – 0.2 μg/L
Pb	0.5 – 300 ug/L
Ni	5 – 50 μg/L
Zn	6.56 – 1300 μg/L

Note: All metals data are for dissolved metals.

Because runoff from the bare soil plots also contained some constituents, the runoff quality from the treatments were compared to that from the bare plots (Tables 5-2 and 5-3). In general, none of the runoff samples had water quality impacts that were considered to be a detriment, in that the runoff quality was generally better than urban runoff.

9.4.1 Additional Selection Criteria

The treatments in this study were ranked in accordance with the criteria that were evaluated as part of the ECPS testing program. However, there are other subjective evaluation criteria that may be considered when selecting an appropriate erosion control measure for a given set of site conditions.

Examples of other selection criteria include:

- Long-term cost (maintenance)
- Environmental compatibility
- Regulatory acceptability
- Availability
- Durability

- Longevity
- Feasibility
- Public acceptability
- Risk/liability
- Suitability for the site

9.5 OVERALL EVALUATION OF PLANT COVER TESTS

The value of the outdoor laboratory myoporum tests is to gain an understanding of how erosion rate varies with vegetative cover. This is important because vegetation takes time to grow to a degree where it can provide effective erosion control, and other erosion control measures should be provided until that effectiveness is achieved. The data show that the erosion rate drops dramatically from 35 percent to 65 percent plant cover, and then tends to reduce more gradually or level off with increased plant cover.

9.6 OVERALL EVALUATION OF FIELD EROSION RATE TESTS

The value of the field erosion rate tests is in comparing non-irrigated grass/forb complex, irrigated myoporum, irrigated iceplant, and non-irrigated coastal sage scrub vegetation types in terms of their relative erosion control effectiveness at 90 to 100 percent plant cover on highway cut and fill slopes. The results of that evaluation showed that the coastal sage scrub and iceplant were the most effective at controlling erosion on cut slopes and fill slopes. Myoporum ranked next in effectiveness. The least effective vegetation type was grass/forb.

Interestingly, three types of vegetation (coastal sage scrub, iceplant, and myoporum) on cut slopes and two types of vegetation (iceplant and coastal sage scrub) on fill slopes exhibited the same or less erosion than off-highway, undisturbed coastal sage scrub.

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Form 1	Site Characteristics Monitoring Form – Erosion Rate Test Plots
Form 2	Site Characteristics Monitoring Form – Plant Establishment Test Plots
Form 3	Rainfall Monitoring Form
Form 4	Irrigation System Operating Record – Irrigated Plant Establishment Test Plots
Form 5	Erosion Rate Monitoring Form
Form 6	Species Diversity and Vegetation Cover Monitoring Form – Erosion Rate Test Plots
Form 7	Plant Density Monitoring Form – Erosion Rate Test Plots
Form 8	Species Diversity, Vegetation Cover, and Plant Density Monitoring Form – Plant Establishment Test Plots
Form 9	Seedling Vigor Monitoring Form – Plant Establishment Test Plots
Form 10	Growth Rate and Root Depth Monitoring Form – Plant Establishment Test Plots
Form 10A	Tag Locations for 1M by 1M Quadrat – Plant Establishment Test Plots
Form 11	Soil Analysis Request Form and Work Orders
Form 11A	Soil Analysis Work Order – Soil Foodweb
Form 11B	Soil Analysis Work Order – Agri Service
Form 13	Site Inspection Form – Plant Establishment Test Plots
Form 14	Plot Plan for Plant Establishment Test Plots
Form 14A	Supplemental Comments – Plot Plan for Plant Establishment Test Plots

FORM 1

SITE CHARACTERISTICS MONITORING FORM
EROSION RATE TEST PLOTS

Type of Site / Test Plot	Site Number	SITE CHARACTERISTICS[1]					Monitors	Date	Photo ID
		Cut/Fill or Natural	Soil Type[2]	Slope		General Comments[3]			
				Gradient	Aspect				
REFERENCE SLOPES									
Coastal Sage Scrub	210-1	Cut	Sandy Clay		W/SW 241°	none	Blanc/Griswold	12/2/98	
Coastal Sage Scrub	210-10	Fill	Sandy Clay w/gravel		S/SW 211°	Rain 0.2 [illegible] 1:30 pm	Blanc/Griswold	12/2/98	
Grass/Forb Complex	57-4	Cut	Silty Sand w/gravel		E/SE 140°	many gophers	Blanc/Griswold	12/2/98	
Grass/Forb Complex	10-2	Fill	Clayey Sand		S/SE 160°	many gophers - old mounds	[illegible]	12/2	
Iceplant	105-6	Cut	Silty Sand		N/NW 336°	Clean [illegible]	Griswold	12/4/98	
Iceplant	405-6	Fill	Silty Sand w/gravel		S/SE 171°	clean [illegible] depressions where [illegible]	Griswold	12/4/98	
Myoporum	105-8	Cut	Silty Sand		N/[illegible] 351°	[illegible] material [illegible] top [illegible]	Griswold	12/4/98	
Myoporum	105-3	Fill	Clayey Silty Sand		N/NE 10°	same [illegible]	[illegible]	[illegible]	
BASELINE SLOPES									
Bare ground	57-4	Cut	Silty Sand w/gravel		E/SE 130°	Minor gophers	Blanc/Griswold	12/2/98	
Bare ground	10-2	Fill	Clayey Sand		S/SE 160°	No gophers	Blanc/Griswold	12/2/98	
RESEARCH SLOPE									
Coastal Sage Scrub	R1	Natural	Clayey Sand		West 280°	slick paths	Blanc/Griswold	12/2/98	

(1) Data will be recorded only once per test plot, when the test plot is established.
(2) Soil type from laboratory tests performed for that purpose; Unified Soil Classification System (USDA textural classification also available).
(3) Including indications of previous disturbance.

FORM 2

SITE CHARACTERISTICS MONITORING FORM
PLANT ESTABLISHMENT TEST PLOTS

Type of Site / Test Plot	Site Number	SITE CHARACTERISTICS(1)					Monitors	Date	Photo ID
		Cut/Fill	Soil Type(2)	Slope		General Comments(3)			
				Gradient	Aspect				
Non-irrigated	57-4	Cut	Silty Sand w/gravel		E/SE 121°	gophers	Blane/ Griswold	12/2/98	
Non-irrigated	10-2	Fill	Clayey Sand		S/SE 160°	"	"	12/2/98	
Irrigated	57-4	Cut	Silty Sand w/gravel		E/SE 121°	"	"	"	
Irrigated	10-2	Fill	Clayey Sand		S/SE 160°	"	"	"	

(1) Data will be recorded only once per test plot, when the test plot is established.
(2) Soil type from laboratory tests performed for that purpose; Unified Soil Classification System (USDA textural classification also available).
(3) Including indications of previous disturbance.

FORM 3

RAINFALL MONITORING FORM

Site No.: R-1 Site Location: [illegible]

Type of Test Plots (circle one):

Erosion Rate (veg. type: [illegible]) Plant Establishment

Date	Time	Rain Gauge ___ Indiv.(1) Meas. (inches)	Cum. Meas. (inches)	Comment	Monitor
3/26/99	1205	0.50"	0.50"	Storm 3/25 0700 - 3/25 1300	GO.
4/2/99	1145	0.05"	0.05"	Scattered showers 4/1 1200 - 4/1 1300	GO
4/5/99	1130	0.03"	0.03"	Brief storm 4/3 1600 - 4/3 2200	GO.
4/7/99	1045	1.21"		Major storm 4/6 1300 - 4/7 1300	GO.
4/8/99	0800	0.02"	1.23"	"	GO
4/10/99	1315	0.01"	0.01"	Brief storm 4/8 2000 hrs - 2200 hrs	GO.
4/12/99	1005	0.82"		Major storm 4/11 1400 - 4/12 1600	GO
4/13/99	1345	0.14"	0.96"	"	60
4/26/99	1245	0.00"	0.00"	Widely scattered showers 4/23 pm	GO.
5/3/99	1030	0.00"	0.00"	Scattered showers 4/30 1600 - 1600	GO.
6/2/99	1145	0.55"		Unseasonable storm 6/2, 0100 -	60
6/4/99	1140	0.28"	0.83"	Continuing intermittent storms to 6/4 0600	60.
11/9/99	1500	0.24"	—	SCATTERED SHOWERS 11/8 0500 - 11/9 1200	DI
11/18/99	0940	0.00"	0.00"	WIDELY SCATTERED SHOWERS 11/17 0400 - 0900	DI
11/23/99	0900	0.00"	0.00"	WIDELY SCATTERED SHOWERS 11/20 0200 - 0600	DI
1/4/00	1300	0.00"	0.00"	WIDELY SCATTERED SHOWERS OFF + ON FROM 12/31-noon to 1/2/00 - 0200	DI
1/26/00	0800	0.70"	0.70"	STORM FROM 1/25 - 0500 to 1/26 - 0400	DI
2/1/00	0900	0.20"	0.20"	BRIEF STORM 1/31 - 0100 to 1/31 - 0500	DI
2/15/00	1050	1.42"	1.42"	STORM FROM 2/10 - 0600 - 2/13 1700	DI
2/18/00	1100	0.97"	0.97"	STORM FROM 2/16 - 0400 - 2/16 - 2200	DI
2/24/00	1230	3.61"	3.61"	STORM FROM 2/20 0300 to 2/23 - 1600	DI
2/29/00	1130	0.35"	0.35"	STORM 2/27 - 1300 2/27 - 2100	DI
3/7/00	1315	1.60"	1.60"	STORM FROM 3/3 - 0700 to 3/5 - 1200	DI

(1) Empty and reset rain gauge after each reading

FORM 4

IRRIGATION SYSTEM OPERATING RECORD
IRRIGATED PLANT ESTABLISHMENT TEST PLOTS

Site Number: 57-4 Site Location: Brea Canyon Rd

Date	Irrigation Times			Amount of Water Applied* (inches)							General Comments on Soil Conditions	Operator
	Start	Stop	Duration	1	2	3	4	5	Avg.	Total Vol. (gals. or c.f.)		
12/11/98	1005	1018	13 MIN	↓	↓	↓	↓	↓	↓	190 gal	Adjust 3 of sprinkler heads to achieve more uniform coverage	GO.
12/11/98	1211	1225	14 MIN	2mm	3mm	2mm	3mm	4mm	2.8mm	190 gal	Depth of soil penetration 3/4"-1" ±	GO.
12/15/98	1116	1129	13 MIN	↓	↓	↓	↓	↓	↓	200 gal	Santa Ana winds today	GO.
12/15/98	1217	1229	12 MIN	3mm	3mm	2mm	2mm	3mm	2.6mm	185 gal	Depth of soil penetration 1" ±	GO
12/18/98	1046	1058	12 MIN	↓	↓	↓	↓	↓	↓	190 gal		GO.
12/18/98	1339	1352	13 MIN	3mm	2mm	2mm	3mm	3mm	2.6mm	190 gal	Depth of soil penetration 1"-1½" ±	GO
12/27/98	0657	0709	12 MIN	↓	↓	↓	↓	↓	↓	190 gal		GO.
12/27/98	0728	0741	13 MIN	3mm	4mm	3mm	3mm	5mm	3.6mm	190 gal	Depth of soil penetration 1"-1¼" ±	GO
12/30/98	1132	1144	12 MIN	↓	↓	↓	↓	↓	↓	190 gal	12/30 Santa Ana wind condition	GO
12/30/98	1201	1214	13 MIN	4mm	4mm	3mm	4mm	4mm	3.8mm	190 gal	Depth of soil penetration 3/4"-1¼" ±	GO.
1/3/99	0854	0907	13 MIN	↓	↓	↓	↓	↓	↓	190 gal.	1/3 Santa Ana wind condition	GO
1/3/99	0930	0943	13 MIN	0.11"	0.08"	0.09"	0.09"	0.08"	0.09"	190 gal.	Soil penetration 1/2"-3/4"	GO.
1/4/99	1311	1313	2 MIN	↓	↓	↓	↓	↓	↓	35 gal	1/4 Santa Ana winds	GO
1/4/99	1324	1332	8 MIN	↓	↓	↓	↓	↓	↓	155 gal	Change sprinkler head nozzels from #5 to #7 (2 orifice to 3 orifice) to achieve more even distribution	GO.

* Irrigation gauges are numbered left-to-right, top-to-bottom

FORM 5

EROSION RATE SAMPLE LOG
EROSION RATE TEST PLOTS

Site No.: 57-4 Site Location: BREA CANYON Rd Plot No. (circle one): (A) B C

Type of Test Plots (circle one): (Baseline) Iceplant Myoporum Coastal Sage Scrub Grass/Forb Complex

Sediment Collection		Rainfall Event			Sample Information					Comments	Date/Time Del. to Lab	Monitor
		Date		Amount [1]								
Date	Time	From	To	(inches)	Sample No.	Sample Source (note 2)	Type of Container (note 3)	No. of Containers	Approx. Vol.			(note 4)
2/25/00	0700	2/20-0300	2/23-1600	3.65"	451	CATCH BUCKET	BUCKET	1	5 gal.		2/25 [illegible]	[illegible]
"	"	"	"	"	"	PRIMARY BARREL	"	9	5 gal.	CATCH BUCKET OVERFLOW	"	DI
"	"	"	"	"	"	"	BARREL LINER	1	1 gal	LINER PLACED IN BUCKET	[illegible]	DI
"	"	"	"	"	"	"	BUCKET	1	4½ gal.	FLUSH WATER	[illegible]	DI
"	"	"	"	"	"	OVER FLOW BARREL	"	8	5 gal.	OVER FLOW DRUM	[illegible]	DI
"	"	"	"	"	"	"	BARREL LINER	1	1 gal	LINER PLACED IN BARREL	"	DI
2/29/00	0700	2/27-1300	2/[illegible]-2[illegible]	0.22"	—	—	—	—	2 gal.	RUNOFF DRAINED	[illegible]	[illegible]
3/[illegible]/00	1100	3/3-1300	3/5-1800	1.64"	50[illegible]	PRIMARY BARREL	BUCKET	5	25 gal.	CATCH BUCKET OVERFLOW	3/[illegible] [illegible]	DI
3/7/00	1000	"	"	"	"	CATCH BUCKET	"	1	5 gal.		3/[illegible] [illegible]	[illegible]
"	"	"	"	"	"	PRIMARY BARREL	BARREL LINER	1	3 [illegible]	LINER PLACED IN BUCKET		[illegible]
"	"	"	"	"	"	FLUME & PIPE	BUCKET	1	4 gal.	FLUSH WATER		[illegible]
3/9/00	1000	3/7-2400	3/8-1400	0.77"	550	CATCH BUCKET	"	1	5 gal.		3/9 [illegible]	[illegible]
"	"	"	"	"	"	PRIMARY BARREL	"	2	9 gal.	CATCH BUCKET OVERFLOW	[illegible]	[illegible]
"	"	"	"	"	"	"	BARREL LINER	1	1 gal.	LINER PLACED IN BUCKET	[illegible]	[illegible]
"	"	"	"	"	"	FLUME & PIPE	BUCKET	1	4½ gal.	FLUSH WATER	[illegible]	DI

(1) Cumulative rain gauge measurement from Form 3.
(2) Sample sources include: catch bucket; primary and overflow barrels; and flume.
(3) Sample types include: buckets; barrel liners; and baggies.
(4) Name(s) of monitor(s) for collecting samples and delivering samples to the laboratory.

FORM 6

SPECIES DIVERSITY AND VEGETATION COVER MONITORING FORM
EROSION RATE TEST PLOTS

Date of Data Collection: 4/24/00 Monitor(s): [illegible] / Griswald

Site No.: 10-2 Site Location: DeVry

Type of Test Plots (circle one): Iceplant Myoporum Coastal Sage Scrub **(Grass/Forb Complex)**

Plot Size and Sampling Area: 8 meters by 2 meters

	Species[1]	Cover Class, Daubenmire Scale[2] (circle one)	Comment
Plot No.[3] A	BRA NIG	1 2 3 4 (5) 6	
	BRO DIA	1 2 3 4 (5) 6	
	SIL MAR	(1) 2 3 4 5 6	
Total Cover Daubenmire	RHA SAT	1 (2) 3 4 5 6	
Scale: 6		1 2 3 4 5 6	
Plot No. B	BRA NIG	1 2 3 4 (5) 6	
	BRO DIA	1 2 3 4 (5) 6	
	SIL MAR	(1) 2 3 4 5 6	
Total Cover Daubenmire	RHA SAT	(1) 2 3 4 5 6	
Scale: 6		1 2 3 4 5 6	
Plot No. C	BRA NIG	1 2 3 4 (5) 6	
	BRO DIA	1 2 3 4 (5) 6	
	SIL MAR	(1) 2 3 4 5 6	
Total Cover Daubenmire	RHA SAT	(1) 2 3 4 5 6	
Scale: 6		1 2 3 4 5 6	

(1) List all species to determine diversity
(2) Estimate cover of live vegetation only
(3) Plots are numbered left-to-right, looking upslope

Daubenmire Scale

Range of Cover		Cover Class	Range of Cover		Cover Class
0 - 5 %	=	1	50 - 75 %	=	4
5 - 25 %	=	2	75 - 95 %	=	5
25 - 50 %	=	3	95 - 100 %	=	6

FORM 7

PLANT DENSITY MONITORING FORM [1]
EROSION RATE TEST PLOTS

Date of Data Collection: 4-25-0[illegible] Monitors: [illegible]

Site Number: 10-2 Site Location: DeVry Plot No. (circle one): A (B) C

Type of Test Plots (circle one): Iceplant Myoporum Coastal Sage Scrub (Grass/Forb Complex)

Plot Size: 8 meters by 2 meters

Sampling Area: Four-¼ meter by ¼ meter quadrats randomly placed within test plot

PLANT TYPE Species	Density				Comment
SHRUB SPECIES:					PLANT CODE
None					
PERENNIAL SPECIES:					
None					
ANNUAL GRASS/FORB SPECIES:					
Brassica nigra	4	–	15	8	BRA NIG
Silybum marianum	1	–	1	3	SIL MAR
Bromus diandrus	65	15	19	40	BRO DIA
Sonchus asper	1	–	–	–	SON ASP
Raphanus sativus	–	1	–	–	RA SA
dead [illegible]	–	1		–	SIL MAR DEAD

(1) Density within the erosion rate test plots will be measured only once, during the final monitoring event

FORM 8

SPECIES DIVERSITY, VEGETATION COVER, AND PLANT DENSITY MONITORING FORM
PLANT ESTABLISHMENT TEST PLOTS

Date of Data Collection: 11/10/99 Monitors: Gary Deckert/Jake Gusman

Site Number: 57-4 Site Location: Brea Cyn. Rd. Plot Number: 3-13 Treatment: PMG

Irrigated: X Non-Irrigated:

Plot Size: 2 meters by 2 meters Sampling Area: 1 meter by 1 meter quadrat per plot

EST. OF TOTAL VEGETATION COVER WITHIN QUADRAT USING DAUBENMIRE SCALE:

0 1 2 3 [4] 5 6 BARDERVINE 75%

PLANT TYPE Species	Density(1), (2)	Cover Class, Daubenmire Scale(2) (circle one)	Comments
SHRUB SPECIES:			
ART CAL	0	[0] 1 2 3 4 5 6	
ENC CAL	1	0 [1] 2 3 4 5 6	
ERI FAS	5	0 [1] 2 3 4 5 6	
ISO MEN	0	[0] 1 2 3 4 5 6	
LOT SCO	1	0 [1] 2 3 4 5 6	
SAL MEL	0	[0] 1 2 3 4 5 6	
PERENNIAL GRASSES:			
HOR CAL	0	[0] 1 2 3 4 5 6	
NAS PUL	0	[0] 1 2 3 4 5 6	
ANNUAL GRASS/FORB SPECIES:			
LAS CAL	--	[0] 1 2 3 4 5 6	
LUP BIC	--	[0] 1 2 3 4 5 6	
VUL OCT	--	0 [1] 2 3 4 5 6	
WEEDS/OTHER:			
Total Non-Native Grasses	--	0 1 2 3 [4] 5 6	
Total Non-Native Broadleaves	--	0 1 [2] 3 4 5 6	
Unknown Grasses	0 --	[0] 1 2 3 4 5 6	

(1) Measure density within 1 m x 1 m quadrat.
(2) Enter or circle "0" to indicate species not observed.

Daubenmire Scale

Range of Cover		Cover Class	Range of Cover		Cover Class
0 - 5 %	=	1	50 - 75 %	=	4
5 - 25 %	=	2	75 - 95 %	=	5
25 - 50 %	=	3	95 - 100 %	=	6

FORM 9

SEEDLING VIGOR MONITORING FORM
PLANT ESTABLISHMENT TEST PLOTS

Date of Data Collection: 11/10/99   Monitors: Gary Deckert/Jake Gusman

Site Number: 57-4   Site Location: Brea Cyn. Rd.   Plot Number: 3-13   Treatment: PMG

Irrigated: X   Non-Irrigated:

Plot Size: 2 meters by 2 meters   Sampling Area: 1 meter by 1 meter quadrat per plot

PLANT TYPE Species	Vigor[1] (circle one)	Comments[2]
SHRUB SPECIES:		
ART CAL	(M) 0 1 2 3 4 5 6 7 8	
ENC CAL	M 0 1 2 3 4 5 6 7 (8)	
ERI FAS	M 0 1 2 3 4 5 6 7 (8)	
ISO MEN	(M) 0 1 2 3 4 5 6 7 8	
LOT SCO	M 0 1 2 3 4 5 6 7 (8)	
SAL MEL	(M) 0 1 2 3 4 5 6 7 8	
PERENNIAL GRASSES:		
HOR CAL	(M) 0 1 2 3 4 5 6 7 8	
NAS PUL	(M) 0 1 2 3 4 5 6 7 8	
ANNUAL GRASS/FORB SPECIES:		
LAS CAL	(M) 0 1 2 3 4 5 6 7 8	
LUP BIC	(M) 0 1 2 3 4 5 6 7 8	
VUL OCT	M 0 1 2 3 4 5 6 (7) 8	
WEEDS:		
Non-Native Grasses	M 0 1 2 3 4 5 6 (7) 8	
Non-Native Broadleaves	M 0 1 2 3 4 5 6 (7) 8	
Unknown Grasses	(M) 0 1 2 3 4 5 6 7 8	

(1) Overall condition of plants within entire 1 m by 1 m quadrat. Assess plant vigor by assigning descriptor:

M = Species not present
0 = Dead
1 = Stunted growth/declining vigor
2 = Vigorous/robust growth
3 = Stunted growth / flower production
4 = Vigorous growth / flower production
5 = Stunted growth / seed production
6 = Vigorous growth / seed production
7 = Life cycle complete (annual species only)
8 = Summer dormant (shrubs/perennials only)

(2) Add comments on pests, disease or other conditions as noted.

FORM 10

GROWTH RATE AND ROOT DEPTH MONITORING FORM
PLANT ESTABLISHMENT TEST PLOTS

Date of Data Collection: 11/10/99 Monitors: Gary Deckert/Jake Gusman

Site Number: 57-4 Site Location: Brea Cyn. Rd. Plot Number: 3-13 Treatment: PMG

Irrigated: X Non-Irrigated:

Plot Size: 2 meters by 2 meters

Sampling Area: Measure the same three individuals of each shrub species at each sampling event.

Shrub Species	New (put an "X")	Tag No.(1)	Plant Height(1), cm	Root Depth(2), cm (longest plant root, up to 70 cm)	Comments
ART CAL		1			
		2			
		3			
ENC CAL		1	1.1		NEARLY DEAD
		2			
		3			
ERI FAS		1	2.8		
		2	5.2		
		3	1.5		NEARLY DEAD
ISO MEN		1			
		2			
		3			
LOT SCO		1	20.7		
		2			
		3			
SAL MEL		1			
		2			
		3			

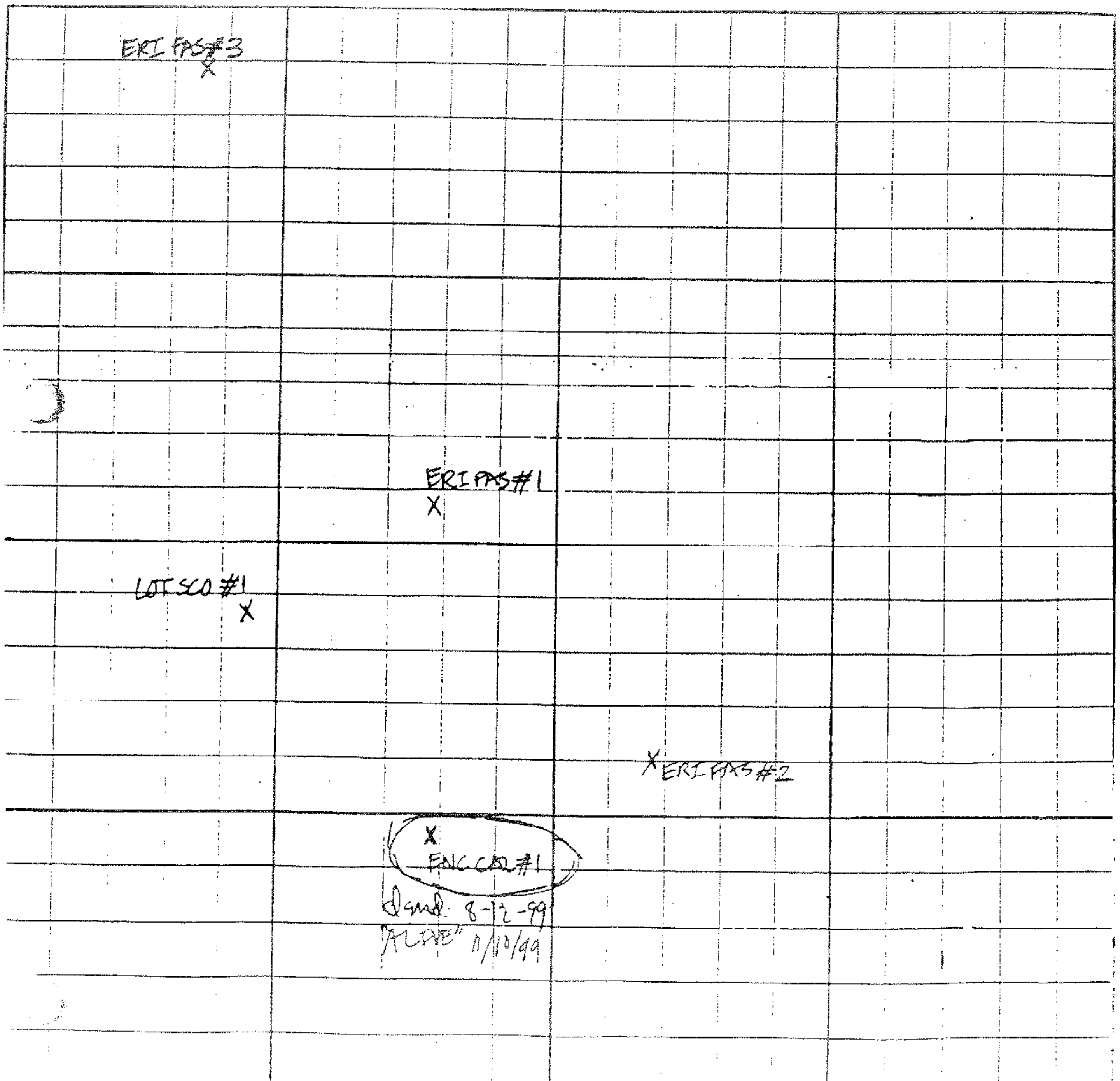
(1) Measure three of each shrub species nearest to diagonal line in each 1 m by 1 m quadrat.
(2) Sampling to be performed at end of last monitoring event of study period.

FORM 10A

TAG LOCATIONS - 1M BY 1M QUADRAT
PLANT ESTABLISHMENT TEST PLOTS

SITE: 57-4 PLOT: 3-13 TREATMENT: PMG

Irrigated: (Y) N



FORM 11

SOIL ANALYSIS REQUEST

Caltrans District 7 Erosion Control Pilot Study

URS Greiner Woodward Clyde
(formerly Woodward-Clyde International, Inc.)
2020 East First Street, Suite 400
Santa Ana, CA 92705
Phone:(714) 835-6886
Fax:(714) 667-7147

To: ☐ SOIL FOODWEB ☒ AGRI SERVICE
P.O. Number: 4-977001NM
Send Results and Invoice To: Jean Hill

Directions to URS Greiner Woodward Clyde Staff:

1. Select Soil Foodweb (microbial analysis) or Agri Service (chemical analysis) above, and complete the Purchase Order Number *(3-977001NM for Soil Foodweb, and 4-977001NM for Agri Service)*.
2. Fill in soil sample and site information in the table below. Use additional forms as required.
3. Complete a work order form *(see file T:\1997\977001NM\Soil Testing\Purchase Order)*.
4. Send soil samples, a completed copy of this form, and a completed work order form to the lab by OVERNIGHT DELIVERY *(see addresses at bottom of this form)*. Retain a copy of completed forms for the project file.

Sample No.	Site No.	Plot No.	Date of Sample (mm/dd/yy)	Time of Sample (24-hr clock)	Irrigation	Additional Information / Comments
30	405-6	RA	6/7/99	0700	(Y) N	
31	"	RB		"	(Y) N	
32	"	RC		"	(Y) N	
33	105-6	RA		0830	(Y) N	
34	"	RB		"	(Y) N	
35	"	RC		"	(Y) N	
36	105-8	RA		0930	(Y) N	
37	"	RB		"	(Y) N	
38	"	RC		"	(Y) N	
39	105-3	RA		1030	(Y) N	
40	"	RB		"	(Y) N	
41	"	RC	↓	"	(Y) N	
					Y N	
					Y N	
					Y N	
					Y N	
					Y N	

AGRI SERVICE
Attn: Ms. Mary Mataiva
2142 "B" Industrial Court
Vista, CA 92083
Phone: (760) 727-5454
Fax: (760) 727-0784

SOIL FOODWEB
Attn: Ms. Lynn Rogers
980 NW Circle Blvd.
Corvallis, OR 97330
Phone: (541) 752-5066
Fax: (541) 752-5142

FORM 11A

WORK ORDER NO. 16

WOODWARD-CLYDE INTERNATIONAL-AMERICAS ("Woodward-Clyde")
2020 East First Street, Suite 400 • Santa Ana, California 92705
714-835-6886 • fax: 714-667-7147

Vendor Name:	Soil Foodweb Inc.	Order Date:	6/8/99
		P.O./Project No.:	3-977001NM (10/19/98)
Address:	980 Northwest Circle Rd. Corvallis, OR 97330	Project Name:	Caltrans District 7 Erosion Control Pilot Study
Phone:	541-752-5066	Location:	Los Angeles County
Fax:	541-752-5142		
Contact:	Lynn Rogers	Project Manager:	Jean Hill

QUANTITY	DESCRIPTION / REQUIREMENTS[1]	UNIT PRICE	TOTAL COST(S)
15	Active Bacterial Biomass Assay	$ 7.50	$112.50
15	Active Fungal Biomass Assay	$ 7.50	$112.50
15	Protozoa Numbers (Flagellates, Amoebae, Ciliates)	$30.00	$450
15	VAM Root Colonization (where roots are present)	$30.00	$450
	TOTAL COST OF ORDER		$1125

1. Tests will be performed in accordance with Standard Operating Procedures developed by Elaine R. Ingham, Dept. of Botany and Plant Pathology, Oregon State University, Corvallis, OR 97331, unless otherwise mutually agreed upon in writing.

Submit invoices to the attention of the Project Manager at the above address.

This order is subject to the Terms and Conditions stated on the referenced Purchase Order.

Work Order By: [signature] A. JAKE GUSMAN

Date: 6/8/99

FORM 11B

WORK ORDER NO. 16

WOODWARD-CLYDE INTERNATIONAL-AMERICAS ("Woodward-Clyde")
2020 East First Street, Suite 400 • Santa Ana, California 92705
714-835-6886 • fax: 714-667-7147

Vendor Name:	Agri-Service	Order Date:	6/8/99
		P.O./Project No.:	4-977001NM (10/19/98)
Address:	2142 'B' Industrial Court Vista, California 92083	Project Name:	Caltrans District 7 Erosion Control Pilot Study
Phone:	760-727-5451	Location:	Los Angeles County
Fax:	760-727-0784	Project	
Contact:	Mary Mataiva	Manager:	Jean Hill

QUANTITY	DESCRIPTION / REQUIREMENTS	UNIT PRICE	TOTAL COST(S)
15	Chemical Soil Analysis, consisting of: • Saturation Percentage (Method S 1.00) • Soil pH (Method S 1.10) • Electrical Conductivity (Method S 1.20) • Chloride (Method S 1.40) • Boron (Method S 1.50) • Sodium Adsorption Ratio (Method S 1.60) • Nitrogen (Method S 3.10) • Phosphorus (Method S 4.10) • K, Ca, Mg, Na (Method S 5.10) • Zn, Mn, Fe, Cu (Method S 6.10) • Cation Exchange Capacity (Method S 10.10)	$ 40.00	$600
15	Organic Content (Method S 9.20)	$ 10.00	$150
		TOTAL COST OF ORDER	$750

Submit invoices to the attention of the Project Manager at the above address.

This order is subject to the Terms and Conditions stated on the referenced Purchase Order.

Work Order By: [signature] A. JAKE GUSMAN

Date: 6/8/99

FORM 12

SITE INSPECTION FORM
EROSION RATE TEST PLOTS

Site Number: 57-4 Site Location: BREA CANYON RD.

