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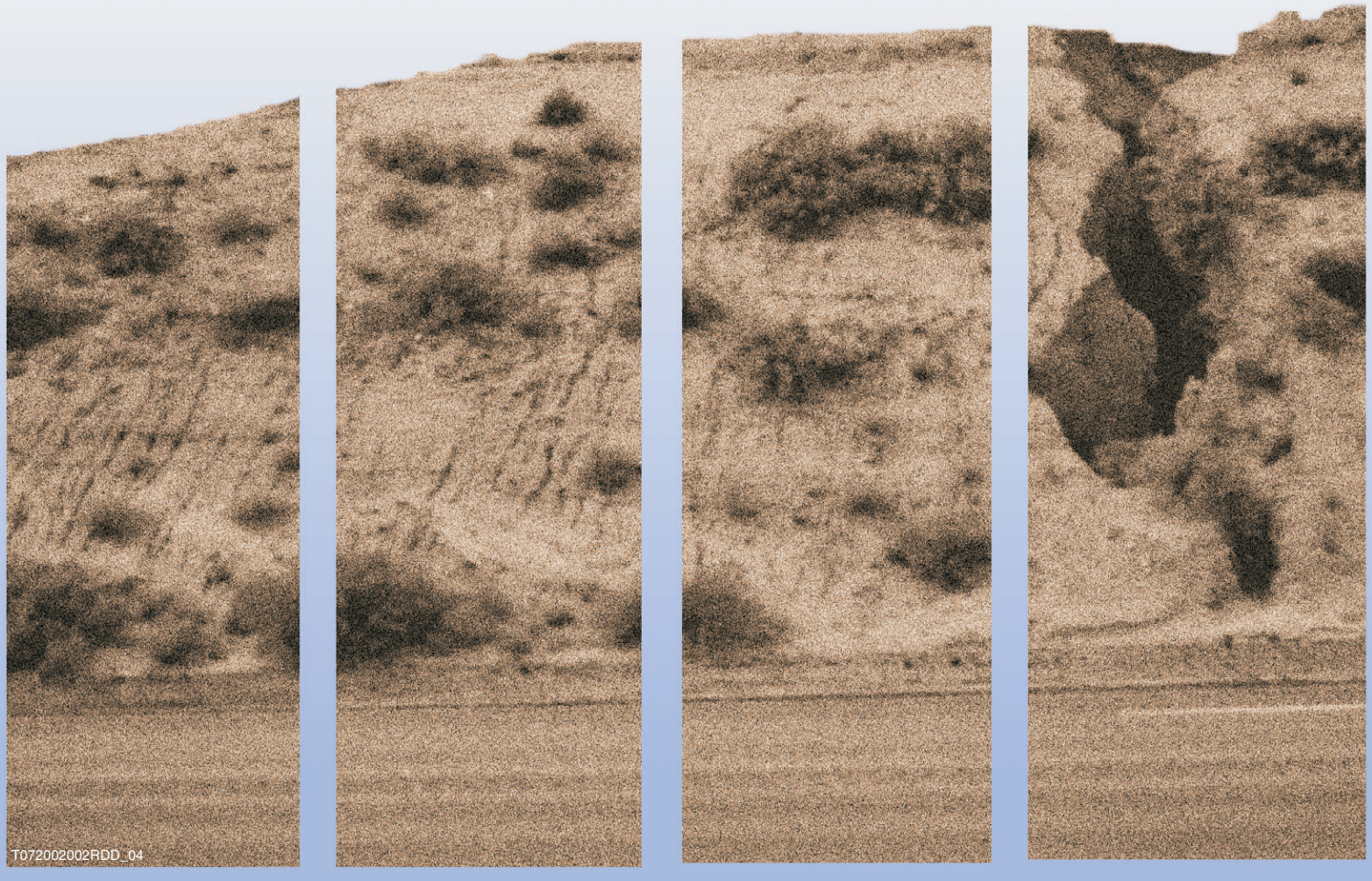
FINAL

CALTRANS ARID REGION NON-VEGETATIVE EROSION CONTROL

Study Plan and Experimental Design

July 2002



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Executive Summary

Introduction

This Caltrans Arid Region Non-vegetative Erosion Control Study Plan and Experimental Design (Study Plan) develops the protocol for selecting and testing a variety of non-vegetative erosion control products applicable to arid regions of California. These products usually consist of a topical application of soil binding agents (e.g., spray-on products) or some type of surface cover (e.g., riprap). In arid regions, vegetative cover is often difficult to establish because of climatic extremes and soil limitations. These conditions are typical of the southeastern desert (arid) regions of California. Non-vegetative erosion control technologies provide an alternative to vegetative control in these arid regions of California. There is a continuing need for understanding the suitability of non-vegetative erosion control technologies for various environments. The purpose of this Study Plan and Experimental Design is to address the effectiveness of selected non-vegetative erosion control technologies in roadside conditions that are typical of arid regions of California where vegetative systems may not be successful.

Experimental Design

The objective of the Experimental Design is to evaluate the effectiveness of non-vegetative erosion control products (e.g., soil stabilizers, rolled erosion control products, and other structural and chemical products) at reducing soil erosion caused by wind or water. The Experimental Design allows comparison among plots with different erosion control products and slope lengths within roadside sites, and among different roadside sites in arid areas of California (<250 millimeters [mm] precipitation). The following general comparisons are conducted as part of the Study Plan:

- Measure erosion losses caused by wind or water
- Compare erosion control effectiveness among five non-vegetative erosion control products
- Evaluate effectiveness of erosion control products over two slope lengths and various slope gradients
- Evaluate the effectiveness of non-vegetative erosion control products on varying degrees of slopes
- Evaluate the effectiveness of these products on different soil types
- Evaluate erosion control products over several locations within a site
- Compare effectiveness of erosion control products among several sites

As is evident in the above list, differences in erosion control products are compared within specific areas, providing replication, as well as among sites, providing comparisons of factors such as slope, aspect, or soil type.

Product Selection

The products evaluated in this Study Plan offer a range in flexibility of use and type. This Study Plan includes a selection process and compares the suitability of products that fall in the following general categories:

- Soil stabilizers
- Riprap
- Rolled erosion control products
- Resins
- Block systems
- Binding agents mixed with the surface soils

Products chosen from these general categories are used in the Study Plan. Product costs, from both a capital (installed) cost and from a long-term operations and maintenance cost are presented in this Study Plan. Cost was a main factor in the selection of products; other factors influencing product selection included:

- Long-term effectiveness – time interval between application
- Broad application – relative applicability on a wide range of sites
- Performance – proven track record of a successful product
- Installation – time and relative ease associated with installation
- Maintenance – maintenance activities between applications
- Aesthetics – blends with the natural environment
- Environmental impacts – all products evaluated are not known to have adverse environmental impacts as listed by the manufacturer—material safety data sheets for chosen products are located in Appendix A

These factors were weighted and used as the primary selection criteria for the products suggested. The final product list for use in this Study Plan includes:

- **Soil Master WR™ –** Soil Master WR™ is an acrylic, polymer-based soil stabilizer. It is a spray-on erosion control product that forms a thick crust on the soil surface. Soil Master WR™ is frequently used on highway erosion control projects in arid regions including several state and federal projects.
- **Road Oyl® –** Road Oyl® is an organic, resin-based emulsion soil stabilization product. It is a spray-on product that forms an asphalt-like crust on the soil surface. The crust maintains a natural appearance with the characteristic coloration of the constituent aggregate materials.

- **PolyPavement™ –** PolyPavement™ is a polymer, emulsion-based soil stabilizer. PolyPavement™ does not alter the color of the soil and is also suitable for many soil conditions. This product is applied hydraulically and requires little maintenance.
- **Rock Blanket –** Rock blankets have been used successfully for many erosion control projects in arid regions. Although the cost for this erosion control method is high compared to other selected products, rock blankets are a standard application used by Caltrans on problem sites where vegetation is not feasible. Because this is the accepted application to problem slopes in many cases, it was considered important to include in this Study Plan for comparison with other non-vegetative products and methods.
- **Soil Cement –** Soil cement is a mixture of cement with native soil material. Cement is mixed with native soil material and water by blading onsite, and then compacted to form a cemented soil surface that is similar to the natural soil appearance.

Site Selection

Selection Criteria

Site selection criteria were developed to aid in selection of sites that are representative of roadside conditions in arid regions of California. Additionally, these criteria focus on fulfilling the needs of the Experimental Design and construction activities, excluding undesirable environmental variability, and providing conditions necessary for safe construction and monitoring of the study. Site selection criteria include:

- Soil type
- Elevation
- Aspect
- Slope and topography
- Site size and slope length
- Design components
- Surrounding environment
- Accessibility/safety
- Security
- Permits
- Number of sites

To meet the needs of the Experimental Design, sites that differed in soil type were needed to compare product performance on various soil types. Sites that differ in slope steepness were also needed to compare product performance on various slopes. (Slope length comparisons are made within each site, not between sites). The criteria are intended to aid in selection of sites that provide the paired comparisons, as well as provide a suite of conditions that can be used to evaluate erosion control products in a number of aspects.

Selected Sites

Using the site selection criteria above, the sites that were selected for the Study Plan are Red Rocks West (east-facing slope), Barstow South (north-facing slope), Hinkley South (north-

facing slope), and El Centro South (northeast-facing slope). The location of these sites is presented on Figure ES-1.

Paired Slope Comparison

Red Rocks West and El Centro South were selected for the paired slope comparison. The Red Rocks site is a road cut located on U.S. Route 14 south of the Red Rocks Canyon State Park. El Centro South is located on a road cut on both sides of Interstate 8, approximately 16 kilometers (km) west of El Centro and 128 km east of San Diego. Both sites are composed of sand textures, exhibit similar aspects (east versus northeast), and are adequately safe and accessible for construction and research. Their slopes are representative of a typical slope (40 to 50 percent, or 2:1) used by Caltrans, as well as a steeper slope (65 percent).

Soil Texture Comparison

For the soil texture comparison, Barstow South and Hinkley South are established as a pair. The Barstow site is located in District 8 at the intersection of Interstate 15 and U.S. Route 58. The Hinkley site is located along U.S. Route 58, several km west of the towns of Hinkley and Boron, and approximately 40 km west of Barstow. Both sites have approximately 48-percent slopes, north aspects, and, because of close proximity to one another, similar climates. Given the sites available and the constraints of the paired statistical comparisons, Barstow South and Hinkley South exhibited nearly as wide a range in soil textures as is likely to exist in arid California. Barstow South represents soils with relatively finer textures (sandy loams and sandy clay loams), and Hinkley South is composed of coarser-textured materials (loamy sands). Because the presence of fines (e.g., clay) can impact the cohesiveness of soils, its capacity to remain intact during rain, and its potential to be eroded by wind when it is dry, the Hinkley South/Barstow South comparison will provide a unique and valuable comparison.

Performance Criteria

Performance criteria were developed to evaluate relative erosion control achieved by products. These criteria aim to assess products according to primary diagnostic factors associated with erosion. The criteria include both quantitative and qualitative measurements. Performance criteria include:

- Sediment loss
- Total runoff
- Water retention and infiltration
- Soil movement
- Water quality
- Erosion types
- Product integrity
- Occurrence of incidental vegetation

Performance criteria will be monitored during the 2-year duration of the experiment.

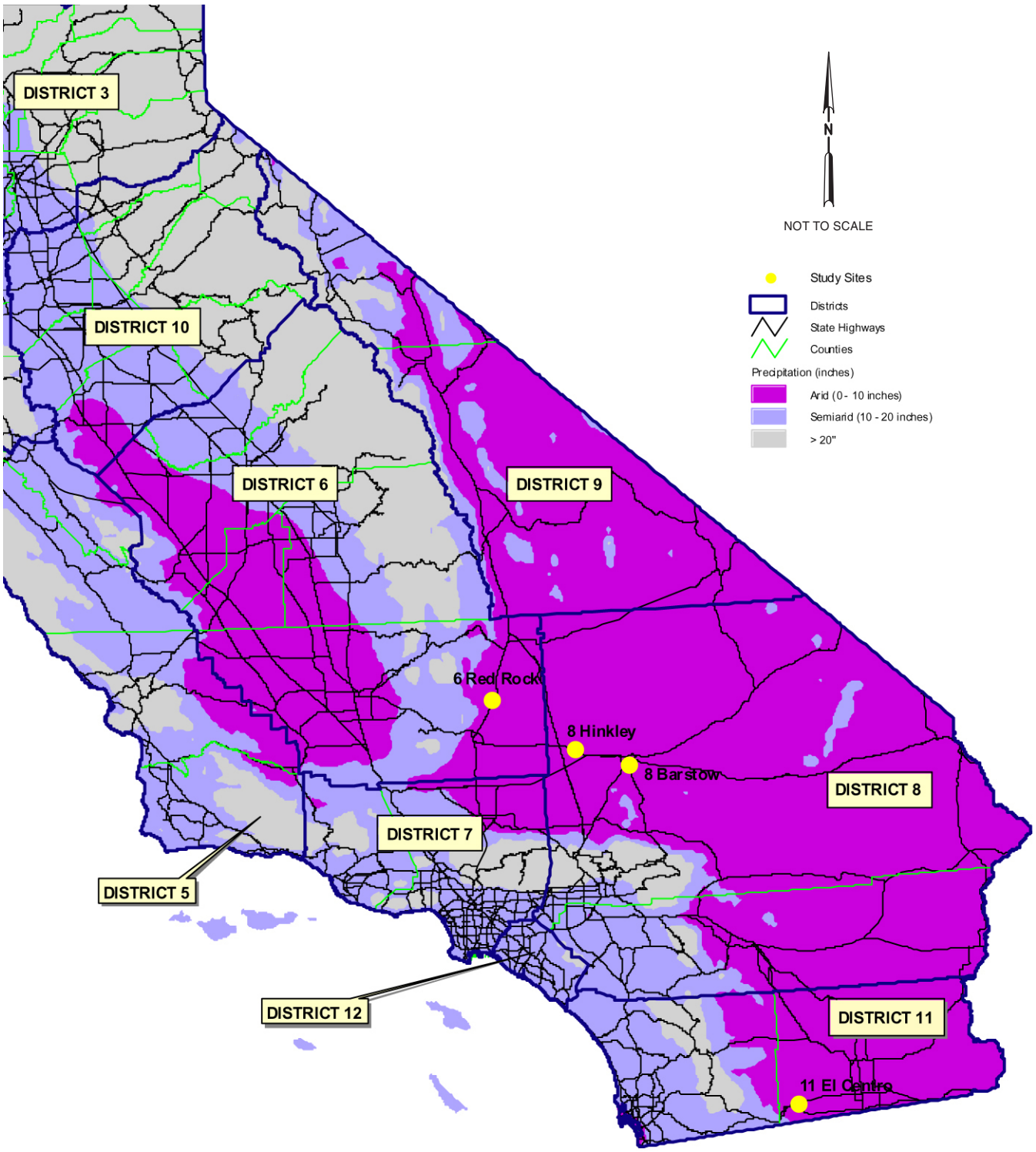

FIGURE ES-1
SITES SELECTED IN CALIFORNIA'S ARID AREAS FOR POTENTIAL STUDY PLAN IMPLEMENTATION
CALTRANS ARID REGION NON-VEGETATIVE EROSION CONTROL STUDY PLAN AND EXPERIMENTAL DESIGN

Operations and Maintenance

Sites will be operated and maintained for a minimum of 2 years beginning at the completion of construction. Prior to construction, each site will be evaluated for potential monitoring and maintenance issues that may occur during the study. The following regular operation and maintenance activities will be conducted on a monthly basis and as needed to ensure proper system function and data integrity:

- Routine site inspections
- Equipment calibration
- Plot maintenance
- Monitoring and sampling equipment maintenance
- Offsite point-source prevention and repair

Summary

The purpose of this Study Plan is to select and evaluate non-vegetative erosion control products on several sites that are representative of roadsides in arid regions of California. A literature review was conducted to gather information about erosion control products and methods used to assess their performance. An experiment was designed as part of this Study Plan to compare the performance of the erosion control products on various soil types, slopes, and slope lengths.

Several erosion control products were evaluated according to product selection criteria, and five have been chosen for experimental evaluation. Four sites in arid regions of California were chosen according to site selection criteria developed to select sites that meet experimental needs and represent a range of roadside conditions. Performance criteria were developed as a means to evaluate erosion control products used in various soil types, slopes, and slope lengths on roadsides.

This Study Plan includes detailed descriptions of monitoring and statistical analysis of performance criteria. Construction, operations and maintenance, and health and safety plans are also included, as well as a project schedule.


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1. Introduction

1.1 Background and Justification

Many areas of California experience dry and windy conditions, and implementing vegetative erosion control technologies is challenging. This is especially true in the southeastern desert (arid) regions of the state. Usually, vegetative establishment is the most common method of erosion control following construction activities on roadsides. In desert regions, however, it is commonly difficult to establish adequate vegetative cover.

Characteristics of an area affected by arid climate include limited vegetation and an absence of water. Arid climates are described to have less than 250 millimeters (mm) precipitation per year. Daytime temperatures can exceed 55 degrees Celsius (°C) in summer, and temperatures can fluctuate by as much as 22°C in the course of 1 day, and 43°C annually. Strong winds, hot in summer and cold in winter, reach velocities of up to 35 meters per second (m/s) and may cause sand storms. It is evident that these harsh environments require special attention and management when evaluating erosion control technologies.

The costs associated with sediment loss from the surrounding environment can be very high. Amendments to the Federal Water Pollution Control Act in 1972 mandated a reduction in discharges to natural waterways of the U.S. Since the passage of the amendments, U.S. businesses, government, and individuals have spent over $300 billion for water pollution control. Effective erosion control technologies could reduce these costs.

1.2 Project Focus

This Caltrans Arid Region Non-vegetative Erosion Control Study Plan and Experimental Design (Study Plan) develops a comprehensive strategy to evaluate different products for relative success as influenced by different environmental factors including soil type, slope, slope length, aspect, and precipitation. It is evident, from past successes and failures documented in the literature reviewed, that certain non-vegetative erosion control products will perform better under conditions suited to the individual product capacities.

The purpose and objectives of this Study Plan are to:

- Provide a document that will describe a scientific-based field evaluation for testing of non-vegetative erosion control products in the arid regions of California
- Provide objective and justifiable product selection criteria and recommendations for the final products to be evaluated
- Provide objective and justifiable site selection criteria and recommendations for the final sites chosen for product testing
- Provide a reliable, cost-effective, comprehensive, and simple data gathering and monitoring program for a multi-year project

- Provide a Microsoft Excel®-based software program designed to analyze the data taken in the field and provide quantifiable and statistical interpretation

1.3 Anticipated Results

The anticipated results of this Study Plan, once installed in the field and implemented, will be a relative comparison of actual products and sites that have been previously chosen according to a vigorous screening process. The influence of slope, soil type, slope length, and other environmental conditions will be the main variables of concern. Through implementation of this Study Plan, products will be recommended for actual construction activities in arid regions of California with specific site characteristics in mind. The project results will complement previous laboratory research on product performance.

2. Literature Review

2.1 Introduction

This literature review includes information collected primarily from reports and journals documenting different aspects of permanent and temporary erosion control.

Areas of study that were researched include:

- Arid regions and climates
- Erosion control products including product design and erosion control effectiveness
- Performance criteria
- Vegetative and non-vegetative studies

Complete article summaries for this section are included in Appendix B. Additional abstract summaries evaluated as research materials for this literature review that were not used herein are presented in Appendix C. The three paragraphs that follow are used in this introduction to emphasize the magnitude and relevance of erosion control issues in the U.S. and the need for ongoing studies for development of superior products and erosion control methods.

Amendments to the Federal Water Pollution Control Act in 1972 mandated a reduction in discharges to natural waterways of the U.S. Since the passage of the amendments to the Federal Water Pollution Control Act (now called the Clean Water Act), U.S. businesses, government, and individuals have spent over $300 billion for water pollution control. It has been estimated that erosion-related pollutants cost the U.S. $3.2 to $13 billion annually (Forrest, 1990).

Erosion from highways and roadways contributes to a decline in water quality. Although erosion- and sediment-control practices in highway construction and maintenance have been implemented for more than 20 years, recent environmental awareness and regulations have highlighted the issue. One of the leading causes of erosion onto highways is slope failure adjacent to the roadway. Costs for repair and maintenance of slope failures for U.S. highways alone have been estimated to exceed $100 million annually (Turner and Schuster, 1996).

Slope failure is primarily linked to the eroding action of rainfall, wind, and runoff. The problem is complex and multidisciplinary; and hydraulic, hydrological, chemical, biological, geotechnical, and pedological factors must be considered (Cazzuffi et. al, 1991).

2.2 Arid Climates

Arid regions are defined in many different ways. They can be characterized by ecosystem components or climatic factors. Arid climates are described as having less than 250 mm precipitation per year. Daytime temperatures can exceed 55°C in summer, and temperatures can fluctuate by as much as 22 degrees in the course of 1 day, and 43 degrees annually.

Fierce winds, hot in summer and cold in winter, reach velocities of up to 35 m/s and may cause sand storms. Characteristics of an area affected by arid climate include limited vegetation and an absence of water.

In some cases, even with precipitation during summer months, vegetation may decrease. This situation occurs when temperatures are unusually increased and the rate of evapotranspiration is high. This is common in the extremely warm southwestern desert areas of California. Prolonged periods of intensely high temperatures or drought in grassland vegetation can have negative consequences both for productivity of existing plants and for propagation of new ones. It was found that during low rainfall years, the productivity of perennial grasses by seed is insignificant (Mauz et al., 2000).

Common to arid regions is a distinct lack of productive vegetative coverage. When vegetation is not anchoring soil to the ground, the potential for erosion can be significant. Erosion types that tend to occur in arid and semiarid regions include wind-, water-, and gravity-induced erosion. Several items of importance include:

- Lack of vegetative coverage in arid areas is largely determined by the lack of precipitation. Other factors include temperature and wind velocities.
- Most desert soils are poorly developed and are generally composed of coarse-grained sediments. These textural classes tend to have an increased potential for erosion.
- Wind erosion may lead to strong and violent dust storms and can be a significant contributor to soil loss onsite.
- Dust storms often occur in arid regions where wind velocities are increased and sustained, and there is generally a lack of vegetative cover. The effects of sediment loss from dust storms can be hazardous to human health and increase the potential for traffic accidents.
- Erosion control, through either vegetative control applicable to arid regions or non-vegetative methods, is necessary in these climate zones to combat sediment loss.

2.2.1 Precipitation and Temperature Effects in Arid Regions

Arid regions historically receive limited amounts of precipitation throughout the year. The lack of precipitation has contributed to minimal vegetation growth in desert regions throughout the world. In the Mojave Desert during 1990 and 1991, approximately 10,000 hectares were eroded because of reduced vegetative cover caused by 8 years of subnormal precipitation and 2 years of severe drought. Bach (1997) determined that severe and prolonged drought will eventually result in the loss of most shrubs and other vegetation. In China, drought during the 1930s led to the extensive destruction of vegetation coverage and the expansion of wind erosion (Dong et al., 2000).

Temperature may also have an adverse effect on vegetative growth in arid regions. In warm, southwestern deserts, despite increased precipitation during the summer months, unusually high temperatures may result in relatively high rates of evapotranspiration. This can have negative consequences both for productivity of existing plants and for propagation and stand replacement (Mauz et al., 2000).

2.2.2 Wind Erosion

Wind erosion is mainly a phenomenon that occurs in arid and semiarid areas where precipitation is rare and vegetation sparse (Dong et al., 2000). Early signs include disposition of sand particles around existing plants and microripples on the surface of exposed areas (Food and Agriculture Organization of the United Nations [FAO], undated). The potential for wind erosion can be attributed to several factors, the most important being soil quality. Arid regions characteristically have poorly developed soils composed of coarse-grained sediments. These soils have a moderate to high potential for erosion. Other factors include precipitation and vegetation (Bach, 1997).

Severe wind may also lead to dust storms, which have several negative effects. In Australia, dust storms occur over large areas of arid and semiarid lands and are responsible for eroding large quantities of topsoil (McTainsh et al., 1998). The dust storms of the 1930s in the U.S., central Asia, and the former Soviet Union are related to vegetation clearance caused by land reclamation against dry climate (Dong et al., 2000).

2.3 Erosion Types

The erosion types listed in this section are indicative of climatic conditions caused primarily by meteorological systems specific to arid regions of the world. The most common erosion types that occur in arid regions are water erosion, wind erosion, and gravity-induced erosion. Erosion caused by fire is a common occurrence in arid climates as well. Wind erosion, water erosion, and erosion caused by fire are discussed below.

2.3.1 Wind Erosion

Wind erosion is mainly a phenomenon that occurs in arid and semiarid areas where precipitation is rare and vegetation sparse (Dong et al., 2000). Early signs include disposition of sand particles around existing plants and microripples on the surface of exposed areas (Food and Agriculture Organization of the United Nations [FAO], undated). The potential for wind erosion can be attributed to several factors, the most important being soil quality. Arid regions characteristically have poorly developed soils composed of coarse-grained sediments. These soils have a moderate to high potential for erosion. Other factors include precipitation and vegetation (Bach, 1997).

Severe wind may also lead to dust storm events, which have several negative effects. These are defined internationally as "blowing dust events associated with visibility reductions of less than 1k (km)" (Bach, 19970). In Australia, dust storms occur over large areas of arid and semiarid lands and are responsible for eroding large quantities of topsoil (McTainsh et al., 1998). The dust storms of the 1930s in the U.S., central Asia, and the former Soviet Union are related to vegetation clearance caused by land reclamation against dry climate (Dong et al., 2000). These events historically have had and currently have significant impacts on atmospheric pollution, health, and air quality.

2.3.2 Water Erosion

When rainfall events occur in arid regions, two common erosion problems may occur: sheet erosion and gully erosion. The problems of water erosion are magnified in arid regions

because rainfall often has a highly erosive force (Freer-Hewish, 1991). Sheet erosion occurs when unprotected soil particles are loosened through disturbance by rainfall impact. The soil particles are transported by rainwater surface flow to adjacent water conveyance systems (e.g., rivers and streams). Sheet erosion is characterized by the lowering of the soil level. This type of erosion can contribute to a significant amount of soil loss.

Gully erosion is the most obvious and dramatic demonstration of erosion. It occurs in conjunction with sheet erosion. Gullies can be formed in areas of concentrated streamflow during rains (e.g., flash flooding).

2.3.3 Effects of Fire

Wildfire has a wide range of effects on the vegetation, soils, water, and watershed resources in arid regions. Fire characteristics, season of burning, and pre-burn and post-burn environmental conditions create highly variable responses of vegetation to fire in desert ecosystems.

Erosion by wind, water, or gravity usually increases following fire. Large areas cleared by fire are vulnerable to erosion and can yield substantial amounts of eroded material if subjected to high-intensity summer storms immediately following burning. In a study conducted at the A-7 Ranch in Tucson, Arizona, increased rates of surface runoff and erosion on burned sites were reported in comparison to surface runoff and erosion on unburned sites (Mauz et al., 2000).

2.4 Standard Terminology

In this literature review of vegetative erosion control studies, several terms are discussed that may need further clarification. Driver and Kostielney (1997) have defined terms relating to manufacturer-provided literature on erosion control products. These terms will help readers understand results of American Society for Testing and Materials (ASTM) tests performed on erosion control products. The terms and definitions are as follows:

- Index vs. performance parameters—Index parameters are methods used to describe the physical components and characteristics of products such as weight per unit and thickness.
- Elongation—Elongation is a measurement of how much a material stretches before it breaks. ASTM prescribes several test methods to determine elongation; results may vary significantly, even on the same material. A piece of material with a specified size is put into a tensile testing machine, and tensile pressure is applied automatically by the machine.
- Tensile strength—Test procedures for tensile strength are the same as for elongation, as they are tested simultaneously. Results may also vary significantly. Higher tensile strengths are required on sites with steeper slopes than on shallow slopes.
- Flexibility/stiffness—This test evaluates the erosion control blanket (ECB) fabric's stiffness or resistance to bending. Anything less than 90-percent contact with soil particles increases the probability that erosion can occur.

- Flow velocity—ASTM D4491 determines the amount and speed of water flow ECB can experience before it tears. Water is supplied by gravity flow at rates up to 4,814 liters per second (170 cubic feet per second) from an upstream reservoir. In general, coir fiber and synthetic fibers can withstand higher velocities than can straw or wood fibers.
- Permissible shear stress—This is the minimum shear stress that an erosion mat must attain in a bare soil channel.
- Absorptive capacity—This test assesses the amount of moisture ECB is capable of absorbing. This value is important because the blanket must be able to hold enough moisture for germination and maintenance of seeds and resulting plants.
- Thickness—This is measured as the distance between one surface and its opposite. In textiles, the distance between the upper surface and lower surface of a material is measured under a specific pressure.
- Manning's "n"—This is the coefficient of roughness. The rougher the erosion control material is, the more readily material is able to slow down the velocity of the water running over it. The higher the number, the rougher the material.
- "C" factor—This factor is another performance parameter and is used in the Universal Soil Loss Equation, which calculates annual erosion rates from disturbed sites.

2.5 Non-vegetative Erosion Control Technologies

This section focuses on non-vegetative erosion control technologies; however, many product types discussed in this section are commonly used in conjunction with or to enhance vegetation. For the purposes of this Study Plan, non-vegetative erosion control technologies are considered implements that provide erosion control as a stand-alone application where incidental vegetation may occur and provide added support, but is not necessary for the erosion control effectiveness of the product.

Many types of non-vegetative erosion control products exist. No standard terminology is currently established for all erosion control products. The Erosion Control Technology Council (ECTC) has established definitions for rolled erosion control products (RECP), which are included where applicable (ECTC, 1997). ASTM has also been working to develop standard terminology for many erosion control products (Northcutt and McFalls, 1998). Erosion control technologies without standard definitions have been categorized according to information and definitions extracted from various literature and applicability to this Study Plan. The descriptions of erosion control products below are not intended as industry standards and are only for use in this Study Plan.

Erosion control technologies with potential for permanent non-vegetative application include:

- RECPs including nets, blankets, textiles, and turf reinforcement mats (TRMs)
- Hydromulches/bonded fiber matrix (BFM)
- Soil stabilizers
- Soil conditioners
- Block systems

- Cellular confinement systems
- Concrete/soil cement
- Riprap
- Slope stabilizers
- Windbreaks

2.5.1 Rolled Erosion Control Products

An RECP is categorized by ECTC as "a temporary degradable or long-term non-degradable material manufactured or fabricated into rolls designed to reduce soil erosion and assist in the growth, establishment and protection of vegetation." RECPs include erosion control blankets, nets, open-weave textiles, and TRMs.

Erosion Control Blankets/Textiles

ECTC defines ECBs as "composed of processed, natural or polymer fibers mechanically, structurally or chemically bound together to form a continuous matrix." Textiles are composed of natural or polymer yarns woven into a matrix. ECTC defines both blankets and textiles as temporary degradable. However, with rot preventative treatment or use of ultraviolet (UV)-stabilized synthetic materials, many of these products can qualify as long term. Therefore, for purposes of this Study Plan, erosion control blankets and textiles will be categorized as either temporary degradable or long-term degradable, depending on the longevity of the product.

Blankets and textiles can consist of woven or non-woven organic and/or synthetic fibers. Both woven and non-woven blankets are used successfully in a variety of applications; however, woven blankets are most commonly applied for soil stabilization and subgrade reinforcement, and non-woven blankets are more commonly used for drainage, lining systems, and asphalt overlays (Ranganathan, 1992).

Blankets and textiles provide erosion control by protecting the soil surface from the erosive effects of wind and water. The textile and loose fibers intercept or slow raindrops, thereby decreasing the amount of soil detachment and transport by raindrop impact. They also create a rougher surface, which slows surface wind and water velocities and decreases their erosivity. Additionally, blankets and textiles can absorb varying amounts of water, decreasing the overall volume of surface flow. Some organic materials can absorb as much as five times their weight in water, which aids in surface moisture absorption and enhances soil contact. The surface cover provided by the geotextile also helps to decrease soil evaporation and retains moisture that is beneficial for plant establishment (Ranganathan, 1992). Proper installation is critical to ensure good soil contact and effective erosion control. Surface debris must be cleared from the application area, and material should be fastened as specified by the manufacturer (Caltrans, 1999).

Temporary Degradable Blankets/Textiles. ECTC defines temporary degradable RECPs as products "composed of biologically, photochemically, or otherwise degradable materials that temporarily reduce soil erosion and enhance the establishment of vegetation." Although some temporary degradable blankets and textiles are composed of photo-degradable synthetics, most are composed of organic materials. Organic materials include natural constituents such as woven coconut (coir), jute, wood excelsior, straw, or other

natural fiber mesh (Northcutt and McFalls, 1998). Jute is a material often used for manufacturing erosion control materials. This cellulose-based material is commonly manufactured into an open-weave textile that provides approximately 40-percent cover and 60-percent open space. However, loose fibers in the weave fill a portion of the open areas, providing some additional erosion control. Natural materials are beneficial in that they degrade into natural organic constituents of soil and some plant nutrients. However, untreated organic products degrade over a short time (maximum of 2 years) and may not remain effective throughout the design life of a project (Ranganathan, 1992).

A number of studies have been conducted to test the effectiveness of coir in rolled erosion control projects. Advantages to coir over other natural fiber erosion control products (such as jute mats) include high durability, low elongation, and high wet strength. Santha and Santha (1995) tested the performance of different types of coir, and the results indicated that bristle fiber coir is stronger than mattress fiber coir or white fiber coir. In addition, the per-unit weight of a product was found to have a significant effect on the strength, decomposition longevity, and installation of woven coir blankets. This study found that weight increases strength, decomposition longevity, workability during installation, and helps ensure that blankets stay in contact with the soil after installation. In other studies (Schurholz, 1991), coir was also found to be effective for use on moderate slopes (slopes less than 2.5:1). The coir filter fabric had a lifetime of several years, but was completely biodegradable.

A study by Krenitsky et al., (1998) compares coir to other rolled products including wood excelsior, jute fabric (human-made materials), and straw and turfgrass sod. The products were compared on two different soil types and two different slope percentages (8-percent slope and 14- to 21-percent slope). Results showed that all materials tested had a statistically significant effect on reducing bare soil erosion by 80 to 90 percent. Of the human-made erosion control products, only open-woven jute fabric reduced runoff and sediment losses significantly at both test locations. Therefore, only sod straw and jute would be expected to effectively reduce both runoff and sediment losses.

Still other studies show that ECBs are more effective than BFMs or hydraulically applied mulch. Results of studies (Cabalka and Clopper, 1997) have shown that BFMs have much lower tensile strength characteristics than ECBs, especially in a wetted condition, and therefore are likely to fail under shear forces and/or hydraulic conditions. Therefore, BFMs are not equivalent to ECBs for all erosion control situations.

Organic materials in many of these products are most commonly used to provide temporary erosion control and to enhance the establishment of vegetation. Used alone, they will provide erosion control for some time; but without incorporation of vegetation, treatment for increased longevity, or reapplication of additional product, they may not be suitable for permanent erosion control. Treated organic products are available that have substantially longer "life" and therefore would not be classified as temporary degradable (Ranganathan, 1992). Those blankets/textiles that are categorized as temporary degradable are not considered permanent erosion control products in this Study Plan.

Long-term Non-degradable Blankets/Textiles. ECTC defines long-term non-degradable blankets as products "composed of non-degradable material that furnishes erosion protection and extends the erosion control limits of vegetation for the design life of a

project." Most non-degradable erosion control material is synthetic, although some organic materials treated for increased longevity are used. A study conducted by the International Jute Organization exposed treated and untreated jute materials to conditions for accelerated degradation. The untreated jute lost 100 percent of its tensile strength after 12 days of exposure to the study conditions, whereas jute with any of three different rot-proofing treatments maintained 100 percent of its original tensile strength after 12 days (Ranganathan, 1992).

Synthetic erosion control materials are composed primarily of human-made constituents such as polypropylene, nylon, and polyvinyl chloride (PVC). Synthetics are usually less degradable, although some have been manufactured to photodegrade in a shorter time, if desired. Synthetic filaments, like organics, can be formed into yarns and woven, or they can be manufactured to form open-tangled structure that can be filled with soil or seed (Cazzuffi et al., 1991). Many synthetic materials are extruded as a mesh fabric with a variety of sizes and thickness. These mesh materials are often used in conjunction with other woven or non-woven matrices to form a three-dimensional mat.

Non-synthetic products include wire mesh, chainlink, other metal products, and organic materials.

Turf Reinforcement Mats

ECTC defines TRM as "a long-term degradable RECP composed of UV stabilized, non-degradable, synthetic fibers, nettings and/or filaments processed into three-dimensional reinforcing matrices designed for permanent and critical hydraulic applications where design discharges exert velocities and sheer stresses that exceed the limits of mature natural vegetation." They consist of a three-dimensional mat of fibers stitched or bonded between two nets or grids. TRMs can be manufactured solely of synthetic materials or of organic materials encased in synthetic netting.

TRMs provide erosion control by catching and retaining soil particles within the tangled mat structure and by providing soil coverage that intercepts or slows rainfall, surface flow, and surface wind. The initial erosion control of TRMs is intended to allow for vegetative establishment. TRMs are structured so that the thickness and void space permit soil filling and the development of a vegetative root system within the matrix. The mat structure provides added support for roots and stems under highly erosive conditions. TRMs are most often used as channel liners in conjunction with vegetation, but are used for slope protection as well. They are either filled with soil material and seeded, or placed unfilled over a seeded surface, relying on sediment capture to eventually fill open spaces.

An RECP study conducted by Berkhout and Ward (1991) compared TRMs to ENKAMAT "S," a reinforced grip layer matting. TRMs have limited application because of the relatively low tensile strength and low modulus. This geocomposite unites the characteristics of the TRMs with those of the high-tenacity, high-modulus polyester grids. The "creep" of the ENKAMAT "S" is less than 1 percent after 2 years at a 50-percent stress ratio. It must be anchored, and the accumulated shear force must be anchored in at the top trench. RGLM can be used as a grip layer for sprayed concrete, such as gunite and shotcrete. Examples of where this can be applied are in areas under bridges where lack of vegetation and continuous dripping of water lead to serious erosion.

Although TRMs provide erosion control during vegetative establishment, the long-term system performance of TRMs depends on vegetation and roots establishing throughout the mat matrix and underlying soil, anchoring the mat to the surface (Caltrans, 2001a). Without vegetation, these systems may eventually fail. Therefore, TRMs are not considered non-vegetative erosion control methods for the purposes of this Study Plan.

2.5.2 Erosion Control Nets

ECTC defines an erosion control net as "a planar woven natural fiber or extruded geo-synthetic mesh used as a component in the manufacture of other RECPs or as a temporary degradable RECP to anchor loose fiber mulches." Because these nets provide little control by themselves and are most commonly used as a component of other products or product implementations, they will not be considered permanent non-vegetative erosion control in this Study Plan. Some nets are used temporarily as silt fences and may have functions for wind control.

2.5.3 Hydromulches/Bonded Fiber Matrix

Hydromulches and BFMs are hydraulically applied products that are primarily designed for standard seeding and revegetation operations, and not typically marketed or designed to provide the same degree of erosion control and sediment loss protection as other permanent erosion control structure or RECPs (Northcutt and McFalls, 1998). They are composed of organic and/or synthetic fibers bound by an adhesive or tackifier. A wide range of bonding agents are used in hydromulches including organic gums and inorganic polyacrylamide (PAM) or copolymers.

Hydromulches and BFMs are primarily used to aid in establishment of vegetation. They provide temporary erosion control, moisture retention, and a medium for plant fertilizers and soil conditioners. They tend to degrade quickly, depending on the bonding agent used and the thickness of the application. Tackifiers can break down in as short a period as 8 weeks (Miller et al., 2001). Most degrade into natural soil constituents that contain plant nutrients. Once the mulch cover begins to degrade, its erosion control effectiveness rapidly decreases, and the system relies on established vegetation for erosion control (Urroz and Israelsen, 1995). Most hydromulch and BFM materials are not suitable for this Study Plan because they are not long-term, stand-alone erosion control methods.

2.5.4 Soil Stabilizers

Soil stabilizers are products that cover and somewhat penetrate surface soil materials and form a cohesive bond between soil particles to create a hardened surface that is resistant to wind and water erosion. The strength of the resulting soil surface is dependent upon the composition of the stabilizer and the application. Stabilizers are often composed of latex acrylic or various copolymers. Calcium chloride and magnesium chloride are also used as soil stabilizers (Caltrans, 2001a).

Soil stabilizers provide erosion control by producing a surface of hardened or cemented soil structure that it is resistant to erosion by wind and water. The permeability of hardened surfaces varies with the product. Some create more porous surfaces that allow greater water penetration, and some are water resistant and may increase surface-flow volumes.

AIRTROL® plaster has been used in a trial experiment using a wind tunnel experiment to study its effectiveness in minimizing soil loss caused by wind erosion (Rector and Socha, 1995). This study took place at the U.S. Department of Agriculture (USDA) Agricultural Research Service Wind Erosion-Dryland Crop Production Research Center, Big Spring, Texas. Criteria for the study included the following:

- Must reduce the amount of topsoil lost to wind
- Must be environmentally benign
- Must need no specialized machinery to apply
- Must be flexible to specific needs
- Must be cost-effective

This study concludes that in of all the areas tested, the AIRTROL® plaster significantly decreased the amount of soil lost compared to the control sampled. At heavier application levels, the amount of soil lost will be decreased. This will allow the applicator to put a heavier application on areas with the severest wind erosion. This product is competitive with products currently on the market. Field tests still need to verify lab results and will be conducted in various locations throughout the U.S.

Polymers influence soil stability through the adsorption of polymer molecules by soil particles, binding them together and bridging between their agglomerations. Nesichi et al. (2001) conducted field experiments evaluating the effectiveness of polymers in sediment and erosion control. Results showed that polymers are effective in the following conditions:

- In sediment reduction on slopes with gradients of up to 60 percent, sediment reductions of 70 to 100 percent were achieved for various polymers on different soil types.
- Polymers are effective in reducing the formation and development of rills and gullies.
- Polymers are easily applied, and the resultant surface lends itself to sowing or planting of vegetation; in addition, the process is usually inexpensive.
- Polymer treatment efficiency is not affected by solar radiation.

The expected life of soil stabilizers varies greatly – from less than 6 months to over 2 years. Those composed of organic materials such as guar or plantago are used primarily as tackifiers for mulch application, and decompose quickly (Duffy and Hatzel, 1991). Tackifiers and stabilizers that have short erosion control duration are not considered for this Study Plan.

2.5.5 Soil Conditioners

Soil conditioners are products added to soil to improve their physical properties. Most soil conditioners contain a flocculating agent, such as PAM, that helps to cohere soil particles; form better soil structure; decrease surface crusting; and improve soil permeability, drainage, and aeration (Caltrans, 2001a). Conditioners differ from stabilizers in that they stabilize individual soil structures and not the entire surface layer of soil as a unit.

PAM has been shown to greatly reduce irrigation-induced soil erosion at numerous locations. A study conducted by Ambrust (1999) evaluated various PAM formulations in the effectiveness of wind erosion. Results indicate that application of PAM to soil surface reduces the amount of loose erodible material by 38 to 39 percent. PAM acts by binding with

soil particles to form a crust. The crust formed by the application of PAM was found to be unstable under the influence of salting particles, i.e., they became loose and thus were more susceptible to wind erosion. The study concludes that application of PAM formulations will protect soil surfaces from wind erosion if the treated area can be protected from incoming salting particles.

These materials provide temporary erosion control by improving soil structure and enhancing soil permeability. Reinforced soil structures are less erodible than small, noncohesive soil particles. However, soil conditioners are more effective when used in conjunction with vegetation. Although conditioners reinforce soil aggregates, exposed aggregates are still subject to wind and water erosion. Because these materials do not independently provide substantial protection from erosive forces of high wind or water velocities experienced in arid regions of California, they are not considered permanent erosion control for the purposes of this Study Plan.

2.5.6 Block Systems

Block systems consist of interlocking units with interspersed void areas that can be filled with pervious material such as sand or gravel. The installed systems are flexible and conform to the contour of the underlying slope. These materials can be composed of synthetics or pre-cast concrete.

Block systems provide erosion control by intercepting rainfall and surface flow and allowing it to infiltrate through structure openings slowly so that water velocities do not have the scouring effect they would have on bare ground. Many of these materials also provide slope support with their combined weight and interlocking structure. Block systems have several applications, including slope protection, retaining walls, and streambank protection and channel liners. Although they can be used in conjunction with vegetation, vegetation is not necessary for blocks to provide erosion control.

2.5.7 Cellular Confinement Systems

Cellular confinement systems are three-dimensional synthetic erosion control materials that, when folded out, provide a honeycomb-like structure with pockets where fill material may be placed. These systems can hold soil on steep slopes, but must also have adequate soil contact to prevent washing out from beneath. Cellular confinement systems may be categorized by the polymer used, the jointing method, or the dimensions of the pockets (usually ranging from 50 to 200 mm deep and 80 to 400 mm in diameter) (Cazzuffi et al., 1991).

Cellular confinement systems work to prevent erosion by supporting fill material in their structure against the forces of gravity and water. The material is expanded to expose its honeycomb structure, anchored to the prepared slope, and filled with soil material. However, the system provides no soil coverage and therefore does not prevent surface erosion by water or wind. They are intended for use in conjunction with vegetation, as the stabilized soil promotes vegetation establishment. Although they are non-vegetative in nature, these products cannot effectively prevent sediment loss from surface soil without the establishment of vegetation, and therefore are not considered a non-vegetative method in this Study Plan.

2.5.8 Concrete/Soil Cement

Concrete formed from cement and non-native aggregate can be poured on slopes or applied hydraulically. It provides obvious protection from rainfall impact and wind, but also provides slope stability. Soil cement is similar to concrete application, but is a mixture of cement and native soil that is placed and then compacted to form a hard, erosion-resistant surface. The first use of soil cement was for dam embankments to protect banks from wave action. This method is more cost-effective than concrete and has proven successful on slopes up to 1H:1V. The required thickness of application increases with increased slope. The method provides erosion control much the same way a soil stabilizer does, in that it adheres soil particles together to form a hard, continuous matrix. Additionally, this method does not rely on establishment of vegetation to provide effective erosion control.

Native soils are usually suitable for soil cement, although the soil characteristics, especially texture, have a significant effect on the strength and durability. Loamy sands are best suited for soil cement composition. Soils with textures outside these limits may still be used, but will require greater amounts of cement and possibly the addition of non-native materials (Bass, 2000). Soil cement is very promising where sites are accessible by machinery and can be reconstructed with existing or new fill material.

2.5.9 Riprap

Riprap consists of particles (typically rock material) of various sizes and shape. Shapes range from rounded to angular, but, typically, angular riprap is more effective for wind and water erosion control because it creates a rougher surface with more particle interlocking. The combined weight and interlocking between particles provides slope stability, and the soil coverage intercepts rainfall, eliminating raindrop impacts. Overland flow velocities are decreased, and infiltration is possible through the permeable surface. Additionally, the rough riprap surface reduces surface wind speed and protects finer soil material from detachment and transport by wind (Abt and Sanders, 1991).

Riprap can be sized to meet various design needs and can actually act as a retaining structure if designed for that purpose. It also has good resistance to flood effects, which are more prevalent in arid regions of southern California. However, different engineering practices yield different results. In a study using crushed rock fragments to armor soils susceptible to erosion, Duffy and Hatzell (1991) found that the development of small rills or microchannels on slopes as steep as 2:1 must be restricted if erosion control is to succeed, and the design of a slope protection system must be directed toward preventing channels. The study also found that the development of natural armoring of slopes by coarse particles is an important property of slope soils. Once formed, the armor should be protected from damage by restricting slope activities. The shape of the coarse particles is also important in retarding erosion. The optimum range of shape factors for slopes being on the order of 2:1 ranges from 4.0 to 9.0.

On a larger scale, results from studies on the application of rock riprap (Abt, 1991) indicated that round-shaped riprap fails at a unit discharge of approximately 40 percent less than angular-shaped rocks of the same median rock size. The slope and the unit discharge at failure can be correlated to the median rock diameter of the riprap. Further, the relationship

can be modified to incorporate the influence of gradation (rock-size uniformity) and layer thickness.

Pebble mulch has been studied to test its effectiveness on soil erosion by wind (Li et al., 2001). Results of the study showed that pebble mulch had two functions in controlling wind erosion: first it could prevent soil from eroding by wind; second, it could trap dust carried by wind. Pebble mulch reduced wind erosion by 84 to 96 percent in wind tunnel simulations. Field study results indicated that pebble mulch could trap 1.6 to 1.8 times more windblown sediments than the control, suggesting that pebble mulch might also be effective in controlling dust storms.

Riprap provides protection similar to the natural soil armoring that occurs in arid climates. Soil armor is created on bare soils when wind and water erode fine materials leaving only coarser particles that cannot be transported by erosive forces and providing erosion protection to underlying soils (Duffy and Hatzel, 1991).

2.5.10 Slope Stabilizers

Non-vegetative slope stabilizers provide stability to slopes susceptible to slides, slumping, or soil creep. They help to reduce gravity-induced erosion. Slope stabilizers include soil pins and geogrids. These implements are often internal to the soil structure and do not provide wind or water erosion control for surface soils. For this reason, these implements cannot be considered independently, but for the purposes of this Study Plan are considered as non-vegetative erosion control if used in conjunction with a surface method.

Stabilization Pins

Slope stabilization pins or micropiles are used to prevent minor slope failure attributed to soil creep, slumping, or slides. Pins may be constructed of wood, steel, and plastic (introduced relatively recently). A study conducted by the Department of Civil and Environmental Engineering at the University of Missouri, Columbia, highlights the potential of plastic pins and their design considerations. Methods for using recycled plastic pins are currently being developed. Plastic pins need special consideration because of their decreased strength and increased ductility compared with wood or steel. The benefit of plastic pins is their non-degradability, tolerance of a wide variety of environmental conditions, and the beneficial use of recycled plastics that may otherwise be disposed of in landfills (Sommers et al., 2000).

Geogrids

Geogrids are composed of synthetic materials manufactured to provide an open grid structure where fill material is placed. Base aggregates confined by these systems resist lateral spreading under load, providing a stiffer, stronger slope.

Geogrids are used primarily in earthen retaining walls and for slope and road base reinforcement. They work to prevent erosion by supporting fill material in their structure against the forces of gravity and traffic, but do not provide protection against surface wind and water erosion. Geogrids may be beneficial where unstable soil materials and underlying bedrock or sediments need additional support to prevent mass failures. However, they would need to be used in conjunction with surface erosion protection (Caltrans, 2001a).

2.5.11 Windbreaks

Windbreaks can be vegetative or non-vegetative. They control erosion by decreasing the velocity and thus the erosivity of wind at the soil surface. Windbreaks interrupt or slow the wind velocity over a ground surface area of 10 to 12 times the height of the barrier (e.g., a 1.2-meter barrier could reduce wind speeds by 20 percent over a distance of 12 to 15 meters ahead of and behind the barrier). Windbreaks do not need to be impermeable. In fact, more permeable windbreaks are more effective at slowing velocities over a shorter distance than solid barriers. This is because solid barriers create turbulent wind flow that dodges the barrier, but maintains a relatively high velocity (FAO, 1996). Many materials could be used to form windbreaks. Most fences, walls, or hedges provide some wind erosion control. Sand and silt fences installed perpendicular to prevailing winds, and in a manner that allows them to withstand wind speed, act as windbreaks.

Results from windbreak studies conducted by Maki and Du (1999) in arid China showed that the effects of two rows of windbreaks on the decrease of the wind speed and climatic alleviation are cumulative in comparison with the effect of a single row of windbreak. Net windbreaks have a similar effect for protection against wind erosion and for climatic improvement, and extension of nets is useful in arid lands. Windbreaks do not provide water erosion control, but are considered for this Study Plan as possible implements in conjunction with a surface application.

2.6 Vegetative and Non-vegetative Studies

This section describes multiple studies of erosion control products that have been conducted by different entities, including universities, state departments of transportation, and private organizations. In general, non-vegetative erosion control products are those that can be successfully implemented either with or without the promotion of vegetative growth. Currently, most non-vegetative erosion control methods are used to promote vegetative growth in areas where natural growth is not successful. A great number of erosion control products are on the market today. The products most often discussed in these articles, and used successfully include:

- Turf reinforcement mats—These have been found to have a highly permissible shear stress and are successful at promoting vegetation.
- Concrete blocks—These are proven by the U.S. Army Corps of Engineers (COE) to be successful in both vegetative and non-vegetative situations.
- Steep-slope protection—Methods such as rock-filled walls, geocell material, and steel sheet piling are discussed.
- Windbreaks—These are used successfully throughout the world to control soil loss caused by wind erosion.
- Erosion control blankets—This method increased biomass production when compared to non-treated slopes.

Many studies used special techniques or erosion control products to enhance the establishment of vegetation in arid and non-arid regions. Some of the methods include ECBs

and matting, mulch, soil stabilizers (at certain concentrations), tackifiers, and geotextiles. These products are used to help establish vegetation, and typically are not successful when used alone.

2.6.1 Studies on Erosion Control Blankets and Mats

A study performed by J.S. Fifield (1992) on 12 erosion control test plots in Parker, Colorado, found that ECBs generally increased biomass production when compared with plots that were not treated. These blankets also appeared to maintain higher moisture content and reduced overall heating during the daylight hours, yet maintained warmth during night hours. A study in Easley, South Carolina, used TRMs successfully in conjunction with seeding. The TRM used (Miramat TM80) was found to have permissible shear strength under high flow conditions (Sprague et al., 2000).

Matting has been unsuccessful in some cases. In Snodland, Kent, matting was unsuccessful in protecting steep slopes from erosion. Two types of natural matting were used to protect the soil that was prone to degradation and erosion. Pre-seeding was used with both coir matting and straw-based matting. Both methods were unsuccessful because of arid temperatures. The matting dried out too rapidly to permit germination, and was not able to be laid fully in contact with the soil surface because of irregularities produced by erosion (Duffin, 1991).

2.6.2 Studies on Soil Stabilizers and Tackifiers

A study conducted by Crowley and Kopp-Holtweische (2001) found that a polyvinyl acetate-based formulation was successful in protection from wind and water erosion. The formulation forms a three-dimensional membrane structure "liquid crust" that holds seeds and soil in place and allows oxygen to penetrate the soil. Observations from field trials in France have shown good protection against soil loss caused by strong winds (up to 140 kilometers per hour [km/hr]). In Australia, it was determined that chemical stabilization can be effective for short-term erosion and sediment control (Freer-Hewish, 1991).

Another study tested two soil tackifiers for effectiveness in controlling erosion at the University of California, Davis Arboretum. The first tackifier was an acrylic copolymer (AC), and the second was a vegetable hydrocolloid. Both had benefits and limitations. The AC tackifier allowed the least amount of sediment to erode from the slope and resisted breakdown more effectively. However, the AC tackifier also had a lower infiltration rate than the vegetable hydrocolloid. The latter allowed for a high infiltration rate, which may benefit plant life; however, it broke down rapidly over the test period of 8 weeks. By the end of the study, the vegetable hydrocolloid had almost as high a rate of sediment loss as the control (Miller et al., 1996). Fifield (1992) found that tackifiers appear to break down during freeze-thaw conditions.

2.6.3 Studies on Geotextiles

A study on geotextiles was performed in Parker, Colorado. Geotextiles were defined as "permeable synthetic fabrics which, when used in association with soil, have the ability to separate, filter, reinforce, protect, or drain". It was determined that some of the more rigid geotextile products did not always remain in close contact with the soil, which resulted in

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crusted soil and rills forming on test plots. When the areal density of a geotextile material is increased, it appears to reduce sediment yield (Fifield, 1992).

2.6.4 Studies on Concrete Blocks and Riprap

In the late 1990s, COE developed and licensed an articulated concrete block system (Corps Block). After performing tests, it was determined that unvegetated blocks remained stable up to a shear stress of 206.4 Pascals and withstood 4 m/s in flow velocity (Lipscomb, 2001). Duffin (1991) found that using concrete-filled mattresses was successful in protecting steep slopes from erosion and sediment loss.

Riprap has also been used as a form of erosion control, and in some cases has resulted in failure. In South Carolina, it was found that riprap overlying a geotextile had been used to prevent erosion, but this method was failing. Riprap had been washed away, leaving only geotextile in some places (Sprague et al., 2000).

2.7 Performance Criteria

This section presents information on performance criteria in the erosion control industry, specifically applied to state departments of transportation and highway erosion control. The studies presented discuss methods for rating erosion control products and interpreting results from performance tests.

Currently no standard formula exists by which an erosion control planner can determine the most cost-effective solution to a specific erosion problem (Harding, 1994). Some manufacturers provide results of ASTM tests performed on their products. References to "performance standards" are found in brochures and many other documents and include values for tensile strength, elongation, flexibility, flow velocity, permissible shear stress, absorptive capacity, resiliency, tear resistance, and Manning's "n" and the "C" factor (Driver and Kostielney, 1997). These standards can help a manager see the strengths and weaknesses of similar erosion control products, but are not designed for comparison of products according to specific site needs, such as ease of installation and acceptance.

Some state departments of transportation have established evaluation methods and/or facilities by which they assess products for erosion control performance and project suitability. The Wisconsin Department of Transportation compiles the Erosion Control Product Acceptability Lists for erosion mats, soil stabilizers, tackifiers, inlet protection, and temporary ditch checks. Products included in these lists must conform to certain standards and are reviewed annually (Wisconsin Department of Transportation, 2000). The Texas Department of Transportation operates an erosion control field laboratory where it evaluates products and develops standards by which the products are evaluated and approved or disapproved for suitable materials on Texas Department of Transportation projects. This erosion control field lab uses the Erosion Control Benefit Matrix (ECBM) to compare products.

ECBM takes performance standards one step further. Similar to performance standards discussed above, ECBMs have been developed to allow the user to compare products according to the specific product needs. It is used to organize large amounts of information on different products to help understand the relative strengths and weaknesses of new

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products being developed for erosion control. In this regard, it can help define the relative niche of a new material or concept by exploring the existing alternatives presently available, their historical use, and their specification for establishing fully the costs of installation and maintenance (Northcutt, 1998). The methods for choosing products vary according to each situation. Unlike performance standards, ECBM highlights six primary product selection criteria including acceptance, cost-effectiveness, ease of installation, vegetation establishment, maintenance, and standards set forth by the state's department of transportation. ECBM breaks these components down further into categories that detail their impact on the erosion control system. ECBM is intended to be used as a vertical checklist whereby two Best Management Practices (BMP) can be evaluated side by side for their erosion control benefits. Numbers can be assigned to derive a final "point total" at the end of the process. Weighted values can be assigned when the user knows which characteristics are most important or most limiting in their particular application. For example, if inexperienced labor crews will be applying BMP with limited training, perhaps the durability or ease of installation will be of more importance than environmental compatibility (Northcutt, 1998).

Using ECBM can be especially valuable in the planning phase of an erosion control project when estimation of the erosion susceptibility of a site can be specified so that a category of equally effective erosion control measures can be identified for the contractor to use as directed (Armstrong and Wall, 1992).

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3. District Interaction

3.1 Selection of Districts

Arid areas, defined as receiving less than 250 mm of rainfall per year, are found in many of the Caltrans districts in California. The vast majority of these areas, however, exist within Districts 8, 9, and 11. The arid areas in these districts are classic desert environments that characteristically possess harsh conditions for vegetation establishment. Districts 8, 9, and 11 are the focus districts for the selection of sites and for the purpose of gaining local knowledge about the performance and relative success of any non-vegetative erosion control products historically used. Some sites in the southeastern part of District 6 were preliminarily evaluated, but the majority of District 6 is located in interior valleys of California, which experience very different weather and wind patterns than the desert regions in southeastern California. For this reason, District 6 was not selected as a focus district for this Study Plan.

3.2 District Meetings

District contacts were made through recommendations from Caltrans headquarters staff and through previous contacts made during the Statewide Vegetative Erosion Control Review (Caltrans, 2001b). Each main district contact is listed below:

- District 8 – Alan Nakano
- District 9 – Jim Pittman
- District 11 – Helene Bell

Preliminary contact was made with each main district contact to prepare a meeting time when the individual district contact could ensure the attendance of representatives from multiple technical disciplines within Caltrans. The disciplines represented at the district meetings included:

- Erosion control specialists
- Landscape architects
- Maintenance staff
- Construction personnel
- Stormwater specialists
- National Pollutant Discharge Elimination System Coordinators

A project summary packet was distributed to all attendees at each district meeting and discussed. The project summary packet included information on the Study Plan background, overall project objectives, arid areas (definitions), product selection criteria, and site selection criteria. The summary packet provided a comprehensive outline for the items necessary to discuss with each district. Through thorough review of the site selection criteria, district staff were able to provide recommendations of suitable sites for final site selection. After the meetings, the project team visited each of the sites recommended by the

district staff and thoroughly evaluated each site with the use of the previously developed Highway Erosion Assessment Tool (HEAT) (Caltrans, 2001b). Completed HEAT data sheets are located in Appendix D.

District staff were also interviewed about their experience with non-vegetative erosion control products and successes or failures. This "first-hand" information provided notable background on district-specific and site-specific considerations when choosing individual, non-vegetative erosion control products.

District staff and the study team discussed many topics. Common discussion items throughout all districts included:

- Safety of application
- Site access
- Product selection
- Successes of products within individual districts
- Climatic trends
- Site selection options
- Site-specific characteristics
- Road characteristics at individual sites
- Assistance from district staff
- Previous work performed in district
- Attempts to control wind erosion

4. Product Selection

4.1 Product Categorization and Initial Determination of Acceptability

This Study Plan evaluates a selection of non-vegetative erosion control technologies. A vast number of products and methods exist. To select prospective products, it is beneficial to organize them categorically according to longevity, composition, and application. Currently in the industry, there is no established terminology for all products or product categories. Therefore, non-vegetative products are categorized and termed for the purposes of this Study Plan as follows:

- Rolled erosion control products
  - Nets
  - Temporary degradable blankets/textiles
  - Long-term non-degradable blankets/textiles
  - Turf reinforcement mats
- Hydromulches/bonded fiber matrix
- Soil conditioners
- Soil stabilizers
- Block systems
- Cellular confinement systems
- Concrete/soil cement
- Riprap
- Slope stabilizers
- Windbreaks

All products in the above-named categories incorporate non-vegetative erosion control technology. However, several products are commonly used in conjunction with and rely on vegetation. For the purposes of this Study Plan, permanent non-vegetative products are considered to be those that do not rely on the establishment of vegetation to provide effective long-term erosion control.

Additionally, the categories evaluated herein include products with a wide range of life spans. Since this Study Plan focuses on permanent erosion control technologies, products with life spans longer than 2 years were chosen for evaluation. This Study Plan evaluates products with a minimum life of 2 years. This duration encompasses a broad range of products, including long-lasting, but expensive, rock and concrete products, as well as less expensive spray-on soil stabilizers that have shorter life spans. The longevity of some shorter-lived products can be increased through re-application or application at higher concentrations.

4.1.1 Product Categories Eliminated Because of Vegetative Dependence or Short Life Span

Several products evaluated were found to provide only short-term erosion control before they rely on the establishment of vegetation and are therefore not considered permanent non-vegetative products. These include:

- Erosion control nets and TRMs (RECPs) – The long-term system performance of TRMs depends on the establishment of vegetation and roots throughout the mat matrix and underlying soil, anchoring the mat to the surface. Without vegetative establishment, these systems may fail.
- Temporary degradable blankets/textiles (RECPs) – Temporary degradable blankets and textiles are most commonly used for temporary erosion control during the establishment of vegetation. Without incorporation of vegetation, treatment for increased longevity, or reapplication, these products may not remain effective through the anticipated design life of this project.
- Hydromulch/BFM – These products provide temporary erosion control, moisture retention, and a medium for plant fertilizers and soil conditioners. They can degrade in as quickly as 8 weeks, depending on the bonding agent used and the thickness of the application. Hydromulches are not intended as stand-alone, long-term erosion control applications but are commonly used when establishing vegetation.
- Soil conditioners – Although conditioners reinforce soil aggregates, exposed aggregates are still subject to wind and water erosion. Because these materials do not independently provide long-term protection from erosive forces of high wind or water velocities experienced in arid regions of California, they are not considered permanent erosion control products for the purposes of this Study Plan.
- Cellular confinement systems – Cellular confinement systems support fill material in their structure, but provide no surface soil protection from water or wind. They usually do not effectively prevent sediment loss from surface soil without the establishment of vegetation, and therefore are not considered a permanent non-vegetative method in this Study Plan.
- Slope stabilizers – Slope stabilizers provide internal support to soils to prevent gravitational soil movement. However, they do not provide protection from the many erosive forces at the soil surface. Usually, complex methods and equipment are required for accurate monitoring of mass soil movement (e.g., sliding or slumping). This Study Plan includes monitoring equipment for primarily surface erosion; therefore, slope stabilizers are not considered.

4.1.2 Acceptable Non-vegetative Erosion Control Technologies

The remaining categories include products that potentially provide long-term erosion control without vegetative establishment. Occurrence of incidental vegetation was not considered in product selection criteria. These product categories include:

- Long-term non-degradable blankets/textiles (RECPs)
- Block systems

- Concrete/soil cement
- Riprap
- Long-term soil stabilizers
- Windbreaks

4.2 Product Selection Criteria

Selection criteria for this Study Plan aim to select products best suited to the diverse conditions of arid climates and to the construction restraints commonly encountered on Caltrans erosion control projects (e.g., cost and maintenance).

Product selection criteria include:

- Long-term Erosion Control and Non-vegetative Application
- Product Application suitability in arid areas
- Broad application
- Proven track record
- Cost
- Ease of installation
- Low maintenance
- Environmental impacts
- Aesthetics
- Limit on number of products/product categories to evaluate

The following sections present product selection criteria and provide details relative to each criterion in this Study Plan.

4.2.1 Long-term Erosion Control and Non-vegetative Application

Products considered for this Study Plan are long term as defined in this Study Plan (2-year minimum life span) and are included in categories previously listed as "acceptable non-vegetative."

4.2.2 Product Application Suitability in Arid Areas

The products selected for evaluation in this Study Plan have been used in arid areas before and are able to tolerate the wide range of environmental conditions that are present in California's arid climates.

4.2.3 Broad Application

Each chosen erosion control product must be suitable for the wide ranging characteristics of arid sites. These characteristics include precipitation intensity, temperature variations, wind velocity, and soil conditions. Successful products will perform adequately, even when exposed to extreme temperatures, wind velocities, rainfall intensity and drought, loose soil, steep slopes, and lack of vegetation.

4.2.4 Proven Track Record

Products and the companies that manufacture them have successful use records on projects with similar circumstances. The product manufacturer has several years of experience in the erosion control industry and successful experience with large-scale projects (e.g., state departments of transportation, Federal Highway Administration [FHA], defense contracts). Products have been tested or used on similar projects and proven successful. If possible, a performance guarantee will be agreed upon with the supplier, providing replacement or repair for the advertised life of the product.

4.2.5 Cost

The long-term cost of product implementation is divided into two categories: (1) the initial installed cost per unit area and (2) the maintenance and reapplication cost for effective erosion control over a period of 10 years. The long-term cost of the products will be feasible with respect to the size and budget of the project.

4.2.6 Ease of Installation

Product installation methods will easily correspond to construction timing and accessibility of roadside sites. Any equipment required for installation is proven, readily available, and maneuverable on steep slopes or at roadsides.

4.2.7 Low Maintenance

The chosen erosion control products will require minimal maintenance within a 2-year time period.

4.2.8 Environmental Impacts

Products do not contain constituents known to have adverse environmental impacts, as listed by the manufacturer. Material safety data sheets (MSDS) for chosen products are provided in Appendix A.

4.2.9 Aesthetics

Products blend with the natural environment. Products also have the flexibility to be altered (e.g., coloring of soil cements and spray-on products) to approach the surrounding environmental conditions.

4.2.10 Limit on Number of Products

To remain within size constraints of the Study Plan, no more than five products are evaluated.

4.3 Final Product Selection

The final product selection involved extensive review of products within the initially selected product categories. An extensive Internet and literature search was conducted to obtain a comprehensive list of products within each category (Appendix E). Additionally, products recommended in meetings with district staff were investigated. From this list, a

selection of products within each category was chosen using information obtained from relevant literature, district staff, product manufacturers, and interviews with erosion control professionals (Harding, 2001, pers. comm.). This preliminary list of products includes those with the highest potential for incorporation in this Study Plan, as indicated by available information pertaining to product performance, environmental impacts, cost, aesthetics, and longevity.

The preliminary product list includes:

- An acrylic polymer soil stabilizer - **Soil Master WR™** or **Soil Seal™**
- Other soil stabilizing polymer emulsions - **PolyPavement™** or **Perma-Zyme 11X™**
- A **Rock Blanket** application (geotextile under a layer of rock obtained from local sources)
- A UV-stabilized blanket such as **Vmax3™** from North American Green or **Pyramat®** from Contech - in natural colors only
- A resin-based soil stabilizer - **Road Oyl®**
- A concrete block system - **Armorflex®** from Armortec, **Turfstone™** from Unilock, or **Geoblock™** from Soil Stabilization Product Company, Inc.
- A **soil cement** application (a native soil and cement mixture)

4.3.1 Product Selection Matrices

To keep the study size manageable, no more than five products/erosion control methods from this list have been selected for the Study Plan. To make the final product selection, a set of matrices was developed to compare products and their fulfillment of the selection criteria. All products in the preliminary list meet all of the following criteria:

- **Non-vegetative –** Product can provide effective erosion control without relying on the establishment of vegetation
- **Arid application –** Product can perform adequately under the extreme conditions present in arid areas (e.g., heat, cold, wind, UV)
- **Environmental impacts –** Product is not known to have negative impacts on water quality or wildlife

Any product not meeting all of these criteria was eliminated in the development of the preliminary product list.

The selection matrix (Table 4-1) lists all criteria with the exception of those that are cost-related. This matrix provided a qualitative scoring system where each product was given a score that related to how well it fulfilled a criterion. The scoring range was from 1 to 10, and was based on relative compliance with criteria and with individual product comparison. Scores were based on conversations with manufacturers, Caltrans personnel, and erosion control specialists with technical knowledge of the products. In addition, each criterion is given a weight of 1 to 4 based on relative importance for Caltrans projects and this Study Plan (a rating of 4 being most important). The criterion weighting is based on how necessary

the criterion is for product suitably in a non-vegetative, arid application. The ratings for criteria are explained below:

- Long Term – Receives a rating of 1 (somewhat important) because all products at this stage met the longevity criterion; impacts from differences in longevity are addressed by other criteria in this matrix, namely maintenance frequency.
- Broad Application – Receives a rating of 4 (essential) because the primary intent of the Study Plan is to identify products that are widely applicable to diverse conditions in arid regions.
- Proven Track Record – Receives a rating of 2 (important) because the proven success of products and experience of manufacturers is desirable. However, some new technologies may not have been used on many projects but may have potential to be very effective and should not be ruled out.
- Installation Time – Receives a rating of 1 (somewhat important) because although the installation time that is required impacts the project schedule and could exclude a product's use on a fast-track project, installation time can be accommodated through pre-planning project efforts.
- Maintenance Frequency – Receives a rating of 3 (very important) because mobilization of maintenance crews for high-maintenance products requires follow-up site management and is less desirable than more maintenance-free applications.
- Aesthetics – Receives a rating of 4 (essential) because products that do not blend in with the natural environment or are not aesthetically appealing are destined for opposition from both the public and project designers. Even if proven effective, such products would not likely be integrated into many designs.

The total weighted product suitability score summarizes how well each product meets the non-cost related criteria.

The second matrix lists long-term costs for all products (Table 4-2). Costs are broken down into initial installed cost per square meter and the long-term cost of maintenance and reapplication for effective erosion control over a period of 10 years. Ten-year maintenance costs include reapplication of products with expected lifetimes of less than 10 years. This cost also includes annual drive-by site checks (unless reapplications are being performed) and repairs of up to 10 percent of the site area. In this way, products with higher initial costs can be compared with lower-cost products that have higher maintenance or reapplication requirements. The total 10-year cost was compared with the product score to determine the cost per 10 product suitability points. Thus, products can be evaluated by the cost relative to suitability for arid and non-vegetative applications.

4.3.2 Final Product List

The final selection of five products is based on the information obtained in the two matrices. Additionally, efforts have been made to include products from different categories. Rock blanket has been chosen since it is considered by some district personnel to be the measure by which other product performance and costs are compared. Two products in the same category are not chosen unless one would expect vast differences in performance.

TABLE 4-1
Scoring Matrix for Non-vegetative Erosion Control Product Suitability Evaluation
Caltrans Arid Region Non-vegetative Erosion Control Study Plan and Experimental Design

			Acrylic Polymer		Polymer Emulsion		Riprap	UV Blankets		Resin	Block Systems			Concrete
Criteria	**Notes on Scoring**	**Weight (1 to 4)[a]**	**Soil Master WR™**	**Soil Seal™**	**Poly Pavement™**	**Perma-Zyme 11X™**	**Rock Blanket**	**Vmax3™/ N.Am.Green**	**Pyramat™ SContech**	**Road Oyl®**	**Armorflex®/ Armortec**	**Turfstone™/ Unilock**	**Geoblock™/ SSPCo**	**Soil Cement**
								Score						
Long-term	Approximate number of years between reapplication (1 to 10+)	**1**	5	2	7	7	10	8	10	5	10	10	10	10
Broad Application	Relative applicability on a wide range of sites (with different slope, size)	**4**	9	9	9	9	5	5	5	9	6	6	6	4
Proven Track Record	Proven reputation and performance of product and company supplying it	**2**	10	10	10	8	10	6	7	10	10	10	10	9
Installation Time Required	Relative time required for installation	**1**	9	9	9	4	5	6	6	9	3	3	3	4
Maintenance Frequency	Approximate frequency (number of years between major maintenance or reapplication)	**3**	5	2	5	5	10	6	6	5	9	9	9	9
Aesthetics	Blends with the natural environment, or otherwise aesthetically appealing	**4**	9	9	9	9	7	2	2	9	8	8	8	8
Weighted Point Total[b]			**121**	**109**	**123**	**114**	**113**	**72**	**76**	**121**	**116**	**116**	**116**	**107**

Note: Products given a score of 1 to 10 in each criterion. (A score of 10 fulfills the criterion; 1 does not meet the criterion.)

[a]4 = most important; 1 = least important.

[b]weighted Point Total Example Calculation:

Weighted point total = Sum [(long-term score x weight) + (broad application score x weight) + (proven track record score x weight)…]

For Soil Master WR™: [(5x1)+(9x4)+(10x2)+(9x1)+(5x3)+(9x4)] = 121

TABLE 4-2
10-year Cost Estimation for Non-vegetative Erosion Control Products and Comparison with Suitability Points
Caltrans Arid Region Non-vegetative Erosion Control Study Plan and Experimental Design

		Acrylic Polymer		Polymer Emulsion		Riprap	UV Blankets		Resin	Block Systems			Concrete
Criteria	**Comments**	**Soil Master WR™**	**Soil Seal**	**PolyPavement™**	**Perma-Zyme 11X™**	**Rock Blanket**	**Vmax3™/ N.Am.Green**	**Pyramat™/ Contech**	**Road Oyl®**	**Armorloc®/ Armortec**	**Turfstone™/ Unilock**	**Geoblock™/ SSPC**	**Soil Cement**
Cost (capital)	Installed cost (dollars per square meter).	$0.69	$0.47	$1.25	$0.40	$30.29	$6.27	$15.54	$0.85	$30.12	$26.46	$46.58	$11.26
Number of Reapplications	Number of maintenance reapplications required over a 10-year period.	1	3	1	1	0	1	0	1	0	0	0	0
Cost (maintenance)[a]	Includes maintenance and reapplication for 10 years of effective erosion control (dollars per square meter). Assumes maintenance repairs over 10 years are 10 percent of initial installed cost.	$1.15	$1.76	$1.77	$11.20	$3.47	$7.30	$2.00	$1.33	$3.46	$3.09	$5.10	$1.57
Total 10-year Cost	**Dollars per square meter.**	**$1.84**	**$2.23**	**$3.03**	**$11.60**	**$33.77**	**$13.57**	**$17.53**	**$2.18**	**$33.57**	**$29.55**	**$51.69**	**$12.83**
Cost Per Product Suitability Point													
Total Suitability Points	From Table 4-1 "Weighted Point Total."	121	109	123	114	113	72	76	121	116	116	116	107
Cost Per 10 Suitability Points	**For erosion control on 1 square meter (dollars).**	**$0.15**	**$0.20**	**$0.25**	**$1.02**	**$2.99**	**$1.88**	**$2.31**	**$0.18**	**$2.89**	**$2.55**	**$4.46**	**$1.20**

[a]Estimated maintenance costs are based on application rates recommended by manufacturers for product use in the absence of vegetation. These costs include any reapplications required over 10 years, as well as annual drive-by maintenance checks and repairs in years that other maintenance activities are not occurring. Maintenance repairs are assumed to equal replacement of 10 percent of the site area (e.g., 10-percent initial installed cost).

Selected Products are shaded.

