Results from a Study
of
EcoBlanket™ and EcoBerm™:

Runoff Characteristics and Sediment Retention Under Simulated Rainfall Conditions

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1.1 Introduction

There are numerous materials and products on the market that are applied to the soil surface to reduce erosion and off-site sedimentation. These best management practices (BMPs) range from the most common applications of straw mulches to more complex, man-made materials such as rolled erosion control products (RECPs) or hydraulic applications of bonded fiber matrices (BFMs).

Designers and specifiers select erosion and sediment control BMPs based, in part, on criteria that are most important for site conditions. These criteria might include:

- Erosion control effectiveness
- Ease of installation
- Water quality impact
- Runoff characteristics
- Cost

At the San Diego State University Soil Erosion Research Laboratory (SDSU/SERL) rainfall simulation tests are conducted to quantify the erosion control effectiveness, runoff characteristics and water quality impact of existing and emerging soil erosion control technologies/

1.2 Study Objectives

While most of the commonly used erosion control BMPs (e.g., tackified straw, RECPs, BFMs, etc.) are highly effective in controlling soil erosion. Few, in of themselves, possess the ability to modify the fertility of a soil and thereby influence plant establishment and growth. Soil amendments and fertilizers are usually considered as a separate step that must be added or incorporated into the erosion control practice (e.g., fertilizer broadcast with seed prior to application of a surface mulch or RECP).

By comparison, compost applications, when applied at appropriate rates and configurations provide beneficial and immediate erosion control as well as positively influence soil fertility for eventual plant establishment. While the beneficial effects of compost application for plant growth and long term soil health have been documented, the purpose of the compost blanket and berm study was to establish the erosion control effectiveness and runoff characteristics derived from:

1. An EcoBlanket™ applied to the soil surface as a uniform blanket cover.
2. Construction of an EcoBerm™ at the base of a slope for sediment control.

1.3 Test Procedures

The test procedures followed for the EcoBlanket™ and EcoBerm™ Study (EBEB) were adapted from portions of the testing protocols developed for the Slope Stabilization for Temporary Slopes study (Caltrans, October 1999) and the Caltrans Erosion Control Pilot Study (June 2000).

The SDSU test method provides a comparative evaluation of temporary erosion control practices (including erosion control blankets) to baseline bare soil conditions under controlled and documented conditions. The SDSU test method is in general conformance with the outlined methods and scope of ASTM D6459, Standard Test Method for Determination of Erosion Control Blanket (ECB) Performance in Protecting Hillslopes from Rainfall Erosion.

Test Conditions

- The soil used was classified as a clayey sand (SC);
- The test area was the standard 2 meters wide x 8 meter length
- The storm event for the tests was a 10-year storm as predicted for the Los Angeles Basin (5mm per hour for 30 minutes/40 mm per hour for 40 minutes/5 mm per hour for 30 minutes)
- The test slope was 1V:2H for the EcoBlanket™ and 1V:3H for the EcoBerm™.
- Data from three replications and two consecutive rainfall events on bare soil controls (previously tested) was used to determine baseline erosion rates
- Two consecutive rainfall events were applied to the EcoBlanket™
- Three replicate rainfall events were applied to the EcoBerm™
- All runoff and sediment from each treated condition was collected for analysis and compared against the bare soil control conditions.
- In addition to collecting runoff water and sediment, a composite sample of the runoff was collected for water quality analysis. This sample was collected during the first replication for each test condition.