Type of Test Plots (circle one): (Bare) Iceplant Myoporum Coastal Sage Scrub Grass/Forb Complex

Date	OBSERVATIONS						Name of Inspector
	Fences, Gates, & Locks	Drums, Pipe, & Fittings	Rain Gauge	Vegetation within Plot Area	Vegetation Growth(1) (Bare Plots)	Inspection Comments/Maintenance Needs/Maintenance Performed(2)	
12/21/98	N/A OK Not OK	(OK) Not OK	(OK) Not OK	(OK) Not OK	Yes (No)	Two brief storms 12/19-12/20, 12/20-12/21 0.14" total rain. Discard water from collection drums. Plant growth nil inside plots. Systems look ok	Photos taken GD
1/3/99	N/A OK Not OK	(OK) Not OK	(OK) Not OK	OK (Not OK)	(Yes) No	New growth observed within baseline erosion rat. plots consisting mostly of grasses, Arroyo lupin (Lup suc) and radish (Rha sa). Apply thorough dose of Roundup.	GD.
1/7/99	N/A OK Not OK	(OK) Not OK	(OK) Not OK	(OK) Not OK	(Yes) No	Weed growth inside plots slow to react to 1/3 Roundup treatment. Open all collection barrels. 5 gallon buckets in primary drum contained live + dead insects, dump out & clean. Buckets dry. Plastic	GD. 4 photos
"	OK Not OK	OK Not OK	OK Not OK	OK Not OK	Yes No	liners in secondary barrels dry, no maintenance reqd. Paint rebar safety caps on pipe supports. Mortar fill voids in ground at connection of flumes with metal edging (ends of flume lip footing ditch)	1 of site 3 of plots
"	OK Not OK	OK Not OK	OK Not OK	OK Not OK	Yes No	clean flumes of organic debris and mortar smears. Rain gage empty. Police site of trash, tighten collection barrel wire supports Gopher activity minimal, one mound near top of B-A and another in B-B,	GD.
"	OK Not OK	OK Not OK	OK Not OK	OK Not OK	Yes No	none observed in B-C.	GD.
1/19/99	N/A OK Not OK	(OK) Not OK	(OK) Not OK	(OK) Not OK	Yes (No)	open collection barrels, dump out insects from 5 gal catch buckets, clean + replace. Paint tops of collection barrels and touch up sides as needed. Fine grade soil along exterior side of metal edging to fill gopher holes and even out the grade. Tighten hose clamps	GD.
"	OK Not OK	OK Not OK	OK Not OK	OK Not OK	Yes No	at connection of 4" flex pvc pipe to flume outlet nipple. Clean organic debris and mortar smears from inside of flume. Rain gage ok, dry. Police trash from around collection barrels.	GD.
2/5/99	N/A OK Not OK	(OK) Not OK	(OK) Not OK	(OK) Not OK	Yes (No)	place "rubber" pad (actually pvc) below catch bucket in B-B primary barrel to hopefully prevent leaks from developing in the barrel liner. Position photo vantage point stakes @ each plot, also on slope south	GD
"	OK Not OK	OK Not OK	OK Not OK	OK Not OK	Yes No	side of Brea Canyon rd. offramp for the triplicate photo. Rain last night + today (0.27"), plots look good with no obvious erosion features (rills, gullys etc). Photographed triplicate each plot	4 photos GD.

(1) For baseline (bare) plots only. If "Yes", then apply Round-up herbicide to emergent vegetation.
(2) Make minor repairs during inspection, if possible, and record. For all comments, record whether comment is applicable to Plot A, B, or C.

A:\forms12_13.doc

FORM 13

SITE INSPECTION FORM
PLANT ESTABLISHMENT TEST PLOTS

Site Number: 57-1 Site Location: BREA CANYON RD

Date	Fences, Gates, & Locks	Edging & Straw Tubes	Treatments within Subplots	Irrigation System	Inspection Comments/Maintenance Needs/Maintenance Performed[2]	Name of Inspector
	OBSERVATIONS					
12/21/98	N/A OK Not OK	OK (Not OK) circled	OK (Not OK) circled *	(OK) circled Not OK N/A	Gradual deterioration of straw tubes from gophers and normal wear + tear (plant weeding in progress). Treatments within subplots suffering gopher damage (holes + piles of loose soil). Need to replace string lines.	GO
12/30/98	N/A OK Not OK	OK (Not OK) circled	OK (Not OK) circled *	(OK) circled Not OK N/A	Irrigate today. "Weeding" of Imxim Quadrate withing plant establishment subplots is in progress. Straw waddles will need patching following the weeding. New gopher disturbance to subplots seems to be on the decline. Still trapping + setting out poison. Replacing subplot string lines with a	GO.
1/3/99	N/A OK Not OK	(OK) circled Not OK	OK (Not OK) circled *	(OK) circled Not OK N/A	more permanent heavy monofilament line.] Irrigate today, relatively strong Santa Ana winds less water in precipitation gages as a result. Gopher activity continuing. 1 killed just below 3-1, irrigated side. New bright green monofilament string line now in place to delineate subplots.	GO.
1/4/99	N/A OK Not OK	(OK) circled Not OK	OK (Not OK) circled *	OK (Not OK) circled N/A	Irrigate again today as dry Santa Ana weather dried out subplots rapidly. Change spray nozzel inserts in upper row of sprinkler heads from # 5 (2 orifice) to # 7 (3 orifice) to increase water fall along upper part of site. Water distribution	GO.
"	OK Not OK	OK Not OK	OK Not OK	OK Not OK N/A	appeared to be favoring the lower section. Seems better now. Also did some hand watering of subplots with garden hose equipped with suitable spray nozzel. Weeding of Imxim Quadrats completed today.	GO
1/7/99	N/A OK Not OK	(OK) circled Not OK	OK (Not OK) circled *	(OK) circled Not OK N/A	Irrigate today. Fairly even water distribution now. Weather still warm + dry. New gopher activity in irrigated plots 2-2 and 1-10, set trap. Rain gage OK. Non irrigated side no new gopher mounds today. Plant growth	2 photos from across freeway GO
"	OK Not OK	OK Not OK	OK Not OK	OK Not OK N/A	definitely suffering from the warm weather. Grasses thin + dark. Plant growth @ irrigated side, however, looks relatively healthy	GO.
1/18/99	N/A OK Not OK	(OK) circled Not OK	OK (Not OK) circled *	OK (Not OK) circled N/A	Irrigate today. Rain gage readings show uneven distribution of water today with heavy @ top, light @ bottom. @ 10-2 using the same system the water is more even. Will try adjusting pressure regulator next time.	GO
"	OK Not OK	OK Not OK	OK Not OK	OK Not OK N/A	Complete new signage on subplot. ID stakes, Gilbert S. did the work. Place rebar safety caps on remaining straw waddles + irrigation pipe steel staking. Gophers still very much a problem. New tunnels + mounds	GO.
"	OK Not OK	OK Not OK	OK Not OK	OK Not OK N/A	observable. Set 4 traps – Both irrigated + non irrigated sides showing about the same amount of gopher activity.	Photos taken on 1/20 1 Triplicate X 6 of plots

(*) Make minor repairs during inspection, if possible, and record. For all comments, record applicable plot number(s).

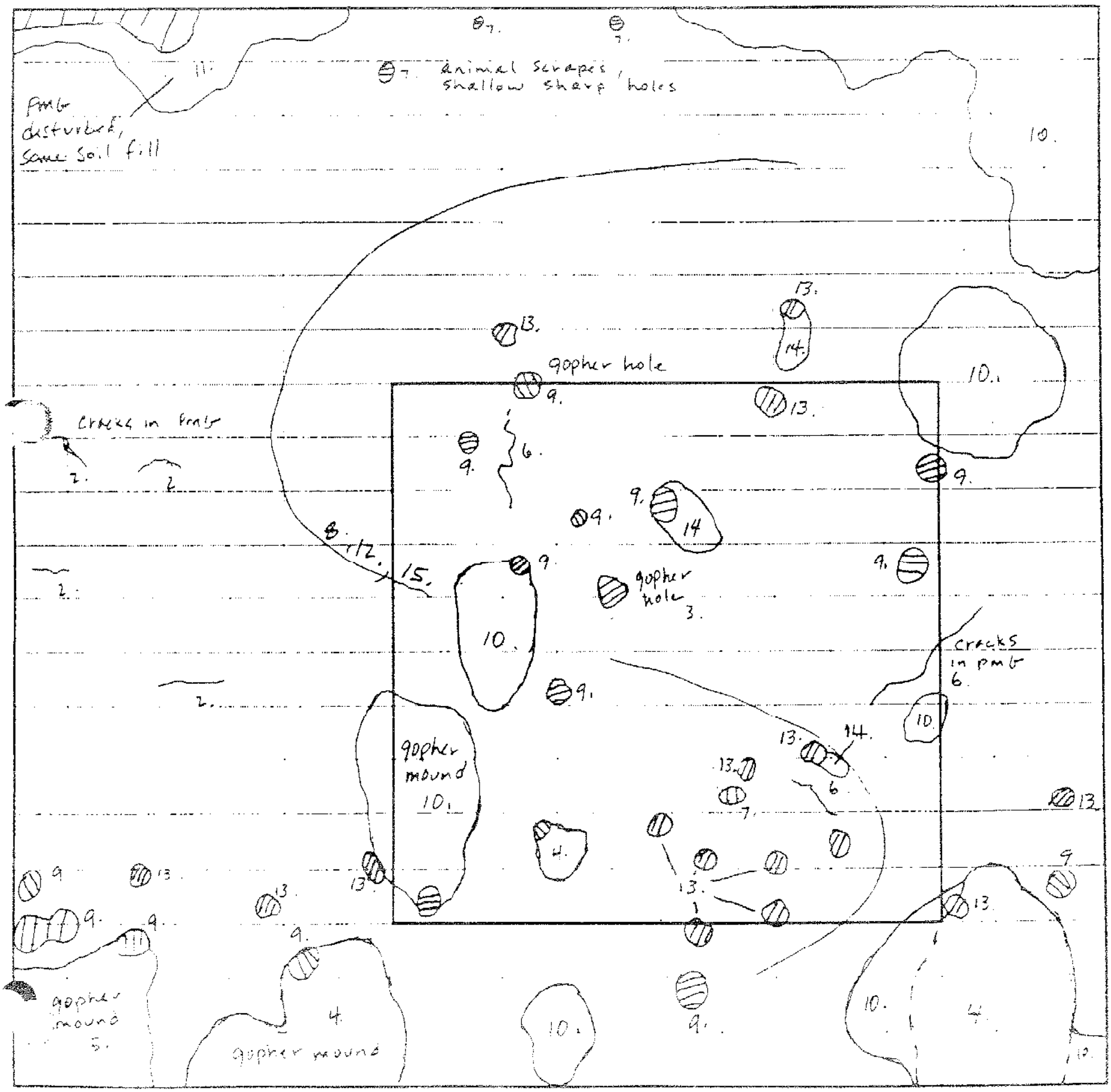
* Gopher disturbance

FORM 14

PLOT PLAN
PLANT ESTABLISHMENT TEST PLOTS

SITE: 57-4 PLOT: 2-6 TREATMENT: PMG

Irrigated: Y (N)



Scale = 1:10

See Forms 13 and 14A for additional comments regarding condition of plot

FORM 14A

SUPPLEMENTAL COMMENTS
PLOT PLAN for PLANT ESTABLISHMENT TEST PLOTS

SITE: 57-4 PLOT: 2-6 TREATMENT: PMG

Irrigated: Y (N)

DATE	COMMENT*	OBSERVER
1/23/99	1. treatment disturbed, soil exposed.	GO.
	2. Cracks in PMG layer, do not extend	GO.
	into subgrade, about 1/8" wide.	
	3. open gopher tunnel.	GO.
	4. gopher mounds, to 4" high.	GO.
4/16/99	5. new gopher mound.	GO.
	6. cracks in PMG, 1/8" wide, not	GO.
	into soil S.G..	
	7. small holes in subgrade, animal	GO.
	scrapes, edges sharp. Maybe	
	birds pecking.	
	8. PMG still more or less intact,	GO.
	rocks + gravels near surface have	
	been washed clean by the rains.	
7/20/99	9. new gopher holes	GO.
	10. new gopher soil mounds	GO.
	11. disturbance due to small	GO.
	vertebrates, some soil fill	
	drifting down onto subplot	
	12. Rocks and gravels @ surface more	GO.
	exposed, treatment still intact	
	where not disturbed as noted.	
9/9/99	13. NEW GOPHER HOLES.	DI
	14. NEW GOPHER MOUND	DI
	15. TREATMENT STILL INTACT - NOT	DI
	NOTICEABLY CHANGED FROM LAST INSP.	

* See Forms 13 and 14 for other comments regarding condition of plot (Form 14 is a graphic).

Form 1	Calibration Form – Erosion Control Treatments (Hydraulically-Applied)
Form 2	Rainfall Simulation Form – Soil Roughness / Erosion Rate Evaluation
Form 3	Sample Log – Soil Roughness / Erosion Rate Evaluation
Form 4	Rainfall Simulation Form – Erosion Control Treatment / Water Quality Evaluation
Form 5	Sample Log – Erosion Control Treatment / Water Quality Evaluation
Form 6	Myoporum Cover Form – Outdoor Myoporum Test Plots
Form 7	Rainfall Simulation Form – Vegetation Cover / Erosion Rate Evaluation
Form 8	Sample Log – Vegetation Cover / Erosion Rate Evaluation
Form 9	Rainfall Monitoring Form – Outdoor Myoporum Test Plots
Form 10	Irrigation System Operating Record – Outdoor Myoporum Test Plots
Form 11	Site Inspection Form – Outdoor Myoporum Test Plots

Form 1

CALIBRATION FORM FOR HYDRAULICALLY-APPLIED EROSION CONTROL TREATMENTS

Treatment	Weight of Material on Test Plot, kg	Weight of Material into Hydroseeder, kg	Replicate No.	Date	Time to Fill 15.1 Liters, sec			Average Fill Time, sec	Water in Hydroseeder, L	Time Required for Hydraulic Application, sec
	MAT_{plot}	MAT_{hydro}			t_4			$\bar{t}_4$	W_{hydro}	t(2)
BFM	Bonded Fiber = 1.36	Bonded Fiber = 27.22	1	5/5/00	35	32	38	35	567	66
WMP	Mulch = 0.91 Polymer = 0.93	Mulch = 11.34 Polymer = 2.95	1	5/19/00	22	21	20	21	378	42
WMS	Mulch = 0.91 Psyllium = 0.36	Mulch = 11.34 Psyllium = 1.13	1	5/12/00	22	22	23	22	378	44
PMP	Mulch = 0.91 Polymer = 0.93	Mulch = 11.34 Polymer = 2.95	1	5/13/00	19	20	20	20	378	40
PMS	Mulch = 2.0 Psyllium = 0.791	Mulch = 25 Psyllium = 2.5	1	5/10/00	20	20	20	20	378	40

(1) Plots were 0.67 m x 8 m in size (three replicates)

(2) Calculated as $\frac{W_{hydro} MAT_{plot} \bar{t}_4}{(15.1 L) MAT_{hydro}}$ and rounded to the nearest second

FORM 2

RAINFALL SIMULATION FORM
SOIL ROUGHNESS / EROSION RATE EVALUATION

Roughness Designation[1]	Storm Designation[2]	Replicate Number	Date	PART 1 Intensity (mm/hr)	PART 1 Duration (min)	PART 1 Start Time[3]	PART 1 End Time[3]	PART 2 Intensity (mm/hr)	PART 2 Duration (min)	PART 2 Start Time	PART 2 End Time	PART 3 Intensity (mm/hr)	PART 3 Duration (min)	PART 3 Start Time	PART 3 End Time
ROL	50yr-1	1	3/7/00	5mm/hr	30	0900	0930	55	25	0930	0955	5	30	0955	1025
		2	3/8/00	↓	↓	0900	0930	55	25	0930	0955	↓	↓	0955	1025
		3	3/9/00	↓	↓	0900	0930	55	25	0930	0955	↓	↓	0955	1025
ROL	50yr-2	1	3/3/00	↓	↓	0900	0930	38	50	0930	1020	↓	↓	1020	1050
		2	3/4/00	↓	↓	0900	0930	38	50	0930	1020	↓	↓	1020	1050
		3	3/6/00	↓	↓	0900	0930	38	50	0930	1020	↓	↓	1020	1050

(1) Roughness Designation: ROL (Smooth Rolling), RIP (Ripping), SFR (Sheepsfoot Rolling), TRW (Track Walking), or IMP (Imprinting)

(2) Storm Designation (see Table 2): 5YR-1, 5YR-2, 10YR-1, 10YR-2, 50YR-1, or 50YR-2

(3) Use 24 hour clock (e.g., 1430) for Start Time and End Time

FORM 3

SAMPLE LOG
SOIL ROUGHNESS/EROSION RATE EVALUATION

Roughness Designation (circle one): (ROL) RIP SFR TRW IMP

Storm Designation (circle one): (5YR-1) 5YR-2 10YR-1 10YR-2 50YR-1 50YR-2

Replicate Number (circle one): (1) 2 3

Date: 2/15/00 Name of Person(s) Collecting Samples: Monica / Derek / Corrin

Sample No. (1)	Rainfall Event Part No. (1, 2, or 3)	Sample Start Time (24 hr Clock)	Sample End Time (24 hr Clock)	Runoff Volume (L)	Dry Weight (kg)	Comments
1	1	0900	0930	30.3	34.1	
2	2	0930	0950	86.3	15.3	
3	2	0930	0950	104.9	14.0	
4	3	0950	1020	68.9	14.7	

(1) Label each sample container with the sample no., roughness designation, storm designation, replicate no., and date.

FORM 4

RAINFALL SIMULATION FORM
EROSION CONTROL TREATMENT / WATER QUALITY EVALUATION

Treatment Designation[1]	Storm Designation	Replicate Number	Date	PART 1 Intensity (mm/hr)	PART 1 Duration (min)	PART 1 Start Time[2]	PART 1 End Time[2]	PART 2 Intensity (mm/hr)	PART 2 Duration (min)	PART 2 Start Time	PART 2 End Time	PART 3 Intensity (mm/hr)	PART 3 Duration (min)	PART 3 Start Time	PART 3 End Time
BARE	10yr-2	1 *	4/28	5 ~~30~~	30	1000	1030	40	40	1030	1110	5	30	1110	1140
		2 *	4/28	5	30	1000	1030	40	40	1030	1110	5	30	1110	1140
		3 *	4/28	5	30	1000	1030	40	40	1030	1110	5	30	1110	1140

* Three replications conducted concurrently for water quality tests by dividing 2m x 8m bed into equal-sized plots .67m x 8m long.

(1) Treatment Designation BARE (No Treatment), BFM (Bonded Fiber Matrix), CB (Coconut Blanket), CCIR (Coir Netting), COMP (Compost), CWFB (Curled Wood Fiber ECB), GYP1 (Gypsum, Rate 1), GYP2 (Gypsum, Rate 2), PMP (Paper Mulch with Polymer), PMS (Paper Mulch with Psyllium), SB (Straw ECB), SCB (Straw/Coconut ECB), WFB (Wood Fiber ECB), WMP (Wood Mulch with Polymer), WMS (Wood Mulch with Psyllium), or WSI (Wheat Straw, Incorporated)

(2) Use 24 hour clock (e.g., 1430) for Start Time and End Time

FORM 5

SAMPLE LOG
EROSION CONTROL TREATMENT/WATER QUALITY EVALUATION

Treatment Designation: BARE Storm Designation: 10-yr-2

Replicate Number (circle one): 1 2 3

Date: 4/28/00 Name of Person(s) Collecting Samples: Jason / Sung / Dan

Sample No. (1)	Rainfall Event Part No. (1, 2, or 3)	Sample Start Time (24 hr Clock)	Sample End Time (24 hr Clock)	Runoff Volume (L)	Comments
A	1	1015	1030	1.9	
B	1	1015	1030	1.9	
C	1	1015	1030	1.9	
A	2	1040	1043	3.8	
B	2	1040	1043	3.8	
C	2	1040	1043	3.8	
A	2	1050	1052	3.8	
B	2	1050	1052	3.8	
C	2	1050	1052	3.8	
A	2	1100	1102	3.8	
B	2	1100	1102	3.8	
C	2	1100	1102	3.8	
A	3	1125	1128	1.9	
B	3	1125	1128	1.9	
C	3	1125	1128	1.9	

(*) Label each sample container with the sample no., roughness designation, storm designation, replicate no., and date.

FORM 6

MYOPORUM COVER FORM
OUTDOOR MYOPORUM TEST PLOTS

Site No. (check one): ☐ 10-2 (fill slope) ☐ 57-4 (cut slope)

Date	MYOPORUM COVER (%)				Is Subplot Average Within 3-5% of a Test Cover Value?(1)	Name of Monitor
	Subplot A	Subplot B	Subplot C	Subplot Average		
					Yes / No	
					Yes / No	
					Yes / No	
					Yes / No	
					Yes / No	
					Yes / No	
					Yes / No	
					Yes / No	
					Yes / No	
					Yes / No	
					Yes / No	
					Yes / No	
					Yes / No	
					Yes / No	
					Yes / No	
					Yes / No	
					Yes / No	
					Yes / No	
					Yes / No	
					Yes / No	
					Yes / No	
					Yes / No	
					Yes / No	
					Yes / No	

(1) Myoporum cover values to be tested: 35%, 50%, 65%, 80%, 95%. When the average cover reaches within 3-5% of a test cover value, contact the study Field Manager to coordinate the next rainfall simulation event.

FO[illegible]7

RAINFALL SIMULATION FORM
VEGETATION COVER / EROSION RATE EVALUATION

Site Number	Plot Number[1]	Storm Designation	Date	PART 1 Intensity (mm/hr)	PART 1 Duration (min)	PART 1 Start Time[2]	PART 1 End Time[2]	PART 2 Intensity (mm/hr)	PART 2 Duration (min)	PART 2 Start Time	PART 2 End Time	PART 3 Intensity (mm/hr)	PART 3 Duration (min)	PART 3 Start Time	PART 3 End Time
57-4	A	10yr-2	1/18/00	5	30	1300	1330	40	40	1330	1410	5	30	1410	1440
	B	10yr-2	1/18/00	5	30	1300	1330	40	40	1330	1410	5	30	1410	1440
	C	10yr-2	1/18/00	5	30	1300	1330	40	40	1330	1410	5	30	1410	1440

(1) Plot Number. Plots are designated "A", "B", and "C" from left to right.

(2) Use 24 hour clock (e.g., 1430) for Start Time and End Time

page ___ of ___

FORM 8

SAMPLE LOG
VEGETATION COVER / EROSION RATE EVALUATION

Treatment Designation: ______________ Storm Designation: ________________

Replicate Number (circle one): 1 2 3

Date: __________ Name of Person(s) Collecting Samples: ______________________________

Sample No. [1]	Rainfall Event Part No. (1, 2, or 3)	Sample Start Time (24 hr Clock)	Sample End Time (24 hr Clock)	Runoff Volume (L)	Dry Weight (kg)	Comments

(1) Label each sample container with the sample no., site no., plot no., and date.

FORM 9

RAINFALL MONITORING FORM
OUTDOR MYOPORUM TEST PLOTS

Site No. (check one): 10-2 (fill slope) 57-4 (cut slope)

Date	Time	Individual[1] Measurement (mm)	Cumulative Measurement (mm)	Comments (e.g.,storm period, current weather, etc.)	Name of Monitor

(1) Empty and reset rain gauge after each reading.

FORM 10

RAINFALL MONITORING FORM
OUTDOR MYOPORUM TEST PLOTS

Site No. (check one): 10-2 (fill slope) 57-4 (cut slope)

Date	Irrigation Times			Total Volume (L or M^2)	General Comments on Soil Conditions	Name of Operator
	Start	Stop	Duration			

FORM 11

SITE INSPECTION FORM
OUTDOOR MYOPORUM TEST PLOTS

Site No. (check one): ☐ 10-2 (fill slope) ☐ 57-4 (cut slope)

Date	OBSERVATIONS						Name of Inspector
	Myoporum Plants	Weed Growth in Subplots	Irrigation System	Drums, Pipe, & Fittings	Rain Gauge	Inspection Comments/Maintenance Needs/Maintenance Performed(1)	
	OK Not OK	Yes No	OK Not OK	OK Not OK	OK Not OK		
	OK Not OK	Yes No	OK Not OK	OK Not OK	OK Not OK		
	OK Not OK	Yes No	OK Not OK	OK Not OK	OK Not OK		
	OK Not OK	Yes No	OK Not OK	OK Not OK	OK Not OK		
	OK Not OK	Yes No	OK Not OK	OK Not OK	OK Not OK		
	OK Not OK	Yes No	OK Not OK	OK Not OK	OK Not OK		
	OK Not OK	Yes No	OK Not OK	OK Not OK	OK Not OK		
	OK Not OK	Yes No	OK Not OK	OK Not OK	OK Not OK		
	OK Not OK	Yes No	OK Not OK	OK Not OK	OK Not OK		
	OK Not OK	Yes No	OK Not OK	OK Not OK	OK Not OK		

(1) Make minor repairs during inspection, if possible, and record. For all comments, record whether comment is applicable to Plot A, B, or C.

San Diego State University
Department of Civil and Environmental Engineering
Environmental Engineering Laboratories

Quality Assurance Program Guide

January 2000

Revision 1

TABLE OF CONTENTS

1.0 Quality Assurance Policy

The entire Environmental Engineering Laboratory (EEL) faculty, staff and graduate students at the San Diego State University (SDSU) are dedicated to providing reliable and superior quality analytical data. The entire EEL personnel believe that Quality Assurance (QA) is every individual's responsibility for ensuring the quality of his/her analytical data. Therefore, each person within the laboratory is fully trained in evaluating data, monitoring control limits, and taking the corrective action(s) necessary to assure both reliability and scientific integrity of work performed.

1.1 Purpose

The purpose of the QA program is to ensure that all information, data, and resulting decisions compiled under a specific task are technically sound, statistically reliable, and properly documented.

The EEL QA program communicates the QA policies and procedures to the laboratory personnel, contracting agencies, and other organizations.

The QA program defines the purpose, organizational structure and operation principles of the laboratory. The QA program governs all activities and personnel of the EEL including all aspects of administration, sample receipt, sample control, sample preparation, inorganic analyses, organic analyses, microbiological analysis, quality assurance, sample and waste disposal, data entry and report production.

1.2 Quality Assurance and Quality Control

The EEL uses Quality Assurance to plan, design, and monitor the frequency and methods of the checks, audits, and reviews necessary to identify problems and dictate corrective actions.

Through Quality Control (QC) activities, the EEL provides the methodical maintenance of strict quality of all activities from sample receipt, through report generation; including standard preparation, instrument maintenance, calculations, recording of results, etc. Therefore, QC is the function and responsibility of each individual within the EEL laboratory.

1.3 General Description

The EEL at San Diego State University Quality Policy Statement:

> *"The entire EEL personnel is committed to providing data which is statistically reliable, technically sound, legally defensible, and of the highest quality."*

The contents of this QA program guide describe the activities, which are utilized in order to ensure this commitment is maintained.

Written analytical procedures are used to ensure strict adherence to approved analytical methods throughout the laboratory. Bench-level quality control measures with established acceptance criteria are included in each analytical procedure employed by the laboratory. The EEL laboratory staff monitors laboratory records and quality control data on a regular basis.

This guide describes the QA program adhered to by EEL and has been written by EEL personnel and approved by the faculty. All EEL personnel have received copies of this guide and are required to comply with the program's stated goals, requirements, and responsibilities. A quality assurance director has been designated to monitor the program and report program findings to the supervising faculty member.

1.4 Objectives

The QA program ensures that the EEL produces accurate and valid data for all analytical procedures. In order to accomplish this objective, the following criteria must be achieved:

- All procedures and practices must be approved and accepted methods;
- A program must be in place to monitor, document, and improve the performance of the EEL;
- There must be a mechanism for correcting problems, which are determined by the QA program.

Specific objectives of performance standards are:

- Laboratory practices and methodologies are routinely updated and developed as new and improved methods and practices become available;
- Only trained personnel having the appropriate expertise will perform assigned tasks;
- All data is reviewed prior to release to ensure validity, completeness, accuracy, and precision.

1.5 Intended Use of Data

This QA program guide applies to the generation of analytical data for internal research activities and externally funded projects. This QA program has been designed to meet the requirements of various Federal and State regulatory agencies with which the analysis need to comply.

2.0 Laboratory Organization and Responsibility

2.1 Address

The EEL is a research facility specializing in environmental science and engineering and related fields. The laboratory is located in the Engineering Building on the Campus of San Diego State University. The address is:

San Diego State University
Environmental Engineering Laboratory, E420
5500 Campanile Drive
San Diego, CA 92182-1324

2.2 Analytical and Technical Specialty

The EEL provides water, wastewater, solid waste, microbiological, air quality monitoring for internal use in fundamental and applied research activities and for utilization in funded projects. The EEL also provides analytical services through cooperative research agreements. Analytical monitoring and laboratory testing include the following:

- Classical (wet) chemistry (titrametric, gravimetric, colorimetric, etc.);
- Inorganic chemistry by atomic absorption (AA) and ion chromatography (IC);
- Organic chemistry by gas chromatography (GC) and mass spectrometry (MS);
- Organic chemistry by IC and high performance liquid chromatography (HPLC);
- Organic chemistry by total organic carbon (TOC);
- Microbiological analysis;
- Unit operation and bench scale studies;
- Applied research studies; and
- Other analysis and research studies as needed.

2.3 Responsibilities

The success of the QA program is the responsibility of all laboratory personnel. All faculty, staff, postdoctoral fellows, research scientists, analysts, and graduate students are vested with the authority to stop work in response to quality and safety related problems. Personnel notify their QA director immediately if any quality related problems or out-of-control events occur. In the temporary absence of their QA director, laboratory personnel notify the supervising faculty.

The QA program responsibilities in the EEL laboratory is assigned as:

2.3.1 Supervising Faculty

Dr. Mirat Gurol, the Blasker Professor of Environmental Engineering, is the supervising faculty of the EEL and oversees all research activities, policies, including the QA policy and goals contained in this QA program. She maintains the ultimate responsibility and authority for quality and safety related matters.

The laboratory supervising faculty responsibilities with respect to the QA program are to:

- Oversee and review work procedures and daily laboratory practices;
- Review analytical data and reporting to contracting agencies;
- Liaison with regulatory and funding agencies;
- Oversee the implementation of valid and reliable QC procedures;
- Review final analytical reports for accuracy and completeness;
- Liaison with other faculty members on the use of the facility;
- Implement and manage all facets of the EEL safety program.

2.3.1 Quality Assurance Director

Dr. Badri Badriyha is the QA director. He is responsible for managing the QA program.

Duties of the QA director are to:

- Oversee the management of the QA program;
- Administer the QC procedures;
- Oversee the implementation of corrective action(s);
- Monitor the performance evaluations and audits;
- Train and monitor all analysts and graduate students in the proper implementation of QA/QC procedures;
- Oversee and coordinate instrument and equipment maintenance;
- Develop mechanisms to carry out the QA objectives;
- Propose QA program amendments and provide feedback to the supervising faculty.

2.3.2 Postdoctoral Fellows and/or Research Scientists

The postdoctoral fellows are responsible for the daily operation of their respective areas. Their duties as they relate to the QA program are to:

- Make recommendations for technical decisions to the QA director or the supervising faculty;
- Review and evaluate test procedures performed;
- Assist in training and monitoring of analysts in the proper implementation of QA/QC procedures;
- Ensure completion of analytical work within the requested turn-around time and prior to expiration of sample holding time;
- Respond to required corrective action(s);

- Report to the QA director if purchase requisitions that request materials vary from prior approved materials;
- Ensure completion of reports with approved report formats deliverable prior to due date.

2.3.3 Laboratory Analysts and Graduate Students

The analysts and students duties as they relate to the QA program are to:

- Comply with the QA program requirements and methods specified in QC;
- Maintain a clean and safe working environment;
- Implement any prescribed corrective action(s);
- Utilize only methodologies as approved by the EEL and follow the standard operation procedures (SOPs);
- Keep accurate laboratory records;
- Routinely check expiration dates of reagents prior to initiating work, and make fresh reagents when necessary.
- Notify the QA director immediately if incoming purchase requisitions request materials of a different quality or source (vendor) than prior orders.
- Ensure completion of reports with approved report formats deliverable prior to due date.

3.0 Facilities

The EEL occupies an approximately 2,000 square foot dedicated to the analytical laboratories. Separate laboratories are dedicated to the instrumental analysis, wet chemistry, oxidation processes, and microbiological analysis. A separate area is used as a cold room for storage of samples and delicate chemicals. Figure 1 presents the EEL map.

A list of the major instruments and equipment used in EEL is presented in Appendix A.

4.0 Quality Commitment

The EEL staff is committed to providing superior service and quality, which are maintained by continual training.