The final product list for use in this Study Plan includes:

- **Soil Master WR™ –** Soil Master WR™ is an acrylic, polymer-based soil stabilizer. It is a spray-on erosion control product that forms a thick crust on the soil surface. This product has a life expectancy of up to 5 years given the application rate of 0.2 liters per square meter (225 gallons per acre). Soil Master WR™ should withstand intense heat or cold, high winds and light traffic. The total 10-year product cost for non-vegetative erosion control indicated by Table 4-2 is $1.84 per square meter or $0.15 per 10 suitability points. The product has a 1-year guarantee. Soil Master WR™ is manufactured and distributed by Environmental Soil Systems, a company with 30 years of industry experience. Soil Master WR™ has been used on many projects and under similar conditions including several state and federal projects. Advantages of this product include low cost, broad application under arid conditions, relatively simple application, and natural appearance. A disadvantage is higher maintenance frequency. This product requires reapplication at least every 5 years.

- **Road Oyl® –** Road Oyl® is an organic, resin-based emulsion soil stabilization product. This product does not contain constituents derived from petroleum-based substances. It is a spray-on product that forms an asphalt-like crust on the soil surface. The crust maintains a natural appearance with the characteristic coloration of the constituent aggregate materials. The expected lifetime for Road Oyl® for arid applications is 5 to 10 years. The total 10-year product cost for non-vegetative erosion control as presented in Table 4-2 is $2.18 per square meter or $0.18 per 10 suitability points. Road Oyl® has been used on many projects under similar conditions. It is manufactured/distributed by Soil Stabilization Products Company, Inc., a company with 30 years of experience in providing erosion control products. Soil Stabilization Products Company, Inc., has experience with large government agencies including FHA, state departments of transportation, and large defense contracts. Advantages of this product include low cost, broad application under arid conditions, relatively simple application, and natural appearance. A disadvantage is that this product requires reapplication between 5 and 10 years.

- **PolyPavement™ –** PolyPavement™ is a polymer that functions as an emulsion-based soil stabilizer. It is a very sturdy asphalt-like product. PolyPavement™ does not alter the color of the soil and is also suitable for many soil conditions. This product is applied hydraulically and requires little maintenance. The total 10-year product cost for non-vegetative erosion control shown in Table 4-2 is $3.03 per square meter or $0.25 per 10 suitability points. With appropriate application, this product has a life expectancy of 5 to 10 years. PolyPavement™ has been applied successfully on several large projects, including projects in Caltrans District 8, where district staff have noted successful performance. Advantages of this product include relatively low cost, broad application under arid conditions, relatively simple application, and natural appearance. A disadvantage is that this product requires reapplication between 5 and 10 years from initial installation.

- **Rock Blanket –** Rock blankets have been used successfully for many erosion control projects under similar environmental conditions. The total 10-year product cost presented in Table 4-2 is $33.77 per square meter or $2.99 per 10 suitability points.

Although the cost for this erosion control method is high compared to other selected products, rock blankets are a standard application used by Caltrans on problem sites where vegetation is not feasible. Because this method is the current default solution to problem slopes in many cases, it is considered important to include in this study for comparison with other non-vegetative products and methods. Advantages of rock blankets include very low maintenance and long-term effectiveness. Disadvantages include high cost, more restricted application, and less natural appearance.

- **Soil Cement –** Soil cement is an application that involves mixture of cement with native soil material. Cement is mixed with native soil material and water by blading onsite and then compacted to form a cemented soil surface that is similar to the natural soil appearance. The total 10-year product cost presented in Table 4-2 is $12.83 per square meter or $1.20 per 10 suitability points. Advantages of soil cement include long-term effectiveness, low maintenance frequency, and relatively natural appearance. Disadvantages include more restricted application and higher cost and installation time.

MSDS for Soil Master WR™, Road Oyl®, PolyPavement™, and Portland Cement are located in Appendix A.

Remaining products were not selected because of higher cost, lower suitability, or inclusion in a category with another selected product. The eliminated products and justification for elimination are outlined below:

- **Soil Seal and PermaZyme 11X™ –** These products are in the same category as a selected product but have higher cost estimates dependent on specified application rates.
- **Erosion control blankets: Vmax3™ and Pyramat™ –** These products are not selected because of higher cost, less natural appearance, and more restricted application where coarse soils decrease the effectiveness of fastening staples.
- **Block systems: Armorflex®, Turfstone™, and Geoblock™ –** These products are eliminated because of higher estimated cost.

5. Site Selection

5.1 Site Selection Criteria

Site selection criteria were developed to aid in selection of study sites representative of roadside conditions in arid regions of California. Additionally, these criteria were chosen to meet the needs of the Experimental Design and construction activities, excluding undesirable variability and providing conditions necessary for safe construction and monitoring of the study.

Site selection criteria include:

- Arid climate factors
- Site Location
- Soil type
- Elevation
- Aspect
- Slope and topography
- Site size and slope length
- Design components
- Surrounding environment
- Accessibility/safety
- Security
- Permits
- Number of sites

The following sections present site selection criteria and provide details relative to each criterion in this Study Plan.

5.1.1 Arid Climate Factors

The Study Plan sites are located within an arid region of California with representative arid climatic characteristics. Several approaches for defining arid regions are available. To compare arid areas throughout the world, aridity would likely be characterized by plant-growing conditions that result in arid ecosystems (International Arid Lands Consortium, 2001). However, to define arid areas within the State of California, a more practical definition can be used. According to this definition, arid areas are those that receive less than 250 mm annual rainfall (Bates and Jackson, 1984). A geographic information system-generated map was used to display data provided by Oregon State University's Spatial Climate Analysis Service, which uses the Parameter Elevation Regression on Independent Slope Model for mean annual rainfall in California. The map categorizes arid, semiarid, and non-arid areas according to mean annual rainfall (Figure 5-1).

The majority of arid areas within California are contained within Caltrans Districts 6, 8, 9, and 11. Districts 2, 5, 7, and 10 contain some arid areas but are primarily semiarid or nonarid (Table 5-1).

TABLE 5-1
Distribution of Arid Areas throughout Caltrans Districts and Counties of California
Caltrans Arid Region Non-vegetative Erosion Control Study Plan and Experimental Design

Caltrans Districts	Counties
6,8,9,11 (Dominantly Arid)	Imperial, Riverside, San Bernardino, Kings, Inyo, and Kern
2,5,7,10 (Contain Some Arid Area)	San Diego, Los Angeles, Ventura, Santa Barbara, San Luis Obispo, San Benito, Fresno, Merced, Tulare, Mono, and Lassen

To select sites within representative arid climates, the following primary climatic characteristics of arid areas were considered for this Study Plan:

- Annual precipitation
- Temperature
- Wind velocity

Precipitation Factors

Sites should receive precipitation that is characteristic of California's arid areas. Arid regions of California vary with respect to rainfall distribution. A large portion of annual precipitation may fall in relatively short-duration rainstorms (Table 5-2). Two dominant trends exist. In the southern San Joaquin and arid interior valleys and mountains of the state, winter and spring precipitation dominates. Highest rainfall days usually occur between December and March. East of the Sierra Nevada Mountains and south and east of the San Gabriel Mountains in the high desert plains and valleys, rainfall is split between winter and late summer. Although a majority of rain falls in the winter, the highest daily rainfall usually occurs in August or September. Rainfall events can be very intense with 1-day totals as high as 125 mm in arid areas of California (Western Regional Climate Center, 2000).

TABLE 5-2
Rainfall Records for Four Weather Stations in Arid Southern California
Caltrans Arid Region Non-vegetative Erosion Control Study Plan and Experimental Design

Weather Station	Mean Annual Precipitation (mm)	100-Year Return Period Maximum 1 Hour Rainfall (mm)	100-Year Return Period Maximum 1 Day Rainfall (mm)
Barstow	100.1	15.5	25.1
Boron	49.3	22.4	59.4
El Centro	94.7	36.3	73.2
Mojave	73.1	17.0	68.8

Information obtained from California Department of Water Resources, 1999.

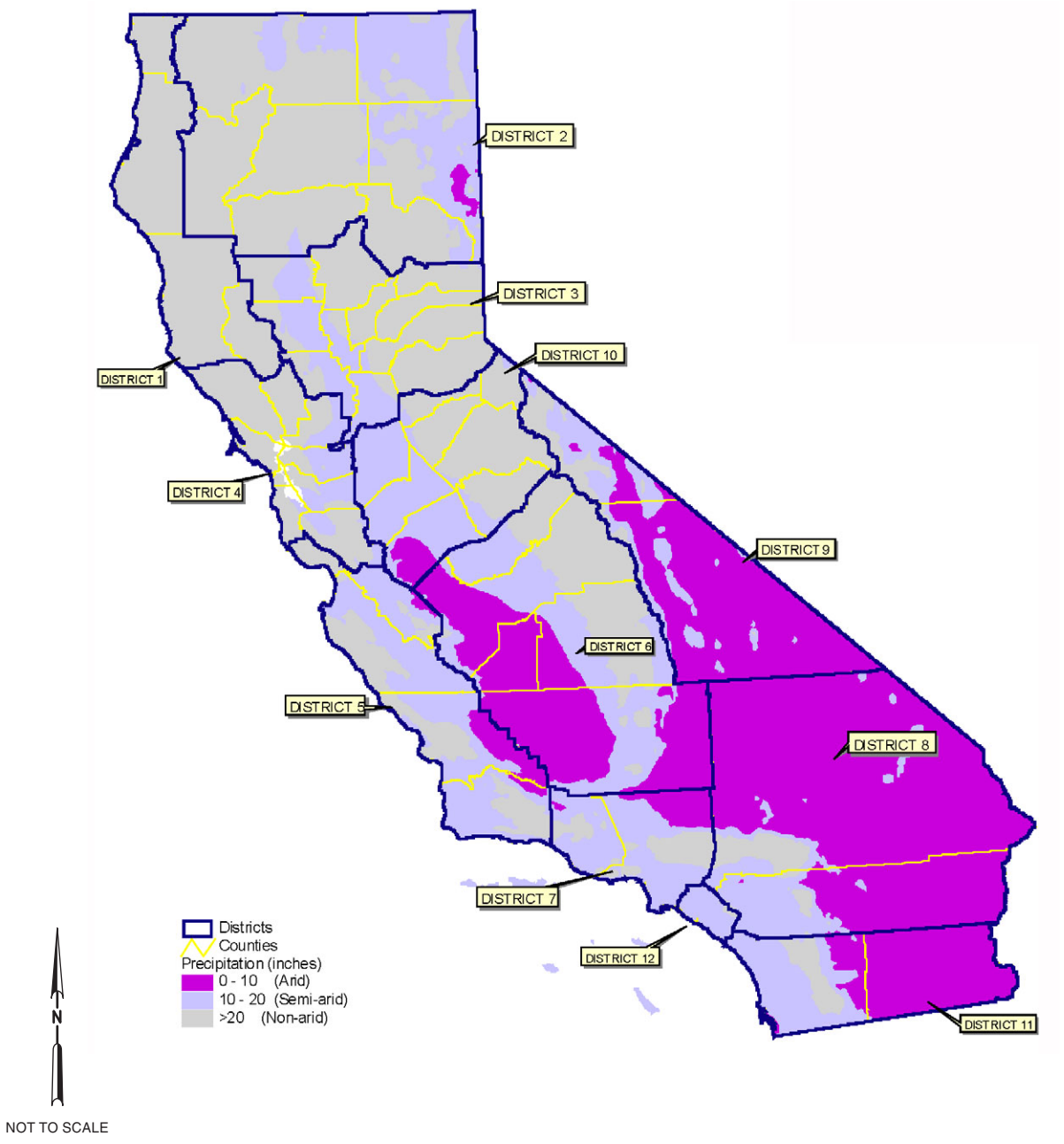

FIGURE 5-1
CALTRANS DISTRICTS AND ARID REGIONS OF CALIFORNIA DELINEATED BY MEAN ANNUAL PRECIPITATION
CALTRANS ARID REGION NON-VEGETATIVE EROSION CONTROL STUDY PLAN AND EXPERIMENTAL DESIGN

Temperature Factors

Temperatures in California's arid regions can range from a maximum daily low of -29°C to a maximum daily high of 55°C as illustrated by California Irrigation Management Information System (CIMIS) data provided by the Western Regional Climate Center (Figure 5-2). The Deep Springs College Station and the Death Valley Station recorded the lowest and highest daily temperature extremes, respectively (Figures 5-2 and 5-3).

Wind Factors

Wind erosion is prevalent in arid regions. Since soils are shallower and vegetation is sparse, high wind velocities have a great effect on erosion. In California's arid Antelope Valley, wind can travel up to 69 km/hr. In the Mojave Desert, wind speeds can reach up to 74 km/hr with an average velocity around 12 km/hr. Prevailing wind direction should be a primary factor considered with respect to wind at potential sites. It is desirable to have sites with similar prevailing wind directions (either parallel or perpendicular to the face of the slope) to minimize variability caused by differences in wind forces. Table 5-3 summarizes wind data received from CIMIS for areas with arid regions throughout California.

TABLE 5-3
Wind Averages for Specific Regions in California[a]
Caltrans Arid Region Non-vegetative Erosion Control Study Plan and Experimental Design

Region (County)	High Average Monthly Wind Velocity (km/hr)	Annual Average Wind Velocity (km/hr)
Shafter- Kern	6.1	5.0
Pomona- Los Angeles	6.1	5.3
U.C. Riverside- Riverside	6.9	6.3
Bishop- Inyo	7.4	5.5
Temecula- Riverside	8.5	6.0
Madera	9.5	7.4
Imperial/Coachella Valley	9.7	8.0
Stratford- Kings	10.8	7.9
Merced	10.9	8.9
Salton Sea- Imperial/Coachella Valley	13.0	9.3
Barstow- San Bernardino	13.5	9.3
Victorville- San Bernardino	13.7	10.8
San Joaquin Valley	13.8	9.1
Indio-Imperial/Coachella Valley	14.6	11.1

[a]Adapted from CIMIS data.

5.1.2 Site Location

The sites for this Study Plan are located in areas where construction is planned or in progress, or in areas that have had repeated erosion control difficulties and implementation of the Study Plan is feasible.

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5.1.3 Soil Type

Soils on the Study Plan sites do not contain any unusual soil conditions relative to most arid soils. They represent common arid soils, whether fine or coarse textured. Arid conditions often result in several distinct soil factors. In arid climates, low moisture content results in slower weathering, and subsequently into shallower and coarser-textured soils than in wetter climates. Low precipitation also results in retention of water-soluble substances that are usually removed by leaching processes in wetter climates. These substances include salts, which are a vegetation-limiting factor and can have corrosive effects on some materials. The shallow characteristics of many arid soils forming from residual parent materials result in less infiltration of rainfall and more runoff. Site soils have adequate depth to infiltrate some precipitation (at least 100 mm) and are relatively uniform over the site.

5.1.4 Elevation

The elevation of arid areas in California ranges from more than 61 meters below sea level to more than 2,440 meters above sea level. A characteristic influenced by elevation is the number of frost-free days. Sites subject to long periods of freeze-thaw conditions may interfere with data collection and study objectives; therefore, sites chosen have greater than 120 frost-free days.

5.1.5 Aspect

Chosen sites have the same approximate aspect (within 90^{o} of compared sites), and the aspect of each site remains uniform. This ensures that aspect does not contribute to variability in study results.

5.1.6 Slope/Topography

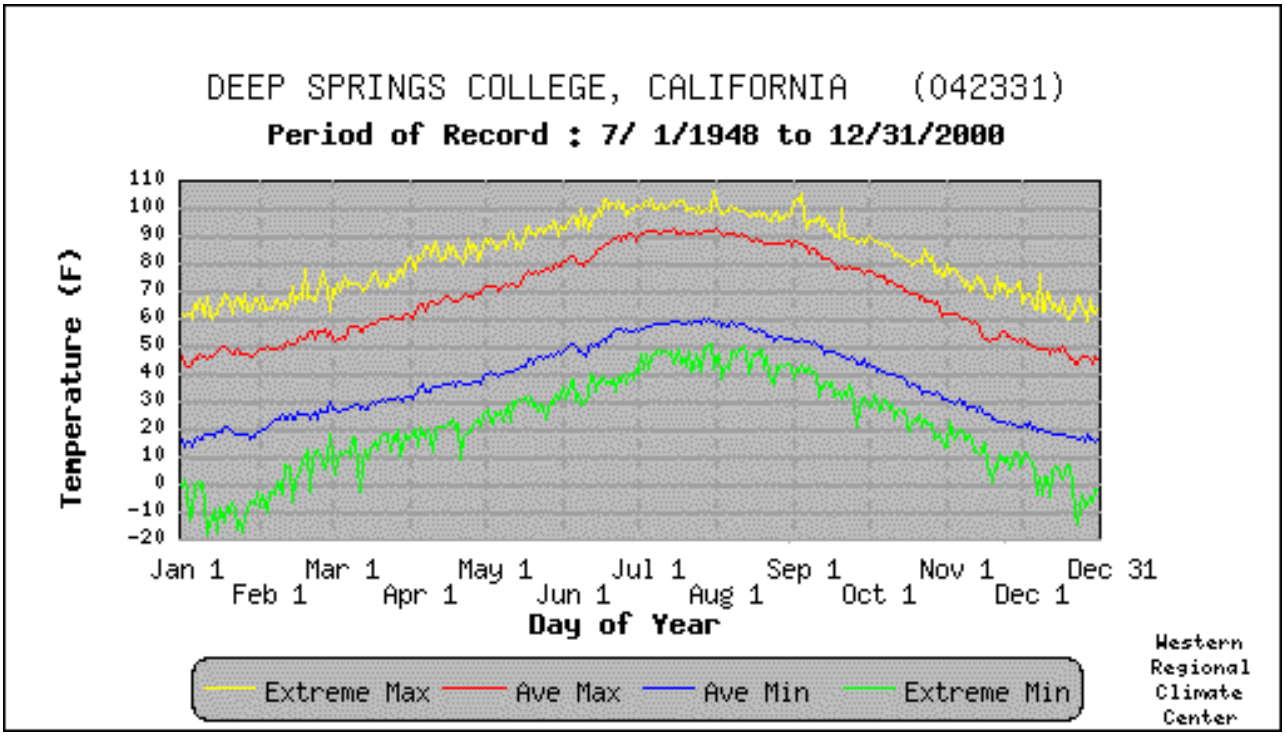
Selected sites comprise no more than two slope angles. If more than one slope angle is chosen for testing, each slope will be evaluated separately to determine influences on product performance. The chosen slope angles are representative of Caltrans construction projects.

5.1.7 Site Size and Slope Length

Site size and slope length of the selected sites are adequate to accommodate the Experimental Design (see Section 6). A minimum slope length of 14 meters and width of 35 meters is required to accommodate one plot (see Section 6.1.1. for the definition of a plot). Furthermore, each site will accommodate at least two plots, requiring a minimum site width of 70 meters.

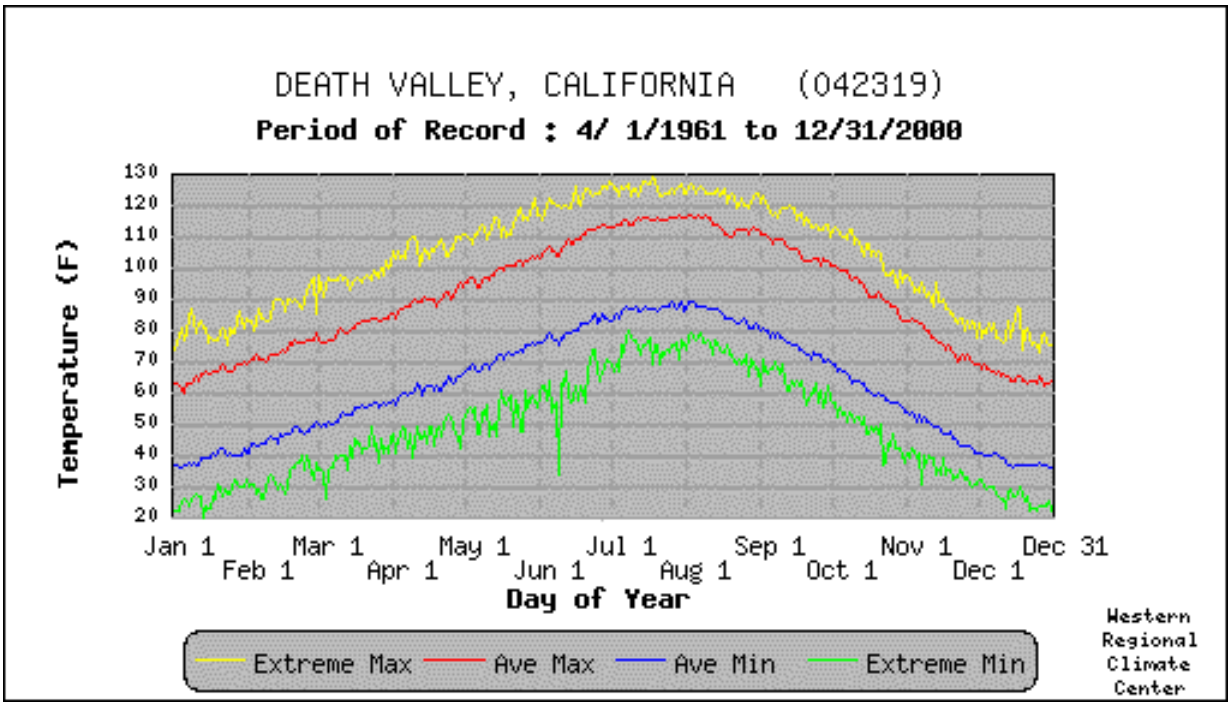
5.1.8 Design Components

Site design components on prospective sites do not influence erosive forces including wind velocities or rainfall impact. However, the design will accommodate diversion of potential runon from offsite watershed areas or point sources around the plots to prevent contribution to site surface flow.



Extreme Max = The maximum of all daily maximum temperatures recorded for the day of the year.
Ave Max = The average of all daily maximum temperatures recorded for the day of the year.
Ave Min = The average of all daily minimum temperatures recorded for the day of the year.
Extreme Min = The minimum of all daily minimum temperatures recorded for the day of the year.

FIGURE 5-2
AVERAGE AND EXTREME HIGH AND LOW TEMPERATURES RECORDED AT DEEP SPRINGS COLLEGE WEATHER STATION
CALTRANS ARID REGION NON-VEGETATIVE EROSION CONTROL STUDY PLAN AND EXPERIMENTAL DESIGN



Extreme Max = The maximum of all daily maximum temperatures recorded for the day of the year.
Ave Max = The average of all daily maximum temperatures recorded for the day of the year.
Ave Min = The average of all daily minimum temperatures recorded for the day of the year.
Extreme Min = The minimum of all daily minimum temperatures recorded for the day of the year.

FIGURE 5-3
AVERAGE AND EXTREME HIGH AND LOW TEMPERATURES RECORDED AT DEATH VALLEY WEATHER STATION
CALTRANS ARID REGION NON-VEGETATIVE EROSION CONTROL STUDY PLAN AND EXPERIMENTAL DESIGN

5.1.9 Surrounding Environment

The surrounding environment does not significantly affect the erosive forces on the site (e.g., wind/rainfall). Structures or extremely rough terrain in the surrounding site area may affect wind velocities and will be avoided. Sites in sensitive habitat areas (designated by Caltrans) are excluded from this Study Plan.

5.1.10 Accessibility/Safety

Selected sites have adequate shoulder and pull-out area to safely accommodate construction and monitoring activities. The selected sites do not include median areas.

5.1.11 Security

Sites with heavily populated surroundings or easy access by normal pedestrians that present vandalism and safety concerns are avoided in this Study Plan. Minor enclosures may be required to protect monitoring equipment from unauthorized access.

5.1.12 Permits

Encroachment permits for site accessibility are easily attainable. Obtaining any additional permits must be arranged for by Caltrans.

5.1.13 Number of Sites

The number of sites chosen accommodates the total area, soil types, and slopes specified in the Study Plan. Multiple sites may be required in order to include soil or slope variability. A maximum of four sites has been selected.

5.2 Site Selection Procedure

The Experimental Design described in this Study Plan requires the specific selection of four sites to allow practical construction, data collection, and a manageable data set (Section 6). Thus, the primary criteria for selecting four ideal sites from the above list are a specific set of slope, aspect, and soil requirements. No site with compromised safety or accessibility is considered with respect to these design issues, and is therefore automatically eliminated from consideration in the Study Plan.

Part of the objective of the Experimental Design of the study is to facilitate comparisons of erosion control product performance as they relate to soils and slopes. Although four sites would ideally provide a relatively wide variety of environmental conditions (including soil type, slope, aspect, and rainfall), two sets of similar sites are necessary to allow isolation of the effects of soils and slope for pairwise statistical comparisons. In other words, the Study Plan requires that (1) two of the sites be similar in aspect, slope, climate, and other factors, but relatively dissimilar in soil texture; and (2) that the other two sites be similar in aspect, soil texture, climate, and other factors, and different in slope. In this manner, differences in erosion control product performance in these paired sites will be attributable to soils or slope (depending on the comparison), with all other factors being relatively equal. Section 8 provides further clarity on the statistical rationale for this type of comparison and more

detailed descriptions of the procedures that will be employed to quantify slope and soil effects on erosion control product performance.

The pairwise approach discussed above provides as much control as is possible in a field study for statistical comparisons of the integral design factors. Although a variety of environmental factors influence performance of erosion control products, slope and soil type are manipulable design factors that are important determinants of erosion control success.

Site information collected from Caltrans district staff (Districts 8, 9, and 11), roadside visits, and previous field experience during the Caltrans Statewide Erosion Control Review (Caltrans, 2001b) indicated a number of sites with potential application for this Study Plan. During site investigations, additional potential sites were identified by the study team. The study team surveyed approximately 30 potential sites.

5.3 Site Visits

Once potential sites that met the selection criteria as defined in Section 5.2 were selected, a series of site visits was conducted to collect site information and obtain soil samples for laboratory analysis. None of the sites are located in areas where site or environmental conditions present unusual challenges to a valid arid land erosion study, such as high elevation (>1,500 meters), fewer than 120 frost-free days, or rainfall greater than 250 mm per year. Six sites were fully evaluated using the HEAT program and all of its parameters (e.g., aspect, area, slope, and soil). The sites selected included those recommended by district staff during interviews as well as those encountered during district site investigations conducted by the survey team. Evaluated sites include:

- Barstow – Highway 15 and 58 interchange at Barstow
- Red Rocks – Highway 14, south of Red Rock Canyon State Park
- Mojave – Highway 14 near Mojave
- El Centro – Highway 8 west of El Centro
- Hinkley – Highway 58 east of Hinkley
- Fish Springs – Highway 395, south of Bishop

A summary of data collected during site visits is presented in Table 5-4.

5.4 Site Selection

The sites ultimately selected for the Study Plan provide the best representation of the characteristics and climate factors to satisfy the requirements of design statistical evaluations and monitoring. Using the safety, accessibility, and design requirements discussed in previous sections, the sites selected for the Study Plan are Red Rocks West (east-facing slope), Barstow South (south side cut slope), Hinkley South (north-facing slope), and El Centro South (northeast-facing slope). Descriptions of these sites are provided in Section 5.5. As is evident in Table 5-4, the paired slope comparisons will be performed using Red Rocks

TABLE 5-4
Matrix of Characteristics for Non-vegetative Erosion Control Study Plan Site Suitability Evaluation
Caltrans Arid Region Non-vegetative Erosion Control Study Plan and Experimental Design

Site	Soil Texture[f]	Slope	Aspect	Slope Length (m)	Approxi-mate Site Area (m^2)	Rainfall (mm)	Temperature (C)	Number of 90-percent Probability Freeze-free Days	Potential for Operation and Maintenance Problems from Upslope Area[a]	Relative Safety Level[b]	Ease of Access[c]
Red Rocks West [d]	S	65	East	25	2,765	105	17.9	195	High	Moderate	High
Red Rocks East	S	55	West	25	2,765	105	17.9	195	Low	Moderate	High
Barstow North	LS	34	South	25	3,000	112	17.8	212	Low	Moderate	Moderate
Barstow South[e]	SCL	45	North	25	4,096	112	17.8	212	Low	Moderate	Moderate
Mohave South	LS	57	East	15	—[g]	149	16.9	197	Low	Low	Low
Hinkley South[e]	LS	48	North	15	14,563	112	17.8	212	Low	High	High
Hinkley North	LS	48	South	15	14,563	112	17.8	212	Low	High	High
Fish Springs	SL/LS	45	East	20	2,190	135	13.3	132	Moderate	Low	Moderate
El Centro South[d]	S	48	Northeast	25	4,617	66	22.4	280	Low	Moderate	Moderate
El Centro North	S	48	Southwest	25	6,571	66	22.4	280	Low	Moderate	Moderate

[a]Rating of “High” correspond to sites with large upslope areas contributing runon to sites; rating of “Low” corresponds to sites with top V-ditches to route runoff or small upslope areas.

[b]Corresponds to the width of the highway shoulder, proximity and nature of vehicular traffic, stability and slope of site, and other hazards.

[c]Corresponds to width of shoulder, presence of parking and laydown areas (e.g., turnarounds, emergency stop areas), presence of fences and other obstructions, right-of-way size

[d]Corresponds to potential site for slope comparison.

[e]corresponds to potential site for soil comparison.

[f]USDA Classification (S = sand, LS = loamy sand, SCL = sandy clay loam, SL = sandy loam

[g]Site was under construction, making it impossible to measure the area.

West and El Centro South. Both sites comprise sands, exhibit similar aspects (east versus northeast), and are adequately safe and accessible for construction and research. Their slopes are representative of a typical (40 to 50 percent, or 2:1) slope used by Caltrans, as well as a steeper slope (65 percent).

The most substantial difference between El Centro and Red Rocks is climate; El Centro receives less annual precipitation. However, both sites are located in arid climates where the erosive effects of precipitation are more attributable to rainfall intensity (e.g., desert flashy rain events) than quantity.

For the soil texture comparison, Barstow South and Hinkley South will be established as a pair. Both sites exhibited 48-percent slopes, north aspects, and, because of close proximity to one another, similar climates. Given the sites available and the constraints of the paired statistical comparisons, Barstow South and Hinkley South exhibit nearly as wide a range in soil textures as is likely attainable on sites in arid California. Barstow South represents soils with relatively finer textures, and Hinkley South exhibits commonly observed loamy sands. Because the presence of fines (e.g., clay) can impact soil cohesivity, capacity to remain intact during rain, and potential to be eroded by wind when it is dry, the Hinkley South/Barstow South comparison will provide a unique and valuable comparison.

As described in Sections 8 and 9, the Study Plan will use a variety of quantitative statistical and observational procedures to evaluate the performance of erosion control products. Thus, the paired comparison, although important, is only one part of the effort to fully measure the relative success of erosion control approaches in arid regions. Nevertheless, the four sites described above provide this study with a suite of conditions that are representative of a range of conditions, but still typical of most arid regions in California. The sites selected for this study are meant to provide an ideal combination of these two points, which are particularly important as Caltrans attempts to further understand which products will provide demonstrated and reliable success for the majority of their erosion control projects.

5.5 Site Descriptions

The following subsections provide brief descriptions of the sites evaluated for this Study Plan, including site design, soils, aspect, and suitability for construction and experimentation. Soil analysis data (Appendix F) indicate that soil chemical constituents are appropriate for the proposed study. A summary of relevant site characteristics is provided in Table 5-4. The descriptions include sites ultimately selected for use in the Study Plan implementation, as well as sites reviewed but not selected.

5.5.1 Evaluated Sites that Were Selected

Barstow (District 8)

The Barstow site is located in District 8 at the intersection of Interstate 15 and U.S. Route 58, and includes a large, sweeping set of cut and fill slopes that constitute a single cloverleaf. Establishment of vegetation at Barstow has been historically difficult because the site is arid and is regularly swept by strong winds from the Mojave Desert (Nakano, 2001, pers. comm.).

The site includes a fill slope constructed to support Interstate 15 as it passes over the U.S. Route 58 cloverleaf, as well as cut slopes on the outside circumference of the cloverleaf. The fill is sloped to 34 percent, and the cut slope is 45 percent, with slightly shallower slopes near the overpass. The fill slope, which includes a drainage channel, faces principally south, with the slopes along the drainage channel facing east and west. Because it constitutes the circumference of the cloverleaf, the cut slope exhibits an aspect ranging from north to west.

Both the cut and fill slopes exhibit channel erosion despite the presence of a cement-lined V-ditch at the flattened top of the cut slope area. Sediment from channel and sheet erosion is present along the shoulder.

The shoulders are narrow, although a wider area is present along the fill slope for vehicle access and equipment staging. A broad area above the fill slope, north of the Interstate 15 overpass, is also a suitable area for access and construction laydown. Both the cut and fill slopes at the Barstow site are greater than 1,350 square meters, the minimum size required for the study plots (see Section 6 for further detail on plot size, configuration, and replication at each site).

Soils at the Barstow site include loamy sand on the fill slope (Barstow North) and sandy clay loam on the cut slope (Barstow South). The coarser-textured material observed on the fill slope may have been topsoil collected during excavation of the underpass area.

Red Rocks (District 6)

The Red Rocks site is a road cut located on U.S. Route 14 south of the Red Rocks Canyon State Park. The road cut includes a relatively steep (65 percent) east-facing slope, and a slightly less steep (55 percent) west-facing slope at the top of a slight rise in the road.

It appears that the road cut was historically removed from highlands sloping toward lower elevation areas south of Ridgecrest. Thus, the back side of the west-facing slope itself slopes towards the valley and likely contributes a relatively small proportion of runon. Conversely, a large channel and other erosion features suggest that the east-facing slope has been adversely affected by relatively large quantities of runon from higher areas west of the slope. Runon appeared to flow over an off-road vehicle trail and east-sloping ground surface.

The Red Rocks site measured over 2,500 square meters, and is therefore sufficiently large for establishment of study plots. Shoulder areas immediately below the site are relatively narrow and most likely unsuitable for construction laydown or vehicle parking. However, this limitation is offset by the presence of a pull-off area on the south side of the east-facing slope.

Soils at the Red Rocks site are sands on both the east- and west-facing slopes. Vegetative cover consists of desert shrubs and some grasses, but is not sufficient to qualitatively consider the site successful. Indeed, adaptation of the site for the Study Plan will require both a repair of the large channel on the east-facing slope, as well as some improvements to reduce or eliminate runon to the east-facing slope.

Barstow (District 8) - Site view of the north-facing slope from ground level.

Barstow (District 8) - Site view of north- and south-facing slope from top of site. Highway interchange of U.S. Routes 15 and 58 in background.

Red Rocks (District 6) – View of east-facing slope showing a large gully that would need to be repaired before site study implementation.

Red Rocks District (6) - Site overview looking to the northwest. Channel erosion and vegetation present onsite.

Hinkley (District 8)

The Hinkley site is located along U.S. Route 58, several km west of the towns of Hinkley and Boron, and approximately 40 km west of Barstow. The site constitutes a 1,000-meter-long road cut that occurs adjacent to the eastbound and westbound lanes of U.S. Route 58 through a small rise in the otherwise relatively flat surrounding desert.

The road cut at Hinkley includes a north-facing slope (Hinkley South) and a south-facing slope (Hinkley North), both of which exhibit 48-percent slopes. The flat slope tops include concrete-lined V-ditches to divert runon to the sides of the slopes and onto the road shoulder The relatively flat topography suggests that, in most cases, the sites will not receive large quantities of runon, particularly with the inclusion of the lined ditches. Water on the tops of the slopes not intercepted by the V-ditches will most likely flow unrestricted to the slope faces and back down into the surrounding area.

Perhaps the most distinct characteristic of the Hinkley site is the unusually large shoulder (>35 meters) along the eastbound lane, as well as the relatively long length of the cuts on both sides of the road (645 meters). These features clearly would allow sufficient space for equipment staging or construction laydown, as well as vehicle parking. Indeed, these characteristics are considered superior to other sites evaluated for use in the Study Plan, and are unique among the sites in the experience of field personnel familiar with many erosion control sites in California.

Hinkley (District 8) - Site view showing large shoulder area at base of north-facing slope.

Both slopes of the Hinkley site are classified as loamy sands and include desert shrub vegetation typical of the region. As with other sites evaluated for use in the Study Plan, the slopes at Hinkley are still largely devoid of vegetation and exhibit evidence of channel and sheet erosion, despite the presence of V-ditches.

No substantial modification of the site before any construction related to study plots appears necessary. Furthermore, the exceptionally large areas of both sides of the Hinkley site (>14,000 square meters) provide no limitations to implementation of the Experimental Design described in this Study Plan.

El Centro (District 11)

The El Centro site is located on a road cut on both sides of Interstate 8, approximately 16 km west of El Centro and 128 km east of San Diego. The site is a road cut through part of a gradual and small-rise elevation over which Interstate 8 was constructed, and includes a northeast-facing cut slope (El Centro South) and a southwest-facing cut slope (El Centro North).

Earthen V-ditches were observed at the tops of both road cut slopes, although the surrounding watershed did not appear substantial. The top of the road cut on El Centro South slopes more toward the flatter desert to the south, and the top of the road cut on El Centro North appears to slope towards the north. On that north road cut, a large channel north of the top of the slope appears to have been formed from runon flowing away from the site. Thus, El Centro North is essentially high ground in the area.

Slopes on both sides of El Centro are 48 percent consistently along the site. At the time of the visit, there was evidence of channel and sheet erosion, despite the relatively small contributing watershed. Both sites exhibit relatively sparse native shrub vegetation and are, as the other sites evaluated for this Study Plan, minimally protected from the erosive forces of wind and rain. As with other sites, this factor is exacerbated by coarse-textured soils that are classified as sands on both road cuts.

The shoulder space at El Centro appears sufficiently wide and visible to oncoming traffic to provide adequate safety for field personnel and space for equipment and vehicles. A relatively flat, accessible median is also present between the eastbound and westbound lanes, although such areas are likely best avoided to limit foot traffic across the road. The site itself is of sufficient size to facilitate the study plots.

5.5.2 Evaluated Sites that Were Not Selected

Mojave (District 6)

The Mojave site is located on U.S. Route 14, several km north of the town of Mojave. All of the site is a fill area added to support an overpass and new southbound lanes that were under construction at the time of the site visit. The Mojave site is a relatively long, narrow, east-facing slope at an angle of 57 percent.

Ongoing construction and the presence of the overpass fill immediately adjacent to the highway resulted in restricted access to the site for complete evaluation. Observations during a brief evaluation indicated the slope and size of the site are suitable for establishment of study plots. The soil, classified as a loamy sand, is also similar to other soils

El Centro (District 11) - Portion of site evaluated. North-facing slope. Channeling and sparse vegetation.

El Centro (District 11) - Site overview looking to the west.

observed in arid parts of California; although, because it was recent fill, it was minimally compacted.

Despite possessing characteristics similar to other more suitable sites, such as Red Rocks and Barstow, the Mojave site is not considered appropriate for Study Plan implementation in its present form. Ongoing construction and a restrictive right-of-way would likely limit site safety and access. Furthermore, the site may not be ready for use as a study subject soon enough to be constructed and instrumented with other sites.

Fish Springs (District 9)

The Fish Springs site is located approximately 15 km north of Lone Pine, California, along a new lane of divided highway construction on U.S. Route 395. The site comprises a series of continuous, east-facing road cuts of varying height constructed as the highway passes through and out of the higher ground north of the Lone Pine area. It is the farthest north of the sites evaluated for this Study Plan.

The slopes at Fish Springs are 45 percent and appear to be consistent through the entire length of the road cut area. At the time of the site visit, the slopes did not exhibit evidence of sheet or channel erosion (e.g., gullies, rills, or sediment deposited at the toe) simply because they were newly constructed. The slopes themselves are somewhat cut and rounded to a steeper incline near the toe, most likely because of the limited-width right-of-way afforded to the highway.

The topography of the surrounding area slopes down toward the road cut, and no V-ditches were observed for runoff diversion. The upslope surrounding area is composed essentially of desert shrubs and, therefore, does not afford much protection from runon. This configuration is considered a potential problem for runon.

The soils at Fish Springs are classified as sandy loams or loamy sands, and had not been hydroseeded or vegetated at the time of the site visit. From observations of construction progress, it was not clear whether the soils, somewhat loose and easily disturbed, would be further compacted or hydroseeded.

The portion of the Fish Springs site evaluated is sufficiently large (2,190 square meters) to facilitate the study plots in this Study Plan. Although the shoulder of the new lane is narrow and the slope steep, the prospect of good site access and relative safety is improved by the presence of a cross street immediately to the north of the site. Shoulder space associated with this intersection would possibly provide an area for parking and staging materials for construction of the study plots.

Fish Springs is not selected for use in the Study Plan because of its very recent construction and narrow shoulder area available for collection instrumentation. Furthermore, the climate at Fish Springs is the least similar to the other sites evaluated.

Mojave (District 6) - Site overview of newly constructed east-facing slope.

Mojave (District 6) - View of shoulder area and toe of slope. Culvert extends through the slope.

Fish Springs (District 9) - Section of construction zone road cuts. East-facing slope.

Fish Springs (District 9) - View of portion of site evaluated.

6. Plot Design

The purpose of the following sections is to provide a detailed summary of the Experimental Design for the Study Plan. Included are descriptions of the physical configuration of the study sites and the nature of data that will be collected during the evaluation.

6.1 Overall Design

The objective of the study is to evaluate the effectiveness of non-vegetative erosion control products in reducing soil erosion caused by wind or water. The Experimental Design will allow comparison among plots with different erosion control products and slope lengths within roadside sites in arid areas of California (<250 mm precipitation) and among different roadside sites. The following general comparisons will be conducted as part of the Study Plan:

- Measure erosion losses caused by wind and water
- Compare erosion control effectiveness among five non-vegetative erosion control products
- Evaluate effectiveness of erosion control products over two slope lengths
- Evaluate erosion control products over several locations within a site
- Compare effectiveness of erosion control products among several sites

As is evident in the above list, differences in erosion control products will be compared within specific areas, providing replication, and among sites, providing comparisons of factors such as slope, aspect, or soil type. Each level of comparison provides additional information about the effectiveness and applicability of specific erosion control products.

Components integral to plot design and a quantified evaluation of the Experimental Design include:

- Plot configuration
- Replication
- Arrangement of split-plots
- Site Comparisons

6.1.1 Plot Configuration

Measurement of erosion requires separation of runoff plots of known area, slope, slope length, and soil type (Morgan, 1986), whereby the effects of a given treatment (e.g., erosion control product) are isolated. In this study, treatments will be assigned to experimental units, where discrete areas of the hill slope are separated by dividers. To construct a study similar to past laboratory erosion control product studies performed for Caltrans (Caltrans, 2000), runoff units will be 8.0 meters long and 2.0 meters wide. This study will use this

configuration for full-length units, and half-length units will be 4.0 meters long and 2.0 meters wide, allowing evaluation of erosion control product effectiveness on two slope lengths. Because the Experimental Design in this Study Plan will be similar to that employed by previous laboratory work, this study will constitute a follow-up that facilitates further understanding of erosion control product effectiveness applied in the field.

Figure 6-1 provides an illustration of 12 experimental units designed for evaluation of five erosion reduction products and an untreated control at two slope lengths ([5 + 1] x 2 = 12 treatments). This is the finest level of detail in the evaluation, where the slope and soils among the experimental units will be kept as constant as possible, reducing small-scale variability. Collectively, the 12 experimental units compose a plot. Overall, this configuration constitutes a split-plot design, because each plot reflects two types of treatment (slope length and erosion control product).

Once the plot has been constructed, assignment of treatment combinations to experimental units will be performed randomly (Figure 6-1). The following number-points illustrate the procedure that will be used for assigning short- and long-length experimental units to each plot:

1. Experimental units will be assigned numbers 1 to 12 from left to right
2. A random number between 1 and 12 will be drawn six times to assign short-length units to six of the experimental units (see left side of Figure 6-1)
3. Remaining experimental units will be assigned as long-length units

Assignment of short-length experimental units will be physically accomplished by placing a runoff collection gutter midway (4.0 meters from top) down the slope of the experimental unit, rather than at the bottom of the slope (8.0 meters from top).

Assignment of erosion reduction products to each of the six short- and long-length experimental units will also be performed using random numbers (see right side of Figure 6-1). The sequence of steps in the assignment process follows:

1. Letters A to F are assigned to each of the five erosion control products and one untreated control (letter U)
2. Numbers 1 through 6 are assigned to short-length and long-length experimental units (left to right)
3. A letter from A to F is randomly drawn to select an erosion control product or untreated control
4. A number from 1 through 6 is randomly drawn to select a short-length experimental unit
5. The letter and number are matched to assign the selected erosion control product or control to the selected short-length plot
6. The above drawing procedure (steps 3 through 5) is repeated five more times to complete assignment of erosion control products or untreated control to the remaining short-length experimental units

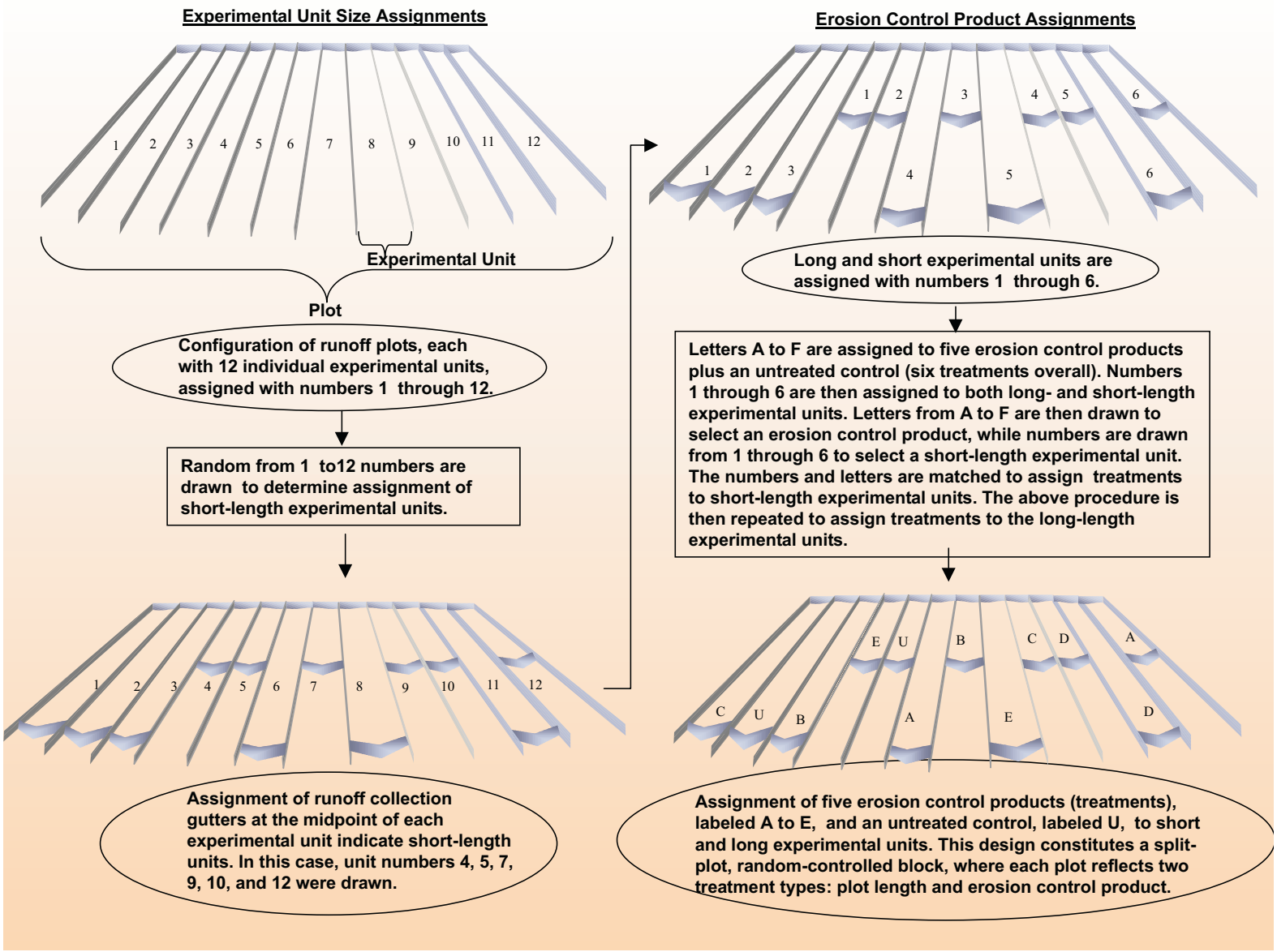


FIGURE 6-1
CONFIGURATION OF SPLIT-PLOTS AND EXAMPLE OF TREATMENT ASSIGNMENT PROCEDURE
CALTRANS ARID REGION NON-VEGETATIVE EROSION CONTROL STUDY PLAN AND EXPERIMENTAL DESIGN

The above procedure (steps 2 through 6) is again repeated to assign erosion control products and the untreated control to the long-length experimental units

The above procedures provide a method to randomly establish each plot used in the Study Plan. The following sections describe the Study Plan in a greater context, such as the configuration of plots within sites and among sites.

6.1.2 Replication

Statistical evaluations require replication of data to provide a sufficient number of data to produce reliable distributions and mathematically meaningful relationships. The greater the replication, the less the opportunity for a distribution of data to be skewed by datum (e.g., a soil runoff volume at a site after a 500-year storm). The replicates in a given study are the measured values that will be compared across various treatments. For this study, values will include soil loss volumes recorded in the runoff collection troughs, calculated for determination of wind erosion, and water runoff volumes measured in the collection troughs. For the purposes of the following statistical discussions, the term "product performance" is functionally equivalent to soil loss volumes measured in the field (caused by both wind and water).

Replication of data in this study will be accomplished (1) "spatially," where measurements for the same treatment combination are taken in different areas at the same time, and (2) "temporally," where measurements will be taken every 4 weeks for the duration of the study. Spatial replication is accomplished using both the split-plots (see Figure 6-2), which accounts for small-scale (i.e., within site) variability, and several sites, which accounts for larger-scale variability (i.e., slope, soils, climate, and site design). Temporal replication, a necessity in any field study, accounts for seasonal changes in wind, rain, temperature, and other random environmental factors while providing sufficient numbers of data for valid statistical analysis.

6.1.3 Arrangement of Split-plots

The plots described in the previous section are called split-plots, a form of random-controlled block. As in any blocked experiment, plots are duplicated to provide replication of treatments in the experiment (Figure 6-2). In this experiment, variation among duplicate blocks in a given site will be minimized by selecting sites with relatively homogeneous conditions (e.g., soils, slope, and aspect). By minimizing variation between the blocks, the effects of erosion reduction products and slope length treatments can be more easily separated from background variation. The effects of treatments in the split-plot will be determined by comparing the variability attributable to treatment to the background variability in the experiment.

6.1.4 Site Comparisons

The performance of an erosion control product may be affected by environmental factors, such as soil properties (e.g., soil texture, structure, and chemistry) or slope. Variability in erosion control product performance attributable to environmental factors will be determined by comparisons among sites.

As previously described, each site will include three plots that provide replication of treatment combinations, whereby variability in conditions among plots of a given site will be minimized. Four sites will be used in the Study Plan. The effects of an environmental factor to erosion control product performance will be determined by comparisons between pairs of sites. Thus, two sites will be as similar as possible in slope, aspect, and climate, but contain different soils (Figure 6-3). Two other sites may possess similar soils, aspect, and climate, but have different slopes. With this Experimental Design, the effects of soils and slope, two critical factors that typically affect erosion control performance, can be isolated and evaluated.

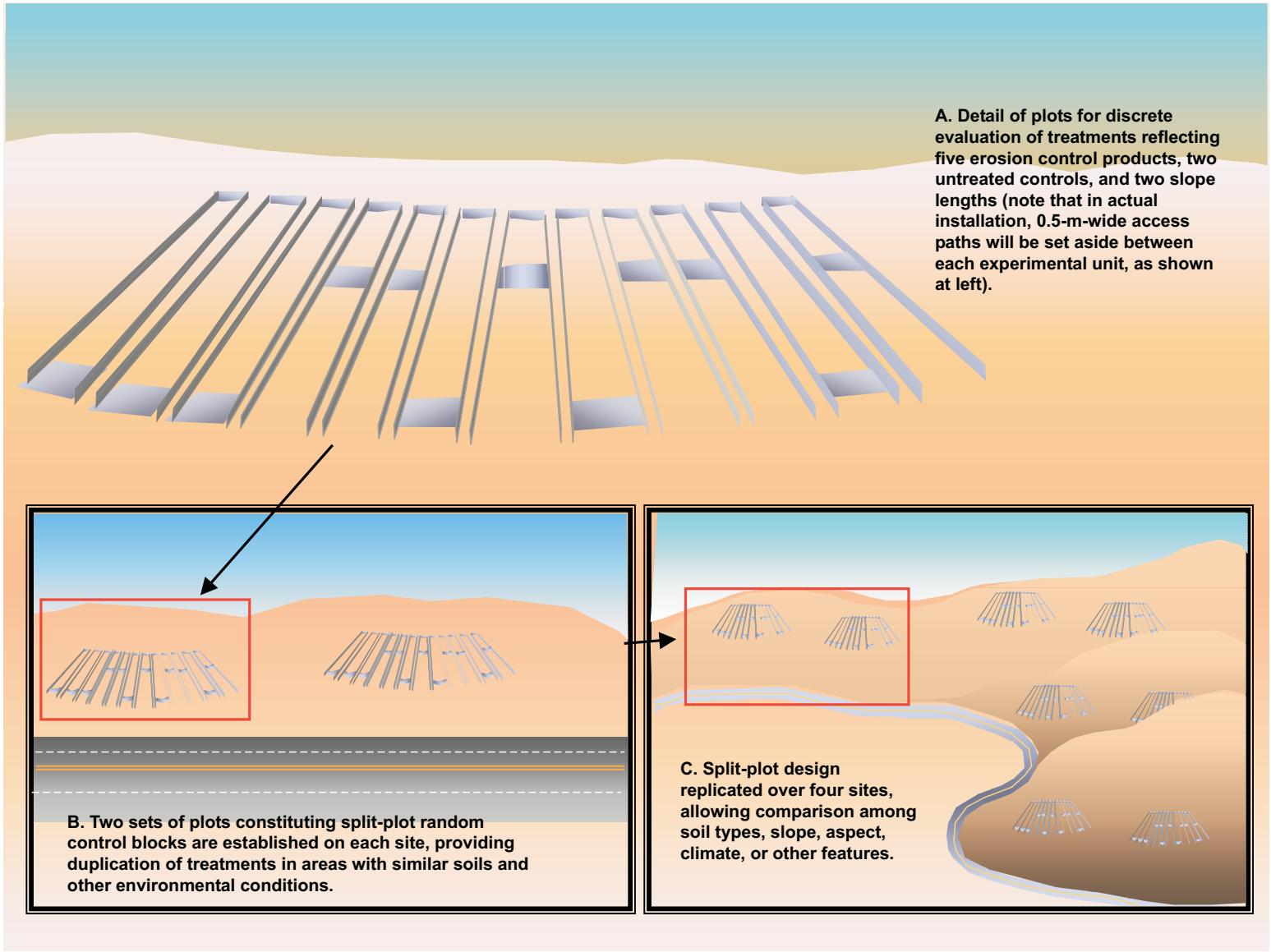
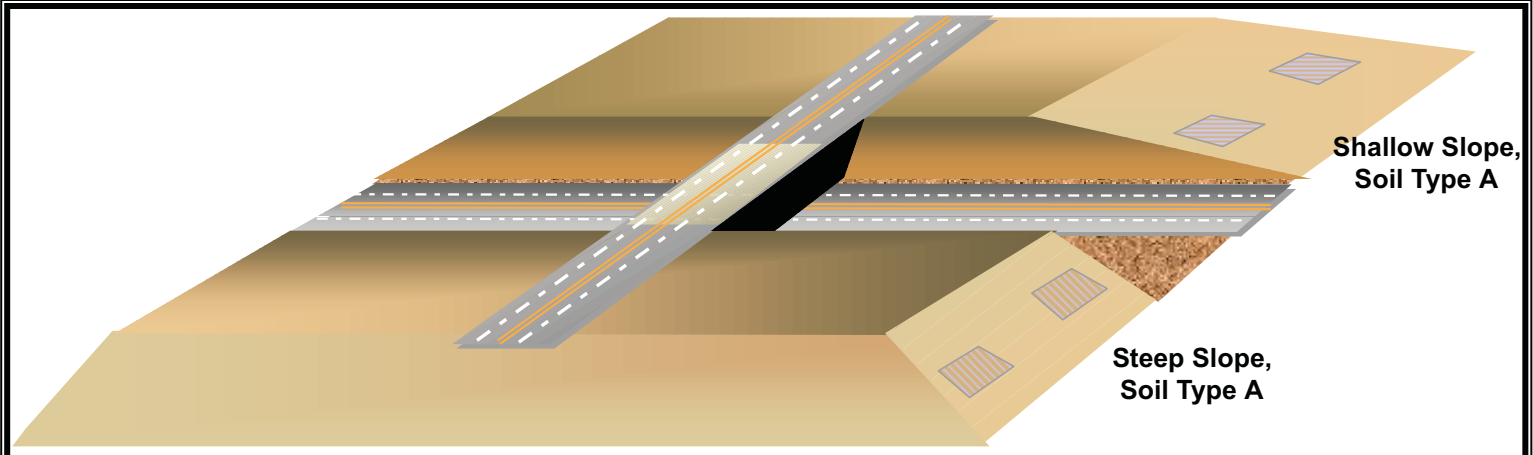
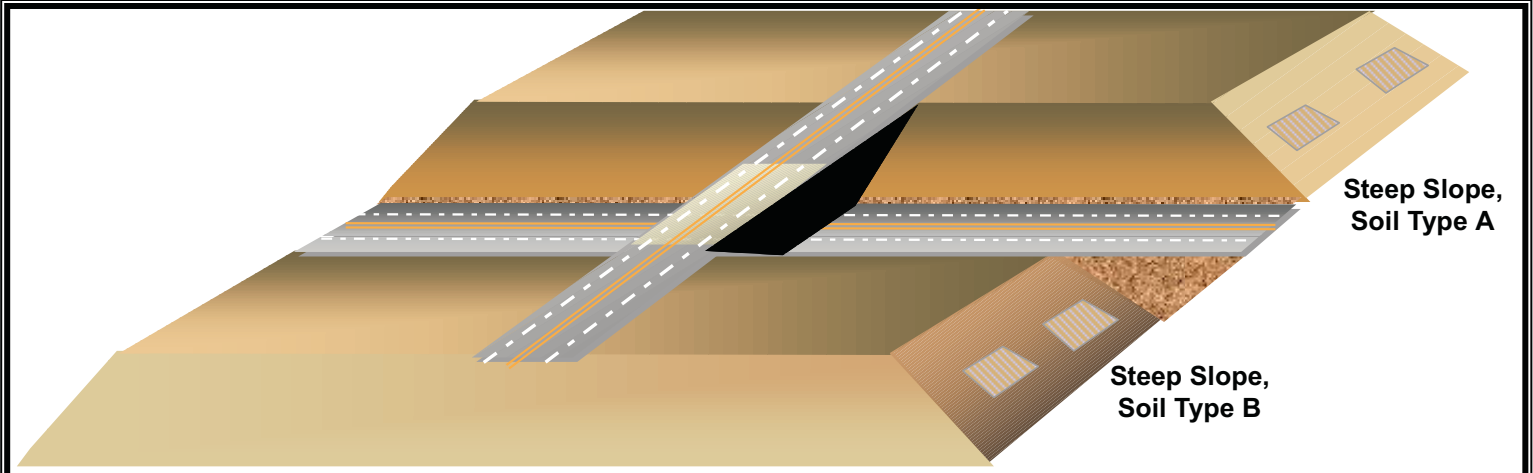


FIGURE 6-2
OVERALL EXPERIMENTAL DESIGN
CALTRANS ARID REGION NON-VEGETATIVE EROSION CONTROL STUDY PLAN AND EXPERIMENTAL DESIGN



A. Example of paired site comparison for evaluation of slope effects. This experimental design assumes that soils, aspect, and climate are similar, ensured by the close proximity of the pairs.



B. Example of paired site comparison for evaluation of soil effects (indicated by different colors). This experimental design assumes that slope, aspect, and climate are similar. Geographically separated sites with similarities in these characteristics may be necessary to allow incorporation of two disparate soil types.

Note: Paired site comparisons allow evaluation of the effects of slope and soils on erosion control product performance.

FIGURE 6-3
PAIRED SITE COMPARISON
CALTRANS ARID REGION NON-VEGETATIVE EROSION CONTROL STUDY PLAN AND EXPERIMENTAL DESIGN

7. Performance Standards and Criteria

The primary measure of product performance will be the function of erosion control products relative to each other and the performance criteria. The measured soil loss and product integrity will be compared among all the products and the control. Some influence on actual soil loss is expected because of effects of experimental unit size and instrumentation. However, these influences will impact all experimental units so that the values obtained will be comparative to one another. Relative product deterioration and runoff water quality will also be evaluated.

There are presently no universally established standards for non-vegetative erosion control product performance. However, some organizations have attempted to establish parameters by which products can be approved or disapproved for use on specified project types. The Texas Department of Transportation has developed standards for erosion control product performance using two performance criteria: (1) sediment loss and (2) vegetative establishment. The maximum sediment loss and vegetative establishment values for Texas Department of Transportation-approved products are presented in Table B-1 in Appendix B of this Study Plan. Although Caltrans has not adopted standards such as these, a general target for vegetative erosion control methods is considered a minimum of 70-percent vegetative cover (including seasonal dead vegetation). The same 70-percent coverage standard will be expected of all non-vegetative products tested.

Other erosion control standards and erosion values, including model predictions (Revised Universal Soil Loss Equation and Morgan, Morgan, and Finney) and other organizations' study results and performance standards should be compared with study results for discussion purposes only. Additionally, the results of this study may be compared to studies of similar types on other non-vegetative products. However, consideration must be made of varied study conditions including climate, design, and study environment (simulated or field).

To evaluate relative erosion control achieved by products, performance criteria have been developed. These criteria aim to assess products using the primary diagnostic factors associated with erosion. The criteria include both quantitative and qualitative measurements.

Performance criteria include:

- Sediment loss
- Total runoff, water retention, and infiltration
- Soil movement/soil surface levels
- Water analysis
- Erosion types
- Product integrity
- Occurrence of incidental vegetation

7.1 Measured Criteria

Sediment Loss

Relative sediment loss is an indicator of a product's ability to withstand and protect the soil surface from the erosive forces of surface water. Sediment carried in runoff will be assessed by measuring the amount of soil that is detached and transported into gutters at the base of the plot. Sediment loss will be measured by analyzing runoff water for total dissolved solids (TDS) and total suspended solids (TSS).

Total Runoff, Water Retention, and Infiltration

Total runoff is an indicator of the product's ability to absorb water and facilitate water infiltration into the soil. Water that is not absorbed or infiltrated will flow over the surface of the plot and be collected as runoff in gutters. The runoff volume can be subtracted from the total plot rainfall volume (calculated from rain gauge data) to determine how much water was infiltrated or absorbed by the product.

The equation is as follows:

Runoff & Sediment Volume - Sediment Volume = Runoff Volume
Total Rainfall Depth x Plot Area – Runoff Volume = Infiltration & Absorption Volume

Soil Movement/Soil Surface Levels

Soil movement can be an indicator of many erosion types including sheet, slump, wind, and channel. To evaluate soil movement, (16) gauged pins will be placed at half-meter intervals in each experimental unit. The height of soil against each pin will be monitored regularly to record any changes. Vertical soil movement will indicate erosion by wind or by surface water. Lateral soil movement will be considered an indication of wind erosion only. The total decline in soil surface level will indicate a cumulative soil loss. Total soil loss will include soil that was removed with runoff and collected in gutters, and soil that was eroded and transported offsite by wind. By subtracting sediment collected from the total soil loss, the amount of soil removed by wind can be estimated. This value will be considered in relative terms, however, since some soil deposition by wind would also be expected and cannot be accounted for by these means.

(Average Decrease in Soil Level x Plot Area) – Sediment Volume = Net Volume Soil Eroded by Wind

Water Analysis

Water samples will be analyzed for general water quality as well as for constituents indicated in the degradation of specific erosion control products (Appendix F). The methods in Table 7-1 are approved by the Standard Methods Committee and documented in Greenberg et al. (1992). Indications of general water quality include pH, electrical conductivity (EC), TDS, and major anions and cations such as phosphorus and total Kjeldahl nitrogen (TKN). The extent of sediment loading is determined by testing for TSS. The test for tannins and lignins is included because of the fatty acid esters that make up Road Oyl™. Methods have been chosen based on the anticipated water quality of the runoff water.

TABLE 7-1
Recommended Water Analyses To Be Conducted
Caltrans Arid Region Non-vegetative Erosion Control Study Plan and Experimental Design

Water Test	Method	Purpose
PH	Electrometric method	Measures intensity of acidity/basicity; influences all aspects of water chemistry.
EC	Conductivity bridge	Measures salinity; influences soil infiltration ability.
Alkalinity	Titration method	Measures concentration of base cations; determines buffer capacity.
Nitrate as Nitrogen	Ion chromatography method	Measures nitrogen in mobile form.
TDS	Gravimetric method	Indicates general water quality.
TSS	Gravimetric method	Indicates sediment load.
Cl	Potentiometric method	Measures Cl in turbid samples; indicates movement of salts.
TKN	Macro-Kjeldahl method	Measures N in its organic and ammonia form; indicated in nutrient loading of surface and ground waters.
Phosphate	Perchloric acid digestion	Measures phosphates in water containing sediment; indicated in nutrient loading of surface waters.
S	Gravimetric method	Measures S; indicated in nutrient loading of surface waters.
Tannins and lignins	Colorimetric method	Measures plant constituents that may enter water through vegetable matter degradation.

Cl = Chloride
S = Sulfur

7.2 Observational Criteria

Erosion Types

Visual observations will provide information on the erosion types, if any, observed in each plot. Products may erode in several different ways. Presence of channels may indicate concentrated flow, and undercutting may indicate incorrect installation or inability of the product to perform over the given topography. Presence of soil particles on sides of pins and plot edging should also be noted and may indicate soil detachment and transport by raindrop impact.

Product Integrity

Empirical observation of the product integrity will help to evaluate relative duration of performance. Cracks or chips in products may indicate why a certain form of erosion is occurring. The way the product drapes on the slope surface should also be noted. Noticeable gaps between product and soil, or sliding of the product over the soil surface would be performance indicators.

Occurrence of Incidental Vegetation

Occurrence of incidental vegetation is not expected, but should be noted, as it may compromise product performance by breaking down surface integrity. Vegetation cover

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8. Monitoring

Accurate and timely monitoring is imperative for providing the data necessary to achieve the study objectives. Data collection should be conducted on a regular schedule and in a consistent manner between sites to avoid unnecessary data variability. Appropriate staff and equipment should be provided to adequately implement monitoring activities. The monitoring described in this section will be conducted on all four study sites. Ideally, the same individual will be assigned measurement duties on a given plot to ensure that precisely the same protocol is being used for each measurement. This is particularly important with wind erosion measurements where measured values are expected to be very small.

8.1 Monitoring Methodology

In previous sections, descriptions of the overall configuration of experimental units, plots, and sites were given, including the method by which treatment combinations will be replicated within sites and further duplicated for site-pair comparisons. The following sections provide descriptions of the procedure by which physical measurements (erosion data) will be collected. Ultimately, these data will be statistically analyzed to determine differences resulting from factors such as the erosion control product, slope length, soil type, and slope.

The following monitoring activities are described in this section:

- Measurement of erosion from runoff
- Measurement of erosion from wind
- Weather station monitoring
- Empirical observations and data collection

8.1.1 Measurement of Erosion from Runoff

The runoff measurement system described below will be tested in a pilot study before the field season begins. Testing will determine what modifications need to be made for use in the field. Significant changes may be required depending on accuracy, durability, and ease of use determined by the pilot study.

The runoff measurement system will consist of a two-barrel system to collect a proportion of the surface runoff flow and sediment (Figure 8-1). A more detailed design can be found in Appendix G. Runoff and sediment will move over the slope, through a V-shaped gutter, and into a collection pipe sized for the flow intensity of a 24-hour, 100-year storm. Runoff and sediments therein will then flow into a splitter barrel, designed with six evenly distributed holes carefully machined at the same level on the barrel. One of these holes will be connected to a second barrel that collects one-sixth of the total flow. This value is based upon the maximum amount of runoff that can be collected by a 189-liter (50-gallon barrel) in a 100-year storm for a full-length experimental unit. The remaining holes will discharge runoff to a collection ditch adjacent to the experimental units, where it will be diverted as storm flow.

The total runoff and sediment volume can be calculated by multiplying the quantity of runoff and sediment collected in the sampling system by six. Depending upon the shape of the experimental unit, ground surface, and barrel configuration, it will be necessary to field-test each collection system using a control amount of water and sediment. This will provide more precise empirically based flow proportion values, which is particularly important if the collection system does not divide flow precisely into sixths.

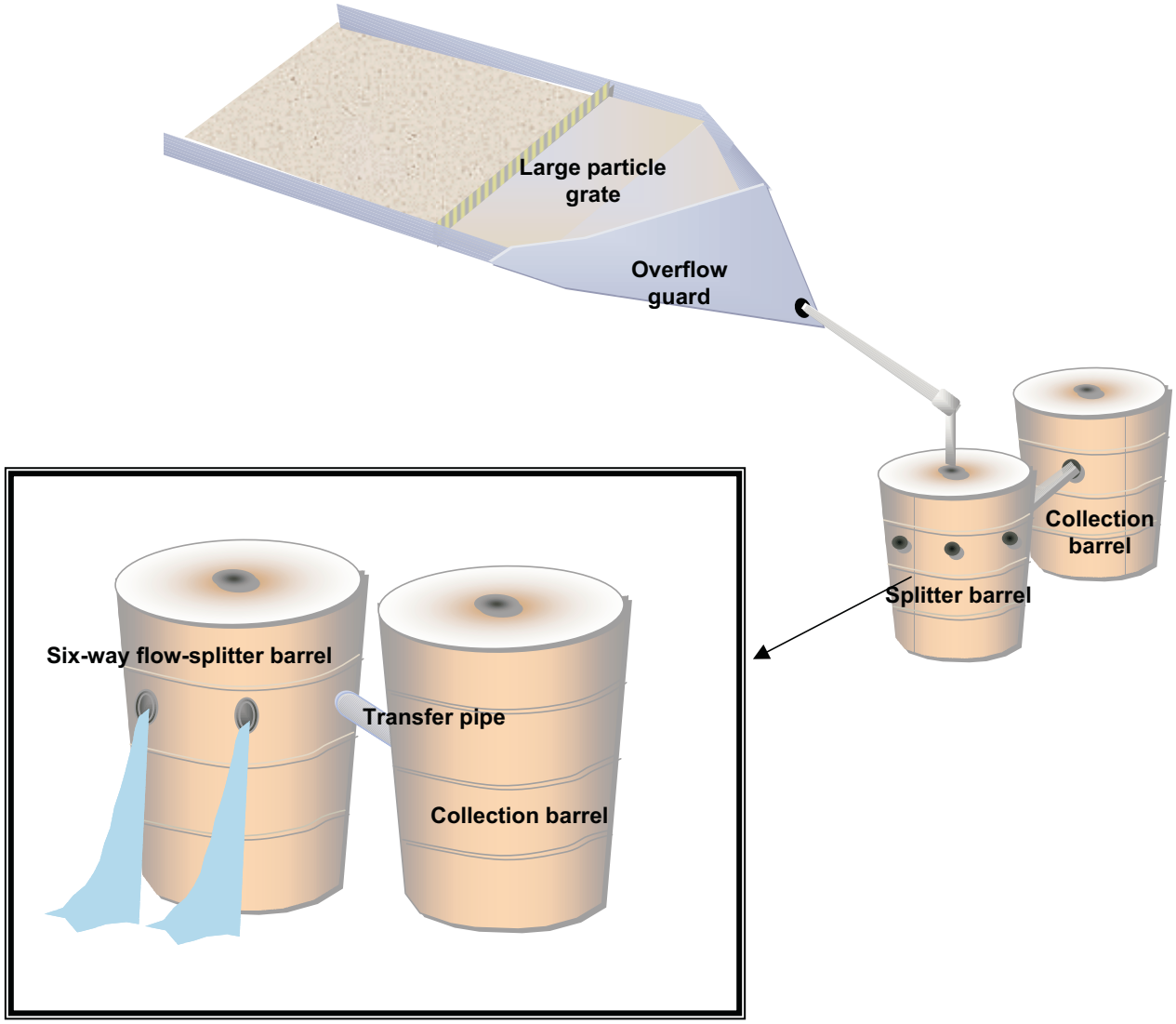
Runoff and sediment may be collected from the collection drum following a storm. The evaluator will agitate both barrels to bring all sediment into suspension. Samples will be drawn from each barrel and analyzed for TSS. Using the measured volume of water in each barrel and correcting for the one-sixth collection in the second barrel, the mass of sediment lost in runoff can be calculated (Figure 8-2). However, soil loss caused by runoff and wind erosion, as determined at the soil elevation measurement pins, will be expressed as a volume. Therefore, it will be necessary to measure the bulk density of the soil on each experimental unit to convert the mass of soil lost as measured in the collection barrel to an equivalent volume of soil.

8.1.2 Measurement of Erosion from Wind

A variety of wind sampling and measurement tools exist for quantification of wind erosion in large areas, such as agricultural fields. These devices typically include weather-vane parts to ensure that the soil erosion measurement device is angled into the wind, so that soil that is deposited from wind erosion may be sampled. However, such sampling configurations are not applicable in the runoff plots employed by this study, as they do not allow isolation and collection of wind-borne soils from individual experimental units.

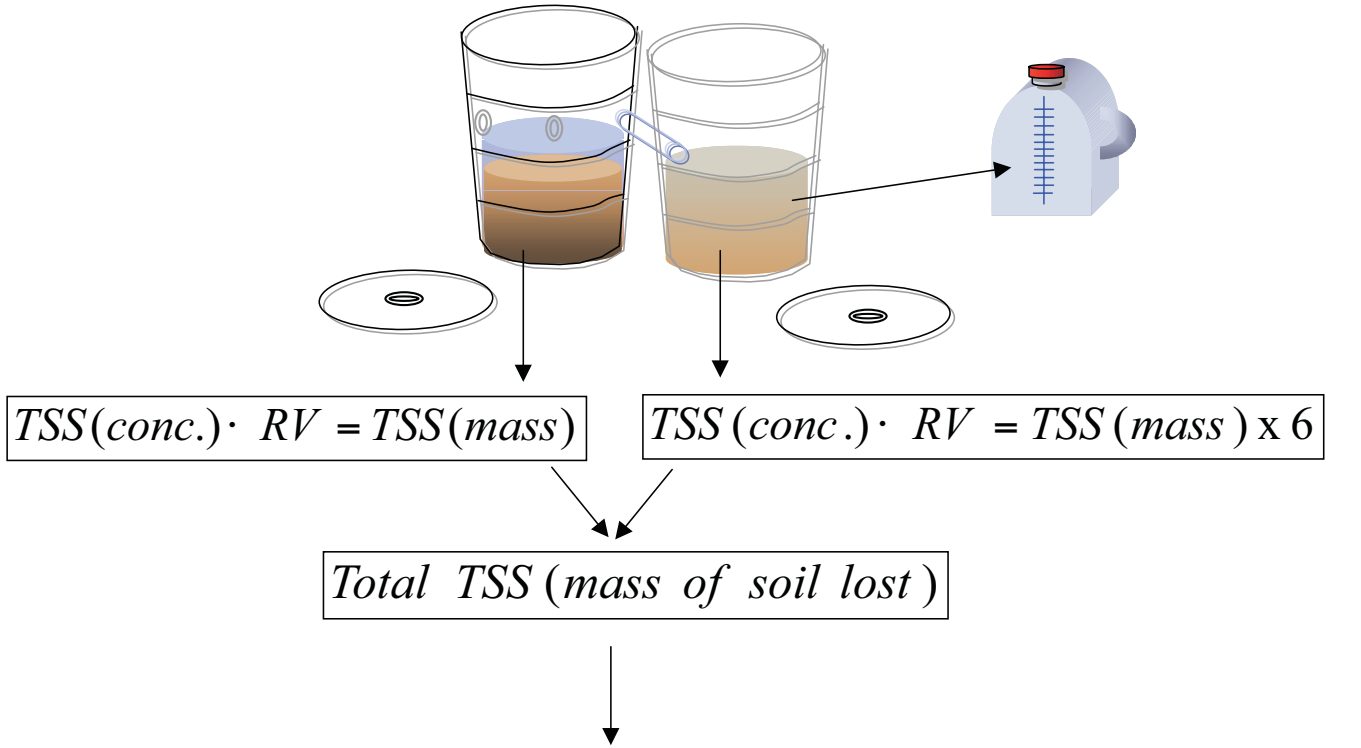
In each experimental unit, 16 measurement pins will be installed in the soil at regular intervals. As indicated on Figure 8-3, these pins will be placed at 1-meter intervals along the length (4 or 8 meters) and width (2 meters) of the experimental unit. At the beginning of the study, the soil surface elevation will be measured along each pin to determine the baseline (time zero) soil level in each experimental unit. The soil surface elevation will be measured at each pin in all subsequent measurements, and subtracted from the previous measurement to calculate the incremental change in soil elevation in the interim between measurements (Figure 8-4). It is critical to note that this incremental change may reflect **any** erosive loss, as it only quantifies the change in the amount of soil in the experimental unit. If soil has been moved short distances and redistributed in the experimental unit, or if soil derived from elsewhere has been deposited, the soil elevation at some pins may increase. Overall, however, it is more likely that erosive forces will result in a decrease in soil inside the experimental units.