Bed Preparation

- Prior to each replicate test (EcoBerm™), wetted soil in the bed was removed to expose untested soil, and additional soil was added as necessary. (Note: This activity was not conducted during the consecutive testing phase for EcoBlanket™).
- The additional new soil was moisturized, tilled and hand-compacted to uniform consistency.
- Edging and flumes were installed to differentiate a 2m x 8m plot.
- Prior to all testing, the surface of the compacted soil was loosely raked.
- Prior to the materials testing, the following application procedures were followed:

1. EcoBerm™: Rexius personnel installed an EcoBerm™ at the base of the test plot, at the interface between the collection flume and the soil surface. The EcoBerm™ was constructed by pneumatic blower application using the Rexius BermBuilder™ mechanical forming machine. The specified Rexius compost/mulch blend material was combined with the Rexius Microblend™ additive injected at time of installation with the blower equipment. This procedure was followed three times in replication.
2. EcoBlanket™: Rexius personnel installed a 5 centimeter (2 inch) thick specified Rexius compost/mulch blend blanket on the 2 meter x 8 meter test bed. The EcoBlanket™ was constructed by pneumatic blower application. The specified Rexius compost blend material was combined with the Rexius Microblend™ additive injected at time of installation with the blower equipment. This procedure was implemented once, in advance of two consecutive rainfall events.

- SDSU/SERL personnel were responsible for preparing the testing apparatus to accept the compost applications.
- Rexius personnel were responsible for all handling of compost/mulch materials, including mixing and installation of the EcoBerm™ and EcoBlanket™ in the test bed.
- The application was allowed to dry or cure as recommended by Rexius.
- The test bed was raised to a 1:2 slope for the EcoBlanket™ and to a 1:3 slope for the EcoBerm™ prior to rainfall.

Rainfall event

Rainfall consisted of a 10-year storm event as modeled from Los Angeles Basin hydrologic data, consistent with those values of the Caltrans SSTS Study (October 1999) and the Caltrans ECPS Study (June 2000). The intensity and duration of the storm was as follows:

Period 1: 5 millimeters per hour of rain for 30 minutes
Period 2: 40 millimeters per hour of rain for 40 minutes
Period 3: 5 millimeters per hour of rain for 30 minutes

Settings on the rainfall simulators to achieve these intensities were based on previous calibrations conducted at the laboratory. Three(3) replicate storms were applied to each EcoBerm™ test condition. Two consecutive storms were applied to the EcoBlanket™ test condition.

Sample Collection and Analysis

- Water and sediment was collected at the downstream (toe) end of the flume in polyethylene lined, 133 liter (35 gallon) containers.
- During the first rainfall event for each test condition, a separate, flow-weighted composite was collected for water quality analysis.
- At the end of each rainfall event, 500 grams (18 ounces)of gypsum was added to each collection barrel to aid in settling out the fine sediments.
- The samples were allowed to settle overnight (24 hours)
- The supernatant, or clear water, was siphoned from each container, and its weight and volume recorded.
- The weight of the remaining wet sediment was recorded.
- A sample of the remaining wet sediment was taken and placed in an oven overnight to determine moisture content of the wet sediment.

The moisture content of the wet sediment sample was used to determine the total dry sediment weight of the collected sediment.

2.0 TEST FACILITY

The San Diego State University Soil Erosion Laboratory (SDSU/SERL) integrates beneficial features from some of the primary soil erosion research facilities in the United States. Funding for the facility was provided by Caltrans, (California State Department of Transportation) as part of a 1998-2000 erosion control pilot study, in which design, construction and operation of the SERL was supervised by URS Greiner Woodward Clyde and SDSU faculty. Actual modification of Industrial Technology Building Room #103 and construction of the soil test bed was carried out by the SDSU Physical Plant.

In designing the SDSU laboratory, members of the Caltrans pilot study team studied the physical layout, testing protocols, and past research activities of the following soil erosion laboratories:

- Utah Water Research Laboratory (UWRL) at Utah State University, Logan, Utah;
- USDA-Agricultural Research Service National Soil Erosion Research Laboratory (NSERL) at Purdue University, West Lafayette, Indiana; and
- Texas DOT/Texas Transportation Institute (TTI) Hydraulics and Erosion Control Laboratory at Texas A & M, College Station, Texas.