4.1 Safety Training and Compliance

The San Diego State University Environmental Health and Safety (EHS) Department is responsible for matters concerning the health and safety in the work place on all University premises. The EHS department is also responsible for collection of hazardous

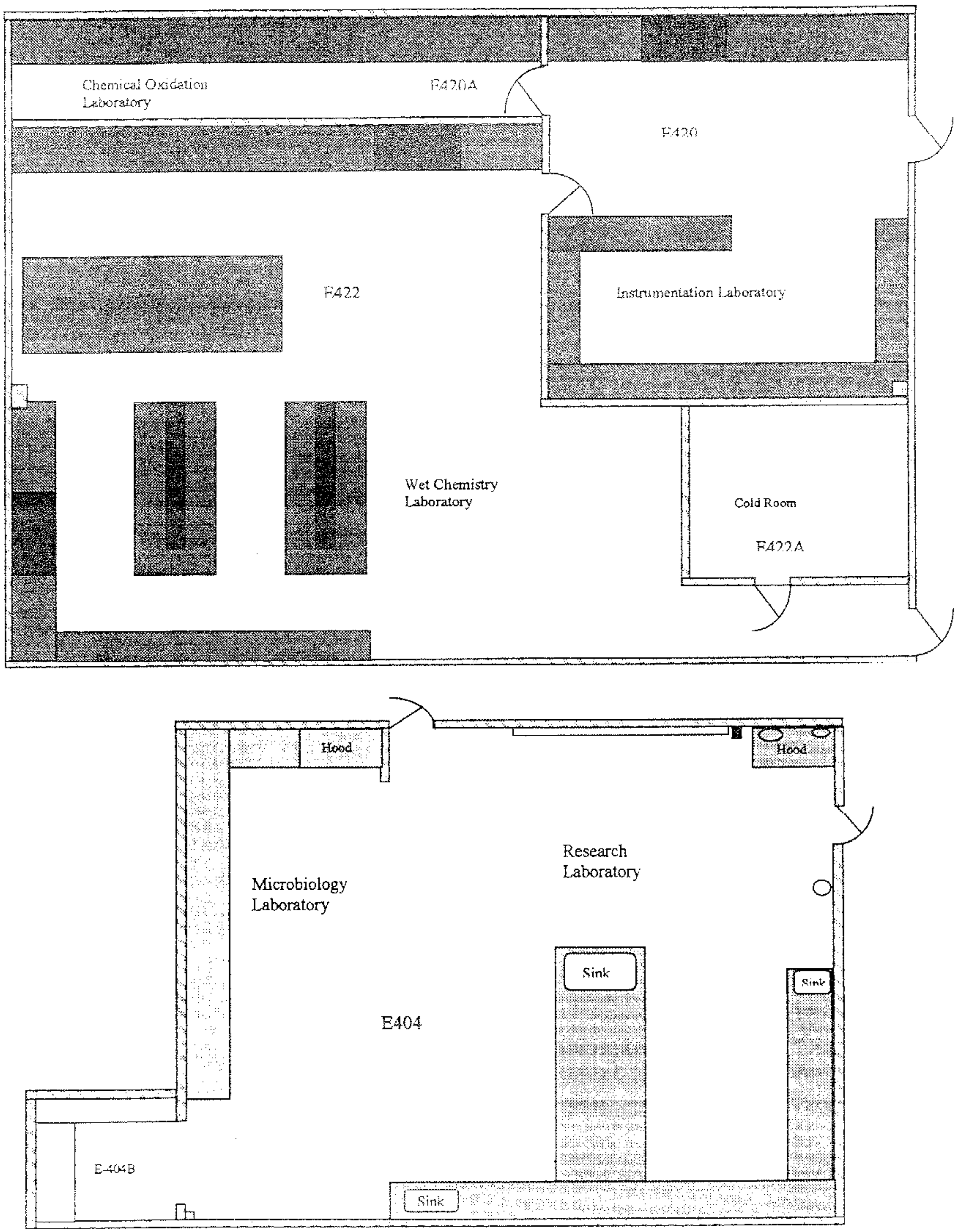


Figure 1. Environmental Engineering Laboratories

wastes from the laboratories for proper disposal. The EEL complies with all health and safety rules and regulation and continually being monitored by the EHS department.

4.2 Qualifications of Laboratory Personnel

The EEL is very proud of its highly qualified and professional staff and graduate students and is committed to furthering their skills at all levels. All personnel have BS, MS, or Ph.D. degrees in respective fields.

Technical training is performed by and qualified individuals to ensure method proficiency. The staff is regularly updated as to current technical advances. All laboratory personnel are required to acknowledge through signature that they have read and understand the SOPs appropriate to their areas. All training beyond acknowledgment of SOPs is documented. Continuing qualification of laboratory personnel is demonstrated through systems and performance audits conducted by the QA director and the supervising faculty. Additionally, the QA director on a regular basis conducts QA training sessions. External courses and conferences are attended when appropriate. The EEL staff furthers their expertise through membership in professional organizations such as:

- American Chemical Society
- American Water Works Association
- American Society of Civil Engineering
- International Ozone Association
- Water Environment Federation
- American Society for Microbiology

All new employees receive a comprehensive orientation to QA, QC, and safety programs administration by the QA director within approximately the first week of employment. All new personnel, or personnel performing a new analysis, must demonstrate proficiency through the analysis of QC check samples prior to conducting independent analysis of real samples.

Copies of all training records, including the results of precision and accuracy studies and single- and double- blind performance evaluations, are maintained in the QA program files. Professional profiles of key personnel and staff members are available for review during a facility visit or upon special request.

5.0 Quality Assurance Objectives

In order to provide precise and accurate data reports for internal research activities and work performed for contracting agencies, data reported are generated and calculated according to recognized standards of environmental laboratories. Data reported by the EEL are calculated and reported in units that are consistent with data produced by other independent organizations/laboratories. The laboratory strives to present data reports that are complete and contain all data elements and supporting documentation for the type of deliverable requested by the contracting agencies and institutions.

The precision and accuracy control limits utilized are based upon limits contained in the published methods. When warranted by the EEL's experience with a particular method, more restrictive control limits than those cited in the method are set.

Method performance characteristics are determined prior to method use for analytical methods. This is accomplished through Precision and Accuracy, Method Detection Limit, and Instrument Detection Limit Studies performed according to standard operation procedures. Additionally, QC reference materials are analyzed to verify method performance characteristics. All method performance data is compiled by the individual analyst and is documented and maintained in the QA program files.

5.1 Data Quality Characteristics

There are five recognized characteristics of data quality as listed below:

5.1.1 Accuracy

It is defined as the degree of agreement of a measurement (or measurement average) with an accepted reference or true value. It is a measure of system bias. It is usually expressed as the difference of "measured" from "true" values, or as a percentage of the differences. The accuracy of laboratory analyses can be evaluated through the concurrent analyses of standard reference materials, if available.

5.1.2 Precision

It is a measure of agreement among individual measurements having the same property under similar conditions. It is expressed in terms of percent differences between replicates or in terms of the standard deviation.

5.1.3 Completeness

It is a measure of the amount of valid data obtained compared to the amount expected to be collected under normal conditions; it is usually expressed as a percentage. The completeness objective is calculated on those samples analyzed, not the remainder archived. Data from samples are considered to be complete if the samples have been properly collected, labeled, stored, prepared, and analyzed and the associated quality control criteria have been met.

5.1.4 Representativeness

It expresses the degree to which data accurately and precisely represents characteristics of data population, process condition, or sample. The samples expected characterization would be compared to that obtained by laboratory analyses to evaluate the representatives of the data to the expected data.

5.1.5 Comparability

It expresses the confidence with which one data set can be compared to another. To achieve comparability, the data generated are reported using units specified in the Standard Operation Procedures as appropriate. Analytical results are comparable to those produced from similar laboratories using the same instrumentation and methodology. This is accomplished through the following practices:

- Demonstrate traceability of standards to EPA sources;
- Use standard and approved methodologies;
- Use standardized units of measure;
- Use standardized quality control acceptance criteria,
- Analyze Performance Evaluation (PE) samples to demonstrate laboratory performance.

5.2 Completeness, Representativeness, and Comparability

Prior to the results being disseminated, the reports are reviewed and evaluated for completeness, representativeness, and comparability. The reports and associated data are evaluated to ensure that they are sufficient for their intended use, representative of the matrix and conditions being measured, and representative of the methods and instruments utilized.

6.0 Sample Custody

The EEL staff is responsible for initiating and maintaining external and internal chain-of-custody, managing and tracking sample storage and distribution, ensuring proper containers, preservation, temperature requirements and adhering to holding time requirements.

The strict adherence to chain-of-custody procedures is critical to legal proceedings and is an integral part of the QA program. Chain-of-custody procedures are initiated during sampling events and continued through laboratory analysis, and ultimately the disposition of the sample.

The EEL chain-of-custody procedures ensure traceability through proper sample handling, QC procedures and internal chain-of-custody. The components of the chain-of-custody include chain-of-custody documentation forms and unique sample identification labels.

The National Enforcement Investigators Center of the EPA defines custody of evidence as:

- In a person's physical possession;
- In view of the person after possession has taken place;
- Secured by that person so that the sample cannot be tampered with, or
- Secured by that person in an area, which is restricted to authorized personnel.

6.1 Laboratory Custody Procedures

The EEL has implemented the following standard procedures with regard to laboratory internal chain-of-custody:

- Samples are stored in a secure area except when being analyzed or prepared;
- Non-employee access to the laboratory is controlled through the use of limited access points to the laboratories.

Sample tracking forms are maintained in an internal chain-of-custody notebook in order to document sample location and responsible party within the laboratory. Any remaining samples are archived in locked storage areas, returned to the customers, or disposed of properly as required by the customer and federal and state regulations.

Internal sample chain-of-custody is maintained through sample tracking forms. These forms are used to log samples in and out of sample storage and indicate sample custody at all times. It is the responsibility of all personnel to document when a sample is in their custody. Upon sample receipt at the laboratory, samples are entered into the sample receipt logbook. Details include customer name, parameters requested, date received, and date due.

The condition of the samples is noted on the associated chain-of-custody form (intact, broken, leaking, etc.). The concerned person is contacted immediately if there is evidence of damage.

EEL staff verifies agreement between the labeled sample containers and the chain-of-custody. In the event of a discrepancy, the customer will be contacted immediately.

The samples are visually inspected to determine that adequate sample volume is collected for the requested parameters, correct sample containers are utilized, and proper preservation is indicated on the label. This is documented on the chain-of-custody form. Any problems warrant immediate customer contact.

All samples that are affected by the problem are placed in the appropriate contaminant free refrigerator and maintained at 4°C until resolved. A record of the telephone call is kept with the chain-of-custody information

If no problems are observed, the samples are placed in the sample storage areas until analysis. The lab staff maintains maximum holding times for samples and maintain strict sample control. Appendix B contains the sample holding times and preservation requirements.

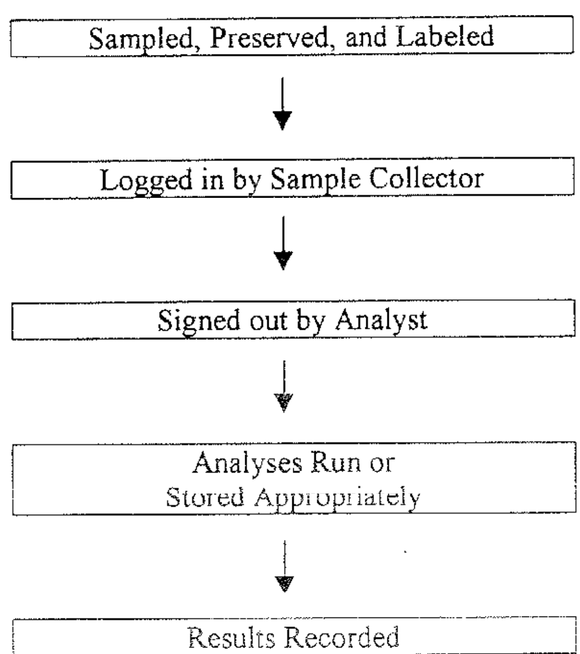
6.2 Chain-of-custody

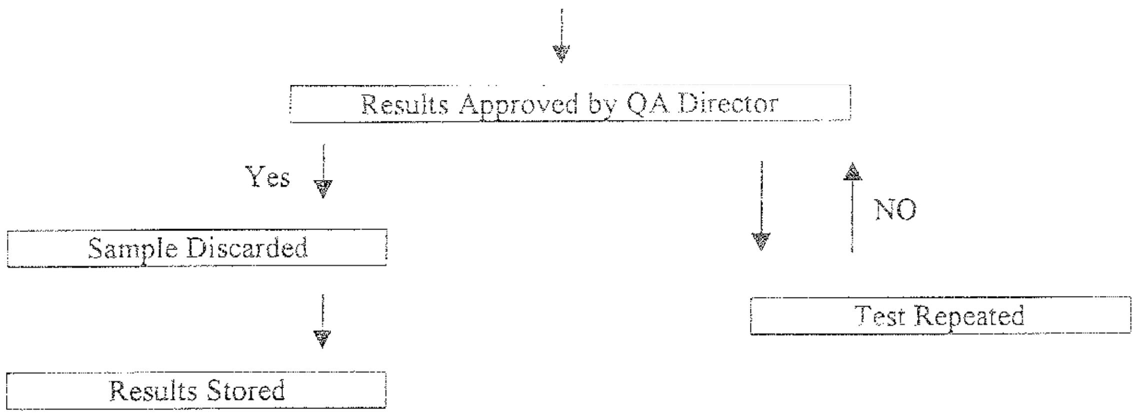
To trace sample possession from the time of collection, a chain-of-custody record is completed and accompanies the sample(s).

The chain-of-custody contains the following information:

- Sample identification label;
- Signature of the collector and any person who had the sample in their possession;
- Date collected;
- Customer name and address;
- Inclusive date of possession;
- Analyses requested;
- Sample condition when received (cold, proper container, etc.);
- Samples properly preserved, as applicable;
- Time and date sample was received;
- Time and date sample was analyzed as well as analyst's name

Sample Flow Chart





The chain-of-custody establishes the documentation and control necessary to identify and trace a sample from sample collection to final analysis. It includes sample labeling to ensure proper identification of each sample, secure custody, and provide the recorded support information for potential litigation.

Chain-of-custody forms are used to document the integrity of all samples. To maintain a record of sample collection, transfer personnel, shipment and receipt by the laboratory, a chain-of-custody form will be filled out for each sample or batch of samples provided by the customer.

Whenever the possession of the samples are transferred, the individual relinquishing the sample(s) signs and records the date and time of sample transfer on the chain-of-custody document. The individual receiving the sample(s) repeats the procedure. This record represents the official documentation for all sample custody transfers until the samples have arrived at the laboratory.

7.0 Sample Security, Storage, and Disposal

The laboratory staff is responsible for ensuring that samples are maintained in secured storage areas and under the appropriate conditions, including temperature.

7.1 Sample Security

Samples are kept in secured storage areas except during laboratory analysis. All laboratory personnel who receive samples are responsible for the care and custody of samples from the time each sample is received into that person's possession until the sample is returned to the secured storage areas.

The following security measures are employed:

- Doors to the sample storage cabinets are secured at all times;

- Authorized personnel escort all visitors and handles deliveries through the laboratory;
- Laboratory personnel are responsible for control and maintenance of sample integrity while they have custody of samples.

- Customer provided information about samples, recorded on the chain-of-custody is available to analysts and can prove useful guidance when analyzing samples. The EEL policies prohibit disclosure of confidential customer information to third parties. All laboratory personnel are instructed to maintain confidentiality of customer information.

7.2 Sample Storage

Once samples are logged into the sample tracking system, the lab staff is responsible for ensuring the following procedures:

- Samples for volatile analyses are stored in a separate area reserved only for volatile samples to avoid contamination;
- Samples are stored in a secured area;
- Samples are removed from the shipping container or cooler and stored in their original containers unless damaged;
- Damaged samples are documented;
- Sample storage areas are kept secured at all times; and
- Standards are not stored with samples.

7.3 Sample and Waste Disposal

Upon completion of the analysis, any remaining sample will be placed into long-term storage, returned to the customer, or disposed of in compliance with all applicable University, federal, state and local laws.

When sample analysis and all QC checks have been completed and a final report has been issued, the unused sample will be discarded.

Laboratory waste is collected in appropriate containers labeled with waterproof labels. Labels identify the hazardous waste collected and all pertinent information from the Material Safety Data Sheets (MSDS). The wastes are then collected by the University Environmental Health and Safety Department for proper disposal.

Non-hazardous waters and/or samples may be disposed in sink drains with dilution of tap water.

7.4 Sample Preservation and Holding Times

It is critical to sample integrity and data validity that EEL analyze samples within the method stated holding times. EEL follows regulatory guidelines for sample preservation and holding time requirements as specified by the method references. Sample holding time begins with the collection of the sample.

Appendix B contains the Sample Holding Times and Preservation Requirements, which identifies holding time requirements by method and parameters for water samples. The time of analysis is reported with analytical results when requested.

8.0 Material Procurement and Control

Only chemicals and supplies of the quality specified in the appropriate method or Standard Operation Procedure are used for analyses. Purchase requisitions are review by the QA director for suitability prior to being issued. This is to ensure that the materials being ordered are of the appropriate grade/quality for the methodologies.

The laboratory staff verifies that materials ordered are of the same grade/quality previously ordered and are requested from an approved vendor.

8.1 Containers and Reagents

The EEL provides required bottles, ultra-pure water (for use for blanks), coolers, sampling instructions, labels, ice packs, and chain-of-custody forms for sample collection. The EEL utilizes EPA approved, cleaned glassware for sample collection. Sample container preservatives are certified free from analytes of interest and contaminants. The lab staff maintains records that indicate freedom from contamination for each lot number of preservative and sample container.

Containers provided to customers are labeled with the date the containers were prepared. All container and preservative lot numbers used for each day are recorded in a container preparation logbook along with the date that the preservative lot number was in use.

8.2 Calibration Standards and Reagents

The chemicals and reagents used by the EEL are selected with care. Reagent lot numbers are recorded for every analytical batch processed. Analytical reagent grade is the minimum quality used within the laboratory. Ultra pure acids are employed for low detection limit metals analysis. Pesticide grade solvents are used for all organic extractions. The extraction solvents are treated to all steps of the sample preparation and analysis process.

The following acceptance criteria applies to solvents:

- No analyte present at concentrations equal to or greater than one-half the reported detection limit.

- No non-analyte peak present in the test chromatogram greater than 10% of the closest internal standard for GC/MS analysis or which would interfere with the identification and quantitation process for GC analysis.

8.3 Equipment Procurement

Only equipment and supplies of the quality specified in the appropriate method or Standard Operation Procedure shall be used for analyses. Purchase requisitions require review by the QA director for suitability prior to purchase orders being issued. This is to ensure that the materials being ordered are of appropriate grade/quality for the methodologies.

Upon receipt of orders, the purchase order and requisition are compared to the grade of the material shipped to ensure that the correct quality/grade was received prior to acceptance by the laboratory. The lab staff is responsible for receiving products and is required to date and initial the invoice as verification of material acceptance.

9.0 Analytical Procedures

The EEL utilizes methodologies from the following accepted standard references:

- Methods for the Chemical Analysis of Water and Wastes, EPA-600/4-79-020, Revised 1983.
- Standard Methods, APHA/AWWA/WEF.
- Test Methods for Evaluating Solid Waste, EPA, PB88-239223, Nov. 1986.

Additional methods are taken from:

- American Society for Testing and Materials (ASTM).
- The United States Geological Survey (USGS).
- Association of Official Analytical Chemists (AOAC).

Customers and contracting agencies are notified by the EEL staff through written or verbal communication when non-standard or significantly modified methods are to be used. Written or documented verbal customer approval is required prior to use of new, non-standard, or significantly modified methods for customer sample analysis. In the absence of customer direction, selection of a method to be used for analysis is determined by the QA director.

Each data report issued by the EEL includes a reference to the exact method employed for the analysis.

As new methods become promulgated and the laboratory demonstrates capability of performing new methods, the SOPs are revised and updated accordingly to replace existing methods. Only the most recent revision for a method is used.

Capability of performing an analytical method must be demonstrated prior to customer sample analysis for all new and modified methods. This is accomplished through personnel training, QC check sample analysis, method detection limit (MDL), instrument detection limit (DL) and precision and accuracy studies.

10.0 Calibration Procedures

10.1 Calibration Procedures and Frequencies

Instrument calibration is critical to generating accurate analytical data. The EEL maintains strict controls on the calibration procedures for the various types of analytical equipment. Each instrument is calibrated prior to sample analysis in accordance with method criteria. The specific criteria for calibration can be found in each method SOP.

Instruments are calibrated in accordance with the appropriate analytical method and the manufacturer instructions. The analytical methods cite the appropriate calibration procedures and frequencies.

Prior to the analysis of samples, instruments are either calibrated or their calibrations verified. Calibration curves of signal versus concentration are generated on each analytical instrument. Calibration curves are established for each analyte of interest.

Most methods use either four or five different calibration points for standardization. Current calibration curves are evaluated daily using a continuing calibration curve verification (CCV) standard or a laboratory control samples (LCS) or a laboratory blank spike (LBS).

It is the EEL's policy to validate all new standards against existing standards prior to use. The new standard's response factor (RF) should be within 10% of the previous standard's RF.

Hardcopy records of all instrument calibrations are maintained in the individual laboratory areas. When calibration acceptance criteria or guidelines are available in a method, those criteria, or more stringent criteria are utilized. In the absence of method-stated criteria or guidelines, calibration acceptance criteria or guidelines from a similar method are considered to be technically sound.

10.2 Laboratory Standards and Reagents

Analytical standards utilized for method calibration and preparation of quality control samples are traceable to standard reference materials, or a certificate of analyses provided by the manufacturer.

Standards are purchased from approved and reputable commercial vendors such as Sigma-Aldrich, Fisher Scientific, Supelco, etc. for use in all laboratory analyses.

Certificates of analysis and expiration date information are received with standards and are maintained.

Standards and reagents are dated upon opening, and the date of expiration recorded (expiration dates are determined by the vendor or indicated in the individual method SOP). This procedure establishes the order of use and eliminates the possibility of exceeding shelf life. A stock or working standard will be assigned an expiration date of the component with the shortest time of expiration.

Standards are protected from degradation; deterioration and contamination based upon storage requirements and are stored properly to ensure chemical compatibility and integrity.

Each analytical batch corresponds to a sample preparation log where all applicable reagent and standard lot numbers are recorded. Control check samples are analyzed with each analytical batch for all analytical procedures to ensure that the reagents used have not degraded or become contaminated. Stock and working standard solutions are prepared fresh as required by their stability, and are checked regularly for signs of deterioration. Standards are properly labeled as to name, concentration, date prepared, solvent/medium, signature of person preparing the standard, and expiration date. Standards are traceable to analytical batches through the use of standard preparation logs and recorded dates on extraction/preparation logs.

The laboratory has established the following guidelines for the preparation of analytical standards:

- Laboratory personnel is trained and experienced in calibration and the use of analytical measuring techniques;
- Analytical reagent grade materials are utilized in preparation of standards;
- Analytical measurement tools are calibrated to obtain accurate measurements;
- All data generated are documented immediately in the appropriate standard preparation notebook;
- Standards are properly labeled and referenced to standard preparation notebooks.

Laboratory contamination is minimized through implementation of a standard operation procedure for glassware and labware cleaning. The SOP is followed to ensure the removal of all traces of compounds of interest and contaminants that could interfere with analysis.

Three grades of reagent water are used in the laboratory:

- Tap water: The tap water used in the laboratory is supplied by The City of San Diego. Its primary use is for the washing of glassware;
- Deionized water (DI): This water is produced by passing tap water through a demineralization system. This water is used for the final rinse for laboratory glassware;

- Ultra pure water: This higher quality water is produced in laboratory by passing the DI water through Milli-Q water purification unit consisting of mixed-beds and UV oxidation system. The Milli-Q water meets and exceeds specifications for Type I ASTM Reagent Water. This water is used for preparing inorganic and organic reagent blanks, reagent, solutions and standards.

Milli-Q and DI waters are analyzed regularly to make sure that they meet pH and conductivity criteria for ASTM Type I and II Reagent Waters, respectively.

10.3 General Laboratory Equipment Calibration Requirements

Laboratory equipment requiring calibration (not operational calibration) is checked on a routine basis for accuracy. These include balances, ovens, refrigerators, automatic pipettes, and thermometers. Additionally, calibration is also performed and documented following maintenance and repair to show a return to control.

Each piece of support equipment is calibrated for use, and calibration is documented in calibration logbooks. Acceptance criteria and correction factors observed are stated below or found in the support documents for individual pieces of support equipment. All out-of-control measurements and their resulting actions are documented on a correction action form. The QA director is notified immediately of the out-of-control event. Non-compliant equipment is not used in the process of analyzing customer samples. All out-of-compliance monitoring and corrective action measures are documented.

Equipment is calibrated against a standard traceable to the National Bureau of Standardization (NBS) or other recognized physical or chemical constants. The manufacturer, regulatory agency or method SOP specifies calibration procedures. Procedures provide step-by-step detail for obtaining and documenting results. The data are kept on file in the laboratory and allow traceability to data generated under each equipment calibration. Calibration due dates are maintained by the lab staff to maintain proper calibration intervals.

10.3.1 Balances

The calibration of balances are verified before each use with standard Class-S built-in calibration weight to within 0.001 grams of "true weight," and are calibrated and certified annually by a licensed specialist across the full weight range of the balance. If any signs of deviation from the calibration are noticed, the calibration and certification is repeated.

10.3.2 Ovens/Furnace

Oven temperatures will be recorded during each use. The required temperature tolerance is + 2°C at the operation range of 60 - 300°C for ovens and 500 - 1500°C for furnaces. If the temperature is found to be out-of-control during analysis, the results of that analysis will not be reported and the analysis will be repeated after the oven has stabilized for 8 hours.

10.3.3 Refrigerators/Cold Room

The temperature in all the refrigerators shall be recorded each working day in the refrigerator logs and maintained at 4°C ± 2°C. In cases where temperatures are out of these limits, the temperature will be adjusted accordingly.

10.3.4 Thermometers

Every thermometer must be checked annually against an NBS thermometer of equal or greater precision. The ASTM E77-92 procedure for calibration is followed. Errors in temperature indications of the thermometer should not exceed the scale errors as expressed in Table 1 of ASTM E1-83.

10.3.5 Pipettes

All automatic pipettes are calibrated according to ASTM gravimetric methods and acceptance criteria. Automatic pipettes are calibrated and preventative maintenance is performed annually by an external service.

10.3.6 Syringes

Calibration certificates from the manufacturer and frequent replacement of syringes ensures accuracy of measurements.

10.4 Sample Storage Temperature Monitoring

Maintaining appropriate temperature during sample storage is of critical importance in the task of attaining valid data. The following procedures must be followed in order to maintain and monitor appropriate sample storage temperatures.

Upon sample receipt, samples for analysis are transferred to the appropriate storage area. A daily temperature check is performed to verify the temperature and these temperature readings are recorded on a logsheet.

The thermometer in each refrigerator is immersed in a liquid such as glycerin or water. If a daily temperature reading exceeds the 4° ± 2°C acceptance criterion, all project samples will be transferred to another refrigerator that is documented to be within the acceptable temperature range. The problem will be corrected, and corrective action will be documented for the faulty refrigerator.

11.0 Analytical Requirements

Analytical instruments are calibrated at regular intervals as recommended by the manufacturer or as required by ASTM, EPA or other agencies. Calibration of all equipment used and documentation of the calibration will be performed by individual chemists/analysts as assigned by the management.

11.1 GC/MS System Calibration

The gas chromatograph/mass spectrometer systems are calibrated for mass and then tuned using specific instrument and method parameters. They are then calibrated for quantitation using the internal standard technique. Specific methods impose variations and/or different acceptance criteria on both the turning and the calibration practices. These specific requirements are followed according to the SOP for each particular method.

Mass Calibration and Tuning: The calibration of each instrument is verified at frequencies specified in the methods calibration and tuning. The GC/MS systems tuning is instrument specific and includes the following:

- GC/MS calibration using perfluorotributylamine (PFTBA);
- The tune of each system is checked using 4-bromofluorobenzene (BFB) for determinations of volatiles and with dacafluorotriphenylphosphine (DFTPP) for determination of semi-volatiles,
- The required ion abundance criteria must be met before determination of any analyte.

The background subtraction performed per the methodologies is straightforward and designed to eliminate column bleed or instrument background ions. Background subtraction actions resulting in spectral distortions for the sole purpose of meeting special requirements are contrary to the objectives of quality assurance and are unacceptable.

11.2 Gas Chromatography System Calibration

The gas chromatography systems are calibrated using either the external or internal standard techniques. The specific acceptance criteria vary for different methods and can be located in the method in question or the EEL SOPs.

11.2.1 External Standard Calibration Procedure

For each analyte, or group of analytes, five concentration levels of standards are prepared by adding aliquots of one or more stock standards to volumetric flasks. The standard solutions are then diluted to volume with the appropriate solvent for the method. One of the standards should be at a concentration with 2 to 5 times the MDL. The other concentrations should define the working range of the system.

Each of the calibration standards is injected into the GC system using the same technique employed for actual samples (direct liquid injection, purge & trap, etc.). A series of calibration factors (CFs) are calculated for each analyte, at each standard concentration. The calibration curve is a plot of the relative response vs. the amount injected. The CF equates to the amount injected/total response (area). Multi-response (multi-peak) compounds use the total area of all peaks for quantitation. The linearity is to be determined and compared to the method requirements. If the criterion is not met, the standard analyses must be repeated before any quantitation of unknown samples is done.

If in certain cases, the quantitation criteria are not met the documentation of the ability to detect the minimum detectable concentration is sufficient to determine the presence or absence of target compounds with "estimated only" concentrations provided for qualitative determination only.

The working average calibration factor or calibration curve must be verified each working day by the injection of the continuing calibration curve verification standard. The frequency of verification is detector dependent and varies from once per day to an average of once every five samples. If the response of any analyte is outside the acceptable response for the specified method, a new calibration curve must be prepared for that analyte.

11.2.2 Internal Standard Calibration Procedure:

For each analyte, or group of analytes, five concentration levels of standards are prepared by adding aliquots of one or more stock standards to volumetric flasks. In addition, a known and constant amount of one or more internal standard (IS) is added to each volumetric flask and they are then diluted to volume with an appropriate solvent. One of the standards should be at a concentration near the method detection limit. The other concentration should define the working range of the system.

Each of the calibration standards is injected into the GC system using the same technique as actual samples. A series of response factors (RFs) are calculated for each analyte, at each standard concentration for the mass peak of interest for each analyte. The RF equates to the relative response of the analyte to that of the IS. The linearity is to be determined and compared to the method requirement. If the criterion is not met, the standard analyses must be repeated before quantitation of unknown samples is done.

The working average response factor must be verified on each day of the sample analysis. The frequency of verification is method specific.

If the response of any analyte is outside the acceptable response for the specific method, a corrective action must be taken before the analysis continues.

If the quantitation criteria are not met, in certain cases, the documentation of the ability to detect the minimum detectable concentration is sufficient to determine the presence or absence of target compounds with "estimated only" concentrations provided for qualitative determination only.

11.3 Atomic Absorption System Calibration

The AA system is calibrated by an external standard calibration process. The calibration specifications may vary from method to method and can be found in the particular reference or the SOP for that method.

Standard Calibration Procedures:

For each analyte, or group of analytes, three concentration levels of standards are prepared by adding aliquots of one or more stock standards to volumetric flasks and diluting to volume with an appropriate solvent. Continuing calibration standards, containing the same analyte(s) as the calibration standards, are prepared in the same manner at an appropriate concentration within the calibration curve for the specified method.

The appropriate initial calibration standard, followed by an appropriate blank solution, is injected into the AA system in duplicate in the same manner as the samples. The AA system calculates a response factor based on the system response to both the standard and blank. This is followed by duplicate introductions of the appropriate continuing calibration standard. The continuing calibration standard is analyzed after every ten samples. Results from the duplicates of each sample or standard must have a percent relative standard deviation (%RSD) of ≤ 20. If this criterion is not met the sample or standard analysis must be repeated.

Results from continuing calibration standards must fall within the method specified acceptance limits. If this criterion is not met, a corrective action must be taken, and the standard analysis must be repeated. If upon reanalysis, the standard again fails to meet this criterion, a corrective action must be taken, and the entire standardization procedure must be repeated.

12.0 Detection and Reporting Limits

12.1 Method Detection Limits

The method detection limit is the minimum concentration of a substance that can be measured with 99% confidence that the analyte concentration is greater than zero. A constituent is added to solvent matrices to make a concentration near (within one to five times) the expected detection limit. Seven or more replicates of this sample are analyzed and the MDL is determined using the standard deviation of the replicates. EEL performs MDL studies on an annual basis and for all new or modified methods. The results of all

MDL studies are reviewed by the QA director for approval before customer samples are analyzed. For all analyses, the MDL can not be higher than the regulatory limit for that parameter of interest, (taking into consideration the instrument and method limitation). For new or modified analytical methods, MDLs must be performed before performing analysis of samples. All MDL data and documentation are maintained by the QA director in the QA program files. Experimentally derived MDLs are evaluated by the QA director and checked against method specific MDL guidelines to ensure method performance comparable to that of peer laboratories.

12.2 Instrument Detection Limits

Instrument Detection Limit (IDL) is the minimum concentration of a substance that can be identified by an instrument with 99% confidence that the analyte concentration is greater than zero. IDL studies are performed after initial setup and verification of any analytical instrument and after any major change in or maintenance being performed. A standard with a concentration near (within one to three times) the expected instrument detection limit is made. Seven aliquots of this standard are analyzed on three non-consecutive days and the IDL is calculated using the pooled standard deviation.

12.3 Reporting Limits

Reporting limits takes into account the sample size, matrix effects, and any dilution factors. The Reporting Limit is always greater than or equal to the MDL.

Reporting limits are evaluated by management to verify that reporting limits are greater than or equal to the experimentally determined MDL and less than or equal to project-specific reporting limit requirements.

12.4 Practical Quantitation Limits

The practical quantitation limit (PQL) is the lower limit of concentration or amount of substance that must be present before a method is considered to provide quantitative results.

13.0 Analytical Quality Control

When a referenced method contains definitive acceptance criteria and performance criteria or guidelines for QC and calibration samples, those criteria, or more stringent criteria are required by the method SOP. Data is reviewed by the analyst to the SOP criteria and accepted or rejected on that basis. When QC and calibration criteria are not listed in the method, criteria from similar methods are considered technically sound for that method. Documenting that an approach is technically sound belongs to the analyst developing a method and is reviewed for technical merit by the QA director.

13.1 Quality Control Checks

Method blanks, laboratory control samples, and matrix spikes are required for every analytical batch. Additional QC and calibration checks requirement, their corresponding frequency and performance acceptance criteria are specified in the method's SOP. In the absence of SOP instruction, the QA director is consulted.

The procedures used in the laboratory to ensure analytical data quality include the followings:

- Matrix spike, matrix spike duplicate, and duplicates are analyzed with every analytical batch or once in twenty samples, whichever is greater. Analytes stipulated by the method or applicable regulations are spiked into the sample. Selection of the sample to be spiked and/or split depends on the information required and the variety of conditions within a typical sample matrix. In most cases, the laboratory's selection is based on the attempt to determine the extent of matrix bias or interference on the analyte recovery and sample to sample precision.

- Trip Blanks: Analysis of a sealed ultra-pure water sample, which accompanied samples during transit, collection, and storage. The trip blank measures cumulative contamination derived from the travel blank source water, sample transit, the sample site, and the sample storage.

- Field Blank: Similar to a trip blank except that the field blank is opened during sample collection process. In order to measure the same contamination that the trip blank measures as well as the volatile airborne contaminants which may be present at the sampling location, which may not infiltrate the closed sample container.

- Rinse Blank: Pure water, which has been poured over field sampling equipment prior to sample collection to determine the possibility of equipment contamination. Should be collected prior to use of equipment at each sampling point. It measures the possible combined contamination associated with field sampling equipment, rinse blank source water, sample transit, the sample site, and sample storage.