It is critical to visit sites and perform the monthly measurement and sampling activities even though rainfall events may be infrequent during the study. A site that has experienced no rainfall may still lose soil to wind, evidenced by a decrease in soil elevation as measured at the wind erosion measurement pins. Absence of any sediment or runoff in the plots, coupled with a decrease in soil elevation at the pins, indicates that erosion is caused entirely by wind, and not water.



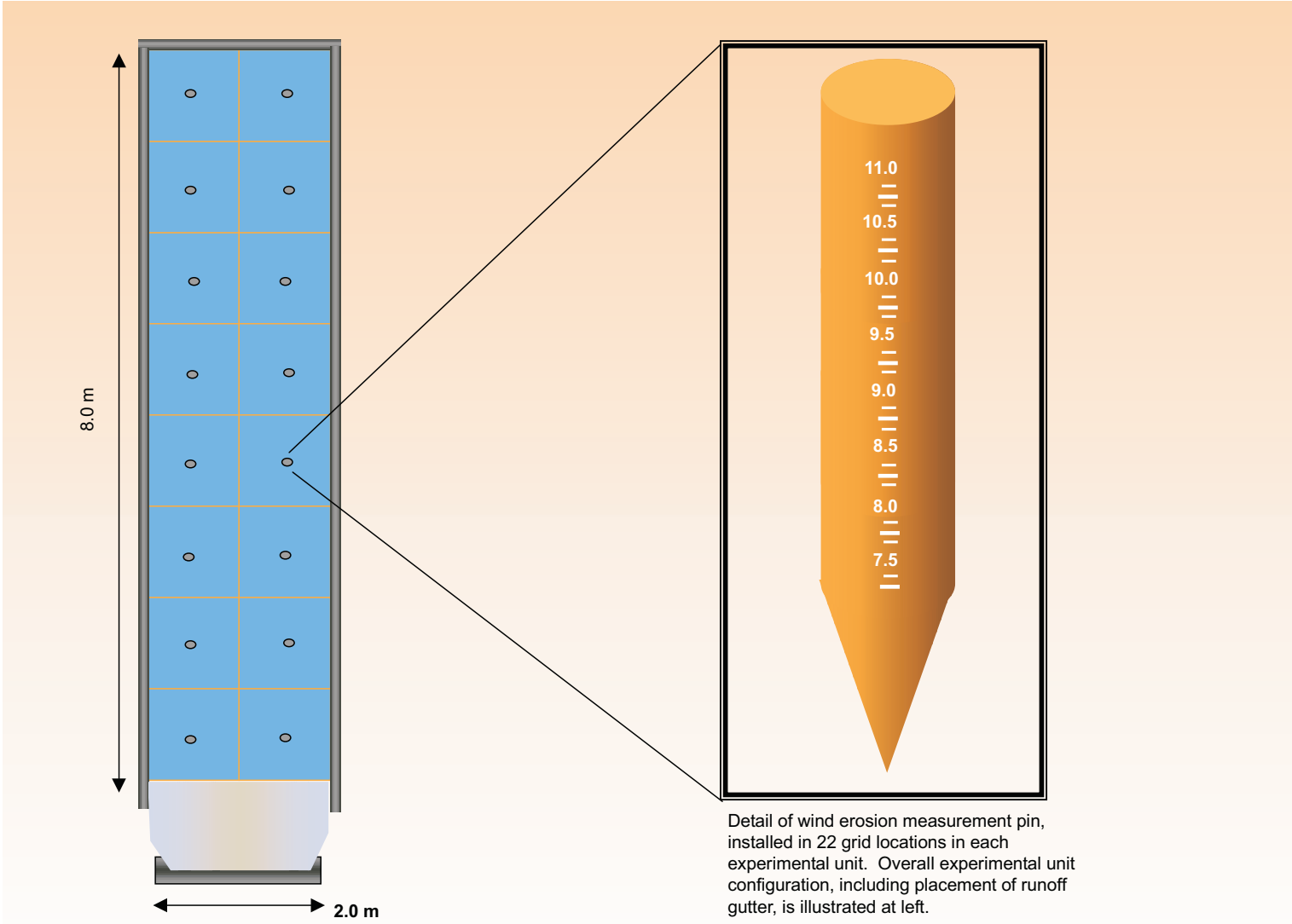
Note: Runoff and sediment collection system are installed at the bottom of the slope run of each experimental unit.

FIGURE 8-1
CONCEPTUAL DESIGN OF RUNOFF AND SEDIMENT COLLECTION SYSTEM
CALTRANS ARID REGION NON-VEGETATIVE EROSION CONTROL STUDY PLAN AND EXPERIMENTAL DESIGN



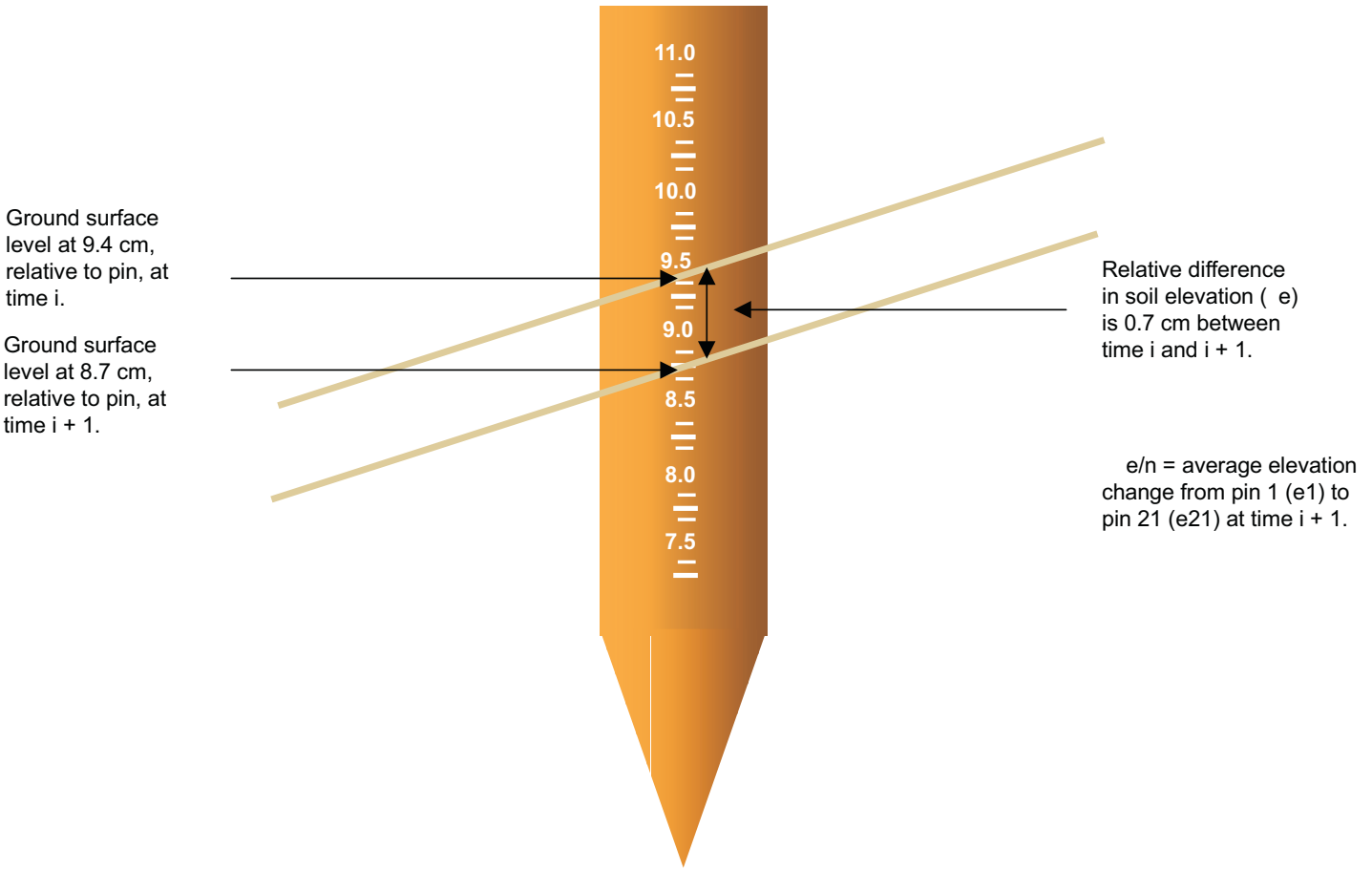
Note: Sample collection includes agitating each barrel to resuspend sediments, then taking a sample of the suspension for TSS measurement. (Note that the contents of the barrel on the left have been undisturbed, but the barrel on right has been stirred and is ready for sample extraction.

FIGURE 8-2
SAMPLE COLLECTION
CALTRANS ARID REGION NON-VEGETATIVE EROSION CONTROL STUDY PLAN AND EXPERIMENTAL DESIGN



Detail of wind erosion measurement pin, installed in 22 grid locations in each experimental unit. Overall experimental unit configuration, including placement of runoff gutter, is illustrated at left.

FIGURE 8-3
CONFIGURATION OF EXPERIMENTAL UNITS FOR WIND EROSION MEASUREMENT
CALTRANS ARID REGION NON-VEGETATIVE EROSION CONTROL STUDY PLAN AND EXPERIMENTAL DESIGN



Measurement of soil loss caused by erosion at wind erosion pins reflects a change in soil elevation relative to the pin at each measurement. Erosive losses that lower the elevation of the soil relative to the pin may also be due to runoff. Thus, wind erosion is calculated as the difference between soil loss, measured in the runoff gutters, and soil loss implied by the pin measurements.

FIGURE 8-4
MEASUREMENT OF WIND EROSION LOSS USING THE SOIL ELEVATION PIN
CALTRANS ARID REGION NON-VEGETATIVE EROSION CONTROL STUDY PLAN AND EXPERIMENTAL DESIGN

Wind Erosion Calculation

The change in soil elevation will be averaged among all of the 16 measurement pins, thereby resulting in a volume of soil lost between measurement intervals. At the same time, soil collected in the runoff gutters will be measured, thereby quantifying erosion caused by runoff. The volume of soil lost from wind erosion will be calculated as the difference between the volume of soil lost as measured at the pins and the volume of soil collected in the runoff gutters:

$$\left(\frac{\sum_{Pin\ 1}^{Pin\ 16} \partial e}{n} \right) \times A - V = WE$$

Where:

∂e = Soil elevation difference, time i and i + 1

A = Area of experimental unit

V = Volume of soil lost in runoff

WE = Volume of soil list in wind erosion

n = number of pins

In the above equation, the left expression (bracketed) represents the calculation of the average elevation change among all of the measurement pins. Although elevation changes at individual measurement pins may reveal important spatial differences in erosion (e.g., more erosion at one area of the slope than others), calculation of the overall loss will require only an average soil elevation change. Figure 8-5 provides this procedure diagrammatically, and is designed to be a convenient field guide to ensure proper execution of measurements and calculations.

In plots with rock blankets, regular soil elevation measurements are neither practical nor physically feasible. In those instances, it will be assumed that because of the rock cover and underlying liner, wind erosion will be negligible. Soil loss will be measured in the sediment collectors, as well as using a limited number of soil elevation pins installed in the experimental units. To prevent damage to the pins during rock blanket installation and removal, they will be constructed of stronger material (e.g., rebar) and installed more deeply into the soil below the experimental unit (Figure 8-6).

8.1.3 Weather Station Monitoring

Each weather station will be connected to a digital data logger that will record rainfall, wind, and temperature. A laptop computer will be used to download weather data onsite. Any necessary batteries must be charged and/or replaced regularly.

8.1.4 Empirical Data Collection

Empirical observation is important for recording and evaluating study conditions that are not quantified by other defined measurements. Datasheets will be developed for collection of this data. The following empirical data will be collected at all study sites:

- Incidental vegetation – During monthly site inspections, personnel should check for any signs of incidental vegetation. If any has developed, personnel should make note of observations in the appropriate section of the empirical data sheet.
- Evidence of raindrop splash erosion – During monthly site inspections, personnel should check plot edging and sides of wind erosion measurement pins for attached soil particles. Personnel should record observations (e.g., location, distribution, and particle size) and brush off affected plot components taking care not to disturb the soil surface around wind erosion measurement pins.
- Product integrity – During monthly site inspections, personnel should inspect products in all plots for cracks, lifting from slope surface, piping underneath product, and any other evidence of product deterioration. Personnel should document all observations in the empirical data recording sheet.

8.2 Monitoring Schedule

The four study sites will be monitored monthly for most parameters. Additional post-storm monitoring events will occur after significant (6.25 mm) rainfall events (Table 8-1). All monitoring will take place over a 2-year period to evaluate the effectiveness of erosion control products.

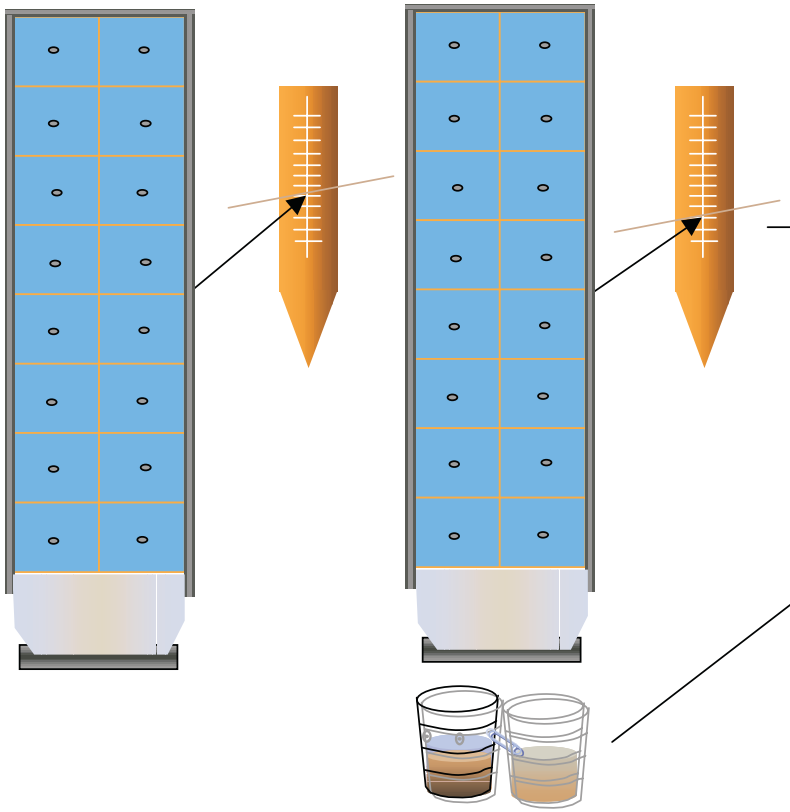
8.2.1 Monthly Monitoring

Monthly monitoring and operational activities will be conducted on all sites regardless of storm activity. In the event a post-storm monitoring event occurs within 1 week of a monthly monitoring event, the monthly monitoring may be skipped, but operational and maintenance activities will still need to be conducted. A rotating schedule may be advantageous for completion of regular monthly monitoring.

8.2.2 Post-storm Monitoring

To determine when post-storm monitoring and pre-storm operational activities (Section 11) will be necessary, weather conditions in the study site areas will need to be monitored carefully. Storms must be tracked to predict and track major storms and determine proper monitoring timing.

In general, monitoring activities will be conducted at the completion of a storm event. However, for high-intensity storm events (>250 mm per day) study sites should be visited during the storm to ensure that sample collection devices have not exceeded capacity, the system is operating correctly, and any damages that could impact data collection are repaired immediately.



1. Soil depths are measured at each of the 21 wind erosion pins at the time of installation.

2. Soil depths are measured at each of the 21 wind erosion pins at time i + 1. Runoff (R) and sediment volume (V) are measured in splitter barrel and collection barrel.

3. Calculation at time i + 1:

$$\left(\frac{\sum_{Pin\ 1}^{Pin\ 16} \partial e}{n} \right) * A - V = WE$$

e = Elevation difference, time i and i + 1

V = Volume of soil lost in runoff

A = Area of experimental unit

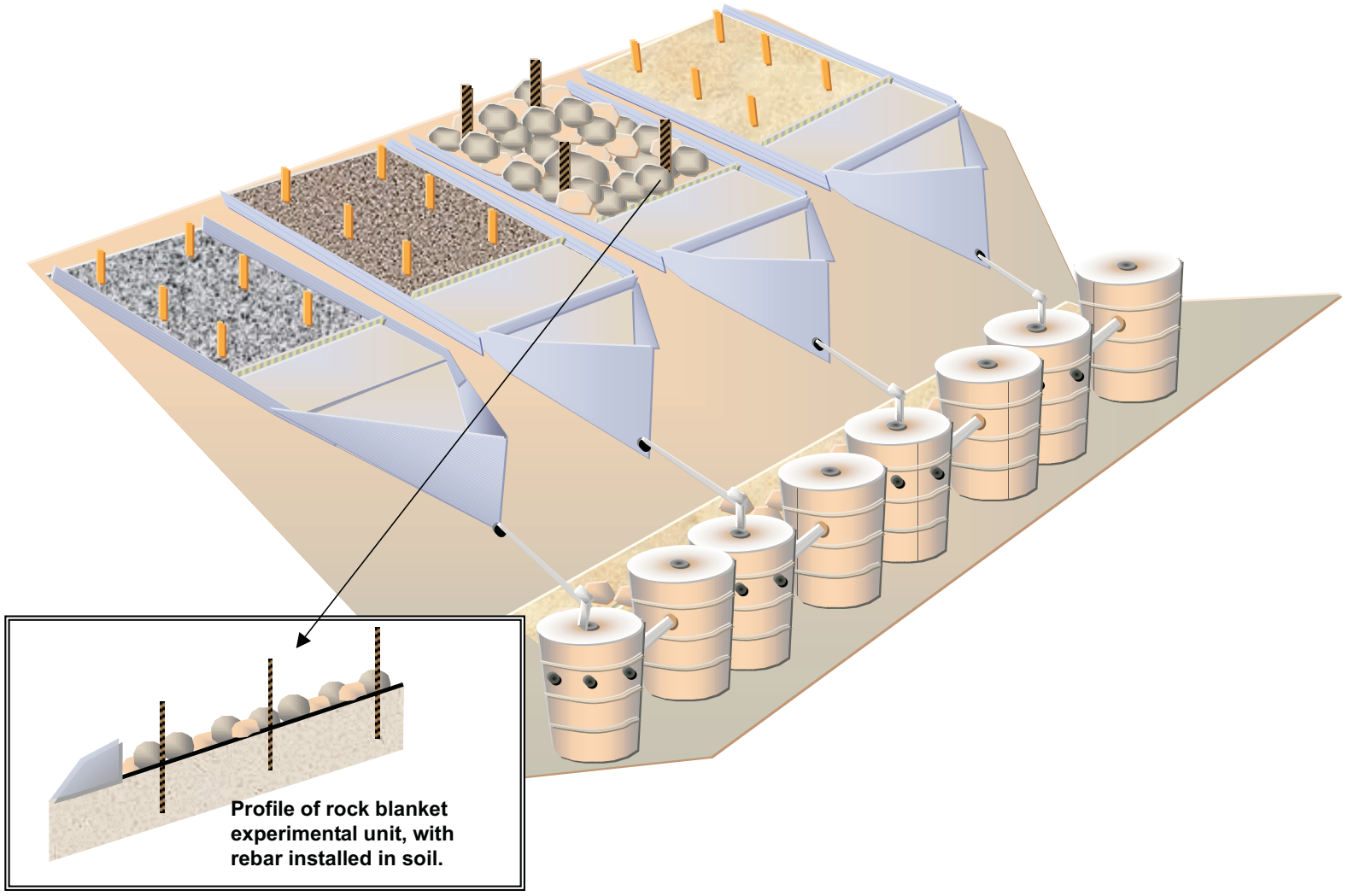
WE = Volume of soil lost in wind erosion

n = Number of pins

4. Calculating the definite integral of relationship between soil elevation and time from i + 1 to i final allows quantification of wind erosion losses:

$$\int_{i}^{n} \frac{\partial e}{\partial t} dx$$

FIGURE 8-5
PROCEDURE FOR DETERMINATION OF WIND AND WATER EROSION LOSSES IN EXPERIMENTAL UNITS
CALTRANS ARID REGION NON-VEGETATIVE EROSION CONTROL STUDY PLAN AND EXPERIMENTAL DESIGN



Note: Soil surface elevation measurements in rock-blanket slopes (second plot from right) will be measured using rebar at the beginning and end of the study, rather than regularly. Wind erosion will be assumed to be negligible. Note rock-lined V-ditch adjacent to barrels to collect, reduce energy, and divert uncollected runoff from the splitter barrels.

FIGURE 8-6
SOIL SURFACE ELEVATION MEASUREMENTS IN ROCK BLANKET TREATMENT
CALTRANS ARID REGION NON-VEGETATIVE EROSION CONTROL STUDY PLAN AND EXPERIMENTAL DESIGN

TABLE 8-1
Summary of Study Monitoring Activities, Methodology, and Frequency
Caltrans Arid Region Non-vegetative Erosion Control Study Plan and Experimental Design

Monitoring Component	Measurement Parameters	Measurement Frequency	Field Procedure	Calculation/Analysis Methodology
Surface water and sediment	Runoff volume and water quality	Post-storm	Subsample runoff water (with suspended sediment) collected in first and second sample containers according to sample protocol. Measure and record volume of water in both containers.	Multiply volume of water in second container by 6 and add to volume of first container, to solve for total runoff from experimental unit..
Weather stations	Rainfall, wind, and temperature	Monthly and post-storm	Download weather station data logger to laptop computer.	N/A
Wind erosion	Soil elevation change	Monthly	Measure and record the soil surface elevation at each pin in the experimental unit.	Total soil lost from wind erosion is calculated as the difference between the volume of soil lost as measured at the pins and the volume of soil collected in the runoff gutters.
Empirical observations	Incidental vegetation	Monthly	Check for any signs of incidental vegetation. If any has developed, make note of observations in the appropriate section of the empirical data sheet.	N/A
	Evidence of raindrop splash erosion	Monthly	Check plot edging and sides of wind erosion measurement pins for attached soil particles. Record observations (e.g., location, distribution, and particle size) and brush off affected plot components taking care not to disturb the soil surface around wind erosion measurement pins.	N/A
	Product integrity	Monthly	Inspect products in all plots for cracks, lifting from slope surface, piping underneath product, and any other evidence of product deterioration. Document all observations on the empirical data recording sheet.	N/A

8.2.3 Monitoring Summary

Table 8-2 summarizes anticipated sampling parameters, frequency, field procedures, and methodology for calculations and analyses. This table is designed to summarize information presented in Sections 4, 5, 6, 7, and 8.

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Table 8-2 Summary of Measurements and Procedures						
	Measurement Parameters	**Frequency of Measurements**	**Procedure and/or Operations**	**Analysis Procedure**	**Special Considerations**	**Reference Section**
Initial Site Measurements						
Aspect	Direction	Initial measurement	Using a compass, record the aspect of the site slope.	N/A	N/A	5.1.5
Slope/Topography	Length and angle	Initial measurement	With a measuring tape, record the length of the slope in metric units. Using an inclinometer, determine the angle of the site slope and record into data sheet.	N/A	N/A	5.1.6
Surrounding Environment	Visual evaluation	Initial measurement	Check for sensitive habitat signs and surrounding items that might have an impact on the study. Make note of any findings.	N/A	N/A	5.1.9
Soil Type	Soil type and chemistry	Initial measurement	Collect samples from various points throughout the site. Send samples to laboratory for analysis.	Laboratory will perform analyses.	N/A	5.1.3
Site Sampling Protocol						
Surface Runoff	Runoff and volume	Immediately following every storm event	Subsample runoff water with suspended sediment. Record volume of total runoff.	Measure total runoff volume and sediment volume. Subtract sediment volume to obtain runoff volume.	N/A	8.1.1
Weather	Rainfall, wind, and temperature	Semimonthly	Each weather station shall be connected to a digital data logger that records rainfall, wind, and temperature. A laptop computer shall be utilized to download weather data onsite.	Actual data are collected.		8.1.3
Wind Erosion	Total soil loss volume	Semimonthly	At beginning of study, soil surface is measured along each pin to determine the baseline soil level in each unit. The soil surface elevation is measured at each pin in all subsequent measurements, and subtracted from the previous measurement to calculate the incremental change in the amount of soil in the experimental unit.	Total soil lost from wind erosion is calculated as the difference between the volume of soil lost as measured at the pins and the volume of soil collected in the runoff gutters.	Ideally, the same individual will be assigned to a specified plot to ensure replication of protocol when collecting measurements.	8.1.2
Incidental Vegetation	Visual evaluation	When necessary	When inspecting site under normal conditions or following storm events, check for any signs of incidental vegetation. If any has developed, make note of observations in the notes section of data sheet.	N/A	N/A	7.1.2
Water Quality						
General Testing	pH	Immediately following storm event	Send runoff sample to laboratory to measure the intensity of acidity/basicity; influences all aspects of water quality.	Electrometric Method	N/A	7.1.1
General Testing	Electrical Conductivity (EC)	Immediately following storm event	Send runoff sample to laboratory for procedure that measures salinity; influences soil infiltration ability.	Conductivity Bridge	N/A	7.1.1
General Testing	Alkalinity	Immediately following storm event	Send runoff sample to laboratory for procedure that measures concentrations of base cations; determines buffer capacity.	Titration Method	N/A	7.1.1
General Testing	Chloride	Immediately following storm event	Send runoff sample to laboratory. Laboratory procedure measures chloride in turbid samples; indicates movement of salts.	Potentiometric Method	N/A	7.1.1
General Testing	Total Kjeldahl Nitrogen (TKN)	Immediately following storm event	Send runoff sample to laboratory. Laboratory procedure measures nitrogen in its organic and ammonia form; indicated in nutrient loading of surface- and groundwaters.	Macro-Kjeldahl Method	N/A	7.1.1

Table 8-2 Summary of Measurements and Procedures						
	Measurement Parameters	**Frequency of Measurements**	**Procedure and/or Operations**	**Analysis Procedure**	**Special Considerations**	**Reference Section**
General Testing	Phosphate	Immediately following storm event	Send runoff sample to laboratory. Laboratory procedure measures phosphates in water containing sediment; indicated in nutrient loading of surface waters.	Perchloric acid digestion	N/A	7.1.1
General Testing	Sulfur	Immediately following storm event	Send runoff sample to laboratory. Laboratory procedure measures sulfates; indicated in nutrient loading of surface waters.	Gravimetric Method	N/A	7.1.1
Constituent of Product	Tannins and lignins	Immediately following storm event	Send runoff sample to laboratory. Laboratory procedure measures plant constituents that may enter water through vegetable matter degradation.	Colorimetric Method	N/A	7.1.1
Sediment Loading	Total Suspended Solids (TSS)	Immediately following storm event	Send runoff sample to laboratory. Laboratory procedure will indicate sediment load.	Gravimetric Method	N/A	7.1.1
Product Integrity						
Riprap	Visual inspections	Annually and as appropriate	Perform an annual product inspection. Check for large cracks and surface erosion. Also check for rocks placed in precarious settings. Contact contractor for any required maintenance and document all activities in the data recording sheet.	N/A	N/A	10.2.4
Road Oyl®	Visual inspections	Annually and as appropriate	Perform annual inspections of this product. Check for and repair any soil movement and/or bare patches of ground. Document all maintenance that was completed onsite in the data recording sheet.	N/A	N/A	10.2.3
Soil Cement	Visual inspections	Annually and as appropriate	Complete a site inspection annually. Check for large cracks and erosion of the surface. Document all maintenance performed on this product in the data recording sheet.	N/A	N/A	10.2.5
PolyPavement™	Visual inspections	Annually and as appropriate	Complete an annual inspection for product performance. If there are signs of soil loss, a spray-on maintenance application should be completed. If there is damage to soil surface, follow instructions for damage repair. Document any maintenance completed in the data recording sheet.	N/A	N/A	10.2.2
Soil Master WR™	Visual inspections	Annually and as appropriate	Complete annual inspection for soil disturbances. This includes patches of bare soil and/or lifted patched of emulsified soil. If necessary, reapply solution at the manufacturer's given application rate. Make note of any reapplication that is necessary in the record-keeping data sheet.	N/A	N/A	10.2.1

9. Statistical Analysis

The following sections provide a detailed summary of the statistical analysis of the Study Plan. Included are descriptions of the statistical organization and computations that will allow quantitative comparisons in the experiment.

As previously stated, the Experimental Design of this study constitutes a split-plot, where various combinations of two treatments (erosion control product and slope length) are duplicated over two plots, or blocks, at each site. The following subsections will describe the type and nature of the statistical analyses that this comprehensive approach will facilitate. Table 9-1 provides a summary of the relevant statistical comparisons.

9.1 Description of Statistical Procedures

Statistical analyses in the Study Plan will employ several types of procedures for comparison among treatments and within treatments. The most important comparisons will be analysis of variance (ANOVA) procedures. ANOVA partitions variability attributed to treatments (Steel and Torrie, 1980), whereby differences among sample means are evaluated. In theory, ANOVA tests whether the variance associated with sample means among treatments indicates that the samples are from different populations (Sokal and Rohlf, 1995). In the case of this study, different populations are potentially equivalent to different treatments (e.g., erosion control products).

Analysis of variance evaluations will principally include comparisons of product effectiveness among all of the sites (thus encompassing a variety of environmental variability in slope, climate, and soil), product effectiveness related to slope and soil type, and product effectiveness at different slope lengths. Comparisons providing finer resolution, such as small-scale variability among split-plots in a given site, spatial variability in erosion losses (as measured at the soil elevation pins), and product performance within sites will also be examined with ANOVAs.

In some cases, direct comparisons will be conducted, such as to analyze whether erosion control product performance is significantly different between two soil texture types. In this instance, performance of a given erosion control product will be compared between two disparate soil textures using the Student's t-test. This will identify if each product exhibits better performance on one soil type than another. This same type of t-test comparison will be used to evaluate the effects of slope on erosion control product performance. As other relationships of interest develop, direct t-test comparisons may be used to identify other trends.

Significance revealed by t-tests and ANOVAs will provide statistical verification that different treatments (e.g., erosion control product) or environmental factors (e.g., soil texture) result in significantly different quantities of soil loss. Evaluation of the nature or magnitude of contribution of various factors to erosion control product performance, such

as soil texture, slope length, and slope, requires the use of multiple linear regression (Kachigan, 1991).

TABLE 9-1
Matrix of Proposed Statistical Analyses [a,b]
Caltrans Arid Region Non-vegetative Erosion Control Study Plan and Experimental Design

Procedure	Treatments	Sites	Comments	Objective
Broad product comparison over all sites and slope lengths (Split-plot ANOVA[c])	1) A, B, C, D, E, U	Red Rocks West, Barstow South, Hinkley South, El Centro South	Data for both long- and short-length experimental units included in each treatment (averaged between plots).	Test product effectiveness considering all of the environmental and design variability of the sites.
Comparison of product performance within slope lengths (Split-plot ANOVA)	1) AL, BL, CL, DL, EL, UL 2) AS, BS, CS, DS, ES, and US	Red Rocks West, Barstow South, Hinkley South, El Centro South	Data separated into treatments in short- and long-length experimental units.	Compare product effectiveness among all sites, but within slope lengths to provide finer resolution in evaluating performance.
Comparison of product performance between two disparate soil textures (Split-plot ANOVA, t-tests)	1) A, B, C, D, E, U	Hinkley South vs. El Centro South	Data for short- and long-length experimental units included in each treatment.	Compare product performance in a coarse-textured soil (loamy sand) and finer-textured soil (sandy clay loam).
Comparison of product performance between two slopes (Split-plot ANOVA, t-tests)	1) A, B, C, D, E, U	Red Rocks West vs. Barstow South	Data for short-and long-length experimental units included in each treatment.	Compare product performance at typical (45 percent) and steep slopes (65 percent).
Comparison of product performance within sites (Split-plot ANOVA)	1) A, B, C, D, E, U	Red Rocks West, Barstow South, Hinkley South, El Centro South	Data for short- and long-length experimental units compared between plots.	Compare product performance to assess small-scale variability within sites.
Analysis of the effects of soil texture and slope on product performance (multiple linear regression)	1) A, B, C, D, E, U	Red Rocks West, Barstow South, Hinkley South, El Centro South	Data for both long- and short-length experimental units included in each treatment (averaged between plots).	Evaluate the magnitude of impact of soil clay and sand content and slope on soil loss.

[a]Comparisons reflect generic treatment names (A, B, C, D, E, and U) for five erosion control products and an untreated control, as well as designations for short-length (S) and long-length (L) experimental units.
[b]Statistical comparisons performed using soil loss data (wind and runoff).
[c]ANOVA = analysis of variance.

Using regression, the relationship of a given variable (e.g., soil texture) with another (e.g., soil loss) will be evaluated in terms of a linear or more complex function (Sokal and Rohlf, 1995).

Unlike ANOVA, where erosion loss values are compared among various treatments or treatment combinations, regression will compare soil loss values with other measured characteristics, such as percent soil clay. While ANOVAs will provide comparisons of the performance of erosion control products, regressions will help to identify which factors most substantially affect the performance of erosion control products. In this manner, regressions provide useful information on the design constraints of a particular product, and may be an effective tool in identifying if a product, including those exhibiting generally better performance than others, is appropriate for a given site.

As with any research effort, execution of this study may suggest relationships of interest for statistical evaluation. This erosion control product study will be iterative, whereby data will be analyzed using any tool that provides a better understanding of product performance. Although the statistical approaches highlighted above and in the following sections are the most likely comparisons, it is important to note that modification, omissions, or additions may be made to this suite of tools as the data are reviewed.

9.1.1 Overall Product Performance

Overall product performance among all of the sites, soil types, and slope lengths will be assessed using an ANOVA that incorporates all of the variability in the study. This type of evaluation will provide information regarding the success of products not only compared to one another, but across the entire range of environmental (e.g., soil type and slope) and design factors (e.g., slope length) incorporated in the study. This type of overall analysis will provide an evaluation of broadness of applicability. A product that exhibits significantly better performance in the overall product performance evaluation (i.e., allows less soil loss) than others will indicate relative success in a broad range of conditions.

9.1.2 Product Performance within Slope Lengths

Some products may exhibit better performance at specific slope lengths. Performing an ANOVA among treatments within slope length sites will provide a means to identify products that may be more appropriate for longer or shorter slope lengths. A product that performs poorly on longer slopes may still be an excellent choice for shorter slopes. This comparison therefore provides a more even basis with which to compare product performance.

To incorporate larger-scale variability necessary to evaluate broadness product applicability, these within-slope treatment analyses will be conducted among all of the sites. Within-slope length comparisons among the erosion control products provide the nature of the comparison.

9.1.3 Product Performance Evaluation between Soil Textures and Slopes

Soil Texture

Product performance may depend upon the nature of the soil matrix on which the product has been applied. Evaluation of product performance related to soil texture will be performed on two sites exhibiting disparate soil textures but similar slope, aspect, and environmental conditions. Sites with relatively different soil textures will be selected in this evaluation to help incorporate the range in soil types possible in the field. With this model,

variability attributed to site and environmental factors can be controlled, thereby isolating the effects of soil texture.

To determine whether soil texture affects the performance of a specific erosion control product, the performance of a given product at one soil texture will be compared to the same product at a disparate soil texture. This evaluation will use measurements from both long and short slope lengths.

Slope

Product performance may also depend upon the slope of the site. Product performance related to slope will be evaluated on two sites exhibiting disparate slopes, but similar soil textures, aspect, and environmental conditions. Sites with both typical (e.g., 2:1) and relatively steep slopes will be selected for this evaluation to incorporate the variety of slope conditions possible. As with the soil texture comparison, variability attributed to site and environmental factors can be controlled, thereby isolating the effects of slope.

To determine whether slope affects the performance of a specific erosion control product, the performance of a given product at one slope will be compared to the same product at a different slope. This evaluation will use measurements from both long and short slope lengths.

9.2 Effects of Environmental Factors

The contribution of site factors such as soil texture and slope on product performance will be evaluated using multiple linear regression. As previously described, multiple regressions measure the degree to which various independent variables, such as clay content (related to texture) and slope, affect dependent variables, such as soil runoff or wind loss. This type of analysis does not compare the effectiveness of one product to another. That comparison is accomplished using the split-plot ANOVA design. Rather, the multiple regression helps to determine which factors may constrain a given erosion control product. Regressions will be performed for each product so that the effects of independent variables may be directly related to the performance of that product.

Small-scale variability may also be of interest, particularly where small variations in slope, soil (texture and structure), or other positions on the slope may impact the performance of erosion control products. Small-scale variability will be evaluated as part of the overall product comparison. In all cases, plots will be established in close proximity to one another and on sites that are typically homogeneous because they have been modified as a result of human activity. Although small-scale variability is expected to be minimal, it is still necessary to evaluate its contribution to variability in the product comparisons. Minimal differences in product performance among plots in a given site will provide support that any significant differences measured among the products are caused by the products themselves.

10. Construction

10.1 Construction Development

Construction activities will take place when building the individual plots, establishing data recording devices, and performing general layout operations at the selected sites. This section is provided to supply general construction considerations. Appendix G of this report discusses site preparation components through detailed site preparation drawings. A detailed Health and Safety Plan provided in Appendix H takes into account many of the safety issues associated with the specific construction activities for this Study Plan. This section is not intended to provide complete construction operations because the bid contractor will develop this information as part of the bid process prior to construction.

The main considerations associated with construction management include:

- Preconstruction services
- Construction administration and oversight
- Experimental unit construction
- Construction inspection and quality control
- Construction closeout

10.1.1 Preconstruction Services

Preconstruction services include all contractor meetings, preconstruction conferences, mobilization, and other organizational components of constructing the plot systems prior to actual mobilization and fieldwork.

A kickoff meeting should be scheduled by the construction manager and should include the contractor, oversight engineer, and appropriate Caltrans staff. The overall bid, permits, and agreements should be reviewed; critical scheduling issues should be discussed; and communications and contact information should be distributed.

A preconstruction conference should take place to introduce key personnel and review administrative procedures, the contractor's preliminary construction schedule, and overall work plan. Other items discussed should include protocols for submittals, work change directives, change orders, permit conditions, safety, and traffic control. The results of the preconstruction conference should be distributed to all attendees in writing.

The onsite team should be mobilized by the contractor and should include a resident engineer. Primary activities should include setting up headquarter locations with appropriate communication equipment, general site equipment mobilization, and in-field review of appropriate health and safety plans.

10.1.2 Construction Administration and Oversight

The construction manager should have the majority of the construction administration and oversight and should serve as the liaison between the contractor, permitting agencies,

Caltrans, utility companies, and other parties. This should include correspondence and records management, organization of site meetings, schedule management including progress and delays, submittals management, change order management, labor compliance, and any claims management.

10.1.3 Experimental Unit Construction

Experimental units will be divided from one another with as much simplicity and little disturbance as possible. Although a variety of materials, including metal flashing or wood boards are possible, it is recommended that experimental units be separated with plastic garden dividers. These products are inexpensive, readily available, and intended for shallow installation in the soil.

10.1.4 Construction Inspection and Quality Control

The correct construction of the Study Plan experimental plots is key to the performance and results received from the study. Therefore, inspection during the construction operations is very important. This will involve observing the work in progress, recording daily inspection reports, progress reports, managing problems, and providing critical decision-making processes.

A separate quality assurance/quality control program should be developed prior to the start of construction. This program should be agreed upon by the construction manager, contractor, Caltrans, and any other interested parties. This will provide the basis for ensuring that the earthwork, plot construction, and equipment installation is installed according to the recommendations in the Study Plan.

10.1.5 Construction Closeout

The construction manager, contractor, and Caltrans shall all agree that construction is complete prior to ending the construction phase of the project. The contractor should be responsible for ensuring that the construction of the project results in the minimum desired components detailed in this Study Plan.

10.2 Product Application

This section discusses the installation and maintenance that may be necessary for each erosion control product to be tested in this study. These recommendations are for installation after basic site preparation activities that may include vegetation removal, light grading, pre-emergence application, or water application for soil moisture optimization. The following products were selected for this Study Plan:

- Soil Master WR™ - Acrylic polymer soil stabilizer
- PolyPavement™ – Polymer soil stabilizer
- Road Oyl® – Pine tree resin-based soil stabilizer
- Rock Blanket
- Soil Cement

These products have individual application rates and maintenance requirements according to manufacturer recommendation or specifications. The following paragraphs explain these recommendations.

10.2.1 Soil Master WR™

Application Instructions – The following instructions are for long-term soil stabilization. Using a water truck or hydroseeder, mix water with Soil Master WR™ concentrate at a 20:1 ratio. Apply by spraying onto soil surface at a rate of 252 kilograms (Soil Master WR™)/ hectare (225 gallons per acre). Spray pattern should be uniform across the site. Keep spray droplets large. For extra stabilization, compact soil with mechanical equipment prior to addition of solution. Let the solution dry for at least 2 days before performing any activities such as walking or driving over soil surface. Clean tools thoroughly after application of product. Flush sprayer with water.

For pure sand soils – mix wood mulch with Soil Master WR™ solution at a rate of 2,240 km per hectare of coverage. This is to prevent percolation of solution into soil without the formation of a crust. To determine the need for wood mulch, first take a sample to find out the sand content and texture of the soil. If the percolation rate of soil is extremely high, then use this method of application.

Maintenance Instructions – The application rate defined previously should stabilize the slope for 5 years. Complete a visual check for soil loss 3 to 6 months after application. Check for patches of lifted soil. If found, then a patch reapplication must be done depending on the area of lost soil. After initial visual inspection, check site annually for soil loss. If any bare patches are visible, re-spray area.

If after 5 years, soil has many bare spots, rework the site and repeat application according to previous instructions.

10.2.2 PolyPavement™

Application Instructions – Grade and compact site prior to application of PolyPavement™ solution. In a water truck or hydroseeder, mix water with PolyPavement™ concentrate at a ratio of 20:1. A 3.8-liter quantity of PolyPavement™ concentrate will cover on average 17 square meters (185 square feet). PolyPavement™ must be installed when the temperature is above 42°F, and the temperature must remain above that level for a sustained period of time to allow for drying and curing of the solution. Spray product on the site uniformly. Make sure that droplet size is comparable to rainfall, and avoid fine mists. Product must be cured before performing any action onsite. The time required for drying and curing is dependent on weather conditions. If the weather is very hot, the curing will be quicker than during cooler temperatures. The complete curing process takes approximately 30 days.

Make sure to clean all equipment thoroughly after application of PolyPavement™ solution.

Maintenance Instructions – The above-mentioned application rate will solidify the soil for an average of 7 years. After 6 months, perform an initial visual inspection of the site. If there are signs of soil loss, a spray-on maintenance application should be completed. Soak the PolyPavement™ natural soil surface with diluted PolyPavement™ soil solidifier at a ratio of

20 parts water to 1 part concentrate. Spray directly onto soil at the maximum amount that it can be applied without runoff.

Damage Repair – If the pavement has become worn or rough, or in the event that the surface has been damaged and needs repairing, the surface can be repaired by applying a mixture of solution and soil. Mix PolyPavement™ soil solidifier with soil and spread over damaged area and compact into place.

10.2.3 Road Oyl®

Installation/Application Instructions - Using a water truck or hydroseeder, mix water with Road Oyl® concentrate at a ratio of 5:1. The concentrate should be applied at 230 milliliters to 320 milliliters per square meter (6.5 ounces to 9 ounces per square yard). The water content will then be 1.30 liters to 1.9 liters per square meter (36.5 ounces to 54 ounces per square yard). Air temperature should be above freezing during application and for 30 days following. Spray product onto site uniformly making sure that droplet size is large (avoid fine mists). Let product dry for 3 days before performing any activity onsite. Curing will take approximately 30 days.

Clean all equipment thoroughly after application of product on the site. Make sure to rinse water truck or hydroseeder with water, or hard resin will form in the tank.

Maintenance Instructions - This product has an average expected lifetime of 7 years. Approximately 6 months after initial application, perform a visual inspection of the site. Check for soil movement and bare patches of ground. If there is evidence of loose soil, a spray-on maintenance application should be done on the affected area. If the initial inspection is successful, check annually from thereon. After it is determined that the crust has deteriorated sufficiently, rework the soil onsite and reapply according to the application instructions.

10.2.4 Riprap

Installation Procedure – Installation of riprap will normally be completed by a construction contractor. To install riprap on an erosion control site, a base application of geotextile netting will be necessary. Netting should be jute mesh or a sufficient polypropylene netting. Riprap will be durable rock, free from cracks and seams. The rock will be graded for light class. The installation procedures are as follows (unless otherwise specified by riprap manufacturer):

1. Proceed with netting installation only when weather conditions comply with manufacturer's recommendations.
2. Netting will be rolled out in place in the direction of drainage flow and will be applied without stretching. It should lie smoothly and loosely on the soil surface.
3. Bury the top and bottom edges of the netting in a 150-mm-deep trench.
4. Overlap and staple netting to slope according to manufacturer's recommendations. Outside edges are to be stapled at 0.6-meter (2-foot) intervals. Cover all outside edges lightly with soil.

5. Netting is to cover all areas where riprap will be placed.
6. Place riprap in a manner that will produce a reasonably well-graded mass of rock with the minimum percentage of voids. The desired distribution of the various sizes of rocks throughout the mass will be obtained by selective loading of the material at the source. The finished riprap will be free of pockets of smaller stones and clusters of larger stones.
7. Place riprap to its full course thickness in one operation without using chutes or other methods, which will cause segregation. Placing riprap in layers will not be accepted.

Maintenance Procedure – Perform annual inspections of project site. Check for rocks in precarious positions that may endanger traffic safety. If riprap is damaged or fallen, contact the contractor to receive instructions. Contractor information will be provided by Caltrans. If the site is considered successful, continue to perform annual inspections for the life of the project.

10.2.5 Soil Cement

Installation Procedure – Installation of this product will normally be completed by a contractor. Laboratory tests must be done to determine the proper cement content, compaction, and water requirements of the soil material to be used. The soil cement can be mixed in a central plant or mixed-in-place. Central plant-mixed soil cement requires a non-cohesive, usually granular, material. For mixed-in-place operations, clay or granular soils can be mixed.

Contractors will follow four basic steps to installation: spreading, mixing, compacting, and curing. After the area has been graded and the soil loosened, spread the proper quantity of cement onto the in-place soil. Use a mixing machine to then thoroughly mix the cement and the required amount of water with the soil. Next, tightly compact the mixture with rollers. The mixture should be shaped to the proper contour and rolled again to achieve a smooth finish. Finally, cure the soil cement mixture by spraying water and sealing with a bituminous mixture to supply and maintain the moisture needed for hydration.

Maintenance Instructions – Perform a site inspection annually to determine the success of the product. Check for large cracks and erosion of the surface. If there is sufficient erosion or bare ground, the contractor should be contacted to perform proper maintenance on the site. If the site is considered successful, continue to perform inspections annually for the life of the project.

11. Operations and Maintenance

This section describes the responsibilities, protocols, and reporting associated with operation and maintenance (O&M) of the sites identified in this Study Plan. The objective of this section is to summarize the tasks required to maintain optimal performance of the study sites, so that reliable data can be obtained for evaluation of the erosion control methods being tested.

11.1 Operation and Maintenance Overview

The four study sites identified in this Study Plan incorporate the same Experimental Design and monitoring equipment. Therefore, these sites will have similar O&M requirements. Sites shall be operated and maintained for 2 calendar years beginning at the completion of construction. Prior to construction, each site will be evaluated for potential monitoring and maintenance issues that may occur during the study. These issues may include pre-existing erosion point sources, erosion features such as rills or gullies, or surrounding influences on the site. Before construction, these conditions will be repaired or accommodated in the study design. During the study, additional maintenance and monitoring of pre-study conditions may be necessary.

The following regular O&M activities will be conducted on a monthly basis and as needed to ensure proper system function and data integrity:

- Routine site inspections
- Equipment calibration
- Plot maintenance
- Monitoring and sampling equipment maintenance
- Offsite point-source prevention and repair

11.1.1 General Operational Activities

Routine Site Inspections

Routine site inspections are important for early detection of system damage and timely repairs to avoid disruption in data collection. Inspections will be made of the structural integrity and working order of all study site components, including:

- Study plot infrastructure (e.g., plot edging, wind erosion measurement pins, and runon diversion structures)
- Runoff collection and sampling devices
- Weather stations
- Surrounding site conditions
- Any site vandalism

Equipment Calibration

Equipment calibration is necessary for optimum performance and accurate data collection. Monitoring equipment will be calibrated at study startup and routinely, as per manufacturer recommendations.

11.1.2 Maintenance Activities

Plot Maintenance

Any structural damage of plots will be repaired. Replacement parts should be stocked to avoid delays in basic plot repairs. Repairs will not be made to the actual erosion control products, as the performance will be measured based on the initial application.

Monitoring and Sampling Equipment Maintenance

All monitoring equipment will be cleaned and repaired as needed or as recommended by the manufacturer. Runoff collection and sampling systems will be cleaned after each monitoring event and checked for operational integrity. Any obstructions in collection devices will be replaced and cleared, and any damages repaired. All weather stations will be maintained as per the manufacturer recommendations. Any security enclosures or batteries provided for monitoring equipment will be repaired or replaced as needed.

Offsite Point-source Prevention and Repair

Efforts should be made to avoid impacts from offsite erosion sources. If erosional point-sources develop and could potentially impact the study plots, these areas should be repaired, or preventative measures should be taken to avoid runon or soil transport into the study areas.

11.2 Operation and Maintenance Frequency

All O&M inspections will be conducted on a monthly basis. Additional operations will take place before major storm events. Storm monitoring will be necessary to determine timing of these activities (Section 8). Table 11-1 summarizes O&M frequency.

TABLE 11-1
Frequency of Operation and Maintenance Activities
Caltrans Arid Region Non-vegetative Erosion Control Study Plan and Experimental Design

O&M Activity	Monthly	Pre-storm	Post-storm	As Needed
Routine Site Inspections	X	x		
Equipment Calibration				x
Monitoring Equipment Maintenance	X		x	x
Plot Maintenance	X		x	x
Offsite Point-source Prevention and Repair				x

11.3 Plot Teardown

At the conclusion of the study, plot infrastructure (e.g., plot edging, runoff collection devices, and sampling and monitoring equipment) will be disassembled and removed. Infrastructure will be disposed of or salvaged at the discretion of Caltrans.

11.4 Record Keeping

Accurate data management is imperative to ensure the security and integrity of data collected as well as to aid in timely data interpretation and evaluation of trends. Complete records of all site operations are useful for quick access to information regarding past maintenance practices, equipment adjustments and repairs, and parts lists. All study site construction, maintenance, operation, and monitoring activities will be recorded. An electronic database corresponding to field data collection will be developed and used to record all operations, maintenance and monitoring activities, and data. Data should be entered routinely in conjunction with field visits. Where possible, a laptop or other electronic device will be used in the field to record data directly into electronic datasheets and reduce data transfer errors.

All electronic data sheets or logs should be backed up regularly to prevent loss of data. Any hardcopy data sheets or notes taken in the field should be stored for reference.

Periodic review of records may indicate that improvements can be made to the overall maintenance management program. This program should be adaptable to account for evolving management and data needs.

11.5 Health and Safety

Proper safety procedures will be followed during all study operations. Total elimination of accidents should be a primary objective. All personnel entering a study site will follow the guidelines in the Health and Safety Plan developed for this study (Appendix H).

12. Schedule and Deliverables

This Study Plan is a 3-year plan that contains a 2-year erosion control study. The Study Plan will occur from July 2002 to June 2005. The Study Plan includes Contract Negotiation and Contractor Bid and Selection, which will occur from July 1, 2002 to September 15, 2002. Any delay in the start date of the actual Study Plan will result in corresponding delays of milestones listed below. The mobilization start date, September 17, 2002, was selected so that mobilization (permitting, district coordination, and California Occupational Safety and Health Administration [Cal/OSHA] consultation) and surveying and construction of the test plots will be complete by January 1, 2003. Final analysis and reporting will occur through June of 2005. Figure 12-1 illustrates the project schedule.

12.1 Schedule Components

The project schedule is broken down into the following five components, and a description of each task is presented below:

1. Mobilization
2. Construction
3. Monitoring and maintenance
4. Reporting and analysis
5. Management

12.1.1 Mobilization

Mobilization will take approximately 10 weeks to complete. The tasks associated with mobilization are district coordination, permitting, and Cal/OSHA consultation. Contracts between headquarters and the consultant performing the study will already be in place, and initial coordination between Caltrans headquarters and the consultant will have occurred. Encroachment permit applications for construction (including environmental compliance, hazardous materials Initial Site Assessment, cultural resources report, and any other necessary assessments) will be completed during this time. Cal/OSHA consultation will also occur at this time.

12.1.2 Construction

Survey and construction of the four study sites and product application will occur over a 15-week period. During this phase, sites will be surveyed, test plots will be constructed, instrumentation will be installed and calibrated, and commissioning (any adjustments and quality control testing) will occur. Complete construction operations are not included in this Study Plan because this information will be developed by the contractor as part of the bid process prior to construction. Refer to Section 10, Construction, for general information on the construction development process and for specific information on product application.

12.1.3 Monitoring and Maintenance

Monitoring and maintenance will occur from January 2003 to February 28, 2005. Monthly monitoring and maintenance will occur throughout this time period, as well as during an end-of-project Phase Down and Site Closure period. For specific operations and monitoring and maintenance information, refer to Section 11, Operations and Maintenance.

12.1.4 Reporting and Analysis

Reporting and analysis will be implemented throughout the study. A data report will be submitted at approximately 6 months, 12 months, and 18 months (from the start date of the monitoring period), each one followed by a progress report and review of the project to date. A final report will be produced at the completion of the 2-year study, with preparation of the report beginning in March 2005.

12.1.5 Management

Project management is one of the most integral components of any project. Management of the study will be ongoing, from project conception until the final report is submitted. In addition to monthly monitoring and reporting by site managers, the project manager will conduct interim quality control reviews that will be included in the progress reports and reviews discussed in Reporting and Analysis above.

Caltrans project review will occur after each progress report and review. Caltrans project review will then be followed by a progress review meeting between Caltrans and the consultant. These meetings will allow preliminary review of data, analysis of project performance to date, and recommendations for any work plan revisions.

Final management review of the project will occur in conjunction with final report development.

Communication among all cooperating teams will be an essential component to the project. Management teams will meet at regularly scheduled intervals to assess the study progress.

12.2 Deliverables

A data report will be submitted approximately every 6 months (a total of three) from the time monitoring and maintenance begins. Each report will be followed by a progress report and review of the project to date, until final report development begins in March 2005. Data report deliverables are listed below:

Data Report 1: August 29, 2003
Data Report 2: February 27, 2004
Data Report 3: August 30, 2004

Final report development will occur from March 2005 to June 30, 2005. A Draft Final Report will be submitted, followed by a Caltrans review before the final product is submitted to Caltrans on June 30, 2005. Final report development deliverables are listed below:

Draft Final Report: March 4, 2005 to April 29, 2005
Caltrans Review: May 2, 2005 to May 20, 2005
Final Report: June 3 to June 30, 2005

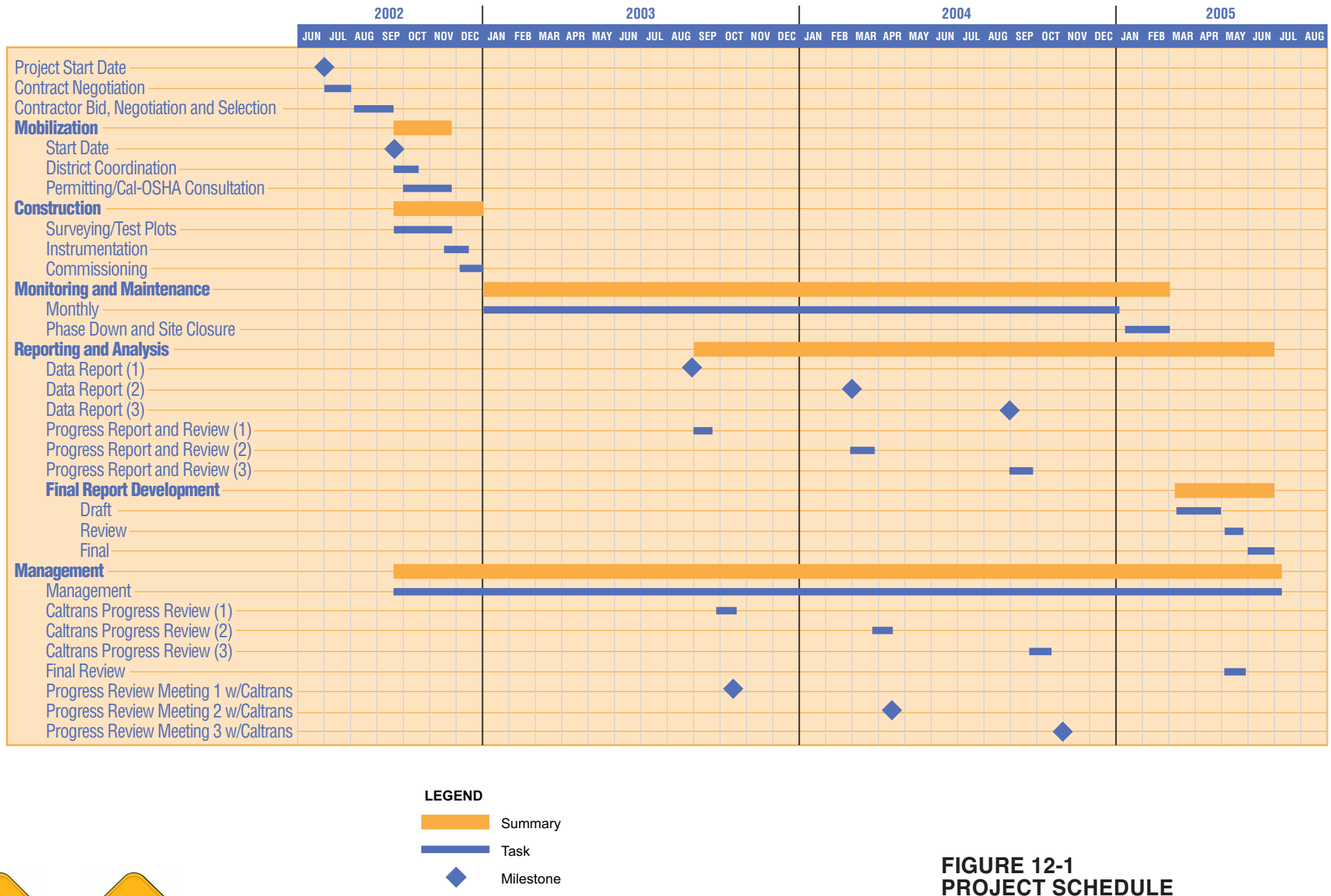

FIGURE 12-1
PROJECT SCHEDULE
CALTRANS ARID REGION NON-VEGETATIVE EROSION CONTROL STUDY PLAN AND EXPERIMENTAL DESIGN

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Appendix A
Material Safety Data Sheets and Product Supporting Information


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Soil Master WR™

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Material Safety Data Sheet

May be used to comply with OSHA's Hazard Communication Standard, 29 CFR 1910.1200. Standard must be consulted for specific requirements.

U.S. Department of Labor
Occupational Safety and Health Administration
(Non-Mandatory Form)
Form Approved
OMB No. 1218-0072

IDENTITY (As Used on Label and List) SOIL MASTER WR

Note: Blank spaces are not permitted. If any item is not applicable, or no information is available, the space must be marked to indicate that.

Section I

Manufacturer's Name: ENVIRONMENTAL SOIL SYSTEMS, INC.	Emergency Telephone Number: 888-368-9664
Address (Number, Street, City, State, and ZIP Code): 16161 VENTURA BLVD. # 703	Telephone Number for Information: CHEMTREC 800-424-9300
ENCINO, CA 91436	Date Prepared: 1/5/98
	Signature of Preparer (optional):

Section II — Hazardous Ingredients/Identity Information

Hazardous Components (Specific Chemical Identity; Common Name(s))	OSHA PEL	ACGIH TLV	Other Limits Recommended	% (optional)
THIS PRODUCT CONTAINS NO INGREDIENT WHICH IS LISTED BY: OSHA PER 29 CFR 1910.1200				
CAS: # MIXTURE				
NON-HAZARDOUS				
PRODUCT NAME: SOIL MASTER WR				
PRODUCT: SYNTHETIC RESIN EMULSION (CO-POLYMER OF METHACRYLATES & ACRYLATES/ TRIPOLYCATE/ ACRYLIC)				
PRODUCT SOLIDS: MINIMUM: 61%+ ACTIVE SOLIDS				
THE INFORMATION ACCUMULATED HEREIN IS BELIEVED TO BE ACCURATE, BUT IS NOT WARRANTED TO BE WHETHER ORIGINATING WITH THE COMPANY OR NOT. RECIPIENTS ARE ADVISED TO CONFIRM IN ADVANCE OF NEED, THAT THE INFORMATION IS CURRENT, APPLICABLE, AND SUITABLE TO THEIR CIRCUMSTANCES.				

Section III — Physical/Chemical Characteristics

Boiling Point: 212° F		Specific Gravity (H_2O = 1):	1.05±.05
Vapor Pressure (mm Hg.): HEAVIER THAN AIR		Melting Point:	N/A
Vapor Density (AIR = 1): HEAVIER THAN AIR		Evaporation Rate (Butyl Acetate = 1):	

Solubility in Water: 100%

Appearance and Odor: MILKY WHITE SLIGHT

Section IV — Fire and Explosion Hazard Data

Flash Point (Method Used): GREATER THAN 212°F C.O.C.	Flammable Limits: N/A	LEL: N/A	UEL: N/A

Extinguishing Media: WATER, CARBON DIOXIDE OR DRY CHEMICAL

Special Fire Fighting Procedures: FIREFIGHTER MUST BE EQUIPPED WITH SELF CONTAINED BREATHING EQUIPMENT AND CLOTHING.

Unusual Fire and Explosion Hazards: NONE KNOWN

Section V — Reactivity Data

Stability	Unstable		Conditions to Avoid
	Stable	XX	KEEP FROM FREEZING

Incompatibility (*Materials to Avoid*)
NONE KNOWN

Hazardous Decomposition or Byproducts
NONE KNOWN-NORMAL CONDITIONS

Hazardous Polymerization	May Occur		Conditions to Avoid
	Will Not Occur	XX	KEEP FROM FREEZING

Section VI — Health Hazard Data

Route(s) of Entry: Inhalation? Skin? Ingestion?
USE ADEQUATE VENTILATION-WASH WITH SOAP/WATER CALL PHYSICIAN AT ONCE

Health Hazards (*Acute and Chronic*)

NONE EXPECTED/NONE EXPECTED

Carcinogenicity: NTP? IARC Monographs? OSHA Regulated?
NONE NO NO NO

Signs and Symptoms of Exposure
SKIN: THIS MATERIAL MIGHT CAUSE A RASH OR SKIN IRRITANT.
THIS MATERIAL MAY BE AN EYE IRRITANT. BREATHING: PROLONG EXPOSURE TO MISTS

Medical Conditions Generally Aggravated by Exposure
MAY CAUSE IRRITATION TO NOSE AND THROAT.

SEE ABOVE.

Emergency and First Aid Procedures
SKIN: WASH WITH SOAP & WATER IMMEDIATELY. EYES: FLUSH WITH COPIOUS AMOUNTS
OF WATER. INGESTION: CALL A PHYSICIAN AT ONCE.

Section VII — Precautions for Safe Handling and Use

Steps to Be Taken in Case Material is Released or Spilled
WASH AREA WITH WATER & ALLOW TO DRY. WASH WITH SALT WATER & SPRINKLE WITH
SAND OR VERMICULITE, SWEEP AND DISPOSE.

Waste Disposal Method
DISPOSE IN ACCORDANCE WITH ALL LOCAL, STATE & FEDERAL REGULATIONS.

Precautions to Be Taken in Handling and Storing
STORE IN COOL DRY AREA, HAVING ADEQUATE VENTILATION.

Other Precautions
NONE

Section VIII — Control Measures

Respiratory Protection (*Specify Type*)
SELF CONTAINED

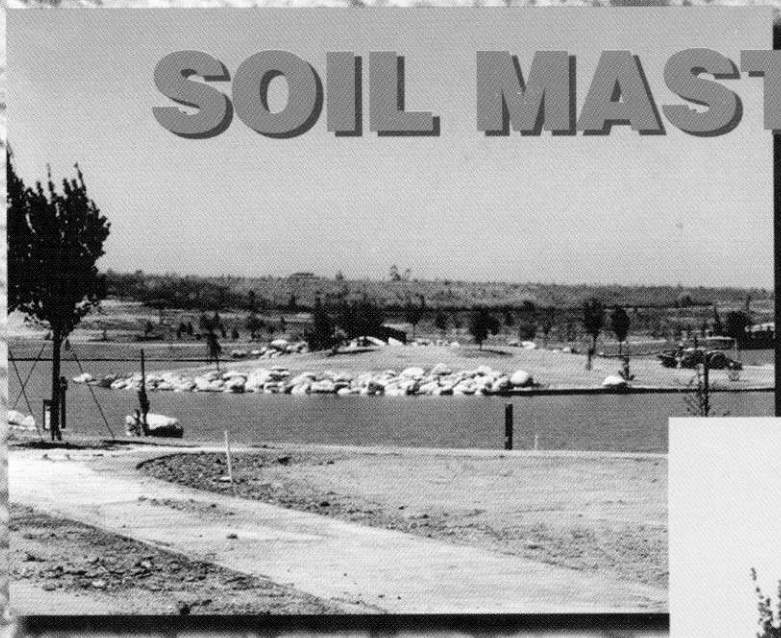
Ventilation NORMAL	Local Exhaust GOOD	Special	
GOOD	Mechanical (General)	Other	

Protective Gloves RUBBER OR PLASTIC	Eye Protection SAFETY GLASSES

Other Protective Clothing or Equipment
RUBBER OR PLASTIC APRONS

Work/Hygienic Practices
NORMAL/ GOOD PRACTICES

SOIL MASTER WR™



The Smartest Way

To Stop

Soil Erosion

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NOW THERE'S A FAST, IN
YOUR SOIL EXACTLY

Erosion control doesn't have to be a time-consuming operation.

Now you can cover lock down topsoil, establish vegetation. And for a lot less than the cost of other methods.

Soil Master WR™ is the height of technology in soil stabilization. Fast, inexpensive and completely effective.

Soil Stabilization:

Soil Master WR™ is a blend of liquid co-polymers (with Tripolycate™) — you simply spray it on. Mixed with water, it bonds soil to create a tough, water-resistant membrane. Use it as is, for treatment against erosion. But you needn't stop there.

Thick or thin: the choice is yours.

Soil Master WR™ is flexible — you blend it just the way you want: Thick will give you maximum control. Thin it, and you have a tremendously effective tackifier in hydroseeding and mulching. Soil Master WR™ forms a semi-permeable, transparent crust, letting in just enough water to ensure proper plant growth. Later the same crust provides a solid foundation for plant roots.

Normal application rates are 55 to 110 gallons of Soil Master WR™ per acre, mixed with 1,800 to 3,000 gallons of water. You adjust the additive and lilut o fit your soil composition plica s.

Dust abatement and sand control.

Soil Master™ works just as well against wind erosion. The crust seals in even tiny particles of dust — and helps you get a handle on wind-blown dust and sand.

Any site, anywhere in the world.

We've put Soil Master WR™ to the test all over the world — Central and South America, Europe, the Middle East, Mexico, the Pacific Rim. It's the major soil and slope stabilization method used in the planned communities of Mission Viejo and Aliso Viejo — two of the largest developments in Southern California. Whatever your environment, whatever your site condition, we can customize Soil Master WR™ to protect against post-fire erosion, establish vegetation, allow water infiltration — in short, to match your specific need.

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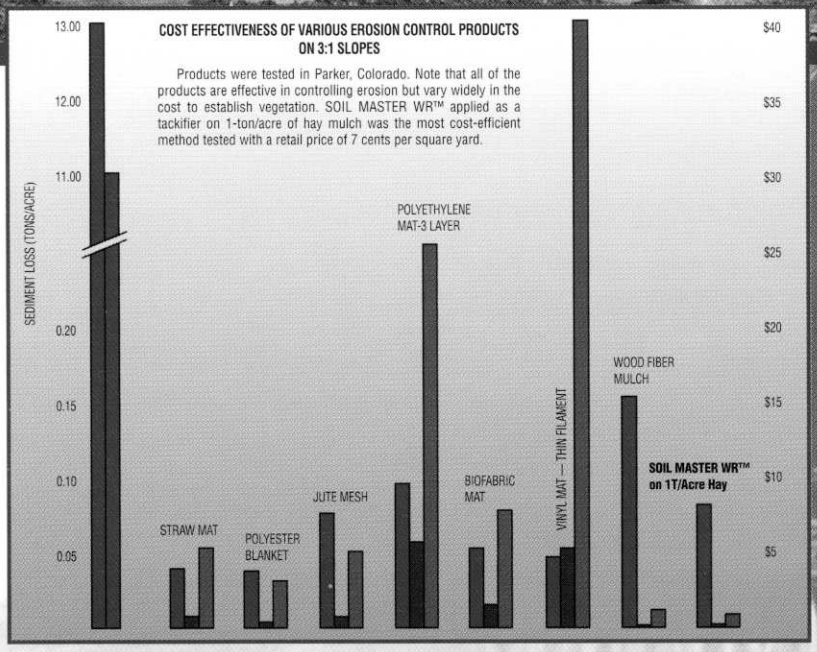
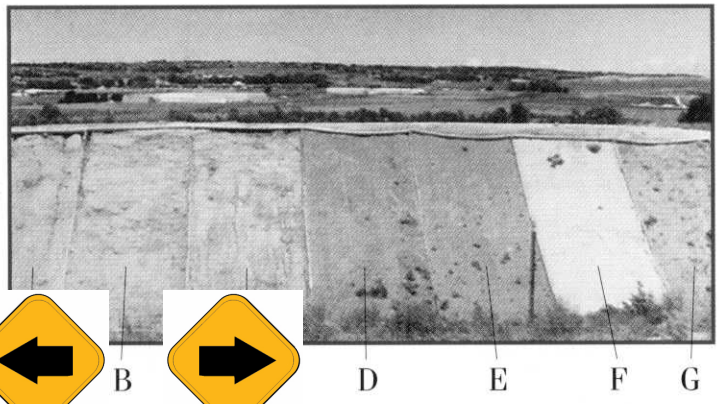
EXPENSIVE WAY TO KEEP WHERE IT BELONGS.



Soil surface condition of test plots on 1.5:1 slopes at Parker, Colorado.

SOIL MASTER™ and hay (G) had a runoff value per inch of precipitation far less than control plot (C) or either of the hydraulic mulches (paper and wood fiber – A and B). SOIL MASTER™ works not only as a tackifier keeping hay in place but acts as a viable sealer of soil particles when used alone – see lower left corner of the ESSI test plot. Also, note that when the geotextiles – jute mesh (D), a coconut mat (E) and a polyester blanket (F) – became saturated with water the resulting weight caused the wood test frame to buckle.



The cost? A lot less than you think.

Soil Master WR™ costs just a fraction of other methods. Plus, it's environmentally safe. Soil Master™ is non-toxic, non-flammable, non-polluting – and absolutely worry-free.

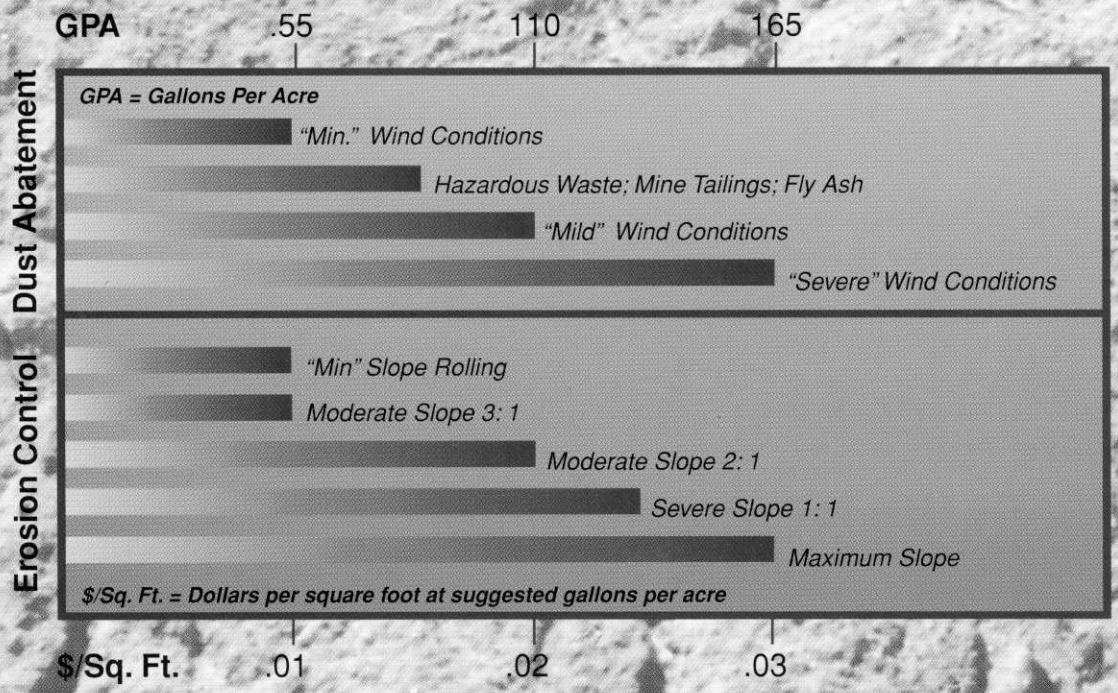
To place your order, just call.

Call us. We'll give you information on prices and application rates for your specific needs.

SOIL MASTER WR™

environmental soil systems, inc.

Suggested Application Rate of SOIL MASTER WR™



Physical Properties:

60%	Co-polymer of Methacrylates/ Acrylates/Acrylics/Tripolycate™
2.0%	Ethoxylated Surfactants
2.0%	Silicates
36.0%	Inert Ingredients
4.6 ± 0.5	pH
Milky White	Color
9.5 lbs ± 0.5 lbs	Lbs. per U.S. Gal.
Non-Toxic	Toxicity
Non-Flammable	Flammability
Slight	Odor

The Soil Master WR Warranty

Material and the values given should not be treated a specifications. Seller makes no other warranty, whether expressed or implied, including warranties of merchantability or fitness for a particular purpose. Buyer accepts liability for determining if the product is suitable for Buyer's intended use. Any recommendation as to use made by seller is done so at Buyer's risk.

Buyer shall assume all risk and liability for and shall defend, indemnify, and hold seller harmless from and against all claims, liabilities, costs, and expenses arising from or connected with the possession, transportation, handling, unloading, storage, processing or use of the product alone or in combination with other substances. Buyer's exclusive remedy and Seller's exclusive liability for damages under contract, tort, strict liability, negligence, or otherwise, shall in no case exceed so much of the purchase price as is applicable to that portion of the particular shipment with respect to which damages are claimed. In no event shall Seller be liable for incidental, indirect, or consequential damages.

SOIL MASTER WR™

environmental soil systems, inc.

16161 Ventura Blvd., #703
Encino, CA 91436
US and Canada: 888-368-9664
Outside US: 213-947-1200
Email: soilmaster_2000@yahoo.com

SOIL MASTER WR™ IS NOT AN INSECTICIDE, FERTILIZER OR PLANT FOOD PRODUCT.
Auxiliary soil and plant substance licensed by the State of California.

ENVIRONMENTAL FRIENDLY PRODUCT AND PACKAGING

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ENVIRONMENTAL
SOIL SYSTEMS, INC.
16161 VENTURA BLVD. #703 ENCINO, CA 91436
Phone & Fax: 888-368-9664 Outside US: 213-947-1200

Heidi,
Here is the information you requested.
Environmental Soil Systems, Inc. has an excellent reputation for providing top quality environmental products for the past 34 years. ESSI has helped in managing the devastating effects of our environment by controlling erosion, dust, and aiding in hydroseeding, vegetation and mine reclamation.