Aspects of the SDSU Soil Erosion Laboratory design that resulted from examination of these facilities include the following:

Table 2.1

Design Features of Soil Erosion LaboratoriesDesign Feature	Erosion Facility
Norton Ladder Rainfall Simulator	NSERL
Hydraulically-lifted soil bed	UWRL
12-inch soil depth placed on porous, open-grid system for drainage	UWRL, NSERL
Procedures for collection of runoff and sediment samples	UWRL, NSERL, TTI
Confirmation of test plot size	UWRL, NSERL
Number of replicates for each test	UWRL, NSERL

The SDSU laboratory is primarily used to provide comparative evaluations of temporary erosion control practices (including erosion control blankets) to baseline bare soil conditions under controlled and documented conditions. The SDSU Soil Erosion Research Laboratory is in general conformance with the outlined methods and scope of ASTM D6459, Standard Test Method for Determination of Erosion Control Blanket (ECB) Performance in Protecting Hillslopes from Rainfall Erosion.

2.1 Norton Ladder Rainfall Simulator

The rainfall simulation device selected for the SDSU Soil Erosion Laboratory is the Norton Ladder Rainfall Simulator, which was developed at the USDA-ARS National Soil Erosion Research Laboratory by Dr. Darrell Norton. This apparatus has been used worldwide, is reasonably inexpensive, and is easily transported and operated.

For testing in the indoor laboratory, multiple simulators (4) have been installed in parallel above the soil test bed to uniformly apply precipitation over the entire test plot area. The pre-fabricated rainfall devices were purchased from Advanced Design & Machine (Clarks Hill, Indiana), an experienced manufacturer specializing in production of the Norton simulator.

Physical Characteristics

The basic unit of the simulator is an aluminum frame 5.3 meters (17 feet) long, 0.32 meters (12 inches) wide, and 0.25 meters (10 inches) deep. Each frame is a self-contained unit that includes nozzles, oscillating mechanism, drive motor, pump, float valve, piping, and sump.

The drop former used for the Norton simulator is the Spraying Systems Veejet 80100 nozzle, and the nozzles are spaced 1.1 meters (3.6 feet) apart. For uniform intensity across the plot, the center of spray patterns from two laterally adjacent nozzles meet at the plot surface. This gives a 2.25 mm (.09 in) median drop size, a nozzle exit velocity of 6.8 meter per second (22.3 feet per second), and a spherical drop.

The impact velocities of almost all drops from the Veejet nozzle are nearly equal to the impact velocities of those from natural rainstorms when the nozzle is at least 2.4 meters (7.9 feet) above the soil surface. For this reason, the rainfall simulators used in the SDSU Soil Erosion Laboratory have been installed such that the nozzles are a minimum of 2.5 meters (8.2 feet) above the soil surface. Rainfall intensity can be changed instantaneously with the simulator in operation, and the maximum intensity produced is 135 mm/hr (5.3 in/hr).

Design of Simulated Rainfall

Prior to testing, the Norton ladder-type simulators are placed into position above the soil test bed. Calibration is achieved by conducting rainfall tests and measuring rainfall volumes in collection devices placed at precise intervals within the 2 meters x 8 meters(6.5 feet x 26 feet) test plot. A full range of rainfall intensities can be achieved by adjusting either one, or both of the following parameters:

- The number of sweeps per minute (spm) of the spray nozzles, ranging from 25 to 125 spm.
- Adjusting the water pressure within the supply system. Each simulator has a system of valves that allow internal water pressure to be adjusted from a low of 2 psi to a high of 6 psi. Gauges atop each simulator allow for accurate, manual adjustment.

Simulated rainstorm events utilized for most of the current testing at the SDSU/SERL have an initial period (Part 1) of low intensity rainfall, followed by a period (Part 2) of relatively high intensity rainfall, and ending with a period (Part 3) of relatively low intensity rainfall.