- Source Water Blank: Analysis of the water used to prepare the rinse blanks which measures the background contaminants present in the water used for the rinse blanks.

- Laboratory Water Blank: The water used to prepare trip blanks sent out by the laboratory is stored at the laboratory. They are analyzed only if the trip blank demonstrates contamination. The laboratory blank water measures contaminants derived from the laboratory pure water and laboratory sample storage facilities

- Instrument Blank: Laboratory pure water or other pure solvent analyzed at the initiation of an analytical run sequence by an instrument or between high level samples. It measures contamination which may be present in the instrument or be residual in the instrument following the analysis of a high level sample. If contamination is present, the chemist must perform maintenance on the instrument prior to analyzing further samples.

- Method Blank/Reagent Blank: Laboratory pure water that has been prepared as if it were an analytical sample. It contains all of the method reagents and measures combined contamination from the laboratory pure water, the instrument, the reagents, and the sample preparation steps. This type of blank is important in distinguishing between low level field contamination and lab contamination.

- Surrogates: Are spiked into samples according to the appropriate analytical methods and provide information on the sample extraction procedure and/or the purge efficiency. Surrogate spike recoveries should fall within the control limits set by the laboratory in accordance with the procedures specified in the method.

- Laboratory Control Sample (LCS): Either a standard used in preparation of the standard curve, or a certified standard reference material is spiked into a reagent blank. It is carried through all steps of sample preparation to demonstrate method performance inclusive of sample preparation steps.

- Reference Standards/Reference Samples: Purchased reference standards and matrix standards are used routinely to evaluate method/analyst performance. These standards are purchased from reputable sources with certified true values.

- Calibration Blanks: A standard is prepared in the same manner as other standards except that it contains no analyte. Calibration blanks are used to verify a calibration curve at a low concentration.

- Calibration Verification Samples: A second source standard is added to samples to verify accuracy of the calibration curve.

- Internal Standards (IS): An element or compound that is not an analyte, which is added to a prepared sample and is used to quantify analytes.

- Internal Check Samples: One or more standards with high concentrations of interfering analytes are analyzed to check compensation for interference.

- Method of Standard Additions: A sample is analyzed and then an aliquot is spiked with the analyte of interest and reanalyzed. The original sample concentration is derived based on the recovery of the standard addition sample. This practice allows for compensation for some matrix effects.

- Instrument Adjustment: The requirements and procedures are instrument and method specific. Analytical instrumentation is tuned and aligned in accordance with requirements, which are specific to the instrumentation procedures employed. All adjustments are documented in the instrument logbook.

- Calibration: Instrument calibration is performed in accordance with the manufactures' requirements and the procedures specified in the applicable method. All calibration procedures are documented.

- Gases: Only ultra-high purity (UHP) gases, filtered on line through a 5-micron molecular sieve are used. All carrier gases also flow through an oxygen removal system and a hydrocarbon trap. Gases are either supplied in cylinders from outside venders or generated in the laboratory utilizing approved gas generators.

- Analytical Batches: An analytical batch consists of no more than 20 samples.

13.2 Control Chart Monitoring

Control charts are used to monitor real-time and long-term assessment of data quality. Control charts for each analyte of control are prepared for water matrix. For organic analyses, the analytes, which are charted, are those analytes required to be present in the spiking solution based upon the current SW 846 methodology.

Each control chart consists of a centerline, an upper and lower warning limit, and an upper and lower control limit. For each chart, a minimum of 20 points is included. Control charts are updated following the completion of each analytical batch analysis.

- The center line of the control chart is the mean of the time ordered points;
- The upper/lower control limit is defined as the mean plus/minus 3 times the standard deviation of the points;
- The upper/lower warning limits are defined as the mean plus/minus 2 times the standard deviation of the mean.

A laboratory method will be considered out of statistical control when the following are observed from the control charts:

- Any one point is outside the control limits;
- Any three consecutive points are outside the warning limits;
- Any eight consecutive points are on the same side of the centerline;
- Any six consecutive points are such that each point is larger or smaller than its immediate predecessor;

If any of the above mentioned examples occur, the management is notified of the out-of-control event, and they investigate and determine if the condition is truly an out-of-control event, or a possible random error. If it is determined to be an out-of-control event, corrective actions such as instrument recalibration and sample reanalysis will be taken. All corrective actions shall be documented and maintained in the QA program files.

14.0 Documentation, Validation of Data and Reporting

14.1 Recording Raw Data

Laboratory data are generated in the following ways; instrument generation of electronic data files, local generation of data using instrument software and in-house spreadsheets, and manual recording of observed measurements. The individual analyst completes report forms. Raw data are maintained in completed notebooks or data packages. The QA director will check reduced raw data for error.

14.2 Data Reduction

Data reduction includes all processes that change either the form of expression (i.e.: units) or the quality of the data values (rounding). Data reduction often involves statistical and mathematical analysis of data and usually results in a reduced subset of the original data set (i.e.: an average of three data points). Wherever employed, mathematical procedures will be verified for accuracy of computation.

All data are generated and reduced in accordance with the method SOP. The data can be reduced by:

- Manual computation directly found on an instrument/analysis logbook page or data sheet or
- Computer processing of input of raw data through direct instrument linkage or manual entry.

The analyst who generates the data is directly responsible for ensuring that the computations are correct and complete and that all data reduction is documented appropriately for subsequent data review and validation. Any additional equations used in the data reduction process are required to be evident in the documentation. The computations are reviewed on a regular basis for accuracy by the QA director.

The analyst is responsible for verifying that the data reduction is correct for the project, sample numbers, calibration RFs and/or correlation coefficients, units, detection limits, dilution factors, and volume used.

14.3 Laboratory Data

The researcher and analyst performing the work document all sample preparation activities in laboratory notebooks or on laboratory worksheets. These serve as the primary record for subsequent data reduction.

Laboratory data are generated in the following ways: instrument generation of electronic data files, local generation of data using instrument software and in-house spreadsheets, and manual recording of observed measurements. Consistent data collection is attached through the existence and use of SOPs.

Outputs from all instruments are monitored for readability and consistency. If clarity is less than desired, corrective actions are undertaken to rectify the output based on instrument manufactures' recommendations.

Laboratory forms, data sheets, logbooks, and reporting forms have a standard format to ensure that all pertinent information is recorded consistently. These forms are generated by the QA director and are regularly monitored to ensure compliance with established requirements.

Analysts have control over and access to all data they have generated. Limited access policies, including password codes for computer generated data access, maintain security of data.

Data are checked for accuracy and precision by the analysts and QA director. The maintenance and inspection of the following records shall support the validity of data:

- Description of calibration
- Documentation of traceability of standards;
- Documentation of analytical methodologies (SOPs) and QC methodology;
- Method blank results to check for contamination and interference;
- Laboratory control sample results will be inspected as to whether they fall inside the acceptable control limits.

14.4 Laboratory Data Validation and Reporting

Data validation is the systematic process of data evaluation for acceptance or rejection based upon a set of criteria. It is a systematic procedure of reviewing a body of data against a set of criteria to provide assurance of validity prior to its intended use.

The analysts and the QA director perform data validation. Validation is accomplished through routine audits of the data collection and flow procedures and by monitoring of the QC sample results.

Data validation includes dated and signed entries by analysts on the worksheets and laboratory notebooks used for all samples; the use of sample tracking and numbering systems to tack the progress of the sample in the laboratory; and the use of quality control criteria to reject or accept specific data.

The raw data are compared with the report forms for agreement. The raw data and/or report forms are compared to the final printed report for agreement. This review is the final assessment of completeness and accuracy of the data. If there is discrepancy of any type, the standard procedure for verification and confirmation is followed.

If raw data do not agree with the forms, the cause will be determined, the source of the problem will be corrected, and all incorrect data from the point of error will be corrected.

A corrective action form will be completed to indicate the corrective action for the results and/or laboratory samples affected. Audit tails are maintained for data chains through analytical batch preparation records.

After all appropriate changes are made, another review of the data in question is performed. This will ensure that forms and raw data agree.

14.5 Data Collection and Flow Audits

Data collection and flow audits are performed routinely and include the followings:

- Daily review of sample documents for completeness;
- Daily review of test results;
- Daily review of performance indicators and QC sample results;
- Random calculation checks;
- Review of all reports prior to and subsequent to data entry;
- Review and approval of final report by the QA director.

14.6 Data Review

Data review is performed prior to release of the data to the customers and contracting agencies. It is performed as soon as possible after data acquisition in order to provide sufficient time for corrective action if required.

In the data review process, the data undergo a minimum of two separate reviews. The data are compared to information such as the expected characteristics of the sample, the sample preparation steps, and QC sample data to evaluate the validity of the results.

Corrective action is minimized through the development and implementation of routine internal system controls. Analysts are provided with specific criteria that must be met for each procedure, operation, or measurement system.

Supporting material, such as chromatograms are compiled by the analyst and incorporated into the data delivered by the data processor.

The final deliverable data is reviewed for transcription and typographical errors by the management prior to release to the customers and other agencies.

14.7 Documentation

Upon completion of the project or job task, the final report will be compiled and includes a brief narrative discussion of the analyses, the analytical results, and the QC results. The final report is reviewed and approved by the QA director.

A documentation control system assures that all documents for a given project are accountable and traceable. It includes chain-of-custody records, all logbooks, graphs, raw data, and other miscellaneous items.

14.8 Record Keeping

The analysts process samples together in a batch. A batch consists of a number of samples carried though the entire analytical procedure, along with QC samples and blanks. All work performed on a sample batch is documented in laboratory logbooks which are described as follows:

- Sample Receiving Logbook: This logbook lists samples as they are received into the laboratory.
- Instrument Maintenance Logbook: A unique logbook is maintained for each system and used to record the maintenance and upkeep of analytical instruments.
- Standard Logbook: This is used to record the preparation and use of all standards in the laboratory. It indicates standard tracebility. Documented in this logbook are all activities associated with the standard preparation process. Laboratory notebooks for each staff member are a functional record and are pre-numbered.
- Data Notebook or Bench Sheets: This is used to document all activities associated with the analytical process and recording raw data of every batch.
- In some instances, analytical data recording and standards preparation may be included in a single notebook.

14.9 Rules Governing the Use of Logbooks

- Bound notebooks with pre-numbered pages are preferred record-keeping forms. Loose sheets, if used, are ultimately secured in notebooks;
- All writing must be legible and in black ink. All numbers are clear. Corrections are made by drawing one line through the incorrect entry, entering the correct information, initialing, and dating the entry;
- Complete information should be entered so that in an examination, it can be determined what was done, when and what the results were;
- If any data are determined to be invalid, reasons are indicated;
- All relevant information is included (i.e.: the manufacturer and lot number of a chemical, the specific procedure reference, etc.);
- When work is continued in another notebook or logbook, the number of the first notebook is written in the first page of the new notebook and vice-versa for easy reference.

15.0 Standard Operation Procedures

The laboratory maintains SOPs for each methodology or procedure used. SOPs are updated frequently for any revisions made. Changes in documents reflect actual procedures being followed. Before any revision is made, documents are submitted to the

QA director for approval of the proposed revision. Minor changes are those which do not affect the content or quality of the action being prescribed in the document.

An addendum, subject to review and approval by the QA director, may be attached to a document to reflect policy and procedural changes, which become effective between revisions. These changes are then incorporated into the body of the document at the time of the next revision.

15.1 Verification of Software

All computer software used to acquire, process or report data shall be verified upon initial use and re-verified after any modification. Limited access policies for software and data maintain security and integrity of these systems.

15.2 Updating of Software

Instrument software is updated regularly as new versions of software becoming available. Performance is verified and compared with older version. Backward compatibility is considered when updating the software to make sure old records will be available on demand.

16.0 Research Project Quality Assurance Plans

Specific quality assurance plans (QAP) for research project may be developed to meet contract and agency requirements on a project specific basis. These plans discuss specific terms, policies, objectives and QA activities to achieve the data quality objectives of the project.

QA Project Plans are generally written in accordance with the US EPA document "Guidelines and Specifications for Preparing Quality Assurance Project Plans."

These plans follow the format listed below as applicable (additional information is added, if required):

- Title Page
- Table of Contents
- Approval Signatory Page
- Introduction
    - Project Description
    - Background
    - Definition of Terms
    - Purpose
    - Scope

- Project Organization and Responsibilities
- QA Objectives for Data Measurement, in terms of precision, accuracy, completeness, comparability and representativeness
- Sampling Requirements
- Sample Custody
- Calibration Procedures and References
- Analytical Procedures
- Data Analysis, Validation, and Reporting
- Quality Control
    - Internal QC Checks
    - Performance and System Audits
    - Preventative Maintenance Procedures and Schedules
- Data Quality Assessment
- Corrective Action
- QA Reports to Management

17.0 Performance and System Audits

Performance and systems audits are conducted semi-annually by the QA director and encompass all activities of the laboratory; to assess compliance with established methods, policies and procedures. These audits are both scheduled and unscheduled.

An audit is defined as a systematic check to determine the quality of the laboratory operation and activities. The following are definitions of audit types:

Performance Audit: Determines the accuracy of the total measurement system, or portions. Test samples are analyzed and results evaluated.

System Audit: An evaluation of all components of the laboratory's measurement systems to determine their proper selection and use, including QC procedures.

Copy of the audit findings and any proficiency test results obtained are submitted to the EEL supervising faculty in the quality assurance reports.

17.1 Performance Audit

A performance audit involves analysis of reference samples of concentrations unknown to laboratory personnel to evaluate analyst/method performance. Reference standards or matrix standards are purchased from reputable suppliers (Environmental Resource Associates and USEPA) or prepared using traceable standards and submitted to the laboratory by the QA director. The true values or reference values are available only to the QA director.

The laboratory through the use of blind check samples accomplishes internal performance audits (when available), replicate measurement evaluations, and individual proficiency test samples. Results are compared to "true" values and evaluated for accuracy and/or precision. The QA director maintains the record of these audits.

17.2 Systems Audit

The laboratory systems audit is designed to verify that all QA/QC practices are being followed and that all procedures and protocols are fully understood and upheld by laboratory personnel. It is also used to find problems which may have entered the system or for which the QA/QC program is insufficient. General audit checklists, which apply to all laboratory areas and procedures have been developed, and are used for documenting audit and surveillance findings.

Audits ensure that laboratory quality control criteria are adhered to and proper corrective actions are implemented, when needed. All inquiries relative to data quality issues are reviewed and any corrective actions identified.

The audits include an evaluation of the work areas, activities, processes, review of documents and records, storage of standards and reagents, housekeeping, good laboratory practice, analytical procedures, and quality control.

The auditor uses a prepared audit checklist, documents the audit in writing, and signs the audit report. The audit report contains sufficient information to stand alone as a document.

Any deficiencies noted during the audit are discussed with the audited department within seven days of the audit. All corrective actions are taken and a formal response submitted to the auditor following receipt of the audit report. The auditor re-audits the area to determine that the corrective action was implemented and the deficiency corrected.

System audits include an evaluation of the following:

- Assessment of compliance with the QA Program;
- Verification of and adherence to written procedures;
- Proper data storage and record keeping ;
- Analytical data review and validation procedures

18.0 Instrument Maintenance Procedures

Preventative maintenance is the program of positive actions for preventing failure of equipment and ensuring that the equipment is in operation with the reliability required for quality results. The actions include specification checks, calibration, lubrication, reconditioning, and adjusting.

A preventative maintenance program for the instruments ensures fewer interruptions of analyses, personnel efficiency, and lower repair costs. It eliminates premature replacement of parts, and reduces discrepancy among test results.

The EEL laboratory staff using the instrumentation are fully trained and have developed troubleshooting skills that enable them to recognize problems, their causes and the appropriate corrective actions, quickly and accurately to reduce equipment failure.

Instrument maintenance is deemed necessary when an instrument is inoperable, is not performing acceptably or as expected, or a change in the performance characteristics of the instrument is noted.

Major maintenance and repair of instrumentation is only performed by qualified analysts and manufacturer recommended service representatives.

Following major instrument maintenance and repair activities, a return to analytical control must be demonstrated and documented through performance according to typical QA/QC requirements.

Written equipment maintenance records are kept to document all maintenance and repair activities. Instrument performance criteria are established to determine the need to make adjustments to the instrument operation conditions.

The following are examples of general measures that are performed throughout the laboratory as a part of the preventative maintenance program.

GC/MS Systems

- Injection port liners and gold seals are replaced daily or as deemed necessary;
- Two to three inches of the front of the pre columns or capillary columns are removed as deemed necessary;
- Septa are inspected and replaced (if necessary) before each batch sequence;
- Ion source is cleaned as required;
- Mass Spectrometers are tuned after every 12 hours of use;
- Compressed gas cylinders are checked daily;
- Autosampler wash bottles are changed at the beginning of each sequence;
- Gas filters on carrier lines are checked weekly.

GC Systems

- Septa are replaced before starting a new sequence run;
- Compressed gas cylinders are checked daily;
- A solvent blank is injected before starting a new sequence rum to demonstrate the system is free of interfering artifacts;
- Flows are checked before starting sequence;
- Autosampler wash bottles are changed at the beginning of each new sequence run;
- Gas filters on carrier lines are checked weekly.

pH Meters

- Gel-type electrodes are inspected prior to use and cleaned with Mico© cleaning solution to remove oily residues;
- The pH meter is calibrated daily before use. If calibration or the slope has deteriorated, the electrode is cleaned and treated with 1N HCL, then recalibrate;
- Calibration is conducted using three standard pH solutions.
- pH electrodes are stored in fresh pH 7.0 buffer solution when not in use.

Analytical Balances

- All balance surfaces are cleaned daily and covered when not in use;
- Analytical balances are calibrated and cleaned annually by manufacturer's representatives;
- Labels are attached to each balance indicating date of last calibration;
- The accuracy of each balance is checked against the built-in weight prior to use.

19.0 Procedures for Assessing Precision, Accuracy and Completeness

19.1 Precision

Reproducibility among duplicate samples provides a determination of precision in analytical testing. Precision is determined by splitting actual samples, which cover a wide range of concentrations, and a variety of commonly encountered interfering materials

Duplicates and duplicate matrix spiked samples are run at a frequency of every 10 to every 20 samples analyzed as specified in the particular method or SOP. Acceptable RPD (relative percent difference) results are <20% or <30% depending upon the sample matrix type analyzed and specific analysis performed.

19.1.1 Duplicate

A duplicate is a regular sample, which is split and carried through the entire sample preparation and analysis procedure with the sample set. Duplicate results provide information regarding the sample matrix effects, and the method efficiency. Duplicate samples are run at a frequency of one for every 20 samples analyzed, or at a minimum of one per batch and matrix analyzed, whichever is greater.

19.1.2 Matrix Spike

A matrix spike is a regular sample that is spit into three sub-samples and two of the replicates are spiked with analyte solution at the same concentration. The two spiked replicates are defined as the matrix spike and the matrix spike duplicate. The matrix spike and the matrix duplicate samples are carried through the sample preparation and analysis procedure with the sample set. Matrix spikes are run at a frequency of every 10 to 20 samples analyzed, or at a minimum of once per analyzed batch and matrix, whichever is greater. The matrix spike and matrix spike duplicate results provide information regarding the precision of the matrix spike and matrix spike duplicate, the sample matrix effects, and the method efficiency.

The difference between the matrix spike and the matrix spike duplicate are reported as RDP as calculated below.

$$RPD = \frac{MS - MSD}{\left[\frac{MS + MSD}{2}\right]} x100$$

RPD = Relative percent difference
MS = Matrix spike result
MSD = Matrix spike duplicate result

19.2 Accuracy

Accuracy is the degree of difference between observed and actual (known) values. Accuracy is determined by analyzing reference samples. Acceptable percent recoveries for matrix spikes are based upon statistical control limits. Control limits are equal to or narrower than the EPA published control limit ranges for each method.

Percent recovery calculations are determined through the following equation:

$$\% \text{ Recovery} = \frac{(C_o - C_{us})}{C} x100$$

C_o = Concentration observed in analysis
C = True value of standard
C_{us} = Concentration observed in unspiked sample

Spike data can be indicative of matrix bias or interference on analyte recovery as well as sample preparation procedure performance. A spiked sample is a regular sample to which a known concentration of analyte is introduced. The sample is then carried through the entire workup or extraction and analysis procedure with the other samples in the sample set. The spike is reported as percent recovery.

20.0 Corrective Actions

20.1 Corrective Actions

The purpose of a formal corrective action process is to identify areas that require improvement and to ensure that long-term corrective action is put in place to resolve the problem in a permanent manner.

Corrective actions are required any time project or method requirements are not met or as a result of deficient audit findings. The laboratory QA director is notified immediately and the approach and time frame of the corrective action is discussed. The out-of-control situation is documented and the customer is notified.

Whenever possible, a long-term resolution to the occurrence is desirable. In some instances involving unusual circumstances, a long-term corrective action may not be appropriate. This process is designed to handle both types of occurrences and to document the action that was taken. A fundamental goal of the corrective action process is to foster continual improvement in laboratory operations. Corrective actions are monitored to make certain that similar problems do not reoccur.

Daily quality control procedures are designed to identify the need for corrective action. Most corrective actions are performed by the analyst doing the analysis, and are usually as simple as re-calibrating an instrument should the instrument check sample or calibration curve verification (CCV) fall outside its acceptable range, or resulting because of a power failure. Most corrective actions are described in methods, SOP, and instrument manuals.

Standard operation procedures for corrective actions are to:

- Define the problem;
- Define the cause of the problem;
- Determine possible solutions to the problem;
- Implement corrective action;
- Verify that the corrective action is effective, and
- Document the corrective action and it's effectiveness

All employees must immediately bring to the QA director's attention any problem or practice, which they feel, may affect data quality. If control parameters are outside acceptability criteria analysis must cease immediately and all affected samples must be reanalyzed when the system is corrected.

The need for corrective action may result from:

- Instrument malfunction;
- Failure of internal QA/QC checks;
- Failure to follow-up on performance or system audit findings;

- And non-compliance with QA requirements.

Corrective actions taken depend on the type of analyses and the extent of the error and are discussed with the laboratory supervisor and/or management. If the problem is indeterminate and cannot be controlled, the laboratory evaluates its impacts on the data.

The QA director shall determine that proposed corrective actions are actually implemented and successful. When corrective actions are implemented, evidence of their success shall be documented. Corrective action documents are to be signed and dated by the analyst, and the QA director.

All corrective action documents are reviewed and maintained by the QA director in the QA program files.

20.2 Criteria Used for Determining an Out-of-Control Event

Factors that affect data quality require investigation and corrective actions. All out-of-control events are investigated to determine whether the condition indicates a procedure that is truly out-of-control, or a possible random error. Any corrective actions taken are to be documented, whether the analytical batch is repeated or the data were reviewed and released to the customers and contracting agencies.

20.3 Procedures for Stopping Analysis

Whenever an analytical system is out-of-control, investigative corrective action is initiated. Once corrective actions have been implemented, samples may be reanalyzed. If a sample batch reanalysis is out-of-control following corrective actions, all analytical work for the method will cease immediately. A detailed investigation shall be conducted to identify the source of the problem. Sample security, integrity of standards, glassware preparation, reagents, notebooks, instrument performance, method adherence shall be included in this investigation. All actions taken will be documented.

21.0 Timeliness of Data Reports

The EEL recognizes the timeliness that data reports are assessed, as an important part of the quality of our services from the customer's respective. The EEL' tracking procedure is designed to monitor and maintain on-time report generation.

22.0 Quality Assurance Reports to Supervising Faculty

The QA director completes quarterly reports regarding the quality activities of the laboratory. A typical report includes such information as:

- Proposed revisions in the QA program;

- Performance evaluation results;
- System audit results;
- Significant QA concerns and recommendations for resolution;
- Accomplishments since previous report.

The QA director keeps and maintains in the QA program files copies of all quality assurance reports.

23.0 Quality Assurance Program Revisions

Revisions to the EEL QA program, Guideline can be made upon written request and approval of the QA director. Guideline revisions are to be presented to the laboratory staff for implementation immediately following approval. Customer-requested QC procedures may be incorporated on a project basis provided the procedures are not in opposition to the objectives of quality assurance and the EEL QA program. Revisions must be documented and kept on file for review.

Appendices

Appendix A: Laboratory Instrument

Appendix B: Sample Holding Times and Preservation Requirements

Appendix A: Laboratory Instrumentation

- Hewlett Packard 6890 Gas Chromatograph with Micro-ECD Detector, 7683 Auto Injector and Chem Workstation;
- Hewlett Packard 5793 Mass Selective Spectrometer Interfaced to the HP-6890 G Equipped with 59864B Ionization Gauge Controller and NIST Search Library;
- Shimadzu 14A Gas Chromatographs with FID and ECD Detectors and AOC-20i Auto Injector;
- Perkin Elmer AutoSystem Gas Chromatographs with FID & ECD Detectors and PE Nelson Workstation;
- Tekmar LSC-3000 Purge & Trap Sample Concentrator;
- Tekmar ALS-2016 Purge and Trap Autosampler with Automatic Sample Heater;
- Dionex DX-500 Ion Chromatograph with 2-channel/pump (GP50) system for parallel simultaneous of two samples. System equipped with conductivity and conductivity electrochemical detectors (ED40);
- Dionex AS-50 Autosampler interfaced with Dionex Ion Chromatograph;
- Waters HPLC-515 High Pressure Liquid Chromatograph with Photodiode Array (Waters 996) and Scanning Fluorescence (Waters 474) Detectors and PC Workstation;
- Shimadzu UV-1601 UV/Vis Spectrophotometer;
- Two Shimadzu TOC-5000A Total Organic Carbon Analyzers;
- Shimadzu ASI-5000A Autosampler interfaced to one of the TOC-5000A;
- Shimadzu SSM-5000A Solid Sample Module Interfaced to the second TOC Analyzer;
- Varian Spectra-220 Atomic Absorption Spectrophotometer with UltraAA-Lamp Power Control Module and PC Workstation;
- Varian GTA-110 Graphite Furnace Interfaced to the Varian Specta-220 with Varian Autosampler;
- Spectronic 1001 UV/Vis Spectrophotometer;
- Durrum Stopped-Flow Spectrophotometer;
- Spectronic Genesis Spectrophotometer;
- Millipore Milli-Q Ultra-clean Low TOC Water Purification System;
- Columbus Instrument Micro-Oxymax 10-Channel Computerized Respirometer with Dual-range O_2 and CO_2 Detectors and PC Workstation;
- Two Osmonic OREC V-10 Ozone Generators;
- Welsbach T-408 Ozone Generator;
- Rayonet Photochemical Reactor with 16 UV lamps;
- COY Anaerobic Chamber, 84 ft^3 capacity (7' [L] x 3' [W] x 4' [H]) with vacuum interlock chamber;
- Two HACH Chemical Oxygen Demand Reactors;
- HACH BODtrack Biochemical Oxygen Demand measuring unit;
- Seven Bausch & Lomb Optical Microscopes;
- Javelin Spectar Microscope Video Camera with Panasonic Monitor;

- COMCON Microscope with Darkfield, Phase Contrast and Fluorescence Vertical Illuminator;
- Hinkle's Otical M1000-D Light Microscope;
- Two Quebec Darkfield Colony Counters;
- Orion Model 407A Specific Ion Meter with a Variety of Selective Ion Probes;
- Two HACH Model 2100A Turbidimeter;
- Whatman 78-40 TOC Gas Generator;
- Whatman Hydrogen Gas generator;
- Whatman Zero Air Generator;
- International Model HN Centrifuge;
- Market Forged STERILMATIC Autoclave;
- American Sterilizer Autoclave;
- Jelrus High Temperature Furnace;
- Lindberg Digital Control Tube Furnace;
- Yamato DX-400 Digital Control Drying Ovens;
- Labline Gravity Drying Oven;
- Yamato IC-600 Digital Control Incubator;
- BOD Incubator;
- Precision Scientific Incubator;
- pH Meters (Acumet 800, Beckman Zeromatic and Corning);
- Three Mettler Analytical Balances;
- Labconco Distillation Unit;
- Barnstead E-Pure Organic-Free Water Purification System;
- Two water purification systems;
- NesLab Endocal RTE-9 Refrigerated Circulating Bath;
- Lindberg/Blue Refrigerated Circulating Shaking Bath;
- Shakers (Eberbach, Precision), pumps Masterflux and FMI), Refrigerators, timers, water baths (Precision, Fisher), stirrers, hotplates . . . etc.; and
- Nine Pentium II & III Computers.

Appendix B: Sample Holding Times and Preservation Requirements*

Adopted from Standard Methods, 19th Edition, 1995.

Determination	Container †	Minimum sample Size ml	Sample type ‡	Preservation §	Maximum Storage Recommended/ Regulatory ¶
Acidity	P, G(B)	100	g	Refrigerate	24 h/14 d
Alkalinity	P, G	200	g	Refrigerate	24 h/14 d
BOD	P, G	1000	g	Refrigerate	6 h/48 h
Boron	P, G	100	g, c	None	28 d/6 months
Bromide	P, G	100	g, c	None	28 d/28 d
Carbon, organic, total	G	100	g, c	Analyze immediately; or refrigerate and add H_3PO_4 or H_2SO_4 to pH<2	7 d/28 d
Carbon dioxide	P, G	100	g	Analyze immediately	stat/N.S.
COD	P, G	100	g, c	Analyze ASAP, or add H_2SO_4 to pH<2; refrigerate	7 d/28 d
Chloride	P, G	50	g, c	none	28 d
Chlorine, residual	P, G	500	g	Analyze immediately	0.5 h/stat
Chlorine dioxide	P, G	500	g	Analyze immediately	0.5 h/N.S.
Color	P, G	500	g, c	Refrigerate	48 h/48 h
Conductivity	P, G	500	g, c	Refrigerate	28 d/28 d
Cyanide, total	P, G	500	g, c	Add NaOH to pH>12, refrigerate in dark	24 h/14 d; 24 h if sulfide present
Cyanide, amenable to chlorination	P, G	500	g, c	Add 100 mg $Na_2S_2O_3$/L	stat/14 d; 24 h if sulfide present
Fluoride	P	300	g, c	None	28 d/28 d
Hardness	P, G	100	g, c	Add HNO_3 to pH<2	6 months/6 months
Iodine	P, G	500	g, c	Analyze immediately	0.5 h/N.S.
Metals, general	P(A), G(A)	500	g	For dissolved metals filter immediately, add HNO_3 to pH<2	6 months/6 months
Chromium VI	P(A), G(A)	300	g	Refrigerate	24 h/24 h
Mercury	P(A), G(A)	500	g, c	Add HNO_3 to pH<2, 4°C, refrigerate	28 d/28d
Nitrogen, ammonia	P, G	200	g, c	Analyze as soon as possible or add H_2SO_4 to pH<2, refrigerate	7 d/28 d
Nitrogen, nitrate	P, G	100	g, c	Analyze as soon as possible or refrigerate	48 h/48 h (28 d for chlorinated samples)
Nitrogen, nitrate + nitrite	P, G	200	g, c	Add H_2SO_4 to pH<2, refrigerate	none/28 d
Nitrogen, nitrite	P, G	100	g, c	Analyze as soon as possible or refrigerate	none/48 h
Nitrogen organic Kjeldahl	P, G	500	g, c	Refrigerate, add H_2SO_4 to pH<2,	7 d/28 d
Odor	G	500	g, c	Analyze as soon as possible or refrigerate	6 h/N.S.
Oil and grease	G, wide-mouth	1000	g, c	Add HCl to pH<2, refrigerate	28 d/28 d
Organic compounds					
MBAS	P, G	250	g, c	Refrigerate	48 h
Pesticides#	G(S), TFE-lined cap	2 x 40	g	Refrigerate, add 1000 mg ascorbic acid/L if residual chlorine present	7 d/7 d until extraction; 40 d after extraction

Determination	Container †	Minimum sample Size ml	Sample type ‡	Preservation §	Maximum Storage Recommended/ Regulatory ¶
Phenols	P, G	500	g, c	Refrigerate, add H_2SO_4 to pH<2	*/28 d
Purgeables* by purge and trap	G, TFE-lined cap	2 x 40	g	Refrigerate, add HCl to pH<2; add 1000 mg ascorbic acid/L if residual chlorine present	7 d/14 d
Oxygen, Dissolved: Electrode	G, BOD bottle	300	g	Analyze immediately	0.5 h/stat
Oxygen, Dissolved: Winkler	G, BOD bottle	300	g	Titration may be delayed after acidification	8 h/ 8 h
Ozone	G	1000	g	Analyze immediately	0.5 h/N.S.
pH	P, G	50		Analyze immediately	2 h/stat
Phosphate	G(A)	100	g	For dissolved phosphate filter immediately; refrigerate	48 h/N.S.
Salinity	G, wax seal	250	g	Analyze immediately or use wax seal	6 months/N.S.
Silica	P	200	g, c	Refrigerate, do not freeze	28 d/28 d
Sludge digester gas	G, gas bottle		g		N.S.
Solids	P, G	200	g, c	Refrigerate	7 d/2-7 d
Sulfate	P, G	100	g, c	Refrigerate; add 4 drops 2N zinc acetate/100 mL; add NaOH to pH>9	28 d/7 d
Taste	G	500	g	Analyze as soon as possible; refrigerate	24 h/N.S.
Temperature	P, G		g	Analyze immediately	stat/stat
Turbidity	P, G	100	g, c	Analyze same day; store in dark up to 24 h, refrigerate	24 h/48 h

* For determination not listed, use glass or plastic containers; refrigerate during storage and analyze as soon as possible.

† P = plastic (polyethylene or equivalent);
G = glass;
G(A) or P(A) = rinsed with 1 + 1 HNO_3;
G(B) = glass, borosilicate;
G(S) = glass, rinsed with organic solvents or baked.

‡ g = grab;
c = composite.

§ Refrigerate = storage at 4°C, in the dark.

¶ EPA, Rules and Regulations. 40 CFR Parts 100-149, July 1, 1992.
N.S. = not stated in cited reference;
Stat = no storage allowed; analyze immediately.

* See analytical method for additional details.