SOIL MASTER *is a copolymer which penetrates the soil, actively bonding the soil particles and forming a cohesive crust. The composition of this crust will deter the adverse effects of wind water and ultraviolet sunlight. The soil stabilizing emulsion is readily miscible in water, non-injurious to seed or animal life, nonflammable, and capable of providing surface soil stabilization in various soil classifications, without inhibiting water infiltration.*

SOIL MASTER *is mixed with water within a hydraulic applicator in accordance to the manufacturers instructions for your specific needs and will not change the pH unit.*

SOIL MASTER WR *is exclusively formulated with Tripolycate (not available in Soil Master DC), for maximum elasticity in order to assure complete protection in adverse weather conditions. The emulsion cures within 36 to 48 hours under normal conditions and will become transparent after drying.*

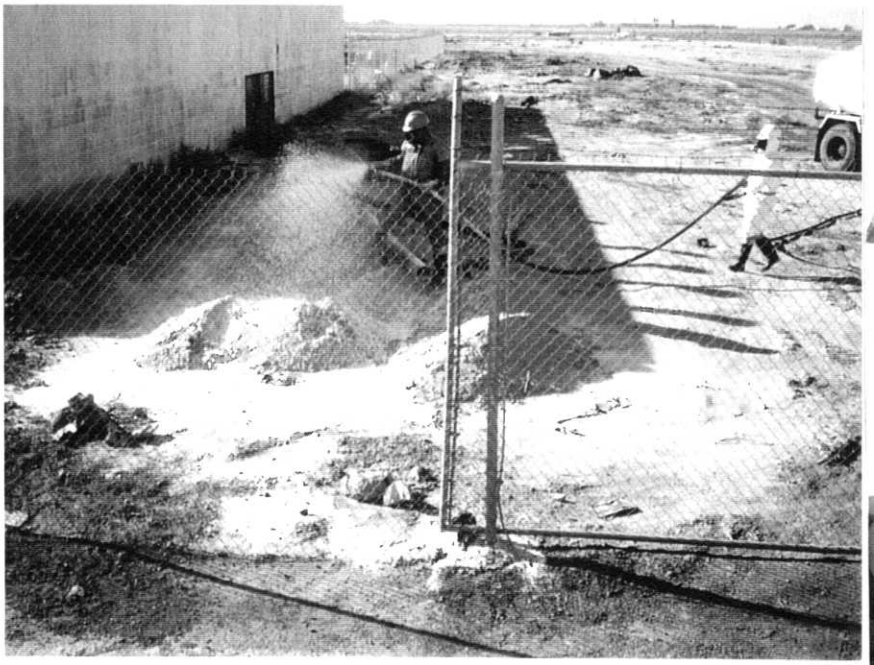
SOIL MASTER *is non-hazardous and is in compliance with both Federal and State of California regulations.*

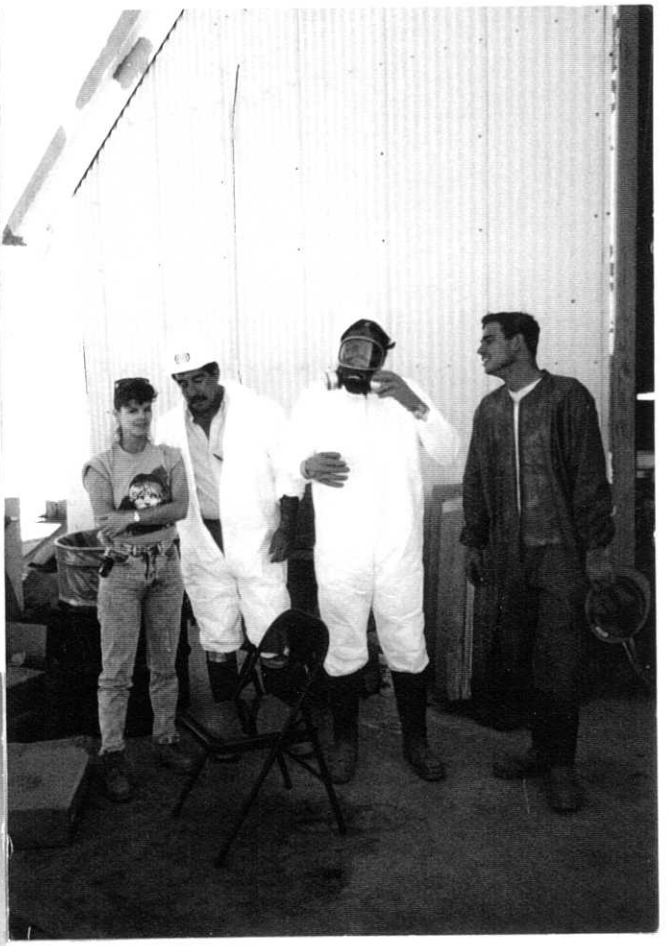
If you have any questions please contact me at 888-368-9664

Sincerely,

Darren Granard
CEO
Environmental Soil Systems, Inc.

Member of the International Erosion Control Association • Member of the Soil and Water Conservation Society
Member of the American Society of Surface & Mining Reclamation





EPA SUPERFUND SITE

HIGH WINDS-DUST CONTROL (PM10)

MOJAVE DESERT, CA.

120 GALLONS OF SOIL MASTER WR ONE APPLICATION

APPLIED OVER 30 MONTHS AGO AND STILL HOLDING

EXTREMELY RESISTANT TO ULTRAVIOLET SUNLIGHT.

SOIL MASTER WR CAN BE APPLIED OUT OF ANY STANDARD WATER TRUCK.

CAN BE USED IN PLACE OF *VISQUEEN*.

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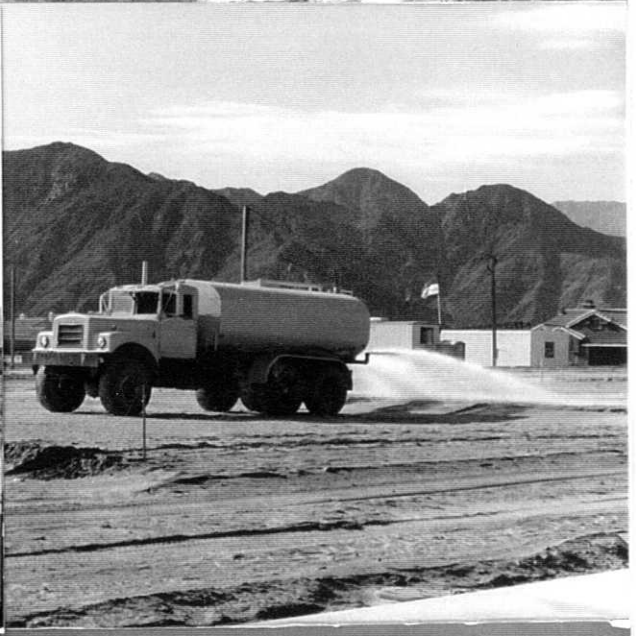

EROSION CONTROL AND DUST ABATEMENT EFFECTIVE APPLICATIONS USING ANY STANDARD WATER TRUCKS.

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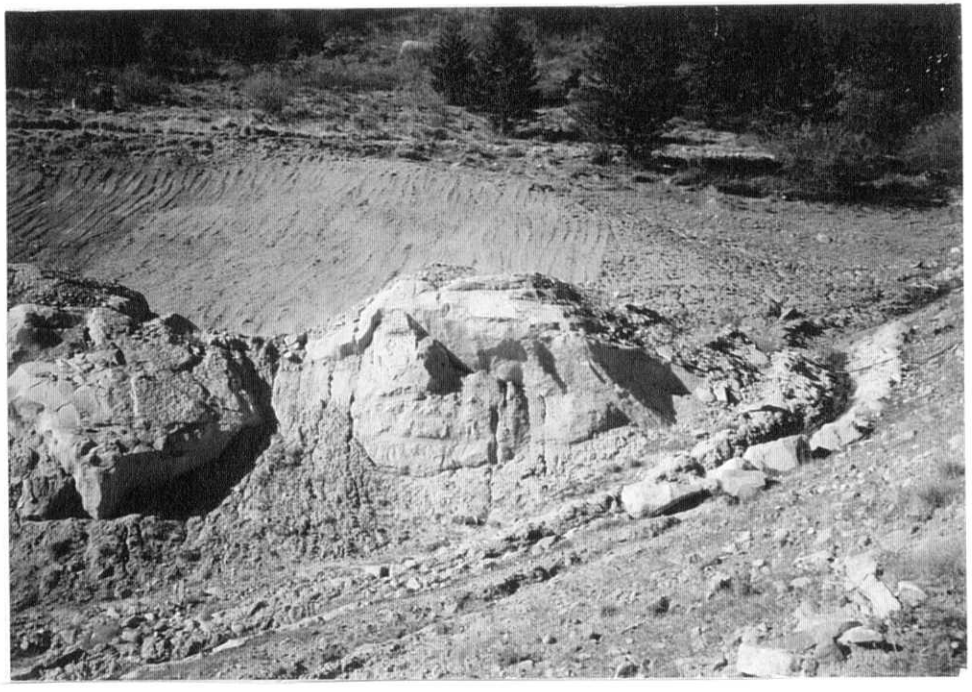

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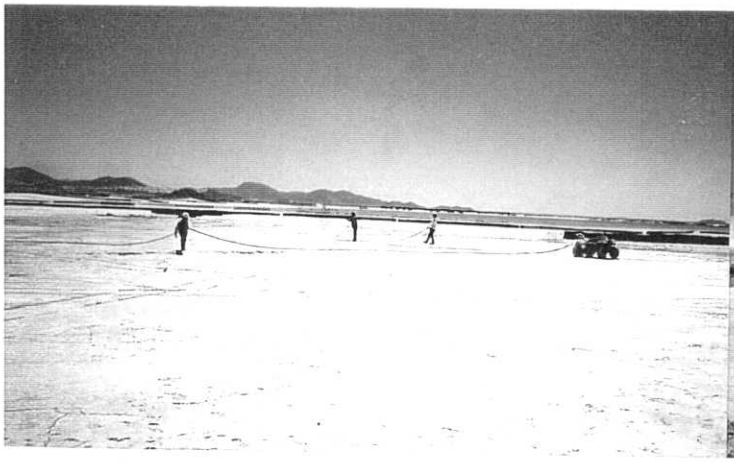
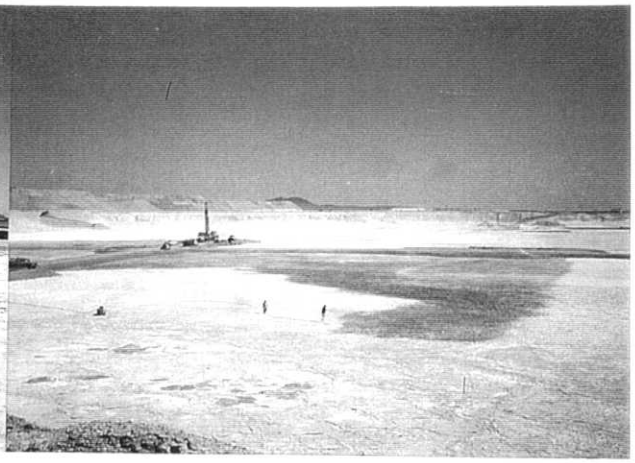
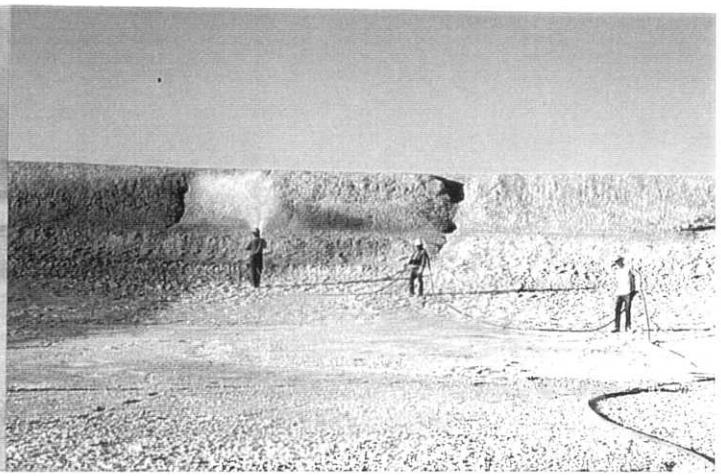
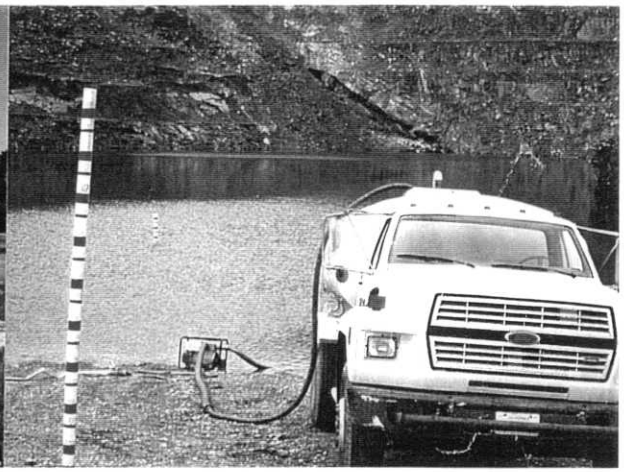
State of the art reclamation of disturbed mined land in Utah









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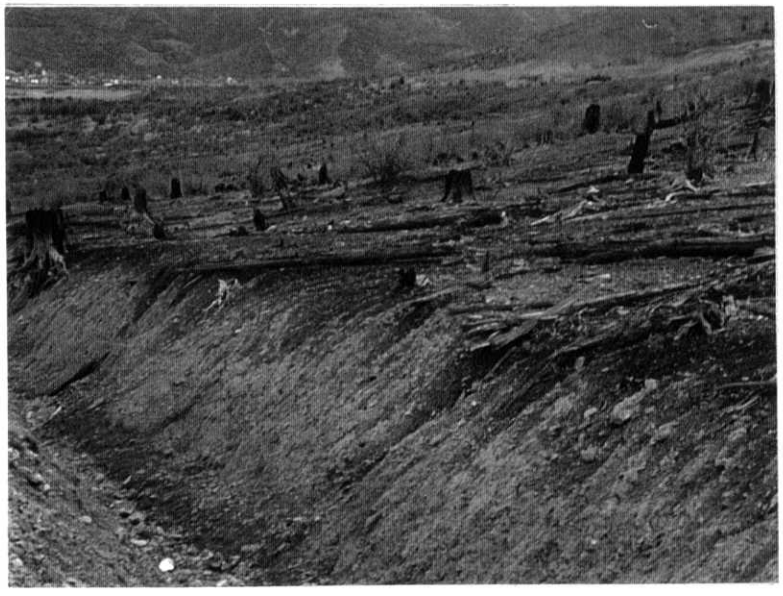

State of the art mine reclamation. SOIL MASTER WR being used at Kellogg, Idaho (Bunker Hill Project)

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Environmental Soil Systems, Inc.
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Email soilmaster_2000@yahoo.com

SOIL MASTER WR™

SOIL STABILIZING COMPOUND

The soil stabilizing substance shall be a co-polymeric emulsion, SOIL MASTER WR™ as supplied by Environmental Soil Systems, Inc., (16161 Ventura Blvd #703 Encino, Ca. 91436 • 888-368-9664) or an approved equal.

The soil-stabilizing compound shall include silicates which facilitate the penetration of the compound into the earth, and which assists in creating a crust through the cohesive bonding of the surface particles to a depth sufficient to stabilize the soil surface.
The compound shall contain an anti-foaming agent, allowing said compound to be mixed within a hydraulic application device to prohibit foaming. The compound shall contain a color additive which will assist the applicator in the uniform application of the product after mixing with water, and which will disappear from the soil surface within two weeks.
The compound shall be formulated for maximum elasticity with tripolycate, in order to assure complete protection in adverse weather conditions, and shall be formulated for maximum resistance from degradation by ultraviolet radiation or sunlight.

The soil-stabilizing solution shall be applied in accordance with the manufacturers instructions. The stabilizing compound shall be poured into a container with water required for its proper mixture. The soil-stabilizing compound shall be added to the water in a quantity so as to achieve the manufacturers recommended solution. The solution shall be applied at a rate to provide coverage of 55 to 110 gallons of soil stabilizing compound per acre. The soil stabilizing solution shall be applied evenly in a homogeneous spray, the droplets of which should not be smaller than those encountered in a moderate rainstorm. All materials shall be delivered to the site in unopened containers, and all containers shall remain tightly closed until used.

The soil-stabilizing emulsion shall consist of not less than 60% active solids, and shall be readily miscible in water, non-injurious to seed or to animal life, non-flammable, and capable of providing surface soil stabilization in various soil classifications without totally inhibiting water infiltration. When the emulsion is mixed with water and applied to the soil, it shall not change the pH of the soil more than one (1) pH unit. The emulsion shall air cure within 36 to 48 hours under normal conditions and must be transparent after drying.

Member of
International Erosion Control Association
Soil and Water Conservation Society American ♦ Society of Surface & Mining Reclamation

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SOIL MASTER WR™

ENVIRONMENTAL SOIL SYSTEMS, INC.

Serving the Erosion Control Industry Worldwide since 1968

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WHAT IS SOIL MASTER WR™?

SOIL MASTER WR™ is a liquid co-polymer, specially formulated, of Methacrylates/ Acrylates/ Acrylics (with TRIPOLYCATE™), Ethoxylated Surfactants, and Silicates.

This special formula has been designed to penetrate the soil and form a long lasting crust through cohesive binding of the soil particles.
SOIL MASTER WR™ is highly resistant to ultra-violet radiation and to breakdown by moisture.
SOIL MASTER WR™ is non-toxic, non-hazardous, and is registered with
The State of California as an auxiliary soil substance.

HOW DOES SOIL MASTER WR™ WORK?

SOIL MASTER WR™ is packaged in a concentrated liquid form and then diluted with water in the field for application. A typical ratio is twenty (20) parts water to one (1) part of concentrate. However, this ratio can vary depending on project conditions.
The SOIL MASTER WR™ is showered onto the soil surface to be treated using a dense soaking spray.

SOIL MASTER WR™ works by penetrating into the soil surface and forming a crust (membrane) through cohesive binding of the soil particles. The crust thickness will vary depending on soil conditions, application rate and dilution ratio (amount of total solution). You can generally expect to obtain between ¼" to ½" crust.
Once SOIL MASTER WR™ is cured, it will not re-emulsify by subsequent rainfall or irrigation.

The life of a SOIL MASTER WR™ application will vary upon the forces of erosion involved soil conditions, application rate, and crust thickness.
SOIL MASTER WR™ can provide satisfactory Erosion, Dust (PM10), and
Blow Sand Control from twelve (12) to eighteen (18) months
at a very economical rate of application.

HOW IS SOIL MASTER WR™ APPLIED?

A standard water truck, hydroseeding equipment, or agricultural spray unit can be employed for the application.
SOIL MASTER WR™ combines readily with water and requires minimal agitation to be properly mixed for application.
A SOIL MASTER WR™ solution should be applied as a dense, soaking spray to promote maximum soil penetration and crust thickness.
SOIL MASTER WR™ is packaged as a concentrate and requires dilution with water at the time of application. The applicator will insure the SOIL MASTER WR ™ is applied in an even and consistent manner [Avoiding excessive runoff during application].

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SOIL MASTER WR™ APPLICATION TIPS

1. Avoid application to excessively damp soils or application during stiff breezes.
2. Do not apply during rainfall or during times when rain is expected.
3. Irrigation should be withheld from a newly treated area until satisfactory curing has occurred.

CURING

A SOIL MASTER WR™ solution will require from twenty-four (24) to forty-eight (48) hours to properly cure, depending on the temperature, humidity, and moisture content of the soil.
Once the SOIL MASTER WR™ treatment has cured, freezing conditions will not generally impair the strength and life of the application.
A treatment can be harmed during the curing period by rainfall, irrigation or freezing weather (below 32 degrees Fahrenheit).

FRIENDLY TO FLORA AND FAUNA

SOIL MASTER WR™ is non-toxic to plants, and animals. It is not harmful to existing vegetation. Areas treated with SOIL MASTER WR™ will continue to exhibit normal weed growth and occurrence of natural plant life.

APPLICATION NOTES

When SOIL MASTER WR™ is applied by a water truck, it is recommended to first fill the water tank partially full with water before adding the appropriate amount of concentrate . Add the SOIL MASTER WR™ concentrate. Complete filling the truck to the full level with water. *This alone* will act to satisfactorily mix the SOIL MASTER WR™ into a homogenous solution. The same approach is suitable for agricultural spray equipment. Hydroseeding units are equipped with a means of agitation, which can be employed for mixing.

CLEAN UP

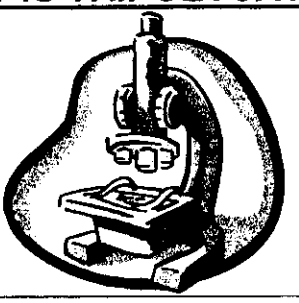
All tools and equipment, including agitators and pumps, should be flushed thoroughly with water, to remove any build up of SOIL MASTER WR™. Care must be taken to control drift and over spray onto adjacent areas. Over spray, as well as spilled concentrate, can be cleaned up with water or diesel fuel. Provided that the concentrate has not been allowed to stand for too long.
Having a small amount of water or diesel fuel on hand to clean up any spill or over sprays can be helpful.

ADDITIONAL INFORMATION

All SOIL MASTER WR™ concentrate containers should be properly stored and kept tightly closed when not in use. Keep out of the reach of children as a matter of good practice.

The foregoing should be taken as specific recommendations for the use of SOIL MASTER WR™ (with TRIPOLYCATE™) **only**. Manufacturers and suppliers of other chemicals, and equipment used in conjunction with SOIL MASTER WR™ should be contacted for specific recommendations regarding the application and used of their respective products.

WHAT IS TRIPOLYCATE™?



TRIPOLYCATE™ is a special formula blend, invented and trademarked by Environmental Soil Systems, Inc. back in 1968. When added to Soil Master WR™, or any of its licensee's formulas, the crust (membrane) achieves an elasticity. TRIPOLYCATE™ allows the crust to expand in the heat and contract in the cold. Thereby preventing possible "pop outs" in the crust.
Other liquid co-polymers, without TRIPOLYCATE™, are known to dissipate in the heat and cold.
TRIPOLYCATE™ adds longevity to Soil Master WR™ and other licensed liquid co-polymer formulations for erosion control, dust (PM10) and blow sand control.

ENVIRONMENTAL SOIL SYSTEMS, INC.
U.S. OR CANADA: 888-368-9664
OUTSIDE U.S.: 213-947-1200
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ROADOIL® Resin Modifie

MATERIAL SAFET

1. CHEMICAL PRODUCT & MANUFACTURER

CHEMICAL NAME.....Mixture
CHEMICAL FAMILY.....Tall Oil Fractions/Proprietary

MANUFACTURER:
Road Products Corporation
P.O. Box 22044
Knoxville, TN 37933 U.S.A.

TELEPHONE:
Health/Regulatory (865) 637-6227
Transportation (865) 637-6227

2. COMPOSITION & INFORMATION ON INGREDIENTS

	wt%	CAS Registry #
A. Tall Oil Fractions/ Proprietary	50	008016-81-7/Proprietary
B. Water	49	None
C. Surfactant	1	Proprietary

3. HAZARDOUS IDENTIFICATION

HMIS CODE: HEALTH 1 FLAMMABILITY 0 REACTIVITY 0
NFPA CODE: HEALTH 1 FLAMMABILITY 0 REACTIVITY 0

POTENTIAL HEALTH EFFECTS

PRIMARY ROUTES OF ENTRY: Eyes, inhalation and skin
TARGET ORGANS: Eyes, upper respiratory tract and skin
EYE CONTACT: Avoid eye contact.
SKIN CONTACT: Avoid skin contact. Repeated or prolonged skin contact may cause skin irritation or sensitization effect in susceptible individuals. Maintain good hygiene practices.
SKIN ABSORPTION: A single exposure is not likely to result in the product being absorbed through the skin in harmful amounts.
INGESTION: Ingestion in large amounts is unlikely. Ingestion of small amount is not likely to cause acute toxicity or internal damage.
INHALATION: Avoid breathing vapors.

4. FIRST AID MEASURES

INHALATION: Using proper protection, remove affected personnel to fresh air. If respiratory irritation occurs or if breathing becomes difficult, get medical attention.
EYE CONTACT: Irrigate eye with plenty of low-pressure water for 15 minutes. Remove contact lenses to insure thorough flushing. Seek medical attention if irritation persists.
SKIN CONTACT: Wash affected areas with soap and running water. If irritation develops, seek medical attention. Do not reuse contaminated clothing without laundering.
INGESTION: Product is not considered toxic in small amounts. Obtain medical treatment if large amounts are swallowed.
NOTES TO PHYSICIAN: The decision of whether to induce vomiting or not should be made by an attending physician. If lavage is performed, suggest endotracheal and /or esophageal control. No specific antidote. Specific treatment must be based on judgment of the physician in response to reactions of the patient.

This MSDS was prepared by the manufacturer, Road Products Corporation, and is provided by Soil Stabilization Products Company, Inc.
For project support, contact SSPCo: Ph: (209) 383-3296 or (800) 523-9992

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5. FIRE FIGHTING MEASURES

FIRE AND EXPLOSION HAZARDS: This product is not defined as flammable or combustible. However, under very extreme fire conditions, it may support combustion and decompose to emit oxides of carbon, acrid dense smoke, trace oxides of sulfur, water and other products of combustion.

FIRE FIGHTING INSTRUCTIONS: Use carbon dioxide, dry chemical or water spray to extinguish fires. Wear self-contained, positive pressure breathing apparatus and full fire fighting protective clothing. Keep nearby containers cool with water spray.

FIRE FIGHTING EQUIPMENT: Use SCBA and thermal protective clothing. Use carbon dioxide, dry chemical, or water spray to extinguish fires.

6. ACCIDENTAL RELEASE MEASURES

CLEANUP: Isolate spill area and restrict non-essential personnel from area.

Small spills should be absorbed with a suitable, inert material (e.g., sand or earth). Remove the absorbed material, and place in an appropriate chemical waste container for disposal. Flush the spill area with detergent and water.

Large spills should be diked to prevent spreading. Pump spilled material to salvage according to a predetermined plan. Remove residual material, and flush spill area with detergent and water.

7. STORAGE AND HANDLING

STORAGE TEMPERATURE: Ambient
STORAGE PRESSURE: Atmospheric

Maintain good housekeeping. Avoid skin contact.

Wear protective equipment when handling this product to prevent eye and skin contact.

Use approved equipment for transport of containers to avoid puncturing or rupturing containers.

Emptied containers may retain product residues. Follow all warnings and precautions even after container is emptied.

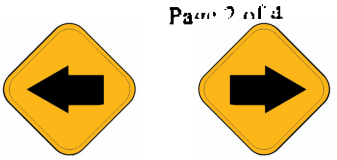
8. EXPOSURE CONTROL/PERSONAL PROTECTION

RESPIRATORY PROTECTION: The intended use of this product is outdoors in a well-ventilated area. For exceptions to these conditions...

Use a NIOSH-approved organic vapor respirator with dust, mist and fume filters to reduce potential for inhalation exposure if use conditions generate vapor, mist or aerosol and adequate ventilation (e.g., outdoor or well-ventilated area) is not available. Where exposure potential necessitates a higher level of protection, use a NIOSH-approved, positive-pressure/pressure-demand, air-supplied respirator.

When using respirator cartridges or canisters, they must be changed frequently (following each use or at the end of the workshift) to assure breakthrough exposure does not occur.

SKIN PROTECTION: Skin contact with this product should be prevented through the use of suitable protective clothing, gloves, and footwear selected with regard for use condition exposure potential. Protective equipment made of neoprene or nitrile rubber is recommended.



EYE PROTECTION: Eye contact with liquid or aerosol must be prevented through the use of chemical safety goggles or a face shield selected with regard for use condition exposure potential.

VENTILATION PROTECTION: Prevent accumulation of vapors with sufficient ventilation.

PERSONAL PROTECTION: For operations where prolonged or repeated contact of product with skin can occur, wear cotton or any type rubber work gloves, safety glasses, long sleeve shirt, and work pants to prevent skin contact with product.

9. PHYSICAL AND CHEMICAL PROPERTIES

Appearance and Odor: Light brown watery liquid emulsion with odor of tall oil pitch.
Specific Gravity: 1.0
pH: 6-8
Boiling Point: 212° F 100° C
Freezing Point: 32° F 0° C
Physical State: Liquid
Percent Volatiles: < 0.5 (EPA Method 24)
VOC: < 5 ppm (Method SW846 8020)
Solubility in Water: Dilutable
Seta Flash Point (°F): >400
Vapor Pressure: <17 @ 20° C

10. STABILITY AND REACTIVITY

GENERAL: This product is stable and hazardous polymerization will not occur.
INCOMPATIBLE MATERIALS AND CONDITIONS TO AVOID: Avoid strong oxidizing agents. Avoid ignition sources.
HAZARDOUS DECOMPOSITION PRODUCTS: Normal products of combustion - carbon monoxide, carbon dioxide, trace sulfur oxides, and water.

11. TOXICOLOGICAL INFORMATION

Not Available

12. ECOLOGICAL INFORMATION

Tall oil pitch consists of predominately saponifiable esters of rosin and fatty acids. The number average molecular weight of pitch is only 700-800, indicating that little or no real polymer is present - just large molecules obtained by thermal dimerization and esterification of the materials present in crude tall oil.

13. DISPOSAL CONSIDERATIONS

Waste Management Information (Disposal): Incineration of waste material in a permitted facility is the recommended disposal method. As an alternative solidified pitch may be buried in a landfill in accordance with all applicable regulations. Any disposal practice must be in compliance with local, state, and federal laws and regulations (Local and state regulations may be more stringent than federal regulations. Contact local or state environmental agency for specific rules).

This product does not contain any CONEG metals above the regulated limits.

14. TRANSPORTATION INFORMATION

D.O.T. SHIPPING NAME:	NOT REGULATED
D.O.T. HAZARD CLASS:	NOT REGULATED
U.N./N.A. NUMBER:	NOT REGULATED

15. REGULATORY INFORMATION

OSHA STATUS: Product, as sold, is not considered hazardous by OSHA standards. See Section 2-OSHA Hazardous Components.

TSCA STATUS: This product and its components are listed on the Toxic Substances Control Act Inventory. This substance is not subject to any rule or order under Sections 4, 5, 6, 7, 8a, 8d or 12b of TSCA.

CERCLA (40 CFR 302.4) REPORTABLE QUANTITY: Not regulated.

SARA TITLE III:

SECTION 302 EXTREMELY HAZARDOUS SUBSTANCES:	NONE
SECTION 311/312 HAZARDOUS CATEGORIES:	NONE
SECTION 313 TOXIC CHEMICALS:	NONE

RCRA STATUS: If discarded in its purchased form, this product would not be a hazardous waste by characteristic per 40 CFR 261, Subpart C or by listing per 40 CFR 261, Subpart D. However, under RCRA, it is the responsibility of the product user to determine at the time of disposal, whether a material containing the product or derived from the product should be classified as a hazardous waste.

State or local hazardous waste regulations may be more stringent than federal regulations.

16. OTHER INFORMATION

Road Oyl® is a registered trademark of Road Products Corporation.

PREPARED BY:	Road Products Corporation, Regulatory Affairs Dept.
APPROVAL DATE:	5-3-01
SUPERCEDES DATE:	4-1-97
REASON FOR REVISION:	New Formulation

This information is furnished without warrantees, expressed or implied, except that it is accurate to the best knowledge of Road Products Corporation. However, since the conditions of handling and use are beyond our control, we make no guarantee of results and assume no responsibility for damages incurred by use of this material. The data on this sheet relates only to the specific material designated herein. Road Products Corporation assumes no legal responsibility for use or reliance upon these data. We do not assume any legal responsibility for nor do we give permission, inducement, or recommendation to practice any patented invention without a license. Before using any product, read its label.

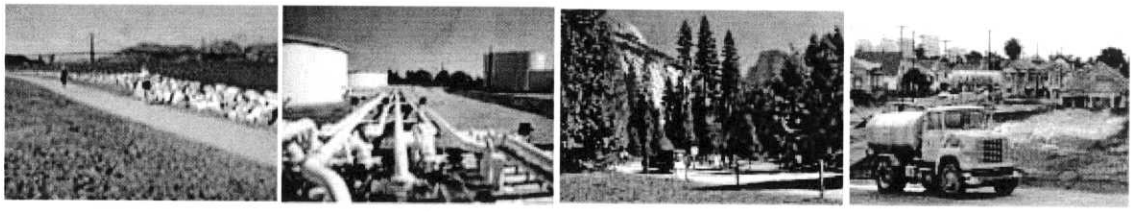
SSPCo®
A registered trademark of Soil Stabilization Products Company, Inc.

ROAD OYL® Resin Modified Emulsi

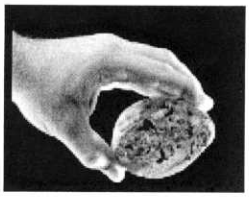
high strength
cold-applied
non-petroleum

environmentally friendly
sustainable product technol

RESIN PAVEMENTS™ & Spray Application



High Strength, Non-Petroleum Binder



The permanence of encapsulation in amber, a fossil resin material, provides striking parallel to the tremendous bonding power of ROAD OYL Resin Modifed Emulsion, a modern emulsion technology incorporating carefully selected fractions of natural tree resins.

This advanced non-ionic formulation is modified with a high fraction of rosin to create one of the strongest and most versatile adhesive binders ever developed. Although it is applied much like an asphalt emulsion, ROAD OYL Resin Modified Emulsion has advantages as a pavement binder over asphalt products in environmental acceptability, in fuel spill resistance, in bonding strength and in its capacity to be applied without the use of heat.

RESIN PAVEMENT ™

constructed with
ROAD OYL®
Resin Modified Emulsion

Pavements are constructed with aggregate mixtures manufactured and selected for sizing, angularity and other engineering properties. Asphalt and concrete are no longer the only two pavement choices. Natural earth materials can now be combined in high strength pavements using advanced emulsion technology combining natural tree resin ingredients as the pavement binder. RESIN PAVEMENTS constructed with ROAD OYL® Resin Modified Emulsion open up a whole new world in regards to performance, versatility, natural appearances and environmentally friendly product technology. The ROAD OYL emulsion is mixed with aggregate materials to produce compacted RESIN PAVEMENT™ surfaces that retain the characteristic coloration of the constituent aggregate materials and which are noted for their comparatively cool summer surface temperatures, natural appearance and exceptionally high pavement Stability measurements. Have a look at a sampling of project applications and test results.

- **RESIN PAVEMENT Highlights Major Urban Parks**
- **Controlling Dust, Erosion and Sediment with ROAD OYL Resin Modified Emulsion (various construction sites, landfills & environmental remediation projects)**
- **Sustainable Pavement Technology**

SURFACE TREATMENT & SPRAY APPLICATIONS

Going beyond the environmentally friendly formulation with natural tree resin ingredients, there are additional benefits that ROAD OYL Resin Modified Emulsion offers as a replacemer spray applied liquid asphalt products. Resin Modified Emulsion is a cold applied emulsion a consequently far simpler and safer to handle. Application crews can avoid the dangers of working around heating equipment and a heate spray product with the constant need for daily transfer from heated storage to heated transpor equipment and vice versa.

The ROAD OYL Resin Modified Emulsion formulation is exceptional in bonding and adhe strength, and it provides an environmentally friendly alternative to asphalt emulsions for pri coats, tack coats, seal coats, fog seals, erosion ar sediment control treatments, and for general du control requirements. The additional energy an labor costs that are required to constantly heat, transfer and store hot asphalt products add significantly to their initial cost and provide str motivation to evaluate a cold applied, user frien alternative. Add all the numbers up - the price the asphalt product, the labor and equipment c for the special application, handling, transporta and storage requirements associated with use of heated product; plus the air quality, worker saf and water quality concerns. In summary, it is cl that many applications can be cost-effectively addressed with labor saving clean technology. ROAD OYL Resin Modified Emulsion - the hig performance and environmentally friendly proc technology of the future is here today.

TESTING FOR SITE SPECIFIC REQUIREMENTS: The ROAD OYL Resin Modified Emulsion product is utilized for treatment of a broad spectrum of aggregate and soil materials and an equally broad spectrum of site conditions, service requirements and application types. Final determination of the suitability of any information or material for use contemplated, or for its manner of use, is the sole responsibility of the user. Individual field or laboratory tests are recommended whenever possible for final determination of the suitability of ROAD OYL Resin Modified Emulsion for specific project and performance requirements.

Road Oyl Project Photographs & Reports - Road Oyl Literature - Road Oyl Test Results

Home - Contact SSPCo Form

Last Updated September 11, 2001

This is not a construction document. These general guidelines have been prepared by the manufacturer, Road Products Corporation, to assist in project planning. For project support contact Soil Stabilization Products Company, Inc. (800) 523-9992.

ROAD OYL® RESIN MODIFIED EMULSION
FOR BARE EARTH EROSION CONTROL APPLICATIONS

HANDLING : **ROAD OYL** Resin Modified Emulsion is a water borne, or resin-in-water emulsion. Because water borne emulsions contain water, they also have similar behavior, freezing at 0°C (32°F) and boiling at 100°C (212°F). When temperatures are near the freezing point, the emulsion must be protected against further cooling. Freezing can destroy the emulsion, separating the binder from the water phase to the extent that it is no longer workable as a construction material.

While **ROAD OYL** is a non-ionic emulsion, neutral in charge, standard practices for handling of charged emulsion (anionic and cationic) should be observed regarding cleanliness of transport, storage, mixing and application tanks, as well as for all plumbing and connecting hoses. Previously handled emulsions, dust palliative products and other chemicals must be completely cleaned out before storing or handling the **ROAD OYL** emulsion. If there is any question regarding remaining residue of a previously handled product and its compatibility with the **ROAD OYL** emulsion, a small-scale compatibility test should be conducted prior to storage and handling of the product.

When transporting the **ROAD OYL** emulsion in container or bulk tanks the container or tank should be loaded as full as possible to avoid sloshing of the emulsion during transport. Tanks used for transport should, whenever possible, have baffle plates to further limit sloshing. Pumping should be as limited as possible in frequency, duration and velocity. Excessive sloshing and turbulence may cause portions of the emulsion to break prematurely, which can create unnecessary cleanup of the storage tank and problems such as plugging of spray nozzles during application.

ROAD OYL Resin Modified Emulsion is formulated so that it can be diluted with water for applications that are spray applied for surface penetration. For erosion control application the dilution ratios normally range from 0 to 20 parts water per one part **ROAD OYL** emulsion. The lower range of dilution ratios may be required for steep slope applications or for applications where a high application rate of the emulsion is required.

When adding dilution water, the water should always be added to the emulsion, as opposed to adding the emulsion to the water. Emulsions can be overdiluted, leading to premature breaking or separation of the binder material from the water phase. This precaution to avoid overdilution of the emulsion should be followed throughout dilution, application and cleanup operations. For this reason, completely flush the emulsion from storage, transport or mixing tanks before adding wash water for cleanup.

Special care should be taken when loading or unloading **ROAD OYL**, and equal care should be taken when adding dilution water. The emulsion should not be handled in a manner which will cause foaming and incorporation of air bubbles as this can cause the emulsion to break.

Bottom loading facilities are recommended, and top loading of emulsion and of dilution water should be done with special care. If top loading into a tank is necessary, minimize turbulence by controlling the add rate and by feeding the fluid in at the bottom of the tank by use of a dipleg apparatus or by placement of the filler hose at the bottom of the tank.

APPLICATION: **ROAD OYL** can be applied by nearly all types of equipment designed to apply liquids, ranging in size from small garden sprayers up to large hydroseeding trucks and water trucks. In all cases, the equipment should be capable of distributing the material in a uniform pattern, applying the solution in large droplets instead of fine mists.

Suggested clothing for your crew is disposable uniforms or old clothes and old shoes. If any of the crew wear eye glasses, safety goggles can be used to protect glasses from overspray. This is particularly appropriate on windy days. When clean-up of equipment or clothing can be immediate, a water wash may be sufficient for this water-based product. If immediate clean-up is not possible, a hot alkali solution, such as a steam genie with a strong soap, may be necessary (not recommended for most textiles).

When possible, try to schedule application of the product when wind conditions are below 5 mph. The **ROAD OYL** product is applied for erosion control applications in multiple spray passes to minimize runoff of the solution and to maximize penetration. Pre-wetting is recommended as dry materials absorb the water out of the emulsion thus inhibiting optimum coating and penetration by the emulsion. The full amount of solution planned for application to a specific area should be applied in a continuous series of spray passes (it is possible to apply part of the product on a second day to a partially treated area but the existing product would already be cured and would inhibit penetration of the second application). Curing time can range from a few hours in hot summer weather to 24 hours or more during periods of high humidity or cold weather. Allow at least 24 to 36 hours drying period for the treated area to develop maximum crust strength.

CAUTION: Care must be exercised to prevent overspray that can result from application of **ROAD OYL** in windy conditions. Each site should be evaluated prior to application for factors such as wind speed and direction. Equipment, vehicles, buildings and other items on-site which require protection from overspray should be moved or properly protected prior to the **ROAD OYL** application.

NOTE: Technical assistance provided by Soil Stabilization Products Company, Inc and Road Products Corporation and their agents is limited; we are not architects, engineers, installers or inspectors. Each site is unique and job specific. Customer is responsible for final design, installation and quality control and for final determination of the suitability of the material for the use and for its manner of use.

SOIL STABILIZATION PRODUCTS COMPANY, INC.
PO Box 2779 Merced, CA 95344-0779 Telephone: (800) 523-9992 or (209) 383-3296 Fax: (209) 383-7849

AN INTRODUCTION TO SURFACE TREATMENTS & SPRAY APPLICATIONS

TECHNICAL BULLETIN NO. 1588. RO 10/1/97

ROAD OYL® Resin Modified Emulsion

PRODUCT DESCRIPTION

ROAD OYL Resin Modified Emulsion is a modern emulsion technology using highly adhesive and sealing tree resin ingredients. This advanced non-ionic formulation is modified with a high fraction of rosin to create ***one of the strongest and most versatile adhesive binders ever developed.*** Although it is applied much like asphalt emulsion products, **ROAD OYL** Resin Modified Emulsion has advantages in bonding strength, in its capacity to be transported and applied without the use of heat and in its environmentally friendly ingredients.

Bonding strength is a measurement commonly used in the evaluation of materials utilized in the construction of flexible pavements such as the asphalt cement compounds used to bind asphaltic concrete or "hot mix" asphalt pavements. Pavement mixtures bound with the cold-applied **ROAD OYL** Resin Modified Emulsion binder typically exhibit higher strength characteristics than hot mix asphalt pavements when aggregate materials of equivalent quality are utilized.[1] This same bonding power also makes this advanced emulsion product highly effective for various surface treatment applications where binder products are spray applied to consolidated and compacted surfaces. **ROAD OYL** Resin Modified Emulsion provides ***a unique alternative to asphalt emulsions and various other low bonding strength emulsions manufactured from forest industry byproducts, latex or petroleum*** ingredients and typically sold only for dust control and erosion control applications.

While the super adhesive characteristics of the **ROAD OYL** product are most directly attributable to its high rosin content, ***it is the advanced non-ionic formulation which makes it so versatile and useful in actual application.*** The non-ionic formulation contributes to the stability of the emulsion product for shipment, storage and application, and it provides for the extended workability time necessary for the emulsion to penetrate and fully coat aggregate and soil materials during mixing and spray application processes. Less advanced emulsion formulations are subject to coalescing prematurely as they have relatively quick reaction times (also known as breaking or setting) which limit their ability to penetrate, coat, and mix - ultimately, limiting their effectiveness as bonding agents.

While **ROAD OYL** Resin Modified Emulsion is non-water soluble, it can be diluted with water for use in spray applications where surface penetration may be desirable such as dust control, erosion control, prime coats, tack coats, fog seals, seal coats and sand seals. As all emulsion types are primarily dependent upon the evaporation of water for development of their curing and adhesion characteristics, addition of dilution water to an emulsion will also have some effect on retarding the breaking or setting time and slowing the curing time beyond that experienced with the undiluted emulsion product. When working in conditions where evaporative rates are high or the surface to be treated is highly absorptive, the ability to dilute the emulsion becomes essential to avoiding premature breaking of the emulsion and loss of its full penetration and bonding capabilities.

SURFACE TREATMENTS

The term "surface treatment" is widely and variously interpreted, and, in general use, includes spray applications of emulsion product as well as applications in which an emulsion product is sprayed on a prepared surface followed by an application of cover aggregate which is then rolled. This section addresses only applications which include use of cover aggregates traditionally known as single and multiple surface treatments or single and multiple chip seals. Chip seals are quite often referred to as surface treatments when they are applied to unpaved surfaces and as seal coats when applied to existing paved surfaces. The "seal coat" terminology is also in general use for application of emulsion to the surface of existing pavements without the additional application of a chip or aggregate material.

ROAD OYL Resin Modified Emulsion is a relatively low-viscosity emulsion as this is essential for application to dense graded aggregates for pavement construction and for spray applications such as dust control, erosion control, fog seals, prime coats and tack coats. Penetration and coating are important to all these applications.

Chip seal and surface treatments, on the other hand, most often use very open graded aggregate materials or single size aggregates which require use of higher viscosity, rapid setting emulsion binders. If circumstances do exist for a particular project where use of a **ROAD OYL** surface treatment (i.e., chip seal type surfacing) might be uniquely appropriate, such as an architectural or historical setting in which a lighter colored surfacing is desired, or at an environmentally sensitive project location, then a dense graded aggregate material must be selected so that a mix of fine sized materials is present along with the larger stone to ensure an aggregate blend with controlled void content and high density.

Surface treatments are specialized applications which must be adapted to job conditions, local usages and anticipated performance requirements. **For any large scale project, a qualified materials testing laboratory should be utilized for testing and design services.** Organizations which desire to develop their own application designs should consult local aggregate suppliers and experienced contractors. **ROAD OYL** ***Resin Modified Emulsion is available in 19 liter (5 gallon) pails, 208 liter (55 gallon) drums, and 1,040 liter (275 gallon) palletized totes as well as bulk shipments so that quantities can be purchased for test pad evaluation programs.*** The best single source of general information regarding chip seal and surface treatment construction is the Recommended Performance Guidelines, Second Edition, published by the Asphalt Emulsion Manufacturers Association (AEMA) [2]

SPRAY APPLICATIONS

Fog Seals, Seal Coats, Tack Coats and Prime Coats: Fog seals, seal coats and tack coats all involve application of an emulsion to the relatively non-absorbent surfaces of existing pavements. Fog seals are light applications of emulsion used primarily to seal existing pavements and to reduce raveling. A slightly heavier application of emulsion to a pavement surface, applied in a similar manner to a fog seal and for the same purposes, is often described as a seal coat or a surface seal. Tack coats are spray applications to existing asphalt or concrete pavements prior to a new pavement overlay or patch to provide a bond between new and existing pavement layers. Prime coats are applications to absorbent surfaces or to a granular base in preparation for placement of a pavement surface course. **ROAD OYL** Resin Modified Emulsion is highly suitable for all these applications and can be applied undiluted or diluted, depending upon project specifications and the surface requirements at time of application. Again, the AEMA's Recommended Performance Guidelines, mentioned above, can be used for additional general reference on these types of application. **ROAD OYL** Resin Modified Emulsion has exceptional adhesive and sealing characteristics which make it ideal for fog seal, tack coat and prime coat requirements in terms of performance, but it really stands out when its versatility for all these application types and its advantages in storage, handling, and safety are considered.

ROAD OYL Resin Modified Emulsion provides an environmentally friendly, non-restricted alternative with excellent stability for bulk storage requirements. Other than protecting the emulsion from freezing temperatures, the ***ROAD OYL product requires no heating for storage, transportation, handling or application.*** Eliminating products which must be maintained at high heat eliminates unnecessary heating costs, but even more important is the elimination of a hazard to construction and maintenance crews who no longer need to transport, handle and apply heated products nor operate heating equipment. A cold applied emulsion has even more advantages in safety and cost reduction for construction and maintenance organizations which have traditionally transported heated emulsion for daily fog seal, tack coat and prime coat applications. Along with the attendant need to pump the material out of heated storage and back in on a regular basis comes the need to flush and clean hoses and lines each time with toxic solvent materials. Cleaning requirements can be greatly reduced with a cold-applied emulsion which can remain in transport tanks for extended periods. Reduction or elimination of solvent materials used in flushing of lines and tanks also reduces costs for proper disposal of these materials.

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[1] For more information about pavement test results using **ROAD OYL** Resin Modified Emulsion as a pavement binder, see **ROAD OYL** Resin Modified Emulsion Test Results (Technical Bulletin 1006.RO, 8/01/97), prepared by Road Products Corporation and available from Soil Stabilization Products Company, Inc.

xmmende s. Asphalt Emulsion Manufacturers Association (AEMA), Annapolis, MD.

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Dust Control for Unpaved Roads: When using emulsion spray applications for dust control of unpaved roads and other trafficked surfaces, many similarities to fog seal, seal coat, and prime coat projects are evident. Application rates are very site specific, depending in large part on the absorbency (or non-absorbency) of the surface. The task with each project is to apply an adequate rate of emulsion to meet project objectives while avoiding an over-application situation in which curing of the surface is greatly retarded and damage to the newly treated surface will be experienced if extended restriction of traffic is not possible.

ROAD OYL Resin Modified Emulsion is diluted with water for spray application to compacted surfaces for dust control. Dilution can range up to 5 to 1 and higher. The dilute solution is applied in repeated light applications with actual quantity dependent on the condition of the surface. If the road is penetrable or contains relatively large surface voids, a greater amount of dilute emulsion can be applied. ***Durability of the treatment will, of course, be highly dependent upon the stability of the underlying aggregate and soil materials.*** As with all spray applications, uniformity of application is essential and pressurized distributor trucks are the recommended application equipment. For less critical dust control applications, water trucks are often used at the project owner's option to apply the emulsion solution. Bulk on-site storage is always preferred so that exact application rates and methods and maintenance frequency can be tailored to the specific road and traffic conditions.

General Information: For all of the above spray applications, high quality results are dependent upon application of the emulsion at a controlled rate by a pressurized distributor. Nozzle angle and spray bar height must be adjusted to ensure correct spray pattern. Two or more successive applications of a portion of the desired total application may be required to minimize loss of emulsion by runoff and to aid in preventing over-application. All applications must be allowed to cure completely before opening to traffic. Localized areas of over-application should be observed with care and, at the discretion of the project engineer, a light cover or dusting of clean fine sand may be applied onto the uncured emulsion to protect the surface from damage when traffic is restored.

If project specifications require rolling of a spray application, the use of pneumatic-tired rollers is recommended and rolling should begin immediately following application. Rolling should be completed before the emulsion begins to break or set in order to avoid tracking and pick up of the tacky curing surface.

For seal coat or surface seal applications for which a light dusting or cover of sand is specified, or for sand seal applications for which heavier rates of emulsion and sand are specified, care should be given to uniform distribution of the sand. Sand spreading equipment should be operated to demonstrate ability to meet project requirements before emulsion or sand is applied.

Bare Earth Erosion Control: **ROAD OYL** Resin Modified Emulsion is an excellent soil surface stabilization treatment for bare earth erosion control and for dust control of untrafficked areas of exposed soils. For additional information, request the Technical Bulletin listed below, "Bare Earth Erosion Control."

SETTING & BREAKING RATES

Emulsion binder products are formulated so that they can be applied to a surface or mixed with an aggregate before they begin to coalesce and adhere to the material. This period of is limit breaking time. While lsion pr d to set or break more rapidly than others, all emulsions depend primarily on the evaporation of water for development of their curing and adhesion characteristics and conditions specific to the particular project control to a large degree the actual setting or breaking time as well as the curing time. Some of the general factors which control the setting rate of an emulsion treatment are listed below:

1. Water is absorbed by the aggregate or soil or pavement material. A highly porous or rough-textured material speeds the setting rate by rapidly absorbing water. Fine particle soils or high fines content aggregates can have the same effect and the mineral composition of the material can also be of influence.

2. The moisture content and temperature of the surface of the aggregate or soil or pavement being treated.

3. Weather conditions have great influence and temperature, humidity and wind speed all affect the rate of setting.

4. Mechanical measures such as rolling or trafficking to a limited extent force water from the treated material.

WEATHER

Application should not continue during rainfall, nor should it begin when rain is expected. The ambient temperature must be above 16°C (60°F) during construction and temperatures above 21°C (70°F) are preferred. Temperature is one of the most important variables influencing evaporation and the setting and curing of the emulsion treatment.

APPLICATION RATE & METHOD

Having reviewed the previous information, it's clear that the problem solving associated with designing effective surface spray applications may be quite different from project to project. The variables and their interaction are specific to each project. While local agency or contractor practice with other emulsion products may be an available reference, on-site experimentation and field testing is often the preferred method of determining application rates, dilution rates and application methods best suited to a particular project. ***Project design engineers often specify construction of test pads preliminary to the actual construction project so that adjustments can be made, if necessary, to suit field conditions*** before approval is given to proceed with the full scale project.

For projects in which dilution of **ROAD OYL** Resin Modified Emulsion is required, but no dilution rate has been specified, on-site evaluation is recommended. While increasing the dilution rate can, in many cases, speed and increase penetration of a surface, dilution adds a complication to the problem solving process. At a higher rate of dilution, more total liquid must be applied to a specific area to achieve the desired application rate of the emulsion binder. As a low-viscosity emulsion, the **ROAD OYL**treatment will flow down slope like water when the application rate exceeds the penetration rate. The problem becomes more acute on steep slopes. While application effectiveness can often be improved by multiple applications applied in succession, there is a practical limit as to how much emulsion can be applied to a surface. Excess runoff and loss of emulsion should be avoided. Ponding or puddling should be avoided on any surface which will be opened to traffic. Application should not be placed in single or multiple application to such thickness that evaporation and curing are greatly retarded, unless extended curing time is not of concern.

All of these complications are quite manageable, of course, with a bit of ***onsite testing to find the best combination of application rate, dilution and method of application.*** Recommendations for your project field testing program, including a range of application rates of the **ROAD OYL** emulsion and a range of dilution rates to evaluate, may be available from the manufacturer. In many cases, these field tests may be conducted with equipment as simple as a hand operated hand sprayer device. As noted above, **ROAD OYL** Resin Modified Emulsion is available in a broad range of container sizes so that quantities can be purchased to suit field testing program requirements.

CONSTRUCTION SPECIFICATIONS

Construction specifications are specific to a particular project. The final construction specification is a document customized by the project design engineer to suit requirements which are unique to the project while also incorporating standards, methods and equipment guidelines which are adapted to the standards and resources of the area or region where the project is located.

TECHNICAL INFORMATION

Having reviewed this introduction, if you are interested in designing, specifying or utilizing **ROAD OYL** Resin Modified Emulsion, please contact Soil Stabilization Products Company, Inc., for the following manufacturer's technical information provided by Road Products Corporation:

- Technical Bulletin No. 1000.RO: "ROAD OYL Resin Modified Emulsion STORAGE PROCEDURES"
- Technical Bulletin No. 1557.RO: "Utilizing **ROAD OYL** Resin Modified Emulsion As A Pavement Binder"
- Technical Bulletin No. 1558.RO: "**ROAD OYL** Resin Modified Emulsion HANDLING GUIDELINES"
- Technical Bulletin No. 1574.RO: "**ROAD OYL** Resin Modified Emulsion For Bare Earth Erosion Control and Sediment Control Applications"
- Technical Bulletin No. 1587.RO: "**ROAD OYL** Resin Modified Emulsion "An Introduction to Pavement Applications"

For additional information contact:
SOIL STABILIZATION PRODUCTS COMPANY, INC.
P.O. Box 2779, Merced, CA 95344-0779 • (800) 523-9992 • (209) 383-3296
FAX: (209) 383-7849 • E-mail: staff@sspco.org

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MATERIAL SAFETY DATA SHEET

Non Toxic Material, Unregulated

I. PRODUCT IDENTIFICATION

TRADE NAME: ***PolyPavement Soil Solidifier***

MANUFACTURER: ***PolyPavement Company*** (As specified by ECO-Polymers)
P.O. Box 36339
Los Angeles, California 90036

Phone: 323 954 2240

DATE REVISED: January, 1997

II. COMPOSITION / INGREDIENTS

NON HAZARDOUS, NON-TOXIC (Acute Static Aquatic Test @ 7,450 ppm or better)

WATER BASED ACRYLIC-LIKE COPOLYMER EMULSION BLEND

Variations in physical properties of emulsified polymer particles and solids content of CF, SS, PP and AMX trade names. (i.e. weight, particle size, viscosity, color, emulsifier)

No contents or ingredients have been identified as a carcinogen or probable carcinogen by NTP, IARC, or OSHA.

III. PHYSICAL PROPERTIES

Vapor Density (Air = 1): Same as Water

Specific Gravity: Approximately 1.1

Solubility in Water: Insoluble/Dilutable

Vapor Pressure, mmHg @ 20 °C: Approx. 17.5

Appearance, Odor: Milky-yellowish fluid,
Slight ester odor

Detection: No special detection methods required.

Melting point or range °F: Not Applicable

Boiling Point: Approximately 212 °F

Evaporation Rate: Non-evaporative, water transported material

NOTE: This format is a modified version of the format provided by Cal/OSHA to assist MSDS preparers and users. It contains all of the required information. Some non applicable categories are omitted.

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IV. FIRE AND EXPLOSION

Flash Point, °F (give method) None wet; dried solid: greater than 400 F if any
Auto ignition temperature, °F Not applicable
Flammable limits in air, volume % Not applicable **lower (LEL)** N/A **upper (UEL)** N/A

Fire extinguishing materials: for dried solids

x water spray	x carbon dioxide	____ other:
x foam	x dry chemical	

Special firefighting procedures: Water may be useful in keeping fire exposed containers cool.
Unusual fire and explosion hazards: None

V. HEALTH HAZARD INFORMATION

SYMPTOMS OF OVEREXPOSURE for each potential route of exposure.

Inhaled: Not applicable
Contact with skin or eyes: Wash with water, a mild soap may be helpful for skin.
Absorbed through skin: Not applicable
Swallowed: Seek medical attention

HEALTH EFFECTS OR RISKS FROM EXPOSURE. Explain in lay terms. Attach extra page if more space is needed.

Acute: None

Chronic: None

FIRST AID - EMERGENCY PROCEDURES

Eye contact: Wash with water.
Skin contact: Wash with water, a mild soap may be helpful.
Inhaled: Not applicable.
Swallowed: Seek medical attention.

SUSPECTED CANCER AGENT?

x **NO: This product's ingredients are not found in the lists below.**

YES: x **Federal OSHA** x **NTP** x **IARC**

California employers using Cal/OSHA - regulated carcinogens must register with Cal/OSHA. The Cal/OSHA and Federal OSHA carcinogen lists are similar.

MEDICAL CONDITIONS AGGRAVATED BY EXPOSURE

N/A

VI. REACTIVITY DATA

Stability: __x__ **Stable** _____ **Unstable**

Conditions to avoid: Not applicable, temperature extremes are not recommended.

Incompatibility (materials to avoid): No hazardous reactions are expected under normal industrial conditions

Hazardous decomposition products (including combustion products):
Combustion may yield carbon monoxide and/or carbon dioxide and/or traces of residual monomer.

Hazardous polymerization: _____ **May occur** __x__ **Will not occur**

VII. SPILL, LEAK AND DISPOSAL PROCEDURES

Spill response procedures (include employee protection measures):
Flush into suitable retaining areas or containers with large quantities of water. Small amounts may be absorbed into an appropriate absorbent. Prevent spill from entering sewers, drainage systems and waterways. Contact local agencies/authorities.

Preparing wastes for disposal (container types, neutralization, etc.):
No special disposal preparation required.

NOTE: Dispose of all wastes in accordance with federal, state and local regulations.

VIII. SPECIAL HANDLING INFORMATION

INDOOR Ventilation and engineering controls
Local exhaust ventilation may be helpful and may be needed if existing ventilation is inadequate.

INDOOR Respiratory protection (recommended type)
Though vapor is harmless, when ventilation is inadequate, the slight ester odor might be annoying. NIOSH approved respirator or gas mask with appropriate cartridges and canisters may be needed to minimize exposure to odor.

Eye protection (type)
Splash or splatter protective goggles recommended to avoid eye contact. Contact with eyes causes burning sensation similar to soap or mild shampoo.

Gloves (specify material)
Impermeable gloves recommended to avoid skin contact. Material is a rubber-like glue that dries to a film. Film is harmless to the skin but it has to be rubbed off.

Other clothing and equipment
Impermeable clothing should be worn as needed. If material comes in contact with clothing, it is not easily cleaned off of the fabric. Clothing may be irreparably damaged.

Work practices, hygienic practices
Keep product containers closed when not in use.

Other handling and storage requirements
Avoid extreme temperatures. AVOID FREEZING. Shocking the emulsion with large quantities of chemicals or extreme shear may cause coagulation.

Protective measures during maintenance of equipment None other than as stated above.

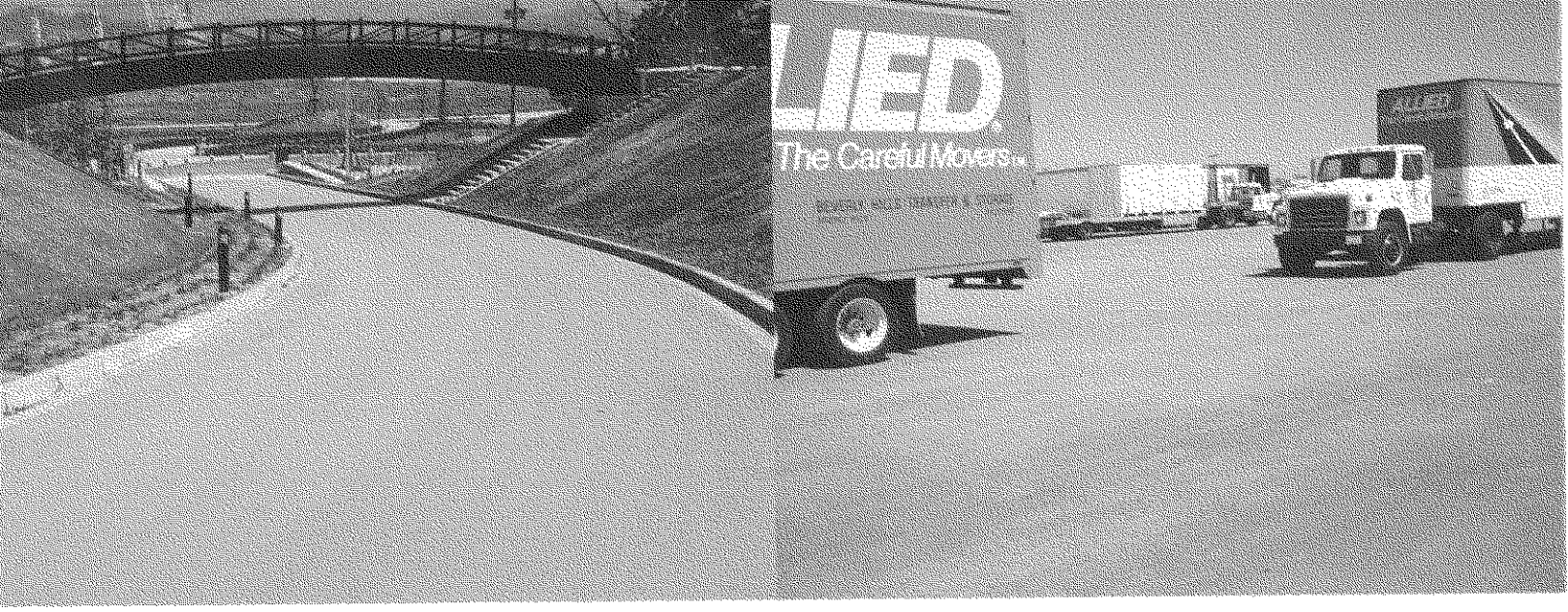
YES, BELIEVE IT OR NOT, THIS PATH IS PAVED.

IT'S ALSO STRONGER THAN ASPHALT AND IT COSTS LESS.

PolyPavement™

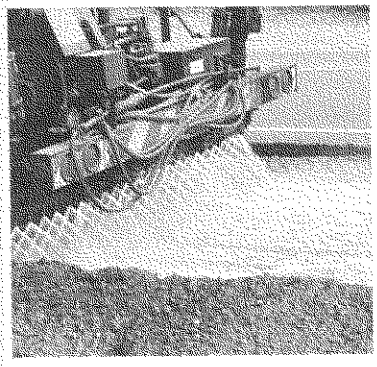
The Natural Soil Pavement

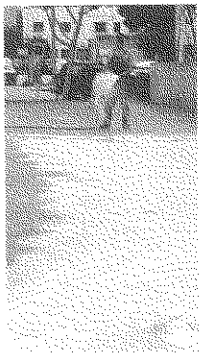
Go Back Next Page



FOR NATURAL LOOKING WALKWAYS, ROADS, PARKING LOTS & TRAILS, THAT ARE STRONGER, EASIER TO MAINTAIN AND COST LESS THAN ASPHALT:

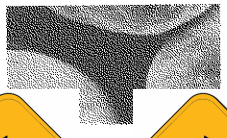
JUST ADD WATER.





We Proudly Bring You PolyPavement™

Simply the best way to pave your next walkway, road, parking lot or trail while maintaining the natural look of your environment.



particle
ement /

Sand particles after
olyPavement application.

The Ultimate Solution for All Your Paving Needs

PolyPavement is a non-toxic, non-corrosive, water-based polymeric compound. When applied to suitable soil, PolyPavement powerfully binds the soil particles forming a durable surface that is more supportive than asphalt, resists erosion, and looks completely natural.

Strong Performer

PolyPavement works in all soil types without changing the natural soil color. It produces a lasting surface that withstands weather and rubber tire vehicle wear. PolyPavement was tested and is recommended by the *U.S. Army Corps of Engineers*.

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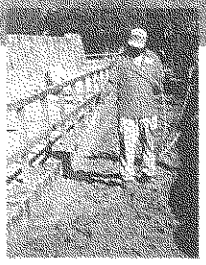
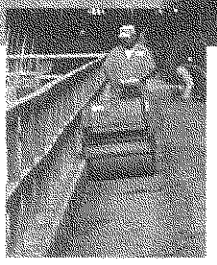




PolyPavement is Easy-to-Install

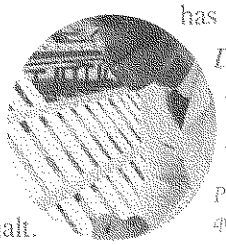
Either mix it into loose soil and compact it; or spray it onto compact soil and let it dry.

A Fraction of the Cost of Installing and Maintaining Asphalt Pavement

Perhaps the best attribute of Poly-Pavement is its low cost of application and low maintenance. Inch-for-inch, PolyPavement is less than half the cost of asphalt. PolyPavement is often installed as a thin surface spray-on application, one-quarter inch thick or less. Depending on the soil, PolyPavement is two to ten times more supportive than asphalt. Properly maintained PolyPavement does not have to be removed and replaced. Should damage occur, the remedy is quick, easy and inexpensive: a slurry mix, batch mix or spray-on application of PolyPavement is all it takes.

Environmentally Friendly Both Ecologically and Esthetically

PolyPavement may be used in ecologically sensitive settings. *The U.S. ...tal P... ...ency* has nc... *California Regional Water Quality Control Board* has approved its use. The *California Department of Fish and Game* tested and proved it to be environmentally safe.



PolyPavement prides itself on its stringent quality control standards.

Mix-in PolyPavement Applications on All Soil Types (Long-term, Heavyweight or Permanent Requirements)

Parking Lots
Storage Yards
Golf Cart Paths
Private Streets
Access and Haul Roads
Walkways and Trails
Service Roads
Driveways
Helipads & Landing Strips
Outdoor Flooring
Staging or Lay-down Areas
Wheelchair Access Ways
Patios and Picnic Areas

We'll Support Your Efforts with Some of Our Own

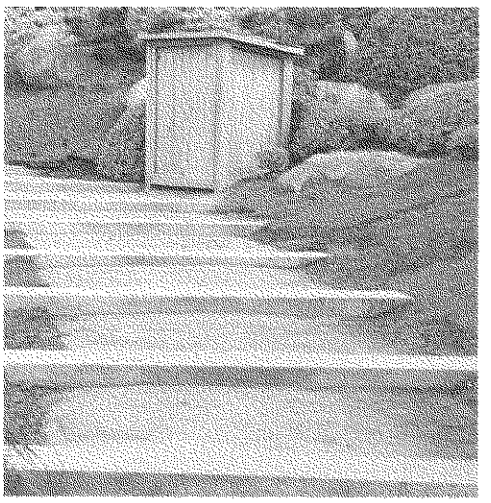
PolyPavement provides easy-to-follow customized installation instructions and free off-site technical support to all customers, ensuring a successful PolyPavement application.

Spray-On PolyPavement Applications on All Soil Types (Short-term, Lightweight or Non Traffic Requirements)

Walkways & Trails
Dust Prevention
Trap & Bunker Lining
Patios & Picnic Areas
Erosion Prevention
Vegetation Prevention

PolyPavement Addresses All Soil Stabilization Problems

Simply by varying the depth of treatment and concentration of PolyPavement, a full range of end-results is achieved.



So, whether the problem is windblown-dust on disturbed soil, an all-weather haul road, or the need for a beautiful walkway that blends into the environment, PolyPavement is the ideal solution.

PolyPavement™

The Natural Soil Pavement

Visit www.polypavement.com

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PolyPavement™

The Natural Soil Pavement

Manufactured to the Exact Specifications Provided by:
ECO-POLYMERS • A California Company
1-800-782-0071


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COST ESTIMATING GUIDE

Application 1. Mix PolyPavement™ Into the Soil, Compact the Soil

To Address Long-Term, Heavy Weight or Permanent Traffic Area Requirements for the following:

- *Private Streets*
- *Parking Lots*
- *Golf Cart Paths*
- *Outdoor Flooring*
- *Helipads and Landing Strips*
- *Service Roads and Driveways*
- *Storage Yards and Areas*
- *Walkways and Foot Paths*
- *Access and Haul Roads*
- *Staging or Lay-Down Areas*
- *Wheelchair Access Ways*
- *Patios and Picnic Areas*

Approximate Cost*: **From 14 to 19 cents per square foot per inch of treatment depth.**
Coverage: **1 gallon covers 75 to 110 square feet per inch of treatment depth.**

Application 2. Spray PolyPavement™ Onto Compact Soil, Let It Dry

To Address Short-Term, Lightweight or Temporary Traffic Area Requirements for the following:

- *Parking Lots*
- *Golf Cart Paths*
- *Outdoor Flooring*
- *Service Roads and Driveways*
- *Storage Yards and Areas*
- *Walkways and Foot Paths*
- *Staging or Lay-Down Areas*
- *Wheelchair Access Ways*
- *Patios and Picnic Areas*

Approximate Cost*: **From 7 to 10 cents per square foot.**
Coverage: **1 gallon covers 150 to 225 square feet.**

Application 3. Spray PolyPavement™ Onto Existing Soil

To Address Short-Term To Long-Term Non-Traffic Area Requirements for the Following:

- *Erosion Prevention*
- *Mud Prevention*
- *Windblown Dust Prevention*
- *Trap and Bunker Lining*
- *Vegetation Prevention*
- *Sand Contamination Prevention*

Approximate Cost*: **From 1 to 7 cents per square foot.**
Coverage: **1 gallon covers 225 to 1,250 square feet.**

The U.S. Army Corps of Engineers tested this technology for cost-effectiveness in desert, tropic and temperate climatic zones under traffic and non-traffic conditions. The tests determined that the technology meets or exceeds the established cost reduction criteria of thirty percent for all applications. (Reference: USACE Technical Report GL-93-25, September 1993, WES Geotechnical Laboratory)

**APPROXIMATE COSTS are based on the purchase of four 55-gallon steel drums at $879.95 each. Costs also depend on the coverage. Trial size five-gallon buckets are available at $159.95 each. Includes application instructions and technical support.*

PolyPavement™

The Natural Soil Pavement

). Box Angeles, California 90036 *Fax: (323) 954 2244 Phone: (323) 954 2240*

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TYPICAL APPLICATION METHODS

Application 1. Mix PolyPavement™ Into the Soil, Compact the Soil

To Address Permanent Heavy Weight Traffic Area Requirements for the Following:

- *Private Streets*
- *Parking Lots*
- *Golf Cart Paths*
- *Outdoor Flooring*
- *Helipads and Landing Strips*
- *Service Roads and Driveways*
- *Storage Yards and Areas*
- *Walkways and Foot Paths*
- *Access and Haul Roads*
- *Staging or Lay-Down Areas*
- *Wheelchair Access Ways*
- *Patios and Picnic Areas*

Application Method*

1. Dilute PolyPavement with water. → 2. Thoroughly mix diluted PolyPavement into the soil.
3. Contour and compact the soil. → 4. Spray-apply diluted PolyPavement onto the soil surface.

Application 2. Spray PolyPavement™ Onto Compact Soil, Let It Dry

To Address Temporary Light Weight Traffic Area Requirements for the Following:

- *Parking Lots*
- *Golf Cart Paths*
- *Outdoor Flooring*
- *Service Roads and Driveways*
- *Storage Yards and Areas*
- *Walkways and Foot Paths*
- *Staging or Lay-Down Areas*
- *Wheelchair Access Ways*
- *Patios and Picnic Areas*

Application Method*

1. Dilute PolyPavement with water. → 2. Spray-apply diluted PolyPavement onto the soil surface.
3. Allow the soil surface to dry. → 4. Spray-apply diluted PolyPavement onto the soil surface.

Application 3. Spray PolyPavement™ Onto Existing Soil

To Address Short-Term to Long-Term Non-Traffic Area Requirements for the Following:

- *Erosion Prevention*
- *Mud Prevention*
- *Windblown Dust Prevention*
- *Trap and Bunker Lining*
- *Vegetation Prevention*
- *Sand Contamination Prevention*

Application Method*

1. Dilute PolyPavement with water. → 2. Spray-apply diluted PolyPavement onto the soil surface.

The U.S. Army Corps of Engineers tested this technology for performance in desert, tropic and temperate climatic zones. The technology met or exceeded all laboratory and field performance criteria specified for rubber tire vehicles and adverse weather in all traffic area and non-traffic area applications. (Reference: USACE Technical Report GL-93-25, September 1993, WES Geotechnical Laboratory)

**DILUTION RATIOS, spread rates and depth of treatment vary depending on factors such as desired end results and specified performance criteria.*

PolyPavement Technical Department provides detailed application instructions in accordance with project performance specifications.

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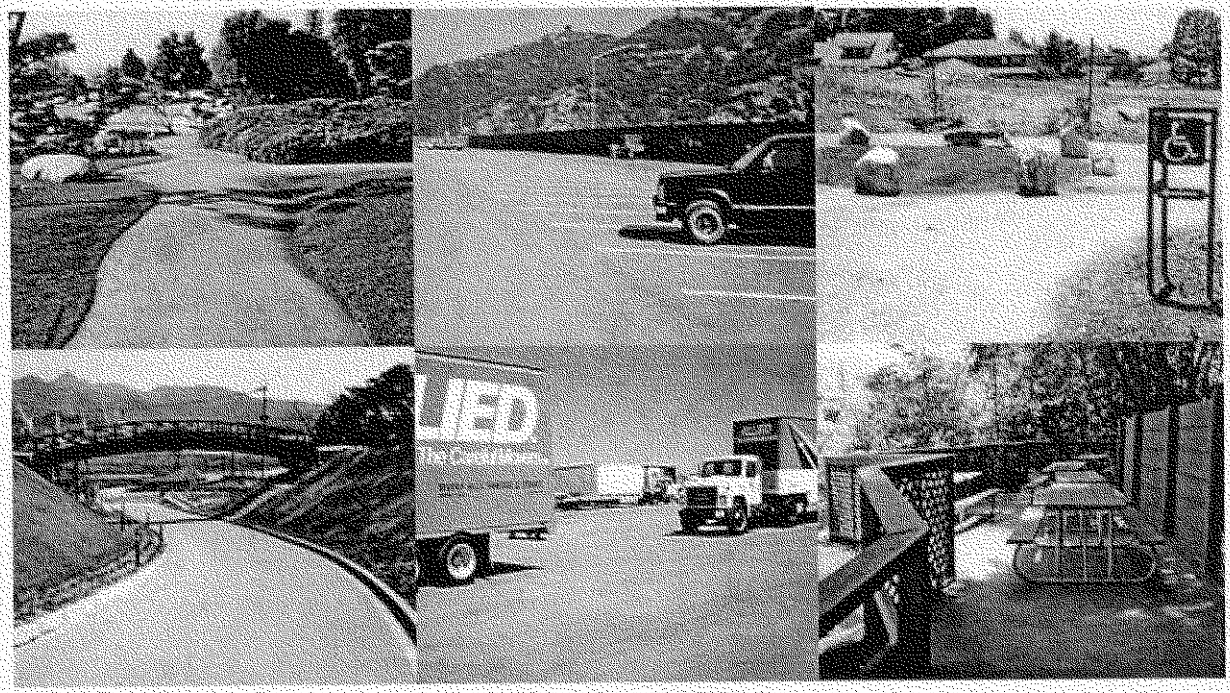
PolyPavement™

The Natural Soil Pavement™

APPLICATION METHODS | COSTS | SPECIFICATIONS | FIELD APPLICATION EQUIPMENT | ENVIRONMENTAL

MORE INFORMATION

BELIEVE IT OR NOT, THESE TRAFFIC AREAS ARE PAVED.



YES! PAVED! IT'S STRONGER THAN ASPHALT AND IT COSTS MUCH LESS.

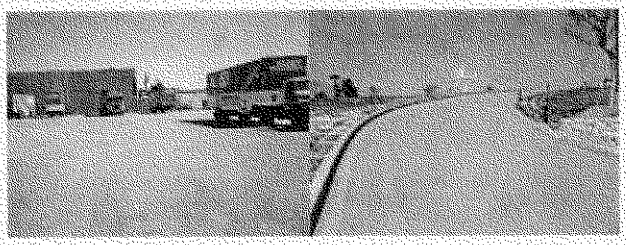
For Natural Looking Roads, Parking Lots and Trails that are stronger than asphalt, cost less and practically

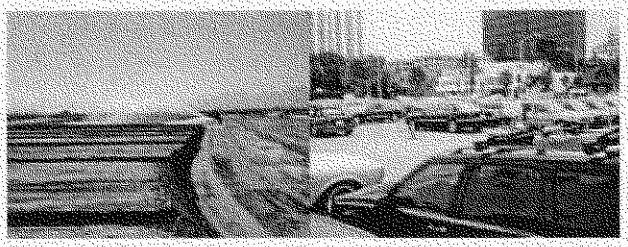
maintenance free: just add PolyPavement and water.