2.2 Soil Test Bed

The soil test bed is a 3-meter wide by 10-meter long (323 square feet) metal frame which rests on a series of pivots located at the lower end of the bed, and is supported by two hydraulic cylinders near the upper end of the bed. These telescopic cylinders extend to tilt the test bed from its horizontal position to a maximum 2H:1V slope gradient.

The test bed is designed to support a 30.5-cm (1-foot) depth of soil. The depth is sufficient to allow placement and compaction of soil and the application of various surface erosion control practices to evaluate their effect on erosion rates.

The sides and ends of the soil test bed are constructed of steel frame-supported 1.0-cm (0.4-in) thick Plexiglas that allows ambient light onto the soil surface, and facilitates viewing of the effects of rainfall impact and runoff. The total usable surface area of the soil bed is 3 meters (10 feet) wide by 10 meters (33 feet) long, but during testing only a portion of the treated bed, 2 (6.5 feet) meters wide by 8 meters (26 feet) long, is generally delineated for evaluation by the use of plastic edging. Runoff and sediment are collected at the toe of the slope by a metal flume.

Drainage grates have been installed in the floor underneath and at the front of the soil bed, and all runoff not collected is directed to a sanitary sewer. As a safety precaution, stationary steel support posts are placed beneath the bed when it is raised for rainfall simulations.

2.3 Hydraulic System

The soil test bed was designed to be lifted hydraulically to the desired slope inclination for testing. Two 5-stage, single-acting, telescopic cylinders are positioned approximately 3.0 meters (10 feet) from the top of test bed. The cylinders, which weigh 230 kilograms (505 pounds) each, have a 20.3-cm (8-inch) diameter as the largest moving stage.

The complete hydraulic system consists of the cylinders, a 227-liter (60-gallon) hydraulic fluid reservoir, a 114 lpm (30 gpm) hydraulic pump, and a 50 hp electric motor with motor starter. Also included are a suction strainer, return oil filter, pressure relief valve, and a directional control valve.

2.4 Sediment Collection System

Water and soil runoff from the test bed is collected by plastic edging, flume, and collection containers. The components of the sediment collection system on the test bed are installed prior to each rainfall simulation. For most erosion control treatment evaluations, the plastic edging is installed prior to application of the erosion control treatment.

2.5 Water Treatment and Storage

In order to obtain accurate results from the rainfall simulation/erosion rate evaluations, the municipal water supply is treated by reverse osmosis and softened to remove minerals. This treatment process produces "softer" water that is more similar in quality to natural rainfall. Using municipal water without treatment would cause a decrease in sediment load, because minerals in the water serve to decrease erosion.

Water Treatment System

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

Delivery of water to the rainfall simulators positioned above the soil test bed is by a pump attached to hard plumbing and flexible hoses. A key aspect of the Norton design is that unused water from within the simulators is returned to the holding tank and available for reuse. Flexible plumbing is installed to accommodate this return flow.

Treated Water Storage

Treated water is stored in a 3,785–liter (1,000-gallon) polyethylene storage tank for use in the laboratory simulations. For outdoor test plots, two 757-liter (200–gallon) tanks are truck or trailer-mounted to deliver treated water to the field for rainfall simulations.

3.0 RESULTS

Tables 3.1 through 3.12 show the results of the laboratory analysis of sediment weight and runoff volumes for each test condition:

Table 3.1
Sediment and Runoff Yield for Bare Soil (Control)
Two Consecutive Storm Events

Sediment Yield

Period		1st Storm (kg)	2nd Storm (kg)	Mean (kg)
1	(30 min)	0.47	0.47	0.47
2A	(10 min)	22.38	8.89	15.64
2B	(10 min)	11.35	7.64	9.50
2C	(10 min)	9.67	7.56	8.62
2D	(10 min)	9.14	7.25	8.20
3	(30 min)	7.07	8.28	7.68
	Total	*60.08*	*40.09*	*50.09*