MEANS AND STANDARD DEVIATIONS FOR WATER QUALITY PARAMETERS

Mean and Standard Deviation of Water Quality Parameters
(with ND set at half of the limit of detection)

Parameter	Unit	Control Mean	WFB Mean	StDev.	WMP Mean	StDev.	PMP Mean	StDev.
pH		6.90	6.67	0.01	7.31	0.17	7.09	0.08
Total Suspended Solids	mg/L	ND	2,904	578	15,983	490	25,531	1657
TOC	mg/L	1.87	27.67	3.94	12.14	2.23	4.86	0.17
COD	mg/L	9.00	120.79	16.30	42.79	11.32	22.20	1.11
BOD_5	mg/L	0.30	34.00	9.17	5.20	0.69	4.40	0.69
Nitrite	mg N/L	ND	0.03	0.00	0.39	0.15	0.17	0.03
Nitrate	mg N/L	ND	1.89	0.35	0.63	0.09	0.25	0.07
Nitrite+Nitrate	mg N/L	ND	1.89	0.35	1.02	0.23	0.42	0.09
TKN	mg N/L	ND	0.05	0.00	0.05	0.00	0.28	0.00
Phosphorous	mg P/L	0.08	0.36	0.06	0.79	0.24	1.00	0.20
Aluminum	µg/L	ND	4.43	5.95	50.47	4.44	23.25	5.19
Arsenic	µg/L	ND	5.00	0.00	5.00	0.00	5.00	0.00
Barium	µg/L	ND	16.20	15.07	113.87	11.12	76.90	3.82
Cadmium	µg/L	ND	0.30	0.00	0.30	0.00	0.30	0.00
Calcium	µg/L	38.00	132.67	28.01	188.00	20.66	251.00	21.07
Copper	µg/L	ND	0.50	0.00	7.00	1.21	4.36	1.20
Chromium	µg/L	ND	5.33	7.19	4.57	2.14	0.50	0.00
Iron	µg/L	ND	40.63	20.38	4.30	1.97	2.43	2.79
Lead	µg/L	ND	6.00	0.00	6.00	0.00	6.00	0.00
Lithium	µg/L	ND	0.20	0.00	0.20	0.00	0.41	0.19
Magnesium	mg/L	ND	2.00	0.00	2.00	0.00	2.00	0.00
Mercury	µg/L	ND	0.10	0.00	0.10	0.00	0.10	0.00
Nickel	µg/L	ND	1.50	0.00	1.50	0.00	1.50	0.00
Vanadium	µg/L	ND	17.00	0.00	17.00	0.00	17.00	0.00
Zinc	µg/L	ND	0.05	0.00	0.17	0.06	0.17	0.05
Thulium	mg/L	ND	0.25	0.00	0.25	0.00	0.25	0.00

Mean and Standard Deviation of Water Quality Parameters (Continued)

(with ND set at half of the limit of detection)

Parameter	Unit	WMS Mean	StDev.	PMS Mean	StDev.	Coir Mean	StDev.
pH		6.49	0.13	6.65	0.07	8.07	0.08
Total Suspended Solids	mg/L	7,028	588	20,036	1301	9,807	634
TOC	mg/L	15.98	3.91	11.21	1.28	3.29	0.33
COD	mg/L	65.08	13.36	42.27	6.12	20.67	1.63
BOD_5	mg/L	16.00	4.58	13.00	4.82	0.05	0.00
Nitrite	mg N/L	0.03	0.00	0.03	0.00	0.25	0.11
Nitrate	mg N/L	0.17	0.07	0.10	0.01	0.30	0.10
Nitrite+Nitrate	mg N/L	0.17	0.07	0.10	0.01	0.30	0.10
TKN	mg N/L	0.56	0.28	0.05	0.00	0.05	0.00
Phosphorous	mg P/L	0.75	0.17	0.49	0.03	0.47	0.16
Aluminum	µg/L	18.63	12.36	34.83	7.66	39.60	13.47
Arsenic	µg/L	5.00	0.00	5.00	0.00	5.00	0.00
Barium	µg/L	90.33	22.42	101.43	9.74	45.47	0.58
Cadmium	µg/L	0.30	0.00	0.30	0.00	0.30	0.00
Calcium	µg/L	190.67	7.77	261.33	15.57	116.67	15.50
Copper	µg/L	4.97	2.11	6.53	1.66	1.63	0.23
Chromium	µg/L	9.13	14.35	1.93	1.99	4.60	3.46
Iron	µg/L	2.42	2.08	5.93	3.78	5.25	4.55
Lead	µg/L	6.00	0.00	6.00	0.00	6.00	0.00
Lithium	µg/L	0.71	0.18	0.20	0.00	0.55	0.07
Magnesium	mg/L	4.00	3.46	14.03	6.81	2.67	1.15
Mercury	µg/L	0.10	0.00	2.00	0.00	2.00	0.00
Nickel	µg/L	1.50	0.00	3.57	1.79	1.50	0.00
Vanadium	µg/L	17.00	0.00	17.00	0.00	17.00	0.00
Zinc	µg/L	0.23	0.12	0.17	0.06	0.15	0.09
Thulium	mg/L	0.25	0.00	0.25	0.00	0.25	0.00

Mean and Standard Deviation of Water Quality Parameters (Continued)

(with ND set at half of the limit of detection)

Parameter	Unit	BFM Mean	StDev.	SCB Mean	StDev.	CB Mean	StDev.
pH		6.43	0.01	6.25	0.06	7.37	0.34
Total Suspended Solids	mg/L	304	215	3,865	239	2,487	701
TOC	mg/L	158.92	81.93	59.96	14.56	3.58	0.18
COD	mg/L	628.33	346.97	85.85	2.89	12.93	1.50
BOD_5	mg/L	220.00	139.37	40.50	1.50	2.60	0.35
Nitrite	mg N/L	0.03	0.00	0.03	0.00	0.14	0.06
Nitrate	mg N/L	1.04	0.81	1.44	0.21	0.31	0.03
Nitrite+Nitrate	mg N/L	1.04	0.81	1.44	0.21	0.44	0.09
TKN	mg N/L	0.05	0.00	0.59	0.05	5.04	0.28
Phosphorous	mg P/L	0.63	0.19	3.61	0.79	0.60	0.23
Aluminum	µg/L	37.00	7.06	136.57	56.87	106.00	73.06
Arsenic	µg/L	5.00	0.00	5.00	0.00	5.00	0.00
Barium	µg/L	96.20	17.24	98.97	10.01	56.83	11.85
Cadmium	µg/L	0.30	0.00	0.30	0.00	0.30	0.00
Calcium	µg/L	173.33	6.81	216.67	12.50	219.67	18.50
Copper	µg/L	7.53	4.85	15.30	10.15	3.60	1.11
Chromium	µg/L	2.43	0.95	14.33	8.55	7.93	8.46
Iron	µg/L	2.92	2.16	0.77	0.55	0.87	0.72
Lead	µg/L	6.00	0.00	6.00	0.00	6.00	0.00
Lithium	µg/L	0.20	0.00	0.87	0.59	0.30	0.17
Magnesium	mg/L	7.93	10.28	6.30	4.51	5.33	4.16
Mercury	µg/L	0.10	0.00	0.10	0.00	0.10	0.00
Nickel	µg/L	1.50	0.00	1.50	0.00	1.50	0.00
Vanadium	µg/L	17.00	0.00	17.00	0.00	17.00	0.00
Zinc	µg/L	0.28	0.36	0.33	0.21	0.23	0.15
Thulium	mg/L	0.25	0.00	0.25	0.00	0.25	0.00

Mean and Standard Deviation of Water Quality Parameters (Continued)
(with ND set at half of the limit of detection)

Parameter	Unit	WSI Mean	StDev.	COMP Mean	StDev.	SB Mean	StDev.
pH		5.27	0.07	7.61	0.17	5.94	0.30
Total Suspended Solids	mg/L	4,476	1496	26,227	1151	4,274	445
TOC	mg/L	171.32	16.78	6.39	0.45	135.80	17.74
COD	mg/L	310.56	13.43	18.57	1.83	522.00	92.02
BOD_5	mg/L	180.00	15.00	5.00	0.35	220.00	37.75
Nitrite	mg N/L	0.20	0.05	0.19	0.04	0.37	0.31
Nitrate	mg N/L	3.91	0.43	0.24	0.02	3.47	0.64
Nitrite+Nitrate	mg N/L	4.11	0.48	0.43	0.05	3.84	0.40
TKN	mg N/L	1.49	0.16	0.05	0.00	1.03	0.16
Phosphorous	mg P/L	3.91	1.35	0.31	0.02	4.29	0.42
Aluminum	µg/L	39.33	23.78	13.93	2.51	138.00	80.95
Arsenic	µg/L	5.00	0.00	5.00	0.00	5.00	0.00
Barium	µg/L	29.93	19.47	149.47	11.34	7.50	0.00
Cadmium	µg/L	0.30	0.00	0.77	0.81	0.30	0.00
Calcium	µg/L	244.33	11.50	261.67	2.08	180.00	11.14
Copper	µg/L	11.10	4.25	4.43	0.35	9.37	1.46
Chromium	µg/L	1.00	0.87	2.60	0.66	27.27	18.49
Iron	µg/L	16.30	13.08	24.13	21.46	638.67	366.98
Lead	µg/L	0.45	0.00	0.45	0.00	0.45	0.00
Lithium	µg/L	0.20	0.00	1.83	0.32	1.73	1.50
Magnesium	mg/L	18.70	3.01	87.37	36.44	4.27	0.76
Mercury	µg/L	0.10	0.00	0.10	0.00	0.10	0.00
Nickel	µg/L	1.50	0.00	1.50	0.00	1.50	0.00
Vanadium	µg/L	17.00	0.00	17.00	0.00	17.00	0.00
Zinc	µg/L	0.05	0.00	0.57	0.38	0.45	0.57
Thulium	mg/L	0.25	0.00	0.25	0.00	0.25	0.00

Mean and Standard Deviation of Water Quality Parameters (Continued)
(with ND set at half of the limit of detection)

Parameter	Unit	BARE-1 Mean	StDev.	BARE-2 Mean	StDev.
pH		8.40	0.08	8.15	0.07
Total Suspended Solids	mg/L	39,764	2425	40,531	2508
TOC	mg/L	3.07	0.53	2.90	0.20
COD	mg/L	13.59	2.04	13.59	1.51
BOD_5	mg/L	1.03	0.51	0.50	0.17
Nitrite	mg N/L	0.08	0.02	0.08	0.01
Nitrate	mg N/L	0.38	0.20	0.50	0.14
Nitrite+Nitrate	mg N/L	0.46	0.20	0.58	0.15
TKN	mg N/L	0.05	0.00	0.05	0.00
Phosphorous	mg P/L	0.21	0.01	0.22	0.06
Aluminum	µg/L	67.97	32.66	40.69	15.33
Arsenic	µg/L	5.00	0.00	5.00	0.00
Barium	µg/L	50.97	10.92	116.60	25.60
Cadmium	µg/L	0.30	0.00	0.30	0.00
Calcium	µg/L	224.33	12.74	258.33	2.08
Copper	µg/L	4.43	1.27	5.62	1.47
Chromium	µg/L	4.90	1.71	4.13	0.45
Iron	µg/L	13.77	5.33	5.97	1.70
Lead	µg/L	0.45	0.00	0.45	0.00
Lithium	µg/L	0.80	0.20	0.65	0.07
Magnesium	mg/L	9.57	0.65	19.03	14.60
Mercury	µg/L	0.10	0.00	0.10	0.00
Nickel	µg/L	1.50	0.00	3.87	4.10
Vanadium	µg/L	17.00	0.00	17.00	0.00
Zinc	µg/L	0.18	0.13	0.15	0.13
Thulium	mg/L	0.25	0.00	0.25	0.00

NATIVE SEEDLINGS

ART CAL
Artemisia California
California sage brush

ENC CAL

Encelia california

Bush sunflower

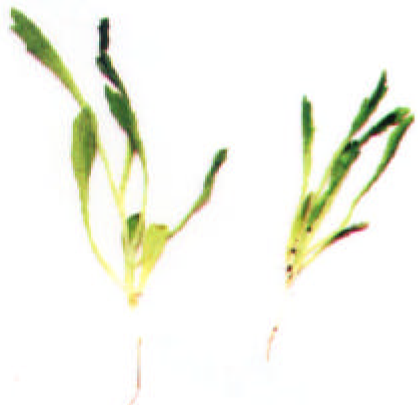
ERI FAS

Eriogonum fasciculatum

California buckwheat

HOR CAL

Hordeum californicum
California barley



ISO MEN

Isocoma menziesii

Goldenbush

LAS CAL

Lasthenia californica

Goldfields

LOT SCO

Lotus scoparius var. scoparius

Deerweed

LUP BIC

Lupinus bicolor

Lupine

NAS PUL

Nasella pulchra

Purple needlegrass

SAL MEL

Salvia mellifera

Black sage

VUL OCT

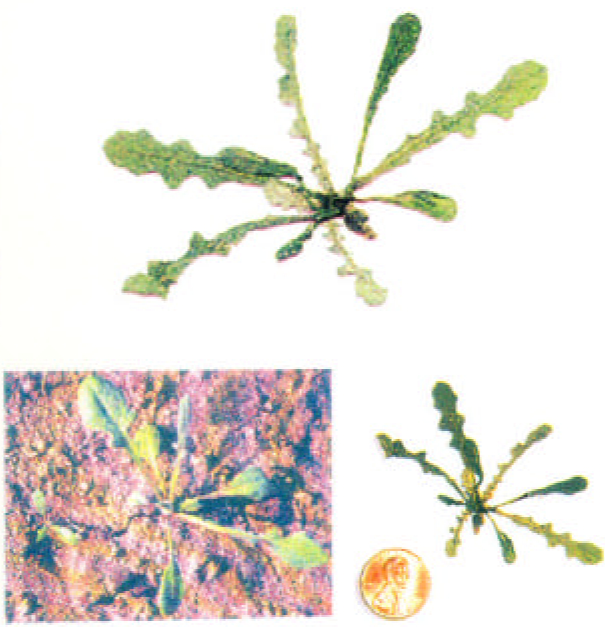
Vulpia octoflora

Six-weeks fescue

WEED SEEDLINGS

Weed species from
10-2 (De Vry) site
December 2, 1998

BRA NIG
Brassica nigra
Black mustard



CEN MEL
Centaurea melitensis
Yellow star thistle

BRO SPP
Bromus spp.
Ripgut brome

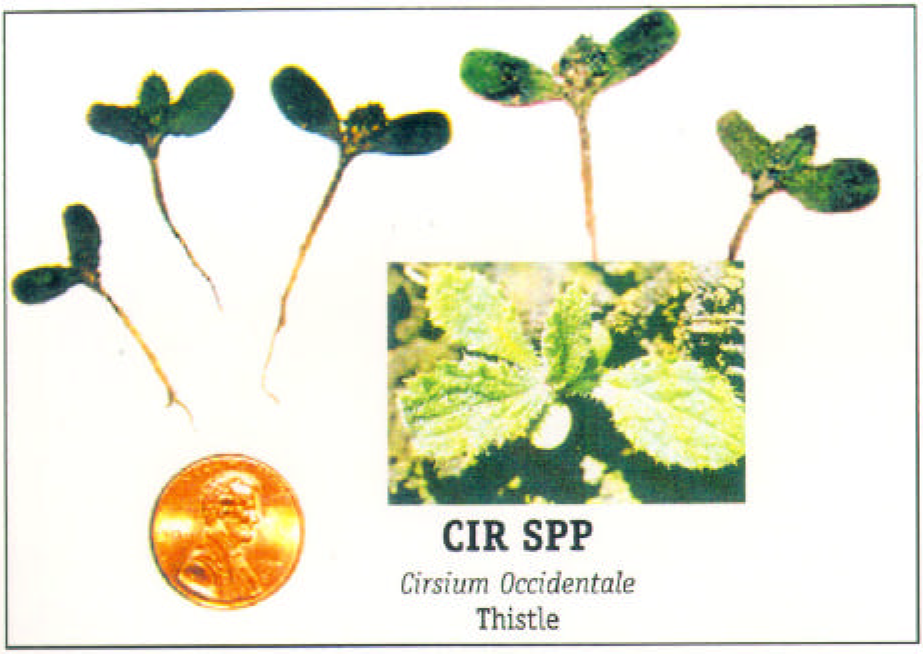
Weed species from
10-2 (De Vry) site
December 2, 1998

CHE ALB
Chenopodium album
Lamb's quarters

ERO SPP
Erodium spp
Filaree

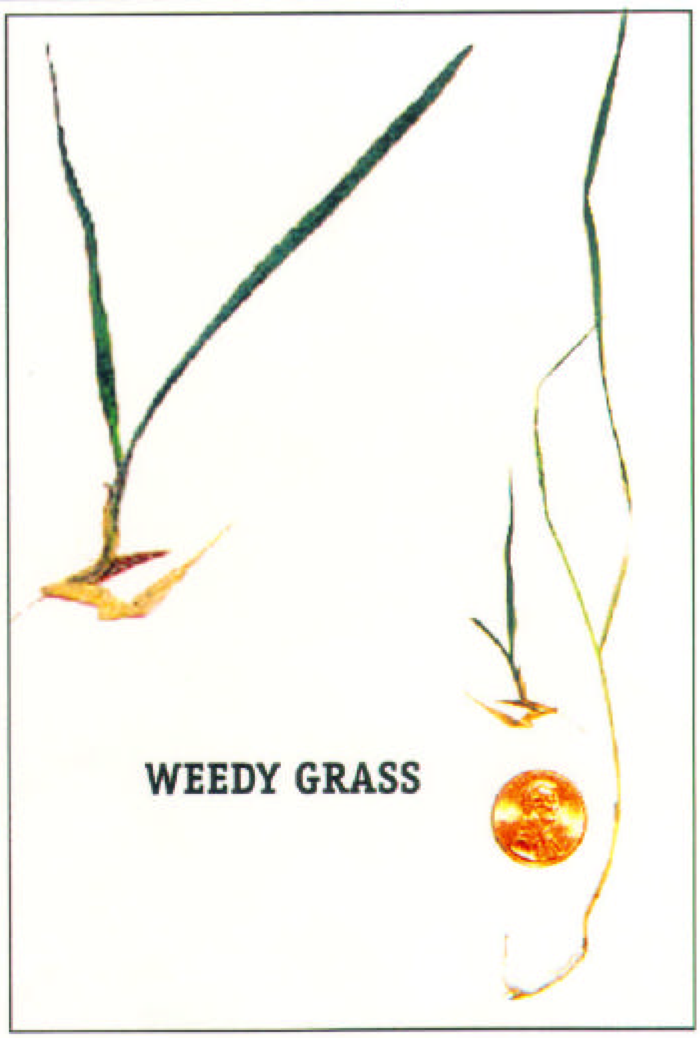
HIR INC
Hirschfeldia incana
Short-pod mustard

Weed species from
57-4 (Longhorn) site
December 2,1998



CIR SPP
Cirsium Occidentale
Thistle

LUP SUC
Lupinus succulentus
Arroyo lupine

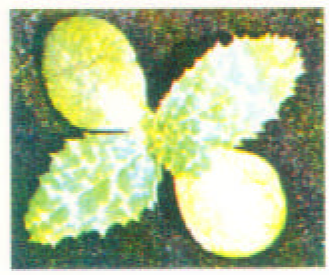


WEEDY GRASS

Weed species from
10-2 (De Vry) site
December 2, 1998

RAF CAL

Rafinesquia californiea
California chickory



SIL MAR

Silybum marianum
Milk thistle

EROSION CONTROL PERFORMANCE
CRIMPED AND TACKED STRAW

By

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Research Scientist
Texas A&M University

and

Jett A. McFalls
Associate Transportation Researcher
Texas Transportation Institute

Erosion Control Performance of Crimped and Tacked Straw

By

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Research Study Number 404901
Research Study Title:
Evaluating Crimped/Tacked Straw for Erosion Control

Sponsored by:
URS Greiner Woodward Clyde

May 2000

TEXAS TRANSPORTATION INSTITUTE
The Texas A&M University System
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NOTICE

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TABLE OF CONTENTS

ABSTRACT

Considerable comparative testing of temporary erosion control measures has been preformed at facilities throughout the United States. However, there is a lack of comparative performance data for a wide range of materials and installation methods. The Texas Transportation Institute's (TTI), Hydraulics and Erosion Control Laboratory has been conducting standardized performance tests of erosion control products and channel lining materials for the Texas Department of Transportation (TxDOT) since 1990. This standardization provides a basis for broad performance comparisons between materials related to sediment reduction and vegetation establishment.

The California Department of Transportation's (CalTrans) use of crimped or tacked straw mulch as an erosion control tool had not been tested. This made comparison to other Best Management Practices (BMPs) difficult. In response to the lack of comparison data, the TTI facility tested crimped and tacked straw performance. The data generated by these tests will facilitate comparison of these materials to other BMPs. This report outlines the testing methods and installation procedures used for crimped and tacked straw mulch. It further summarizes the results of the tests for the 1999 testing cycle.

Based on the study results, none of the straw-tack or crimped straw applications would meet minimum requirements for inclusion on the TxDOT Approved Product List.

INTRODUCTION

This study tested crimped straw and straw-tackifier applications as erosion control Best Management Practices (BMPs). The tests generated data that will allow direct comparison of the erosion control and vegetation establishment performance of these materials. This study will provide California Department of Transportation (CalTrans) consultants a more defensible basis for the comparison of the performance of straw applications to other available erosion control BMPs.

METHODS

Research Plots

Plot preparation, seeding, rainfall simulation, and vegetation measurements were made in accordance with the TTI Procedures and Evaluation Criteria for Erosion-Control Blankets, Flexible Channel Lining Material, and Hydraulically-Applied Mulch Products. A copy of this document is provided in Appendix A.

Six plots were used for this study: (2) 2:1 clay, (1) 2:1 sand, (2) 3:1 clay, (1) 3:1 sand. A soil analysis is provided in Appendix B. This soil analysis is run annually after the plots are rebuilt to ensure that the soil texture and composition are similar to all preceding years. The 2:1 plots are 20' wide x 50' long and the 3:1 plots are 20' wide x 70' long, horizontal measure.

Materials

Rice straw was acquired from a local source. The tackifier used was a psyllium based organic material. All seed was obtained from local commercial sources and certified for pure live seed content.

Soil Preparation

Before installation, each test plot was cleared of vegetation, repaired, and brought back to uniform grade using standard TxDOT highway construction methods. Each plot was fumigated with a soil sterilant to reduce the native seed source. Immediately prior to installation, each plot was fine graded to remove any rills by hand-raking the surface.

Seeding

Each plot was seeded according to the TxDOT Standard Specification, Item 164, *Seeding for Erosion Control*. The seeding specification is broken down by TxDOT Districts to recognize regional variation in vegetation types. The Bryan District seeding standards are different for sandy and cohesive soils. The composition of the seed mix is as follows:

Sandy Soils:

- Bermudagrass 1.7 kg/ha
- Green Sprangletop 1.2 kg/ha
- Bahiagrass 7.5 kg/ha

Clay Soils:

- Bermudagrass 0.9 kg/ha
- Green Sprangletop 0.7 kg/ha
- Little Bluestem 1.2 kg/ha
- Indiangrass 1.7 kg/ha
- K R Bluestem 0.8 kg/ha
- Switchgrass (Alamo) 1.3 kg/ha

Seeding and fertilizer is applied hydraulically. Installation occurs in a two-step process, seed and fertilizer first, followed by the application of the crimped straw and straw tackifier.

Application Rates

Table 1 gives the straw application rates for each of the test plots.

Table 1: Straw Application Rates by Soil Type

Plot	Slope/soil	Treatment
CL1	2:1 Clay	4000 lbs./ac. Straw - crimped
CL11	2:1 Clay	4000 lbs./ac. Straw – tacked
SA1	2:1 Sand	4000 lbs./ac. Straw – crimped
C1	3:1 Clay	4000 lbs./ac. Straw – crimped
C7	3:1 Clay	4000 lbs./ac. Straw – tacked
S1	3:1 Sand	4000 lbs./ac. Straw - crimped

TEST PROCEDURES

Beginning two weeks after installation, a series of six simulated rainfall events of increasing intensities are conducted. Each rainfall event is separated by a rest period of approximately two weeks. Each event is run for 10 minutes based on the intensity of a ten-minute storm with a Type III rainfall distribution. This represents the most extreme conditions in Texas.

- 1 – year Design Storm – 30.2 mm/hr (1.2 inches per hour)
- 2 – year Design Storm – 145.5 mm/hr (5.7 inches per hour)
- 5 – year Design Storm – 183.6 mm/hr (7.2 inches per hour)

The sediment generated by the simulated rainfall events is collected, sampled, dried, and weighed. This sediment loss reported is the average for all simulated events and is reported in kilograms of sediment loss per 10 square meters.

The vegetation density is determined using the "Vegetation Coverage Analysis Program" (VeCAP), developed by TTI. VeCAP uses digital photography and computer masking technology to determine the amount of vegetation cover for a sample area. VeCAP is explained in more detail in Appendix A. Final vegetation density is reported as the percentage surface cover achieved at the end of a 9 month growing season.

DATA SUMMARY

The test results in Table 2 provide vegetation cover achieved by November of the 1999 growing season. Table 3 shows the average sediment loss for each plot for the six test simulations. The numbers in parenthesis indicate TxDOT Approved Products List requirements for the percent of vegetation cover required or the maximum allowable sediment loss permitted for a material or BMP.

Table 2: Vegetation Cover for Straw-Tackifier and Crimped Straw Applications

Plot	Slope/Soil	Treatment	Vegetation Cover (%)
CL1	2:1 Clay	4000 lb/ac. Straw - crimped	58.11% (80%)
CL11	2:1 Clay	4000 lb/ac. Straw - tacked	70.25% (80%)
SA1	2:1 Sand	4000 lb/ac. Straw - crimped	44.37% (70%)
C1	3:1 Clay	4000 lb/ac Straw - crimped	63.45% (80%)
C7	3:1 Clay	4000 lb/ac Straw - tacked	73.55% (80%)
S1	3:1 Sand	4000 lb/ac Straw - crimped	49.26% (70%)

Table 3: Sediment Loss for Straw-Tackifier and Crimped Straw Applications

Plot	Slope/Soil	Treatment	Sediment Loss
			(kg per 10 sm)
CL1	2:1 Clay	4000 lb/ac Straw - crimped	1.94 (0.34)
CL11	2:1 Clay	4000 lb/ac Straw - tacked	2.05 (0.34)
SA1	2:1 Sand	4000 lb/ac. Straw - crimped	30.20 (26.64)
C1	3:1 Clay	4000 lb/ac Straw - crimped	1.33 (0.34)
C7	3:1 Clay	4000 lb/ac Straw - tacked	1.08 (0.34)
S1	3:1 Sand	4000 lb/ac. Straw - crimped	19.10 (12.20)

Table 4: Sediment Loss by Plot and Storm Intensity

Plot	Sediment Loss in kg/10sm						
2:1 Clay	**1Year Storm**		**2 Year Storm**		**5 Year Storm**		AVG.
Crimped	0.58	2.73	0.44	1.08	3.72	3.09	1.94
Tackifier	0.01	0.02	0.61	2.10	4.59	4.95	2.05
Difference	**0.57**	**2.71**	**-0.17**	**-1.02**	**-0.87**	**-1.86**	
2:1 Sand	1y1	1y2	2y1	2y2	5y1	5y2	AVG.
Crimped	2.66	2.08	32.66	29.35	59.55	54.90	30.20
3:1 Clay	1y1	1y2	2y1	2y2	5y1	5y2	AVG.
Crimped	0.11	0.08	0.52	0.43	3.49	3.36	1.33
Tackifier	0.05	0.06	0.48	0.60	2.81	2.45	1.08
Difference	**0.06**	**0.02**	**0.04**	**-0.17**	**0.68**	**0.91**	
3:1 Sand	1y1	1y2	2y1	2y2	5y1	5y2	AVG.
Crimped	1.32	1.09	22.45	18.22	32.86	38.66	19.10

Appendix C includes the raw vegetation cover data for all of the plots.

CONCLUSIONS

In the summary table, the tacked straw appears to provide the best performance for both sediment reduction and vegetation cover. However, this could be misleading. The figures also suggest, as demonstrated in Table 4, that crimped straw may perform as well or slightly better in more intense rainfall events. The early difference in sediment reduction performance between crimped straw and tacked straw can possibly be attributed to loosening of the surface during crimping, which loosens the soil and makes it more available for transport.

The apparent difference in vegetation density could also be related to the disturbance of soil particles during the crimping process. Since seed is applied prior to crimping a percentage of the seed could be pressed into the soil to a depth that reduces or prevents germination.

It would be interesting to repeat this test to see if these differences could be confirmed, particularly with respect to the long-term performance of crimped straw. If, as hypothesized, the initial rainfall events remove soil particles loosened during the crimping process, results should indicate that crimped straw actually holds the surface better in heavier rainfall events. Therefore, crimped straw could prove to be better practice. This would be particularly significant in areas of steep slope with shorter growing seasons and more frequent rainfall.

Clearly none of the straw applications meet the TxDOT standards for the Approved Products List for erosion control materials. This is somewhat surprising. Particularly in the case of the straw-tack applications, which form a bound mat very similar in appearance to some rolled materials. Rolled materials that use straw exhibit some of the best erosion control performance characteristics. The chief difference in the physical properties of the rolled material compared to the straw-tack mat is stem diameter, length and overall flexibility. The stem size and overall gradation of the straw material in the blanket is small by comparison to baled rice straw, which was composed of longer thicker stems. This resulted in a very stiff mat that easily bridged small rills on the surface. Experience has shown that when any material bridges the surface, sediment will increase.

APPENDIX A
Procedures and Evaluation Criteria for Erosion-Control Blankets, Flexible Channel Lining Materials, and Hydraulically-Applied Mulch Products

PROCEDURES AND EVALUATION CRITERIA FOR EROSION-CONTROL BLANKETS, FLEXIBLE CHANNEL LINING MATERIALS, AND HYDRAULICALLY-APPLIED MULCH PRODUCTS

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IMPLEMENTATION STATEMENT

This document provides the basic parameters of the research program conducted by the Texas Transportation Institute to meet the research objectives and goals set forth by the Texas Department of Transportation. Periodic updates will be written to keep current with the research program.

The findings from this work will have immediate application in the planning, design, construction, and maintenance of sites requiring erosion control and vegetation establishment. Methods used to evaluate the field performance of erosion-control blankets (soil retention blankets) in two different classes (Slope Protection and Flexible Channel Liners) two different slopes and two different soil types should provide engineers and landscape architects with current performance characteristics related to the highway environment. Field performance data on the performance of hydraulically-applied mulches, two different soil types, and a single slope condition will provide current information on vegetation establishment techniques.

Results from the study are used by TxDOT to produce an Approved Material List required by the standard specifications for the construction of highways. An important benefit is an annually updated listing of the erosion control materials and mulches which meet and exceed the minimum performance standards. This should encourage competitive marketing within the State of Texas. Research performed at this facility will continue to keep TxDOT as a pro-active leader in highway-related environmental concerns.

DISCLAIMER

AUTHOR'S DISCLAIMER

The contents of this report reflect the views of the authors who are responsible for the facts and the accuracy of the data presented herein. The contents do not necessarily reflect the official view or policies of the Texas Department of Transportation (TxDOT). This report does not constitute a standard, specification, or regulation, nor is it intended for construction, bidding, or permit purposes.

PATENT DISCLAIMER

There was no invention or discovery conceived or first actually reduced to practice in the course of or under this contract, including any art, method, process, machine, manufacture, design or composition of matter, or any new useful improvement thereof, or any variety of plant, which is or may be patentable under the patent laws of the United States of America or any foreign country.

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SUMMARY

Storm water management for large-scale construction and maintenance operations relies upon several factors including: proper design and application of erosion principles; planning and coordination of land disturbing activities, and the application of erosion and sediment control products, when necessary. Responsible transportation agencies, such as the Texas Department of Transportation (TxDOT), who try to meet stringent federal and state regulations need data which support recommendations for products which will help meet these requirements.

Within the erosion industry, limited resources were available for current performance data related to the highway environment. Independent laboratories supplied manufacturers with product characteristics such as strength, UV resistance, and fiber qualities; but they did not focus on important factors such as soil-fabric interaction and installation techniques. Most other erosion and sediment control related research came from the agriculture discipline and associated agencies such as the Soil Conservation Service. Physical and functional characteristics of agricultural systems do not provide an adequate resource or comparison for engineered systems like the highway system. TxDOT desired to create a formal testing facility through which products could be evaluated to help the Department meet its goals.

In concert with TxDOT, the Texas Transportation Institute (TTI) researchers developed methodologies and procedures to document the performance for evaluating the most pressing needs of erosion-control blankets, flexible channel liners, and hydraulically-applied mulches. At the TTI proving grounds, a research facility known as the Hydraulics and Erosion Control Laboratory was designed and constructed to meet the long-term needs of the Department. Since 1991, TTI has coordinated the erosion control research program and conducted the studies at this facility. While basic methodologies remain unchanged, the procedures have been altered to better meet TxDOT's needs.

Results produced from this work are provided to TxDOT who produces the Approved Materials List for standard specification Item 169 - Soil Retention Blanket. Approximately twenty erosion-control blankets, ten mulches, and nine channel liners have been approved for use by the Department. The researchers continue to conduct their research for the Department with each evaluation cycle synchronized around the growing season (March - November).

This document is a written research program guide developed to communicate the research objectives, study development, participation procedures, and evaluation procedures used by the researchers and TxDOT. Future modifications to this document may be necessary.

INTRODUCTION

The erosion control industry and the Federal Highway Administration (FHWA) recognize a variety of generic materials used as erosion control protection. Erosion-control blankets that met the Texas Department of Transportation's (TxDOT) standard specifications for the past twenty years consisted of two products. The specification and bidding process did not provide for material selection other than these two products because of the material-based requirements. In response to this practice, TxDOT has shifted from a material-type specification for hydraulically-applied mulches (termed "cellulose fiber mulches" within Standard Specification Item 164 *Seeding For Erosion Control*), and for roll-type erosion control mats (termed "soil retention blankets" within Standard Specification Item 169 *Soil Retention Blanket*,) into an "approved product"-type specification. The approved product list (APL) is based upon the demonstrated field performance of products tested through TxDOT's formal evaluation program.