PolyPavement *is a liquid soil solidifier. The grounds-maintenance crew or a landscape contractor installs it. The existing natural soil or decorative soils such as decomposed granite or suitable fine particle sand may be used. PolyPavement does not change the color of the soil. Natural Soil Pavement is more then two times stronger than asphalt. It is not damaged by rain. It supports heavy vehicles. And it requires little or no maintenance. Foot-traffic areas, parking lots, service roads, etc. may be specified to meet any and all design requirements.*

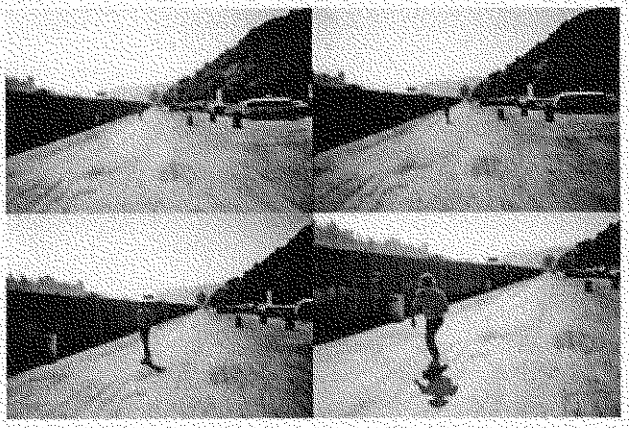
PolyPavement Has Many Uses *PolyPavement is an esthetically pleasing alternative to asphalt and concrete. With PolyPavement, the existing in-place soil or a suitable imported soil is used for 98% of the pavement construction material. There are many traffic area applications and non-traffic area applications for PolyPavement. Consider these:*

- *SERVICE ROADS*
- *DRIVEWAYS*
- *PARKING LOTS*
- *STORAGE YARDS*
- *LANDING STRIPS*
- *STAGING AREAS*
- *TENNIS COURTS*
- *GOLF CART PATHS*
- *WHEELCHAIR ACCESS*
- *PATIOS & PICNIC AREAS*
- *PATHS & WALKWAYS*
- *TRAP & BUNKER LINING*
- *DUST PREVENTION*
- *EROSION PREVENTION*
- *SLOPE PROTECTION*
- *VEGETATION PREVENTION*

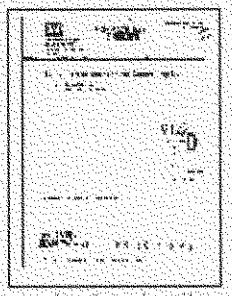




Proven Performance *The U.S. Army Corps of Engineers tested PolyPavement's natural soil pavement technology. Approximately 350 other methods and materials were also tested by the Corps of Engineers.*



PolyPavement passed all USACE performance criteria for rubber tire traffic and non traffic applications in all climates. No other material performed as well as PolyPavement and no other material had equivalent versatility, easy installation or as low a cost. Based strictly on the performance test results, USACE recommends PolyPavement for roads, helicopter landing pads, and other traffic and non-traffic surfaces in desert, tropic and temperate climates. No other method or material was recommended as highly.



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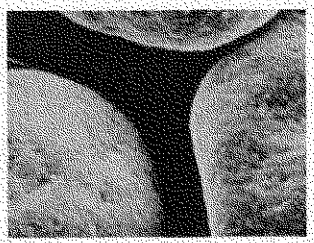
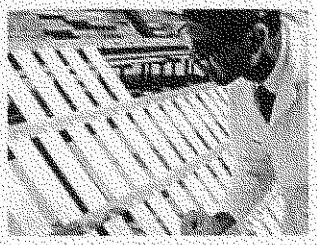


Sand particles before PolyPavement

Sand particles after PolyPavement

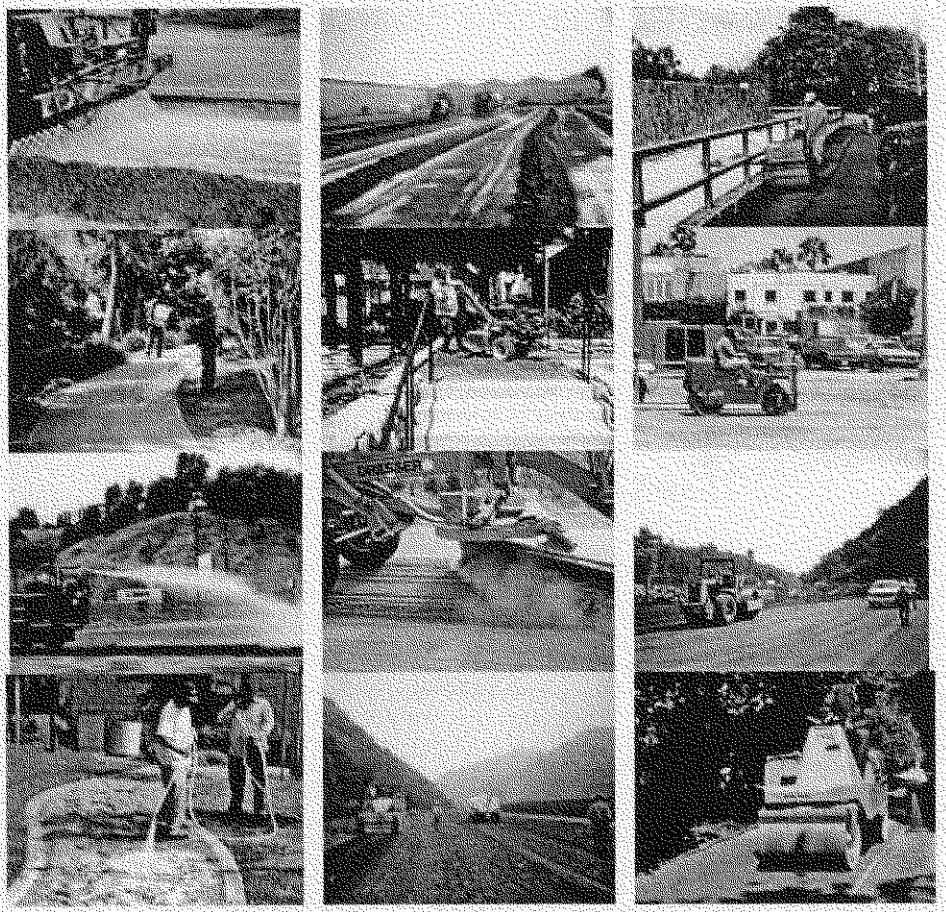
Strict Quality Control



UV Test in progress

Easy To Install *PolyPavement may be installed by the maintenance crew utilizing readily available equipment. Simply dilute it with water and spray it onto compact soil; or mix it into loosened soil and compact it. A roto-tiller, a smooth drum compactor and a dilution tank with hose & nozzle are recommended. PolyPavement does not damage equipment. Easy-to-follow application instructions are provided. Unused portions of PolyPavement soil solidifier can be stored in the drums and used whenever needed for small or large areas.*

SPRAYING ***MIXING*** ***COMPACTING***



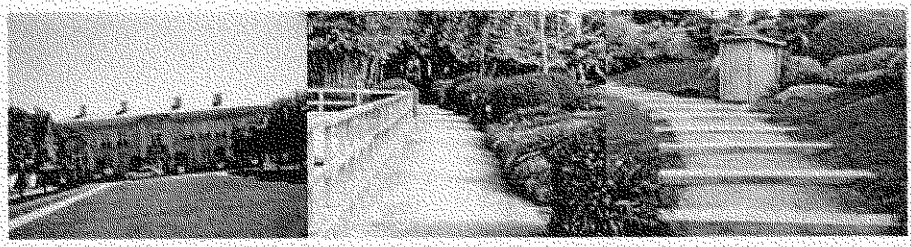
Low Cost plus Many Benefits *One inch of PolyPavement is more supportive than one inch of asphalt. Inch for inch, PolyPavement costs significantly less than asphalt. Spray-on applications of PolyPavement are effective for light traffic*

areas. Spray-on applications of PolyPavement are less than one-half inch thick, for outstanding cost effectiveness.

PolyPavement requires little or no maintenance. If damage occurs from spikes or other point forces, it is repaired easily by filling the holes with a pourable mixture of PolyPavement and the natural soil or patching by spreading and compacting a drier PolyPavement and soil mix into the damaged area.

*PolyPavement **never** needs to be removed and replaced as with asphalt and concrete. Instead, after it wears, more PolyPavement can be applied on top of old PolyPavement inexpensively to extend the life of a Natural Soil Pavement application indefinitely.*

***Environmentally Safe** PolyPavement is non-toxic to plants and animals. It has been tested and proven safe for sensitive aquatic life. It does not leach into the ground water. PolyPavement may be applied in environmentally sensitive areas without worry or concern.*



***Easy to Specify** PolyPavement may be specified on construction plans by using one of the construction plan specifications provided by PolyPavement. Simply call out the recommended PolyPavement thickness, and specify the soil material that meets the architect's or the owner's esthetic requirements.*

Application Methods | Costs | Specifications | Field Application Equipment | Environmental | Home | More Information

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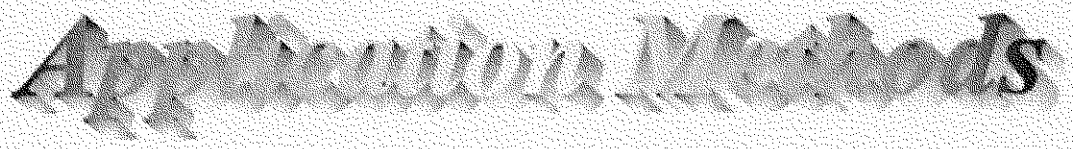
PolyPavement™
The Natural Soil Pavement™
P.O. Box 36339, Los Angeles, California 90036
Phone: (323) 954-2240 • Fax: (323) 954-2244
E-mail: tech@polypavement.com



Typical Application Methods

Application 1. Mix PolyPavement™ Into the Soil, Compact the Soil

To Address Permanent Heavy Weight Traffic Area Requirements for the Following:

- *Private Streets*
- *Parking Lots*
- *Golf Cart Paths*
- *Outdoor Flooring*
- *Helipads and Landing Strips*
- *Service Roads and Driveways*
- *Storage Yards and Areas*
- *Walkways and Foot Paths*
- *Access and Haul Roads*
- *Staging or Lay-Down Area*
- *Wheelchair Access Ways*
- *Patios and Picnic Areas*

Application Method* 1

1. Dilute PolyPavement with water. → 2. Thoroughly mix diluted PolyPavement into the soil.
3. Contour and compact the soil. → 4. Spray-apply diluted PolyPavement onto the soil surface.

Application 2. Spray PolyPavement™ Onto Compact Soil, Let It Dry

To Address Temporary Light Weight Traffic Area Requirements for the Following:

- *Parking Lots*
- *Golf Cart Paths*
- *Outdoor Flooring*
- *Service Roads and Driveways*
- *Storage Yards and Areas*
- *Walkways and Foot Paths*
- *Staging or Lay-Down Ar*
- *Wheelchair Access Ways*
- *Patios and Picnic Areas*

Application Method* 2

1. Dilute PolyPavement with water. → 2. Spray-apply diluted PolyPavement onto the soil surface.
3. Allow the soil surface to dry. → 4. Spray-apply diluted PolyPavement onto the

soil surface.

Application 3. Spray PolyPavement™ Onto Existing Soil

To Address Short-Term to Long-Term Non-Traffic Area Requirements for the Following:

- *Erosion Prevention*
- *Mud Prevention*
- *Vegetation Prevention*
- *Windblown Dust Prevention*
- *Trap and Bunker Lining*
- *Sand Contamination Prevention*

Application Method* 3

1. Dilute PolyPavement with water. → 2. Spray-apply diluted PolyPavement onto the soil surface.

The U.S. Army Corps of Engineers tested this technology for performance in desert, tropic and temperate climatic zones. The technology met or exceeded all laboratory and field performance criteria specified for rubber tire vehicles and adverse weather in all traffic area and non-traffic area applications. (Reference: USACE Technical Report GL-93-25, September 1993, WES Geotechnical Laboratory)

***DILUTION RATIOS,** spread rates and depth of treatment vary depending on factors such as desired end results and specified performance criteria. PolyPavement Technical Department provides detailed application instructions in accordance with project performance specifications.*

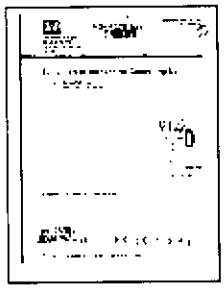
***Application Method 1** - Detailed Instructions for Permanent Traffic Areas*
Mix PolyPavement™ Into the Soil, Compact the Soil

***Application Method 2** - Detailed Instructions for Temporary Traffic Areas*
Spray PolyPavement™ Onto Compact Soil, Let It Dry

***Application Method 3** - Detailed Instructions for Non-Traffic Areas*
Spray PolyPavement™ Onto Existing Soil

Field Application Equipment

USACE PERFORMANCE TEST RESULTS



In September 1993, the U.S. Army Corps of Engineers completed the evaluation and comparison of the performance and cost of existing soil additive materials for traffic area and non-traffic area soil applications in desert, tropic and temperate temperate climates. A total of 347 materials and methods were evaluated. Each material and method had to pass all of the Corps' laboratory test criteria to qualify for further testing under actual field conditions.

The laboratory researchers tested all 347 materials and methods for:

1. *Resistance to water erosion, sheet-flow and rainfall*
2. *Resistance to ultra violet rays from sunlight*
3. *Resistance to jet fuel spillage*
4. *Resistance to extreme heat*
5. *Resistance to simulated wind and prop wash air blasts*

Only 7 materials of the total 347 materials and methods tested passed all of the laboratory test criteria and qualified for further testing under actual field conditions.

The field application tests were conducted under desert, tropic and temperate climatic conditions and the materials and methods were tested for:

1. *Resistance to M927 truck traffic*
2. *Resistance to UH-1 helicopter traffic*
3. *Resistance to wheeled vehicle roadway traffic*
4. *Resistance to wind and water erosion in non-traffic areas*
5. *Reduction of manpower requirements by 30% or more*
6. *Reduction of material cost by 30% or more*

The test results showed PolyPavement (Sand/Dirt Glue) to be the only material that passed all of the Corps' criteria for traffic and non-traffic applications in desert, tropic and temperate climates. None of the other soil polymers met a single one of the

Corps' field evaluation test criteria for traffic area or non-traffic area soil applications. In addition, PolyPavement was the the only material and method that significantly reduced the manpower requirements and the cost for materials by 30% or more.

As a result of the U.S. Army Corps of Engineers tests and evaluation, PolyPavement is the only material recommended by the Corps of Engineers for all the following applications:

1. *Traffic Areas, Desert Climates*
2. *Traffic Areas, Temperate Climates*
3. *Traffic Areas, Tropical Climates*
4. *Non Traffic Areas, Desert Climates*
5. *Non Traffic Areas, Temperate Climates*
6. *Non Traffic Areas, Tropical Climates*
7. *Low Manpower and Material Costs*

The U.S. Army Corps of Engineers' extensive study and evaluation of all existing soil additive materials and methods demonstrated that PolyPavement is far superior to all other materials and methods for soil stabilization and soil solidification applications.

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The Natural Soil Pavement™
P.O. Box 36339, Los Angeles, California 90036
Phone: (323) 954-2240 • Fax: (323) 954-2244
E-mail:tech@polypavement.com

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CONSTRUCTION PLAN SPECIFICATION EXAMPLES

The construction plan specifications presented here are intended as examples to illustrate the simplicity of specifying and installing PolyPavement. When PolyPavement is specified for bid purposes, experienced and inexperienced bidding contractors may call PolyPavement for detailed application and cost information. PolyPavement's technical staff includes applications engineers with more than 10 years experience on PolyPavement projects.

Example construction plan specifications are presented for:

Application 1 - Permanent Traffic Areas
Mix PolyPavement Into The Soil, Compact The Soil

Application 2 - Temporary Traffic Areas
Spray PolyPavement Onto Compact Soil, Let It Dry

Application 3 - Non Traffic Areas
Spray PolyPavement Onto Existing Soil

Click here to see Field Application Equipment

EXAMPLE CONSTRUCTION PLAN SPECIFICATION FOR

Application 1 - Permanent Traffic Areas

Mix PolyPavement into the Soil, Compact the Soil

MODIFIED CALTRANS FORMAT FOR FREQUENT VEHICULAR TRAFFIC AREAS

SOIL SOLIDIFYING EMULSION - Soil Solidifying Emulsion shall be PolyPavement Soil Solidifier OR equivalent. PolyPavement is an environmentally safe water-based polymer emulsion. PolyPavement Soil Solidifier has been developed specifically for use as natural soil pavement. PolyPavement is a non-corrosive and water-dilutable emulsion which utilizes a non-ionic, biodegradable emulsifier. PolyPavement Soil Solidifier dries and cures to a colorless, water insoluble, binding and cementing agent.

INSTALLATION - Installation shall consist of blending PolyPavement Soil Solidifier with the top 4 inches of existing roadway soil after grading and compacting the existing soil material to final elevations, and re-compacting. Then applying a a surface toughening spray-on application of diluted solidifying emulsion. And last, applying a final spray-on application of diluted PolyPavement Soil Solidifier. PolyPavement Soil Solidifier shall be applied according to the manufacturer's custom prepared application instructions and as specified in these plans and the special provisions.

SAMPLE APPLICATION INSTRUCTIONS -- Prior to selecting, delivering and/or placing imported soil material:

(1) The soil material shall be tested for suitability. (See Soil Suitability Tests in the special provisions of these plans.)

(2) After final grading and compacting, the soil material shall be scarified to a depth of 4 inches.

PolyPavement Soil Solidifier shall be diluted at the appropriate dilution ratio. (See Soil Moisture Field Test in the special provisions of these plans.)

(3) Diluted PolyPavement shall be spray-applied to the scarified soil material at the spread rate calculated to achieve optimum moisture content for compaction (OMC) and to obtain a residual PolyPavement emulsion content of 2.0 percent by total volume of compacted soil material.

(4) The diluted PolyPavement emulsion shall be thoroughly mixed and blended with the soil material to the measurable depth of 4 inches.

(5) The treated soil material shall then be graded and compacted to final elevations with steel drum compacting equipment that weighs not less than 6 tons.

If required by the manufacturer, upon completing the soil compaction process, a spray-on application of properly diluted PolyPavement Soil Solidifier shall be applied at the Minimum Spread Rate of 0.25 gallon per square yard and allowed to dry. If required by the manufacturer, a second spray-on application of properly diluted PolyPavement Soil Solidifier shall be applied at the Minimum Spread Rate of 0.125 gallon per square yard and allowed to dry.

The contract price paid per square yard for PolyPavement shall include full compensation for furnishing all labor, materials, tools, equipment, and incidentals, and for doing all the work involved in the PolyPavement installation process, complete in place, as shown on the plans, as specified by the Manufacturer and these special provisions, and as directed by the Engineer.

EXAMPLE CONSTRUCTION PLAN SPECIFICATION FOR FOR

Application 2 - Temporary Traffic Areas

Spray PolyPavement onto Compact Soil, Let It Dry

MODIFIED CALTRANS FORMAT FOR PATHWAYS AND FOOT TRAFFIC AREAS

SOIL SOLIDIFYING EMULSION - Soil Solidifying Emulsion shall be PolyPavement Soil Solidifier OR equivalent. PolyPavement is an environmentally safe water-based polymer emulsion. PolyPavement Soil Solidifier has been developed specifically for use as natural soil pavement. PolyPavement is a non-corrosive and water-dilutable emulsion which utilizes a non-ionic, biodegradable emulsifier. PolyPavement Soil Solidifier dries and cures to a colorless, water insoluble, binding and cementing agent.

INSTALLATION - Installation shall consist of spraying properly diluted PolyPavement Soil Solidifier onto the existing native soil surface in 4 spray-on applications. There will be (1) a surface preparation spray pass, (2) a surface penetration

spray pass, (3) a surface toughening spray pass and (4) a surface sealing spray pass of properly diluted PolyPavement Soil Solidifier. PolyPavement Soil Solidifier shall be diluted and and applied according to the manufacturer's custom prepared application instructions and as specified in these plans and the special provisions.

SAMPLE APPLICATION INSTRUCTIONS--After final grading and compaction, if the soil is bone dry:

(1) The soil shall be wet with an even spray application of plain water at a minimum wetting of 0.5 gallon of water per square yard.

(2) The surface shall then be treated with PolyPavement diluted at a ratio of 20 to 1 (20 gallons of water to one gallon of PolyPavement), applied to the moistened soil material at a Minimum Spread Rate of 0.5 gallon per square yard. Multiple spray applications might be required required to prevent run-off. The surface shall be allowed to dry.

(3) Upon drying, a surface toughening application of 20 to 1 diluted soil solidifying emulsion shall be applied at the minimum spread rate of 0.125 gallon per square yard and allowed to dry.

(4) Upon drying, a surface sealing application of 20 to 1 diluted soil solidifying emulsion shall be applied at the minimum spread rate of 0.125 gallon per square yard and allowed to dry.

The above dilutions and spread rates may be adjusted in the field by the Engineer or the Soil Solidifying Emulsion Manufacturer as required to address specific field conditions such as the type of soil and/or the moisture content of the soil. All field adjustments shall be made in a manner that does not change the amount of soil solidifying emulsion that is applied to the soil per unit area and/or in a manner that does not change the depth of treatment

The contract price paid per square yard for soil solidifying emulsion shall include full compensation for furnishing all labor, materials, tools, equipment, and incidentals, and for doing all work involved installing soil solidifying emulsion, complete in place, as shown on the plans, as specified in the Standard Specifications and these special provisions, and as directed by the Engineer.


EXAMPLE CONSTRUCTION PLAN SPECIFICATION FOR FOR

Application 3 - Non Traffic Areas

Spray PolyPavement onto Existing Soil

MODIFIED CALTRANS FORMAT FOR EROSION PREVENTION, NON TRAFFIC AREAS

SOIL SOLIDIFYING EMULSION - Soil Solidifying Emulsion shall be PolyPavement Soil Solidifier OR equivalent. PolyPavement is an environmentally safe water-based polymer emulsion. PolyPavement Soil Solidifier has been developed specifically for use as natural soil pavement. PolyPavement is a non-corrosive and water-dilutable emulsion which utilizes a non-ionic, biodegradable emulsifier. PolyPavement Soil Solidifier dries and cures to a colorless, water insoluble, binding and cementing agent.

INSTALLATION - Installation shall consist of spraying properly diluted PolyPavement Soil Solidifier onto the existing native soil surface in 3 spray-on applications. There will be (1) a surface preparation spray pass, (2) a surface penetration spray pass and (3) a surface toughening spray pass of properly diluted PolyPavement Soil Solidifier. PolyPavement Soil Solidifier shall be diluted and applied according to the manufacturer's custom prepared application instructions and as as specified in these plans and the special provisions.

SAMPLE APPLICATION INSTRUCTIONS - If the soil is bone dry:

> *(1) The soil shall be wet with an even spray application of plain water at a minimum wetting of 0.25 gallon of water per square yard.*
>
> *(2) The surface shall then be treated with PolyPavement diluted at a ratio of 18 to 1 (18 gallons of water to one gallon of PolyPavement), applied to the moistened soil material at a Minimum Spread Rate of 0.25 gallon per square yard in one spray pass. The surface shall be allowed to dry.*
>
> *(3) Upon drying, a surface toughening application of 12 to 1 diluted soil solidifying emulsion shall be*

applied at the minimum spread rate of 0.125 gallon per square yard and allowed to dry.

The above dilutions and spread rates may be adjusted or changed prior to the application by the Engineer or the Soil Solidifying Emulsion Manufacturer as required to address specific field conditions such as the type of soil and/or the moisture content of the soil. All field adjustments shall be made in a manner that does not change the amount of soil solidifying emulsion that is applied to the soil per unit area and/or in a manner that does not change the depth of treatment

The contract price paid per square yard for soil solidifying emulsion shall include full compensation for furnishing all labor, materials, tools, equipment, and incidentals, and for doing all work involved installing soil solidifying emulsion, complete in place, as shown on the plans, as specified in the Standard Specifications and these special provisions, and as directed by the Engineer.

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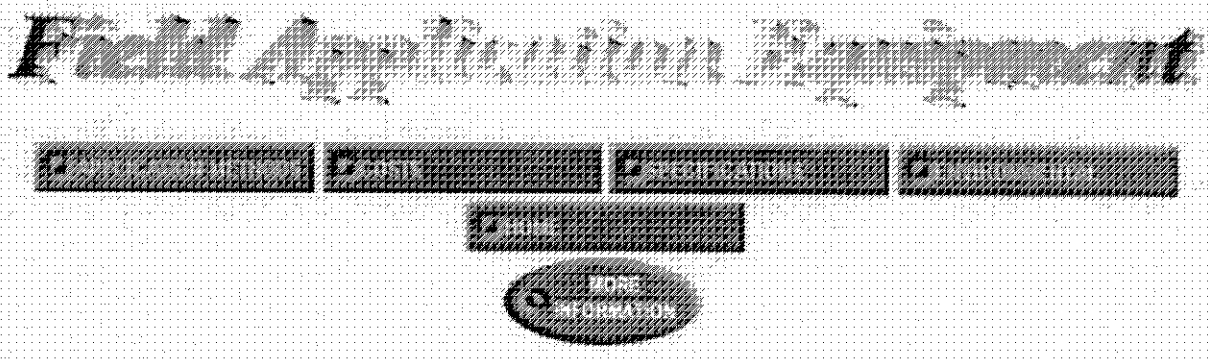
P.O. Box 36339, Los Angeles, California 90036
Phone: (323) 954-2240 • Fax: (323) 954-2244
E-mail:tech@polypavement.com



FIELD APPLICATION EQUIPMENT

PolyPavement spray-on and mix-in applications require no specialized tools or equipment. Tools and equipment are only needed for the following purposes:

1. Storing PolyPavement Soil Solidifier
2. Transferring PolyPavement from storage to application tanks tanks
3. Spraying water and diluted PolyPavement Soil Solidifier
4. Tilling or mixing PolyPavement Soil Solidifier into soil
5. Grading, leveling and contouring the soil surface
6. Compacting the soil to the specified depth
7. Measuring areas and calculating quantities

***The equipment is always selected to match the size and type of job**. For example, a typical PolyPavement mix-in application requires 5 to 10 times more water than PolyPavement. If the project specifies that 500 gallons of PolyPavement be applied, it it will require between 2,500 and 5,000 gallons of water for dilution. Obviously, this would not be a project for a back-pack sprayer. The point is to select an application or dilution tank with sufficient capacity to handle the volume of fluid to be applied.*

Similarly, if a project specification called for PolyPavement to be mixed into the soil to a depth of 4 inches, it is obvious that the weight of the compactor must be sufficient to compact the soil thoroughly to the depth of 4 inches.

***The following is a list of Equipment Selection Packages** to help the Applicator select the appropriate equipment for PolyPavement Applications based on the size or area of a given project. Upon selecting the appropriate equipment package, the applicator can expect to complete the project in minimal time. If equipment is selected other than that which is recommended for a job of a given size, then the estimated time required to complete a project of a given size will increase.*

APPLICATION EQUIPMENT PACKAGES

FOR MIX-IN PROJECTS:

EQUIPMENT PACKAGE 1

PROJECTS UP TO 500 SQUARE FEET
(5 to 15 Gallons of PolyPavement)

1. STORAGE EQUIPMENT
5-Gallon Buckets

2. TRANSFER EQUIPMENT
Measuring Cup or Small Bucket

3. SPRAYING EQUIPMENT
Garden Watering Can, or Back Pack Sprayer

4. SOIL MIXING EQUIPMENT
Cement Batching Pan with hand held tools, or Small Roto-tiller

5. GRADING, LEVELING & CONTOURING EQUIPMENT
Rake, Hand Held

6. COMPACTING EQUIPMENT
Vibratory Plate or Hand-held Tamper
Walk-behind Steel Drum Roller

EQUIPMENT PACKAGE 2

500 TO 5,000 SQUARE FEET
(15 to 125 Gallons of PolyPavement)

1. STORAGE EQUIPMENT
5 Gallon Buckets or 55-Gallon Drums

2. TRANSFER EQUIPMENT
Water Pump, electric, or Hand operated; or Metering Bucket, 1-gallon to 5-gallon
Hoses, Garden type or smaller *Hose Fittings*
Work Gloves *Safety Goggles*

3. SPRAYING EQUIPMENT
Pump w/Hose & Nozzle or Gravity Feed Tank w/Hose & Nozzle

4. SOIL MIXING EQUIPMENT
Walk-behind Roto-tiller

5. GRADING, LEVELING & CONTOURING EQUIPMENT
Tractor with Blade attachment or Rakes, Hand-held

6. COMPACTING EQUIPMENT
Walk-behind Steel Drum Roller

EQUIPMENT PACKAGE 3
5,000 TO 10,000 SQUARE FEET
(125 to 250 Gallons of PolyPavement)

1. STORAGE EQUIPMENT
5 Gallon Buckets or 55-Gallon Drums

2. TRANSFER EQUIPMENT
Water Pump, electric, or Hand operated; or Metering Bucket, 1-gallon to 5-gallon
Hoses, Garden type or smaller *Hose Fittings*
Work Gloves *Safety Goggles*

3. SPRAYING EQUIPMENT (Tank Size: 500 Gallons)
Water Trailer with Spray Bar or Hand-Held Wand w/Hose or Fertilizer Sprayer, adapted

4. SOIL MIXING EQUIPMENT
Walk-behind Roto-tiller, or Tractor Drawn Roto-tiller

5. GRADING, LEVELING & CONTOURING EQUIPMENT
Tractor with Back-Blade attachment
Rakes, Hand Held

6. COMPACTING EQUIPMENT
Walk-behind Steel Drum Roller or Ride-on Steel Drum Roller

EQUIPMENT PACKAGE 4
10,000 TO 20,000 SQUARE FEET
(250 to 750 Gallons of PolyPavement)

1. STORAGE EQUIPMENT
5-Gallon Buckets or 55-Gallon Drums

2. TRANSFER EQUIPMENT
Water Pump, Gasoline operated *Water Pump,*

electric,
Hoses, 2-1/2", 2" or smaller *Hose Fittings*
Work Gloves *Safety Goggles*

3. SPRAYING EQUIPMENT
Water Truck with Spray Bar, or Spreader Truck (Computerized)

4. SOIL MIXING EQUIPMENT (Tank Size: 1,000 Gallons)
Roto-tiller, Tractor Drawn

5. GRADING, LEVELING & CONTOURING EQUIPMENT
Tractor with Back-blade attachment

6. COMPACTING EQUIPMENT
Steel Drum Roller, ride-on or Steel Drum Roller, walk-behind

EQUIPMENT PACKAGE 5
20,000 TO 50,000 SQUARE FEET
(750 to 2,000 Gallons of PolyPavement)

1. STORAGE EQUIPMENT
55-Gallon Drums or Polyethylene Tanks

2. TRANSFER EQUIPMENT
Water Pump, Gasoline operated or Water Pump, electric,
Hoses, 2-1/2", 2" or smaller *Hose Fittings*
Work Gloves *Safety Goggles*

3. SPRAYING EQUIPMENT
Water Truck with Spray Bar, or Spreader Truck (Computerized)

4. SOIL MIXING EQUIPMENT
Traveling Mixer; Tractor-drawn Roto-tiller or Motor Grader, Blade

5. GRADING, LEVELING & CONTOURING EQUIPMENT
Motor Grader, Blade or Tractor with Back-blade attachment

6. COMPACTING EQUIPMENT
Steel Drum Roller, ride-on

EQUIPMENT PACKAGE 6
ABOVE 50,000 SQUARE FEET
(2,000 Gallons or More of PolyPavement)

1. STORAGE EQUIPMENT
55-Gallon Drums or Polyethylene Tanks

2. TRANSFER EQUIPMENT
Water Pump, Gasoline operated or Water Pump, electric,
Hoses, 2-1/2", 2" or smaller *Hose Fittings*
Work Gloves *Safety Goggles*

3. SPRAYING EQUIPMENT
Spreader Truck (Computerized) or Feeder Tank Truck with 3 inch Hose

4. SOIL MIXING EQUIPMENT
Traveling Mixer, BOMAG, CAT or CMI (equipped with liquid injection system)

5. GRADING, LEVELING & CONTOURING EQUIPMENT
Motor Grader, Blade

6. COMPACTING EQUIPMENT
Steel Drum Roller, ride-on

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Environmental

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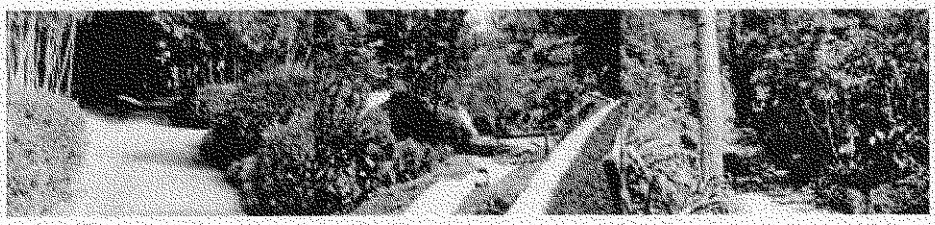
Environmentally Safe PolyPavement is non-toxic to plants and animals. It has been tested and proven safe for sensitive aquatic life. It does not leach into the ground water. PolyPavement may be applied in environmentally sensitive areas without worry or concern.



In the event of an accidental spill, static acute toxicity tests show that PolyPavement poses no threat to sensitive aquatic life. Tests indicate that in order for PolyPavement to harm sensitive aquatic life in a lake (20 feet deep by 5 acres), two rows of fully loaded tank trucks parked end-to-end would have to completely encircle the lake and pump their loads of PolyPavement into the lake simultaneously.

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Portland Cement


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LEHIGH PORTLAND CEMENT COMPANY

MATERIAL SAFETY DATA SHEET

FOR

PORTLAND CEMENT

MSDS NUMBER: **EFFECTIVE DATE: OCTOBER 1997**

1. PRODUCT/COMPANY IDENTIFICATION

Manufacturer's Name & Address:

Lehigh Portland Cement Company
7660 Imperial Way
Allentown, PA 18195

Chemical Family:

Calcium Compounds

Chemical Name and Synonyms:

Portland Cement (CAS # 65997-15-1), Hydraulic Cement

Telephone Number for Information:
800-523-5488

Trade Name and Synonyms:

Lehigh Portland Cement Types I, II, III, V
Lehigh White Cement Types I, III, V
Lehigh Colored Portland Cement
Lehigh Portland/Lime Cement Types N, S

2. EMERGENCY AND FIRST AID

EMERGENCY INFORMATION:

Portland cement is a light gray or white powder. When in contact with moisture in eyes or on skin, or when mixed with water, portland cement becomes highly caustic (pH > 12) and will damage or burn (as severely as third-degree) the eyes or skin. Inhalation may cause irritation to the moist mucous membranes of the nose, throat and upper respiratory system or may cause or may aggravate certain lung diseases or conditions. Use exposure controls or personal protection methods described in Section 10.

EYES:

Immediately flush eye thoroughly with water. Continue flushing eye for at least 15 minutes, including under lids, to remove all particles. Call physician immediately.

SKIN: Wash skin with cool water and pH-neutral soap or a mild detergent. Seek medical treatment if irritation or inflammation develops or persists. Seek immediate medical treatment in the event of burns.

INHALATION: Remove person to fresh air. If breathing is difficult, administer oxygen. If not breathing, give artificial respiration. Seek medical help if coughing and other symptoms do not subside. Inhalation of large amounts of portland cement require immediate medical attention.

INGESTION: Do not induce vomiting. If conscious, have the victim drink plenty of water and call a physician immediately.

3. COMPOSITION INFORMATION

DESCRIPTION: This product consists of finely ground portland cement clinker mixed with a small amount of gypsum (calcium sulfate dihydrate). The portland cement clinker is made by heating to a high temperature a mixture of substances such as limestone, sand, clay and shale. Portland cement is essentially hydraulic calcium silicates contained in a crystalline mass, not separable into individual components. Major compounds are:

$3CaO•SiO_2$	Tricalcium Silicate	CAS #12168-85-3
$2CaO•SiO_2$	Dicalcium Silicate	CAS #10034-77-2
$3CaO•Al_2O_3$	Tricalcium Aluminate	CAS #12042-78-3
$4CaO•Al_2O_3•Fe_2O_3$	Tetracalcium aluminoferrite	CAS #12068-35-8
$CaSO_4•2H_2O$	Calcium Sulfate dihydrate (Gypsum)	CAS #7778-18-9 (CAS #13397-24-5)

4. HAZARDOUS INGREDIENTS

COMPONENT	OSHA PEL (8-Hour TWA)	ACGIH TLV-TWA (1995-1996)	NIOSH REL (8-Hour TWA)
Portland Cement (CAS #65997-15-1) 50 to 95% by weight	5 mg respirable dust/m^3 15 mg total dust/m^3	10 mg total dust/m^3	


Calcium sulfate (CAS #7778-18-9) [Gypsum (CAS #13397-24-5)] 0 to 10% by weight	5 mg respirable dust/m^3 15 mg total dust/m^3	10 mg total dust/m^3	
Iron oxide (CAS #1309-37-1) 0 to 15% by weight	10 mg/m^3	5 mg/m^3	
Calcium carbonate (CAS #1317-65-3) 0 to 5% by weight	5 mg respirable dust/m^3 15 mg total dust/m^3	10 mg total dust/m^3	
Magnesium oxide (CAS #1309-48-4) 0 to 5% by weight	15 mg total dust/m^3	10 mg total dust/m^3	
Calcium oxide (CAS #1306-78-8) 0 to 5% by weight	5 mg/m^3	2 mg/m^3	
Crystalline silica (CAS #14808-60-7) 0 to 0.1% by weight	10 mg of respirable dust/m^3 % SiO_2 + 2 30 mg of total dust/m^3 % SiO_2 + 2 250 million particles/ft^3 % SiO_2 + 5	0.10 mg respirable quartz/m^3	0.05 mg respirable quartz dust/m^3

TRACE INGREDIENTS:

Due to the use of substances mined from the earth's crust, trace amounts of naturally occurring, potentially harmful constituents may be detected during chemical analysis. Portland cement may contain up to 0.75% insoluble residue. A small amount of this residue includes free crystalline silica. Portland cement also may contain trace (<0.05%) amounts of chromium salts or compounds (including hexavalent chromium) or other metals (including nickel compounds) found to be hazardous or toxic in some chemical forms. These metals are present mostly as trace substitutions within the principal minerals. Other trace constituents may include potassium and sodium sulfate compounds.

5. HAZARD IDENTIFICATION


POTENTIAL HEALTH EFFECTS:	NOTE: Potential health effects may vary depending upon the duration and degree of exposure. To reduce or eliminate health hazards associated with this product, use exposure controls or personal protection methods as described in Section 10.
EYE CONTACT:	(Acute/Chronic) Exposure to airborne dust may cause immediate or delayed irritation or inflammation of the cornea. Eye contact by larger amounts of dry powder or splashes of wet portland cement may cause effects ranging from moderate eye irritation to chemical burns and blindness.
SKIN CONTACT:	(Acute) Exposure to dry portland cement may cause drying of the skin with consequent mild irritation or more significant effects attributable to aggravation of other conditions. Discomfort or pain cannot be relied upon to alert a person to a hazardous skin exposure. (Chronic) Dry portland cement coming in contact with wet skin or exposure to wet portland cement may cause more severe skin effects, including thickening, cracking or fissuring of the skin. Prolonged exposure can cause severe skin damage in the form of chemical (caustic) burns. (Acute/Chronic) Some individuals may exhibit an allergic response upon exposure to portland cement. The response may appear in a variety of forms ranging from a mild rash to severe skin ulcers.
INHALATION:	(Acute) Exposure to portland cement may cause irritation to the moist mucous membranes of the nose, throat and upper respiratory system. Pre-existing upper respiratory and lung diseases may be aggravated by inhalation of portland cement. (Chronic) Inhalation exposure to free crystalline silica may cause delayed lung injury including silicosis, a disabling and potentially fatal lung disease, and/or cause or aggravate other lung diseases or conditions.
INGESTION:	(Acute/Chronic) Internal discomfort or ill effects are possible if large quantities are swallowed.
CARCINOGENIC POTENTIAL:	Portland cement is not recognized as a carcinogen by NTP, OSHA, or IARC. However, it may contain trace amounts of heavy metals recognized as carcinogens by these organizations. In addition, IARC classifies crystalline silica, a trace constituent, as a known human carcinogen (Group I). NTP has characterized respirable silica as "reasonably anticipated to be a carcinogen." (See also Section 13.)

6. PHYSICAL/CHEMICAL DATA

APPEARANCE/ODOR:	Gray, white or colored powder, odorless	PHYSICAL STATE:	Solid (Powder)


BOILING POINT:	> 1000ƒC	MELTING POINT:	Not applicable
VAPOR PRESSURE:	Not applicable	VAPOR DENSITY:	Not applicable
pH (IN WATER) (ASTM D 1293-95)	12 to 13	SOLUBILITY IN WATER:	Slightly soluble (0.1% to 1.0%)
SPECIFIC GRAVITY (H_2O = 1.0):	3.15	EVAPORATION RATE:	Not applicable

7. FIRE AND EXPLOSION

FLASH POINT:	None	LOWER EXPLOSIVE LIMIT:	None
AUTO IGNITION TEMPERATURE:	Not combustible	UPPER EXPLOSIVE LIMIT:	None
FLAMMABLE LIMITS	Not applicable	SPECIAL FIRE FIGHTING PROCEDURES:	None
EXTINGUISHING MEDIA:	Not combustible	UNUSUAL FIRE AND EXPLOSION HAZARDS:	None
HAZARDOUS COMBUSTION PRODUCTS:	None		

8. STABILITY AND REACTIVITY DATA

STABILITY:	Product is stable. Keep dry until used.
CONDITIONS TO AVOID:	Unintentional contact with water. Contact with water will result in hydration and produces (caustic) calcium hydroxide.
INCOMPATIBILITY:	Wet portland cement is alkaline. As such, it is incompatible with acids, ammonium salts and aluminum metal.
HAZARDOUS DECOMPOSITION:	Will not occur.
HAZARDOUS POLYMERIZATION:	Will not occur.

9. PRECAUTIONS FOR HANDLING, STORAGE AND DISPOSAL

HANDLING AND STORAGE	Keep dry until used. Handle and store in a manner so that airborne dust does not exceed applicable exposure limits. Use adequate ventilation and dust collection. Use exposure control and personal protection methods as described in Section 10.
SPILL:	Use dry clean-up methods that do not disperse dust into the air or entry into surface water. Material can be used if not contaminated. Place in an appropriate container for disposal or use. Avoid inhalation of dust and contact with skin and eyes. Use exposure control and personal protection methods as described in Section 10.


DISPOSAL:	Comply with all applicable local, state and federal regulations for disposal of unusable or contaminated materials. Dispose of packaging/containers according to local, state and federal regulations.

10. EXPOSURE CONTROLS/PERSONAL PROTECTION

RESPIRATORY PROTECTION:	Use local exhaust or general dilution ventilation to control dust levels below applicable exposure limits. Minimize dispersal of dust into the air. If local or general ventilation is not adequate to control dust levels below applicable exposure limits or when dust causes irritation or discomfort, use MSHA/NIOSH approved respirators.
EYE PROTECTION:	Wear safety glasses with side shields or goggles to avoid contact with the eyes. In extremely dusty environments and unpredictable environments, wear tight-fitting unvented or indirectly vented goggles to avoid eye irritation or injury. Contact lenses should not be worn when handling cement or cement containing products.
SKIN PROTECTION:	Wear impervious abrasion- and alkali-resistant gloves, boots, long-sleeved shirt, long pants or other protective clothing to prevent skin contact. Promptly remove clothing dusty with dry portland cement or clothing dampened with moisture mixed with portland cement, and launder before re-use. If contact occurs, wash areas contacted by material with pH neutral soap and water.

11. TRANSPORTATION DATA

Portland cement is not hazardous under U.S. DOT or TDG regulations.

12. TOXICOLOGICAL AND ECOLOGICAL INFORMATION

For a description of available, more detailed toxicological and ecological information, contact Lehigh Portland Cement Company.

13. OTHER REGULATORY INFORMATION

Status under US OSHA Hazard Communication Rule 29 CFR 1910.1200:	Portland cement is considered a hazardous chemical under this regulation and should be included in the employer's hazard communication program.
Status under CERCLA/Superfund, 40 CFR 117 and 302:	Not listed.
Hazard Category under SARA (Title III), Sections 311 and 312:	Portland cement qualifies as a hazardous substance with delayed health effects.
Status under SARA (Title III), Section 313:	Not subject to reporting requirements under Section 313.


Status under TSCA (as of May 1997):	Some substances in portland cement are on the TSCA inventory list.
Status under the Federal Hazardous Substances Act:	Portland cement is a hazardous substance subject to statutes promulgated under the subject act.
Status under California Proposition 65:	This product contains crystalline silica, a substance known to the State of California to cause cancer. This product also may contain trace amounts of heavy metals known to the State of California to cause cancer, birth defects or other reproductive harm.
Status under Canadian Environmental Protection Act:	Not listed.
Status under Canadian WHMIS:	Portland cement is considered to be a hazardous material under the Hazardous Products Act as defined by the Controlled Products Regulations (Class D2A, E - Corrosive Material) and subject to the requirements of WHMIS.

14. OTHER INFORMATION

This MSDS provides information on various types of portland cement products. A particular product's composition may vary from sample to sample. The information provided herein is believed by Lehigh Portland Cement Company to be accurate at the time of preparation or prepared from sources believed to be reliable. Health and safety precautions in this data sheet may not be adequate for all individuals or situations. Users have the responsibility to comply with all laws and procedures applicable to the safe handling and use of the product, to determine the suitability of the product for its intended use, and to understand possible hazards associated with mixing portland cement with other materials. SELLER MAKES NO WARRANTY, EXPRESS OR IMPLIED, CONCERNING THE PRODUCT OR THE MERCHANTABILITY OR FITNESS THEREOF FOR ANY PURPOSE OR CONCERNING THE ACCURACY OF ANY INFORMATION PROVIDED BY LEHIGH PORTLAND CEMENT COMPANY.

ABBREVIATIONS

ACGIH American Conference of Governmental Industrial Hygienists

ASTM American Society for Testing and Materials

CAS Chemical Abstract Service

CERCLA Comprehensive Environmental Response, Compensation and Liability Act

CFR Code of Federal Regulations

ft^3 Cubic foot

IARC International Agency for Research on Cancer

m^3 Cubic meter

mg Milligram


MSHA Mine Safety and Health Administration

NIOSH National Institute for Occupational Safety and Health

NTP National Toxicology Program

OSHA Occupational Safety and Health Administration

PEL Permissible Exposure Limit

REL Recommended Exposure Limit

SARA Superfund Amendments and Reauthorization Act

TDG Transportation of Dangerous Goods

TLV Threshold Limit Value

TSCA Toxic Substance Control Act

TWA Time Weighted Average

WHMIS Workplace Hazardous Materials Information System

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Appendix B
Literature Review Article Summaries


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APPENDIX B

Literature Review Article Summaries

Relevant Reports

Reports relevant to the five categories listed below were reviewed.

- Arid Regions and Climates
- Erosion Control Products Including Product Design and Erosion Control Effectiveness
- Vegetative and Non-vegetative Studies
- Performance Criteria
- Other Pertinent Studies

Arid Regions and Climates

The information presented in this section indicates a distinct lack of productive vegetation coverage in arid regions. When vegetation is not anchoring soil to the ground, the potential for erosion can be significant. Erosion types that tend to occur in arid and semiarid regions include wind-, water-, and gravity-induced erosion. Several items of importance include:

- Lack of vegetative coverage in arid areas is largely determined by the lack of precipitation. Other factors include temperature and wind velocities.
- Most desert soils are poorly developed and are composed of fine- to very fine-grained sediments. These textural classes tend to have an increased potential for erosion.
- Wind erosion may lead to strong and violent dust storms and can be a significant contributor to soil loss on site.
- Dust storms often occur in arid regions where wind velocities are increased and sustained, and there is generally a lack of vegetative cover. The effects of sediment loss from dust storms can be hazardous to human health and increase the potential for traffic accidents.
- Erosion control, through either vegetative control applicable to arid regions or non-vegetative methods, is necessary in these climate zones to combat sediment loss.

Bach, A. 1997. "Assessing Conditions Leading to Severe Wind Erosion in the Antelope Valley, California. 1990 – 1991." ***Professional Geographer*****, 1998: 87-97.**

The Antelope Valley is located in the semiarid Mojave Desert and normally supports sufficient vegetative cover to impede wind erosion. In 1990 and 1991, however, approximately 10,000 hectares were eroded due to reduced vegetative cover caused by eight years of subnormal precipitation and 2 years of severe drought. The occurrence of wind erosion in the Antelope Valley and elsewhere depends on a number of environmental control factors including: wind characteristics, sediment availability and erodibility, vegetative cover, and surface moisture characteristics.

The author discusses previous studies that have suggested vegetative cover and precipitation are most important in controlling wind erosion in the Mojave Desert. A specific area was targeted as posing an immediate threat to a community and actions were taken to combat the erosion. This included installing silt fences and seeding with native shrubs and grasses. This response became one of the nation's largest and most successful methods of deterring wind erosion.

The potential for wind erosion in the Antelope Valley can be attributed to several factors. An important component is soil quality. Most of the soils are poorly developed and are composed of fine to very fine grained sediments. These soils have a moderate to high potential for erosion. Another factor is the amount and seasonality of precipitation. Prolonged drought will eventually result in the loss of most shrubs and other vegetation. The severe drought of 1989 to 1990 (63 mm and 47 mm annual totals, 139 mm and 155 mm below normal, respectively) and especially the virtual absence of fall season precipitation, led to the destabilization of these surfaces.

McTainsh, G.H., A.W. Lynch, and E.K. Tews. 1998. "Climatic Controls Upon Dust Storm Occurrences in Eastern Australia." ***Journal of Arid Environments*****, 39: 457-466.**

Dust storms occur over large areas of arid and semiarid Australia and are responsible for eroding large quantities of topsoil, yet the climatic controls on their occurrence are poorly understood. This article discusses an Evapotranspiration Index (Et Index) of wind erosion that uses readily available meteorological data to identify two major wind erosion areas in eastern Australia.

The Et model describes the important influences of rainfall, evaporation (through its influence upon vegetative cover), and wind conditions upon dust storm occurrence and wind erosion in eastern Australia. The results contribute to the understanding of drought-dust storm relationships and raise the possibility of being able to predict dust storms and wind erosion in the future.

Mauz, K., R. Krenzer, and L. Cevera. 2000. "Vegetation, Fire, and Climate History, Adapting Land Use to Climate Variability in Arid Lands: Ranching and the Concept of Grass Banks in Southern Arizona." ***Use and Management of Arid Lands*****, 31p.**

This is a study of the A-7 Ranch on the west side of the San Pedro River Valley located east of Tucson, Arizona. This study discusses the elements of the physical environment that structure human land use practices. The applicable points presented in this study include:

- In warm, southwestern deserts, despite increased precipitation during the summer months, unusually high temperatures may result in relatively high rates of ET. Prolonged drought in grassland can have negative consequences both for productivity of existing plants and for propagation and stand replacement.
- Wildfire has a wide range of effects on the vegetation, soils, water, and watershed resources. Fire characteristics, season of burning, and pre-burn and post-burn environmental conditions create highly variable responses of vegetation to fire in desert ecosystems.

- Erosion by wind, water, or gravity usually increases following fire. Increased rates of surface runoff and erosion on burned sites compared with those of unburned sites were reported. Large areas cleared by fire are vulnerable to erosion and can yield substantial amounts of eroded material if subjected to high-intensity summer storms immediately following burning.

Dong, Z., X. Wang, and L. Liu. 2000. "Wind Erosion in Arid and Semiarid China: An Overview." ***Journal of Soil and Water Conservation*****, 55: 439-444.**

This article presents an overview on wind erosion in arid regions of China and historical background on the effect wind erosion has on dust storms and vegetation. The main points of this article include:

- Wind erosion is mainly a phenomenon that occurs in arid and semiarid areas where precipitation is rare and vegetation is sparse.
- In arid and semiarid regions of China, wind erosion usually occurs on loose deposits or those loosened by natural or human factors.
- Dry sub-humid lands are frequently threatened by wind erosion when strong winds coincide with dry periods.
- Drought in China in the 1930s led to the extensive destruction of vegetation coverage and the expansion of wind erosion.

This article discusses climatic erosivity and surface erodibility of areas in China. It also describes methodologies that attempted to estimate the intensity of wind erosion. The influence of climate on wind erosion depends not only on wind but also other variables, mainly precipitation and temperature. In 1994, Dong and Kang employed a formula proposed by the Food and Agricultural Organization (FAO) to predict the wind erosion climatic factor. The formula uses recorded events such as mean monthly wind speed, precipitation, and evaporation to determine the solution.

Dust storms are also discussed. These storms are a severe environmental problem and occur on several continents. Dust storms of the 1930s in the United States, central Asia, and the former Soviet Union are related to vegetation clearance caused by dry climate land reclamation. Dust storms in China have a long history, dating back to 205 B.C.

Measures that have been taken to combat the erosion problems in China include:

- Vegetative measures including constructing shelter forests, shelter belts, or networks to protect the oasis, and air seeding to generate grasses and shrubs.
- Non-vegetative measures including fences, straw check boards, sand transporting boards, feather-like sand-conducting fence arrays, and sand separating ditches.
- Application of chemical treatment to loose, shifting sand to add bonding agents and form non-erodible crusting.
- Land management practices on farmlands, including striped and alternating cultivation, leaving harvest residue, deep tillage, and non-tillage.

FAO. Undated. "Erosion Indicators-Arid and Semiarid Areas." Food and Agricultural Organization. < www.fao.org >

The loss of vegetative coverage, which may be caused by long-term climate change, is the trigger for accelerated erosion in arid and semiarid areas. Loss of vegetative coverage exposes soils to wind and water erosion, and this subsequent loss of soils also decreases the potential for vegetative production.

Three forms of erosion characterize degraded arid and semiarid areas:

- Sheet erosion: the most common form of erosion. Unprotected soil particles are loosened by disturbance, through wind erosion, and by the impact of rainfall. The soil particles are then transported by rainwater surface flow to adjacent water conveyance systems (e.g., rivers and streams). Sheet erosion is characterized by a general lowering of the soil level, sometimes leaving raised pedestals where the root mass protects the soil.
- Wind erosion: early signs include disposition of sand particles around existing plants and micro-ripples on the surface of exposed areas. The extreme is the classic sand desert dune land forms.
- Gully erosion: the most obvious and dramatic demonstration of erosion, although in most areas actually less significant in terms of total land degradation. Gully erosion rarely occurs without sheet erosion. The trigger for gullying can be the loss of vegetation in areas where the microtopography results in concentrated streamflow during the rains.

Grantz, D.A., D.L. Vaughn, M. Zeldin, R.L. Campbell, and R. Dean. 1994. "Mojave Desert Wind Erosion Fugitive Dust PM_{10}." International Erosion Control Association Conference Proceedings. 1994: 171-183.

This study pertains to the Antelope Valley in the Mojave Desert in California. Fugitive dust has resulted in several traffic accidents. An Emergency Watershed Protection (EWP) program was installed to stabilize the areas most subject to serious emissions of fugitive dust. The program involved installation of wind fences and seeding after ripping and furrowing soil.

The key to stabilizing these arid lands is generally to establish native vegetation. This is a difficult task because of low levels of annual rainfall, high evaporative demand, and, often, depleted soil seed banks. In an area that was primarily sandy loam, had no aggregates, and responded poorly to furrowing and seeding , wind fences were used. Three parallel wind fences were therefore established across the area, perpendicular to prevailing winds. The fences were 1 meter (m) high and spaced 10 m apart.

A preliminary assessment of the EWP program was performed between April and June 1992. Control of the fugitive dust from the wind fences was evaluated. It was determined that the wind fences provided significant control at all three sampling heights under higher (gust) wind conditions.

Erosion Control Products Including Product Design and Erosion Control Effectiveness

The literature information presented in this section discusses various erosion control products and their effectiveness as indicated by completed erosion control projects and field and laboratory experiments. Themes and general trends presented in this section include:

- Erosion control materials successfully decrease erosion.
- Both synthetic and natural materials have beneficial characteristics and constraints associated with their erosion control effectiveness.
- Effective water erosion control measures (based on certain criteria) include (coconut fiber (coir) used in conjunction with synthetic materials, polymers, riprap, polypropylene top nets with wood fibers, reinforced grip layer matting (RGLM), cement, crushed rock fragments, and non-vegetative mulch polyacrylamide (PAM).
- Effective wind erosion control measures (based on certain criteria) include polyethylene windbreaks, non-vegetative mulch PAM, pebble mulch, and plaster.

Krenitsky, E.C., M.J. Carroll, R.L. Hill, and J.M. Krouse. 1998. "Runoff and Sediment Losses from Natural and Man-Made Erosion Control Materials."*Crop Science Journal*, 38: 1042-1046.

Whenever soil is disturbed, it is best to provide surface cover to minimize raindrop impact energy. Raindrop impact on bare soil may be as much as 260 times greater than the impact exerted by sheet flow. The force of the impact breaks up soil aggregates, causing sediment to become suspended in runoff. Erosion control materials can dissipate the force caused by the impact of rainfall on bare surfaces, thereby preventing the detachment of soil particles.

A rainfall simulation study was designed where four man-made materials (wood excelsior, jute fabric, coconut fiber blanket, and coconut strand mat) and two natural materials (straw and turfgrass sod) were evaluated. They were evaluated on a Sassafras loamy sand having an 8-percent slope and on a Sassafras sandy clay loam having a 14- to 21-percent slope. Runoff and sediment loss rates were evaluated every 5 minutes for 35 minutes. Runoff was defined as whenever rainfall intensity exceeds the infiltration rate of the soil.

The results showed that runoff from all materials was less than bare soils for the first 5 minutes; however, only straw, jute, and sod reduced runoff for the entire storm event. The total amount of runoff, compared with bare soil results, were as follows:

- Decreased by 61 percent for sod
- Decreased by 25 percent for straw
- Decreased by 16 percent for jute

The erosion control materials had a statistically significant effect on reducing bare soil erosion by 80 to 90 percent. Of the man-made erosion control materials, only open-woven jute fabric reduced runoff and sediment losses significantly at both test locations. Therefore, of the materials tested, only sod, straw, and jute would be expected to effectively reduce both runoff and sediment losses.

Maki, T. and M. Du. 1999. "Evaluation of Evapotranspiration, Micro-meteorological and Prevention of Wind Erosion by Windbreaks at Arid Land in China." International Erosion Control Association Conference Proceedings. 1999: 481-487.

This study was performed in arid lands located at the Turpan Desert Research Station, Xinjiang, China, from 1990 to 1997. China has recently experienced a rapid progression of desertification. Prevention of this process may be achieved through improvement of meteorological conditions and prevention of wind erosion by using windbreaks.

The climate of the observation area is described as a continental arid type with large differences in the temperature ranging between 48°C and –28°C and an annual precipitation of 16.4 mm. Low relative humidity below 10 percent is frequently observed. The period of strong west-northwest to west winds lasts from April to July.

An automatic meteorological station was placed in the study area. It measured air temperature, soil temperature, humidity, wind speed, wind direction, sunshine duration, net radiation, heat flow, and precipitation. Two polyethylene windbreaks were used for observations of meteorological parameters and sand accumulation. The first and second windbreaks were set in two rows at 50-m intervals and were 10 m and 5.5 m high and 20 m and 15 m wide, respectively.

The results showed a marked meteorological improvement through the use of these windbreaks. The findings from this study include:

- The effects of two rows of windbreaks on the decrease of the wind speed and on climatic alleviation are cumulative in comparison with the effect of a single row of windbreak.
- Net windbreaks have similar effects for protection against wind erosion and for climatic improvement, and extension of nets is useful in arid lands.

Santha, L. and C.R. Santha. 1995. "Standards for Coir Erosion and Sedimentation Control Products." International Erosion Control Association Conference Proceedings. 95: 421-429.

This paper discusses the performance and properties related to the type of coir used in blankets for two widely used coir erosion products (coir polypropylene netted blankets and woven coir blankets). Coir, the coconut fiber, is an alternative natural fiber that is increasingly being used for erosion and sedimentation control. A comparison of the physical properties of three types of woven coir blankets, typically available in the market, are compared. The paper discusses several of the characteristics of coir blankets that need to be considered when choosing a product for a particular need.

The paper discusses early natural fiber erosion control (such as jute mats) and its low wet tensile strength and low durability. These properties restricted their use to less severe erosion problems. Advantages of coir over other organic natural fibers include high durability, low elongation, and high wet strength. Higher machine direction (MD) tensile strength is important in standard applications such as rolling down a slope. The cross direction (CD) is more important in biotechnical applications such as streambank and shoreline stabilization or reconstruction.

When selecting a coir blanket, higher wet tensile strengths in both MD and CD are important characteristics to consider. Erosion control blankets with higher wet tensile strengths in both MD and CD yield higher shear stress resistance in flow conditions and better performance in steep slopes and streambanks. The type of coir used in the twine is also important. The results from this study indicate that bristle fiber coir is stronger than mattress fiber coir or white fiber coir. The per unit weight of a product was also found to have a significant effect on the strength, decomposition longevity, and installation of woven coir blankets. Higher weight increases strength, decomposition longevity, workability during installation, and also helps ensure that blankets stay in contact with the soil after installation.

Nesichi, S., S. Reznik, and L. Lyahovetsky. 2001. "Engineering Testing and Evaluation of Polymeric Liquids for Erosion and Sediment Control." International Erosion Control Association Conference Proceedings. 2001: 167-179.

The paper presents the results of a study done to examine and compare the erosion control effectiveness of various polymers on different types of soils and slopes using limited laboratory and field experiments. Polymers influence soil stability through the adsorption of polymer molecules by soil particles, binding them together and bridging between their agglomerations. The laboratory portion of the study tested 42 samples under the most characteristic conditions for Israel: slope – 1V:2H; quantity of irrigation - 350 mm; soil types – sand, loess, red loam, and clay. The field experiments involved 28 different plots on 6 sites. In evaluating the polymers, the researchers used the following criteria:

- Effectiveness of polymers under various experimental conditions; sediment control as evaluated in the laboratory experiments and erosion control (i.e., rill and gully formation as evaluated in field experiments)
- Characteristics of the polymer-tested soil crust, such as water permeability, strength, and thickness

For the field experiments, application of the polymers was done before the rainy season. The products were prepared and applied as recommended by the suppliers and manufacturers.

The conclusions from the study include:

- Polymers are an effective means for sediment reduction on slopes with gradients of up to 30° (60 percent). Sediment reductions of 70 to 100 percent were achieved for various polymers on different soil types.
- Polymers are effective in reducing the formation and development of rills and gullies.
- Polymers are easily applied, and the resultant surface lends itself to sowing or planting of vegetation. In addition, the process is usually inexpensive.
- Polymer treatment efficiency is not affected by solar radiation.

Ambrust, D.V. 1999. Effectiveness of Polyacrylamide (PAM) for Wind Erosion Control. Proceedings: Wind Erosion: An International Symposium/Workshop. USDA Wind Erosion Research Unit at Kansas State University. Internet site: <www.weru.ksu.edu/symposium/proceedings/armbrus2.pdf>

Vegetative and non-vegetative mulches have been used in the control of wind erosion. PAM has been shown to greatly reduce irrigation-induced soil erosion at numerous locations. PAM can be applied in liquid as well as dry powder form through furrow and sprinkler irrigation. The objective of the current study was the evaluation of the various PAM formulations for their effectiveness in controlling wind erosion. Results indicate that application of PAM to soil surface reduces the amount of loose erodible material (LEM) by 38 to 39 percent. PAM acts by binding with soil particles to form a crust.The crust formed by the application of PAM was found to be unstable under the influence of salting particles, i.e., the crust became loose and the soil was more susceptible to wind erosion.

The conclusion of the study is that "application of PAM formulations will protect the soil surface from wind erosion if the treated area can be protected from incoming salting particles."

Schurholz, M. 1991. "Erosion Control on Cut Slopes with the Light Weight Coir Fibre at the New European High-Speed Railroads." International Erosion Control Association Conference Proceedings. 91: 211-215.

Steep cut slopes created during the construction of the high-speed railroad resulted in exposing predominantly limestone soils while creating new drainage for hidden springs as well as any runoff. Changes in weather (frost and heat) also contribute to the degradation of the rocks. To help prevent erosion, the slopes were humidified and then hydroseeded with standard mixture. A large part of the south slope was completely eroded despite the presence of vegetation following a very wet winter (1988/89). As a solution against any repeats, the engineers involved in the project developed a design where they covered the whole slope with lightweight coir fiber fabric fixed in place with special rock nails and washers. The nails were 10 inches long and had a self-cutting end that made it possible to insert them into the parent material without predrilling. The entire slope was then hydroseeded with a special mixture using heat- and drought-resistant grass seed. The coir fiber fabric had a life time of several years, yet was completely biodegradable. The fabric was designed for erosion control on moderate slopes (e.g., <2.5:1).

Cabalka, D.A. and T. Lancaster. 1997. "Comparative Study of Erosion Control Blankets (ECBs) and Bonded Fiber Matrices." International Erosion Control Association Conference Proceedings 1997: 539-551.

The authors of this article contend that hydraulically applied mulch (also known as "bonded fiber matrix" or "spray-on blankets") is not equivalent to ECBs. Unlike ECBs, bonded fiber matrices are applied using hydraulic mulching equipment and use chemical adhesives to secure the organic mulch to the exposed subgrade. The study purposed to show that bonded fiber matrices are inferior to ECBs.

ECBs are typically produced from a wide variety of organic fibers and nettings, all of which share the following four common characteristics:

1. Substantial natural fiber
2. Necessary open space
3. Structural continuity
4. Absence of chemical additives

The organic component of ECBs is a biodegradable fiber of wood excelsior, straw, or coconut fiber, and the netting and/or stitching of ECBs provides the necessary tensile strength and load distribution to resist sliding forces on steep slopes and shear stresses in channel applications. ECBs are typically anchored using steel wire staples, or in some cases, wooden stakes. The unique internal interlocking and external anchoring is one of the primary differences between ECBs and bonded fiber matrices.

In contrast, bonded fiber matrices are composed of small wood fibers that are held together with a variety of chemical adhesives or gypsum-based plaster compounds. The fibers are smaller than ECB fibers and similar to those used in conventional hydraulically applied mulches. Bonded fiber matrices have much lower tensile strength characteristics than ECBs, especially in a wetted condition, and therefore are likely to fail under shear forces and/or hydraulic conditions.

ECBs have been in use longer than bonded fiber matrices and have been tested under various conditions; bonded fiber matrices have only been in use for a short time. Bonded fiber matrices are not equivalent to ECBs for all erosion control situations.

Abt, S.R. 1991. "Slope Erosion Protection with Riprap." International Erosion Control Association Conference Proceedings. 91: 225-233.

This study discusses the application of rock riprap that has traditionally been used to provide erosion control and energy dissipation in channels and hydraulic structures and discusses the design and placement of riprap or rock mulch to protect exposed slopes. The flume studies performed encompassed the testing of near-prototype slopes, ranging from 1 to 20 percent, that were protected with riprap having median rock sizes of 1 to 6 inches. Test parameters included the rock shape, gradation, and layer thickness. All tests were conducted and results evaluated for overtopping, or sheet flow, conditions.

The results indicate that the slope and the unit discharge at failure can be correlated to the median rock diameter of the riprap. Further, the relationship can be modified to incorporate the influence of gradation (rock-size uniformity) and layer thickness. The article provides a computation for estimating the design median rock size to assure slope stability.

Rock riprap has been used for many years as a stabilization material associated with applications to river and bank aspects of channels, hydraulic structures for energy dissipation, and embankment face protection.

Twenty-six flume tests were conducted where riprap-protected slopes were subjected to overtopping, or sheet flows. The test slopes (slopes of 1, 2, 8, 10, and 20 percent) were composed of a compacted sand covered with a geotextile. A bedding material made of sands and gravels ranging in size from 4 mm to 8 mm in diameter was placed on the geotextile. The riprap was placed on the bedding with median stone sizes of 1, 2, 4, 5, and/or 6 inches. Both angular- and round-shaped rocks were tested. Each riprap layer was tested to failure.

The failure criterion for the riprap layer was when the bedding, or in some cases the geotextile, was exposed because of the overtopping flow. In many cases, flow would scour a localized zone along the slope face. However, rock movement from upslope would subsequently fill and stabilize the scour area. When rock movement could no longer adequately

replenish rock to the scour or failure zone, catastrophic failure was observed. The times from the initiation of flow to the rock layer failure ranged from 2 to 4 hours, depending on riprap size.

Round-shaped riprap fails at a unit discharge of approximately 40 percent less than angular-shaped rocks of the same median rock size. Since it is imperative that a riprap layer be designed to prevent failure, the median rock size should be sized to resist rock movement. Riprap gradation has an important influence on riprap stability.

Santha, L. and C.R. Santha. 1997. "Design Factors of Erosion Control Products and Role of Coir Products in Erosion Control." International Erosion Control Association Conference Proceedings. 97: 111-120.

This paper discusses the problem of selecting suitable erosion control products in different erosion situations. The three main factors in an erosion control design—engineering, environmental suitability, and economic feasibility (the 3 "E"s)—are directly related to engineering, environmental suitability, and economic feasibility factors of erosion control products. A successful erosion control design will identify the optimum erosion control design for each erosion situation.

The article then discusses various coir erosion control products, their applications, and their compliance to the 3 "E"s. Results showed that most of the products comply to the 3 "E"s. Those who design and write specifications should educate themselves about various properties of erosion control products and their compliance to the 3 "E"s. This will allow them to identify and understand how to use coir erosion control products in their designs to yield optimum erosion control designs.

Wagner, H.R. 1999. "Steep Slopes at High Altitudes Pose Erosion Control and Revegetation Challenges: A Success Story." International Erosion Control Association Conference Proceedings. 91: 351-360.

This paper discusses the process and design-build approach that was used to select and prescribe the most appropriate erosion control materials and revegetation techniques for a challenging erosion control project undertaken in the arid high desert of Mexico.

The project was located in the State of Oaxaca Mexico at high altitude and in mountainous terrain. Long, uninterrupted, steep slopes constructed from rocky and highly erosive mountain soils at high altitudes are subjected to significant solar radiation. This area experiences extreme heat and seasonally arid conditions, punctuated by brief but intense rainy periods. The total area of critical slopes totaled approximately 58,300 square meters.

After two failed attempts at stabilizing the slope with local coconut fiber and straw blankets, a polypropylene top net and wood fibers were successfully applied. The wood fibers made contact with and lodged into the slope surface, thereby reinforcing the bond between the blanket and the soil. The slope was seeded with a native plant mix laden with polymer pellets to ensure the appropriate levels of moisture were retained in the seedbed during the initial dry periods.

Xiao-Yan L., L. Lian-You, and G. Jia-Dong. 2001. "Influence of Pebble Mulch on Soil Erosion by Wind and Trapping Capacity for Windblown Sediment." ***Soil and Tillage Research*****, 59: 137-142.**

This paper discusses the effect of pebble mulch on soil erosion by wind. Results of a wind tunnel simulation and a field experiment showed that pebble mulch had two functions in controlling wind erosion: first, it could prevent soil from eroding by wind; second, it could trap dust carried by wind. Results of the wind tunnel experiment showed pebble mulch reduced the wind erosion rate by 84 to 96 percent at different wind velocities in comparison with the controls. The field study indicated that pebble mulch could trap 1.6 to 1.8 times more windblown sediments than the control, suggesting that pebble mulch might also be effective in controlling dust storms.

Duffy, D.M. and H. Hatzell. 1991. "The Use of Inorganic Surface Treatments to Mitigate Erosion." International Erosion Control Association Conference Proceedings. 91: 143-151.

This article discusses a study that addressed the effectiveness of using crushed rock fragments to armor soils susceptible to erosion. The main focus is the process of armoring, which is the development of a surface comprising particles too large to be transported by surface flow to form a resistant layer, thereby protecting the more erodible underlying soil. Freeway observations on Central Arizona freeways showed typical rill patterns to occur as the slopes transition from about 16 to 9 degrees at a hinge point. Rills always terminated at the hinge point, and in the areas where channeling did not occur, either there were very short upper segments with slopes less than 3 degrees or the upper segments drained away from the slope. The authors examined the slopes and found many discontinuous channel segments. The failure of the slope resistance at several points also pointed to the presence of a rather thin, fragile surface zone of protection.

A study based on simulation was then designed to attempt to produce a "design" slope micro-basin drainage system. Conclusions showed the following:

- Relative erosion resistance for soil slopes can be determined in a laboratory setting when both precipitation and channel flow stress are applied.
- The development of small rills or micro-channels on slopes as steep as 2:1 must be restricted if erosion control is to succeed. The design of a slope protection system must be directed toward preventing channels.
- The development of natural armoring of slopes by coarse particles is an important property of slope soils. Once formed, this armor should be protected from damage by restricting slope activities.
- Man may enhance the protection of slopes against erosion by the addition of coarse particles to slope materials. The suite of soils tested indicate that soils, natural or augmented, with more than 20-percent coarse particles can realize great resistance to channel development. The minimum "coarse" particle size observed during testing was found to be the material retained on the number 4 US sieve.
- The shape of the coarse particles is important in retarding erosion. The optimum range of shape factors for slopes on the order of 2:1 ranges from 4.0 to 9.0.

- Micro-channel flows as high as 8 gallons per minute (gpm) with velocities on the order of 167 feet per minute on 2:1 slopes can be resisted by particles as small as 1.5 inches and shape factors greater than 2.0.

Lehrsch, G.A., D.C. Kincaid, and R.D. Lentz. 1996. "Polyacrylamide Sprayed on Soil Surfaces Can Stabilize Soil Aggregates." International Erosion Control Association Conference Proceedings. 96: 531-538.

This paper discusses the effectiveness of PAM applications, known to stabilize surface soil in irrigated furrows, that may effectively stabilize soil aggregates as well. The field experiment evaluated the effects of spray-applied PAM and sprinkler droplet energy on surface soil aggregated stability, measured before and after 31 mm of irrigation.

Conclusions from this study indicated the following:

- PAM sprayed on soil surfaces increased aggregate stability, provided the energy input from sprinkler drop impact was not too great.
- The spray application of the PAM used in this study was not effective in preventing the physical deterioration of the soil surface when it was exposed to sprinkler droplet energy of 15 J kg^{-1}.
- In this study, droplet energy appeared to be a more important cause of the change in aggregate stability than the PAM that was studied.

Rector, W.G. and D.A. Socha. 1995. "The Study and Modification of Parameters Affecting Wind Erosion." International Erosion Control Association Conference Proceedings. 95: 431-440.

This study discusses completion of a trial experiment using a wind tunnel to study the use of AIRTROL® plaster to minimize soil loss caused by wind erosion. This study was conducted by United States Gypsum in conjunction with the U.S. Department of Agriculture (USDA) Agricultural Research Service Wind Erosion-Dryland Crop Production Research Center, Big Spring, Texas. The study's criteria for an effective wind-erosion system included the following:

- Must reduce the amount of topsoil lost to wind
- Must be environmentally benign
- Must need no specialized machinery to apply
- Must be flexible to specific needs
- Must be cost-effective

The conclusions of this study were that in of all the areas tested (control, rain, and abrader), the AIRTROL® plaster significantly decreased the amount of soil lost compared to the control sampled. At heavier application levels, the amount of soil lost will be decreased. This will allow the applicator to put a heavier application on areas with the severest wind erosion. This product is competitive with products currently on the market. Field tests still need to verify lab results and will be conducted in various locations throughout the United States.

Berkhout, H.C. and L.E. Ward. 1991. "Introduction of the Reinforced Grip Layer Matting Design and Performance." International Erosion Control Association Conference Proceedings. 91: 181-190.

This study discusses the effectiveness of turf reinforcement mattings (TRM). Although they have been widely used with aesthetically pleasing vegetation and have established themselves as an alternative to concrete, asphalt, and riprap in erosion control, they have been limited in their application because of relatively low tensile strength and low modulus. Recent developments have provided a means to produce a geocomposite that unites the characteristics of the TRMs with those of the high-tenacity, high-modulus polyester grids. The RGLM offers new possibilities in various uses as a grip layer for sprayed concrete such as gunite and shotcrete, as well as in vegetating steep, weathered rock walls.

The paper describes the ENKAMAT "S" by Akzo Industrial Systems, which is an RGLM in which the nylon filaments of the grip layer completely entangle the strands of the grid. The grid is a specially interwoven structure made of high modulus polyester yarns covered by an additional layer of polyvinyl chloride (PVC). It is available in several types with various tensile strengths. The "creep" of the ENKAMAT "S" is less than 1 percent after 2 years at a 50-percent stress ratio. It is necessary to anchor the RGLM; the accumulated shear force must be anchored in at the top trench.

RGLM can be used as a grip layer for sprayed concrete, such as, gunite and shotcrete. Examples of areas where this can be applied includes areas under bridges where lack of vegetation and continuous dripping of water lead to serious erosion under the bridge.