Runoff Volume

Period		1st Storm (L)	2nd Storm (L)	Mean (L)
1	(30 min)	18.19	52.25	35.22
2A	(10 min)	89.40	89.99	89.70
2B	(10 min)	89.81	90.08	89.95
2C	(10 min)	88.71	92.70	90.71
2D	(10 min)	92.80	91.08	91.94
3	(30 min)	62.06	61.29	61.68
	Total	*440.97*	*477.39*	*459.18*

Tables 3.1 and 3.2 provide the sediment yield and runoff volumes for bare soils subjected to a) two consecutive 10-year storms and b) three replicate 10-year storms. These data represent the "control" conditions against which the various compost treatments are compared. For two consecutive storm events, an average of 50.09 kilograms of sediment were lost with a corresponding runoff volume average of 459.18 liters (Figure 3.1)

Table 3.2
Sediment and Runoff Yield for Bare Soil (Control)
Three Replicate Storm Events

Sediment Yield

Period		1st Storm (kg)	2nd Storm (kg)	3rd Storm (kg)	Mean (kg)
1	(30 min)	0.37	1.18	0.88	0.81
2A	(10 min)	12.79	14.13	15.92	14.28
2B	(10 min)	7.82	15.64	17.27	13.58
2C	(10 min)	8.21	10.38	12.38	10.32
2D	(10 min)	7.58	9.83	12.05	9.82
3	(30 min)	3.35	2.34	2.10	2.60
	Total	*40.12*	*53.49*	*60.60*	*51.40*

Runoff Volume

Period		1st Storm (L)	2nd Storm (L)	3rd Storm (L)	Mean (L)
1	(30 min)	12.73	24.44	21.17	19.45
2A	(10 min)	91.29	85.34	89.05	88.56
2B	(10 min)	77.86	90.24	95.21	87.77
2C	(10 min)	93.62	90.11	97.27	93.66
2D	(10 min)	91.11	93.75	95.44	93.43
3	(30 min)	61.4	65.01	71.08	65.83
	Total	*428.01*	*448.89*	*469.22*	*448.71*

During three replicate 10-year storm events, an average of 51.40 kilograms of soil were lost with each rain event, with a corresponding average runoff volume of 448.71 liters.

Table 3.3
Sediment and Runoff Yield for Rexius EcoBerm™:
Three Replicate 10-year Storm Events

Sediment Yield

Period		1st Storm (kg)	2nd Storm (kg)	3rd Storm (kg)	Mean (kg)
1	(30 min)	0.00	0.00	0.02	0.01
2A	(10 min)	0.89	1.33	1.35	1.19
2B	(10 min)	0.74	0.80	0.52	0.69
2C	(10 min)	0.59	0.81	0.57	0.66
2D	(10 min)	0.45	0.75	0.47	0.56
3	(30 min)	0.01	0.37	0.17	0.18
	Total	*2.68*	*4.06*	*3.10*	*3.28*

Runoff Volume

Period		1st Storm (L)	2nd Storm (L)	3rd Storm (L)	Mean (L)
1	(30 min)	2.31	2.04	4.64	3.00
2A	(10 min)	51.70	57.69	62.40	57.26
2B	(10 min)	75.90	81.43	75.56	77.63
2C	(10 min)	80.24	82.99	79.64	80.96
2D	(10 min)	81.14	85.74	81.82	82.90
3	(30 min)	71.06	84.33	78.49	77.96
	Total	*362.35*	*394.22*	*382.55*	*379.71*

Table 3.3 illustrates that when three replicate 10-year storms were applied to a bed of bare soil, but with an EcoBerm™ placed across the toe of the slope, an average of only 3.28 kilograms of soil were lost off-site, with a corresponding runoff volume averaging 379.71 liters.