TxDOT's current specifications for cellulose fiber mulches (See Appendix A), and for soil retention blankets (See Appendix B), do not include any of the typical ASTM-type material requirements, such as weight, tensile strength, elongation, water-holding capacity, pH, etc.

TxDOT has defined critical performance measures and has established minimum performance standards for selected erosion control and revegetation products which are promoted by industry for use within TxDOT's construction and/or maintenance activities. In cooperation with the Texas Transportation Institute (TTI) Environmental Management Program, TxDOT has funded the construction and annual operation of an extensive, outdoor, field-testing facility designed to collect performance data which may be used by TxDOT to produce and maintain a defensible APL. Laboratory tests and field observations indicate there is great variation in strength, durability, soil-blanket interaction and vegetation response between generic material classifications and between manufactured brands of similar materials. Soil-fabric interaction, vegetation establishment, and installation methods are critical factors to consider in figuring out field performance characteristics.

With respect to soil retention blankets, TxDOT felt that the critical performance factors were:

- how well does the product protect the seedbed or the geometry of a channel from the loss of sediment; and
- how well does the product promote the establishment of a warm-season, perennial vegetative cover over a single March - November growing season.

Further, TxDOT recognized that retention blankets should be divided into two distinct types:

- products designed for normal overland flows associated with typical embankment protection; and
- products designed for concentrated water flows associated with drainage channels.

With respect to cellulose fiber mulches, TxDOT felt that sediment loss was not a critical performance factor, in that TxDOT recommends limiting the use of these products to slopes of 1:3 or flatter. The single performance factor adopted is the amount of warm-season perennial vegetation produced within a single March - November growing season. In the case of soil retention blankets, products must meet the minimum performance standards for both of the critical performance measures, vegetation establishment and sediment loss. Failure within either of the measures will automatically reject the product from being placed upon the APL.

Through formal, field performance testing at the TxDOT/TTI Hydraulics and Erosion Control Laboratory (HECL), TxDOT has adopted minimum performance standards for each application. In order for a product to be placed upon TxDOT's APL, it must meet (or exceed) the currently adopted performance standards associated with that application.

TxDOT and TTI developed evaluation methodologies to document the performance of erosion-control blankets in varying slope applications, flexible channel liners subjected to varying shear stresses, and hydraulically-applied mulches for vegetation establishment. The methods and procedures, are acceptable test methods to determine field performance within the highway rights-of-way. Subsequent work included the design and construction of a research proving facility. The HECL, a state-of-the-art facility, was constructed during two consecutive years and is a unique laboratory dedicated to transportation research. Today, the facility covers 8.5 ha with an earthen fill embankment that is approximately 300 linear meters by 6.7 meters, vertically, ten at-grade channels, two water reservoirs, pumping stations, rainfall simulators, weather station, and various instrumentation.

Since 1991, the researchers conduct annual evaluations on erosion control products at the HECL. Private industry, TxDOT, and TTI cooperatively work together to further this important area of environmental research and development. The purpose of this document is to provide general background on the adopted methodology, describe the Hydraulics and Erosion Control Laboratory facility, and to set forth the research program for performance evaluation of erosion-control blankets, hydraulically-applied mulches, and flexible channel liners.

INDUSTRY ADVISORY COUNCIL

The primary objective of this research program is to develop a defensible Approved Material list for use in TxDOT's construction and maintenance activities and to provide manufacturers of erosion control and vegetation establishment products with a fair program through which their individual products may be evaluated for use by the Texas Department of Transportation. To accomplish this objective, industry participation is necessary. To provide a vehicle for the desired industry coordination, an Industry Advisory Council (IAC) has been formed.

The following criteria have been established through the work of past advisory members:

- Membership of the council consists of one representative from each participating manufacturer, one representative from TxDOT, one representative from TTI, and one representative from the International Erosion Control Association (IECA). TTI solicits representatives before each evaluation cycle.

- A Technical Subcommittee formed for the channel lining research consists of three manufacturing representatives selected by the IAC.

- Representatives of the IAC call meetings to discuss procedures, results, or other items of business.

- All statistical analysis reports will be performed and distributed by TxDOT except for evaluation procedures and final reports. Deliverables such as the final report, video footage, slides, or photographs may be purchased for the cost of reproduction through the Texas Transportation Institute.

- Changes to procedures will be handled through an open meeting, fax, E-mail, or other appropriate communication method by discussion and majority opinion. TTI and TxDOT will make every effort to accommodate the recommendations made by the advisory group. Final decision with respect to the activities and operation of the research program and laboratory will remain with TxDOT.

STUDY OBJECTIVES

OBJECTIVES

The objectives for the research program at the TxDOT/TTI Hydraulics and Erosion Control Laboratory are as follows:

- To collect data which will enable TxDOT to produce a defensible Approved Material List, for flexible channel linings, soil retention blankets, and hydraulically-applied mulches.
- To establish a timely and fair evaluation program, through which new erosion control products developed by industry may be evaluated for possible use in TxDOT's construction and maintenance activities.

METHODOLOGY

The methods adopted for use in the research program provide a reproducible, defensible experiment for surface erosion control products. The design and construction of each study area, slope and channels, is at a scale that adequately represents the highway environment. Experimental designs are completely randomized.

EROSION-CONTROL BLANKET STUDY

For the erosion control products on a sloped condition, there are treatment plots and control of two replicates, one for each soil type (sandy, clay) by slope. Treatments consist of an erosion-control blanket (soil retention blanket) overlaying seeded soil (clay and sandy loam) in a 1:2 and/or 1:3 slope condition. Experimental control consists of four plots receiving the same vegetative treatment for each soil type with no erosion-control measure in place. Treatment plot data, relative to each product's sediment retention performance and apparent vegetative density coverage with respect to slope's soil type and slope condition, is collected and provided to TxDOT for statistical analysis.

Erosion control criteria are as follows:

- Acceptable erosion-control blankets should reduce the sediment loss from the protected treatment area significantly greater than from bare ground (Control).
- Erosion-control blankets should effectively protect the seed bed from a short duration and one-year return frequency (99% probability of occurrence within a given year) within the first month after installation.
- Erosion-control blankets should effectively protect the seed bed from a short duration and two-year return frequency (50% probability) within the first three months of installation.

- Erosion-control blankets should effectively protect the seed bed from a short duration and five-year return frequency (20% probability of occurrence within a given year) for the duration of the test cycle.

- In cohesive soils (clay) and a sloped condition, sediment loss should be no greater than 0.34 kg/10 m^2 for the duration of the test cycle.

- In non-cohesive soils (sandy) and slopes steeper than 1:3, sediment loss should be no greater than 26.84 kg/10 m^2 for the duration of the test cycle.

- In non-cohesive soils (sandy) and slopes flatter than 1:3, sediment loss should be no greater than 12.20 kg/10 m^2 for the duration of the test cycle.

Vegetation establishment criteria will be as follows:

- Acceptable erosion-control blankets should promote significantly greater vegetative cover on the protected treatment area as compared to the bare ground (Control).

- Acceptable erosion-control blankets should promote a vegetative cover within the first six months after installation by protecting the seed bed from the impacts of rain splash and preventing damaging rill formations.

- In cohesive soils (clay) and sloped conditions, vegetative density should reach a minimum coverage of 80% for the duration of the test cycle.

- In non-cohesive soils (sandy) and sloped conditions, vegetative density should reach a minimum coverage of 70% for the duration of the test cycle.

Material (natural or synthetic) performance criteria will be as follows:

- Acceptable erosion-control blankets, installed in accordance with the manufacturer's published guidelines, should be able to retain their physical properties for the duration of the test cycle without developing major rips, sags, tears, joint gaps, or become undermined by excessive rill formations.

- Acceptable erosion-control blankets should provide protection for the seed bed until a sufficient stand of vegetation is established or for the duration of the test cycle.

Study Development

Before the implementation of the research program, TxDOT's standard specification for soil retention blankets was a material type specification. This specification technically excluded products that did not meet this strict material specification. In response to this practice, TxDOT elected to establish a timely, fair, but formal testing program to select erosion control products based upon their performance.

Limited quantitative data existed for erosion from highway rights-of-way during the soil stabilization process, which occurs during construction (temporary or permanent vegetation establishment), or problems that developed from routine maintenance operations. The vast majority of existing research on effective erosion control methods came from agricultural, range, and forest management studies. Applying methods generated from these sources into an engineered system with much different physical and operational constraints does not always work well.

Governing bodies continue to set stringent requirements for controlling erosion and sediment during highway construction or other large-scale, land disturbing activities. A lack of industry standards and testing methods further complicates the issue of product reliability and performance characteristics. This places an increasing burden for state transportation agencies to implement more effective controls that are cost-effective to the taxpaying citizens. These factors combined, led to the development of the research program and the Hydraulics and Erosion Control Laboratory construction.

As stated earlier, the erosion industry and the Federal Highway Administration recognize a variety of generic materials used for erosion and sediment protection (5). Existing laboratory tests used to describe standard physical properties, do not adequately describe or test field performance. Soil-fabric interaction, vegetation establishment, and installation methods are critical factors to consider in determining product performance characteristics (10). A facility or laboratory that could simulate the highway environment would be beneficial in providing this information to TxDOT.

Previous studies sponsored by TxDOT used portions of the highway rights-of-way for collecting this data. Many subsequent problems occurred that would invalidate or compromise the resulting data. Problems cited included, but are not limited to, the following: roadside fire, herbicide spraying, mowing and equipment damage, plowing, unequal water distribution, and vehicle-induced damage. TxDOT elected to establish a full scale facility to conduct controlled tests in an environment which closely simulated a highway environment.

Rainfall Simulation

To maintain uniformity throughout a multi-year testing program, all results are based on artificially generated rainfall. There is no way of controlling natural rainfall over the course of the study. All results include a profile of the on-site weather conditions, and any unusual or mitigating events are noted and considered in the analysis.

Starting within two weeks after installation, each product is subjected to a series of six (6) simulated rainfall events. Each product receives two each, ten-minute duration repetitions of the following design storms:

1-Year = 30.2 mm/hr;
2-Year = 145.5 mm/hr; and
5-Year = 183.6 mm/hr.

Sediment is collected, dried and weighed after each individual rainfall event. The average sediment loss, expressed in kilograms per 10 square meters, collected in the six individual rainfall events is compared to the adopted maximum sediment loss standard to determine acceptance or rejection.

Rainfall intensity determination was based upon rainfall intensities of anticipated storms during a typical vegetation establishment period. To adequately model the rainfall simulations for the State of Texas, the researchers chose to derive the rainfall intensity values from a thirty-six-county area that reaches between Houston, Dallas, and Austin. This area was chosen since it contains the highest percentage of state maintained highways. The method used to derive the intensity values was the *modified Steel Formula* (7) as shown below:

$$I = \frac{b}{(t_c + d)^e}$$

The values of the constants b, d and e are from the National Oceanic and Atmospheric Administration (NOAA) National Weather Service (NWS) Technical Paper No. 40, "Rainfall Frequency Atlas of the United States." Table 6 of the SDHPT (TxDOT) Hydraulics Manual contains the I values for each county. The researchers derived the intensity values for the erosion-control blankets study by computing the values of I for the thirty-six county areas based upon a short storm duration. The researchers assumed that more damage occurs by the impacts of rain splash in a steep slope situation (1:3 or greater) subjected to a short duration, high probability design storms than from a moderate slope situation (1:4 or less) with a larger runoff area. Therefore, the storm duration, t_c, was ten minutes since the majority of disturbed slopes (cut slopes and embankments) are at the upper limit of the micro-watershed.

Vegetation coverage

The seeding mixtures selected by the research team are from TxDOT's standard seeding specification, *Item 164 - Seeding for Erosion Control* published in the 1993 *TxDOT Standard Specifications for Construction of Highways, Streets, and Bridges* (8). Since the laboratory is located in the Bryan District, the rural area species for warm-season perennial vegetation were hydraulically applied. Specific mixtures selected included a mixture for clay or tight soils and a mixture for sand or sandy soils. In clay or tight soils, the recommended seed mixture includes the following species and rates given in kilograms of pure live seed per hectare:

- Green Sprangletop 0.7 kg/ha
- Bermudagrass 0.9 kg/ha
- Little Bluestem 1.2 kg/ha
- Indiangrass (Lometa) 1.7 kg/ha
- K-R Bluestem 0.8 kg/ha
- Switchgrass (Alamo) 1.3 kg/ha

In sand or sandy soils, the recommended seed mixture includes the following species and rates given in kilograms (pounds) of pure live seed per hectare:

- Green Sprangletop 1.2 kg/ha
- Bermudagrass 1.7 kg/ha
- Bahiagrass (Pensacola) 7.5 kg/ha

The research team needed data that would accurately depict the vegetative density or apparent vegetative cover for the first growing season. After experimenting with several data collecting methods, the researchers chose a computer-based process, *VeCAP*, to analyze the samples. The process selected is reproducible and is a cost efficient data collection method. *VeCAP* or Vegetation Coverage Analysis Program calculates the percentage of pixels in a sample image by color. Sample images recorded in the field are converted to single digital images using a Targa 16 board and TIPS software, and imported into the *VeCAP* program. Each product is sampled for vegetation density production over the March - November growing season. The initial sample is normally taken on or about the fourth week following product installation. The final sample is normally taken during November. The vegetative density production which has been achieved by the final sampling round only, is compared to the adopted minimum vegetative density standard to determine acceptance or rejection The researcher records the percentage of vegetation for each analyzed image.

The sediment retention and vegetative density data is furnished to TxDOT for analysis using the Statistical Analysis System, SAS; Duncan's Multiple Range Test ($P<0.05$) which separates sample means into similar groupings. Material performance is documented, but no data is included in the Duncan's Multiple Range test.

HYDRAULICALLY-APPLIED MULCH STUDY

The Texas Department of Transportation hydraulically-applied mulch specification, originally written in 1982 and slightly modified in 1993, adopted the methodology that a two-step application process was better for vegetation establishment than a one-step application process (6). TxDOT elected to test this premise by recording vegetative density achieved within both application methods. Sufficient data has been collected regarding the significance of vegetative density production between these two application techniques and TxDOT now recommends the one-step hydraulically-applied mulch application.

Vegetation establishment criteria is as follows:

- Acceptable hydraulically-applied mulch products should promote significantly greater vegetative cover on the protected treatment area as compared to the bare ground (Control).
- Acceptable hydraulically-applied mulches should promote a vegetative cover for the duration of the test cycle by protecting the seed bed from the impacts of rain splash.

- In cohesive soils (clay) and sloped conditions, final vegetative density must reach a minimum coverage of 50% during the test cycle.

- In non-cohesive soils (sandy) and sloped conditions, final vegetative density must reach a minimum coverage of 50% during the test cycle.

Currently, this method of application is repeated for each product: (1) A one-step process where seed, fertilizer and mulch are applied to the plot in a single application.

Cellulose fiber mulch products are not subjected to simulated rainfall events, as TxDOT feels they should not be used to protect a slope to the degree capable by a soil retention blanket. Each treatment, however, is sprinkle irrigated to provide sufficient moisture for vegetative growth. For the first three months, water is applied evenly to each plot to provide a minimum of 25 mm of water per month per plot. After the initial three month period, no supplemental water is provided except in the event of a drought in excess of 30 days. Vegetation density data is recorded throughout the duration of the March - November growing season. The vegetation density achieved by the final measurement round is compared to the adopted minimum vegetation density standard to determine acceptance or rejection. The vegetative density data are furnished to TxDOT for analysis using statistically analyzed by the Statistical Analysis System, SAS; Duncan's Multiple Range Test ($P<0.05$) which separates sample means into similar groupings.

FLEXIBLE CHANNEL LINER STUDY

For the erosion control products in a channel condition, there are treatment plots and a control of one replicate on a cohesive (clay) soil in either a 7% or 3% centerline gradient. Treatments consist of flexible channel liners (erosion-control blanket) overlaying seeded soil. Experimental control consists of one channel receiving the same vegetative treatment with no erosion-control blanket in place. Treatment plots are analyzed for their sediment retention performances (channel deformation) and apparent vegetative density coverage with respect to shear stress capacity range. Material performance will be documented but no statistical data will be included in the analysis.

Study Development

The first year for flexible channel liner trials was in 1994. The original adopted procedures with a few minor alterations governed the study methods. Adjustments were expected since this type of proving (large-scale, open channels) has not been replicated in many laboratories around the country. A brief discussion of the procedure development is included for reference.

Clearly, from the literature (Chow, Chen, and Cotton, FHWA Hydraulic Engineering Circular Numbers 3,11,14,15) the maximum permissible tractive force theory is the favored method for making design decisions and selecting flexible channel lining materials (2,3). The researchers developed field performance evaluation procedures based upon these findings and designed laboratory facilities to accomplish the research objectives.

In the laboratory open-channel design, the researchers selected a trapezoidal cross-section. Common practice among most transportation agencies is to construct a trapezoidal cross-section channel for unlined earth channels. The side slopes of this profile provide better stability versus other artificial channels. In addition, the hydraulic properties of an artificial channel may be designed to meet specific requirements or controlled to an extent needed for testing purposes (3). Therefore, the application of hydraulic theories to artificial channels will produce results fairly close to actual conditions. Reasonable accuracy may be achieved for practical design purposes.

In the facility design, the researchers assumed that peak discharge rate, Q_n, estimated with an accepted method for estimating runoff is acceptable. Based upon this theory, the channel could be sized to achieve a desired depth of flow. Uniform flow characteristics described by Manning's equation would depend on the hydraulic radius of the channel (R), the channel slope (S), velocity (V), flow rate (Q), flow cross-sectional area normal to the direction of flow (A), and the value of Manning's n as shown in the formula below.

$$Q_n = \left(\frac{1.486}{n}\right) R^{2/3} S^{1/2} A$$

where (continuity equation): $Q = Va$

and:

$$V = \left(\frac{1.486}{n}\right) R^{2/3} S^{1/2}$$

The hydraulic radius and slope controlled by having a fixed channel geometry is favorable. However, it is unlikely that all brands of flexible channel liners within a given generic material class will have the same roughness coefficient or "n" values. The depth of flow and resultant tractive force, τ_d, cannot be determined or held constant for all materials in the same generic classification. The ability to determine the value of Manning's n for each of the research materials is critical to making fair and valid comparisons between brands and their resultant performance.

Therefore, the researchers determine Manning's n value before the evaluation cycle in a flume located on the Texas A&M University campus. The development of the procedures was based on a theory by Chow (3) and the *Guide for Selecting Manning's Roughness Coefficients for Natural Channels and Flood Plains,* FHWA-TS-84-204 (1). The Industry Advisory Council, Technical Subcommittee approved these procedures in 1994. A range of Manning's n values is recorded from the flume trials that include minimum, normal, and maximum roughness coefficients. The researchers use these values in the field trials to estimate the roughness coefficient prior to a simulated flow.

With the Manning's n values available, the researchers compute flow requirements for each material based upon their normal roughness coefficient value adjusted for the effects of compacted clay soil and irregularities. The researchers are then able to simulate flow conditions that produce the desired shear stress for each individual flexible channel liner. Comparisons of performance related to maximum permissible tractive force are possible with these procedures and methodology.

Shear stress data

In straight line channels, the maximum tractive force occurs on the bottom and near the center of the channel. The force generated at this point is a function of Y, the unit weight of water; d, the depth of flow; and S, the average slope of the channel bottom (energy gradient). This relationship allows the designer to estimate the maximum permissible tractive force with a single calculation as follows:

$$\tau_d = YdS$$

In the Federal Highway Administration's *Hydraulic Engineering Circular No. 15* or *HEC 15* (2), the maximum recommended shear stress values for flexible channel liners were 96 Pascal (2 lb/sf). The research work accomplished at TTI continues the work cited in *HEC 15*. Maximum working shear stresses are approximately 192 Pascal (4 lb/sf) in the 3% sloped channels and 383 Pascal (8 lb/sf) in the 7% sloped channels at the Hydraulics and Erosion Control Laboratory. The data collected should suggest breakdown points in field performance under an incremental level of shear stress.

Following installation, each product experiences a 90-day *rest* period to promote the initial growth of vegetation prior to initiating a series of increasing, shear-stress flows. After the 90-day *rest* period, a series of simulated flows begin.

Flow simulations conducted to emulate field conditions after a short duration, micro-watershed area, drainage ditch flow is the primary data generator. Prior to each flow, channels are pre-wetted to moisten the channel surface. Based upon the determined Manning's n, and the known geometry of the channel, the depth of water is controlled to initiate a series of increasing flows, starting at 96 Pascal, and continuing on a 48 Pascal increment. Each flow is repeated twice and continues for twenty (20) minutes after a stable flow has been achieved.

At the beginning of a flow, the water slowly leaves the vertically-piped opening and travels down the channel reaching uniform flow after 15 m. The water level rises until the desired depth is achieved. Velocity and depth measurements are taken at different locations along the channel during the flow. During the test flows, measurements are taken approximately every four minutes to determine the amount of soil displaced by the flow. Further, data is collected regarding product movement (loss of intimate soil contact.) The average soil displacement exhibited within the channel is compared to the adopted maximum soil displacement standard to determine acceptance or rejection.

All channels are also sampled to determine the growth of vegetation over a single, March-November growing season. Similar to the embankment, channels are initially sampled at the end of the 90-day resting period for vegetation production. The final density sample is normally taken during November. The vegetation density achieved within the channel by the final sampling is compared to the adopted minimum vegetation density standard to determine acceptance or rejection.

Vegetative coverage

The seeding mixtures selected by the research team are from TxDOT's standard seeding specification, *Item 164 - Seeding for Erosion Control* published in the 1993 *TxDOT Standard Specifications for Construction of Highways, Streets, and Bridges* (8). Since the laboratory is located in the Bryan District, the rural area species for warm-season perennial vegetation were hydraulically applied. Specific mixtures selected included a mixture for clay or tight soils and a mixture for sand or sandy soils. In clay or tight soils, the recommended seed mixture includes the following species and rates given in kilograms of pure live seed per hectare:

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The sediment retention and vegetative density data are furnished to TxDOT for analysis using the Statistical Analysis System, SAS; Duncan's Multiple Range Test ($P<0.05$) which separates sample means into similar groupings. Material performance is documented, but no data is included in the Duncan's Multiple Range test.

HYDRAULICS AND EROSION CONTROL LABORATORY

LOCATION

The Hydraulics and Erosion Control Laboratory (formerly the Roadside and Development and Management Field Laboratory) is part of the Texas Transportation Institute's proving grounds. The proving grounds are at the Texas A&M University Riverside Campus, 6.5 km west of Bryan, Texas. The laboratory site bounded on the north, east and west sides by runways and an open field to the south. Because the site (originally a military airport facility) is located on a ridge just above the Brazos River, harsh climatic conditions exist. The soils are generally low in organic content and the site is influenced by heat energy stored in, or reflected from the surrounding pavement. These unique physical conditions provide the most realistic conditions possible for conducting controlled experiments related to the roadside environment.

PHASE I CONSTRUCTION: EARTH EMBANKMENT

The first construction phase occurred on TTI's five hectare tract in 1990. The researchers built an earthen fill embankment constructed with density control as the compaction method. Construction was governed by the 1982 *Texas State Department of Highways and Public Transportation Standard Specifications for Construction of Highways, Streets and Bridges* (9). Density control method in accordance with test method Tex-114-E and test method Tex 115-E was the compaction control. The Texas Department of Transportation District 17 laboratory in Bryan and the TTI Field Laboratory manager performed field testing.

Nominal dimensions for the "L"-shaped embankment measure 6.75 m vertical height, 267 m in length, 1:2 sloped condition on the west side, and 1:3 sloped condition on the east side. Treatment plots are 6.2 m across and 15 m or 21 m lengthwise, depending upon the slope condition. The embankment design provides a total of seventy treatment plots. One-half of the treatment plots are sandy loam soils (SL)[1] (K=0.38)[2] and the other half are clay soils ©[3] (K=0.20)[4]. For the hydraulically-applied mulch evaluations, each treatment plot, "sand" and "clay," is divided into two subplots to collect data on application processes rather than sediment retention characteristics (see Figure 1).

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[1] Post-construction soil sample analyzed by SASI, Inc., with reference made to the National Soils Handbook, July 1983, Figure 603-1, "Soil Texture Triangle."

[2] K value determined on post-construction soil sample following the SCS soil erodibility nomograph Predicting Rainfall Erosion Losses - A Guide to Conservation Planning.

[3] Post-construction soil sample analyzed by SASI, Inc., with reference made to the National Soils Handbook, July 1983, Figure 603-1, "Soil Texture Triangle."

[4] K value determined on post-construction soil sample following the SCS soil erodibility nomograph Predicting Rainfall Erosion Losses - A Guide to Conservation Planning.

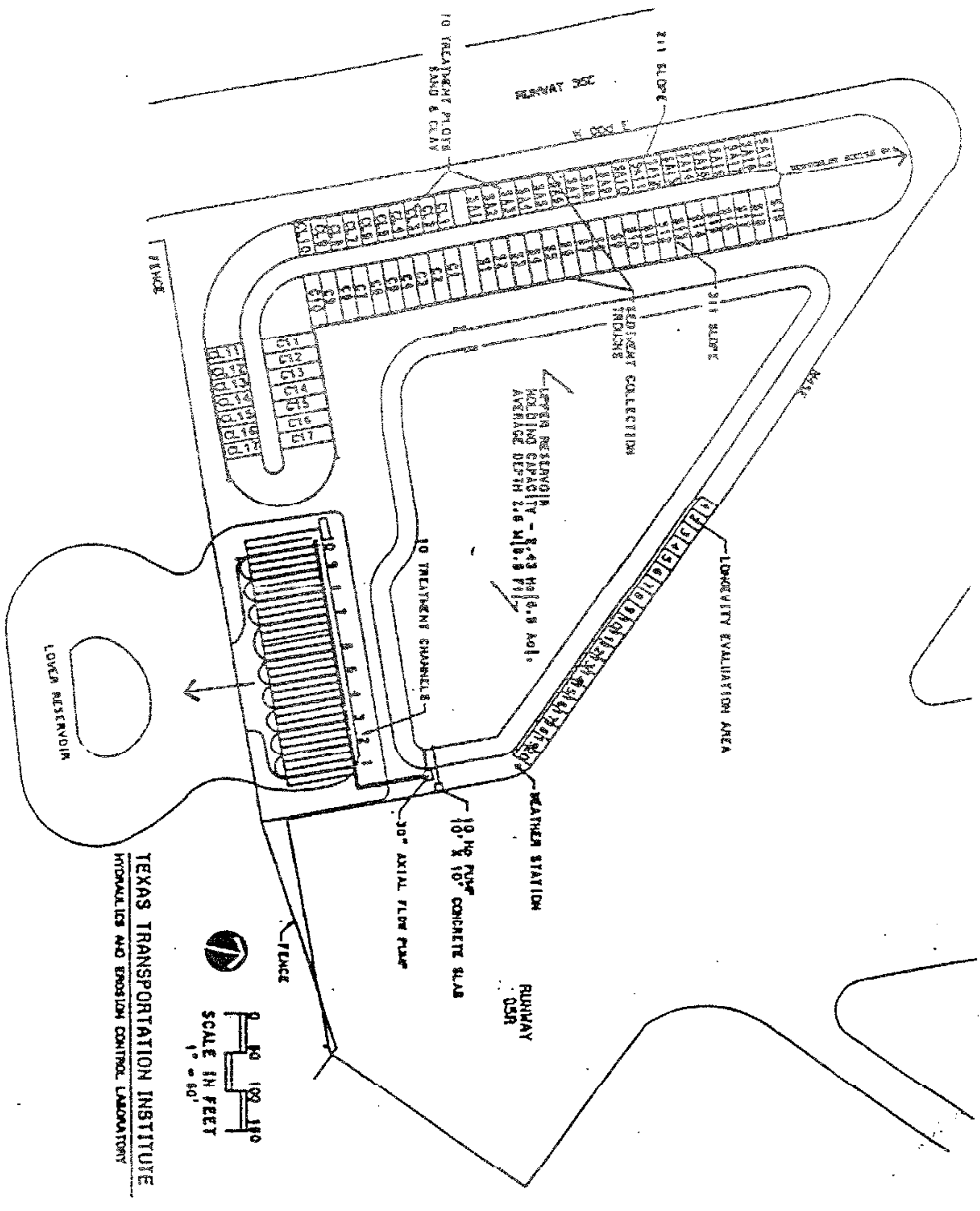

Figure 1. Plan of the Hydraulic and Erosion Control Laboratory

Sediment collection boxes are at the base of each treatment plot. These boxes are precast concrete sections that were set in the field. Physical dimensions of each box are 607 cm by 46 cm wide by 15 cm depth. The flow line is "V" shaped giving the box a holding capacity of approximately 418 liters. Removable plywood dividers separate the boxes (see Figure 2).

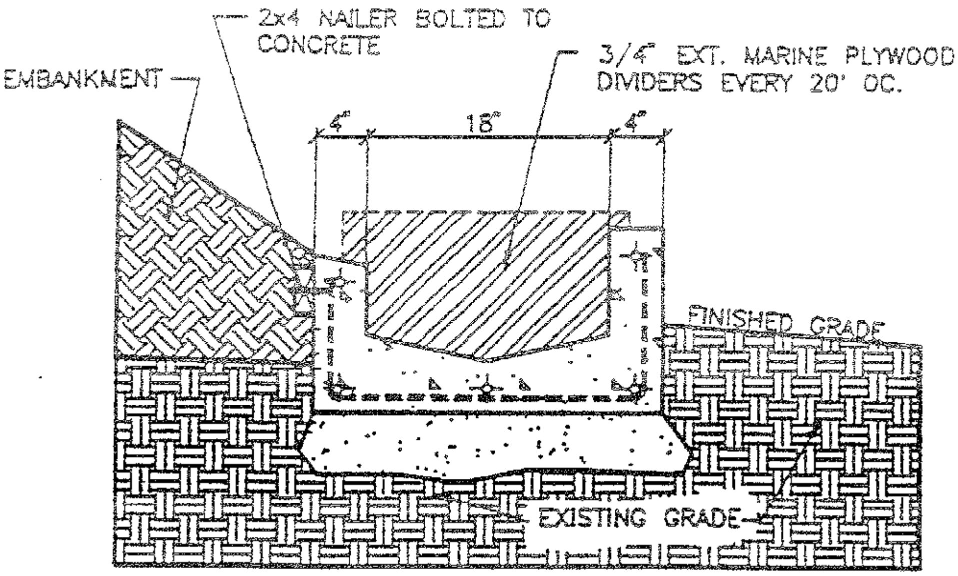

Figure 2. Section through Sediment Collection Trough

Two reservoirs created as the result of the embankment and channel construction have a vertical elevation difference of approximately 1-1/2 m. The upper reservoir surface area is 2.43 ha. This reservoir is the primary water supply source for all of the experimental work. An underground water supply system located along the top of the embankment for the slope treatment plots provides water for simulated rainfall events.

A ten-horsepower centrifugal pump supplies one of four rainfall simulation machines stationed on the embankment. Each simulator unit consists of a series of arms spaced; 1-1/2 m apart mounted on a steel frame and set approximately 0.60 meters above the ground plane. Pressure gauges located on the arms control water flow through the coarse spray, adjustable, irrigation nozzles. The nozzles spray upwards away from the slope face approximately 1 to 1-1/2 m to provide greater drop velocity. Each unit may provide 25 - 300 mm of precipitation per hour as calibrated. Drop size is generally representative of natural rainfall.

The recording weather station equipment was installed at this time and is positioned on-site to provide continuous and accurate climatic conditions. Features of the weather station include a tipping-bucket rain gauge, hygrothermograph, barograph, recording anemometer and pyronometer.

PHASE II CONSTRUCTION: EARTH CHANNELS

The second construction phase occurred in 1992. Construction consisted of placing a water distribution system (pumping stations, corrugated metal piping, and release structures) and ten at-grade channels (six 7% grade and four 3% grade). An earth embankment built between the two reservoirs provided a base for the excavated channels. Each open channel has a trapezoidal cross section that includes a 0.30 m bottom, 1:1 side slopes, and a typical 0.91 m depth beginning 4.5 m downstream of the channel release. Total length of the test channel section equals 26 m as shown in Figure 3. Maximum test flow capacity was provided by modifying the existing south water reservoir and installing a return pumping station to aid in the reuse of test water. Water supplied by an industrial grade, high volume, low head, axial flow pump is capable of producing 136,260 liters per minute.

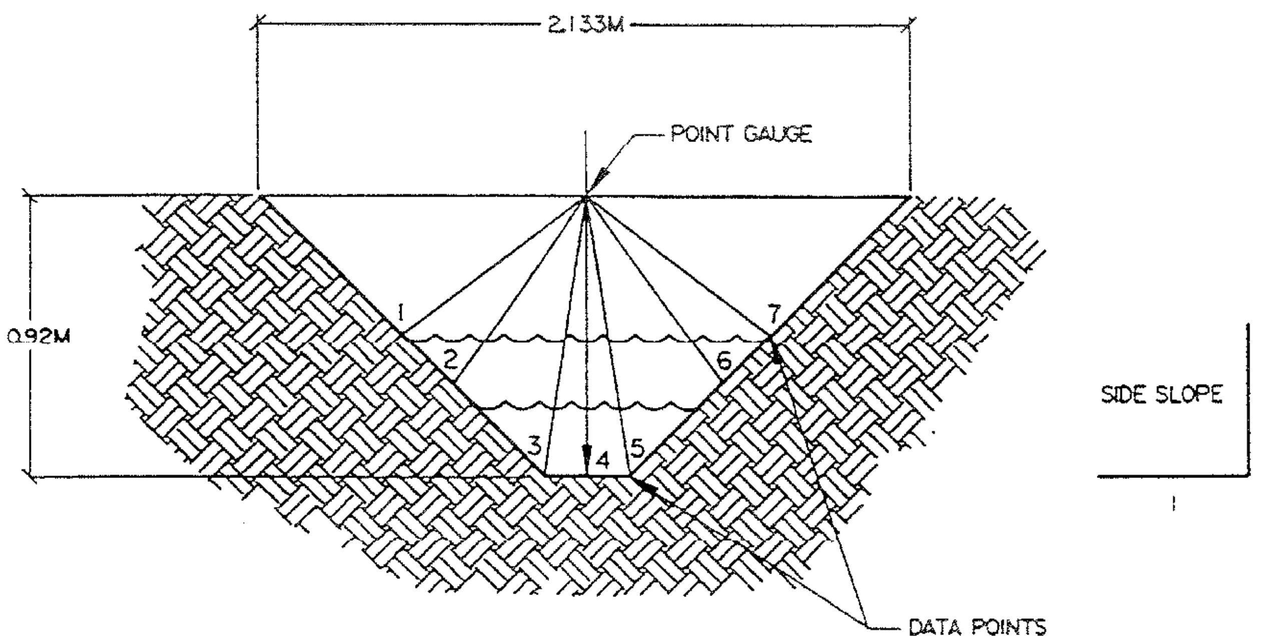

Figure 3. Treatment Channel and Station Locations.