Vegetative and Non-vegetative Studies

The information presented in this section describes multiple studies of erosion control products that have been conducted by different entities, including universities, states' department of transportation, and private organizations. In general, non-vegetative erosion control products are those that can be successfully implemented either with or without the promotion of vegetative growth. Currently, most non-vegetative erosion control methods are used to promote vegetative growth in areas where natural growth is not successful. A great number of erosion control products are on the market today. The products most often discussed in these articles and used successfully include:

- Turf Reinforcement Mats—These have been found to have a highly permissible shear stress and are successful at promoting vegetation.
- Concrete blocks—These are proven by the U.S. Army Corps of Engineers (COE) to be successful in both vegetative and non-vegetative situations.
- Steep-slope protection—Methods such as rock-filled walls, geocell material, and steel sheet piling were discussed.
- Windbreaks—These are used successfully throughout the world to control soil loss caused by wind erosion.
- Erosion control blankets—This method increased biomass production when compared to non-treated slopes.

Fifield, J.S. 1992. "How Effective Are Erosion Control Products in Assisting with Dry Land Grass Establishment with No Irrigation?" International Erosion Control Association Conference Proceedings. 1992: 321-333.

Erosion control products are used throughout the United States on steep slopes to temporarily or permanently curb sediment loss. For arid regions of the country, precipitation is often minimal, resulting in dry lands. Establishing sufficient dry land grasses without irrigation in these regions for adequate erosion control usually takes at least two growing seasons.

Twelve erosion control products were tested in the semiarid environment of Parker, Colorado, to evaluate what product parameters have the greatest impact on assisting with dry-land grass production. Fifteen test plots were developed so that erosion control products could be tested for dry-land grass establishment on slopes having an easterly and westerly aspect. These plots were divided by wood barriers into subplots. Data collected consisted of precipitation, soil temperature, soil moisture, and biomass production. The erosion control products tested included recycled paper blanket, wood excelsior blanket, polymer blankets, straw/coconut blankets, soil tackifier, and a control of bare ground.

The average precipitation throughout the year ranged from 28.0 mm to 59.7 mm. The results from the study after one growing season were as follows:

- Erosion control blankets generally increased biomass production when compared to slopes not treated.
- Tackifiers do not substantially increase biomass production.
- It appears that natural erosion control blankets allow for greater percentage of cool-season grasses when compared to production from untreated slopes. Also, synthetic erosion control blankets may allow for a greater percentage increase in warm season grasses when compared to untreated slopes.
- Erosion control blankets appear to impact heating of the soil from solar radiation by reducing overall heating during the daylight hours and maintaining warmth during night hours.
- Erosion control blankets appear to maintain higher soil moisture content.

Texas Natural Resource Conservative Commission. 2000. "Description of BMPs (Tier1 Projects) Erosion Control BMPs." State of Texas. August 4.

This document describes practices that can be implemented for erosion control in the State of Texas. The Texas Department of Transportation (TxDOT) defines critical performance factors for these types of erosion control products. The following erosion control techniques are described:

- Blankets and matting—These can be used as an aid to control erosion on critical sites during the establishment period of protective vegetation. The products that have been approved by TxDOT are also appropriate for construction site stabilization.
- Mulch—This is the process of applying a material to the exposed soil surface to protect it from erosive forces and to conserve soil moisture until plants may become established.

- Sandbag berm—The purpose of a sandbag berm is to detain sediment runoff from disturbed areas. The objective is accomplished by intercepting runoff and causing it to pool behind the sandbag berm. Sediment carried in the runoff is deposited on the upstream side of the sandbag berm because of the reduced flow velocity.
- Silt fence—This fence is a barrier consisting of geotextile fabric supported by metal posts to prevent soil and sediment loss from a site.

Palmer, P. Undated. "Soil Erosion, Agriculture and the Environment."
<www.science.plym.ac.uk>

This internet site references several previous studies that have been conducted in regards to land degradation (a global problem). According to a 15-year global assessment of soil degradation, 15 percent of the world's land areas has been degraded by human activities. Of the areas affected, more than half (55 percent) was caused by water erosion, and nearly one-third (28 percent) was caused by wind erosion (Conacher, 1995).

This study discusses various countries and continents and how they deal with the problems of soil erosion. The following summarizes each area:

- United States: Wind erosion of soils is most widespread in the American Great Plains. USDA (1998) states that 70 million acres of cropland are subject to wind and water erosion.
- Canada: Commercial agriculture has always had the potential to degrade the soil. The problems of prairie wind erosion are ongoing, and windbreaks, strip cropping, and summer fallow practices are only partial solutions.
- United Kingdom: Boardman and Evans (1994) noted that there was potential for widespread soil damage in Britain in 1971, with the emphasis placed on water and wind erosion.

This study also describes the following solutions to global soil erosion problems.

- Terraces: earth embankments constructed across the slope to intercept surface runoff and convey it to a stable outlet.
- Windbreaks: shelter breaks built as "living windbreaks" at right angles to the erosive winds.
- Conventional earthen structures: structures, such as bunds (contour-lined banks), have been used successfully in Africa. These banks are up to 2 m wide.

Sprague, C.J., C.A. Carver, and J. Rikken. 2000. "Reinforced Turf vs. Hard Armor – A Case History." International Erosion Control Association Conference Proceedings. 2000: 247-259.

The paper discusses the replacement of conventional erosion control materials, e.g., cast-in–place concrete or riprap with "softer" vegetation-oriented techniques that provide economically and technically superior approaches to erosion and sediment control. The project study area is the Sedgewood Subdivision in Easley, South Carolina. Continued expansion of Highway 153, which is close to the subdivision, has resulted in erosion in a

constructed channel and a natural creek that flows through the subdivision. Riprap overlying a geotextile had been used to prevent erosion along the drainage facilities, but the riprap and geotextile were failing. The riprap had been washed away leaving the textile in many places. The solution was the replacement of the riprap with TRMs, a rolled erosion control product (RECP). The particular TRM used (Miramat TM80) had been found to have permissible shear strength in excess of 335 kilonewtons per square meter (kN/m^2) (20 pounds per square foot [psf]) under high flow conditions in a flume at Utah State University. Once the TRM was installed, seeding took place. A thin layer of topsoil, which was also seeded, then followed. Finally, straw mulch was applied to the sides of the channel to "provide limited protection to the seed."

Lipscomb, C.M. 2001. "Performance of Articulated Concrete Blocks in Vegetated and Un-Vegetated Conditions." International Erosion Control Association Conference Proceedings. 2001: 295-306.

The COE developed and licensed an articulated concrete block system (Corps Block) in the late 1990s. The objective of the current study is to carry out a laboratory test on the Corps Block to identify the design, application, and performance limits of the system in an open-channel condition. In addition, an investigation into the possibility of establishing vegetation within the block voids and the effects of the vegetation on the stability of the Corps Block system was also undertaken. The results indicate that unvegetated blocks remained stable up to a shear stress of 206.4 Pascals (or approximately 4 m/s in velocity), while the vegetated block system remained stable up to a shear stress of 292.1 Pascals (or 4.2m/s). In the case of the unvegetated block system, blocks began to lift from the system and oscillate at the transitional instability limit of 206.4 Pascals, but in the case of the vegetated system, vegetal elements were removed in small groups at the transitional instability limit of 292.1 Pascals. The conclusion is that "vegetation reduces the shear stress directly on the block system thereby increasing stability." The study does point out that shear stress associated with the transitional instability of the system is less than the shear stress associated with a catastrophic system failure.

Glaser, D.E. and R.A. Kusmierczyk. 1997. "Steep Grass-Lined Slope Reinforcement Alternatives for Limited Construction Access." International Erosion Control Association Conference Proceedings. 1997: 77-90.

The Pinellas Park Water Management District (PPWMD) is a special district charged with the management of the primary drainage system for a portion of central Pinellas County, Florida. PPWMD hired an engineering consultant (Camp Dresser & Mckee Inc. [CDM]) to update the stormwater master plans for each of its five drainage basins. The stormwater master plan identified a number of open channels that needed improvement. Many of the channels earmarked for improvement have limited access (because of proximity to private property) for maintenance activities and future construction. The alternatives developed to deal with these obstacles included designing open channels with steeper slopes. The steeper slope design was adopted to allow adequate conveyance of stormwater while reducing the top width of the open channel so as to allow greater access. A drawback of steeper slopes is slope instability. To reduce the problem of unstable slopes, PPWMD asked CDM to develop alternative designs for steepened slopes that would be stable, durable, easy to maintain, and cost effective.

A test project was established consisting of a variety of slope reinforcement and erosion protection options within a 300-foot section of unimproved open channel. Six different slope treatments were developed ranging from sections having significant slope stability protection to sections with no slope protection. The systems with slope protections are composed of manufactured materials that could be installed during construction of embankment and were installed in the north slopes. The south slopes (or the slopes with no protection) are constructed with erosion-resistant materials constructed on the surface of the embankment. The south slope erosion protection methods included a geocell erosion veneer and a jute erosion veneer. The north slope alternatives included rock-filled gabion wall, horizontal synthetic grid-reinforcement, terraced synthetic geocell material, and steel sheet piling.

The results indicate that erosion protection methods did not work. The south bank lost stability. On the other hand, the north slope alternatives worked very well, although their cost effectiveness varied. The most expensive was the rock-filled gabion baskets, and the most cost-effective was the geogrid and fabric.

Crowley, J., D. Bell, and B. Kopp-Holtweische. 2001. "Environmentally-Favorable Erosion Control with a Polyvinyl Acetate-Based Formulation." International Erosion Control Association Conference Proceedings. 2001: 91-100.

A polyvinyl acetate-based formulation is a biodegradable, liquid soil stabilizer for soil and seed protection from wind and water erosion. The formulation forms a three-dimensional membrane structure that holds seeds and soil in place and also allows oxygen to penetrate the soil. It can be applied through hydroseeding.

The formulation acts as a "liquid crust" and strengthens the surface of the soil. It forms a three-dimensional network structure that fixes seed material to the soil grains and promotes vegetation.

The effects of polyvinyl acetate-based formulation on slope protection is successful. Slope protection is highly efficient under simulated high precipitation (using a 1:3 slope of loamy sand). Slopes treated with this method experienced less than 30-percent soil loss compared to untreated slopes.

Observations reported from field trials in France have shown this product to have good protection against soil loss caused by strong winds. Depending on soil type, the formulation can resist wind speeds up to 140 km per hour.

Freer-Hewish, R.J. 1991. "Erosion of Road Shoulders from Rainfall and Runoff." International Erosion Control Association Conference Proceedings. 91: 263-273.

Unbound materials without a treated surface are the most common form of road shoulder for paved roads in the hotter regions of the world. The Australian maintenance organizations are committed to addressing the effect (erosion) that these shoulder deficiencies have on the total life performance of that pavement/shoulder edge. The problems of erosion are magnified in arid regions because rainfall often has a highly erosive force, and the soils tend to be highly erodible.

This article presents some control measures that may be used to combat erosion of road shoulders.

- Reduce soil erodibility—Chemical stabilization can be effective for the short term. Also, a fully sealed shoulder with a bituminous surface will alleviate shoulder maintenance problems, but this is a highly expensive option.
- Reduce or divert runoff before it reaches the shoulder—Changing the material type at the pavement/shoulder interface creates a change in flow conditions that encourages an erosion trough.
- Cover the soil to protect it from raindrop impact and runoff—This may be achieved through the use of geotextiles or vegetative measures.
- Increase the infiltration capacity of the soil to reduce runoff—Create a shoulder from permeable materials.

Duffin, M.J. 1991. "Steep Slope at Snodland, Kent." International Erosion Control Association Conference Proceedings. 91: 235-247.

This paper presents methods to protect steep slopes from erosion. The area of the testing was conducted at a distribution depot within an abandoned sand quarry. Various vegetative methods of surface stabilization were tested and found to not work effectively. A method using concrete-filled mattresses, usually used for shallow slope protection in marine or river environments, was used successfully.

The cut slopes at this site were at angles of 60 degrees. The soil material was prone to degradation and erosion. Gullying occurred wherever surface water flow was concentrated over quarry faces.

Unsuccessful vegetative measures used to deter erosion included:

- Spray seeding with a fibrous mulch
- Spray seeding with a plain binder
- Spray seeding with bitumen binder
- Pre-seeding straw-based matting
- Spray seeding coir matting

Because of the arid temperatures, these methods of erosion control were not successful. Matting and soil-filled solutions dried out before having a chance to germinate.

Non-vegetative treatments were then tested and used successfully. The method used was the construction and installation of concrete mattresses. Two types of mattresses were laid, a "crib" mattress that incorporates porous panels that allow surface water to drain, and a "constant thickness" mattress that was a 75 mm thick. The construction procedure follows:

- Survey area.
- Remove all loose sand and debris from terraces.
- Fill terrace mattresses with concrete.
- Prior to filling of the face mattress, cast a continuous concrete stool to fill the gap between the bottom of the mattress and the top of the permacrib filling. Install drainage pipes to prevent build-up of water pressure behind the mattress.

- "Dry fix" upper slope panels with pins driven along top edge; these are driven into the sand to throw surface water out and over the mattress.
- Use a conventional plasticised mortar mix.
- Fill the mattress in stages and let out slack to minimize fissures opening up in the back of the mattress.

These mattresses proved to be an economical and permanent solution to a potentially large erosion control problem.

Miller, T.J., R. Edberg, and A.M. Berry. 1996. "Soil Tackifier Performance on an Exposed Slope." International Erosion Control Association Conference Proceedings. 96: 445-453.

Two soil tackifiers were tested for effectiveness in controlling erosion at the University of California, Davis Arboretum. The first tackifier was an acrylic copolymer (AC), and the second was a vegetable hydrocolloid. Water and sediment runoff were collected and measured. The results showed that the AC tackifier allowed the least amount of sediment to erode from the slope and resisted breakdown more effectively throughout the 8-week study period than the vegetable hydrocolloid tackifer. The AC tackifier also had the lowest infiltration. The vegetable hydrocolloid tackifier resisted erosion better than the control (no soil tackifier) and had a higher infiltration rate. The vegetable hydrocolloid tackifier broke down rapidly over the test period, and by the end of the study had almost as high a rate of sediment loss as the control. The infiltration rates for both the control and the vegetable hydrocolloid plots increased during the 8-week study, while the rates for the AC plots stayed approximately the same. The difference in infiltration rates between plots with grass and those without was statistically significant in plots with a tackifier and negligible in the control plots.

Both of the tackifiers tested had positive and negative attributes. The vegetable hydrocolloid tackifier allowed for a high infiltration rate, which may benefit plant life, but broke down within 8 weeks. It also did not protect the soil adequately against splash and gully erosion. The AC tackifier had a lower breakdown rate, but did not allow for enough infiltration to adequately support survival of the grasses used in this experiment.

Performance Criteria

This section presents information that pertains to the selection of erosion control products. The methods for choosing products vary according to each situation. Cost may not always be the limiting factor. Selection of erosion control products is based on the following criteria:

- Acceptance
- Cost effectiveness
- Ease of installation
- Vegetation establishment
- Maintenance
- Standards set forth by the states' Department of Transportation

Harding, M.V. 1994. "Comparing Best Management Practices: The Erosion Control Benefit Matrix (ECBM)." International Erosion Control Association Conference Proceedings. 94: 455-466

This study focuses on the process of taking into account all of the variables that influence the decision-making process when one selects a best management practice (BMP) for erosion control. The ECBM is introduced, which highlights the six characteristics most designers consider in the selection process—acceptance, cost effectiveness, installation, vegetation, establishment, and maintenance.

A wide range of erosion and sediment control problems has resulted in a variety of technology designed to provide solutions; but how do erosion control specialists decide on which material or technique to use? Should cost always be the limiting factor? Can dissimilar products be compared for the same application? At the present time, there exists no standard formula by which an erosion control planner can determine the most cost-effective solution to a specific erosion problem. The method of comparison described in this paper is not presented as a mathematical model, but attempts to separate and take into account all of the variables that influence the decision-making process when one selects a BMP for erosion control.

Northcutt, P. 1998. "Performance Testing of Erosion Control Products-What Have We Learned After Five Complete Evaluation Cycles?" International Erosion Control Association Conference Proceedings. 98: 198-218

This paper discusses the few standardized methods for evaluating erosion control product performance. Some state departments of transportation have established evaluation methods and/or facilities by which they assess products for erosion control performance and project suitability. TxDOT has an erosion control field laboratory where it evaluated products and developed standards by which all products are evaluated and approved or disapproved for suitable materials on TxDOT projects. They evaluate products under sandy or clayey soil conditions for density of vegetative establishment and sediment loss. Erosion control blankets must meet or exceed the performance standards summarized in Table B-1.

The ECBM allows the user to compare products according to the specific product needs. The ECBM highlights six primary product selection criteria including acceptance, cost effectiveness, installation, vegetation, establishment and maintenance. The ECBM breaks these components down further into categories that detail their impact on the erosion control system.

The ECBM is intended to be used as a vertical checklist whereby two BMPs can be evaluated side by side for their erosion control benefits. Numbers can be assigned at the user's discretion to derive a final "point total" at the end of the process, but since there are no importance values assigned to each variable, the vale of the final number would seem to be useless.

TABLE B-1
Texas Department of Transportation Performance Standards for Soil Retention Blankets[a]
Caltrans Arid Region Non-vegetative Erosion Study Plan and Experimental Design

Parameter	Slope	Clay soil	Sandy soil
Minimum Vegetation Density (in approximately 12 months)	All slopes	80 percent	70 percent
Maximum Sediment Loss	3:1 or flatter	0.70 lbs/100 sq-ft	25.00 lbs/100 sq-ft
Maximum Sediment Loss	Steeper than 3:1	0.70 lbs/100 sq-ft	55.00 lbs/100 sq-ft

[a]average 1-year, 3-year, and 5-year design storms
Source: P.E. Northcutt, 1993
lbs = pounds
sq-ft = square feet

Weighted values can be assigned when the user knows which characteristics are most important or most limiting in their particular application. For example, if inexperienced labor crews will be applying the BMP with limited training, perhaps the durability or ease of installation will be of more importance than environmental compatibility.

The ECBM can be used to understand the relative strengths and weaknesses of new products being developed for the erosion control marketplace. In this regard, it can help define the relative niche of a new material or concept by exploring the existing alternatives presently available, their historical use, and their specification for establishing fully the costs of installation and maintenance.

This method could provide some guidance in selection of products suitable for the needs of permanent non-vegetative projects in arid climates.

Driver, T. and J.L. Kostielney. 1997. "How to Interpret ASTM Index Tests and Performance Parameters for Rolled Erosion Control Products." International Erosion Control Association Conference Proceedings. 1997: 143-151.

Some manufacturers include in their literature detailed information about the result of American Society for Testing and Materials (ASTM) tests performed on their products. References to "performance standards" are found in brochures and many other documents. Values are provided for tensile strength, elongation, flexibility, flow velocity, permissible shear stress, absorptive capacity, resiliency, tear resistance, and Manning's "n" and the "C" factor. This paper describes each of these categories to help a user better understand the performance capabilities of the products.

- Index vs. performance parameters—Index parameters are methods to describe the physical components and characteristics of products such as weight per unit and thickness.
- Elongation—Elongation is a measurement of how much a material stretches before it breaks. ASTM prescribes several test methods to determine elongation; results may vary significantly, even on the same material. A piece of material with a specified size is put into a tensile testing machine, and tensile pressure is applied automatically by the machine.

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- Tensile strength—Test procedures for tensile strength are the same as for elongation, as they are tested simultaneously. Results may also vary significantly. Higher tensile strengths are required on sites with steeper slopes than on shallow slopes.
- Flexibility/stiffness—This test evaluates the erosion control blanket fabric's stiffness or resistance to bending. Anything less than 90-percent contact with soil particles increases the probability that erosion can occur.
- Flow velocity—ASTM D4491 determines the amount and speed of water flow the erosion control blanket can experience before it tears. Water is supplied by gravity flow at rates up to 170 cubic feet per second (cfs) from an upstream reservoir. In general, coir fiber and synthetic fibers can withstand higher velocities than can straw or wood fibers.
- Permissible shear stress—This is the minimum shear stress that an erosion mat must attain in a bare soil channel.
- Absorptive capacity—This test assesses the amount of moisture the erosion control blanket is capable of absorbing. This value is important because the blanket must be able to hold enough moisture for germination and maintenance of seeds and resulting plants.
- Thickness—This is measured as the distance between one surface and its opposite. In textiles, the distance between the upper surface and lower surfaces of a material is measured under a specific pressure.
- Manning's "n"—This is the coefficient of roughness. The rougher the erosion control material is, the more readily material is able to slow down the velocity of the water running over it. The higher the number, the rougher the material.
- "C" factor—This factor is another performance parameter and is used in the Universal Soil Loss Equation (USLE), which calculates annual erosion rates from disturbed sites.

Armstrong, J.J. and G.J. Wall. 1992.. "Comparative Evaluation of the Effectiveness of Erosion Control Materials." International Erosion Control Association Conference Proceedings. 92: 77-92..

This paper describes the use of performance indices of surficial erosion control materials in the control of surficial erosion, particularly during the planning and design stages of highway development. The paper reports on the second year of work where four hydraulic mulches and three erosion control blankets were tested. The results continue to confirm the validity of the original model based on USLE. The model is especially useful in categorizing equitably the effectiveness of surficial erosion control materials that vary widely in their composition, mode of operation, and effectiveness.

Equally important is the highway designers' ability to estimate the erosion susceptibility of their proposed highway cuts and fills using USLE, and then specify the contract so that a category of equally effective erosion control measures is identified for the contractor to use as directed. This ability is also very important to the environmental designers and planners who are attempting to minimize potential environmental impacts associated with the construction of modern highway facilities.

Armstrong, J.J. 1993. "Effective Use of Surface Erosion Control Materials." International Erosion Control Association Conference Proceedings. 93: 105-118

This paper describes the use of performance indices of surficial erosion control materials in the control of surficial erosion, particularly during the planning and design stages of highway development.

Armstrong reviews models currently used to predict soil loss, including USLE and the Water Erosion Prediction Project (WEPP), and traditional erosion control approaches in planning and design. The study focuses on erosion control capability, erosion susceptibility, surficial erosion control, and structural erosion control alternatives when surgical erosion control materials are inadequate for the conditions encountered. The structural erosion control alternatives follow:

- Reduce the height or cut or fill through profile alteration. This will result in the reduction of the length/slope (LS) value.
- Create a benched slope and provide an interceptor ditch to reduce the LS value and therefore the erosion caused by runoff over the slope.
- Flatten the gradient of the slope.
- Consider the use of the least erodible topsoil available in conjunction with the other approaches involving a reduction in the LS value.
- Use gravel sheeting or riprap as an erosion control cover placed over a suitable geotextile.
- Identify other approaches that involve the reduction of any of the values of the parameters of USLE.

Other Pertinent Studies

This section includes other information pertinent to this study but cannot be categorized into any of the above listed headings. The reports present information on the Wisconsin Department of Transportation's Product Acceptability List (PAL), the Federal Highway Administration's (FHA) compilation of an erosion and sediment control manual, and water quality laws in the United States by which many erosion and sediment control programs and initiatives are driven.

- The Wisconsin Department of Transportation has compiled the erosion control PAL for erosion control materials. Products included in the list must conform to certain standards and are reviewed annually.
- The FHA compiled a manual of erosion and sediment control measures that has been used by Region 5 of the FHA. Other states have taken active roles in erosion and sediment control in their highway construction programs.
- The implications of degraded water quality in the United States, the enactment of federal laws to restore water quality, and the need for increased consistency between local regulatory programs are presented.

Wisconsin Department of Transportation (WisDOT). 2000. Erosion Control Product Acceptability Lists (PAL) for Multi-Modal Applications-January 2000 Edition.

The WisDot compiles the Erosion Control Product Acceptability Lists for erosion mats, soil stabilizers, tackifiers, inlet protection, and temporary ditch checks. Products included in these lists must conform to certain standards and are reviewed annually. These guidelines apply to methods of installation for all of the following project locations applicable: slopes, channels, shorelines, high wind locations, and areas next to traffic lanes (WisDOT, 2000).

Mitchell, G.F. and T. Masada. 1992. "A Review of Erosion and Sediment Control Specifications of Departments of Transportation." International Erosion Control Association Conference Proceedings. 92: 101-118.

The FHA compiled a manual of erosion and sediment control measures that had been used by Region 15 of the FHA. Some states have taken an active role in erosion and sediment control in their construction programs, especially highway construction.

The departments of transportation in the 50 states were contacted, and copies of their standard specifications and other documents on erosion and sediment control were requested. The states were ranked on the amount of information on erosion and sediment control that was available in all documents provided and in their standard specifications.

Points were assigned to represent the level of detail available for each of 54 components of erosion, and sediment control was then calculated for each state. States were then ranked on the basis of the amount of information that was available and provided in their documents.

Individual tables were prepared on 56 items relating to erosion and sediment control with material provided by individual states. Items included, among others, topics on specific control measures, both temporary and permanent measures; exposed area; erosion control managing and inspections; water pollution; and earthwork. Out of a possible score of 100 percent, the first place state scored a 49.7 percent. The twenty-fifth-ranked state scored 26.9 percent.

Forrest, C.L. 1990. "Erosion Control in the United States Today: An Overview." International Erosion Control Association Conference Proceedings. 90: 3-10.

This paper discusses the practice of erosion control concerns as they relate to water quality in the United States. This concern has resulted in the enactment of federal laws with the intent of restoring and maintaining the chemical, physical, and biological integrity of the waters in the United States.

This paper's conclusions include:

- An increase in the concentration of suspended solids in the waterways threaten water quality to humans and the environment.
- Implementation of erosion control measures consistent with sound agricultural and construction operations are desired to minimize the adverse impacts associated with increased sediment yield. Particular emphasis has been placed in recent years on the restoration of vegetation as the preferred erosion control method.

- There is still a need for increased consistency between local regulatory programs. Additionally, there is a need for more product performance and effectiveness information derived from both case studies as well as comparative testing.

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Appendix C
Additional Research Material — Abstracts


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APPENDIX C

Abstracts

Title: EVALUATION OF SLOPE STABILIZATION METHODS (US-40 BERTHOUD PASS)
Author(s): Price, D.A.
Publication Date: 1996
Source: CDOT-DTA-R-96-6, Construction Report

Abstract:
SH-40 west of Berthoud Pass as seen in 1995 was built in the early 1960s. Standard practices for erosion control (in effect during the 1960s) were applied to the cut and fill slopes. The slopes consist of highly erodible and unstable sandy soils mixed with a large quantity of rocks, which vary in size to over 2 meters in diameter. The snowmelt runoff combined with the severe rainstorms of spring and summer wash away the top layer of soil and thereby prevent vegetation from establishing itself. Enhancement funds became available for the 1995 construction season to rehabilitate some of the eroded slopes. The purpose of this project is to test various cost-effective erosion control materials and installation techniques to provide data for application on future projects in this and similar areas. Sixteen materials, from erosion mats and mulches to different tackifiers, are being used within three work zones. The three zones will be evaluated for constructibility and overall performance on the better 1 to 1 slopes that are normal for Berthoud Pass.

Title: HOW TO MAKE VEGETATION STAND UP UNDER PRESSURE
Author(s): Theisen, M.S.
Journal Title: Civil Engineering News, **Volume**: 8, **Issue:** 4
Publication Date: May 1996

Abstract:
Geosynthetic turf reinforcement mats (TRM) improve the natural ability of plants to control erosion by retaining seeds in soil, stimulating seed germination, accelerating seedling development, and synergistically meshing with developing plant roots and shoots. Two applications of TRMs are steep highway embankments and drainage ditches. This article describes why TRMs, in conjunction with properly selected vegetation, are a cost-effective alternative to hard armor techniques. Properties to consider when selecting a TRM product are thickness, porosity, strength, flexibility, dimensional stability, durability, and ultraviolet stability. Long-term performance considerations and installation guidelines are discussed. In addition, a case study of a stormwater drainage channel project is presented.

Title: MANAGING THE ROADSIDE
Journal Title: Texas Transportation Researcher, **Volume:** 32, **Issue:** 3
Publication Date: 1996

Abstract:
Roadside vegetation plays an important role in the roadside ecosystem. Plants stabilize soils against erosion and provide a visible boundary at the pavement edge. But too much of a good thing can create havoc. When plants and insects threaten the traveling public, measures must be taken to control the vegetation. Texas Department of Transportation uses maintenance measures designed to encourage the growth of good plant species, thereby reducing the need for excessive spraying of chemicals and overall reducing the total cost of roadside maintenance. By continuing to explore treatment methods that are environmentally sound and promoting the growth of

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native species, Texas Department of Transportation will assure responsible, safe, and fiscally sound maintenance practices.

Title: HIGH STRENGTH EROSION CONTROL MAT SUPPORTS VEGETATION ON A CUT ROCK SLOPE
Author(s): Trolinger, B.; Austin, D.N.
Source: Conference, Geosynthetics 1997
Publication Date: 1997

Abstract:
During the widening of U.S Highway 25E from Clinch Mountain to U.S. Highway 11W in Grainger County (USA), the Tennessee Department of Transportation (TNDOT) was faced with the challenge of cutting a 0.5H:1V rock slope and preventing fragile limestone, sandstone, and hale deposits from falling near passing motorist. Although hard armor solutions such as retaining structures and shotcrete were considered, concern over the aesthetics of highway expansion and costs associated with 7.5 kilometers of potential hazards forced TNDOT to create an innovative vegetative solution. These 42.5-meter-tall rock slopes were hydraulically seeded, anchored with wire mesh and rock bolts, and stabilized with a unique three-dimensional woven geotextile erosion control mat. Presented herein is a detailed case history of a unique application of a high-strength permanent erosion control mat on a challenging project. This project summary documents the feasibility study, design parameters, specification and contract document preparation, and supply and installation of specially fabricated 3.6-meter-wide rolls. Also included are cost comparisons and construction techniques for future users. A series of installation photographs accompanies this paper to create a practical technical reference for all involved in geosynthetics.

Title: ARTIFICIAL GRASS PREVENTS EROSION NEAR REPAVED ROAD
Author(s):
Journal Title: American City and County **Volume:** 113, **Issue:** 8
Publication Date: July 1998

Abstract:
When the Missouri Department of Transportation (DOT) repaved a 3-mile (5-kilometer) stretch of Route 370, the project involved land along the Missouri River floodplain. Contractors needed to dredge fill material out of the riverbed to raise the highway elevation. However, the sandy fill material, while minimizing susceptibility to flooding, increased the threat of erosion. In response, the DOT decided to install a 5-foot-wide (1.5-meter) transition strip of dirt adjacent to the repaved surface and plant grass seeds. A native grass seed mix was used in conjunction with Curlex I Quickgrass, an erosion control blanket manufactured from biodegradable aspen wood fibers and polypropylene netting that protects the seed from rain and runoff, reduces the likelihood of burnout, and increases moisture retention, thus fostering seed germination and growth.

Title: APPLICATION OF ANCHORED GEOSYNTHETIC SYSTEMS FOR IN SITU SLOPE STABILIZATION OF FINE-GRAINED SOILS
Author(s): Vitton, S.J.; Harris, W.W.; Whitman, M.F.; Liang, R.Y.
Journal Title: Transportation Research Record **Issue:** 1633
Publication Date: 1998

Abstract:
The use of an anchored geosynthetic system (AGS) was proposed by Koerner et al. for the stabilization of slopes at or near their failure state. AGS provides in situ stabilization of soil slopes by combining a surface-deployed geosynthetic with an anchoring system of driven reinforcing rods

similar to soil nailing. Installation of the system involves tensioning a geosynthetic over a slope's surface by driving anchors through the geosynthetic at a given spacing and distance. By tensioning the geosynthetic over the slope's surface, a compressive load is applied to the slope. Benefits of AGS are described to include the following: (a) increased soil strength caused by soil compression, including increased compressive loading on potential failure surfaces; (b) soil reinforcement through soil nailing; (c) halt of soil creep; (d) erosion control; and (e) long-term soil consolidation. Following installation of AGS and 1 year of monitoring, it was found that AGS provided only some of the reported benefits and in general did not function as an active stabilization system. This was in part because the system could not provide and maintain loading on the geosynthetic. The geosynthetic, however, did tension when slope movement occurred, preventing the slope from failing. Thus, the system functioned more as a passive restraint system and appeared to function well over the monitoring period. **ID:** 00759177

Title: DESERT VARNISH: ROCKY POINT VIADUCT
Author(s): Brooks, E.W.
Publication Date: 1998
Report No: Oregon Department of Transportation Final Report ,OR-EF-99-09

Abstract:
In 1995, the Oregon Department of Transportation (ODOT) sprayed the reinforced shotcrete slope stabilization project near Port Orford on US 101 with Permeon, a rock-coloring material also called desert varnish. The application colored the shotcrete to a weathered-looking dull brown, masking its gray-white concrete appearance. Some weathering in the last 3 years has changed the color. Water and mud running from the above cliff have added white and brown streaks. Also, wind and salt air erosion have faded some of the coloring. The test area is still darker than the control section that received no application. The value of the desert varnish appears to be marginal. If the 3-year trend continues, the salt air and strong winds will discolor the entire treatment.

Title: HYDRAULIC BEHAVIOR OF GEOTEXTILE FILTERS IN THE FIELD
Author(s): Mlynarek, J.
Journal Title: Geotechnical Fabrics Report **Volume:** 16, **Issue:** 8
Publication Date: October 1998

Abstract:
Filters are often used to prevent particles from migrating into a drainage system, while simultaneously evacuating excess water from soils. The water must percolate through the soil and then the filter before entering the system. Therefore, a filter must be selected that will restrain the piping of migrating particles while simultaneously permitting water discharge. The advantages of using geotextile filters in drainage are the following: geotextiles act as a filter to allow water entry but prevent migration of fine soil particles into drainage, geotextiles effectively increase the inlet of the drainage system, and geotextiles reduce hydraulic gradients near drain tubes. Geotextile filters also have important advantages over mineral filters: they are easier and less costly to install, and they allow easier quality control. This article, which is the eighth installment of this journal's filtration series, applies the hydraulic principals discussed in previous series articles to three varied case histories involving geotextile filters: subsurface agricultural drainage systems in Ormstown, Canada; municipal roadway drainage in LaSalle, Montreal, Canada; and coastal erosion protection in Miami Beach, Florida. After 3 to 30 years of service, geotextile filters were found to be efficient in retaining soil particles without restricting water flow.

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Title: TEXAS DOT TESTS EROSION CONTROL MATERIALS
Author(s): Northcutt, P.E.
Journal Title: Better Roads **Volume:** 67, **Issue:** 9
Publication Date: September 1997

Abstract:
About 15 years ago, the Texas Department of Transportation found itself in a dilemma. Texas Department of Transportation engineers believed in the capabilities of roll-type erosion control mats and of hydraulic mulches for stabilizing and revegetating disturbed construction sites. This article describes tests performed by the Texas Transportation Institute on products designed to inhibit soil erosion.

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Better Roads
P.O. Box 558
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Title: INNOVATIVE SLOPE COVER PROTECTS ROAD THROUGH CUMBERLAND GAP
Author(s): Austin, D.;Trolinger, B.
Journal Title: Roads and Bridges **Volume:** 35, **Issue:** 3
Publication Date: March 1997

Abstract:
During a recent project to widen a road running through the Cumberland Gap, engineers discovered that cutting a rock slope would expose pyrrhic rock, which would produce acid leachates. There were concerns about environmental damage to local streams and the water table. To solve the problem, Tennessee Department of Transportation decided to specify a combination of wire mesh and a permanent erosion and reinforcement matrix (PERM) to stabilize the face of the slope, initiate development of vegetation, prevent rockfall from endangering motorists, and provide long term aesthetics. The PERMs provide long-term performance of vegetation cover, soil retention capacity, increased hydraulic performance limits, and tensile strengths up to 40,000 N per meter. Long-term evaluations will have to wait, but the short-term performance has been very promising.

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Title: EROSION EATEN AWAY BY NEW AGENT
Author(s): Martin, P.
Journal Title: Roads and Bridges **Volume:** 38, **Issue:** 3
Publication Date: March 2000

Abstract:
Pennzoil has developed and patented a unique product that has proven effective in stabilizing erosion problems that sometimes occur during road and bridge construction projects. PennzSuppress EC is a unique soil binder that prevents erosion on sloping embankments during critical soil stabilization and turf establishment periods without the need for mulch. The environmentally safe agent eliminates wind and water erosion problems on steep embankments bordering highway overpasses and bridges, roads, airport runways, and stormwater channels. It performs in demanding weather conditions to stabilize the soil and prevent erosion from occurring. When applied properly, PennzSuppress EC will not pollute water, air, or plant life and will not harm wildlife in rivers or streams. Rather, it is shown to promote vegetation growth. It works as a soil sealant by penetrating several millimeters below ground and binding soil particles together to improve the cohesion of the soil surface.

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Title: THE EFFICACY OF EROSION CONTROL BLANKETS AND SOIL STABILIZERS
Author(s): Benik, Scott R.; Wilson, Bruce N.; Biesboer, David D.;Hansen, Brad J.
Publication Date: 2000
Pagination: p 119
Report No: Final Report ,MN/RC-2000-15
Publisher/Corporate Author(s):

Minnesota Department of Transportation
Transportation Building, 395 John Ireland Boulevard
55155

University of Minnesota, St Paul
Department of Biosystems and Agricultural Engineering, 1390 Eckles Avenue
St Paul MN 55108
USA

Abstract:
This report presents the results of a 2-year field study on the performance of erosion control products under natural and artificial rainfall conditions. Vegetation, runoff, and erosion data were collected at a newly constructed roadway. Runoff and erosion data were gathered using natural rainfall events and using a rainulator to spray water onto the surface. Treatments included a wood fiber blanket, a straw/coconut blanket, a straw blanket, a bonded fiber matrix, and disk-anchored straw mulch for natural rainfall events. For the rainulator events, a bare soil treatment also was used. Biomass, percent cover, and species composition also were measured at the research site. Five runoff events from natural rainfall were measured and revealed very little difference in sediment production between the straw, straw/coconut, and the wood fiber blankets. These blankets had approximately one-tenth the erosion that was observed for the straw-mulch plots. The impact of the erosion control treatment was substantial for early-season

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artificial events. The sediment loading rates from the blankets and bonded fiber matrix plots were roughly 100 times smaller than the bare soil plots and 10 times smaller than the straw mulch plots. For late-season events, the erosion from these products were approximately one-half of that from straw mulch treatments.

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Title: NEW MEXICO ROADSIDE DEVELOPMENT PROJECT
Author(s): Dick-peddie, W.A.
Publication Date: 1964
Publisher/Corporate Author(s):
New Mexico State University
USA

Abstract:
Important aspects of vegetation establishment on roadsides in arid (average annual rainfall less than 8.5 inches) New Mexico were investigated in this 4-year study. Grasses, mulches, fertilization, plant propagation, and tree and shrub planting technique and erosion studies were included in the project. Of 24 species of grasses tested under nursery conditions, only five were selected for planting on the roadside. Of these, only two species of lovegrass indicated adaptability for the roadside environment. Because of limited availability of water, no significant increases in growth were produced as a result of nitrogen applications. Desert willow (*Chilopsis linearis*) and apache plum (*Fallugia paradoxa*) are native species that grew comparatively well under roadside conditions and showed adaptability for erosion control purposes. Transplanting plants from areas adjacent to the right-of-way was a disappointing operation. Arid conditions result in extensive root systems that cannot be successfully moved by conventional methods. It was found that untreated cuttings taken from dormant plants of native species in November rooted well. The limited availability of nursery-grown stock of many native species should no longer be a major problem. Medium-size gravel served as an effective mulch, providing excellent moisture retention and protection against erosion. /bpr/

Title: ASSESSMENT OF EROSION/SEDIMENT CONTROL IN HIGHWAY CONSTRUCTION PROJECTS. FINAL REPORT: APPENDIX C AND D
Author(s): Mitchell, G.F.
Publication Date: 1993
Publisher/Corporate Author(s):
Federal Highway Administration
400 7th Street, SW
Washington 20590
USA

Ohio Department of Transportation
25 South Front Street, P.O. Box 899
Columbus DC 43216-0899
USA

Ohio University, Athens
Center for Geotechnical and Environmental Research, Civil Engineering Department
Athens OH 45701
USA

Abstract:
An assessment and comparison of erosion and sediment control practices, as applied to highway construction, were made through the following methods: surveys of personnel from state departments of transportation and project engineers in the State of Ohio, comparison of state departments of transportation standard specifications and other materials, and field investigation at three sites in Ohio. Both of the surveys yielded similar responses on several items. Some of these were as follows: the individual had a higher perception of the importance of erosion and sediment control than the state; hydroseeding with mulching for temporary and permanent erosion control and filter fabric fence with bales for temporary sediment control received top ranking; and major problems were encountered in weather conditions, lack of contractor cooperation, and lack of personnel/time. Analyzing the results of the surveys and rating the state documents on erosion and sediment control, in conjunction with the field assessment, provided some recurring themes and recommendations: emphasizing the importance of presenting and discussing erosion and sediment control plans with the contractor at the preconstruction conference; requiring that a pre-winterizing meeting be held with the contractor to discuss plans for maintenance of control items during the winter season; providing more specific guidelines for maintenance procedures that are needed on control items such as sediment basins, ditch checks, filter fabric fence; emphasizing the importance of implementing erosion control measures in a timely fashion; and developing and implementing a training program for project engineers and/or others involved in providing erosion/sediment control during highway construction. This volume contains appendices C and D of the final report.

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Title: CASE HISTORY. A LABORATORY INVESTIGATION OF THE ROLE OF GEOSYNTHETICS IN INTERRILL SOIL EROSION AND SEDIMENT CONTROL
Author(s): Rustom, R.N.; Weggel, J.R.
Journal Title: Geotechnical Fabrics Report
Publication Date: April 1993
Pagination: pp 16-33

Abstract:
The choice of a particular geosynthetic system for controlling soil erosion depends on whether it is intended to provide long- or short-term protection; the degree of protection it can provide under different climatic, topographic, and physiographic conditions; and the cost-protection efficiency measure. The systems are also categorized according to their underlying mechanisms. This article describes the mechanism of interrill soil erosion. Soil erosion from interrill areas is a function of soil detachment by raindrop impact and transport capacity of the thin sheet flow. Experiments to evaluate erosion-control systems are described, and the results are presented and discussed.

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Title: THE PERFORMANCE OF FLEXIBLE EROSION CONTROL MATERIALS. INTERIM REPORT
Author(s): Godfrey, S. H.; Landphair, H. C.; Long, J. P.; McFalls, J. A.
Publication Date: 1993
Report No: Res Rept 1914-1 ,TTI: 2-18-90-1914 ,TX/93-1914-1
Publisher/Corporate Author(s):
Texas Department of Transportation
Transportation Planning Division, P.O. Box 5051
Austin 78763
USA

Texas Transportation Institute
Texas A&M University
College Station TX 77843
USA

Abstract:
A series of evaluation procedures to determine the field performance of flexible erosion control materials were conducted at the Texas Transportation Institute/Texas Department of Transportation Hydraulics and Erosion Control Laboratory. The objectives of the study were to determine the effect of flexible materials on the germination and growth of native grasses, as well as to determine the effectiveness of the materials to prevent erosion on typical steep, roadside slopes before the establishment of permanent vegetation. Researchers repeated the vegetation establishment and soil retention portions of the evaluations on two soil types with the option for two different slopes, according to the manufacturer's preference. Researchers conducted the vegetation establishment evaluation by hydraulically applying the seed and fertilizer mixture on the plot, installing the erosion control product according to the manufacturer's published literature, and collecting data periodically throughout the growing season. The apparent vegetative cover of each plot is averaged for every round of data collection. Results include the four rounds of vegetation coverage data or the final round of vegetation data, depending on the analysis level. Researchers calculate the minimum amount of vegetation establishment from statistically analyzing the data set for significant difference ranges to the analysis level. Researchers conducted the erosion control portion of the study by artificially simulating various rainfall events with the greatest probability of occurrence during highway construction periods. The total dry sediment weight is calculated to achieve the total sediment loss per 100 square feet of plot area. The report averages the results of each series of simulated design storms for each round of data collection. The result of total sediment loss is established by averaging the totals of each round of design storm values. Researchers established the maximum amount of sediment loss from statistically analyzing the data set for significant difference ranges according to the analysis level.

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Title: ROCK FOR EROSION CONTROL
Editor(s): McElroy, C.H.;Lienhart, A.
Publication Date: 1993
Report No: ASTM STP 1177
Publisher/Corporate Author(s):
American Society for Testing and Materials
1916 Race Street
Philadelphia PA 19103
USA

Abstract:
This book examines ways to measure and evaluate the durability and performance of rock used for riprap, gabions, canal and channel linings, and other erosion control applications. Thirteen papers on durability testing and specification conformance testing explore such aspects as a new method for evaluating the wear resistance of protection stone, an index test for predicting durability, the mechanics of freeze-thaw deterioration, and a proposal for standard rock riprap sizes.

Available From:
American Society for Testing and Materials
1916 Race Street
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Title: TTI BUILDS WORLD'S FIRST FULL-SCALE EROSION CONTROL LAB
Journal Title: Texas Transportation Researcher **Volume:** 29, **Issue:** 1
Publication Date: 1993
Pagination: p 7
Publisher/Corporate Author(s):
Texas Transportation Institute
Texas A&M University
College Station TX 77843-3135
USA

Abstract:
The article describes the Texas Department of Transportation/Texas Transportation Institute's Hydraulics and Erosion Control Laboratory, a full-scale research facility for evaluating erosion control, that is tailored specifically to the highway. The facility is capable of evaluating about 36 materials (including mats, blankets, and other geotextiles) per year to determine their effectiveness in controlling erosion, their strength and durability, and their effectiveness in establishing vegetative cover. The importance of this facility to highway departments who are trying to comply with Environmental Protection Agency requirements is pointed out.

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Title: EMERGING AND FUTURE DEVELOPMENTS OF SELECTED GEOSYNTHETIC APPLICATIONS
Author(s): Koerner, R.M.
Journal Title: Journal of Geotechnical and Geoenvironmental Engineering
Volume: 126, **Issue:** 4
Publication Date: April 2000
Pagination: pp 293-306
Publisher/Corporate Author(s):
American Society of Civil Engineers
1801 Alexander Bell Drive
Reston VA 20191-4400
USA

Abstract:
This paper presents 17 separate applications within the current technology of geosynthetics. They were selected as being illustrative of the wide range of applications that can utilize geosynthetics in geotechnical, transportation, hydraulics, and geoenvironmental engineering. All are permanent or critical applications wherein design by function is required, thereby necessitating the calculation of a product-specific test result versus a site-specific design requirement. This calculation results in a factor of safety, which must be assessed accordingly. In this regard, geosynthetics are no different from any other engineering material. The paper, however, does not go into calculation details, which are available in the literature. References are provided in this regard. The various applications presented were selected to illustrate that both emerging developments and future possibilities are ongoing. The approach illustrates the dynamic nature of the field of geosynthetics and speaks well for future endeavors.

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Title: EVALUATION OF THE GEOWEB AND J.K. STRUCTURE SLOPE STABILIZATION METHODS
Author(s): Wilson, J.
Publication Date: 2000
Pagination: p 28
Publisher/Corporate Author(s):
Federal Highway Administration
State Office Building, 4802 Sheboygan Avenue
Washington DC 53707-7910
USA

Wisconsin Department of Transportation
Bureau of Highway Construction, 3502 Kinsman Boulevard
Madison WI 53704-2507
USA

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Abstract:
In the fall of 1994, two different slope stabilization products (J.K. Structure manufactured by J.K. Structure of France and Geoweb Cellular Confinement System, manufactured by Presto Products Company of Appleton, Wisconsin) were installed adjacent to State Trunk Highway 35 along the Mississippi River in west central Wisconsin in an effort to evaluate their effectiveness for erosion control and slope stabilization. J.K. Structure is a metal paneling, and the Geoweb System is an expandable plastic mesh. The natural slope of the talus material was approximately 11/4:1, but because of space constraints between the bluff and the Mississippi River, the back slopes were left at 3/4:1. The test site was 20 to 30 feet (6.1 to 9.1 meters) high and approximately 300 feet (914 meters) long. Each test section (one with J.K. Structure and one with Geoweb) was approximately 200 square meters. After 5 years, the performance of these products was rated as better than the control area (no treatment), preventing small localized areas of erosion and major slope failures. However, because of costs and installation difficulties, these products were not recommended for widespread use in Wisconsin, as the investment return was minimal. However, these products did perform satisfactorily enough so that they could be considered for use on a case by case basis where major slope failures are common.

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Title: EROSION CONTROL PRODUCT ACCEPTABILITY LISTS (PAL) FOR MULTI-MODAL APPLICATIONS - JANUARY 2000 EDITION
Publication Date: 2000
Pagination: p 40
Publisher/Corporate Author(s):
Wisconsin Department of Transportation
Bureau of Highway Construction, 3502 Kinsman Boulevard
Madison WI 53704
USA

Abstract:
Each year, the Wisconsin Department of Transportation (WisDOT) compiles the Erosion Control Product Acceptability Lists (PAL) for erosion mats, soil stabilizers, tackifiers, inlet protection, and temporary ditch checks. All products in these lists shall meet WisDOT's Standard Specifications for Road and Bridge Construction. Products included in these lists shall be manufactured with the same quality and composition as the test material originally submitted for evaluation. The lists below are organized into four major erosion control product categories. Each category is supplemented by a section intended to clarify the criteria in the PAL and outlines the general requirements for product acceptability. The lists are updated quarterly and distributed to WisDOT engineering staff, erosion control manufacturers, distributors, contractors, consulting engineers, and other interested parties. All installation instructions submitted by the manufacturer, or the distributor, to WisDOT shall contain reliable methods of installation for all of the following project locations applicable: slopes, channels, shorelines, high wind locations, and areas next to live traffic lanes.

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Title: USE OF GEOSYNTHETICS TO VEGETATE STEEP SLOPES - CASE HISTORIES
Author(s): Ward, L.E.; Luna, J.
Language: English
Conference Title: Geosynthetics 1997
Publication Date: 1997
Pagination: pp 595-605
Report No: Volume 1

Abstract:
One of the first uses of a geosynthetic material for a permanent erosion control application was on the dikes of Holland around 1973. Since then, millions of square meters of geosynthetic mats have been used successfully to reinforce vegetation on steep slopes, channels, and streambanks. The turf reinforcement mats (TRM) work with the root system of the vegetation to protect the soil from the erosive forces of rain, wind, and wave action far above the ability of a vegetative layer alone. This paper will provide case histories of three permanent erosion control installations. Before-and-after descriptions, as well as installation techniques will be discussed. Design considerations will be presented when available. The installations include a ½:1 cut slope, a cut slope with a loose rocky face, and a steep slope with surface erosion, as well as sloughing problems.

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Title: SPECIFIER'S GUIDE 2000
Journal Title: Geotechnical Fabrics Report **Volume:** 17, **Issue:** 9
Publication Date: December 1999
Pagination: p 186

Abstract:
This journal issue is a guide to companies that manufacture or offer services related to specific geosynthetic products. The Industry Directory is an alphabetical listing of all firms found in the guide. The Products, Applications, and Services Directories list the generic products, applications, and services offered by the companies included in the Industry Directory. Manufacturers or exclusive marketers of geosynthetic products have supplied data about the physical and mechanical properties of specific products that are presented in specification charts according to generic groupings of geotextiles, geomembranes, geosynthetic clay liners, drainage products, erosion control products, geocells, and geogrids.

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Title: EROSION CONTROL PRODUCTS—A COMPREHENSIVE LIST
Journal Title: Civil Engineering News **Volume:** 11, **Issue:** 11
Publication Date: December 1999
Pagination: p 2

Abstract:
This feature lists companies that sell various erosion control products. Contact information is provided for 31 companies, along with which long-term and short-term problems their products may address, including loose mulches, erosion control netting, open-weave meshes, erosion control blankets, fiber roving systems, erosion control and revegetation mats, turf reinforcement mats, fabric-formed revetments, gabions, articulating concrete blocks, and geocellular confinement systems.

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USA

Title: WIRE MESH REINFORCED EROSION CONTROL MAT
Author(s): LePage, D.L.; Vanscavish, R.A.
Publication Date: 1999
Pagination: p 21
Report No: Final Report ,RP 96-052,
Publisher/Corporate Author(s):
Federal Highway Administration
Forum Place, 555 Walnut Street
Washington DC 17101-1900
USA

Pennsylvania Department of Transportation
Bureau of Construction and Materials, 1118 State Street
Harrisburg PA 17120-
USA

Abstract:
This study involved evaluating the constructibility and performance of the wire mesh reinforced erosion control mat, installed on SR 00724-03M, in Berks County. The purpose of this MacMat-R8 was to address a persistent erosion control condition. These three areas exhibit soil and friable rock surfaces at a 1.4:1 slope that persistently had rocks fall onto SR 0724. The wire mesh performed satisfactorily and is recommended for acceptance as an alternative to other control mats.

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Title: LET IT BLOW!
Author(s): Cabalka, D.
Journal Title: Geotechnical Fabrics Report **Volume:** 17, **Issue:** 3
Publication Date: April 1999

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Pagination: pp 44-48
Publisher/Corporate Author(s):
Industrial Fabrics Association International
345 Cedar Building, Suite 800
St Paul MN 55101-1088
USA

Abstract:
In late 1996, San Antonio-based Diamond-Shamrock decided to construct a new refined-products pipeline in eastern Colorado. Company officials knew they would have to pay special attention to the Chinooks and their impact on reclamation activities, as would their contractors. Two different means of erosion protection were required to minimize soil loss and to enhance revegetation. The first material, agricultural wheat straw, was used on flat areas with minimal erosion potential. The second technique, installing Erosion Control Blankets (ECB), was applied to all areas where significant erosion potential existed: slopes greater than 12 deg (0.21 rad) and areas where "blow" sand was encountered. Pipeline construction work--clearing and grubbing, trenching, pipe installation, and backfilling--began in August 1996. Just a few months later--December 24, 1996--the first petroleum product flowed through the line. Before reclamation began in October, each prime contractor graded the disturbed right-of-way back to pre-existing conditions and disked the surface to enable drill seeding. Site-restoration work continued through January 1997. Today, thanks to a well-conceived comprehensive reclamation plan, quality-conscious contractor, and an ECB, the pipeline lays quietly below the surface, unaffected by the powerful Chinooks.

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Title: SOIL CONDITIONS AND MYCORRHIZAL INFECTION ASSOCIATED WITH REVEGETATION OF DECOMPOSED GRANITE SLOPES
Author(s): Claassen, V.P.; Zasoski, R.J.; Southard, R. J.
Language: English
Publication Date: 1995
Pagination: p 151
Publisher/Corporate Author(s):
California Department of Transportation
Division of New Technology, Materials & Research, P.O. Box 19128
Sacramento DC 95819
USA

California University, Davis
Department of Land, Air and Water Resources
Davis CA 95616
USA

Federal Highway Administration
400 7th Street, SW
Washington 20590

Abstract:
This project surveys soil chemical, microbiological, and mineralogical conditions influencing plant growth on disturbed decomposed granite materials. The project compares soil conditions of native vegetated soils and adjacent, poorly vegetated cut and fill slopes. It identifies several potential growth-limiting conditions, including low nitrogen availability, low endomycorrhizal infection, potential phosphorus deficiency, differential plant response of annual and perennial grasses to solution nitrogen concentration, and poor soil physical condition. Many of these characteristics are related to the decomposed granite mineralogy and to a low inherent soil organic matter content. Supplemental phosphorus did not increase plant growth or change mycorrhizal infection at the amendment rates used. Mycorrhizal fungal inoculum established by sparsely vegetated soils provided a viable, site-adapted inoculum. Soil solution nitrogen concentrations of less than 100 micrometers support growth of a perennial grass while restraining growth of an annual grass. This result can be used to guide development of slow-release nitrogen amendments for preferential establishment of perennials. Mineralogical analysis of the decomposed granite (saprolite) indicates that as the rock matrix weathers, silt and clay contents increase, but the cation exchange capacity and nutrient cation contents decrease. Precipitation of low-charge clays at particle surfaces contributes to the poor physical structure of decomposed granite materials.

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USA

Title: EFFECTIVENESS OF SELECTED EROSION CONTROL MATERIALS UNDER SIMULATED RAIN AND SUNLIGHT
Author(s): Urroz, G.E.; Israelsen, C.E.
Publication Date: 1995
Pagination: p 30
Report No: MPC Report No. 95-44

Abstract:
The results of an erosion control testing study are presented in this report. The purpose of the study was to compare the performance of selected erosion control products under simulated rainfall and sunlight conditions in terms of soil loss reduction and vegetation growth. A total of 19 materials—11 mulches and 8 erosion control blankets—were chosen for the test program. Tests were performed in a rainfall simulator facility where the variables of soil, slope, and rainfall rate and duration can be controlled. The data derived from the study can be used to select the most appropriate erosion control material for a particular situation.

Available From:
Mountain-Plains Consortium
North Dakota State University, P.O. Box 5074
Fargo ND 58105-
USA

Title: CONTROLLING EROSION WITH RIPRAP
Author(s): Fisher, H.H.
Language: English
Journal Title: ASTM Standardization News **Volume:** 24, **Issue:** 3
Publication Date: March 1996
Pagination: pp 22-27

Go Back Next Page

Abstract:
Approximately 3.5 million miles of streams are in the U.S., and the U.S. Army Corps of Engineers has reported that streambank erosion is occurring on approximately half a million miles of channels. Since soil is not as durable as rock, it has to be protected from erosion. The two most common ways to protect soil are with vegetation and riprap. Riprap is the term given to loose blocks of rock placed on soil to absorb the energy of moving water and thereby decrease downslope movement of soil. Riprap is placed along streambanks, in manmade waterways, on the shorelines of lakes and oceans, on the faces of dams, and on construction sites. It can be used in combination with geotextiles (fabrics placed against soil). Uniform pieces of riprap can be placed in gabions (wire baskets) that are stacked on top each other. Riprap must be heavy and large enough to withstand the forces of erosion, stable enough to remain in place, durable and long-lasting, and economically justifiable. The sources of riprap are most often commercial rock quarries.

Title: RELIABILITY ANALYSIS OF OPEN DRAINAGE CHANNELS UNDER MULTIPLE FAILURE MODES
Author(s): Easa, S.M.
Journal Title: Journal of Irrigation and Drainage Engineering **Volume:** 120, **Issue:** 6
Publication Date: November 1994
Pagination: pp 1007-24

Abstract:
Designing an open drainage channel involves uncertainty when considering factors such as runoff and channel capacity. Because the performance of the channel system is also uncertain, system performance is based on reliability analysis. This paper examines the reliability of open drainage channels under three possible failure modes. Those three failure modes are when (1) the runoff exceeds channel capacity, (2) the actual flow velocity exceeds the maximum allowable velocity for erosion control, and (3) the actual flow velocity is less than the minimum allowable velocity for deposition control. The minimum and maximum allowable velocities are considered random variables. Using the advanced first-order second-moment (AFOSM) method, the failure probability is estimated. Also presented is the overall failure probability of the system that accounts for the correlation between the three failure modes. The AFOSM method was verified using Monte Carlo simulation. In practice, the method has applications in determining the reliability of an existing channel under multiple failures, evaluating the effects of alternative improvements, and designing new channels at specified reliability levels.

Available From:
American Society of Civil Engineers
345 East 47th Street
New York NY 10017
USA

Title: LAND DEVELOPMENT: EROSION AND SEDIMENT CONTROL
Author(s): Dewberry, S.O.
Journal Title: Civil Engineering News **Volume:** 9, **Issue:** 11
Publication Date: December 1997
Pagination: pp 42-48

Abstract:
Erosion and sediment control has become one of the most important considerations in the land development process. Heightened awareness of how land-disturbing activities impact water quality and the overall ecosystem have led to stricter regulations addressing site clearance, con

struction activities, and post-development drainage. Erosion and sediment control may be thought of as the first line of defense for mitigating the adverse environmental impacts associated with urban construction activities. The erosion and sediment control plan should not be created as an afterthought simply because regulations require one. Often, designers add erosion and sediment controls when the plan is nearly complete and without any thought to the practicality of the controls. It is easy to put symbols on paper, but the engineer has to ask if the control can be built and will function as intended during a particular construction phase. This article offers guidance to the land development professional in developing and implementing an effective erosion and sediment control plan.

Available From:
Civil Engineering News, Incorporated
1255 Roberts Boulevard, Suite 230
Kennesaw GA 30144-
USA

Title: PERFORMANCE SPECIFICATIONS FOR WOOD WASTE MATERIALS AS AN EROSION CONTROL MULCH AND AS A FILTER BERM
Author(s): Demars, K.R.; Long, R.P.
Language: English
Publication Date: 2001
Pagination: p 32
Report No: Final Report, NETCR 25, Project No. 97-3

Abstract:
The filtration properties of wood waste mulch were evaluated for use in an erosion control berm application. Four wood waste materials were subjected to laboratory testing to determine their hydraulic properties in the unaltered state and the modified state. The modifications consisted of adding small particles to the grain-size distribution of the wood waste. The filtration behavior of these materials was evaluated for the 1-D condition in a permeameter and for the 2-D flow condition in a sloping plexiglas box. The 2-D tests simulated field use of wood waste as an erosion control berm. The tests used a series of glass beads of known size and an erodible soil from the field test site consisting of a silty fine sand that were mixed with water and passed through the test apparatus. The suspended solids content of the effluent was used as a measure of filter effectiveness. The results of this study and the earlier phases were used to prepare model procurement specifications for wood waste material as erosion control mulch and as an erosion control filter berm, which are appended to the report.

Available From:
National Technical Information Service
5285 Port Royal Road
Springfield VA 22161
USA

Title: POLYACRYLAMIDE AS A SOIL STABILIZER FOR EROSION CONTROL
Author(s): Nwankwo, K.N.
Publication Date: 2001
Pagination: p 28
Report No: Final Report, PE-97-06, WI-06-98,

Abstract:
Erosion control costs per acre on Wisconsin Department of Transportation (WisDOT) construction projects have been on the increase for the last several years. In the past, WisDOT has primar

Go Back Next Page

ily relied on the use of expensive erosion mats to control soil erosion problems on earthen slopes and channels. This report investigates the effectiveness of using a polyacrylamide soil stabilizer for controlling soil erosion on WisDOT construction projects. The performance of polyacrylamide in controlling erosion is based on the fact that it is a flocculant. It forms ionic bonds of small soil particles to make larger particles. This makes the soil more resistant to the erosive forces of dispersion and shear. Further, the polyacrylamide enhances the intrusion of water into the soil, resulting in increased soil moisture to promote seed germination, lower runoff, and less soil detachment from erosion. Comparison of the polyacrylamide (CFM 2000, PAM) with other erosion control products that are currently used by WisDOT shows that this product is effective in controlling erosion. In addition, it is relatively inexpensive when compared to erosion mat, is very easily applied, is not affected by weather conditions, and, when applied following the manufacturer's recommendations, is environmentally safe.

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USA

Title: BEHAVIOR OF CEMENT-STABILIZED FIBER-REINFORCED FLY ASH-SOIL MIXTURES
Author(s): Havanagi, V. G.; Kaniraj, S.R.
Journal Title: Journal of Geotechnical and Geoenvironmental Engineering
Volume: 127, **Issue:** 7
Publication Date: July 2001
Pagination: pp 574-584

Abstract:
An experimental program was conducted to study the individual and combined effects of randomly-oriented fiber inclusions and cement stabilization on the geotechnical characteristics of fly ash-soil mixtures. An Indian fly ash was mixed with silt and sand in different proportions. The geotechnical characteristics of the raw fly ash-soil specimens and fly ash-soil specimens containing 1-percent randomly oriented polyester fiber inclusions were studied. Unconfined compression tests were carried out on fly ash-soil specimens prepared with 3-percent cement content alone and with 3-percent cement and 1-percent fiber contents, after different periods of curing. The study shows that cement stabilization increases the strength of the raw fly ash-soil specimens. The fiber inclusions increase the strength of the raw fly ash-soil specimens as well as that of the cement-stabilized specimens and change their brittle behavior to ductile behavior. Depending on the type of fly ash-soil mixture and curing period, the increase in strength caused by the combined action of cement and fibers is either more than or about equal to the sum of the increase caused by them individually.

Available From:
American Society of Civil Engineers
1801 Alexander Bell Drive
Reston VA 20191-4400
USA

Title: LANDSLIDE STABILIZATION USING WICK DRAINS
Author(s): Santi, P.M.; Elifrits, C.D.
Journal Title: NCHRP-IDEA Program Project Final Report
Publication Date: March 2001
Pagination: p 87
Report No: NCHRP-IDEA Project 57

Abstract:
This project investigated the use of horizontal wick drains to stabilize slopes and landslides. Several landslide sites identified with the assistance of the Missouri and Colorado Departments of Transportation and the Colorado Geological Survey, were stabilized by wick drains and monitored. The field experience led to several improvements in the design and installation of wick drains. Simulation and interpretation of rainfall at the test embankment were accomplished, and guidelines for wick layout were developed. The results showed that wick drainage was highly dependent on hydraulic conductivity of shallow soil and that drains significantly lowered the water table and reduced soil settlement. Using test results, guidelines for drain design have been suggested.

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Springfield VA 22161-
USA

Title: POLYMER GEOGRIDS: THEIR ROLE IN THE DESIGN AND CONSTRUCTION OF STEEP SLOPES
Author(s): Beck, D.E.
Journal Title: Civil Engineering News **Volume:** 12, **Issue:** 5
Publication Date: June 2000
Pagination: pp 58-61

Abstract:
Polymer geogrids became commercially available in the early 1980s and quickly became established as soil-reinforcing products. These materials generally have a higher tensile modulus than geotextiles. Additionally, their higher soil interaction properties increase pullout resistance beyond that of geotextiles. As their engineering and performance advantages become more widely recognized, future uses of geosynthetics will likely expand beyond the initial geocategories; already the roadway industry has adopted geosynthetic technology for pavement rehabilitation work. The capacity to interlock with the surrounding soil is what sets geogrids apart from geotextiles and other types of reinforcement systems without grid structures. The tensile strengths of geogrids can be significantly varied when loaded in different planar directions relative to the orientation of the longitudinal or transverse ribs. When designing and constructing a geogrid-reinforced slope or embankment, particular attention is required to ensure that orientation and corresponding tensile capacities are clearly identified. A necessary distinction is required when considering the matter of reinforced slopes because these are typically limited to face angles not exceeding 70 degrees. Geogrid-reinforced slopes have been used successfully in the construction of new embankments, the creation of more usable land area, the widening of existing embankments, the repair of failed slopes, the construction of permanent levees and temporary flood control structures, and the building of abutments with steeper slopes to decrease bridge spans.

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Title: MODEL STUDIES ON GEOCELL SUPPORTED EMBANKMENTS CONSTRUCTED OVER A SOFT CLAY FOUNDATION
Author(s): Krishnaswamy, N.R.; Rajagopal, K.; Madhavi Latha, G.
Language: English
Journal Title: Geotechnical Testing Journal, **Volume:** 23, **Issue:** 1
Publication Date: March 2000
Pagination: pp 45-54
ISSN: 01496115
Features: FIGS: 12 Fig. TABS: 4 Tab. REFS: 11 Ref.
Publisher/Corporate Author(s):
American Society for Testing and Materials
100 Barr Harbor Drive
West Conshohocken PA 19428-2959
USA

Abstract: The use of geosynthetics for the construction of earth structures is simple and more economical compared with other forms of soil improvement techniques. Geosynthetic reinforcement has successfully been used to construct embankments over soft clays. A more recent advancement of reinforced soil is to provide three-dimensional confinement to the soil by using geocells. These geocells are honeycombed interconnected cells that completely encase the soil and provide all-around confinement, thus preventing the lateral spreading of soil. This paper describes the results of laboratory model tests on geocell-supported earth embankments constructed over a soft clay foundation. The soft clay foundation was prepared in a large test tank to a depth of 600 millimeters. A single geocell layer (thickness varied with each test) was formed on this clay foundation, and embankments were constructed above this layer. Four different types of geogrids were used for the formation of the geocell layer. The embankments were subjected to uniform surcharge pressure on the crest until failure. The vertical and horizontal deformations and the strains developed within the geocell layer were measured during the test. The influence of various parameters, such as tensile stiffness of geogrids used to fabricate the geocell material, height and pocket size of the geocell layer, length of the geocell layer, and type of fill material inside the geocell, on the behavior of the embankments was investigated through a series of laboratory tests.

Index Terms:
Deformation, Embankment foundations, Embankments, Failure, Geosynthetics, Geotextiles, Laboratory tests, Soft clays, Soil stabilization
Model tests, Geocells

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100 Barr Harbor Drive
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USA
Order Number: 0309066883

Title: STABILIZATION OF A VERTICAL TIRE CHIP EMBANKMENT WITH GEOGRIDS
Author(s): Hsieh, C.W.; Wu, J.H.
Language: English
Journal Title: Transportation Research Record **Issue:** 1721
Publication Date: 2000
Pagination: pp 39-44
ISBN: 0309067308
ISSN: 03611981
Features: FIGS: 10 Fig. TABS: 1 Tab. REFS: 9 Ref.
Publisher/Corporate Author(s):
Transportation Research Board
2101 Constitution Avenue, NW
Washington DC 20418
USA

Abstract:
A research project that involves the construction of a full-size geogrid-reinforced test embankment was conducted. Waste tire chips were used as the lightweight backfill for the embankment. The joint research project involved participants from government agencies, academic research institutes, consulting firms, and material suppliers. To meet the function requirements, the north side of the embankment had to be built essentially as a vertical wall. To maintain stability, the vertical side of the embankment was reinforced with geogrids and covered with segmental retaining-wall facing. The objectives of the research study were to evaluate the feasibility of using waste tire chips as embankment backfill material when coupled with geogrid reinforcement and to evaluate the performance of various types of geosynthetic drainage products in the test embankment. To minimize settlement caused by compression of the tire chips, various combinations of tire chips and soil mixtures or interlayers were used in the embankment construction. The details of the design and construction of the test embankment are described. Performance of the test embankment is evaluated using available observation data.

Supplemental Information:
This paper appears in Transportation Research Record No. 1721, Geomaterials 2000.

Index Terms:
Soil stabilization, Retaining walls, Scrap, Tires, Construction, Design, Drainage, Embankments, Geogrids, Geosynthetics, Performance evaluations
Taiwan
ID: 00804640

Title: EFFECTS OF FIBER REINFORCEMENT ON STRENGTH AND VOLUME CHANGE IN EXPANSIVE SOILS
Author(s): Puppala, A.J.; Musenda, C.
Language: English
Journal Title: Transportation Research Record **Issue:** 1736
Publication Date: 2000
Pagination: pp 134-140
ISBN: 0309067375
ISSN: 03611981
Features: FIGS: 4 Fig. TABS: 4 Tab. PHOT: 3 Phot. REFS: 13 Ref.

Go Back Next Page

Publisher/Corporate Author(s):
Transportation Research Board
2101 Constitution Avenue, NW
Washington DC 20418
USA

Abstract:
The results of a research study to investigate the influence of discrete and randomly oriented polypropylene fiber reinforcement on expansive soil stabilization are presented. Two expansive soils were used as control soils in the testing program. Two types of fibers and four fiber dosages (0, 0.3, 0.6, and 0.9 percent by dry weight of soil) were considered. Both raw and fiber-reinforced clayey samples were prepared and subjected to unconfined compressive strength (UCS), volumetric shrinkage, three-dimensional free swell, and swell pressure tests. Test results were statistically analyzed to investigate the effectiveness of fiber reinforcement on strength, swell, and shrinkage characteristics of expansive clays. Results indicated that the fiber reinforcement enhanced the UCS of the soil and reduced both volumetric shrinkage strains and swell pressures of the expansive clays. The fiber treatment also increased the free swell potential of the soils. Practical implications of the findings and future research directions are discussed.

Supplemental Information:
This paper appears in Transportation Research Record No. 1736, Soil Mechanics 2000.

Index Terms:
Compressive strength, Expansive clays, Fibers, Future, Polypropylene, Reinforcement (Engineering), Research, Shrinkage, Soil stabilization, Swelling, Swelling soils, Volume changes

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USA
Order Number: 0309067375
Order Document From Transportation Research Board (TRB)
ID: 00812168

Title: SOIL STABILIZATION/SOIL CEMENT MARK-LANG, INC.'S APPROACH
Author(s): Boswell, W.F.
Language: English
Journal Title: ASCE Geotechnical Special Publication **Issue:** 95
Conference Title: Soil-Cement and Other Construction Practices in Geotechnical Engineering. Proceedings of Sessions of Geo-Denver 2000
Sponsored by: The Geo-Institute, Construction Division and Materials Division of the American Society of Civil Engineers
Location: Denver, Colorado
Date Held: 20000805-20000808
Publication Date: 2000
Pagination: pp 26-35
ISBN: 078440500X
Features: FIGS: 7 Fig.

Publisher/Corporate Author(s):
American Society of Civil Engineers,
Geo Institute, 1801 Alexander Bell Drive,
Reston VA 20191-4400
USA

Abstract:
Bidding soil cement is somewhat unique. The nature of mix-in-place soil cement does not allow a 7 a.m. to 3 p.m. work schedule. When the cement is applied, the material cannot be left overnight. The operation must be completed even if overtime work is necessary. Working around utilities can be a very challenging matter. Of major concern during a soil cement operation is the amount of rock in excess of softball size. Successful completion of a project requires the use of proper equipment. It is important to determine and use the appropriate pulvermixer for the soil type.

Index Terms: Cement, In place density, Mixing, Operations, Rocks, Soil cement, Soil stabilization, Soils, Utility poles

Available From:
American Society of Civil Engineers
1801 Alexander Bell Drive
Reston VA 20191-4400
USA

Title: VARIOUS SLOPE TREATMENT ALTERNATIVES
Author(s): Ellis, R.; Bloomquist, D.; Coffey, M.A.; Guertin, B.D.
Language: English
Publication Date: 1999
Pagination: p 67
Period Covered: 9709-9906
Report No: State Proj 99700-3601-119 ,UF No. 49104504613-12, ,WPI 0510853, Final Rept, Features: FIGS: Figs. PHOT: Phots. REFS: 28 Ref.
Publisher/Corporate Author(s):
Federal Highway Administration
400 7th Street, SW
Washington 20590
USA

Florida Department of Transportation
605 Suwannee Street
Tallahassee DC 32399-0450
USA

University of Florida, Gainesville
Department of Civil Engineering, P.O. Box 116580
Gainesville FL 32611-6580
USA

Abstract:
The objective of this paper is to compare various slope treatment alternatives based on lifecycle cost analysis. A preliminary database of alternatives, their costs, and a spreadsheet program is used for the analysis. The method of comparison will be based on construction cost, maintenance cost, maintenance schedule, and usable life. Time value of money formulas are used to calculate

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lifecycle cost. Constructibility, soil properties, site characteristics, and aesthetic considerations are additional variables entered into the decision-making process.

Index Terms:
Decisionmaking, Aesthetics, Alternatives Analysis, Life Cycle Costing, Slopes, Soil Stabilization, Spreadsheets, Constructibility

Available From:
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Springfield VA 22161
USA

Title: BALLISTIC SOIL NAILING FOR SLOPE MAINTENANCE
Foreign Title: LE CLOUAGE BALISTIQUE POUR LA MAINTENANCE DES TALUS
Author(s): Bastic, M.J.; Myles, B.; Guilloux, A.
Editor(s): Barends, F.B.J.; Lindenberg, J.; Luger, H.J.; de Quelerij, L.;Verruijt, A.
Language: French
Conference Title: Twelfth European Conference on Soil Mechanics and Geotechnical Engineering (Proceedings)
Sponsored by: The Netherlands Society of Soil Mechanics and Geotechnical Engineering; Ministry of Transport, Public Works and Water Management; A. P. van den Berg Machinefabriek; Fugro N.V.; GeoDelft; Holland Railconsult
Location: Amsterdam, Netherlands
Date Held: 19990607-19990610
Publication Date: 1999
Pagination: pp 1203-06
Report No: Volume 2
ISBN: 9058090477
Features: FIGS: 3 Fig. REFS: Refs.
Publisher/Corporate Author(s):
Balkema (AA)
P.O. Box 1675
3000 BR Rotterdam
Netherlands

Abstract:
Ballistic soil nailing satisfies this requirement of fast and non-disruptive repair for maintenance of roads: nails are inserted at high speed in the soil by an air pressure launcher, mounted on a light prime mover. After a description of the technique, applicability of the process according to soil parameters is presented, as well as the principles of analysis and charts for predicting nail penetration, and the possible use of the observational method.

Index Terms:
Highway maintenance, Nails, Repairing, Slope stability, Soil mechanics, Soil stabilization

Available From:
Balkema (AA) Publishers
Old Post Road
Brookfield VT 05036
Netherlands
ID: 00782088

Title: MAINTENANCE WORKS FOR STABILIZING A NATURAL SLOPE BY DEEP DRAINAGE AND SOIL IMPROVEMENT TECHNIQUES
Author(s): Manas, L.M.S.; de las Heras Meco, C.; Rodrigues, J.L.S.
Editor(s): Barends, F.B.J.; Lindenberg, J.; Luger, H.J.; de Quelerij, L.;Verruijt, A.
Language: English
Conference Title: Twelfth European Conference on Soil Mechanics and Geotechnical Engineering (Proceedings)
Sponsored by: The Netherlands Society of Soil Mechanics and Geotechnical Engineering; Ministry of Transport, Public Works and Water Management; A.P. van den Berg Machinefabriek; Fugro N. V.; GeoDelft; Holland Railconsult
Location: Amsterdam, Netherlands
Date Held: 19990607-19990610
Publication Date: 1999
Pagination: pp 1367-73
Report No: Volume 2
ISBN: 9058090477
Features: FIGS: 6 Fig.
Publisher/Corporate Author(s):
Balkema (AA)
P.O. Box 1675
3000 BR Rotterdam
Netherlands

Abstract:
This paper describes the stability problem affecting a natural slope near Sort, Spain, caused by a period of heavy rains during 1995 to 1996. The case analyzed refers to a natural slope located in a potentially unstable area that has periodically been subject to problems that are similar to the one described here, which are also associated with periods of heavy rains. The instability problem considered is affecting Bressui, a small community, lying 150 meters (493 feet) above the Noguera Pallaresa riverbed. The corrective measures designed and carried out consist of reinforcing the clay layer by jet grouting, and intercepting and draining away the subsurface water flows through the construction of deep wells.