Table 3.4
Sediment Yield and Runoff for Rexius EcoBlanket™:
Two Consecutive 10-year Storm Events

Sediment Yield

Period		1st Storm (kg)	2nd Storm (kg)	Mean (kg)
1	(30 min)	0.00	0.00	0.00
2A	(10 min)	0.02	0.02	0.02
2B	(10 min)	0.07	0.02	0.05
2C	(10 min)	0.01	0.02	0.02
2D	(10 min)	0.03	0.02	0.03
3	(30 min)	0.01	0.02	0.02
	Total	*0.14*	*0.10*	*0.12*

Runoff Volume

Period		1st Storm (L)	2nd Storm (L)	Mean (L)
1	(30 min)	2.84	3.20	3.02
2A	(10 min)	10.87	21.11	15.99
2B	(10 min)	34.56	94.35	64.46
2C	(10 min)	62.65	81.80	72.23
2D	(10 min)	67.55	60.01	63.78
3	(30 min)	99.75	91.53	95.64
	Total	*278.22*	*352.00*	*315.11*

Table 3.4 illustrates that when a 5 centimeter (2 inch) EcoBlanket™ was applied to the soil test bed, sediment yield off-site was reduced to 0.12 kilograms, with a corresponding runoff volume averaging 315.11 liter.

Table 3.5 illustrates an average reduction of 25.79% in runoff volume from three replicate 10-year storms when an EcoBerm™ was constructed at the toe of the slope. Table 3.6 illustrates a 99.47% reduction in sediment delivery when compared to bare soil losses.

When two consecutive 10-year storms were applied to a 5 cm (2 inch) EcoBlanket™, a 21.38% reduction in runoff volume was achieved (Table 3.7) along with a 99.76% reduction in off-site sediment delivery (Table 3.8).

Table 3.5
Relative Runoff for Rexius EcoBerm™:
Three Replicate 10-year Storm Events

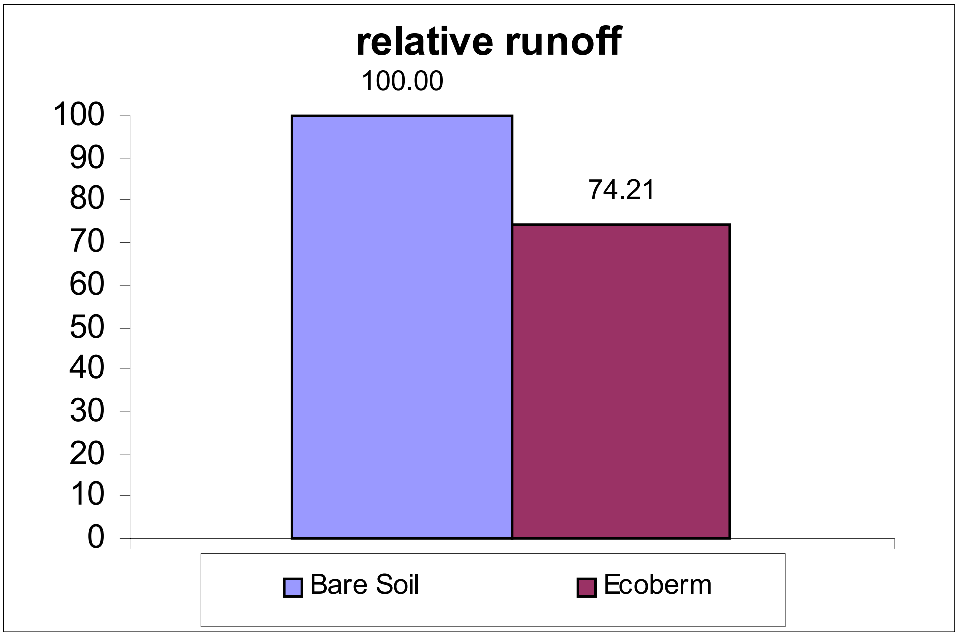


Table 3.6
Relative Sediment Yield for Rexius EcoBerm™:
Three Replicate 10-year Storm Events