EROSION CONTROL PRODUCT SELECTION

SELECTION OF PRODUCTS FOR EROSION CONTROL EVALUATION

Manufacturers interested in participating in the TxDOT/TTI erosion-control product evaluations for erosion-control blankets (soil retention blankets), hydraulically-applied mulches, or flexible channel liners may contact TTI at any time during the year. If a waiting list is necessary for any of the product evaluations due to full laboratory capacity, the list shall work in the following manner to facilitate fair and timely product evaluations for each manufacturer:

- **On going process.** The principal investigator, TTI representative, is responsible for mailing a package of information to the manufacturer once TTI is made aware of the manufacturer's interest in the research program. TTI refers to this package as the "Request for Performance Evaluation". Basic information and complete literature on the product, physical samples, manufacturer and distributor addresses, private label certification, contact person(s) name, and IAC representative is necessary for TTI to enter the manufacturer as a participant. The manufacturer is responsible for returning the package to TTI. The date *postmarked* on the **COMPLETED PACKAGE** or on the faxed entry forms is the entry date for the waiting list (if necessary). Personal memoranda or letters to the TTI facility manager will **NOT** be utilized to determine a product's position on the waiting list.

- **January through March 1 Participation Events.** TxDOT will notify participants regarding their performance within the previous evaluation cycle. In the event that the product has failed to meet TxDOT's performance standards, the participant may elect to retest the identical product within the next evaluation cycle. The participant shall confirm this decision by notifying the Hydraulic and Erosion Control Lab facilities manager by the date established by TTI. In the event the participant elects not to retest the identical product, and requests evaluation of either a different product, the participant will be placed upon the waiting list and slotted into the first available evaluation cycle. A test slot will be reserved for a product that has failed TxDOT's performance standards only once.

- **March 1 through installation.** TTI will begin product installations upon the final treatment plot preparation. Installation scheduling will be coordinated with TTI and the manufacturer's designated contact person. Manufacturers have three options for their product installation and shall notify TTI as to which option they have chosen.

TxDOT or TTI do not charge a testing or evaluation fee. Participants are given the following three installation options:

Option 1. The manufacturer donates the product(s) for evaluation and also the labor required to install the product. *

Option 2. The manufacturer donates the product(s) for evaluation and contracts the labor and equipment required to install the product with TTI, Environmental Management Program. *

Option 3. Manufacturer contracts the products purchased and installation with TTI, Environmental Management Program. *

*The Hydraulics and Erosion Control Laboratory manager will supervise and/or approve the installation process for all three options to provide continuity with compliance to the manufacturer's <u>published</u> literature and guidelines.

Rate of payment for labor is figured on an hourly basis depending upon the individual employee's rate. Cost for products and installation materials will be a direct cost reimbursable to TTI. TTI will provide a schedule of hourly rates as requested by the manufacturer. TTI will not prepare cost estimates for product installation.

Costs associated with the installation process include the following items. Table A shows a cost breakdown and assignment of responsible parties depending upon the installation options detailed above.

Table A. Installation Costs.

Item	Responsible Party	Alternative
Treatment plot preparation: Remove products after evaluation Earthwork (rough grade) Soil sterilization	TxDOT funds TxDOT funds TxDOT funds	
Fine grading	Option 1 - Manufacturer**	Option 2,3 - TTI
Hydro seeding application Seed/fertilizer mixture	TxDOT funds	
Purchase products, staples, wood stakes, etc.	Option 1,2 - Manufacturer**	Option 3 - TTI
Install product (labor)	Option 1 - Manufacturer**	Option 2,3 - TTI
Clean up	Option 1 - Manufacturer**	Option 2,3 - TTI

**The manufacturer will be required to complete the listed items below before performing any work at the HECL as a requirement of the Texas A&M University System and the Texas Transportation Institute.

Requirements for non-Texas A&M University System (TAMUS) entities:

1) Show a **Certificate of Worker's Compensation** to the TTI representative who is the HECL facility manager. The certificate shall show who is covered and that the company is covered.

2) Show proof of **General Liability** coverage policy to the TTI representative (HECL manager). The minimum limits required are the following:

Bodily injury -	$300,000 each occurrence
	$500,000 aggregate
Property damage -	$100,000 each occurrence
	$300,000 aggregate

3) Show **Employer's Liability** that will cover items not covered by the Worker's Compensation.

4) An authorized signature(s) on the **TTI Release Agreement Form** releasing the Texas Transportation Institute for responsibility in case of accident or damages.

5) No bonding required.

Based upon space availability, TTI will offer an evaluation slot to new participants in the order of the postmarked date shown on the **completed** "Request for Performance Evaluation" packet. In the event that a participant fails to commit to testing by the deadline established by TTI, the next product on the waiting list will be offered the evaluation slot.

TTI and TxDOT reserve the right to restrict the number of products any single company, manufacturer or distributor may evaluate during any given evaluation cycle.

INSTALLATION OF SELECTED PRODUCTS FOR EVALUATION

For the erosion control research program, each erosion-control blanket or flexible channel liner product shall be installed in the following manner:

- Installation of the selected erosion control materials will be done in strict accordance with the manufacturer's published technical materials and recommendations.

- All work is accomplished under the supervision of the TTI representative (HECL facility manager).

- Manufacturer's Technical Representatives will be invited to inspect the installation to satisfy themselves that all published recommendations and installation requirements have been met prior to initiating formal evaluation procedures. It will be the responsibility of the manufacturers to confirm their installation schedule.

- If any problems occur during the installation, the Manufacturer's Representative must notify the TTI representative, HECL facility manager, in writing, within twenty-four hours of the site visit. The HECL facility manager will be the final authority as to whether the adjustments requested by the manufacturer are indeed oversights and that the changes requested are consistent with the manufacturer's published technical materials.

For the erosion control research program, each hydraulically-applied mulch product shall be installed in the following manner:

- Installation of the selected hydraulically-applied mulch materials will be done in strict accordance with the Texas Department of Transportation's Item 164.3, *Seeding for Erosion Control, Construction Methods*. The rate of application shall remain consistent with TxDOT's specifications in the current version of the TxDOT Standard Specifications for Construction of Highways, Streets, and Bridges.

- All work will be accomplished under the supervision of the TTI representative (HECL facility manager).

- Manufacturer's Technical Representatives will be invited to inspect the installation to satisfy themselves that all installation requirements have been met before initiating formal evaluation procedures. It will be the responsibility of the manufacturers to confirm their installation schedule.

- If any problems are noted in the installation, the Manufacturer's Representative must notify the TTI representative, HECL facility manager, in writing, within twenty-four hours of the site visit. The HECL facility manage will be the final authority about whether the adjustments requested by the manufacturer are oversights and that the changes requested are consistent with the standard specifications of TxDOT.

APPROVAL BY EXTENSION

For Class 1 "Slope Protection Products", if a product is evaluated on the severe-slope conditions only (Types C and D), and successfully meets the current minimum performance standards established by TxDOT for the particular application, the product will also be included as an approved product (by extension) on the associated, less-severe conditions as well. For example, if a product is evaluated on both Types C and D slopes (Slopes Steeper than 1:3 - Clay and Sand soils, respectively), and successfully meets the performance standards for Type C (Slopes Steeper than 1:3 - Clay Soils), the product will be added by extension to the approved product list for Type A (Slopes 1:3 or Flatter - Clay Soils).

Conversely, if a product is evaluated on the less-severe slope conditions only (Types A and B), the product will not be added to the severe-slope conditions as an approved equal regardless of the performance of the material.

If a product elects to test on each of the four available Class 1 applications, the product's performance, as documented within each individual application shall determine placement on the approved product list, and approval by extension shall not apply.

RELEASE OF PERFORMANCE DATA

With the exception of the final research report as published by TTI, all performance data will be released by TxDOT only. Data will only be released at the end of a complete evaluation cycle. As the annual operation of the HECL is funded with state funds, all performance data will be released regardless of the performance of any individual product.

Performance data for all products evaluated to date are available from TxDOT without charge to any interested party. Final research reports, as published by TTI are available for a fee through the Texas Transportation Institute Information and Technology Exchange Center.

RETEST PROCEDURES

Class 1 "Slope Protection" and Cellulose Fiber Mulch Products

If, after the initial test at the HECL, a product fails to meet the established minimum performance standards for any application, as established by TxDOT, TTI will reserve an evaluation slot within the next available evaluation cycle for that product. The participant must commit to retesting the identical product by the deadline established by TTI. In the event the participant fails to confirm retesting by the deadline established by TTI, the evaluation slot will be offered to the next product on the waiting list.

In the event a product is retested at the HECL and again fails to meet the established minimum performance standards for any application as established by TxDOT, an evaluation plot will not be guaranteed the product during the next available evaluation cycle. The product representative must complete a new "Request for Performance Evaluation" packet and the product will be scheduled for retesting according to the postmark date on the completed "Request for Performance Evaluation" and the procedures established within the normal waiting list process.

Class 2 "Flexible Channel Liner" Products

Due to the limited number of evaluation channels available at the HECL and the number of individual products currently requesting Class 2 applications evaluation, a product cannot be guaranteed an evaluation slot within the next available evaluation cycle in the event that product fails to meet any of the established minimum performance standards established by TxDOT.

The product representative must complete and forward to TTI, a new "Request for Performance Evaluation" packet if they desire to retest the identical product. The product will be scheduled for retesting according to the postmark date on the completed "Request for Performance Evaluation" packet, and the procedures established within the normal waiting list process.

REVISION OF MINIMUM PERFORMANCE STANDARDS

TxDOT reserves the right to revise the minimum performance standards for the APL as produced through the HECL.

In the event that a product's performance no longer meets the revised minimum performance standards, the product will be notified by TxDOT and provided the opportunity to retest the product within the next available evaluation cycle as determined by TxDOT.

The product will remain on the APL pending results of the next available evaluation cycle. In the event that the product fails to meet the revised standards at the end of the evaluation cycle retest, the product will be removed from the APL during the next scheduled revision. In the event that the product's performance meets the newly adopted minimum performance standards, the product will remain on the Approved Material List.

In the event that the participant fails to commit to retesting the product within the next available evaluation cycle by the deadline established by TTI, the product will be removed from the APL during the next scheduled revision.

CONTRACTOR'S OPTION

The APL will be maintained by TxDOT according to the Class and Type as may be appropriate for any given product. It is the Contractor's option to use any of the products provided that the product is listed by brand name on the current APL for the Class and Type specified, and provided the Contractor installs the product in strict accordance with TxDOT specifications and the manufacturer's installation literature.

PRIVATE LABELING

If the original manufacturer of a product tested and approved at the HECL will, to TxDOT's satisfaction, certify that the brand name tested is also distributed under other trade names (private labels), TxDOT will include those private label names on the APL for the appropriate Class and Type. Addition and/or revision of the APL due to private labels will only be made by TxDOT during the normally scheduled revision of the APL.

APPROVED PRODUCT LIST

Based upon the data collected through the HECL, TxDOT will establish and maintain a current approved product list. New products which are placed on the approved product list will become eligible for use by Contractors after statewide distribution of the official approved product list, normally issued in the form of a special provision to Item 169 *Soil Retention Blanket*. This event typically occurs during the May or June following the close of the previous March - November evaluation cycle.

Copies of the current approved material list for soil retention blankets, may be requested through the Director, Construction and Maintenance Division , Attn.: Mr. Paul Northcutt, 125 East 11th Street, Austin, TX 78701-2483.

EROSION-CONTROL BLANKET PROCEDURES

SOIL PREPARATION

All sloped treatment plots are cleared of vegetation, repaired with stockpiled or dug soil, and brought back to a reasonably uniform grade before installation. The soil is left in a loose condition and graded with a chain link drag. Each treatment plot is fumigated with a soil sterilant as recommended by the chemical manufacturer for soil sterilization. Immediately before the product installation, the plot is fine graded by hand raking the surface.

SEEDING

As mentioned earlier, seeding is done according to the TxDOT Standard Specification, Item 164, *Seeding for Erosion Control*. Fertilizer is applied, integrally with the seed mixture, at the recommended rate of 252 kg/ha. The slurry is hydraulically applied with a hydro seeder immediately before product installation.

RAINFALL SIMULATION CYCLES

During the evaluation period, a series of three simulated rainfall events at the one-year, two-year, and five-year return frequencies are completed. The first set of simulated rainfall events is a one-year return frequency, 30.226 mm/hr, simulated within one month after material installation. The second set of simulated rainfall events is a 2-year return frequency, 145.542 mm/hr, simulated one-three months following material installation. The third set of simulated rainfall events is a five-year return frequency 183.642mm/hr, simulated three-five months following material installation. All of the rainfall simulations are accomplished within six months of material installation. All simulations have a ten minute duration.

To conduct a rainfall simulation, the following conditions must be met:

- Rainfall simulations will not occur within twenty-four hours of a natural rainfall or during any precipitation.
- The simulations will not be performed when, in the opinion of the HECL facility manager, the wind conditions are such that most of the water is blown onto the adjacent plots.
- If the wind is calm and it is not raining, the researchers cover the adjacent treatment plots with a plastic film immediately before the rainfall simulation. Once the simulation is completed, the plastic film is removed and the sediment and water is collected in the trough(s).

In case a drought period of more than thirty (30) consecutive days, each plot will receive a simulated rainfall of twenty-five mm at an intensity equivalent to the two-year return frequency. All natural precipitation events will be recorded on a daily basis.

SEDIMENT DATA COLLECTION

After each simulated rainfall event, the sediment and water vacuumed with a wet-dry vacuum into buckets is labeled, covered, and temporarily stored. The sediment is allowed to settle for at least twenty-four hours before the top layer of water is vacuumed off and discarded. Soil samples will be collected from each bucket, capped, labeled, and stored in the lab trailer. The remaining soil in the buckets will be weighed, recorded, and discarded at this time. To determine the moisture-to-sediment ratio, the soil samples are used to calculate the total dry weight of sediment.

Each soil sample goes through a drying process to arrive at the wet/dry ratio. First, the soil sample will be weighed, recorded, and emptied onto a microwave cooking dish. Any material left in the sample bottle is rinsed with water and added to the cooking dish. The soil will be cooked for several minutes and weighed. This process occurs until three consecutive weighs are equal. The dry sample weight is recorded and averaged with the other samples to determine an average wet/dry ratio. This ratio is divided into the total weight of sediment to obtain the dry weight of the collected sediment. Finally, the dry sediment weight total is divided by the number of 9.3 m^2 for each plot to figure total sediment loss.

VEGETATIVE DENSITY DATA

Vegetation establishment observations begin after completion of the two 1-year rainfall simulations and subsequently after the two 2-year and two 5-year rainfall events. The researchers use a random numbers table for the random sampling pattern. From an 8mm video camera positioned perpendicular to the surface, the researchers record thirty random observations (on the 1:3 slope). Twenty random observations are recorded in the same manner on the 1:2 sloped plots. The video images captured in digital form are equal to an area of one-half meters squared. Each image is processed to determine the percent of the apparent area covered by vegetation. Total cover will be based on the average of the observations.

MATERIAL PERFORMANCE DATA

Intermittently throughout the growing season, the treatment plot is visually inspected for any damage or undermining of the material. Any significant rips, tears, pulling away at the seams, etc. are recorded on a plot diagram and photographed.

PERFORMANCE DATA RESULTS

All of the performance data is submitted to TxDOT for analysis and production of approved list. The Texas Transportation Institute does not develop standards for the Department. Release of statistical analysis reports is through the Texas Department of Transportation, Construction and Maintenance Division. Other research deliverables are available for purchase through the TTI, Information & Technology Exchange Center, The Texas A&M University System, College Station, TX 77843-3135.

HYDRAULICALLY-APPLIED MULCH PROCEDURES

SOIL PREPARATION

All sloped treatment plots cleared of vegetation, repaired with stockpiled or dug soil, and brought back to a reasonably uniform grade before installation. The soil is left in a loose condition and graded with a chain link drag. Each treatment plot is fumigated with a soil sterilant as recommended by the chemical manufacturer for soil sterilization. Immediately before the product installation, the plot is fine graded by hand raking the surface. Unless otherwise specified by TxDOT, hydraulically-applied mulch plots will be limited to 1:3 plots only.

SEEDING

As mentioned earlier, seeding is done according to the TxDOT Standard Specification, Item 164, *Seeding for Erosion Control*. Fertilizer is applied, integrally with the seed mixture, at the recommended rate of 252 kg/ha.

MULCH APPLICATION

A one-step process is used on the treatment plot consisting of the seed, fertilizer, and mulch mixed and applied together. This is applied to both the clay soil and sand soil test plots.

RAINFALL

The hydraulically-applied mulch products will not be subjected to simulated rainfall events. Each treatment plot is sprinkle irrigated to provide sufficient moisture for vegetation growth. For the first three months, natural rainfall and/or supplemental water will be applied evenly to each plot to provide a minimum of 25 mm of water per month per plot. After the initial three months, the natural rainfall will be the source of moisture unless there is a prolonged period of drought. In case a drought period of more than thirty (30) consecutive days, each plot will be subjected to sprinkle irrigation. All natural precipitation events will be recorded on a daily basis.

VEGETATIVE DENSITY DATA

Vegetative density observations begin on or about the fourth week after treatment installation and continue at approximately six-week intervals for the duration of the growing season (March - November). Ten random observations are taken for each treatment area using an 8mm video camera positioned perpendicular to the soil surface. The researchers process each video image to determine the percent of the apparent area covered by vegetation. Total apparent vegetative density is based on the average of the ten observations.

FLEXIBLE CHANNEL LINER PROCEDURES

FLOW SIMULATIONS IN THE FLUME

To determine Manning's *n* for each flexible channel liner, the researchers use an indoor flume facility located at the College of Ocean Engineering, Texas A&M University. Physical dimensions of the box-shaped flume are approximately 0.46 m in width, 1.22 m in height, and 21 m in length. The energy gradient is 2% along the flume bottom. The researchers view the flows through the plexiglass sides of the flume. The flume bottom is plywood.

The researchers attach each material to the plywood flume bottom with carriage bolts and washers placed 0.46 m on center. Once installed, a simulated flow at a predetermined rate of flow (Q) begins. A series of three, twenty minute flows are run in the flume replicated at two different depths to collect data. Using a digital flow meter, the velocity of the water measured at 60.96 mm and 243.84 mm depths[5] is recorded. A point-gauge instrument calculates the flow depth. Both the velocity and flow depth measurements are collected in a uniform flow location. These measurements are recorded every four minutes during the twenty minute flows.

Therefore, Manning's *n* may be determined since the rate of flow (Q), the channel geometry and slope, the measured resultant mean water velocity and depth of flow, and effects of the plywood bottom are factored into the calculations. From these procedures, the researchers figure a minimum, normal, and maximum roughness coefficient.

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[5]Based on Chow's, *Open-Channel Hydraulics*, 1959 (3).

Table B. Laboratory Index Tests Conducted by TxDOT.

Material Property	Test Method
Synthetic Products	
Polymer Type(s)	ASTM E 1252
Weight	ASTM D 3776
Thickness	ASTM D 1777
Tensile Strength	ASTM D 1682, Grab Method G
Elongation, ultimate	ASTM D 1682, Grab Method G
Tensile Modulus	ASTM D 1682, at 10% Elongation
UV Resistance	ASTM D 4355, Tensile D 1682
Flexibility	ASTM D 1388-64
Biodegradable Products	
Weight	ASTM D 3776 (Total Roll Only)
Netting: Composition	ASTM E 1252
Aperture Size	Direct Measure
Placement	Visual
Weight	ASTM D 3776
Color	Tex-839-B
Number of Nets	Visual
Net/Matrix Binding Method	Visual/Direct Measure
Jute Products	
Fabric Weave/Yarn Count	Threads/Foot
Weight	ASTM D 3776

SOIL PREPARATION

All sloped treatment plots are cleared of vegetation, repaired with stockpiled or dug soil, and brought back to a reasonably uniform grade before installation. The soil is left in a loose condition and graded with a specialized trapezoidal-shaped tool. Each treatment plot is fumigated with a soil sterilant as recommended by the chemical manufacturer for soil sterilization.

SEEDING

As mentioned earlier, seeding is done in accordance with the TxDOT Standard Specification, Item 164, Seeding for Erosion Control. Fertilizer is applied, integrally with the seed mixture, at the recommended rate of 252 kg/ha.

The researchers install each channel liner at this time according to the manufacturer's published literature. To help ensure vegetative growth during the evaluation period, there will be a ninety (90) day vegetation establishment or *rest* period after the material installation beginning with the 1995 cycle.

FLOW SIMULATIONS IN THE FIELD

After the ninety (90) day *rest* period, a series of simulated flows will begin. Before each flow the channels are pre-wetted to moisten the channel surface. After this process, the researchers turn on the pumping station to deliver the flow water at a steady rate. Similar to natural flows seen along roadside drainage ditches, the water rises within the system and begins to flow out of the treatment channel opening. Within three to four minutes, the water flows at the desired depth and continues for twenty minutes. During the twenty minutes, velocity and depth measurements are taken every four minutes. After the measurements are taken, the researchers close the pumping station and the water subsides within one to two minutes.

Since the channels are of a fixed shape, the depth of flow is the critical element to determine the performance range of tractive forces. The researchers recommend that the simulated flows begin at 96 Pascal in a vegetated state (2) and that each flow event be replicated twice. An incremental increase of 48 Pascal shear stress to the channel bottom will occur to each series of flow events until the material *fails*.

"Failure" in this context refers to the material physically pulling away from the surface and moving downstream leaving bare ground in its place. From the first cycle of channel evaluations, the researchers witnessed rapid channel degradation once the channel was denuded of the channel liner. The researchers will collect data for each "successful" flow event and cease to record data beyond an obvious material "failure." Currently, the channel liner facility is capable of producing shear stress ranges from 96 Pascal to 383 Pascal with a maximum depth of 0.70 m for uniform flow.

The researchers will not add supplemental water to the channels after the initial *rest* period unless a protracted period of drought occurs. In case of a drought period of more than thirty

(30) consecutive days, each treatment channel will receive supplemental irrigation. All natural rainfall events are reported as part of the weather records for the HECL.

CHANNEL DEGRADATION

Before and after each simulated flow, the researchers survey the channel profile to record deformation. To collect this data, the researchers use a point gauge to take section profiles at four stations located lengthwise along the treatment channel. These stations are at 10.675 m, 15.25 m, 19.825 m, and 24.4 m from the upper end of the channel (see Figure 3). Each individual profile sample consists of seven readings taken at each station as shown in Figure 4. This procedure enables the researchers to quantify sediment loss and sediment bed load migration, and all data is furnished to TxDOT for final analysis.

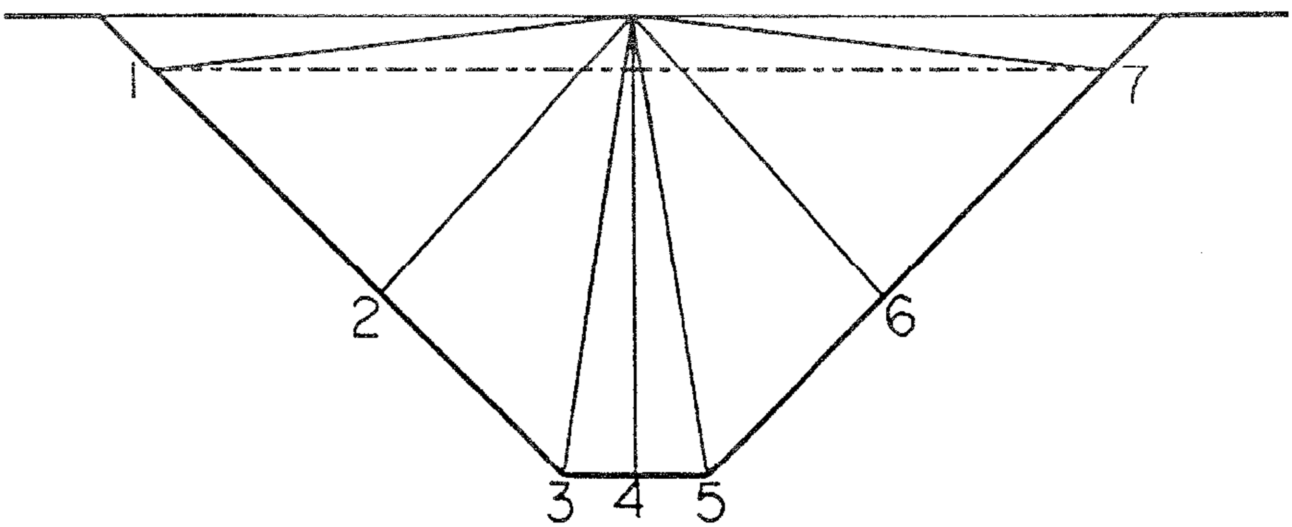

Figure 4. Section through Treatment Channel.

VEGETATIVE DENSITY

The vegetative density sampling begins on about the end of the ninety (90) day *rest* period. The first sample is taken before the channel test flows begin and subsequently after each test flow. The researchers use random patterns, established by a random number's table, for the bottom and sides of the channel to collect thirty-six (36) samples for each round of data collection. The researchers record their observations with an 8mm camera positioned perpendicular to the channel surface. From the video, single images are captured using a Targa 16 and TIPS software with the center of the image equal to 0.50 m^2. The researchers process each image (sample) with the VeCAP program to determine the percentage of apparent vegetation coverage. The average of the observations equals the total cover value. All data is furnished to TxDOT for analysis.

MATERIAL PERFORMANCE

Periodically during the evaluation cycle, each treatment channel is visually inspected for any damage or undermining of the material. Significant rips, tears, pulling away at the seams or loss of material, etc., are recorded on a channel diagram and photographed by the researchers. No material performance data is statistically analyzed.

PERFORMANCE DATA

The researchers submit all of the performance data to TxDOT for analysis. The Texas Transportation Institute does not develop standards for the Department. Release of statistical analysis reports is through the TxDOT, Construction and Maintenance Division. Other research deliverables are available for purchase through the TTI, Communications Division.

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APPENDIX A
GLOSSARY

GLOSSARY

Definitions of terms as approved by the International Standards Organization (ISO), related to geo-textiles and erosion control.

Drainage: The collecting and carrying of precipitation, groundwater, and/or other fluids in the plane of a geotextile.

Filtration: The restraining of soil or other particles subjected to hydrodynamic forces while allowing the passage of fluids.

Geocomposite: An assembled material using at least one geotextile or geotextile-related product among the components.

Geogrid: A polymeric, planar structure consisting of a regular open network of integrally connected tensile elements used in geotechnical and civil engineering applications.

Geonet: A polymeric, planar structure, used in geotechnical applications, whose openings are much larger than the constituents and in which the mesh is linked by knots.

Geotextile: A permeable, polymeric, woven, nonwoven, or knitted material used in geotechnical and civil engineering applications.

Geotextile-related products: Permeable, polymeric, sheet or strip-like construction materials used in geotechnical and civil engineering applications.

Knitted geotextile (Geoknitted): A geotextile produced by interlooping one or more yarns, fibers, filaments, or other elements.

Nonwoven geotextile (Geononwoven): A geotextile in the form of a manufactured sheet, web or batt of directionally or randomly orientated fibers, bonded by friction, and/or cohesion and/or adhesion (See ISO 9092:1988).

Protection: The limiting or preventing with a geotextile of local damage to a geotechnical system.

Reinforcement: The use of the tensile properties of a geotextile to improve the mechanical properties of a soil layer.

Separation: The preventing from intermixing of dissimilar soils and/or fill materials.

Woven geotextile (Geowoven): A geotextile produced by interlacing, usually at right angle, two or more sets of yarns, fibers, filaments, tapes, or other elements. (Knitted fabrics are excluded).

APPENDIX B

ITEM 164

SEEDING FOR EROSION CONTROL

(PARTIAL SPECIFICATIONS)

ITEM 164
SEEDING FOR EROSION CONTROL
(partial specifications)

164.1. Description. This Item shall govern for preparing ground, providing for sowing of seeds, mulching with straw, hay, or cellulose fiber and other management practices on areas shown on the plans and in accordance with this Item.

It includes seeding for permanent erosion control and seeding for temporary erosion control during the initial winter season.

164.2. Materials.

(1) Seed. All seed must meet the requirements of the Texas Seed Law including the labeling requirements for showing pure live seed (PLS = purity x germination), name and type of seed. Seed furnished shall be of the previous season's crop and the date of analysis shown on each bag shall be within nine months of the time of use on the project. Each variety of seed shall be furnished and delivered in separate bags or containers. A sample of each variety of seed shall be furnished for analysis and testing when directed by the Engineer. Buffalograss shall be treated with a dormancy method approved by the Engineer. The species and varieties of seed shall be from among the types specified in Table 1A.

Table 1A.
List of Selected Grass Species
with Their Scientific and Common Names

Scientific Name	Common Name (Acceptable Varieties)	Season Warm/Cool	Native Introduced
Agropyron smithii	Western Wheatgrass	C	N
Andropogon hallii	Sand Bluestem	W	N
Avena sativa	Oats	C	I
Bothriochloa ischaemum	K-R Bluestem	W	I
Bouteloua curtipendula	Sideoats Grama (see seed mix table for appropriate varieties)	W	N
Bouteloua eriopoda	Black Grama	W	N
Boutloua gracilis	Blue Grama (see seed mix table for appropriate varieties)	W	N
Buchloe dactyloides	Buffalograss	W	N

Cenchrus ciliaris	Buffalograss	W	I
Chloris guyana	Rhodesgrass	W	I
Cynodon dactylon	Bermudagrass	W	I
Eragrostis trichodes	Sand Lovegrass (see seed mix table for appropriate varieties)	W	N
Festuca arundinaceae	Tall Fescue	C	N
Hordeum vulgare	Barley	C	I
Leptochloa dubia	Green Sprangletop	W	N
Panicum virgatum	Switchgrass (see seed mix table for appropriate varieties)	W	N
Paspalum notatum	Bahiagrass (Pensacola variety)	W	I
Schizachyrium scoparium	Little Bluestem (Texas origin only)	W	N
Setaria italica	Foxtail Millet	W	I
Setaria macrostachya	Plains Bristlegrass	W	N
Sorghastrum avenaceum	Indiangrass (see seed mix table for appropriate varieties)	W	N
Sporobolus cryptandrus	Sand Dropseed	W	N
Triticum aestivum	Wheat (Red, Winter)	C	I

(2) Fertilizer. Fertilizer shall conform to the requirements of Item 166, "Fertilizer." The fertilizer used shall have the analysis as shown on the plans.

(3) Water. Water shall conform to the requirements of Item 168, "Vegetative Watering."

(4) Mulch.

(a) Straw Mulch or Hay Mulch. Straw mulch shall be oat, wheat or rice straw. Hay mulch shall be prairie grass, bermudagrass or other hay as approved by the Engineer. The straw mulch or hay mulch shall be free of Johnson grass or other noxious weeds and foreign materials. It shall be kept in a dry condition and shall not be molded or rotted.

(b) Cellulose Fiber Mulch. It shall meet the requirements of and be approved by the Director of Maintenance and Operations. A list of pretested and approved materials will be maintained and can be obtained by writing the Director of Maintenance and Operations, 125 East 11th Street, Austin, Texas 78701-2483.

The mulch shall be designed for use in conventional mechanical planting, hydraulic planting of seed or hydraulically-applied mulching of grass seed, either alone or with fertilizers and other additives. The mulch shall be such that, when applied, the material shall form a strong, moisture-retaining mat without the need of an asphalt binder. It shall be kept in a dry condition until applied and shall not be molded or rotted.

(5) **Soil Retention Blanket.** Soil retention blanket shall meet the requirements of Item 169, "Soil Retention Blanket."

(6) **Tacking Agents.** Tacking agents for straw or hay mulch shall be SS-1, unless otherwise shown on the plans. A biodegradable tacking agent may be used in lieu of the SS-1 tacking agent when approved by the Engineer. Asphaltic material shall conform to the requirements of Item 300, "Asphalt, Oils and Emulsions."

164.3. Construction Methods. After designated areas have been completed to the lines, grades and cross sections shown on the plans and as provided for in other items of this contract, seeding shall be performed in accordance with the requirements hereinafter described. Unless otherwise approved by the Engineer, all areas to be seeded shall be cultivated to a depth of at least four (4) inches, except where seeding is to be done using a seed drill suitable for seeding into untilled soil. The seedbeds shall be cultivated sufficiently to reduce the soil to a state of good tilth when the soil particles on the surface are small enough and lie closely enough together to prevent the seed from being covered too deeply for optimum germination. Cultivation of the seedbed will not be required in loose sand where depth of sand is four (4) inches or more.

The cross section previously established shall be maintained throughout the process of cultivation. Any necessary reshaping shall be done prior to any planting of seed.

(1) Planting Season and Seed Mixes. All planting shall be done between the dates specified for each highway district except as specifically authorized in writing by the Engineer.

The pure live seed planted per acre shall be of the type specified in Table 2 for rural areas (warm season).

Table 2.

Rural Area Species-Specific Warm-Season Seeding Mixtures in Pounds of Pure Live Seed Per Acre, by District.