Index Terms:
Soil stabilization, Reinforced earth, Slope stability, Clay soils, Drainage, Improvements, Rainfall, Spain

Available From:
Balkema (AA) Publishers
Old Post Road
Brookfield VT 05036

Title: MECHANICALLY STABILIZED EARTH WALLS AND REINFORCED SOIL SLOPES DESIGN AND CONSTRUCTION GUIDELINES FHWA DEMONSTRATION PROJECT 82, REINFORCED SOIL STRUCTURES WSEW AND RSS.
Foreign Title: FHWA DEMONSTRATION PROJECT 82, REINFORCED SOIL STRUCTURES WSEW AND RSS
Author(s): Elias, Victor; Barry, P.E.; Christopher, R.
Language: English
Publication Date: 1999

Go Back Next Page

Report No: FHWA-SA-96-071
Publisher/Corporate Author(s):
U.S. Dept. of Transportation,
Federal Highway Administration,
Washington, D.C.
USA

Abstract:
No abstract provided.

Supplemental Information: Xiii, 371 P.: Ill.; Includes Bibliographical References (P. 321-322) United States. Earth Engineering & Sciences, Inc. Cover Title. "Report Date: August 1997"--Technical Report Documentation Page. "Reprinted September 1998."

Index Terms:
Design, Retaining walls, Slopes, Soil stabilization, Slopes (Soil mechanics), Design and construction

Available From:
National Technical Information Service, Ntis, Microfiche. 4 Microfiches: Negative; 11 X 15 Cm. Acknowledgement of Document Source: UC, Berkeley, Institute For Transportation Studies
ID: 00749201

Title: TOUGH CONDITIONS, INNOVATIVE SOLUTIONS
Author(s): Roy, P.A.; Lambrechts, J.R.; Winsor, D.S.
Language: English
Journal Title: Civil Engineering **Volume:** 68, **Issue:** 4
Publication Date: April 1998
Pagination: pp 40-43
ISSN: 08857024
Features: FIGS: 3 Fig. PHOT: 2 Phot.
Publisher/Corporate Author(s):
American Society of Civil Engineers
345 East 47th Street
New York NY 10017-2398
USA

Abstract:
Two major innovations in U.S. construction practice are part of the solution to a complex and difficult portion of the Massachusetts Highway Department's $8.5 billion Central Artery/Tunnel project. Deep soil mixing (DSM) and tunnel jacking, both extensions of technologies used overseas, are helping engineers and contractors to work in extremely weak soil conditions in the area. DSM deals with the most perplexing challenge, open excavations 40 to 60 ft (12 to 18 meters) deep and 200 feet (61 meters) wide in the thick deposit of soft clay beneath and adjacent to Fort Point Channel. More than 900,000 cubic yards (688,140 cubic meters) of soft clay and organic soils are being cement-stabilized. These stabilized soils will hold back lateral earth loads and Fort Point Channel tidal waters, resist basal heave in large open excavations, and provide permanent foundation support for cut-and-cover tunnels. Jet grouting creates soil-cement in areas difficult to reach with the large mixing equipment. The second major innovation is the jacking of full-section, multi-lane tunnels beneath the heavily trafficked railroad yard at the busy South Station Transportation Center. Three separate tunnels will advance 35 to 64 feet (11 to 20 meters) under

active tracks. Each of the 180- to 350-foot (46- to 107-meter) long tunnels is cast in a deep, internally braced excavation adjacent to the tracks. Then, while trains remain in full operation, shield tunneling methods advance one tunnel at a time by incremental jacking and excavating. Special measures, including grouting and ground freezing, are stabilizing the ground before the tunnels advance.

Index Terms:
Boston (Massachusetts), Cement, Construction practice, Deep soil mixing, Grouting, Jacking, Organic soils, Soft clays, Soil conditions, Soil stabilization, State highway departments, Technological innovations, Tunnel construction, Tunnel excavation, Tunnel support, Tunneling

Available From:
American Society of Civil Engineers
345 East 47th Street
New York NY 10017-2398
USA
ID: 00760318

Title: GEOTECHNICAL INVESTIGATION OF THE POTENTIAL USE OF SHREDDED SCRAP TIRES IN SOIL STABILIZATION
Author(s): Shakoor, A.
Language: English
Publication Date: 1997
Pagination: p 251
Report No: FHWA/OH-98/004, ,Final Report
Features: FIGS: Figs. TABS: Tabs. PHOT: Phots. REFS: Refs. APPS: 12 App.
Publisher/Corporate Author(s):
Federal Highway Administration
400 7th Street, SW
Washington 20590
USA

Kent State University
Water Resources Research Institute
Kent OH 44242-
USA

Ohio Department of Transportation
25 South Front Street
Columbus DC 43215
USA

Abstract:
Silt-tire and clay-tire mixtures, containing zero-percent to 100-percent shredded tire material by weight, with tire chips ranging in size from 7 to 13 millimeters, 13 to 25 millimeters, and 25 to 38 millimeters, were tested for a series of engineering properties including compaction characteristics, permeability, unconfined compressive strength, friction angle, cohesion, and compression index. In addition, the leachate samples from shredded tire material, soil-tire mixtures, and a test embankment, containing 70-percent clay and 30-percent shredded tire material by weight, were analyzed for chemical composition. The results show that density and unconfined compressive strength decrease, and permeability increases, with increasing shredded tire content for both soil types and all three tire sizes used in the study. In general, the addition of

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shredded tire material improves the friction angle for both silt and clay by a few degrees but also increases their compression index values. The results of leachate analyses show that concentrations of trace elements from soil-tire mixtures are less than the maximum allowed contaminant levels specified in the United States Environmental Protection Agency's regulations. As indicated by these results, soil-tire mixtures have the potential for use as a lightweight fill material for highway embankments, as well as for stabilization of slopes.

Supplemental Information:
Date on title page: November 1998.

Index Terms:
Trace elements, Silts, Soil stabilization, Tires, Shredding, Permeability, Scrap, Fills, Leachate, Lightweight materials, Compressive strength, Density, Embankments, Compaction, Chemical composition, Clay cohesion, Compression index, Friction angle, Scrap tires, Slope stabilization, Unconfined compressive strength

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Springfield VA 22161
USA
ID: 00740407

Title: THE ECTC'S INSTALLATION GUIDELINES FOR ROLLED EROSION CONTROL PRODUCTS
Author(s): Lutyens, D.
Language: English
Journal Title: Geotechnical Fabrics Report, **Volume:** 15, **Issue:** 6
Publication Date: August 1997
Pagination: pp 28-32
ISSN: 08824983
Features: FIGS: 6 Fig. TABS: 1 Tab.
Publisher/Corporate Author(s):
Industrial Fabrics Association International
345 Cedar Building, Suite 800
St Paul MN 55101-1088
USA

Abstract:
During the International Erosion Control Association's 1995 conference, the Erosion Control Technology Council (ECTC) offered attendees a generic poster presentation on installation standards for rolled erosion-control products.

The ECTC has since revised this presentation into generic recommendations for the proper installation of rolled erosion control products (RECPs). This article provides the ECTC's installation guidelines, based on application (slopes vs. channels) and product type (temporary vs. long-term nondegradable).

Index Terms:
Channel stabilization, Erosion control, Installations, Rolled erosion control products, Slope stabilization, Soil stabilization, Standards

Available From:
Industrial Fabrics Association International
345 Cedar Building, Suite 800
St Paul MN 55101-1088
USA
ID: 00795489

Title: DESIGN OF GABION-GEOSYNTHETIC RETAINING WALLS ON THE TELLICO PLAINS TO ROBBINSVILLE HIGHWAY
Author(s): Simac, M.R.; Bathurst, R.J.; Fennessey, T.W.
Language: English
Conference Title: Geosynthetics 1997 Sponsored by: Industrial Fabrics Association International, North American Geosynthetics Society, International Geosynthetics Society Location: Long Beach, California, U.S.A.
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Publisher/Corporate Author(s):
Industrial Fabrics Association International
345 Cedar Building, Suite 450
St Paul MN 55101
USA

Abstract:
During construction of the Tellico Plains to Robbinsville Highway, several mechanically stabilized earth (MSE) walls were built with hybrid wall system components, consisting of geogrid reinforcement and polyvinyl chloride-coated gabion baskets. The selection of these materials was based primarily on the presence of a chemically active soil environment, availability of an economical fill source, aesthetic appearance, and overall cost. This paper summarizes the design procedures utilized to ensure wall stability along a mountainous highway alignment. It examines how the general MSE design guidelines presented in the project specifications can be augmented with currently accepted methods of analysis to provide a safe but economical wall design. Project- and product-specific test results used in the engineering analysis of a 10-meter-high MSE wall system that also functions as a toe buttress for a 30-meter-high slope are presented.

Index Terms:
Geosynthetics, Highways, Analysis, Design, Engineering, Gabions, Mountains, Polyvinyl chloride, Reinforcing materials, Retaining walls, Slopes, Soil stabilization, Stability (mechanics), Tests, Geogrids

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St Paul MN 55101
USA

Title: DEVELOPING EROSION CONTROL PLANS FOR HIGHWAY CONSTRUCTION
Author: Roberts, B.C.
Publication Date: 1994
Pagination: p 38-40
Publisher/Corporate Author(s):
Transportation Research Record
National Research Council
Washington, DC
USA

Abstract:
A recommended procedure for developing erosion control plans for highway construction is presented. These procedures can be found in Best Management Practices for Erosion and Sediment Control, a Federal Highway Administration manual developed through the Federal Lands Highways Coordinated Technology Implementation Program. These recommendations result in part from recent legislative requirements under the U.S. Environmental Protection Agency's National Pollutant Discharge Elimination System regulations. Erosion control plans are developed by following basic principles of erosion and sediment control. In addition, a three-phase approach based on construction stages is presented to guide the designer through the process. Finally, a brief overview of best management practices is presented.

Title: ENVIRONMENTAL TESTING OF ROCK USED AS EROSION PROTECTION IN ARID ENVIRONMENTS
Author: Duffy, D.M. and Hatzell, H.H.
Language: English
Publication Date: 1992/1993
Source: ASTM Special Technical Publication, Symposium on Rock for Erosion Control, Jun 18 1992, 1993, Louisville, KY, USA

Abstract:
Crushed rock fragments are used in arid environments to control slope erosion. A test technique was developed to assess the durability of these fragments when solar-heated to summer temperatures and then "quenched" by thunderstorms containing hail. Aggregates were heated to 66 degrees Celsius and maintained at that temperature for 23 hours. At the completion of the heating cycle the rock fragments were cooled to room temperature, over a 1-hour period, then soaked for 24 hours in water. The water was decanted and the particles placed back in the oven for another 24 hours of heating. This 48-hour cycle was repeated a minimum of 50 times. At the completion of the 50-cycle test period, the grain-size distributions of the materials were compared to the original size distributions. Each of the rock types experienced some distress, although most were judged suitable for use as slope protection. Observation of actual slope protection endurance is continuing for several of the rock types placed on freeway slopes.

Title: EVALUATION AND STANDARDIZATION OF ROLLED EROSION CONTROL PRODUCTS
Author: Allen, S.R.
Language: English
Journal Title: Geotextiles and Geomembranes **Volume:** 14, **Issue:** 3-4,
Publication Date: March/April 1996
Pagination: p 207-221

Publisher/Corporate Author(s):
Elsevier Science Ltd.
Oxford
England

Abstract:
The erosion control industry has grown significantly in response to continued infrastructure development and increased awareness of water quality problems. A wide variety of rolled erosion control products are widely available, representing a broad spectrum of product construction and corresponding applications. While significant improvements in erosion control technology during the past several years have outpaced associated standards and research, several important steps are underway to meet critical needs for standardization. This paper outlines the history of advancements in rolled erosion control technology. In addition, a summary is presented of the many efforts currently underway by the Erosion Control Technology Council to establish erosion control industry standards for terminology, index tests, and performance criteria.

Title: GEOSYNTHETIC EROSION CONTROL MATERIALS: A LANDFILL COVER FIELD STUDY
Author: Koerner, G.R. and Carson, D.A. (Drexel Univ)
Language: English
Publication Date: 1998
Pagination: p 77-91
Source: Geotechnical Special Publication, Proceedings of the 1998 Geo-Congress, sponsored by: ASCE ASCE, Reston, VA, USA

Abstract:
This paper presents information gathered as part of a study to examine landfill slope stability. Geosynthetic erosion control materials were placed on the surface of thirteen field test plots at two slope angles commonly found in landfill applications: i.e., 2H:1V (26.6 degrees) and 3H:1V (18.4 degrees). A control plot was constructed without any erosion control material. This study consists of visual observations vis-a-vis the respective plot. The general effectiveness of the geosynthetic erosion control materials is summarized over 4 years of service.

Title: HIGHWAY EROSION REMEDIAL MEASURES
Author: Diyaljee, V. and Stoeck, J.
Publication Date: 1989
Source: Sediment Transport Modeling: Proceedings of the International Symposium, New Orleans, LA, USA

Abstract:
Soil erosion from highway ditches, cut slopes, and fill slopes present a continuous problem to roadway designers, geotechnical engineers, and construction and maintenance personnel from environmental, aesthetics, and roadway maintenance viewpoints. Very often the prevention of sediment transportation is required before vegetative cover establishes itself on a newly constructed grade. This is required to minimize stream pollution in environmentally sensitive areas, to prevent deep slope and ditch gullying, and to prevent blockage of culvert drainage structures. Over the last 5 to 8 years, Alberta Transportation and Utilities have given serious consideration to the problems of soil erosion along the highway system that have defied treatment by conventional methods of erosion control. Such problems have been remedied using improved strawbale designs, concrete mats, geosynthetics, synthetic products, and gabions.

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Title: INFLUENCE OF ROLLED EROSION CONTROL SYSTEMS ON SOIL MOISTURE CONTENT AND BIOMASS PRODUCTION: PART II. A GREENHOUSE EXPERIMENT
Author: Sutherland, R.A., Menard, T. and Perry, J.L.
Language: English
Journal Title: Land Degradation & Development **Volume:** 9, **Issue:** 3
Publication Date: June 1998
Pagination: p 217-231
Publisher/Corporate Author(s):
John Wiley & Sons Inc.
New York, NY
USA

Abstract:
A controlled greenhouse experiment conducted under high shortwave radiation flux explored the relationship between seven rolled erosion control systems (RECS) and a bare control treatment on soil moisture content (SMC), ryegrass yield, and ryegrass nutrient assimilation. All RECS conserved more moisture in the soil profile than the bare treatment, but differences between RECS occurred. Geojute was the poorest performer, with mean SMC values commonly 18 to 30 percent lower than the other RECS studied; and under drought-induced conditions SMC values were as much as 22 to 45 percent lower than the other systems. Ryegrass yields varied with surface cover, with statistical testing indicating that the bare, Geojute, and P300 treatments were not significantly different. However, the remaining RECS (Futerra, BioD-Mat 70, C125, SC150BN and Curlex I) had significantly higher ryegrass yields, with Curlex I being 25 per cent higher than its nearest competitor, SC150BN. Ryegrass nutrient concentrations of nitrogen and sulfur were generally similar between rolled erosion control treatments, and no measured macronutrient was considered to be deficient. This information, coupled with correlation analysis, indicated that the soil thermal regime was the most important limiting factor on biomass production. Additionally, of all variables examined by stepwise regression (microclimate and cardinal properties of RECS), only surface albedo (shortwave reflectivity) was significantly related with ryegrass yield. Closer attention needs to be given to the three-dimensionality of rolled erosion control fibers, and their radiative properties if designers are interested in maximizing biomass production from slopes covered by RECS in subtropical/tropical and semiarid environments.

Title: PERFORMANCE OF GEOTEXTILE SEPARATORS FIVE YEARS AFTER INSTALLATION
Author: Black, P. J. and Holtz, R.D.
Journal Title: Journal of Geotechnical and Geoenvironmental Engineering
Volume: 125, **Issue:** 5
Publication Date: May 1999
Pagination: p 404-409

Abstract:
During the reconstruction of a state highway in 1991, a full-scale test section was established at a site with a history of poor pavement performance, most likely because of a soft silty clay subgrade, high groundwater table, and heavy logging truck traffic. Five different separator geotextiles and a soil-only control section were installed in each lane. Excavations were made in the test section 5 years after installation, and samples of geotextiles, subgrade, and base course materials were exhumed for visual observation and laboratory testing. In addition, in situ soil tests were performed on the exposed subgrade soils. This paper summarizes these observations and test results. Although some fines from the subgrade had migrated through the geotextiles

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into the bottom of the base course, there was no evidence after 5 years of any adverse effect on the pavement itself. Minor geotextile damage that apparently occurred during construction had little effect on the pavement performance. In all, if the sections were of geotextiles, the subgrade soils were found to have consolidated significantly in comparison with the soil-only sections. Overall, the geotextiles performed their intended function well.

Title: RIPRAP QUALITY CRITERIA IN STANDARD SPECIFICATIONS AND ENGINEERING GUIDANCE
Author: Lutton, R.J. and Wong, G.S.
Publication Date: 1992/1993
Source: ASTM Special Technical Publication, Symposium on Rock for Erosion Control, Louisville, KY, USA

Abstract:
Several tests and requirements have been used routinely in the past 30 years for durability and quality of stone for use as riprap and armor. Among the tests are absorption, unit weight, abrasion, sulfate soundness, and freezing-thawing. The tests all give index values reflecting durability only indirectly. Some federal agency guidance and the standard specifications of state highway departments are reviewed in this paper to translate the index values into criteria for evaluating stone quality as to suitability or unsuitability.

Title: ROLE OF GEOSYNTHETICS IN EROSION AND SEDIMENT CONTROL. AN OVERVIEW
Author: Thiesen, M.S.
Language: English
Journal Title: Geotextiles and Geomembranes **Volume:** 11, **Issue:** 4-6
Pagination: p 535-550
Publication Date: 1992

Abstract:
The use of geosynthetic erosion and sediment materials continues to expand at a rapid pace. From their early beginnings in the late 1950s, geosynthetic materials today are the backbone of the erosion and sediment control industry. Geosynthetic components are an integral part of erosion and sediment materials ranging from temporary products such as hydraulic mulch geofibers, plastic erosion control meshes and nettings, and erosion control blankets and silt fences to high performance turf reinforcement mats, geocellular confinement systems, erosion control geotextiles, and fabric-formed revetments. This paper provides a brief overview of these materials and concepts.

Title: ROLLED EROSION CONTROL SYSTEMS FOR HILLSLOPE SURFACE PROTECTION: A CRITICAL REVIEW, SYNTHESIS AND ANALYSIS OF AVAILABLE DATA. I. BACKGROUND AND FORMATIVE YEARS
Author: Sutherland, R.A.
Language: English
Journal Title: Land Degradation & Development **Volume:** 9
Pagination: 9465-486
Publication Date: November/December (year unknown)
ISSN: 10853278

Abstract:
Landscapes disturbed by human activities commonly have erosion rates accelerated by several orders of magnitude over pre-disturbance conditions. New approaches to effectively decrease

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soil erosion rates from disturbed lands are urgently required to decrease non-point source pollution. One such best management practice (BMP) combines the application of rolled erosion control systems (RECSs), composed of either natural or synthetic fibers, with seeding of hillslopes to enhance biomass production. This synergistic approach is thought to be one of the most appropriate for mitigating excessive soil erosion on disturbed non-agricultural hillslopes. Over the past decade an active erosion control industry (ECI) has developed, and a variety of different RECSs have been brought to market. However, limited scientific data are available to the land manager, specifier, or design engineer to assess the relative effectiveness of these products in reducing sediment yield and in enhancing the development of vegetation. Few studies exist that have rigorously compared RECSs using a well-developed experimental design. Most studies lack sufficient replication and/or randomization. Additionally, in many studies there is a failure to control variables between cycles, runs, or events, including antecedent moisture content and sediment availability. The result is a mass of information that can be potentially misused to justify the selection of a given product that may be less effective than a competing product. The objectives of this two-part paper are: (1) to synthesize all available erosion-related literature dealing with RECSs applied to hillslopes during two periods—up to 1990 and post-1990; (2) to highlight important scientific contributions to the literature on RECSs; (3) to assess the scientific rigor of various studies and re-analyze and re-interpret data when available; and (4) to make constructive suggestions to improve future studies to develop a quantitative linkage between the physical characteristics of RECSs, soil erosion processes, and vegetation cover.

Title: SLOPE STABILIZATION USING OLD RUBBER TIRES AND GEOTEXTILES
Author: Poh, P.S.H. and Broms, B.B.
Journal Title: Journal of Performance of Constructed Facilities
Publication Date: 1995

Abstract:
An innovative and inexpensive slope-stabilization scheme is presented that uses old rubber tires and woven geotextile to arrest the deterioration of a hill slope adjacent to a 100-meter (328-foot)-high microwave-transmission tower on the Indonesian island of Batam. Woven geofabric with a warp and a weft tensile strength of 80 kilonewtons per meter (5.5 kips/ft) was used to resist the lateral earth pressure of the up to 2.15-meter (7-foot)- high wall. The internal stability and the sliding resistance, as well as the bearing capacity were checked. Rubber tires that were filled with granite aggregate and quarry waste were used to protect the fabric against direct sunlight and vandalism. Unskilled labor was used for the construction of the wall and of the fill. The total cost was less than 40 percent of the estimated cost of a conventional retaining wall. The paper discusses the design and the construction of the wall, as well as the costs.

Title: SYMPOSIUM ON ROCK FOR EROSION CONTROL
Language: English
Publication Date: 1992/1993
Source: ASTM Special Technical Publication, Symposium on Rock for Erosion Control, Jun 18 1992, 1993, Louisville, KY, USA

Abstract:
This conference proceeding contains 13 papers on durability testing and specification conformance testing of rock used for embankment erosion control. Topics discussed include the testing of riprap for erosion control of embankment dams, the durability of shale as determined by slake testing, the evaluation of the durability of protective rock covers at radioactive waste disposal sites, the use of fractal analysis to characterize the durability of limestone, an abrasion mill test for the wear resistance of armor stone, the characterization of the durability of rock riprap on the basis of insoluble clay residue, environmental testing of rock used as erosion

protection, the mechanism of freeze-thaw deterioration of rock, the durability of limestone and dolomite armor stone, a petrographic examination of the durability of large stones, the production of erosion control stone, size standards for erosion control stone, and riprap quality criteria in standard specification.

Title: THREE-DIMENSIONAL POLYETHYLENE GEOCELLS FOR EROSION CONTROL AND CHANNEL LININGS
Author: Wu, K.J. and Austin, D.N.
Journal Title: Geotextiles and Geomembranes **Volume:** 11, **Issue:** 4-6
Pagination: p 611-620
Publication Date: 1992

Abstract:
As construction budgets tighten and environmental concerns rise, synthetic materials used to prevent soil transport have seen a rapid gain in popularity. Since natural surfaces are susceptible to large soil loss because of the kinetic energy generated by precipitation impact and flowing water, the magnitude of the erosion damage is a function of the surface's resistance to transport. Certain geosynthetic products have been developed specifically to strengthen the soil surface for these types of applications. These materials vary in size, shape, and composition, but are all designed to decrease soil disturbance and increase soil moisture. After all, synthetic material usage in civil engineering has, after years of research and successful installations, gained a level of confidence with the engineering community. Since any increase in the tensile strength and/or density of the soil results in a greater resistance to applied forces, a dimensionally stable containment system is an attractive way of protecting a slope. Geocells are three-dimensional polyethylene structures that physically contain the infill material desired and resist the soil's natural weakness to detach and move downslope. These products are economical, aesthetically pleasing, and quite easy to design and work with when involved in erosion control and channel lining projects.

Title: WIND BARRIERS SUPPRESS FUGITIVE DUST AND SOIL-DERIVED AIRBORNE PARTICLES IN ARID REGIONS
Author: Grantz, D.A.; Vaughn, D.L.; Farber, R.J.; Kim B.; Ashbaugh, L.; VanCuren, T.; Campbell, R.
Journal Title: Journal of Environmental Quality **Volume:** 4:
Pagination: p 946-952
Publication Date: July/August 1998

Abstract:
Areas of abandoned agricultural land in the Antelope Valley, western Mojave Desert of California have proven in our previous studies to be recalcitrant to conventional tillage and revegetation strategies designed to suppress wind erosion of soil and transport of sediment and fugitive dust. These areas represented a continuing source of drifting sand and of coarse and respirable suspended particulate matter. The traditional techniques failed because furrows collapsed and the water holding capacity of the overburden was too low to support seed germination and transplant survival. In this study a variety of wind barriers were evaluated for suppression of sediment transport. Airborne particles were measured with an array of coarse particle samplers at heights of 0.2, 1.0, and 2.0 meters above the soil surface. Discrete artificial wind barriers, consisting of widely spaced roughness elements, were effective in suppressing fugitive emissions (>75 percent at 0.2 meter). Wind fences established along the leeward edge of an area of blowing sand, perpendicular to the prevailing wind, significantly decreased fugitive emissions (>90 percent at 0.2 meter). Control was greatest and precision of the measurements was highest under high wind conditions. These techniques provide rapid and effective suppression of

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fugitive emissions of soil-derived particles under conditions that resist conventional tillage and revegetation techniques. A simple, indirect procedure for determining local wind velocity erosion thresholds requiring only sampling of wind run and suspended particulate mass compared favorably with direct measurement of saltation as a function of wind velocity.

Title: WIND EROSION: FIELD MEASUREMENT AND ANALYSIS
Author: Fryrear, D.W.; Stout, J.E.; Hagen L.J.; and Vories
Date: 1991
Pagination: p 155-160
Source: Trans. ASAE 34(1)

Abstract:
Field equipment and techniques for ascertaining threshold wind velocities and amount and vertical distribution of eroded soil particles are discussed. A power expression will describe the variation in amounts of suspended material to 2 meters high. The quantity of material (f) and height of material (y) within the saltation layer can be explained. With the equipment and the analytical techniques described, the wind erosion process can be studied in the field, and the effectiveness of wind erosion control systems can be evaluated.

Title: LABORATORY SURVIVABILITY OF NONWOVEN GEOTEXTILES ON OPEN GRADED CRUSHED AGGREGATE
Author: Elvidge, C.B. and Raymond, G.P.
Journal Title: IFAI, Journal of Geotechnical and Geoenvironmental Engineering
Volume: 6, **Issue:** 2
Date: 1999

Abstract:
A laboratory method of assessing survivability of a nonwoven geotextile laid on open-graded crushed aggregate was developed. Preliminary suggestions for the application to compaction forces and/or traffic forces are given. Phase 1 involved compaction using a modified California Bearing Ratio (CBR) test with a geotextile sandwiched between two soil layers. Phase 2 involved tension testing of the damaged geotextile. In order to undertake Phase 2, a 200-millimeter wide width strip tensile test methodology that did not use grips was developed and is presented. The test variables examined in the CBR phase of the testing were the particle size of the cover material, the mass of the geotextile, and the compaction energy of the CBR tests (via the ram mass and drop height). The particle size of the bedding material and the thickness of both the cover and bedding material were kept constant. The results, in terms of damage to the geotextile, show (1) the smaller the compaction energy, the less geotextile damage; (2) the greater the mass per unit area, or thickness, of the geotextile, the less geotextile damage; and (3) the smaller the particle size of the aggregate overlying the geotextile, the less geotextile damage. This last result was very evident when the particle size was < 2 millimeters. The tensile testing technique used a geotextile loop joined with a rapidly applied hot glue that permitted immediate testing. The loop technique also avoided the lateral restraining effect of full-width grips.

Keywords: Nonwoven, Geotextile, Survivability, Laboratory testing, Wide width strip, Strength

Title: WIND EROSION ASSESSMENT AND CONTROL
Author: Skidmore, E.; Huang, X.; Fox, F.; Wagner, L.
Start Date: 09/25/98 **Term Date:** 09/24/03
Source: Natural Resources Conservation Service, CRIS 5430-11120-005-00D - Cooperative Research and Development Agreement

Abstract:
Problem: Wind erosion of soil continues as a major environmental and agricultural problem. It degrades the land resources, threatens the sustainability of agriculture, and pollutes air and water. To reduce soil erosion on marginal cropland, the U.S. Congress established the Conservation Reserve Program (CRP). The CRP was highly successful in reducing wind erosion. But now as many of the contracts are expiring, the Natural Resources Conservation Service (NRCS) recognizes new challenges and supports high-priority wind erosion research.

Objectives: Project objectives are to determine the change in soil erodibility and other soil quality measures resulting from CRP, to develop a device to measure standing crop residues after harvest using laser technology, and to develop modular soil erosion systems (MOSES) common interface for water and wind erosion models used by NRCS.

Results and Impact: Various soil properties were measured from continuously cropped land and nearby land that had been in the CRP program for 10 years and compared. We found that land that had been in CRP was less susceptible to erosion compared to continuously cropped land. Land managed in CRP tends to improve some soil properties.

Quick, accurate and repeatable measurement of standing plant residue is necessary for the development of land use practices that minimize the potential for a soil to erode by wind. Experiments were set up and executed at WERU to test the concept of a laser scanning system to measure and count standing plant residue stems and their aggregate height and width, and construction of a field portable device was initiated. Experimental data were obtained, analyzed, and reported, and hardware was assembled for a field portable device. Requests for information indicate that there is interest in both the concept and the method among cropping system researchers and potential impact with tillage systems research.

Goals for 2001 and 2002: Specific tasks in 2001 include (1) continuing to monitor the spatial variation of soil properties over time for land going into CRP, coming out of CRP, and never in CRP; and (2) prepare interim reports (publications). Specific tasks in 2002 include (1) continuing to monitor the spatial variation of soil properties over time for land going into CRP, coming out of CRP, and never in CRP.

Supplemental Information:
2000 Publications:
01. Skidmore, E.L., Huang, X. and Tibke, G.L. Aggregate status as influenced by CRP. Agronomy Abstracts, American Society of Agronomy. November 1999. p. 174.

02. Huang, X., Skidmore, E.L. and Tibke, G. Change in soil quality indicators resulting from CRP. Agronomy Abstracts, American Society of Agronomy. November 1999. p. 173.

03. Fox, F.A. and Wagner, L.E. A Laser Distance Based Method for Measuring Standing Residue. ISTRO-2000, 15th Conference of the Int. Soil Till. Res. Org., Fort Worth, TX. 2-7 July 2000.

Available From:
Dr. Ed Skidmore
Telephone - (785) 532-6726
FAX - (785) 532-6528
email - skidmore@weru.ksu.edu

Appendix D
HEAT Data Sheets


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Output

Site Information

Characteristic	Value
Date	10/12/2001
Site	11EC - El Centro
Highway mile marker	15 Imperial
Highway	8 Westbound
District and contact	Bell
Field personnel	AJS/MMH/LAK
Soil family	NA
Mean annual temperature	22.4
Mean annual precipitation (mm)	66
Area (ha)	0.461 / 0.657
Slope percent	48%
Slope length	25m
Aspect	Northwest /Southeast
Cut or fill slope	Cut
Number of slope breaks	none

Site Information

Characteristic	Value
Nearest weather data center	El Centro
Soil survey	NA
Seed mix type	NA
Planting date	NA
Planting and preparation practices	NA
High rain intensity events since construction	NA
High intensity rain months	NA
Number of days with > 1.0 inch rainfall	0
Specified irrigation	none
Construction completion date	NA
Number of 90% probability freeze-free days	280
Erosion types observed	Channel, Wind, Sheet
Current irrigation	None

GPS Points

Corner	North	West
NE		
NW		
SE		
SW		

Soil Profile Descriptions

Soil Profile Description, Auger Hole 1

Sample ID	Depth	Texture	Strucure	Color	Roots	AWHC	Organic Matter	pH	Eh	Gravel %	Sample Analyzed?	% Clay	% Sand
11ECA1	0-15	sand	SG	10 YR 5/4	None	1.1	0.5	9.5	0.2	5	YES	4	94
											NO		
											NO		

Soil Profile Description, Auger Hole 3

Sample ID	Depth	Texture	Strucure	Color	Roots	AWHC	Organic Matter	pH	Eh	Gravel %	Sample Analyzed?	% Clay	% Sand
11ECB1	0-15	sand	SG	10 YR 5/4	None	1.1	0.5	9.2	0.4	5	YES	4	94
											NO		
											NO		
											NO		

Soil Profile Description, Auger Hole 3

Sample ID	Depth	Texture	Strucure	Color	Roots	AWHC	Organic Matter	pH	Eh	Gravel %	Sample Analyzed?	% Clay	% Sand
											NO		
											NO		
											NO		
											NO		

Overall Soil Permeability Class	Parent Material
Very High	Alluvium

Channel Volume Calculation

Slope Region	Width (m)				Height (m)				Length (m)			Total (m3)
	1	2	3	4	1	2	3	4	1	2	3	--
Shoulder Slope												
Back Slope												
Toe Slope												
Total	--	--	--	--	--	--	--	--	--	--	--	

Revised Univeral Soil Loss Equatior

Revised Univeral Soil Loss Equatior	
Rainfall Factor (R)	10
Soil Erodibility Factor (K)	0.1
Length-Slope Factor (LS)	5.65
Vegetative Cover and Management Factor	0.45
Practices for Erosion Control (P)	1

Erosion Loss (tons/ac/yr)
2.543

Morgan, Morgan, and Finney Model

Soil-Environmental Inputs	
Soil Moisture Content at Field Capacity (MS)	0.08
Soil Bulk Density (BD)	1.5
Soil Detachability Index (K)	0.7
Topsoil Rooting Depth (RD)	0.0015
Sine of Slope Angle (S)	0.743
Annual Rainfall in mm (R)	66
Number of Rain Days (Rn)	12
Typical Intensity of Erosive Rain (I	10

Months	Number of Months	A (%)	Et/Eo	C
January - December	12	0.001	0.05	1

Weighted A	Et/Eo	C
0.001	0.050	1.000
Log_{10} A	Soil Loss (kg m^{-2})	
-3.000	-0.656	

Field Notes

Surrounding Site Observations	Erosion Point Sources	Wildlife Observations	Current Erosion Control Effectiveness	Photo Index
Surrounding area is sparsely covered with native shrubs.	None observed.	None observed.	A very long road cut present on both east and westbound sides of the road. Has fairly wide shoulder. Drainage from upgradient area is diverted with an earthen V-ditch. Upgradient watershed area is not substantial. Erosion types observed included extensive channel, wind, and sheet erosion.	Site overview of areas A and B.

Current Erosion Control

See above field notes ("Current Erosion Control") for specific information regarding the following practices

Method	Used Successfully	Used Unsuccessfully	Not Used
Fertilizer/amendments			*
Seed and hydroseed			*
Sod/turfgrass			*
Mulch			*
Compost			*
Emulsion/tackifier			*
(i.e., ivy and iceplant)			*
Shrubs and trees			*
Straw (punched or tacked)			*
Coconut			*
Geotextile/jute			*
Cellular confinement			*
Rock blanket			*
Concrete			*
Gravel filter			*
Sand bags			*
Curb and gutters			*
Silt fence			*
Straw bales			*
Wattles/bundles			*
Willow inbeds			*
Retaining walls			*
Slope benches			*
Infiltration structure			*
Dry wells			*
Water bars			*
Drainage control			*
Culverts			*
V-ditches	*		
Pipe/down drains			*
Inlet structures			*
Outfall dissipator			*
Water ladders			*
Horizontal drains			*
Serated slope terraces			*
Vegetation strips			*
Check dams			*
Retention basins			*

Plant Coverage by Step Point

Cover Type	Area A Cover %	Area B Cover %	Area C Cover %
Bare ground			
Litter or mulch			
Coarse fragments			
Bedrock			
Grass and bare ground			
Legumes and bare ground			
Trees and bare ground			
Shrubs and bare ground			
Upand herbaceous and bare ground			
Wetland species and bare ground			
Grass and litter			
Legumes and litter			
Trees and litter			
Shrubs and litter			
Upland herbaceous and litter			
Wetland species and litter			
Grass and coarse fragments			
Legumes and coarse fragments			
Trees and coarse fragments			
Shrubs and coarse fragments			
Upland herbaceous and coarse fragments			
Wetland species and coarse fragments			
Grass and bedrock			
Legumes and bedrock			
Trees and bedrock			
Shrubs and bedrock			
Upland herbaceous and bedrock			
Wetland species and bedrock			

Flow Rate (gph)

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Output

Site Information

Characteristic	Value
Date	10/11/2001
Site	6MO - Mojave
Highway mile marker	19-19.5 Kern
Highway	14 Southbound (old)
District and contact	Jim Pitman
Field personnel	AJS/LAK/MMH
Soil family	NA
Mean annual temperature	16.9
Mean annual precipitation (mm)	149
Area (ha)	NA (not accessible)
Slope percent	57%
Slope length	15
Aspect	East
Cut or fill slope	Cut
Number of slope breaks	none

Site Information

Characteristic	Value
Nearest weather data center	Mojave
Soil survey	NA
Seed mix type	Under construction
Planting date	NA
Planting and preparation practices	NA
High rain intensity events since construction	NA
High intensity rain months	NA
Number of days with > 1.0 inch rainfall	1
Specified irrigation	none
Construction completion date	NA
Number of 90% probability freeze-free days	197
Erosion types observed	Channel, Wind, Sheet
Current irrigation	None

GPS Points

Corner	North	West
NE		
NW		
SE		
SW		

Soil Profile Descriptions

Soil Profile Description, Auger Hole 1

Sample ID	Depth	Texture	Strucure	Color	Roots	AWHC	Organic Matter	pH	Eh	Gravel %	Sample Analyzed?	% Clay	% Sand
6MOA1	0-12	ls	1MSBK	7.5 YR 5/3	None	.08cm/cm	1	8.3		8	YES	10	84
											NO		
											NO		

Soil Profile Description, Auger Hole 3

Sample ID	Depth	Texture	Strucure	Color	Roots	AWHC	Organic Matter	pH	Eh	Gravel %	Sample Analyzed?	% Clay	% Sand
					None					9	YES	9	80
											NO		
											NO		
											NO		

Soil Profile Description, Auger Hole 3

Sample ID	Depth	Texture	Strucure	Color	Roots	AWHC	Organic Matter	pH	Eh	Gravel %	Sample Analyzed?	% Clay	% Sand
											NO		
											NO		
											NO		
											NO		

Overall Soil Permeability Class	Parent Material
V. High	Fill

Channel Volume Calculation

Slope Region	Width (m)				Height (m)				Length (m)			Total (m3)
	1	2	3	4	1	2	3	4	1	2	3	--
Shoulder Slope												
Back Slope												
Toe Slope												
Total	--	--	--	--	--	--	--	--	--	--	--	

Revised Univeral Soil Loss Equation

Revised Univeral Soil Loss Equation	
Rainfall Factor (R)	10
Soil Erodibility Factor (K)	0.22
Length-Slope Factor (LS)	4.19
Vegetative Cover and Management Factor	0.45
Practices for Erosion Control (P)	1

Erosion Loss (tons/ac/yr)
4.148

Morgan, Morgan, and Finney Model

Soil-Environmental Inputs	
Soil Moisture Content at Field Capacity (MS)	0.17
Soil Bulk Density (BD)	1.3
Soil Detachability Index (K)	0.25
Topsoil Rooting Depth (RD)	0.0012
Sine of Slope Angle (S)	0.839
Annual Rainfall in mm (R)	149
Number of Rain Days (Rn)	24
Typical Intensity of Erosive Rain (I)	10

Months	Number of Months	A (%)	Et/Eo	C
January - December	12	0.001	0.05	1

Weighted A	Et/Eo	C
0.001	0.050	1.000
Log_{10} A	Soil Loss (kg m^{-2})	
-3.000	-0.529	

Field Notes

Surrounding Site Observations	Erosion Point Sources	Wildlife Observations	Current Erosion Control Effectiveness	Photo Index
Will be a median when southbound lanes are completed - may have access or point source problems, depending on design.	Depends on design.	None observed.	Under Construction – NA. However, prevailing winds were south to north during evaluation. Evidence of wind erosion in surrounding area is prevalent.	Overview from north to south ends of site.

Current Erosion Control
See above field notes ("Current Erosion Control") for specific information regarding the following practices.

Method	Used Successfully	Used Unsuccessfully	Not Used
Fertilizer/amendments			*
Seed and hydroseed			*
Sod/turfgrass			*
Mulch			*
Compost			*
Emulsion/tackifier			*
(i.e., ivy and iceplant)			*
Shrubs and trees			*
Straw (punched or tacked)			*
Coconut			*
Geotextile/jute			*
Cellular confinement			*
Rock blanket			*
Concrete			*
Gravel filter			*
Sand bags			*
Curb and gutters			*
Silt fence			*
Straw bales			*
Wattles/bundles			*
Willow inbeds			*
Retaining walls			*
Slope benches			*
Infiltration structure			*
Dry wells			*
Water bars			*
Drainage control			*
Culverts	*		
V-ditches	*		
Pipe/down drains			*
Inlet structures			*
Outfall dissipator			*
Water ladders			*
Horizontal drains			*
Serated slope terraces			*
Vegetation strips			*
Check dams			*
Retention basins			*

Plant Coverage by Step Point

Cover Type	Area A Cover %	Area B Cover %	Area C Cover %
Bare ground			
Litter or mulch			
Coarse fragments			
Bedrock			
Grass and bare ground			
Legumes and bare ground			
Trees and bare ground			
Shrubs and bare ground			
Upand herbaceous and bare ground			
Wetland species and bare ground			
Grass and litter			
Legumes and litter			
Trees and litter			
Shrubs and litter			
Upland herbaceous and litter			
Wetland species and litter			
Grass and coarse fragments			
Legumes and coarse fragments			
Trees and coarse fragments			
Shrubs and coarse fragments			
Upland herbaceous and coarse fragments			
Wetland species and coarse fragments			
Grass and bedrock			
Legumes and bedrock			
Trees and bedrock			
Shrubs and bedrock			
Upland herbaceous and bedrock			
Wetland species and bedrock			

Flow Rate (gph)

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Output

Site Information

Characteristic	Value
Date	10/11/2001
Site	6RR - Red Rock
Highway mile marker	36, Kern
Highway	14 Southbound
District and contact	6, (Jim Pitman - 9)
Field personnel	AJS, MMH, LAK
Soil family	NA
Mean annual temperature	17.9
Mean annual precipitation (mm)	105
Area (ha)	0.276
Slope percent	65, 55%
Slope length	25
Aspect	East (A1) /West
Cut or fill slope	Cut
Number of slope breaks	None

Site Information

Characteristic	Value
Nearest weather data center	Cantil
Soil survey	NA
Seed mix type	NA
Planting date	NA
Planting and preparation practices	NA
High rain intensity events since construction	NA
High intensity rain months	NA
Number of days with > 1.0 inch rainfall	1
Specified irrigation	None
Construction completion date	NA
Number of 90% probability freeze-free days	195
Erosion types observed	Channel, Wind, Sheet
Current irrigation	None

GPS Points

Corner	North	West
NE		
NW		
SE		
SW		

Soil Profile Descriptions

Soil Profile Description, Auger Hole 1

Sample ID	Depth	Texture	Strucure	Color	Roots	AWHC	Organic Matter	pH	Eh	Gravel %	Sample Analyzed?	% Clay	% Sand
6RRA1	0-12	S	1MSBK	10 YR 4/3	None	1	1	8.4	0.3	5	YES	8	88
											NO		
											NO		

Soil Profile Description, Auger Hole 3

Sample ID	Depth	Texture	Strucure	Color	Roots	AWHC	Organic Matter	pH	Eh	Gravel %	Sample Analyzed?	% Clay	% Sand
											NO		
											NO		
											NO		
											NO		

Soil Profile Description, Auger Hole 3

Sample ID	Depth	Texture	Strucure	Color	Roots	AWHC	Organic Matter	pH	Eh	Gravel %	Sample Analyzed?	% Clay	% Sand
											NO		
											NO		
											NO		
											NO		

Overall Soil Permeability Class	Parent Material
Very High	Residuum

Channel Volume Calculation

Slope Region	Width (m)				Height (m)				Length (m)			Total (m3)
	1	2	3	4	1	2	3	4	1	2	3	--
Shoulder Slope												
Back Slope												
Toe Slope												
Total	--	--	--	--	--	--	--	--	--	--	--	

Revised Univeral Soil Loss Equation

Revised Univeral Soil Loss Equation	
Rainfall Factor (R)	10
Soil Erodibility Factor (K)	0.15
Length-Slope Factor (LS)	5.72
Vegetative Cover and Management Factor	0.45
Practices for Erosion Control (P)	1

Erosion Loss (tons/ac/yr)
3.861

Morgan, Morgan, and Finney Model

Soil-Environmental Inputs	
Soil Moisture Content at Field Capacity (MS)	0.08
Soil Bulk Density (BD)	1.5
Soil Detachability Index (K)	0.7
Topsoil Rooting Depth (RD)	0.0012
Sine of Slope Angle (S)	0.819
Annual Rainfall in mm (R)	105
Number of Rain Days (Rn)	17
Typical Intensity of Erosive Rain (I)	10

Months	Number of Months	A (%)	Et/Eo	C
January - December	12	0.001	0.05	1

Weighted A	Et/Eo	C
0.001	0.050	1.000
Log_{10} A	Soil Loss (kg m^{-2})	
-3.000	-1.044	

Field Notes

Surrounding Site Observations	Erosion Point Sources	Wildlife Observations	Current Erosion Control Effectiveness	Photo Index
East-facing slope had upslope watershed area that imparts some run-on. One area had concentrated and formed a large channel. Road drainage from two lanes and shoulder is diverted from site.	Off-road vehicle trail may have potential to become a point source, though no evidence of erosivity was observed.	None observed.	Both sides of the road have potential for study. Prevailing wind was toward the north. Evidence of channel, wind, and sheet erosion. No non-vegetative erosion control observed. Vegetation was not sufficient.	1- West-facing overview.

Current Erosion Control

See above field notes ("Current Erosion Control") for specific information regarding the following practices.

Method	Used Successfully	Used Unsuccessfully	Not Used
Fertilizer/amendments			*
Seed and hydroseed			*
Sod/turfgrass			*
Mulch			*
Compost			*
Emulsion/tackifier			*
(i.e., ivy and iceplant)			*
Shrubs and trees			*
Straw (punched or tacked)			*
Coconut			*
Geotextile/jute			*
Cellular confinement			*
Rock blanket			*
Concrete			*
Gravel filter			*
Sand bags			*
Curb and gutters			*
Silt fence			*
Straw bales			*
Wattles/bundles			*
Willow inbeds			*
Retaining walls			*
Slope benches			*
Infiltration structure			*
Dry wells			*
Water bars			*
Drainage control			*
Culverts			*
V-ditches			*
Pipe/down drains			*
Inlet structures			*
Outfall dissipator			*
Water ladders			*
Horizontal drains			*
Serated slope terraces			*
Vegetation strips			*
Check dams			*
Retention basins			*

Plant Coverage by Step Point

Cover Type	Area A Cover %	Area B Cover %	Area C Cover %
Bare ground			
Litter or mulch			
Coarse fragments			
Bedrock			
Grass and bare ground			
Legumes and bare ground			
Trees and bare ground			
Shrubs and bare ground			
Upand herbaceous and bare ground			
Wetland species and bare ground			
Grass and litter			
Legumes and litter			
Trees and litter			
Shrubs and litter			
Upland herbaceous and litter			
Wetland species and litter			
Grass and coarse fragments			
Legumes and coarse fragments			
Trees and coarse fragments			
Shrubs and coarse fragments			
Upland herbaceous and coarse fragments			
Wetland species and coarse fragments			
Grass and bedrock			
Legumes and bedrock			
Trees and bedrock			
Shrubs and bedrock			
Upland herbaceous and bedrock			
Wetland species and bedrock			

Flow Rate (gph)

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Output

Site Information

Characteristic	Value
Date	10/11/2001
Site	Barstow 2 (8BS2)
Highway mile marker	0 (interchange)
Highway	58 at 15
District and contact	8 - Alan Nakano
Field personnel	Hart, Sloan, Karren
Soil family	Mixed, thermic Typic torripsamments (Cajon)
Mean annual temperature	17.8
Mean annual precipitation (mm)	111.8
Area (ha)	0.41
Slope percent	45%
Slope length	25
Aspect	North
Cut or fill slope	Cut
Number of slope breaks	0

Site Information

Characteristic	Value
Nearest weather data center	Barstow
Soil survey	San Bernadino (Mojave River)
Seed mix type	NA
Planting date	NA
Planting and preparation practices	NA
High rain intensity events since construction	NA
High intensity rain months	NA
Number of days with > 1.0 inch rainfall	0 (21 rain days)
Specified irrigation	None specified
Construction completion date	NA
Number of 90% probability freeze-free days	212
Erosion types observed	Sheet, channel, wind
Current irrigation	None

GPS Points

Corner	North	West
NE		
NW		
SE		
SW		

Soil Profile Descriptions

Soil Profile Description, Auger Hole 1

Sample ID	Depth	Texture	Strucure	Color	Roots	AWHC	Organic Matter	pH	Eh	Gravel %	Sample Analyzed?	% Clay	% Sand
8BS2A1	0-12	SCL/SL	MA	7.5 YR 4.3	0	1.2	1.3	8.5	1	12	YES	20	60
											NO		
											NO		

Soil Profile Description, Auger Hole 3

Sample ID	Depth	Texture	Strucure	Color	Roots	AWHC	Organic Matter	pH	Eh	Gravel %	Sample Analyzed?	% Clay	% Sand
											NO		
											NO		
											NO		
											NO		

Soil Profile Description, Auger Hole 3

Sample ID	Depth	Texture	Strucure	Color	Roots	AWHC	Organic Matter	pH	Eh	Gravel %	Sample Analyzed?	% Clay	% Sand
											NO		
											NO		
											NO		
											NO		

Overall Soil Permeability Class	Parent Material
High	Alluvium

Channel Volume Calculation

Slope Region	Width (m)				Height (m)				Length (m)			Total (m3)
	1	2	3	4	1	2	3	4	1	2	3	--
Shoulder Slope	0.12	0.16	0.12	0.15	0.06	0.13	0.15	0.2	9	7	6	38.0044
Back Slope	0	0	0	0	0	0	0	0	0	0	0	0
Toe Slope	0	0	0	0	0	0	0	0	0	0	0	0
Total	--	--	--	--	--	--	--	--	--	--	--	38.0044

Revised Univeral Soil Loss Equatior

Revised Univeral Soil Loss Equatior	
Rainfall Factor (R)	10
Soil Erodibility Factor (K)	0.31
Length-Slope Factor (LS)	5.55
Vegetative Cover and Management Factor	0.45
Practices for Erosion Control (P)	1

Erosion Loss (tons/ac/yr)
7.742

Morgan, Morgan, and Finney Mode

Soil-Environmental Inputs	
Soil Moisture Content at Field Capacity (MS)	0.28
Soil Bulk Density (BD)	1.2
Soil Detachability Index (K)	0.3
Topsoil Rooting Depth (RD)	0.001
Sine of Slope Angle (S)	0.707
Annual Rainfall in mm (R)	112
Number of Rain Days (Rn)	21
Typical Intensity of Erosive Rain (I	30

Months	Number of Months	A (%)	Et/Eo	C
January - December	12	0.001	0.05	1.00

Weighted A	Et/Eo	C
0.001	0.050	1.000
Log10 A	**Soil Loss (kg m-2)**	
-3.000	-0.477	

Field Notes

Surrounding Site Observations	Erosion Point Sources	Wildlife Observations	Current Erosion Control Effectiveness	Photo Index
Rolling to flat bare ground. Very sparse shrubs (<3%).	None observed.	None observed.	This site is the north-facing slope opposite the 8BS site across the highway. Site is long and curved ranging from north to northwest in aspect. Winds were westward during the observation. Site is completely bare with no evidence of any erosion control measures. Channel, sheet, and wind erosion were evident. An earthen V-ditch diverts run-on. Shoulder is moderately wide, narrower than opposite side of roadway.	Photos taken of the site overview.

Current Erosion Control
See above field notes ("Current Erosion Control") for specific information regarding the following practices

Method	Used Successfully	Used Unsuccessfully	Not Used
Fertilizer/amendments			*
Seed and hydroseed			*
Sod/turfgrass			*
Mulch			*
Compost			*
Emulsion/tackifier			*
(i.e., ivy and iceplant)			*
Shrubs and trees			*
Straw (punched or tacked)			*
Coconut			*
Geotextile/jute			*
Cellular confinement			*
Rock blanket			*
Concrete			*
Gravel filter			*
Sand bags			*
Curb and gutters			*
Silt fence			*
Straw bales			*
Wattles/bundles			*
Willow inbeds			*
Retaining walls			*
Slope benches			*
Infiltration structure			*
Dry wells			*
Water bars			*
Drainage control			*
Culverts			*
V-ditches	*		
Pipe/down drains			*
Inlet structures			*
Outfall dissipator			*
Water ladders			*
Horizontal drains			*
Serated slope terraces			*
Vegetation strips			*
Check dams			*
Retention basins			*

Plant Coverage by Step Point

Cover Type	Area A Cover %	Area B Cover %	Area C Cover %
Bare ground			
Litter or mulch			
Coarse fragments			
Bedrock			
Grass and bare ground			
Legumes and bare ground			
Trees and bare ground			
Shrubs and bare ground			
Upand herbaceous and bare ground			
Wetland species and bare ground			
Grass and litter			
Legumes and litter			
Trees and litter			
Shrubs and litter			
Upland herbaceous and litter			
Wetland species and litter			
Grass and coarse fragments			
Legumes and coarse fragments			
Trees and coarse fragments			
Shrubs and coarse fragments			
Upland herbaceous and coarse fragments			
Wetland species and coarse fragments			
Grass and bedrock			
Legumes and bedrock			
Trees and bedrock			
Shrubs and bedrock			
Upland herbaceous and bedrock			
Wetland species and bedrock			

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Rainfall Simulator Results

Area A				Area B				Area C			
Storm Duration (h)	Rainfall depth (mm)	Volume of Soil Captured (L)	Volume of Runoff Captured (L)	Storm Duration (h)	Rainfall depth (mm)	Volume of Soil Captured (L)	Volume of Runoff Captured (L)	Storm Duration (h)	Rainfall depth (mm)	Volume of Soil Captured (L)	Volume of Runoff Captured (L)

Flow Rate (gph)

Output

Site Information

Characteristic	Value
Date	10/11/2001
Site	8 HI - Hinkley
Highway mile marker	11.5 San Bernardino
Highway	58 Westbound
District and contact	Alan Nakano
Field personnel	LAK/AJS/MMH
Soil family	NA
Mean annual temperature	17.8
Mean annual precipitation (mm)	112
Area (ha)	1.46
Slope percent	48%
Slope length	15 (ave)
Aspect	North /South
Cut or fill slope	Cut
Number of slope breaks	None

Site Information

Characteristic	Value
Nearest weather data center	Barstow
Soil survey	NA
Seed mix type	Under construction
Planting date	NA
Planting and preparation practices	NA
High rain intensity events since construction	NA
High intensity rain months	NA
Number of days with > 1.0 inch rainfall	0
Specified irrigation	None
Construction completion date	NA
Number of 90% probability freeze-free days	212
Erosion types observed	Channel, Wind, Sheet
Current irrigation	None

GPS Points

Corner	North	West
NE		
NW		
SE		
SW		

Soil Profile Descriptions

Soil Profile Description, Auger Hole 1

Sample ID	Depth	Texture	Strucure	Color	Roots	AWHC	Organic Matter	pH	Eh	Gravel %	Sample Analyzed?	% Clay	% Sand
8HIA1	0-12	ls	SG	7.5 YR 5/3	None	1.2	0.9	8.8	0.4	6	YES	10	80
											NO		
											NO		

Soil Profile Description, Auger Hole 3

Sample ID	Depth	Texture	Strucure	Color	Roots	AWHC	Organic Matter	pH	Eh	Gravel %	Sample Analyzed?	% Clay	% Sand
8HIB1	0-15	ls	SG	"	None	1.2	0.9	9.2	0.5	6	YES	12	82
											NO		
											NO		
											NO		

Soil Profile Description, Auger Hole 3

Sample ID	Depth	Texture	Strucure	Color	Roots	AWHC	Organic Matter	pH	Eh	Gravel %	Sample Analyzed?	% Clay	% Sand
											NO		
											NO		
											NO		
											NO		

Overall Soil Permeability Class	Parent Material
V. High	Alluvium/Residuum

Channel Volume Calculation

Slope Region	Width (m)				Height (m)				Length (m)			Total (m3)
	1	2	3	4	1	2	3	4	1	2	3	--
Shoulder Slope												
Back Slope												
Toe Slope												
Total	--	--	--	--	--	--	--	--	--	--	--	

Revised Univeral Soil Loss Equation

Revised Univeral Soil Loss Equation	
Rainfall Factor (R)	10
Soil Erodibility Factor (K)	0.22
Length-Slope Factor (LS)	4.75
Vegetative Cover and Management Factor	0.45
Practices for Erosion Control (P)	1

Erosion Loss (tons/ac/yr)
4.703

Morgan, Morgan, and Finney Model

Soil-Environmental Inputs	
Soil Moisture Content at Field Capacity (MS)	0.17
Soil Bulk Density (BD)	1.3
Soil Detachability Index (K)	0.25
Topsoil Rooting Depth (RD)	0.0015
Sine of Slope Angle (S)	0.743
Annual Rainfall in mm (R)	112
Number of Rain Days (Rn)	21
Typical Intensity of Erosive Rain (I)	10

Months	Number of Months	A (%)	Et/Eo	C
January - December	12	0.001	0.05	1

Weighted A	Et/Eo	C
0.001	0.050	1.000
Log_{10} A	Soil Loss (kg m^{-2})	
-3.000	-0.398	

Field Notes

Surrounding Site Observations	Erosion Point Sources	Wildlife Observations	Current Erosion Control Effectiveness	Photo Index
Native shrubs, but no run-on onto either facing cut slope.	None observed.	None observed.	No non-vegetative erosion control observed. Prevailing winds were toward the east. A concrete v-ditch effectively diverts run-on. Very wide shoulder. Very long (Approximately 0.40 mile).	Site overviews of north and south facing slopes showing large shoulder area.

Current Erosion Control

See above field notes ("Current Erosion Control") for specific information regarding the following practices.

Method	Used Successfully	Used Unsuccessfully	Not Used
Fertilizer/amendments			*
Seed and hydroseed			*
Sod/turfgrass			*
Mulch			*
Compost			*
Emulsion/tackifier			*
(i.e., ivy and iceplant)			*
Shrubs and trees			*
Straw (punched or tacked)			*
Coconut			*
Geotextile/jute			*
Cellular confinement			*
Rock blanket			*
Concrete			*
Gravel filter			*
Sand bags			*
Curb and gutters			*
Silt fence			*
Straw bales			*
Wattles/bundles			*
Willow inbeds			*
Retaining walls			*
Slope benches			*
Infiltration structure			*
Dry wells			*
Water bars			*
Drainage control			*
Culverts			*
V-ditches	*		
Pipe/down drains			*
Inlet structures			*
Outfall dissipator			*
Water ladders			*
Horizontal drains			*
Serated slope terraces			*
Vegetation strips			*
Check dams			*
Retention basins			*

Plant Coverage by Step Point

Cover Type	Area A Cover %	Area B Cover %	Area C Cover %
Bare ground			
Litter or mulch			
Coarse fragments			
Bedrock			
Grass and bare ground			
Legumes and bare ground			
Trees and bare ground			
Shrubs and bare ground			
Upand herbaceous and bare ground			
Wetland species and bare ground			
Grass and litter			
Legumes and litter			
Trees and litter			
Shrubs and litter			
Upland herbaceous and litter			
Wetland species and litter			
Grass and coarse fragments			
Legumes and coarse fragments			
Trees and coarse fragments			
Shrubs and coarse fragments			
Upland herbaceous and coarse fragments			
Wetland species and coarse fragments			
Grass and bedrock			
Legumes and bedrock			
Trees and bedrock			
Shrubs and bedrock			
Upland herbaceous and bedrock			
Wetland species and bedrock			

Flow Rate (gph)

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Output

Site Information

Characteristic	Value
Date	10/11/2001
Site	9FS - Fish Springs
Highway mile marker	97 Inyo
Highway	395 southbound
District and contact	Jim Pitman
Field personnel	AJS
Soil family	NA
Mean annual temperature	13.3
Mean annual precipitation (mm)	135
Area (ha)	
Slope percent	45%
Slope length	20
Aspect	East
Cut or fill slope	Cut
Number of slope breaks	none

Site Information

Characteristic	Value
Nearest weather data center	Bishop WSO
Soil survey	NA
Seed mix type	NA
Planting date	10/15/2001
Planting and preparation practices	Duff replaced
High rain intensity events since construction	NA
High intensity rain months	NA
Number of days with > 1.0 inch rainfall	1
Specified irrigation	none
Construction completion date	Fall 2001
Number of 90% probability freeze-free days	132
Erosion types observed	Channel, Wind, Sheet
Current irrigation	None

GPS Points

Corner	North	West
NE		
NW		
SE		
SW		

Soil Profile Descriptions

Soil Profile Description, Auger Hole 1

Sample ID	Depth	Texture	Strucure	Color	Roots	AWHC	Organic Matter	pH	Eh	Gravel %	Sample Analyzed?	% Clay	% Sand
9FSA1	0-12	LS	1MSBK	10 YR 4/3	None	1	1	8.2	0.6	9	YES	4	84
											NO		
											NO		

Soil Profile Description, Auger Hole 3

Sample ID	Depth	Texture	Strucure	Color	Roots	AWHC	Organic Matter	pH	Eh	Gravel %	Sample Analyzed?	% Clay	% Sand
9FSB1	0-23	SL	1MSBK	10 YR 4/3	none	1.8	1.5	8	0.9	9	YES	8	68
											NO		
											NO		
											NO		

Soil Profile Description, Auger Hole 3

Sample ID	Depth	Texture	Strucure	Color	Roots	AWHC	Organic Matter	pH	Eh	Gravel %	Sample Analyzed?	% Clay	% Sand
											NO		
											NO		
											NO		
											NO		

Overall Soil Permeability Class	Parent Material
High	Colluvium/Alluvium

Channel Volume Calculation

Slope Region	Width (m)				Height (m)				Length (m)			Total (m3)
	1	2	3	4	1	2	3	4	1	2	3	--
Shoulder Slope												
Back Slope												
Toe Slope												
Total	--	--	--	--	--	--	--	--	--	--	--	

Revised Univeral Soil Loss Equation

Revised Univeral Soil Loss Equation	
Rainfall Factor (R)	10
Soil Erodibility Factor (K)	0.29
Length-Slope Factor (LS)	4.92
Vegetative Cover and Management Factor	0.45
Practices for Erosion Control (P)	1

Erosion Loss (tons/ac/yr)
6.421

Morgan, Morgan, and Finney Model

Soil-Environmental Inputs	
Soil Moisture Content at Field Capacity (MS)	0.15
Soil Bulk Density (BD)	1.4
Soil Detachability Index (K)	0.2
Topsoil Rooting Depth (RD)	0.0023
Sine of Slope Angle (S)	0.707
Annual Rainfall in mm (R)	135
Number of Rain Days (Rn)	29
Typical Intensity of Erosive Rain (I)	10

Months	Number of Months	A (%)	Et/Eo	C
January - December	12	0.001	0.05	1

Weighted A	Et/Eo	C
0.001	0.050	1.000
Log_{10} A	Soil Loss (kg m^{-2})	
-3.000	-0.383	

Field Notes

Surrounding Site Observations	Erosion Point Sources	Wildlife Observations	Current Erosion Control Effectiveness	Photo Index
Native shrubs and grasses. No run-on. A fencline runs along the top of the slope, but does not impact erosion. Not a large toe area. Toe has a 2- to 3-foot cut.	None observed.	None observed.	Under construction. Bare soil.	1- Overview of site. 2- View of series of sites along highway.

Current Erosion Control

See above field notes ("Current Erosion Control") for specific information regarding the following practices.

Method	Used Successfully	Used Unsuccessfully	Not Used
Fertilizer/amendments			*
Seed and hydroseed			*
Sod/turfgrass			*
Mulch			*
Compost			*
Emulsion/tackifier			*
(i.e., ivy and iceplant)			*
Shrubs and trees			*
Straw (punched or tacked)			*
Coconut			*
Geotextile/jute			*
Cellular confinement			*
Rock blanket			*
Concrete			*
Gravel filter			*
Sand bags			*
Curb and gutters			*
Silt fence			*
Straw bales			*
Wattles/bundles			*
Willow inbeds			*
Retaining walls			*
Slope benches			*
Infiltration structure			*
Dry wells			*
Water bars			*
Drainage control			*
Culverts			*
V-ditches			*
Pipe/down drains			*
Inlet structures			*
Outfall dissipator			*
Water ladders			*
Horizontal drains			*
Serated slope terraces			*
Vegetation strips			*
Check dams			*
Retention basins			*

Plant Coverage by Step Point

Cover Type	Area A Cover %	Area B Cover %	Area C Cover %
Bare ground			
Litter or mulch			
Coarse fragments			
Bedrock			
Grass and bare ground			
Legumes and bare ground			
Trees and bare ground			
Shrubs and bare ground			
Upand herbaceous and bare ground			
Wetland species and bare ground			
Grass and litter			
Legumes and litter			
Trees and litter			
Shrubs and litter			
Upland herbaceous and litter			
Wetland species and litter			
Grass and coarse fragments			
Legumes and coarse fragments			
Trees and coarse fragments			
Shrubs and coarse fragments			
Upland herbaceous and coarse fragments			
Wetland species and coarse fragments			
Grass and bedrock			
Legumes and bedrock			
Trees and bedrock			
Shrubs and bedrock			
Upland herbaceous and bedrock			
Wetland species and bedrock			

Flow Rate (gph)

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Appendix E
Soil Analysis Report


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APPENDIX E
Soil Analysis Report

		Organic Matter		Phosphorus		Potassium	Magnesium	Calcium	Sodium	pH	Hydrogen	Cation Exchange Capacity	Percent Cation Saturation (Computed)					Nitrogen	Sulfur	Zinc	Manganese	Iron	Copper	Boron		Soluble Salts	Particle Size Analysis			
Sample No.	Lab No.	% Rate[a]	ENR lbs/A[b]	P1 (Weak Bray) ppm-P Rate[c,d]	N_8HCO_3-P (Olsen Method ppm-P Rate[c,d]	K ppm-K Rate[c,d]	Mg ppm-Mg Rate[c,e]	CA ppm-Ca Rate[c,e]	Na ppm-Na Rate[c,e]	Soil pH	H meg/100g	C.E.C meg/100g	% K	% Mg	% Ca	% H	% Na	NO_3-N ppm NO_3-N Rate	So4-S ppm-S Rate	Zn ppm-Zn Rate	Mn ppm-Mn Rate	Fe pm-Fe Rate	Cu ppm-Cu Rate	B ppm-B Rate	Excess Lime Rate	mmhos/cm Rate	% Sand	% Silt	% Clay	Soil Texture
9FSA1	53484	1.0L	49	13	6L	428H	366H	1788M	106M	8.2	0.0	13.5	8.1	22.3	66.1	0.0	3.4	9L	8L	0.3VL	2L	5VL	0.4L	0.9M	L	0.6L	84	12	4	Loamy Sand
9FSB1	53485	1.5L	60	38	15H	614VH	259H	1226M	46L	8.0	0.0	10.0	15.7	21.3	61.1	0.0	2.0	33H	7L	1.0L	9M	7L	0.4L	1.2M	L	0.9M	68	24	8	Sandy Loam
8BSB1	53486	1.3L	56	3	6L	227M	264M	2262M	825VH	8.5	0.0	17.6	3.3	12.3	64.0	0.0	20.4	13M	20M	0.4VL	1VL	2VL	0.2VL	3.5VH	M	1.0M	60	20	20	Sandy Clay Loam
8HIB1	53487	0.9L	48	7	3VL	87L	179L	2255M	881VH	9.2	0.0	16.8	1.3	8.8	67.1	0.0	22.8	5L	2VL	0.1VL	1VL	1VL	0.1VL	1.2M	M	0.5L	82	12	6	Loamy Sand
8HIA1	53488	0.9L	49	15	5L	204M	174L	2391VH	313H	8.8	0.0	15.2	3.4	9.4	78.3	0.0	8.9	6L	2VL	0.4VL	2L	1VL	0.2VL	1.3H	H	0.4L	80	10	10	Loamy Sand
6MOA1	53489	1.0L	50	8	7L	132M	207M	2730VH	147M	8.3	0.0	16.3	2.1	10.4	83.6	0.0	3.9	8L	34H	0.2VL	2L	4VL	0.1VL	0.6M	H	0.6L	84	6	10	Loamy Sand
11ECA1	53490	0.5L	40	3	4L	50	34	398	239	9.5	0.0	3.4	3.7	8.2	57.9	0.0	30.2	5L	1VL	0.1VL	1VL	1VL	0.1VL	0.4L	L	0.2VL	94	2	4	Sand
11ECB1	53491	0.5L	40	2	3VL	61	42	774	80	9.2	0.0	4.7	3.3	7.3	82.0	0.0	7.3	6L	1VL	0.1VL	1VL	1VL	0.1VL	0.2VL	L	0.4L	94	2	4	Sand
6RRA1	53492	1.0L	49	9	3VL	135M	138L	3001VH	28VL	8.4	0.0	16.6	2.1	6.8	90.3	0.0	0.7	7L	2VL	0.3VL	1VL	1VL	0.1VL	0.4L	L	0.3L	88	4	8	Sand

Source: A&L Western Agricultural Laboratories, October 2001.
[a]Code to Rating: Very Low (VL), Low (L), Medium (M), High (H), Very High (VH), and None (N)[c]
[b]ENR – estimated nitrogen release
[c]Weak Bray unreliable at M or H excess lime or pH > 7.5
[d]Multiply the results in ppm by 4.6 to convert to lbs. per acre P_2O_5
[e]Multiply the results in ppm by 2 to convert to lbs. per acre of the elemental form
[f]Multiply the results in ppm by 2.4 to convert to lbs. per acre K_2O
Most soils weigh two (2) million pounds (dry weight) for an acre of soil 6-2/3 inches deep

Appendix F
Erosion Control Products List


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Appendix F
SUMMARY LIST OF PRODUCTS

Company	*Name Brand/Product Type*
NON-BIODEGRADABLE BLANKETS/MATS	
Agrotwine Pvt. LTD.	Coir-based erosion control products
American Excelsior Co.	Enforcer
Cady Industries, Inc	Bon Terra
Contech Const. Products	PYRAMAT
Conwed Plastics	Misc. blanket components - geotextile
Donnelly Fabricators	Distributor of Presto Products
Erosion Control Systems	Coconut mat and excelsior blankets
Integra Plastics	Woven coated polypropylene products
North American Green	Vmax3
Permathene Ltd	Landlok
Revegetation Exchange Inc	PYRAMAT
RoLanka International	3DTRM-PP and 3DTRM-CC (TRMs)
Santa Fe Bag Company, Inc.	Misc. geotextile
Web Tec Inc	Terra Jute
SOIL STABILIZERS	
Aqua-Shed Manufacturing Corporation	Misc. stabilizers
Conwed Fibers	Conwed
Conwed Plastics	Bonded Fiber Matrix
Energy Forever	Dirtcrete
Finn Corporation	HydroGel
General Chemical Industrial	Misc. stabilizers
Georgia Pacific	Gypsum products
Happy Pondering Products	Earthcrete
Hercules Environmental	Soiloc
Idaho Enzymes, Inc.	Perma-Zyme 11X
IMC Global	Phosphate products
Midwest Industrial Supply	Soil~Sement
Pennzoil	PennzSupress
Poly Pavement	Poly Pavement
Profile Products	Terra Mulch
Quattro Environmental	Terra Control/SoiLok
Quattro Environmental	Atlas SoiLok
Reclamare Company	J-Tac Soil Mulch Tackifier
Reclamare Company	Marloc
REINCO, Inc	Multiple products for tackifier and mulch
Revegetation Exchange Inc	Soil Master
Soil Seal Corporation	Soil Seal
SSPCo	Road Oyl, Envirotac II
SSPCo	Envirotac II
Terra Firma Industries	HYDROPAM/ Terra Tak
Terra Novo, Inc.	Earth Guard
CONCRETE/BLOCK SYSTEMS	
American Excelsior Co.	Tri-Lock
Armortec	Armorloc, Armorflex
Construction Techniques, Inc	Unimat□Fabriform
Contech Const. Products	Petraflex
Excel High Inc	Coco Gabion
Foresight Products LLC	MANTA RAY
Green Banks Erosion Control Systems	Armor Flex
Green Fix America	THIS IS NOT CONCRETE
Hydrotex Fabric Forms	Filter Point Lining

Appendix F
SUMMARY LIST OF PRODUCTS

Company	*Name Brand/Product Type*
Maccaferri	Gabion
MCCA Inc	GrassPave2
Nilex	Nilex
Pavestone Company	CONLOCK
Permathene Ltd	Permathene Gabions
Progressive Concrete Works Inc.	Grasscrete
Royal Enterprises America	CABLE CONCRETE
R&M Chemical Technologies	concrete
Serrot International, Inc.	Hydrotex
Soil Stabilization Products Company, Inc	GEOBLOCK
Submar, Inc.	Submar Revetment Mats
Unilock Ltd.	Turfstone
Westcon	Westcon

LONG-TERM BLANKETS

Company	Product Name
AET Nets and Nonwovens	Delnet
Armtec Limited	ECO-CO-C
Belton Industries	GeoCoir, AASHTO-M-288
BP Amoco Chemicals	Amoco
Bradley Industrial textiles	Does not apply-geosynthetic tubes/containers
Cady Industries, Inc	Bon Terra
Carthage Mills	SITE IS UNDER CONSTRUCTION
Colbond Geosynthetics	Enkagrid
Crow Company	GeoJute
Drainage Products Inc	Drain away
Emco Limited	GeoJute
Geo-Civ Products, Inc	Curlex Excelsior, Formed Concrete
Integra Plastics	Woven coated products, multiple
King Fibre Inc.	Mulchmat
Maccaferri	Mactex
MCCA Inc	Long-term blankets
National Geotextile Exchange	geocoir
Nedia Enterprises Inc	Koirmat
Nilex	Erosion Control Blankets
North American Green	Vmax3 P550
Permathene Ltd	Raugrid
Poly-Flex, Inc.	Single and Double sided Geocomposites
Presto Products Company - Geosystems Products	geoweb
Revegetation Exchange Inc	Kior Mats, Kior Rolls
RoLanka International	BioND-TRM
Serrot International, Inc.	Geonets/geocomposites
SI Geosolutions	Geotex
Strata Systems Inc	Strata Pec
Synthetic Industries	Distributors of Earthscape and Geotex
TC Mirafi	Mirafi
TENAX International	MS 330 MS220
The Reinforced Earth Company	Matrex
Weather Busters	

ROCK BLANKET

Homegold Resources LTD	Riprap/Rock

Appendix G
Specifications


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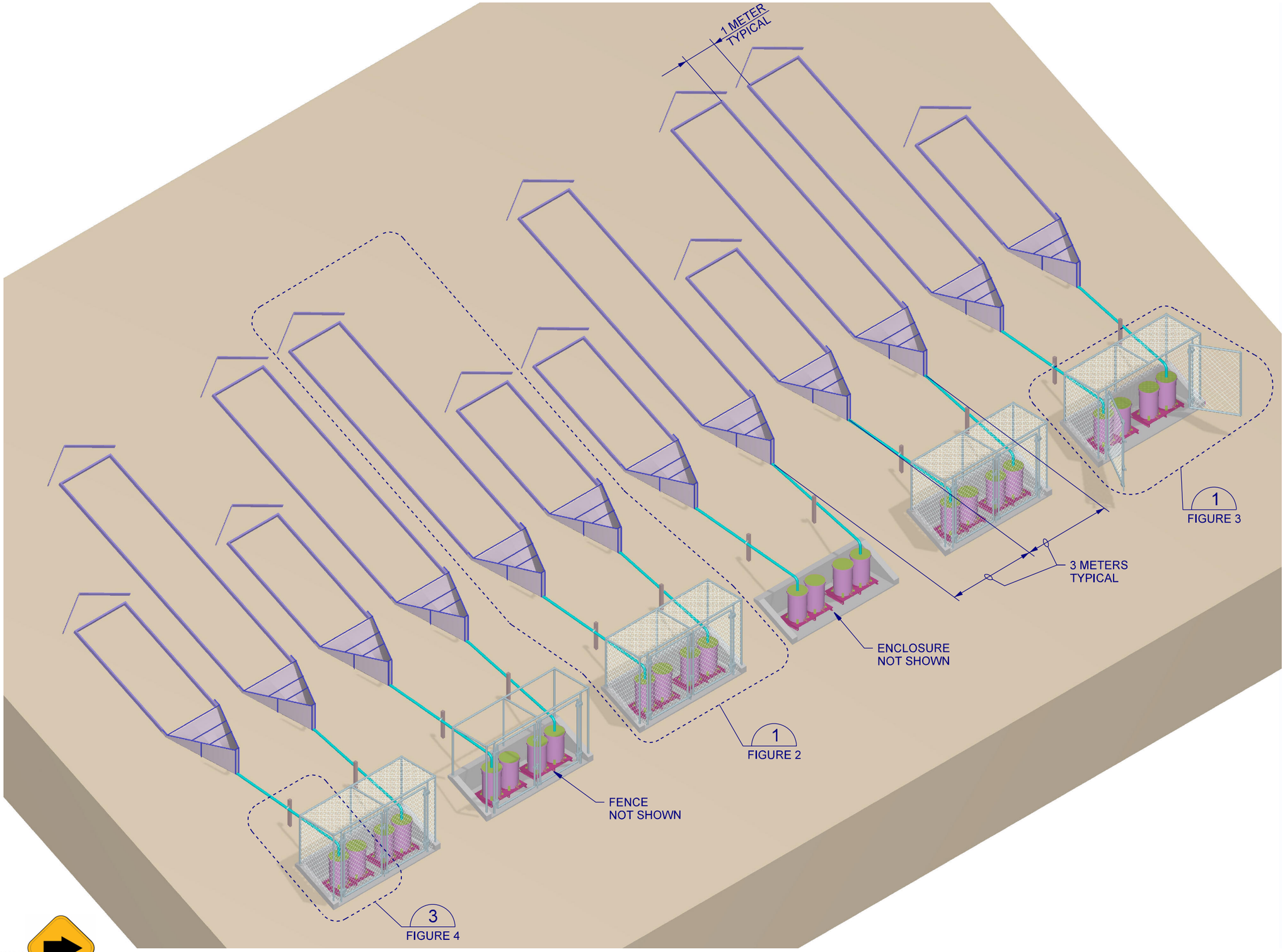
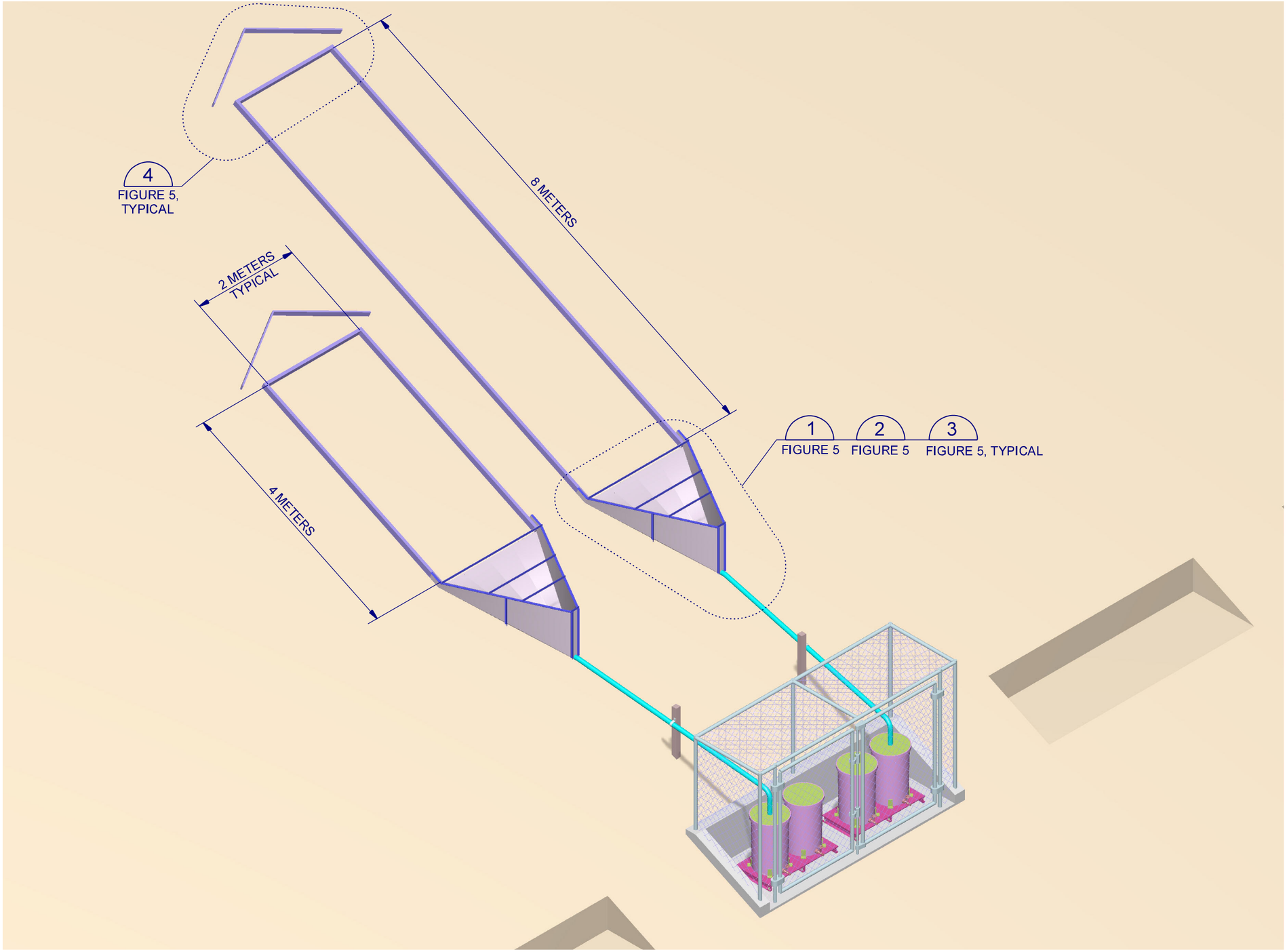


FIGURE 1
SITE PLAN
45-PERCENT SLOPE
CALTRANS ARID REGION
NON - VEGETATIVE
EROSION CONTROL



DETAIL 1
NTS FIGURE 1

FIGURE 2
4- AND 8-METER UNITS
CALTRANS ARID REGION
NON - VEGETATIVE
EROSION CONTROL

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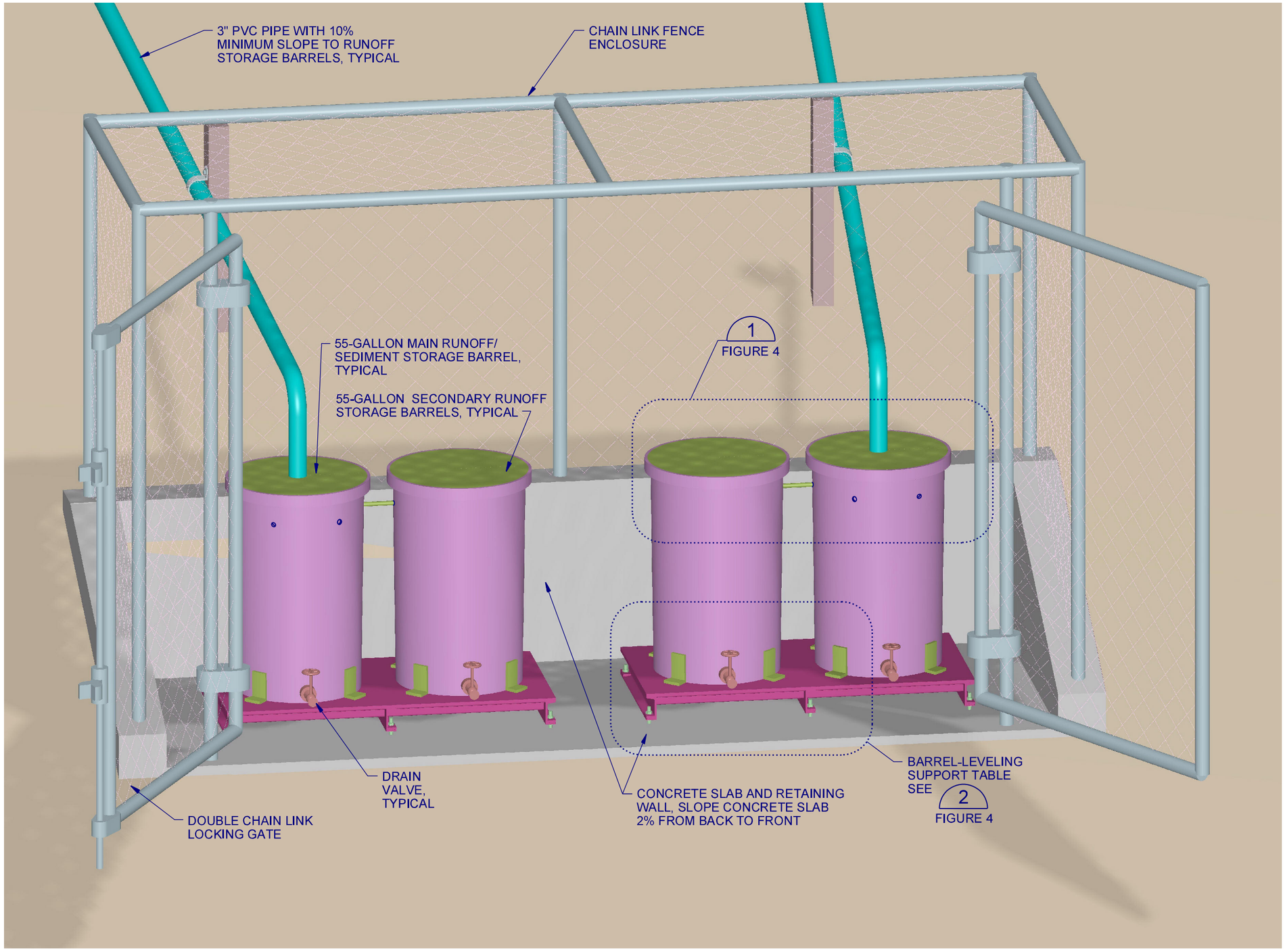
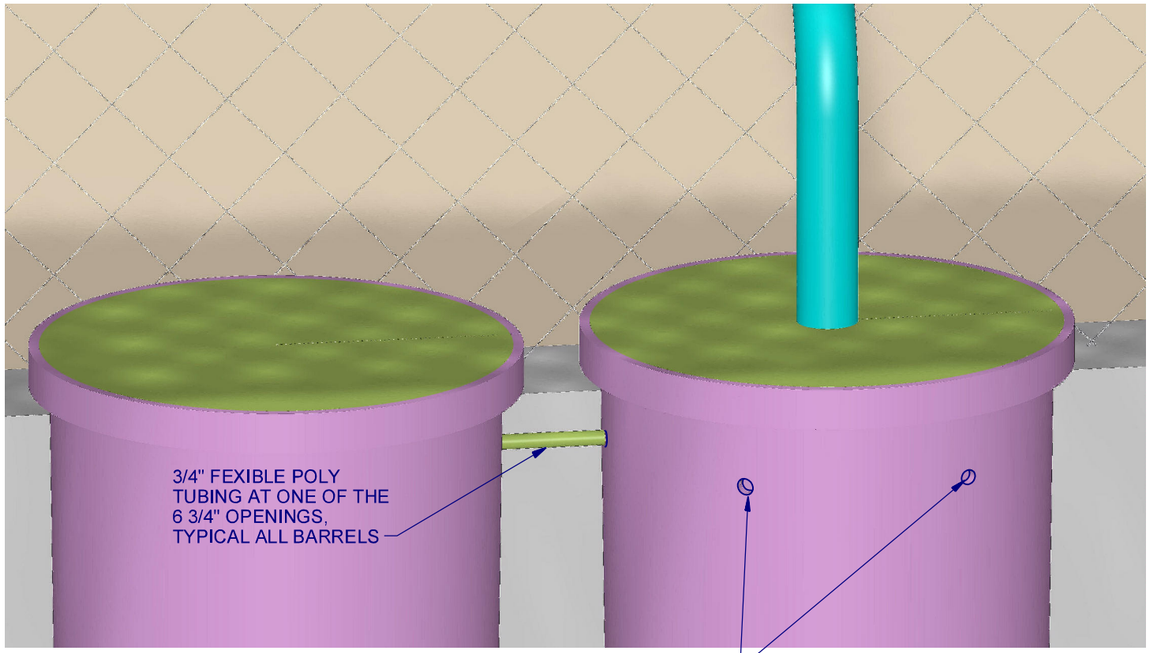
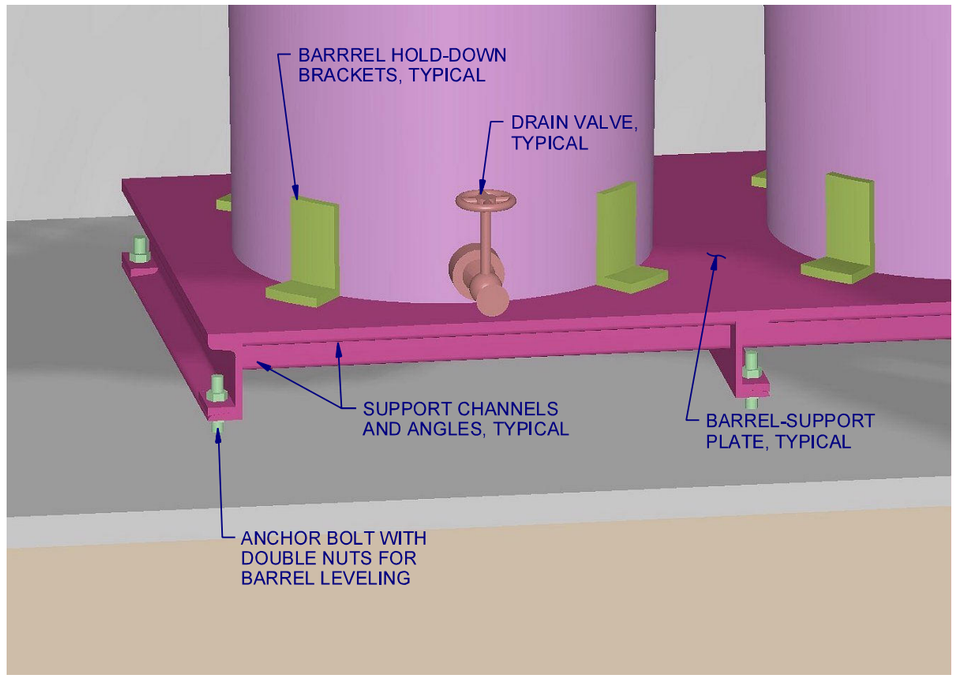


DETAIL 1
NTS FIGURE 1

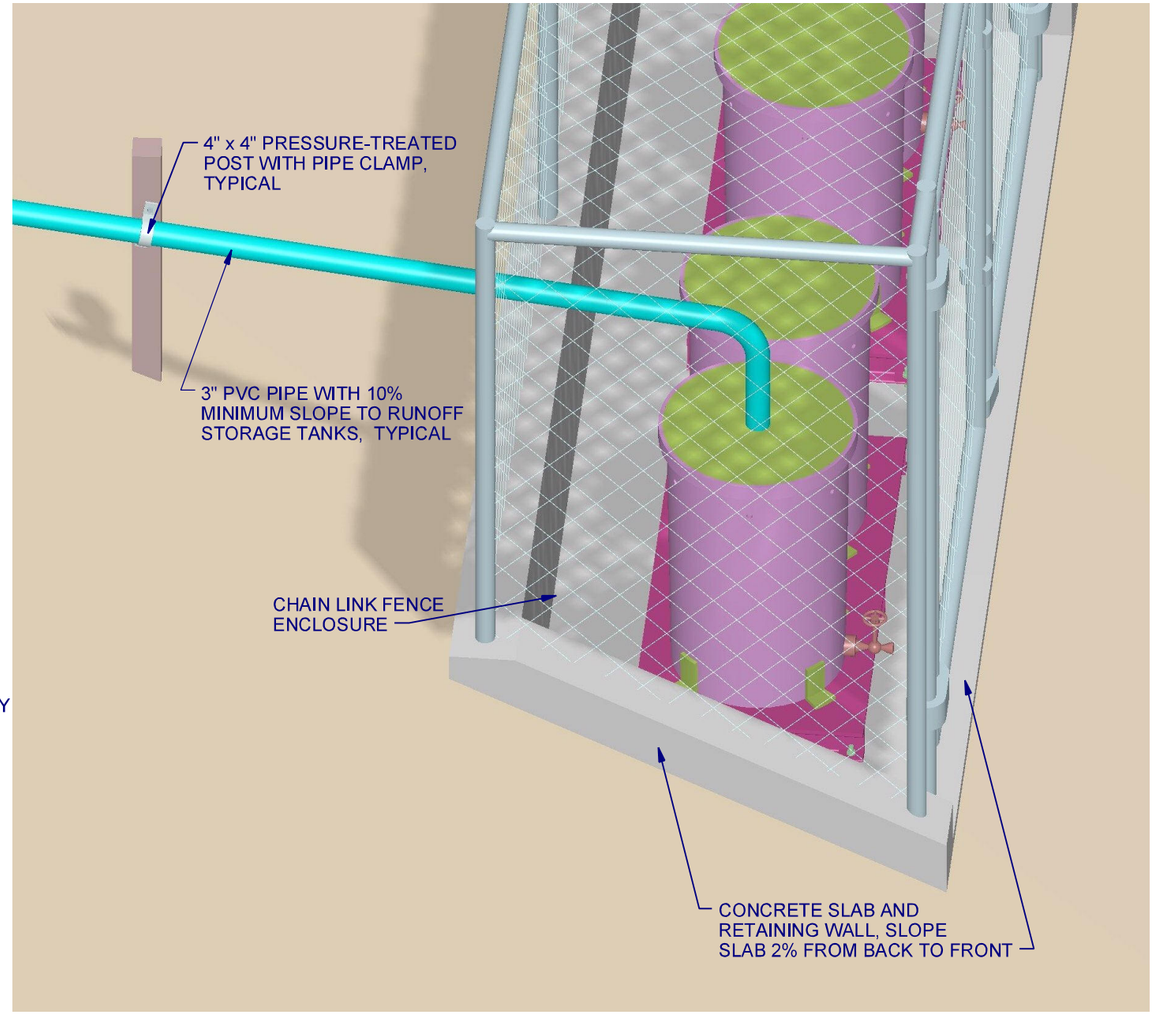
FIGURE 3
BARREL
ENCLOSURE
CALTRANS ARID REGION
NON - VEGETATIVE
EROSION CONTROL



DETAIL 1
NTS FIGURE 3

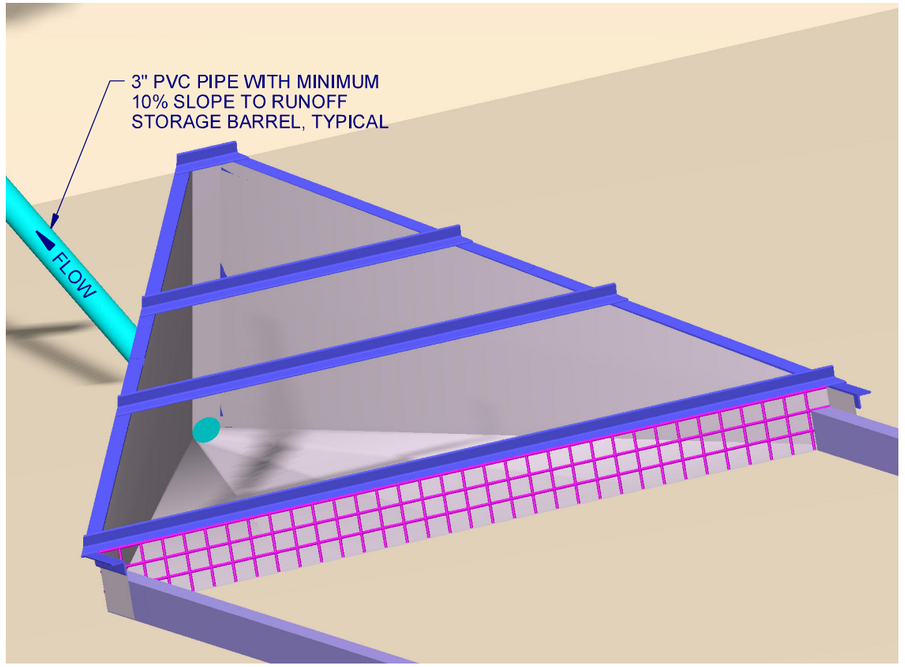


DETAIL 2
NTS FIGURE 3

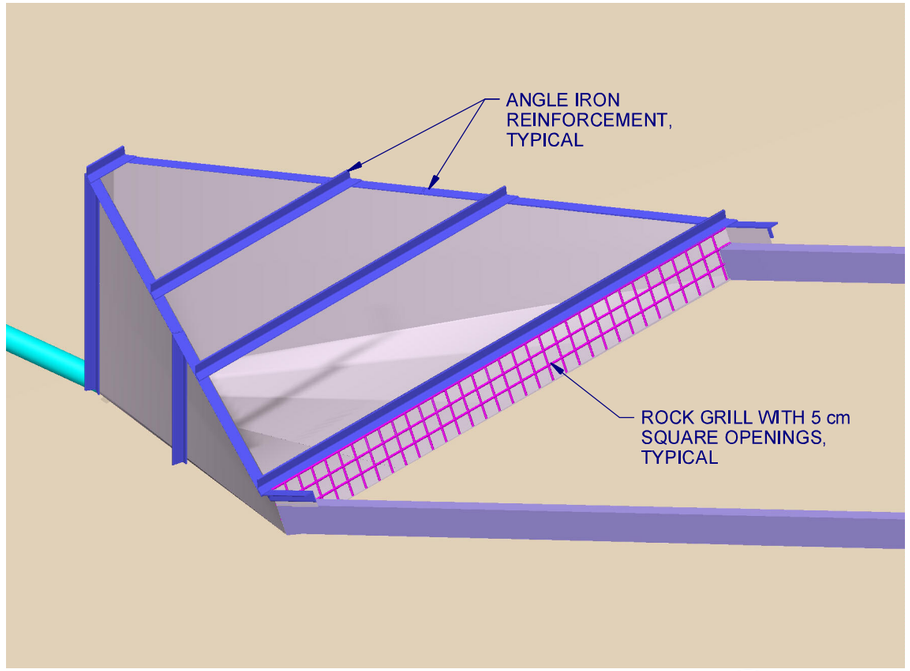


DETAIL 3
NTS FIGURE 1

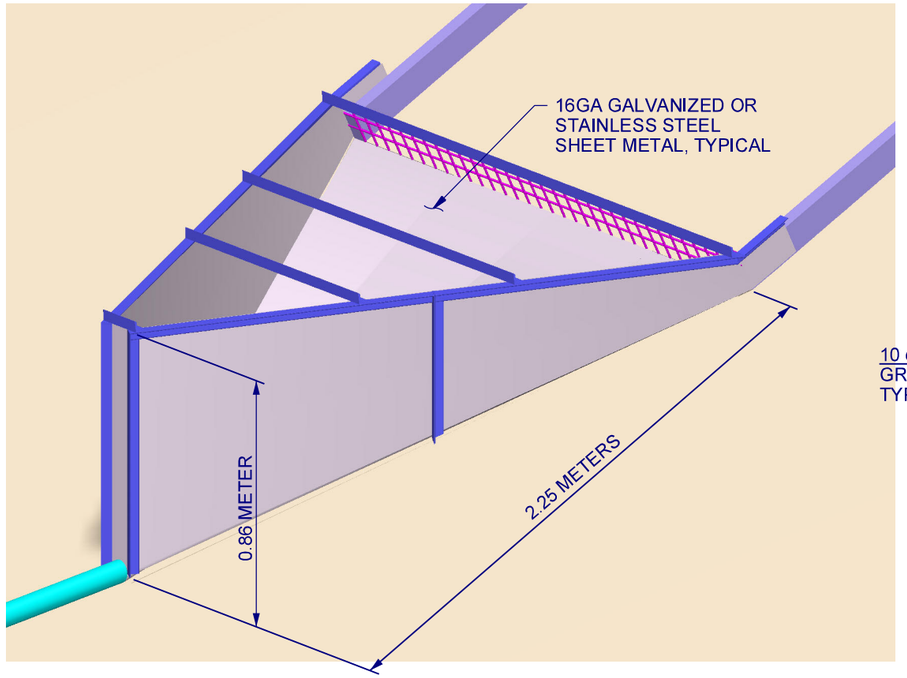
FIGURE 4
BARREL DETAILS
CALTRANS ARID REGION
NON - VEGETATIVE
EROSION CONTROL



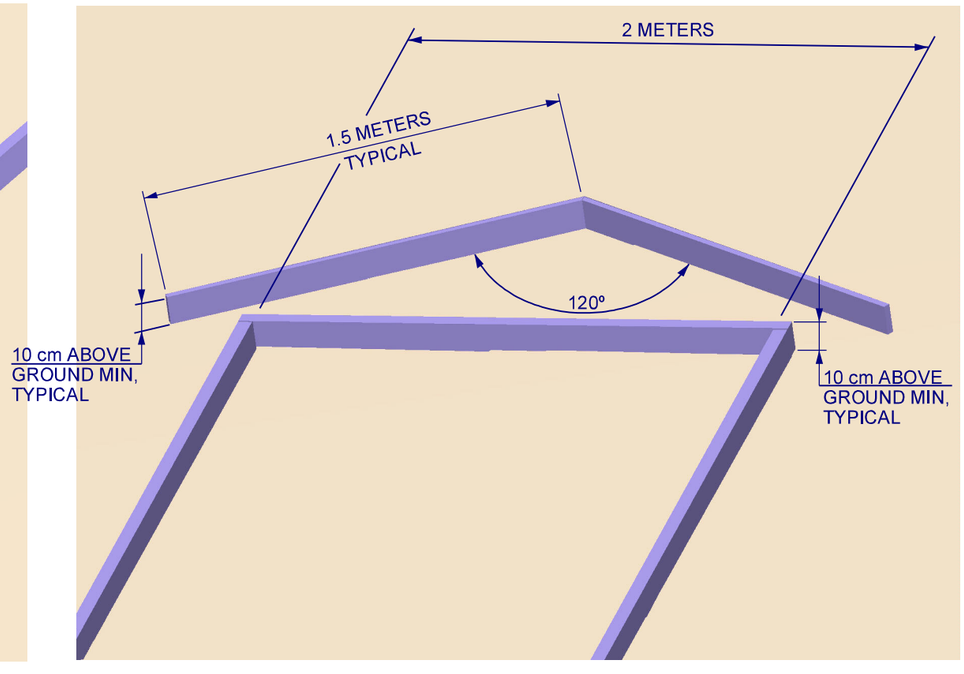
RUNOFF COLLECTION DEVICE 1
NTS FIGURE 2



RUNOFF COLLECTION DEVICE 2
NTS FIGURE 2



RUNOFF COLLECTION DEVICE 3
FIGURE 2



RUNOFF DIVERSION 4
NTS FIGURE 2

FIGURE 5
COLLECTION AND DIVERSION DETAILS
CALTRANS ARID REGION
NON - VEGETATIVE
EROSION CONTROL

SECTION 02200
SITE PREPARATION

PART 1 GENERAL

1.1 DEFINITIONS

A. Interfering or Objectionable Material: Trash, rubbish, and junk; vegetation and other organic matter, whether alive, dead, or decaying; topsoil.

B. Clearing: Removal of interfering or objectionable material lying on or protruding above ground surface.

C. Grubbing: Removal of vegetation and other organic matter including stumps, buried logs, and roots greater than 1 inch caliper to a depth of 6 inches below subgrade.

D. Scalping: Removal of sod without removing more than upper 3 inches of topsoil.

E. Stripping: Removal of topsoil remaining after applicable scalping is completed.

F. Project Limits: Areas, as shown or specified, within which Work is to be performed.

1.2 SCHEDULING AND SEQUENCING

A. Prepare site only after adequate erosion and sediment controls are in place. Limit areas exposed uncontrolled to erosion during installation of temporary erosion and sediment controls to maximum of 1 acre.

PART 2 PRODUCTS (NOT USED)

PART 3 EXECUTION

3.1 GENERAL

A. Clear, grub, and strip areas actually needed for waste disposal, borrow, or site improvements within limits shown or specified.

B. Do not injure or deface vegetation that is not designated for removal.

3.2 LIMITS

A. As follows, but not to extend beyond Project limits.

1. Excavation 5 feet beyond top of cut slopes.
2. Fill:
   a. Clearing and Grubbing: 5 feet beyond toe of permanent fill.
   b. Stripping 2 feet beyond toe of permanent fill.
3. Waste Disposal:
   a. Clearing: 5 feet beyond perimeter.
   b. Scalping and Stripping: Not required.
   c. Grubbing: Around perimeter as necessary for neat finished appearance.
4. Roadways: Clearing, grubbing, scalping, and stripping 10 feet from roadway shoulders.
5. Overhead Utilities:
   a. Clearing and Grubbing: Entire width of easements and rights-of-way.
   b. Scalping and Stripping: Wherever grading is required.

B. Remove rubbish, trash, and junk from entire area within Project limits.

3.3 TEMPORARY REMOVAL OF INTERFERING PLANTINGS

A. Remove and store, as specified in Section 02930, TREES, PLANTS, AND GROUND COVERS, shrubs and trees that are not designated for removal but do interfere with construction or could be damaged by construction activities.

B. Photograph and document location, orientation, and condition of each plant prior to its removal. Record sufficient information to uniquely identify each plant removed and to assure accurate replacement.

3.4 CLEARING

A. Clear areas within limits shown or specified.

B. Fell trees so that they fall away from facilities and vegetation not designated for removal.

C. Cut stumps not designated for grubbing flush with ground surface.

D. Cut off shrubs, brush, weeds, and grasses flush with ground surface.

3.5 GRUBBING

A. Grub areas within limits shown or specified.

3.6 SCALPING

A. Do not remove sod until after clearing and grubbing is completed and resulting debris is removed.

B. Scalp areas within limits shown or specified.

3.7 STRIPPING

A. Do not remove topsoil until after scalping is completed.

B. Strip areas within limits to minimum depths shown or specified. Do not remove subsoil with topsoil.

C. Stockpile strippings, meeting requirements of Section 02911, SOIL PREPARATION, for topsoil, separately from other excavated material.

3.8 TREE REMOVAL OUTSIDE CLEARING LIMITS

A. Remove Within Project Limits:

1. Dead, dying, leaning, or otherwise unsound trees that may strike and damage Project facilities in falling.
2. Trees designated by ENGINEER.

B. Cut stumps off flush with ground, remove debris, and if disturbed, restore surrounding area to its original condition.

3.9 TREE TOPPING

A. Top trees adjacent to Project rights-of-way and easements for overhead utilities so remaining portion will not strike facilities in falling. Where topping will remove more than 1/2 of a tree's crown, remove entire tree.

B. Treat wounds resulting from topping as specified in Section 02930, TREES, PLANTS, AND GROUND COVERS, Article PRUNING.

3.10 DISPOSAL

A. Clearing and Grubbing Debris:

1. Debris may be buried in designated onsite disposal areas to minimum depth of 3 feet below final grade. In lieu of onsite burial, dispose of debris offsite.
2. Burning of debris onsite will not be allowed.
3. Woody debris may be chipped. Chips may be sold to CONTRACTOR's benefit or used for landscaping onsite as mulch or uniformly mixed with topsoil, provided that resulting mix will be fertile and not support

combustion. Dispose of chips that are unsaleable or unsuitable for landscaping or other uses with unchipped debris.

4. Limit offsite disposal of clearing and grubbing debris to locations that are approved by federal, state, and local authorities, and that will not be visible from Project.

B. Scalpings: As specified for clearing and grubbing debris.

C. Strippings:

1. Dispose of strippings that are unsuitable for topsoil or that exceed quantity required for topsoil or approved by ENGINEER
2. Stockpile topsoil in sufficient quantity to meet Project needs. Dispose of excess strippings as specified for clearing and grubbing.

END OF SECTION

SECTION 02315
FILL AND BACKFILL

PART 1 GENERAL

1.1 REFERENCES

A. The following is a list of standards which may be referenced in this section:

1. American Society for Testing and Materials (ASTM):
   a. C117, Standard Test Method for Materials Finer Than 75-Micrometers (No. 200) Sieve in Mineral Aggregates by Washing.
   b. C136, Standard Method for Sieve Analysis of Fine and Coarse Aggregates.
   c. D75, Standard Practice for Sampling Aggregates.
   d. D698, Test Method for Laboratory Compaction Characteristics of Soil Using Standard Effort (12,400 ft-lbf/ft3 (600 kN-m/m3)).
   e. D1556, Standard Test Method for Density and Unit Weight of Soil in Place by the Sand-Cone Method.
   f. D1557, Test Method for Laboratory Compaction Characteristics of Soil Using Modified Effort (56,000 ft-lbf/ft3 (2,700 kN-m/m3)).
   g. D2922, Standard Test Methods for Density of Soil and Soil-Aggregate in Place by Nuclear Methods (Shallow Depth).
   h. D4253, Standard Test Methods for Maximum Index Density and Unit Weight of Soils Using a Vibratory Table.
   i. D4254, Standard Test Method for Minimum Index Density and Unit Weight of Soils and Calculation of Relative Density.

1.2 DEFINITIONS

A. Relative Compaction:

1. Ratio, in percent, of as-compacted field dry density to laboratory maximum dry density as determined in accordance with ASTM D1557.
2. Apply corrections for oversize material to either as-compacted field dry density or maximum dry density, as determined by ENGINEER.

B. Optimum Moisture Content:

1. Determined in accordance with ASTM Standard specified to determine maximum dry density for relative compaction.
2. Determine field moisture content on basis of fraction passing 3/4-inch sieve.

C. Relative Density: Calculated in accordance with ASTM D4254 based on maximum index density determined in accordance with ASTM D4253 and minimum index density determined in accordance with ASTM D4254.

D. Prepared Ground Surface: Ground surface after completion of required demolition, clearing and grubbing, scalping of sod, stripping of topsoil, excavation to grade, and subgrade preparation.

E. Completed Course: A course or layer that is ready for next layer or next phase of Work.

F. Lift: Loose (uncompacted) layer of material.

G. Geosynthetics: Geotextiles, geogrids, or geomembranes.

H. Well-Graded:

1. A mixture of particle sizes with no specific concentration or lack thereof of one or more sizes.
2. Does not define numerical value that must be placed on coefficient of uniformity, coefficient of curvature, or other specific grain size distribution parameters.
3. Used to define material type that, when compacted, produces a strong and relatively incompressible soil mass free from detrimental voids.

I. Influence Area: Area within planes sloped downward and outward at 60-degree angle from horizontal measured from:

1. 1 foot outside outermost edge at base of foundations or slabs.
2. 1 foot outside outermost edge at surface of roadways or shoulder.
3. 0.5 foot outside exterior at spring line of pipes or culverts.

J. Borrow Material: Material from required excavations or from designated borrow areas on or near site.

K. Selected Backfill Material: Materials available onsite that ENGINEER determines to be suitable for specific use.

L. Imported Material: Materials obtained from sources offsite, suitable for specified use.

M. Structural Fill: Fill materials as required under structures, pavements, and other facilities.

N. Embankment Material: Fill materials required to raise existing grade in areas other than under structures.

1.3 SUBMITTALS

A. Samples:

1. Imported material taken at source.

B. Information Submittals:

1. Catalog and manufacturer's data sheets for compaction equipment.
2. Certified test results from independent testing agency.

1.4 QUALITY ASSURANCE

A. Notify ENGINEER when:

1. Structure or tank is ready for backfilling, and whenever backfilling operations are resumed after a period of inactivity.
2. Soft or loose subgrade materials are encountered wherever embankment or site fill is to be placed.
3. Fill material appears to be deviating from Specifications.

1.5 SEQUENCING AND SCHEDULING

A. Complete applicable Work specified in Sections 02200, SITE PREPARATION; and 02319, SUBGRADE PREPARATION, prior to placing fill or backfill.

B. Do not place granular base, subbase, or surfacing until after subgrade has been prepared as specified in Section 02319, SUBGRADE PREPARATION.

PART 2 PRODUCTS

2.1 EARTHFILL

A. Excavated material from required excavations and designated borrow sites, free from rocks larger than 3 inches, from roots and other organic matter, ashes, cinders, trash, debris, and other deleterious materials.

B. Material containing more than 10 percent gravel, stones, or shale particles is unacceptable.

PART 3 EXECUTION

3.1 GENERAL

A. Keep placement surfaces free of water, debris, and foreign material during placement and compaction of fill and backfill materials.

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B. Place and spread fill and backfill materials in horizontal lifts of uniform thickness, in a manner that avoids segregation, and compact each lift to specified densities prior to placing succeeding lifts. Slope lifts only where necessary to conform to final grades or as necessary to keep placement surfaces drained of water.

C. Do not place fill or backfill, if fill or backfill material is frozen, or if surface upon which fill or backfill is to be placed is frozen.

D. Tolerances:

1. Final Lines and Grades: Within a tolerance of 0.1 foot unless dimensions or grades are shown or specified otherwise.
2. Grade to establish and maintain slopes and drainage as shown. Reverse slopes are not permitted.

E. Settlement: Correct and repair any subsequent damage to structures, pavements, curbs, slabs, piping, and other facilities, caused by settlement of fill or backfill material.

3.2 BACKFILL UNDER AND AROUND STRUCTURES

A. Other Areas: Backfill with earthfill to lines and grades shown, with proper allowance for topsoil thickness where shown. Place in lifts of 6-inch maximum thickness and compact each lift to minimum 90 percent relative compaction as determined in accordance with ASTM D1557.

3.3 FILL

A. Outside Influence Areas Beneath Structures, Tanks, Pavements, Curbs, Slabs, Piping, and Other Facilities: Unless otherwise shown, place earth fill as follows:

1. Dress completed embankment with allowance for topsoil, crest surfacing, and slope protection, where applicable.

3.4 SITE TESTING

A. Gradation:

1. ENGINEER will determine the amount of samples taken from the finished product.
2. If test results indicate material does not meet Specification requirements, terminate material placement until corrective measures are taken.
3. Remove material placed in Work that does not meet Specification requirements.

3.5 REPLACING OVEREXCAVATED MATERIAL

A. Replace excavation carried below grade lines shown or established by ENGINEER as follows:

1. Beneath Fill or Backfill: Same material as specified for overlying fill or backfill.
2. Permanent Cut Slopes (Where Overlying Area is Not to Receive Fill or Backfill):
   a. Flat to Moderate Steep Slopes (3:1, Horizontal Run: Vertical Rise or Flatter): Earth fill.
   b. Steep Slopes (Steeper than 3:1):
      1) Correct overexcavation by transitioning between overcut areas and designed slope adjoining areas, provided such cutting does not extend offsite or outside easements and right-of-ways, or adversely impacts existing facilities, adjacent property, or completed Work.
      2) Backfilling overexcavated areas is prohibited, unless in ENGINEER's opinion, backfill will remain stable, and overexcavated material is replaced as compacted earth fill.

END OF SECTION

SECTION 02319
SUBGRADE PREPARATION

PART 1 GENERAL

1.1 REFERENCES

A. The following is a list of standards which may be referenced in this section:

1. American Society for Testing and Materials (ASTM):
   a. D698, Test Method for Laboratory Compaction Characteristics of Soil Using Standard Effort (12,400 ft-lbf/ft3 (600 kN-m/m3)).
   b. D1557, Test Method for Laboratory Compaction Characteristics of Soil Using Modified Effort (56,000 ft-lbf/ft3 (2,700 kN-m/m3)).

1.2 DEFINITIONS

A. Optimum Moisture Content: As defined in Section 02315, FILL AND BACKFILL.

B. Prepared Ground Surface: Ground surface after completion of clearing and grubbing, scalping of sod, stripping of topsoil, excavation to grade, and scarification and compaction of subgrade.

C. Relative Compaction: As defined in Section 02315, FILL AND BACKFILL.

D. Relative Density: As defined in Section 02315, FILL AND BACKFILL.

E. Subgrade: Layer of existing soil after completion of clearing, grubbing, scalping of topsoil prior to placement of fill, roadway structure or base for floor slab.

F. Proof-Rolling: Testing of subgrade by compactive effort to identify areas that will not support the future loading without excessive settlement.

1.3 SEQUENCING AND SCHEDULING

A. Complete applicable Work specified in Sections 02200, SITE PREPARATION, prior to subgrade preparation.

1.4 QUALITY ASSURANCE

A. Notify ENGINEER when subgrade is ready for compaction or proof-rolling or whenever compaction or proof-rolling is resumed after a period of extended inactivity.

1.5 ENVIRONMENTAL REQUIREMENTS

A. Prepare subgrade when unfrozen and free of ice and snow.

PART 2 PRODUCTS (NOT USED)

PART 3 EXECUTION

3.1 GENERAL

A. Keep subgrade free of water, debris, and foreign matter during compaction or proof-rolling.

B. Bring subgrade to proper grade and cross-section and uniformly compact surface.

C. Do not use sections of prepared ground surface as haul roads. Protect prepared subgrade from traffic.

D. Maintain prepared ground surface in finished condition until next course is placed.

3.2 COMPACTION

A. Under Earthfill: Two passes with three-wheeled power roller weighing approximately 10 tons.

B. Two passes with a loaded dump truck or similar heavy-wheeled vehicle.

3.3 MOISTURE CONDITIONING

A. Dry Subgrade: Add water, then mix to make moisture content uniform throughout.

B. Wet Subgrade: Aerate material by blading, discing, harrowing, or other methods, to hasten drying process.

3.4 TESTING

A. Proof-roll subgrade with equipment specified in Article COMPACTION to detect soft or loose subgrade or unsuitable material, as determined by ENGINEER.

3.5 CORRECTION

A. Soft or Loose Subgrade:

1. Adjust moisture content and recompact.

B. Unsuitable Material: Over excavate as specified in Section 02316, EXCAVATION, and replace with suitable material from the excavation, as specified in Section 02315, FILL AND BACKFILL.

END OF SECTION

SECTION 02911
SOIL PREPARATION

PART 1 GENERAL

1.1 REFERENCES

A. The following is a list of standards which may be referenced in this section:

1. American Society for Testing and Materials (ASTM):
   a. C33, Standard Specification for Concrete Aggregates.
   b. C602, Standard Specification for Agricultural Liming Materials.
2. U.S. Bureau of Reclamation (USBR):
   a. 514.4.4, Reclamation Instructions, Series 510—Land Classification Techniques and Standards, Part 514—Laboratory Procedures, Chapter 4—Particle-Size Analyses.
   b. 514.8.7, Reclamation Instructions, Series 510—Land Classification Techniques and Standards, Part 514—Laboratory Procedures, Chapter 8—Soil Chemical Tests.

1.2 SUBMITTALS

A. Shop Drawings: Product labels/data sheets.

B. Samples:

1. Representative of stockpiled topsoil.

1.3 SEQUENCING AND SCHEDULING

A. Perform Work specified in Section 02200, SITE PREPARATION, prior to performing Work specified under this section.

PART 2 PRODUCTS

2.1 TOPSOIL

A. Topsoil will consist of soil present onsite. Soil should be free from objects larger than 1-1/2 inches maximum dimension, and free of subsoil, roots, grass, other foreign matter, hazardous or toxic substances, and deleterious material that may be harmful to plant growth or may hinder grading, planting, or maintenance.

B. Composition: As determined in accordance with USBR 514.4.4:

1. Gravel-Sized Fraction: Maximum15 percent by weight retained on a No. 10 sieve.

2. Sand-Sized Fraction: Maximum 95 percent passing No. 10 sieve and retained on No. 270 sieve.
3. Silt-Sized Fraction: Maximum 50 percent passing No. 270 sieve and larger than 0.002 millimeter.
4. Clay-Sized Fraction: Maximum 25 percent smaller than 0.002 millimeter.

C. Organic Matter: Minimum 1.5 percent by dry weight as determined in accordance with USBR 514.8.7.

D. pH: Range 6.0 to 7.2.

E. Source: Stockpile material onsite, in accordance with Section 02200, SITE PREPARATION. Topsoil will not be imported.

2.2 SOURCE QUALITY CONTROL

A. Topsoil Analysis/Testing: Performed by county or state soil testing service or approved certified independent testing laboratory.

PART 3 EXECUTION

3.1 SUBGRADE PREPARATION

A. Scarify subgrade to minimum depth of 6 inches where topsoil is to be placed.

B. Remove stones over 2-1/2 inches in any dimension, sticks, roots, rubbish, and other extraneous material.

C. Limit preparation to areas which will receive topsoil within 2 days after preparation.

3.2 TOPSOIL PLACEMENT

A. Do not place topsoil when subsoil or topsoil is frozen, excessively wet, or otherwise detrimental to the Work.

B. Uniformly distribute to within 1/2 inch of final grades. Fine grade topsoil eliminating rough or low areas and maintaining levels, profiles, and contours of subgrade.

C. Remove stones exceeding 1-1/2 inches, roots, sticks, debris, and foreign matter during and after topsoil placement.

D. Remove surplus subsoil and topsoil from site. Grade stockpile area as necessary and place in condition acceptable for planting or seeding.

END OF SECTION

Appendix H
Health and Safety Plan


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Health and Safety Plan
Study Plan and Experimental Design for Non-vegetative Erosion Control in Arid Regions

All field personnel working on this project must become familiar with this Health and Safety Plan (HSP) and the site-specific concerns. The Project Health and Safety Officer will be responsible for assuring that all members of the field team are familiar with the requirements of the HSP and have received appropriate training for their specific roles. General Caltrans safety guidelines can be found in Chapter 8: Protection of Workers (Division of Maintenance, revised June, 1993). The Project Health and Safety Officer will be responsible for enforcing site-specific health and safety protocols and the provisions of this HSP along with Caltrans-specific safety procedures. The Project Health and Safety Officer and individual employees have authority to suspend work, if necessary, because of health and safety concerns.

PROJECT NO: TBD

CLIENT: Caltrans

PROJECT/SITE NAME: Study Plan and Experimental Design for Non-vegetative Erosion Control in Arid Regions

PROJECT ADDRESS: To be specified

PROJECT MANAGER: TBD

PROJECT HEALTH AND SAFETY OFFICER: TBD

FIELD TEAM LEADER: TBD

CLIENT NAME AND PHONE NUMBER: To be specified

DESCRIPTION OF SPECIFIC TASKS TO BE PERFORMED: TBD

1. Project Organization and Responsibilities

Attachment 1 contains field safety instruction and an employee signoff form. The following lists project organization and responsibilities.

- All project staff are responsible for performing work in a safe manner and in accordance with the requirements specified in this Plan.
- Staff are to identify site-specific hazards and precautions with other staff and with the client.
- The Project Manager, Project Health and Safety Officer, and the Field Team Leader are to ensure that staff are following this HSP.

- The Project Manager is to ensure that this HSP is current and updated when conditions change.
- The Project Health and Safety Officer is to provide assistance in evaluating concerns, reporting injuries, and supplementing the requirements in these instructions if additional tasks are added.

2. Hazard Controls

This section provides safe work practices and control measures used to reduce or eliminate potential hazards.

2.1 Caltrans Traffic Safety Guidelines

Working roadways has several inherent risks dominated by the possibility of errant vehicles. The motoring public is largely made up of conscientious drivers operating well-maintained equipment. However, some percentage of the vehicles on the road at any given time may be marginally under control because of driver factors such as distractions, fatigue, confusion, or inadequate training, as well as mechanical factors including vehicle age and condition. Any or all of these factors may contribute to a vehicle leaving the traveled lanes and entering the work site. Unfortunately, the leading cause of serious driver impairment is driving under the influence (of alcohol). Between 1990 and 1992, motorists driving under the influence struck 10 of the 11 highway workers killed on their jobs.

Traffic load, posted speed limits, and proximity to travel lanes all have a direct relation to the probability of worker exposure to errant vehicles. Work-site selection can reduce the exposure potential relating to these factors. The contractor will consider these factors when evaluating the merits of candidate sampling sites.

In all cases, the Field Team Leader or the Field Safety Officer will make the final evaluation of the appropriateness of performing work with the conditions present at the site. During this field exercise, all field teams will use signs, cones, and flashing lights when necessary to inform motorists of activities that may impact roadway travel conditions.

To avoid shoulder closures, all attempts will be made to pull all vehicles off the road and perform the work as far from the pavement edge as possible. Vehicle pullouts will be provided at many of the work locations. Should a shoulder closure become necessary, the contractor will comply with Caltrans Traffic Control Standard Plan T-10 and any other site-specific applicable Caltrans requirements and standard provisions listed in the encroach-ment permit for the district of operation. District requirements usually include special notification requirements and specific hours of operation.

Prior to beginning any work on or adjacent to a major roadway, the local highway patrol traffic control department shall be notified. Local highway patrol contact numbers can be found in Attachment 2.

Field team members will wear high visibility vests or clothing and hard hats when working along roadsides. Caltrans now requires the use of green vests instead of the standard orange.

Exiting and entering the highway to and from the shoulder when approaching and leaving sampling sites will be performed in a manner consistent with the roadway conditions present. Use of flashing amber lights and turn signals is required. Drivers will evaluate runoff/runon distances with respect to traffic load and traffic speed before attempting to exit to the shoulder. The Field Team Leader will consider the possibility of significant changes in road conditions taking place within the duration of planned work at the sampling sites.

When working on or near the shoulder, physical barriers should be employed whenever possible to protect workers from errant vehicles. Physical barriers including barrier vehicles; guardrails; fences; and other human-made or natural objects capable of slowing, stopping, or diverting an errant vehicle. Barrier vehicles are to be unoccupied, positioned upstream of the work zone, and parked so as not to roll into the work area or active travel lanes if struck by an errant vehicle.

Workers not protected by a physical barrier should employ the use of a Lookout. A Lookout's sole responsibility is to watch traffic for signs of potential trouble and notify endangered workers to use a pre-planned escape route. The Lookout must have an effective means of communicating with workers in the noise and visual condition present.

2.2 General Safety

In addition to traffic hazards, field crews may face a variety of potential dangers while maintaining the facilities, installing equipment, and performing environmental monitoring. The anticipated dangers include:

- Slippery conditions
- Adverse weather
- Fast-moving water
- Unstable earth
- Poor visibility, especially at night
- Lifting heavy objects
- Transients
- Power tools
- Heavy equipment operation
- Fire
- Cuts, scrapes, fainting
- Heat and cold stress
- Sharp objects (broken glass and metal)
- Biological hazards (i.e., bees, spiders, dogs)

Information associated with the hazards anticipated during site activities is presented below.

Physical Hazards	
Hazard	**Safe Work Practice and Precautions**
General operations.	Wear sturdy footwear appropriate for site walk activities (i.e., hiking boots or work boots). See the Personal Protection Equipment (PPE) section for additional requirements. Observe work area for tripping hazards. Park vehicle in location where it can be accessed easily in the event of an emergency; if that is not possible, carry a cellular phone. Pay attention, constantly observe the work area for hazards, and implement every effort needed to protect site personnel from onsite hazards. Never work alone. Always have a buddy present. Avoid leaving materials, tools, and equipment lying around where someone can trip over them. Keep a phone or other means of communication nearby. Do not use your back to lift heavy objects. Get help. Never use drugs or alcohol while working. Do not use power tools and heavy equipment unless trained in the proper use and care of the specific power tools. Never leave open holes unattended or not barricaded. Clean up the work area before leaving.
Errant vehicles. There is a moderate exposure hazard from errant vehicles while accessing most sites.	While stopped on the shoulder of the highway, personnel will keep well back from the highway lanes and face the approaching traffic. A lookout person is required if two or more workers are engaged in exposed activity within 30 feet of the travel lane.
Buddy system.	Always visit with a partner. Maintain visual and audio location of each other. Because of the increased level of transient person activity and certain other hazards, no one is to visit a site alone or be left alone at a site for any reason.
Steep slopes/uneven ground/rock and shale slopes.	Always avoid these areas whenever possible. “Climbing” in these areas should be minimized and limited to that which does not require climbing equipment. Exercise caution in relying on rocks and trees/tree stumps to support yourself – many times they are loose. Whenever possible, switchback your way up/down steep areas and maintain a slow pace with firm footing.
Water crossings: Traversing streams presents significant hazards, including drowning, hypothermia, and abrasions.	Stay away from the edges of fast-moving bodies of water. These edges are usually slippery and unstable. If sampling is required at the edge of a fast-moving body of water, use a lifeline and a personal flotation device. Have a grabbing device when possible. When crossing streams, seek out the safest route – narrow, low flow, shallow, and not immediately upstream of just the opposite. Avoid areas where there are submerged or partially submerged trees/tree branches – these can create entanglement hazards. Face upstream when crossing, stepping side to side, and using a sturdy walking stick. Use either ropes or wear chest waders if streams are crossed that are deeper than “crotch deep.” Ropes should be tied off on one side and held by the person crossing. Once across, the rope should again be tied off so that the second person can hold to a secure line.

Physical Hazards	
Hazard	**Safe Work Practice and Precautions**
	Streams that are deeper than mid-chest deep should not be crossed – find a crossing that is less deep.
Blisters: Blisters most commonly occur on the feet, especially if someone uses inappropriate socks, wet socks or boots, or boots that do not fit or are not broken in.	Preventing blisters is the most important first aid: if someone feels a "hot spot" starting (from friction between the skin and the boot), stop immediately and do something about it. Place a thin layer of moleskin or duct tape on the affected area. If you don't take care of the hot spot, it will become a blister. In this case, use the moleskin, but with a hole in it, so that you don't place adhesive directly over the blister. Minimize pressure on the blister by building up protective padding around it, but not too much or you'll cause more problems. Generally, do not pop blisters, both because they can become infected and because they may become more painful as you continue to walk.
Sunburn: Sunburn can increase risk of cancer. Also, by the time one feels sunburn, it's too late. This is especially true in winter when one doesn't feel hot even though the sun beats down and reflects off the snow into faces.	We can best prevent sunburn by covering up and by frequently applying generous amounts of sunblock with an SPF rating of 16 or higher. First aid is the same as for any burn: If the skin is blistered, cover it with a loose sterile gauze dressing.
Headaches: Headaches result from many different things: dehydration, sunlight, and tension.	You can best treat a headache by treating the cause, if known. Suggest that the person affected take Aspirin™, acetaminophen™ (e.g., Tylenol™), or ibuprofen (e.g., Advil™); drink water; eat a little; and, if possible, take a rest break. Wearing sunglasses may prevent headaches from too much sunlight.
Manual lifting.	Proper lifting techniques must be used when lifting any object. Plan storage and staging to minimize lifting or carrying distances. Split heavy loads into smaller loads. Use mechanical lifting aids whenever possible. Have someone assist with the lift, especially for heavy or awkward loads. Make sure the path of travel is clear prior to the lift.
Fire prevention.	Fire extinguishers shall be provided so that the travel distance from any work area to the nearest extinguisher is less than 100 feet. Extinguishers must: • Be maintained in a fully charged and operable condition • Be visually inspected each month • Undergo a maintenance check each year Do not park vehicles over dry grass or weeds because of the fire potential of hot exhaust systems.
Nosebleeds: Nosebleeds more commonly occur in cold than in hot weather because of the very dry air.	Try to stop the bleeding by pinching the nostrils with your fingers. Be patient; nosebleeds often take a while to stop. If pinching the nostrils doesn't work, you may insert a small, clean pad of gauze into the affected nostril and pinch it again. If someone is prone to nosebleeds, especially in cold weather, it may help to wear a bandanna over the nose and mouth. As he or she breathes out, the bandanna traps warm, moist air, which may be enough to prevent a nosebleed.
Heat stress: Heat stress is a major hazard, especially for workers wearing protective clothing. The same protective materials that shield the body	All personnel shall practice heat-stress prevention when temperatures are in excess of 75°F. Drink 16 ounces of water before beginning work. Disposable cups and water maintained at 50°F to 60°F should be available. Under severe conditions, drink one to

Physical Hazards	
Hazard	**Safe Work Practice and Precautions**
from chemical exposure also limit the dissipation of body heat and moisture.	two cups every 20 minutes, for a total of one to two gallons per day. Do not use alcohol in place of water or other nonalcoholic fluids. Decrease your intake of coffee and caffeinated soft drinks during working hours. Acclimate yourself by slowly increasing workloads (e.g., do not begin with extremely demanding activities). Use cooling devices, such as cooling vests, to aid natural body ventilation. These devices add weight, so their use should be balanced against efficiency. Use mobile showers or hose-down facilities to reduce body temperature and cool protective clothing. Conduct field activities in the early morning or evening and rotate shifts of workers, if possible. Avoid direct sun whenever possible, which can decrease physical efficiency and increase the probability of heat stress. Take regular breaks in a cool, shaded area. Use a wide-brim hat or an umbrella when working under direct sun for extended periods. Provide adequate shelter/shade to protect personnel against radiant heat (sun, flames, hot metal). Maintain good hygiene standards by frequently changing clothing and showering. Observe one another for signs of heat stress. Persons who experience signs of heat syncope, heat rash, or heat cramps should consult Site Safety Coordinator/ Designated Safety Coordinator (SSC/DSC) to avoid progression of heat-related illness.
Cold stress.	Be aware of the symptoms of cold-related disorders and wear proper, layered clothing for the anticipated fieldwork. Appropriate rain gear is a must in cool weather. Consider monitoring the work conditions and adjusting the work schedule using guidelines developed by the U.S. Army (wind-chill index) and the National Safety Council (NSC): • Wind-Chill Index estimates the combined effect of wind and low air temperatures on exposed skin. The wind-chill index does not take into account the body part that is exposed, the level of activity, or the amount or type of clothing worn. For those reasons, it should only be used as a guideline to warn workers when they are in a situation that can cause cold-related illnesses. • NSC Guidelines for Work and Warm-Up Schedules can be used with the wind-chill index to estimate work and warm-up schedules for fieldwork. The guidelines are not absolute; workers should be monitored for symptoms of cold-related illnesses. If symptoms are not observed, the work duration can be increased. Persons who experience initial signs of immersion foot, frostbite, or hypothermia should consult SSC/DSC to avoid progression of cold-related illness. Observe one another for initial signs of cold-related disorders. Obtain and review weather forecast – be aware of predicted weather systems along with sudden drops in temperature, increase in winds, and/or precipitation.
Heavy equipment operation.	Only authorized personnel are permitted to operate earthmoving equipment. Maintain safe distance from operating equipment and stay alert of equipment movement. Avoid positioning between fixed objects, operating equipment, and equipment pinch points; remain outside of the equipment swing and turning radius. Pay attention to backup alarms, but do not rely on them for protection. Never turn your back on operating equipment. Approach operating equipment only after receiving the operator's attention. The

Physical Hazards	
Hazard	**Safe Work Practice and Precautions**
	operator shall acknowledge your presence and stop movement of the equipment. Caution shall be used when standing next to idle equipment; when equipment is placed in gear it can lurch forward or backward. Never approach operating equipment from the side or rear where the operator's vision is compromised. When required to work in proximity to operating equipment, wear high-visibility vests to increase visibility to equipment operators. For work performed after daylight hours, vests shall be made of reflective material or include a reflective stripe or panel. Do not ride on earthmoving equipment unless it is specifically designed to accommodate passengers. Only ride in seats that are provided for transportation and that are equipped with seat belts. Stay as clear as possible of all hoisting operations. Loads shall not be hoisted overhead of personnel. Earthmoving equipment shall not be used to lift or lower personnel. If equipment becomes electrically energized, personnel shall be instructed not to touch any part of the equipment or attempt to touch any person who may be in contact with the electrical current. The utility company or appropriate party shall be contacted to have the line de-energized prior to approaching the equipment.
Fainting.	Fainting results from loss of blood from the brain and is best treated by lowering the head in relation to the heart. If someone feels faint, have him or her sit, or lie down (on a sleeping pad or some other insulation, if possible) until feeling better. Only allow him or her to stand up slowly when he or she feels able.
Cuts and scrapes.	Take the time to wash the cut with soap and water, or an antiseptic towelette. Cleaning the wound immediately will help prevent infection later.
Cramps.	If someone experiences muscle cramps, have him or her sit or lie down and relax. Massage and stretch the sore muscle slowly, gently, and carefully. Have him or her drink water, eat a little, and start again slowly. Drinking a sports drink that replaces electrolytes (i.e., Gatorade™) will help replace salts lost because of sweating. Replacing these salts may help reduce the muscle cramps and prevent them from recurring.
Sprains.	If the sprain is minor, the victim may be able to walk with little or no assistance. To reduce the swelling of a minor sprain, you must put ice on the injury (of course, be careful of frostbite and hypothermia in cold weather). Tape the injured joint using sports tape or an ace bandage and allow the injured person to take ibuprofen (only if they are not allergic to Aspirin™), if they intend to walk out. Major sprains may appear to be fractures and should be treated as such. Splint the injury and plan the best way to get the victim to medical care.
Drinking water: Many areas are prone to natural contamination (e.g., giardia).	Never drink untreated water from streams or lakes. All drinking water must be packed in or properly treated.
Lightning.	Avoid working during thunderstorms. If caught in a thunderstorm, seek shelter among densely wooded areas. Avoid lone trees as shelter. Avoid open, bare areas. Do not cross water bodies.

Physical Hazards	
Hazard	**Safe Work Practice and Precautions**
	If caught in an open area, place feet close together and crouch down as small as possible, without lying on the ground. Ground strikes are known to be initiated by "leaders," or charges, from the earth making a connection to the charge in the clouds. This may cause your hair to stand up, and since you do not want to be part of a leader that makes the connection to form a cloud-to-ground strike, immediately crouch as described above.
Snakes: Snakes typically are found in underbrush and tall grassy areas.	If you encounter a snake, stay calm and look around; there may be other snakes. Turn around and walk away on the same path you used to approach the area. If a person is bitten by a snake, wash and immobilize the injured area, keeping it lower than the heart if possible. Seek medical attention immediately. **DO NOT** apply ice, cut the wound, or apply a tourniquet. Try to identify the type of snake: note color, size, patterns, and markings.
Ticks: Ticks typically are in wooded areas, bushes, tall grass, and brush. Ticks are black, black and red, or brown and can be up to one-quarter inch in size.	Wear tightly woven, light-colored clothing with long sleeves, and pant legs tucked into boots; spray **only outside** of clothing with permethrin or permanone and spray skin with only DEET™; and check yourself frequently for ticks. If bitten by a tick, grasp it at the point of attachment and carefully remove it. After removing the tick, wash your hands and disinfect and press the bite areas. Save the removed tick. Report the bite to Human Resources. Look for symptoms of Lyme disease or Rocky Mountain Spotted Fever (RMSF): • Lyme—A rash might appear that looks like a bullseye with a small welt in the center. • RMSF—A rash of red spots under the skin 3 to 10 days after the tick bite. In both cases, chills, fever, headache, fatigue, stiff neck, and bone pain may develop. If symptoms appear, seek medical attention.
Poison oak: Poison oak is typically found in brush or wooded areas, and is most commonly found in moist areas or along the edges of wooded areas.	Become familiar with the identity of this type of plant. Wear protective clothing that covers exposed skin and clothes. Avoid contact with plants and the outside of protective clothing. If skin contacts a plant, wash the area with soap and water immediately. If the reaction is severe or worsens, seek medical attention. Products are also available on the market that are very effective in preventing a poison oak reaction. They include Ivy Block™ and TECNU™ Cleaner, which are available at most drug stores.
Bloodborne pathogens (BBP): Exposure to bloodborne pathogens may occur when rendering first aid or CPR, or when coming into contact with landfill waste or waste streams containing potentially infectious material.	The contractor's BBP program shall be implemented whenever coming into contact with potentially contaminated materials.
Spiders and bees: Bee and other stinging insects may be encountered almost anywhere and may present a serious hazard, particularly to people who are allergic.	Watch for and avoid nests. Keep exposed skin to a minimum. Carry a kit if you have had allergic reactions in the past, and inform SSC and/or buddy. If a stinger is present, remove it carefully with tweezers. Wash and disinfect the wound, cover it, and apply ice. Watch for allergic reaction; seek medical attention if a reaction develops.

3. Personal Protective Equipment

PPE consistent with the hazards present should be worn and could include:

- Hard hat
- Work boots or steel-toe work boots
- Safety glasses
- Ear plugs or muffs
- Reflective vest (green)
- Rain gear with reflective striping
- Vehicles equipped with a rotating amber light
- Heavy safety gloves and water contamination gloves (i.e., Nitrix™)

4. Tailgate Safety Training

A designated Safety Officer shall conduct a tailgate safety training session regularly. These meetings will be held onsite prior to work operations. All new personnel working on the site will be required to attend a tailgate meeting prior to work operations. The purpose of the safety training meeting is to ensure that field crew members understand and will abide by all safety and potential emergency response measures that may be necessary for the well-being of the field team. The following items will be discussed at each safety meeting:

- Traffic safety
- Safely entering and exiting the freeway
- Site hazards and control measures
- Use and care of personal protective clothing and equipment
- Nearest hospital information
- Emergency response procedures
- Any other site-specific safety issues

All field crew members must sign the tailgate safety meeting form (Attachment 3) in acknowledgement of understanding all issues discussed.

5. Emergency Response

5.1 Pre-emergency Planning

The Field Health and Safety Officer is responsible for performing the applicable pre-emergency planning tasks before starting field activities and coordinating emergency response with onsite personnel. This includes:

- Determining what onsite communication equipment is available (e.g., two-way radio, air horn).

- Determining what offsite communication equipment is needed (e.g., nearest telephone, cell phone).

- Confirming and posting emergency telephone numbers, evacuation routes, assembly areas, and route to hospital; communicating the information to onsite personnel.
- Communicating emergency procedures for personnel injury, exposures, fires, explosions, and releases.
- Designating one vehicle as the emergency vehicle; placing hospital directions and map inside; keeping keys in ignition during field activities.
- Making inventory and checking site emergency equipment, supplies, and potable water.

5.2 Emergency Equipment and Supplies

The Field Health and Safety Officer should verify that these supplies are available, and in proper working order, and mark the locations of emergency equipment on the site map, when provided.

Emergency Equipment and Supplies	Location
10-lb fire extinguisher (A, B, and C classes)	Project vehicle
First aid kit	Project vehicle
Personal eye wash	Project vehicle
Potable water	Project vehicle
BBP kit	Project vehicle
Additional equipment (specify):	

5.3 Emergency Medical Treatment

The procedures listed below may also be applied to non-emergency incidents. Injuries and illnesses must be reported to Human Resources and the company Safety Manager. During non-emergencies, follow these procedures as appropriate:

- Notify appropriate emergency response authorities listed in Attachment 2 (e.g., 911).
- Prevent further injury.
- Initiate first aid and CPR where feasible.
- Get medical attention immediately.
- Make certain that the injured person is accompanied to the emergency room.

5.4 Incident Notification and Reporting

- Upon any project incident (fire, spill, injury, near miss, death), immediately notify the Project Manager and the company Health and Safety Manager.
- Complete the appropriate Injury Report.
- Notify and submit reports to client as required in contract.

6. Approval

This HSP is written for the specific site conditions, purposes, dates, and personnel specified and must be amended if those conditions change.

6.1 Original Plan

Written By: **Date:**

Approved By: **Date**

6.2 Revisions

Revisions Made By: **Date:**

Revisions to Plan:

Revisions Approved By: **Date:**

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7. Attachments

Attachment 1: Employee Signoff Form – Field Safety Instructions

Attachment 2: Emergency Contacts

Attachment 3: Tailgate Safety Briefing Form

Attachment 1

EMPLOYEE SIGNOFF FORM

Field Safety Instructions

The project employees and subcontractors listed below have been provided with a copy of this HSP, have read and understood it, and agree to abide by its provisions.

Project Name: **Project Number:**

EMPLOYEE NAME (Please print)	EMPLOYEE SIGNATURE	COMPANY	DATE

Attachment 2

Emergency Contacts

Medical Emergency – 911	**Company Health & Safety Manager** Name: TBD Phone:
Fire/Spill Emergency – 911	**Project Manager** Name: TBD Phone:
Security & Police – 911	**Workers' Compensation and Auto Claims Reporting Information** Name: TBD Phone:

Hospital Name/Address:	**Hospital Phone #:**
Barstow Site: Barstow Community Hospital 555 S. 7th Avenue Barstow, CA 92311	**Barstow: (760) 255-4224**
Redrocks Site: Tehachapi 115 West E. Street Tehachapi, CA 93561	**Tehachapi: (661) 822-3241**
Redrocks Site: Ridgecrest 1081 North China Lake Boulevard Ridgecrest, CA 93555	**Ridgecrest: (760) 446-3551**
El Centro Site: El Centro Regional Medical Center 1415 Ross Avenue El Centro, CA 92243	**El Centro: (760) 339-7271**

Directions to Hospital

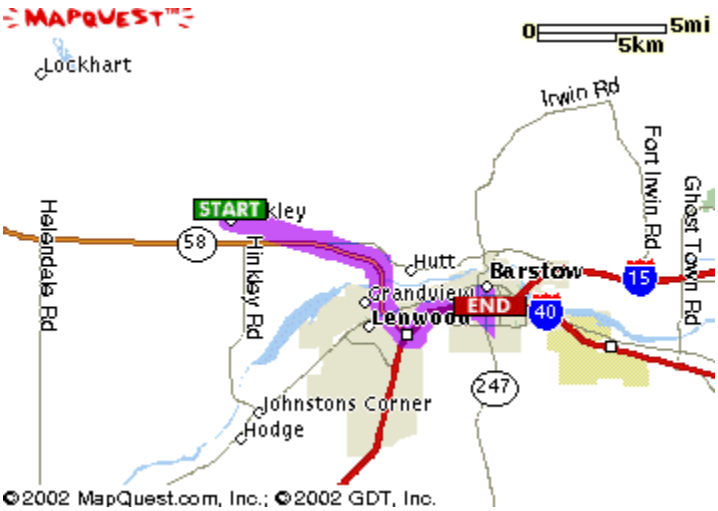
Include written directions and attach a hospital route map.
Maps and written directions are included on the following separate pages.

Go Back
Next Page

Driving Directions

From Hinkley Site

Take CA-58.
Take the I-15 N exit on the left towards LAS VEGAs 14 miles
Merge onto I-15 N. 2.53 miles
Take the CA-247/BARSTOW RD exit.0.29 miles
Turn LEFT onto BARSTOW RD/CA-247.0.12 miles
Stay straight to go onto BARSTOW RD.0.48 miles



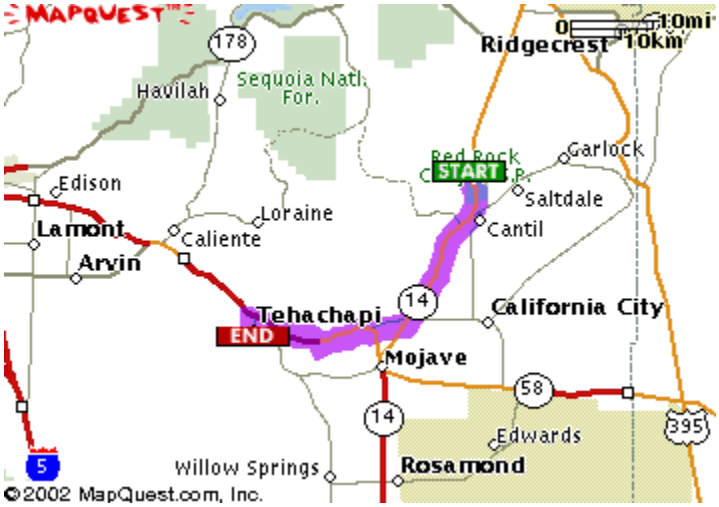
From Barstow Site

Take Highway 15 towards Barstow
Left on Barstow Rd.

Area and Local Map

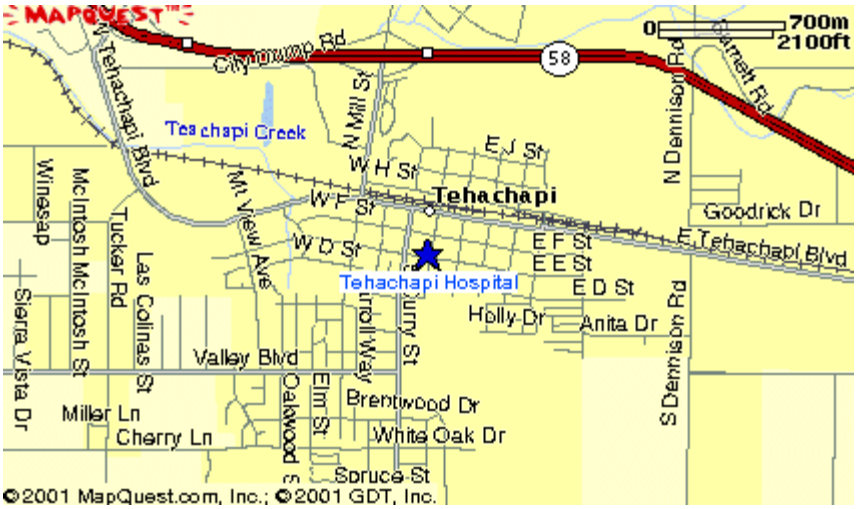
Driving Directions

South on Route-14 19.30 miles
Turn SLIGHT RIGHT onto RANDSBURG CUTOFF RD. 4.65 miles
Stay straight to go onto CA-58 W.14.90 miles
Take the MILL ST exit.0.21 miles
Turn LEFT onto N MILL ST/CAPITAL HILL PKWY. 0.22 miles
Stay straight to go onto N MILL ST. 0.30 miles
N MILL ST becomes DENNISON RD.0.29 miles
Turn RIGHT onto GREEN ST. 0.07 miles
Turn RIGHT onto W TEHACHAPI BLVD/CA-58 BR. 0.09 miles
Turn LEFT onto CA-202.0.14 miles
Approximately 41 miles



Area and Local Maps

Go Back Next Page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S Dennison Rd
Holly Dr
Anita Dr
Valley Blvd
Brentwood Dr
White Oak Dr
Spruce St
Miller Ln
Cherry Ln
Sierra Vista Dr
Winesap
McIntosh
Tucker Rd
Las Colinas St
Mt View Ave
Oakwood
Elm St
Troll Way
Curry St
58
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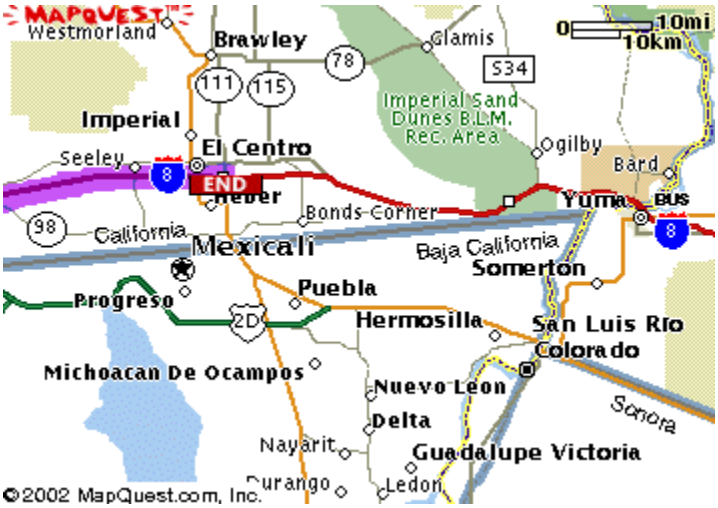
Driving Directions

North on CA 14 approximately 20 miles
Right (E) onto CA 178 approximately 13 miles

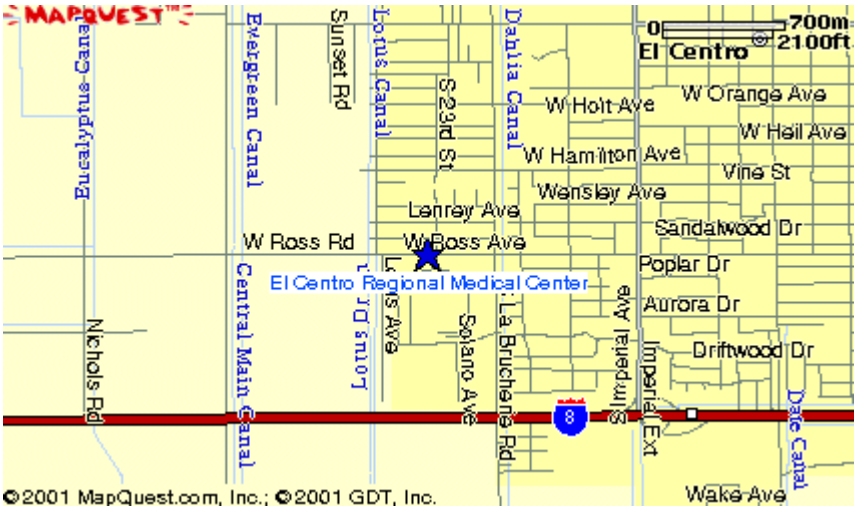
Driving Directions

Take I 8 East.
Take the CA-111 N exit towards BRAWLEY.0.19 miles
Merge onto CA-111 N.

There are 0.17 miles between the end of your directions and your destination. Use maps to get from the end of your route to your destination.



Area and Local Map



Attachment 3

Daily Tailgate Safety Briefing Form		
Project Name:	Project Number:	
Date:	Start Time:	Completed Time:
Site Location:		
Type of Work (general):		

Safety Issues
Tasks (this shift):
PPE Requirements:
Chemical Hazards:
Air Monitoring Requirements:
Physical Hazards:
Control Measures:
Hazard Communication Overview (MSDSs):
Special Topics (i.e., incidents, near misses, etc.)

Daily Checklist		
HSP up to date and present onsite?	Yes	No
Personnel training current?	Yes	No
Hospital Route Map and Emergency Phone Numbers posted onsite?	Yes	No
PPE present and worn by personnel?	Yes	No
Comments:		

Attendees	
Print Name	Sign Name
Meeting conducted by:	