District and Planting Dates*	Mixture for Use in Clay or Tight Soils		Mixture for Use in Sand or Sandy Soils	
17 (Bryan)	(All Sections)		(All Sections)	
Feb 1	Green Sprangletop	0.6	Green Sprangletop	1.1
May 15	Bermudagrass	0.8	Bermudagrass	1.5
	Little Bluestem	1.1	Bahiagrass (Pensacola)	6.7
	Indiangrass (Lometa)	1.5		
	K-R Bluestem 0.7			
	Switchgrass (Alamo)	1.2		

(2) Broadcast Seeding. The seed or seed mixture, in the quantity specified, shall be uniformly distributed over the areas shown on the plans or where directed by the Engineer. If the sowing of seed is by hand, rather than by mechanical methods, the seed shall be sown in two directions at right angles to each other. If mechanical equipment is used, all varieties of seed as well as fertilizer, may be distributed simultaneously provided that each component is uniformly applied at the specified rate. When seed and fertilizer are to be distributed as a water slurry, the mixture shall be applied to the area to be seeded within 30 minutes after components are placed in the equipment. After planting, the planted area shall be rolled with a light corrugated drum roller or another type of roller approved by the Engineer. All rolling of the sloped areas shall be along the contour of the slopes.

(3) Cellulose Fiber Mulch Seeding. The seed or seed mixture, in the quantity specified, shall be uniformly distributed over the areas shown on the plans or where directed by the Engineer. If the sowing of seed is by hand, rather than by mechanical methods, the seed shall be sown in two directions at right angles to each other. If mechanical equipment is used, all varieties of seed, as well as fertilizer, may be distributed simultaneously, provided that each component is uniformly applied at the specified rate. When seed and fertilizer are to be distributed as a water slurry, the mixture shall be applied to that area to be seeded within 30 minutes after all components are placed in the equipment.

Immediately upon completion of planting of the seed, cellulose fiber mulch shall be spread uniformly over the seeded area at the following rates:

Sandy soils with 1:3 slope or less	min. 2000 lbs./acre
Sandy soils with greater than 1:3 slope	min. 2300 lbs./acre
Clay soils with 1:3 slope or less	min. 2500 lbs./acre
Clay soils with greater than 1:3 slope	min. 3000 lbs./acre

Cellulose fiber mulch rates are based on dry weight of mulch per acre. When used, a mulching machine, approved by the Engineer, shall be equipped to eject the thoroughly wet mulch material at a uniform rate to provide the mulch coverage specified.

APPENDIX C
ITEM 169
SOIL RETENTION BLANKET

ITEM 169
SOIL RETENTION BLANKET

169.1. Description. This Item shall govern for providing and placing wood, straw or coconut fiber mat, synthetic mat, paper mat, jute mesh or other material as a soil retention blanket for erosion control on slopes or ditches or for short-term or long-term protection of seeded or sodded areas as shown on the plans or as specified by the Engineer.

169.2. Materials.

(1) Soil Retention Blankets. All soil retention blankets must be prequalified by the Director of Maintenance and Operations prior to use.

Prequalification procedures and a current list of prequalified materials may be obtained by writing to the Director of Maintenance and Operations, 125 East 11th Street, Austin, Texas 78701-2483. A 12" X 12" sample of the material may be required by the Engineer in order to verify prequalification. Samples taken, accompanied by the manufacturer's literature, will be sent, properly wrapped and identified, to the Division of Maintenance and Operations for verification.

The soil retention blanket shall be one (1) of the following classes and types as shown on plans:

(a) Class 1. "Slope Protection"

- (I) **Type A.** Slopes 3:1 or flatter - Clay soils
- (ii) **Type B.** Slopes 3:1 or flatter - Sandy soils
- (iii) **Type C.** Slopes steeper than 3:1 - Clay soils
- (iv) **Type D.** Slopes steeper than 3:1 - Sandy soils

(b) Class 2. "Flexible Channel Liner"

- (I) **Type E.** Short-term duration (Up to 2 years)
  Shear Stress (t_d) < 1.0 lb./sq. ft.
- (ii) **Type F.** Short-term duration (Up to 2 years)
  Shear Stress (t_d) 1.0 to 2.0 lb./sq. ft.
- (iii) Type G. Long-term duration (Longer than 2 years)
  Shear Stress (t_d) > 2.0 to < 5.0 lb./sq. ft.

(iv) **Type H.** Long-term duration (Longer than 2 years)
Shear Stress (t_d) $\geq$ 5.0 lb./sq. ft.

(2) **Fasteners.** Fasteners shall conform to the requirements shown on Standard Detail sheet "Soil Retention Blanket (SRB)".

169.3. Construction Methods.

(1) **General.** The soil retention blanket shall conform to the class and type shown on the plans. The Contractor has the option of selecting an approved soil retention blanket conforming to the class and type shown on the plans and according to the current approved material list.

(2) **Installation.** The soil retention blanket, whether installed as slope protection or as flexible channel liner in accordance with the approved materials list, shall be placed within 24 hours after seeding or sodding operations have been completed, or as approved by the Engineer. Prior to placing the blanket, the area to be covered shall be relatively free of all rocks or clods over 1-1/2 inches in maximum dimension and all sticks or other foreign material which will prevent the close contact of the blanket with the soil. The area shall be smooth and free of ruts and other depressions. If as a result of rain, the prepared bed becomes crusted or eroded or if any eroded places, ruts or depressions exist for any reason, the contractor shall be required to rework the soil until it is smooth and to reseed or resod the area at the Contractor's expense.

Installation and anchorage of the soil retention blanket shall be in accordance with the Manufacturer's recommendations and the Standard Detail Sheet "Soil Retention Blanket (SRB)".

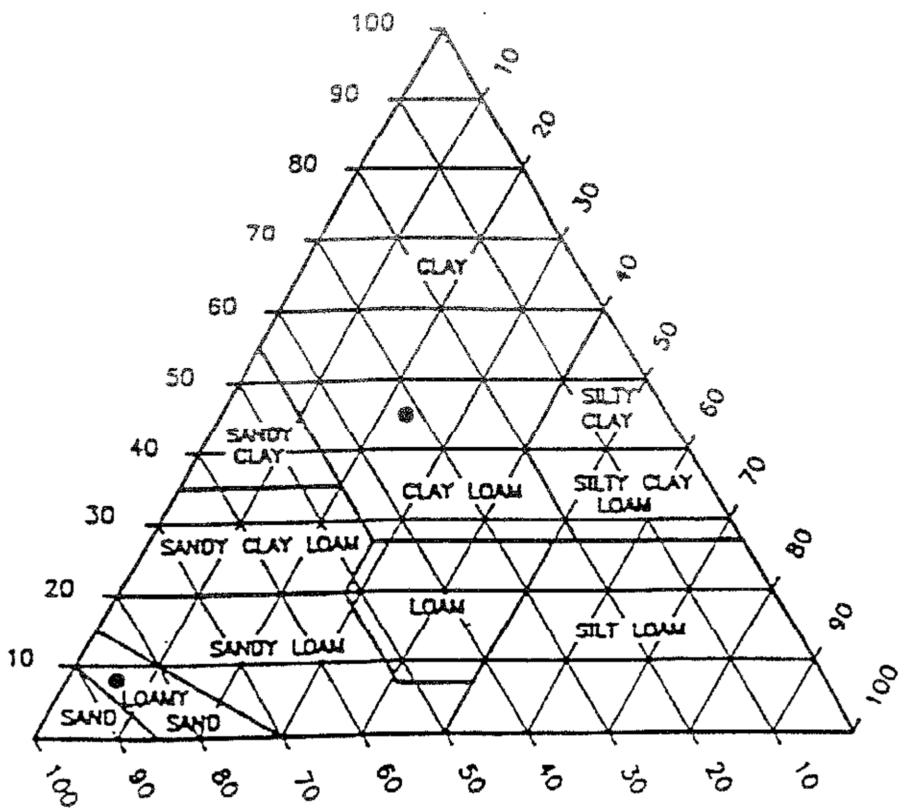
(3) Literature. The Contractor shall submit one (1) full set of manufacturer's literature and manufacturer's installation recommendations for the soil retention blanket selected in accordance with the approved material list.

169.4. Measurement. This Item will be measured by the square yard of surface area covered.

169.5. Payment. The work performed and materials furnished in accordance with this Item and measured as provided under "Measurement" will be paid for at the unit price bid for "Soil Retention Blanket" of the class and type shown on the plans. This price shall be full compensation for furnishing all materials, labor, tools, equipment and incidentals necessary to complete the work. Anchors, checks, terminals or junction slots, and wire staples or wood stakes will not be paid for directly but will be considered subsidiary to this item.

APPENDIX D
SOIL TEXTURE TRIANGLE

The soil texture triangle is from the National Soils Handbook, Figure 603-1, which shows the two soil types used in the 1994 evaluations of erosion control materials at the Hydraulics and Erosion Control Field Laboratory, Bryan, TX.



APPENDIX B
Soil Analysis

SUMMARY OF LABORATORY TEST DATA

CLIENT: TEXAS TRANSPORTATION INSTITUTE
PROJECT: TTI Project No. 419149 DATE: August 16, 1999
PROJECT NO.: 992152

BORING NO	DEPTH IN FEET	SAMPLE NO.	SAMPLE IDENTIFICATION	MOISTURE CONTENT (%)	DRY DENSITY (Pcf)	ATTERBERG LIMITS LL	PL	PI	HYDROMETER (%) SAND	SILT	CLAY	% PASSING NO. 200 SIEVE
		1	FWHA 3:1 (2)S-17			(Non-plastic)			89	4	7	14.4
		2	Control chn			34	15	19	48	18	34	63.8
		3	Chan #4			33	15	18	51	15	34	59.4
		4	Chan #8			39	19	20	40	21	39	72.8
		5	3:1 S-4			(Non-plastic)			90	3	7	11.4
		6	2:1 SA-03			(Non-plastic)			91	3	6	10.0
		7	2:1 SA-11 Envirn			(Non-plastic)			90	4	6	12.6
		8	3:1 C-02			37	17	20	37	22	41	68.7
		9	3:1 C-07			24	14	10	57	14	29	53.5
		10	2:1 CL-02			29	15	14	62	9	29	50.2
		11	2:1 CL-06			25	13	12	66	10	24	42.0

NOTE: Samples delivered to B/SMI by client August 13, 1999.
Tests performed in general accordance with TxDOT test method Tex-110-E, in which sand is defined as larger than 0.05 mm, and clay is defined as smaller than 0.005 mm, which agrees with definitions of the U.S. Department of Agriculture

BUCHANAN/SOIL MECHANICS, INC.

APPENDIX C
Raw Vegetation Cover Data

2:1 Sand

Year	Plot/Year	Slope	Soil	Round	Sample	% Vegetation	Average
99	SA199	2	S	4	1	62.74	
99	SA199	2	S	4	2	34.26	
99	SA199	2	S	4	3	40.55	
99	SA199	2	S	4	4	36.88	
99	SA199	2	S	4	5	39.46	
99	SA199	2	S	4	6	40.55	
99	SA199	2	S	4	7	36.59	
99	SA199	2	S	4	8	54.91	
99	SA199	2	S	4	9	33.48	
99	SA199	2	S	4	10	48.16	
99	SA199	2	S	4	11	26.59	
99	SA199	2	S	4	12	22.87	
99	SA199	2	S	4	13	58.80	
99	SA199	2	S	4	14	51.66	
99	SA199	2	S	4	15	55.46	
99	SA199	2	S	4	16	39.56	
99	SA199	2	S	4	17	48.15	
99	SA199	2	S	4	18	46.30	
99	SA199	2	S	4	19	45.41	
99	SA199	2	S	4	20	65.05	44.37

3:1 Sand

Year	Plot/Year	Slope	Soil	Round	Sample	% Vegetation	Average
99	S199	3	S	4	1	13.16	
99	S199	3	S	4	2	12.94	
99	S199	3	S	4	3	46.26	
99	S199	3	S	4	4	36.93	
99	S199	3	S	4	5	55.26	
99	S199	3	S	4	6	72.09	
99	S199	3	S	4	7	43.34	
99	S199	3	S	4	8	67.28	
99	S199	3	S	4	9	58.77	
99	S199	3	S	4	10	42.95	
99	S199	3	S	4	11	48.15	
99	S199	3	S	4	12	47.35	
99	S199	3	S	4	13	62.91	
99	S199	3	S	4	14	67.88	
99	S199	3	S	4	15	75.18	
99	S199	3	S	4	16	44.07	
99	S199	3	S	4	17	36.92	
99	S199	3	S	4	18	32.19	
99	S199	3	S	4	19	56.81	
99	S199	3	S	4	20	35.42	
99	S199	3	S	4	21	39.49	
99	S199	3	S	4	22	58.22	
99	S199	3	S	4	23	48.27	
99	S199	3	S	4	24	58.78	
99	S199	3	S	4	25	47.30	
99	S199	3	S	4	26	72.80	49.26

2:1 Clay

Year	Plot/Year	Slope	Soil	Round	Sample	% Vegetation	Average
99	CL199	2	C	4	1	66.69	
99	CL199	2	C	4	2	42.88	
99	CL199	2	C	4	3	65.23	
99	CL199	2	C	4	4	48.23	
99	CL199	2	C	4	5	36.25	
99	CL199	2	C	4	6	46.46	
99	CL199	2	C	4	7	45.12	
99	CL199	2	C	4	8	60.61	
99	CL199	2	C	4	9	74.67	
99	CL199	2	C	4	10	68.90	
99	CL199	2	C	4	11	70.59	
99	CL199	2	C	4	12	72.01	
99	CL199	2	C	4	13	77.34	
99	CL199	2	C	4	14	32.59	
99	CL199	2	C	4	15	45.19	
99	CL199	2	C	4	16	46.21	
99	CL199	2	C	4	17	57.00	
99	CL199	2	C	4	18	51.01	
99	CL199	2	C	4	19	62.33	
99	CL199	2	C	4	20	72.98	58.11
99	CL1199	2	C	4	1	77.26	
99	CL1199	2	C	4	2	63.29	
99	CL1199	2	C	4	3	59.92	
99	CL1199	2	C	4	4	57.68	
99	CL1199	2	C	4	5	72.32	
99	CL1199	2	C	4	6	75.29	
99	CL1199	2	C	4	7	82.46	
99	CL1199	2	C	4	8	86.22	
99	CL1199	2	C	4	9	87.19	
99	CL1199	2	C	4	10	58.85	
99	CL1199	2	C	4	11	59.07	
99	CL1199	2	C	4	12	69.28	
99	CL1199	2	C	4	13	62.36	
99	CL1199	2	C	4	14	75.79	
99	CL1199	2	C	4	15	84.38	
99	CL1199	2	C	4	16	68.75	
99	CL1199	2	C	4	17	69.44	
99	CL1199	2	C	4	18	50.28	
99	CL1199	2	C	4	19	51.98	
99	CL1199	2	C	4	20	93.09	70.25

3:1 Clay

Year	Plot/Year	Slope	Soil	Round	Sample	% Vegetation	Average
99	C199	3	C	4	1	89.33	
99	C199	3	C	4	2	79.26	
99	C199	3	C	4	3	75.48	
99	C199	3	C	4	4	63.02	
99	C199	3	C	4	5	78.22	
99	C199	3	C	4	6	62.55	
99	C199	3	C	4	7	61.33	
99	C199	3	C	4	8	59.61	
99	C199	3	C	4	9	55.48	
99	C199	3	C	4	10	64.24	
99	C199	3	C	4	11	60.12	
99	C199	3	C	4	12	66.25	
99	C199	3	C	4	13	59.24	
99	C199	3	C	4	14	57.60	
99	C199	3	C	4	15	53.23	
99	C199	3	C	4	16	50.26	
99	C199	3	C	4	17	45.68	
99	C199	3	C	4	18	55.81	
99	C199	3	C	4	19	67.93	
99	C199	3	C	4	20	44.33	
99	C199	3	C	4	21	69.57	
99	C199	3	C	4	22	66.48	
99	C199	3	C	4	23	59.44	
99	C199	3	C	4	24	65.55	
99	C199	3	C	4	25	66.58	
99	C199	3	C	4	26	53.01	63.45
99	C799	3	C	4	1	8.89	
99	C799	3	C	4	2	75.03	
99	C799	3	C	4	3	74.79	
99	C799	3	C	4	4	58.89	
99	C799	3	C	4	5	84.16	
99	C799	3	C	4	6	74.03	
99	C799	3	C	4	7	86.22	
99	C799	3	C	4	8	81.97	
99	C799	3	C	4	9	84.79	
99	C799	3	C	4	10	80.06	
99	C799	3	C	4	11	84.52	
99	C799	3	C	4	12	81.09	
99	C799	3	C	4	13	76.00	
99	C799	3	C	4	14	58.91	
99	C799	3	C	4	15	88.22	
99	C799	3	C	4	16	82.03	
99	C799	3	C	4	17	66.98	
99	C799	3	C	4	18	84.75	
99	C799	3	C	4	19	88.40	
99	C799	3	C	4	20	59.62	
99	C799	3	C	4	21	62.10	
99	C799	3	C	4	22	79.25	
99	C799	3	C	4	23	72.88	
99	C799	3	C	4	24	65.97	
99	C799	3	C	4	25	72.40	
99	C799	3	C	4	26	80.31	73.55

This section presents a summary of several relevant field and laboratory studies performed by others in California related to the effect of topsoil or the effect of mycorrhizal inoculation on native plant establishment.

F1.1 EFFECTS OF TOPSOIL ON NATIVE PLANT ESTABLISHMENT

Field and laboratory studies on the effect of topsoil and on native plant establishment were reviewed. The review focused on recent studies conducted in southern California and other arid parts of the southwest. The results of these studies are provided, along with descriptions of how topsoil is used.

The use of topsoil for revegetation and other types of plantings has been studied for many years. The studies have shown that topsoil has beneficial characteristics not found in substrate materials. Topsoil provides: 1) higher water-holding capacity, 2) higher nutrient levels, and 3) site-adapted seeds and beneficial microorganisms. Native topsoil adds diversity to a site by providing more seed species than might be available for purchase or collection (D'Antonio and Howald, 1989). These characteristics contribute in large part to the natural establishment of healthy, long-lived plantings. In arid climates, where soil development and nutrient cycling occur very slowly, topsoil use is especially important. Many revegetation specialists consider the use of native topsoil to be the critical factor in assuring plant establishment and development of self-sufficient plantings.

Because most slopes along highways are cut slopes in parent material or are manufactured fill slopes constructed with excess "soil" from cut slopes, soil is often not suitable for adequate plant establishment. Providing suitable soil conditions prior to planting is necessary to ensure growth of the plants that will provide short- and long-term erosion control. Because topsoil provides optimal soil conditions, resulting in increased drought-tolerance, long-term stability and longevity of plantings, maximum erosion control from vegetation can be achieved with its use.

Salvaging and reuse of native topsoil requires specific planning efforts and handling of soils. The process generally consists of the following activities:

1. Salvaging 25 cm (1 in.) to 102+ cm (4+ in.) of topsoil from a suitable area (a non-weedy site that is slated for disturbance);
2. Moving the soil to the planting area or storing it offsite until the planting area is prepared;
3. Protecting stored topsoil from disturbance, erosion and weed growth;
4. Preparing planting areas by roughening the surface sufficiently to unify it with the topsoil layer; and
5. Placing the topsoil on the planting area as the final layer of soil in a manner that binds the topsoil with the underlying soil surface.

A 51-cm (2-in.) to 102-cm (4-in.) layer of topsoil is generally considered sufficient to provide significant benefits. Even as little as 2.5 cm (1 in.) of topsoil can provide many benefits that would otherwise be unavailable.

F1.1.1 Topsoil Studies Reviewed

Bainbridge, D., M. Darby, M. Fidelibus and P. Kemp. 1996. *Topsoil Salvage for Desert Revegetation*. A section of the 1996 technical report. Revegetation in Arid Environments. Prepared for Caltrans Biology, San Diego. Soil Ecology and Restoration Group, SDSU. San Diego, CA. David Bainbridge, project manager. Dr. M.F. Allen, PI.

The thin layer of topsoil in desert climates is extremely important as the primary source of water and nutrients, and usually contains a rich microbial biota responsible for many of the important aspects of nutrient cycling. Desert revegetation could be expedited through reuse of topsoil. The obvious situations where soil salvage should be considered are those in which a planned surface disturbance will remove the topsoil and leave sterile geologic material at the surface, such as in road construction (especially cut and fill), borrow pits, mining, buried pipelines and other similar disturbances. Salvaged topsoil from roadbeds could be applied to areas damaged by vehicle traffic to provide fresh, uncompacted surfaces for revegetation after construction. Salvaged topsoil may also be very useful for recovery on abandoned rights-of-way or agricultural lands, where almost all native plants, organisms and propagules have been removed. At Joshua Tree National Park, respreading of topsoil is now regularly done and has proved valuable for both visual and biological recovery. At Canyon Lands National Park topsoil salvage is also commonly done, often substantially diluted as an inoculum. The many propagules found in fresh soil, have improved recovery after disturbance. Elsewhere in California, topsoil respreading has dramatically improved recovery. In coastal sage scrub, fresh topsoil has much improved recovery where it has been salvaged from relatively weed-free sites. It has also been very effective in many other parts of the world.

Claassen, V. P. and R. J. Zasosski. 1994. *The Effects of Topsoil Reapplication on Vegetation Reestablishment*. Soils and Biogeochemistry Section, Dept. of Land Air and Water Resources, University of California, Davis. Davis, CA. Sponsoring Agency: Division of New Technology, Material and Research, Environmental and Engineering Services, California Department of Transportation, Sacramento, CA.

Reuse of topsoil on a northern California road improved plant growth by 250 percent after three years when compared to slopes with no topsoil. Both slopes had equivalent application of all nutrients, erosion control and seed materials. This study strongly recommended topsoil use for improved regeneration of plant-soil systems.

Claassen, V. P., R. J. Zasosski and R. J. Southard. 1995. *Soil Conditions and Mycorrhizal Infection Associated with Revegetation of Decomposed Granite Slopes*. Soils and Biogeochemistry Section, Dept. of Land Air and Water Resources, University of California, Davis. Davis, CA. Sponsoring Agency: New Technology and Research Program, California Department of Transportation, Sacramento, CA.

Because of its high organic matter content, topsoil is an excellent method of providing the slow release, high nitrogen content needed to regenerate barren decomposed granite slopes. The well-stabilized nitrogen, as well as the plant seeds and microbial inoculum found in topsoil, make it ideal for reestablishing plant communities.

EARTHWORKS Construction & Design. (in preparation) *San Joaquin Hills Toll Road Coastal Sage Scrub Slope Mitigation Performance.*

In two comparisons, at one and two years after planting, slopes which received topsoil along the San Joaquin Hills Toll Road showed no significant differences in total percent cover for native species (shrubs and grass/forb species combined) when compared to slopes that did not receive topsoil. However, when the cover of only shrub species was compared, it was significantly greater on the topsoil slopes, while native grass/forb species cover was higher on slopes that did not receive topsoil. These results indicate that there was possibly greater survival and faster growth rate for shrubs on the topsoil slopes. Data from five years of performance monitoring reports are summarized and restoration methods evaluated.

D'Antonio, C. M. and A. M. Howald. 1989. *Evaluating the Effectiveness of Hydroseed Mixes, Topsoil Conservation and Other Revegetation Techniques: A case study in Santa Barbara County, California.* The Society for Ecological Restoration, 1st Annual Conference Proceedings.

Topsoil conservation appeared to be very important for regeneration of many species within a pipeline corridor in Santa Barbara County. Many native annual and perennial plant species (including several rare plants) occurred in the plots in the first year that had not been used in the seed mixes and were not a result of migration during the time of construction. Some non-native grass and broadleaf species (i.e., *Brassica nigra, Silybum marianum, Carpobrotus edulis*) also appeared. Weeds occurred primarily in sections of the pipeline where there had been previous disturbance. In retrospect, due to the resulting high density of weeds, the topsoil from the weedy sections of the pipeline should have been discarded rather than salvaged.

Martha Blane & Associates. 1996. *Annual Revegetation Monitoring Report, San Bernardino Plant, Phases A-2 and B2.* Prepared for CalMat Co.

At this aggregate mining site, where topsoil was spread over planting areas, the five-year goal for native shrub cover establishment was exceeded three years after planting. The qualitative and quantitative monitoring found that the dominant shrub components, as well as a host of other species that are part of a Riversidian sage scrub plant community, were established within the Phase 2 revegetation area after only three years. The dominant shrubs were already reproductive, and pioneer species such as deerweed (*Lotus scoparius*) were declining, indicating that the natural transition from early successional species to longer-lived shrub species was occurring. The occurrence of weed species had decreased compared to previous years. The quantitative monitoring results showed the average native shrub cover to be 31.6 percent, more than two times the 15 percent performance standard for total cover. With native forbs/grasses added, the total average native vegetation cover was 32.6 percent. In comparison, the reference areas (mature, undisturbed habitat) had an average shrub cover of 33 percent.

U.S. Department of the Interior, Office of Surface Mining. 2000. http://www.osmre.gov/ocphotos5.htm.

Surface Mining Law requires the removal and replacement of all topsoil unless it is demonstrated that selected subsoil or spoil is better suited to grow plants. Topsoil is removed as a separate layer before mining and is either spread on nearby graded areas or, if necessary, temporarily stockpiled. Topsoil is also reused on mined farmlands to successfully restore areas to agricultural production. This web site contains numerous photos of topsoil handling, as well as before- and after-photos of reclaimed areas.

F1.1.2 Conclusions

Because studies have shown that topsoil has numerous beneficial characteristics not found in substrate materials, topsoil use on plantings areas should be considered whenever feasible. When used, it has dramatically improved recovery and regeneration of plant-soil systems. It is especially advantageous in arid climates such as southern California, where soil development and nutrient cycling occur very slowly. Spreading a 5- to 15-cm (2- to 6-in.) layer of native topsoil (free of weed seeds) on planting areas is the minimum amount to use. However, use of as little as 2.5 cm (1 in.) of topsoil will likely provide many benefits.

F1.2 EFFECTS OF MYCORRHIZAL INOCULATION ON NATIVE PLANT ESTABLISHMENT

Field and laboratory studies on the effect of mycorrhizal inoculation on native plant establishment were reviewed. The review focused on recent studies conducted in southern California and other arid parts of the southwest. The results of these studies are provided, along with descriptions of how mycorrhizae is used.

Mycorrhizae are specialized fungi found on plant roots. A mutually beneficial relationship exists between plant roots and mycorrhizae. Plants that benefit from this relationship are referred to as mycorrhizal. Plants benefit from an increased ability to take up nutrients and withstand drought when mycorrhizae are present. This relationship is essential to the growth rate, vigor and longevity of plantings. Soil disturbances can suppress or kill mycorrhizal fungi. Although the fungi can reestablish if suitable host plants and other conditions are in place, this process is often very slow (Miller, 1985). Plant utilization of mycorrhizal fungi markedly increases the success of revegetation on disturbed or degraded lands (Skujins and Allen, 1986). The presence of mycorrhizal fungi is known to favor native plant establishment over weeds. Additionally, it has been demonstrated that the presence of the fungi is critical for regeneration of natural ecosystems in arid lands.

The majority of plants in the world are mycorrhizal. The fungi positively affect soil structure and increase uptake of several plant nutrients, but especially phosphorus (Franson, 1989). Various studies show that: mycorrhizal inoculated plants had greater survival rates, wider basal diameters and more above-ground biomass than did non-inoculated plants (Call and Davies, 1988). Mycorrhizal plants out-perform non-inoculated plants by factors ranging up to 30 times (St. John, 1992); artificial watering and fertilization are likely to reduce or eliminate any growth response related to mycorrhizal inoculation (St. John, 1992). Results of mycorrhizal fungi use show nearly twice the plant species diversity in inoculated areas, 500 times the survival rate, and enhanced soil structure with benefits that include improved infiltration, better aeration, reduced erosion and better root growth (St. John, 1996). Mycorrhizae increases growth of native plants; it may help decrease the abundance of weed species since many weeds are non-mycorrhizal.

Generally, mycorrhizae are added to planting areas when no topsoil is available. Additionally, mycorrhizae are added to disturbed soils where root or soil tests show little or no native mycorrhizae present in the soil.

Mycorrhizal fungi can be applied in granular form directly to soil during seeding operations. This granular form can be applied through drill seeding, imprinting and hydroseeding. Review of project specifications and manufacturer recommendations indicate mycorrhizae application rates of about 3,600,000 live propagules per acre. Additionally, container-grown plant materials can be inoculated with mycorrhizal fungi at the nursery. The benefits of inoculating container-grown plant materials with mycorrhizae may include greater transplant success, increased plant growth and greater reproductive success.

F1.2.1 Mycorrhizae Studies Reviewed

Allen, M. F., E.B. Allen and C.F. Friese. 1989. *Responses of the Non-mycotrophic Plant Salsola kali to Invasion by VA Mycorrhizal Fungi.* New Phytologist 111:45-49.

VA (vesicular-arbuscular) mycorrhizal fungi reduced the growth and survival of the non-mycotrophic weed Russian thistle (*Salsola kali)* in southern California field experiments and in greenhouse experiments. The Russian thistle reacted to the mycorrhizal fungi as if they were pathogens, by developing areas of root that turned yellow and then brown in the places where VA mycorrhizal fungi had penetrated the root.

Claassen, V. P., R. J. Zasosski and R. J. Southard. 1995. *Soil Conditions and Mycorrhizal Infection Associated with Revegetation of Decomposed Granite Slopes.* Soils and Biogeochemistry Section, Dept. of Land Air and Water Resources, University of California, Davis. Davis, CA. Sponsoring Agency: New Technology and Research Program, California Department of Transportation, Sacramento, CA.

Successful mycorrhizal infection was achieved using sieved spores and root fragments directly from local, moderately revegetated areas. This source of inoculum is recommended for mycorrhizal colonization of barren decomposed granite sites because the fungi are site adapted. Small volumes (100-200 ml [3.4 – 6.8 oz.]) from similar vegetated materials should be placed in planting holes (10 cm [4 in.] depth) scattered throughout the revegetation site.

EARTHWORKS Construction & Design. 1998. *San Joaquin Hills Toll Road Slope Mitigation Performance Monitoring Report.* Prepared for the Transportation Corridor Agencies.

Mycorrhizae were incorporated into the soil of revegetation slope plantings along the San Joaquin Hills Toll Road mainly by using VA inoculated needlegrass (*Nassella pulchra)* liners planted at 3.75 m (12.3 ft.) on center, and inoculated container shrub species planted in groups in the upper half of the slopes. The slopes were also seeded with coastal sage scrub species. Examination of roots of native plant seedlings on these slopes at 1½ years after planting and 2½ years after planting showed VA mycorrhizae in 67 percent and 91 percent, respectively, of the seedlings.

In a 6 ha (15 ac.) area where topsoil was applied to the roadway slopes, 1½ year old plantings showed 100 percent of the seedling roots were mycorrhizal. The topsoil slopes were not planted with needlegrass liners, but some inoculated container shrub species were planted in groups in the upper half of these slopes.

A test slope was inoculated with VA mycorrhizae directly onto the soils using a two-step hydroseeding method. The slope was too steep and rocky to be inoculated using container plants. Half of the slope was inoculated with VA mycorrhizae during hydroseeding, and the other half of the slope received no mycorrhizae. To test whether VA mycorrhizae could be successfully hydroseeded, roots of foothill needlegrass seedlings (*Nassella lepida*) were sampled from both areas of the slope one year after seeding. Examination of the needlegrass roots showed a significant difference in the number of roots with VA mycorrhizae from the half of the slope that was hydroseeded with mycorrhizae compared with the half of the slope that received no VA mycorrhizae. This is the first test to show clearly that it is possible to hydroseed VA mycorrhizae directly on the soil to provide inoculum for developing seedlings.

Reiffner, R., T. St. John, and D. Pryor. 1998. *Restoration at San Onofre State Beach, California.* Land and Water July/August 1998:15-18.

Mycorrhizae application in combination with mulch treatment of mowed weeds (mustard) increased establishment of imprint seeded coastal sage scrub species in highly disturbed areas at San Onofre State Park. On average, the inoculated plots had five times the survival rate of native seedlings compared to non-inoculated plots. Species diversity in the inoculated plots was double that of the non-inoculated plots. Four years after initiation of the test, weeds still dominate the non-inoculated plots while native coastal sage scrub species dominate the inoculated plots.

St. John, Ted. 1998. *Mycorrhizal Inoculation in Habitat Restoration.* Land and Water. September/October 1998.

Practical details for inoculation of restoration sites, and some background on the importance of mycorrhizal fungi to habitat restoration are presented. Both the general and specific advantages of mycorrhizae in restoration are explained. It found mycorrhizae benefits the soil and ecosystem in general, and seeded plants specifically. A healthy native soil is filled with a mycorrhizal network that helps define soil structure. Mycorrhizal hyphae link soil particles to each other and to plant roots, in part by producing Glomalin that binds soil aggregates. These aggregates hold soil together while allowing water, nutrients, roots and soil fauna to move within the soil. The difference between the concepts of "mycorrhizal plants" and the "mycorrhizal network" between plants and soil is described.

The best way to inoculate a restoration site is with a layer of properly stored topsoil, since it contains mycorrhizal fungi as well as many other soil organisms, organic matter and native seeds. If that is not possible, mycorrhizae inoculum must be applied into the root zone using imprinting, drill seeding or hand application. However, there is also documented evidence of successful inoculation using a two-step hydroseeding process. The need to include aggressive mycorrhizal plant hosts in the seed mix to ensure the rapid spread of the fungi in the soil is addressed, as is the use of native mycorrhizal versus commercial mycorrhizal inoculum, and the cost of inoculation.

F1.2.2 Conclusions

Use of mycorrhizal fungi is beneficial when native topsoil is not available to spread on planting areas. It has been demonstrated that mycorrhizae is essential to plant growth rate, vigor and longevity, is critical for regeneration of native plants in arid lands, and is known to favor native plant establishment over weeds. Soils of a planting areas can be easily inoculated with mycorrhizal fungi. It can be applied in granular form directly to soil during seeding operations (imprint, drill or hydroseeding). Generally, specifications provide inoculum application rates of about 3,600,000 live propagules per acre. Additionally, if container-grown plant materials are to be installed, inoculating them with mycorrhizal fungi while being grown at the nursery should be considered.