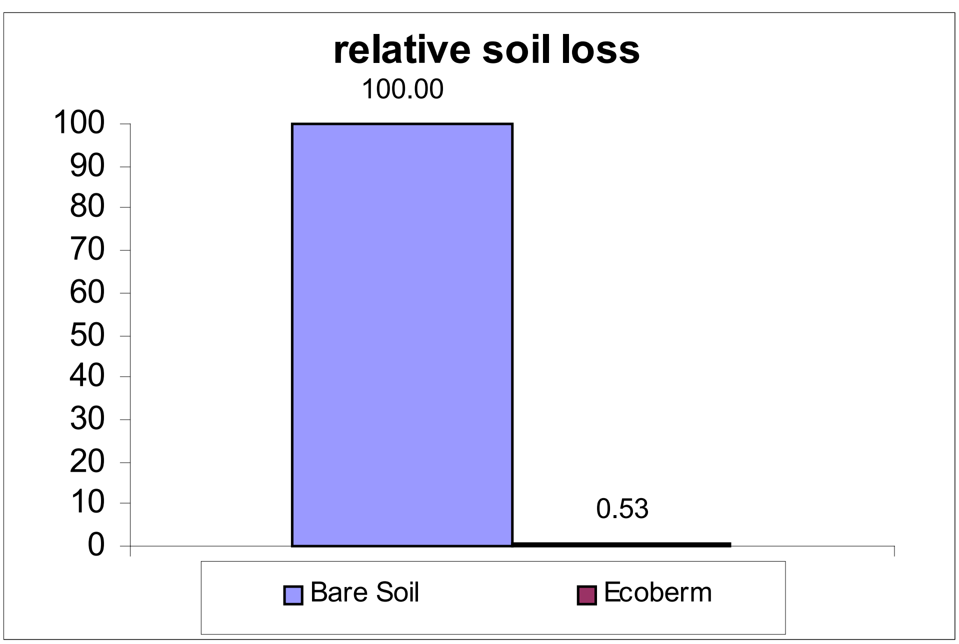


Table 3.7
Relative Runoff for Rexius EcoBlanket™:
Two Consecutive 10-year Storm Events

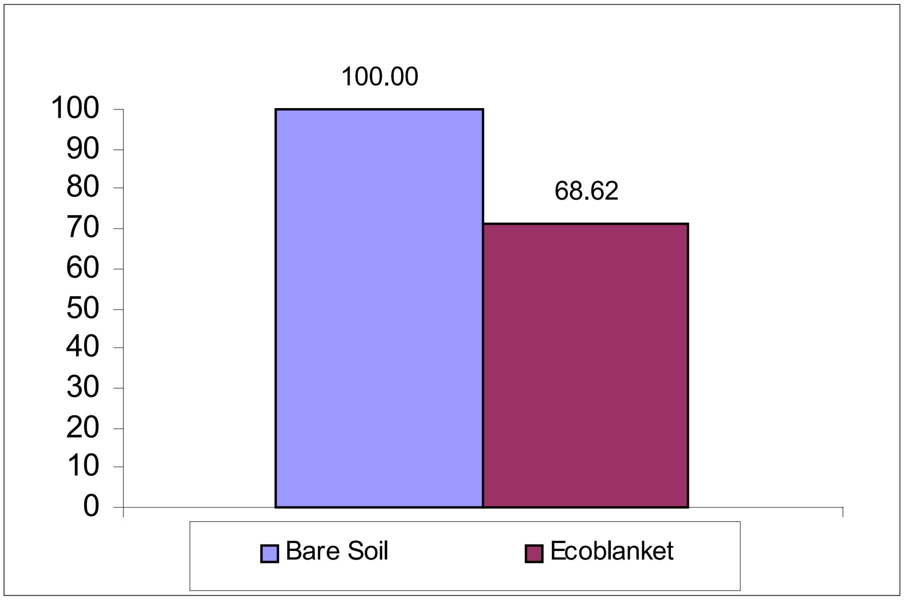


Table 3.8
Relative Sediment Yield for Rexius EcoBlanket™:
Two Consecutive 10-year Storm Events

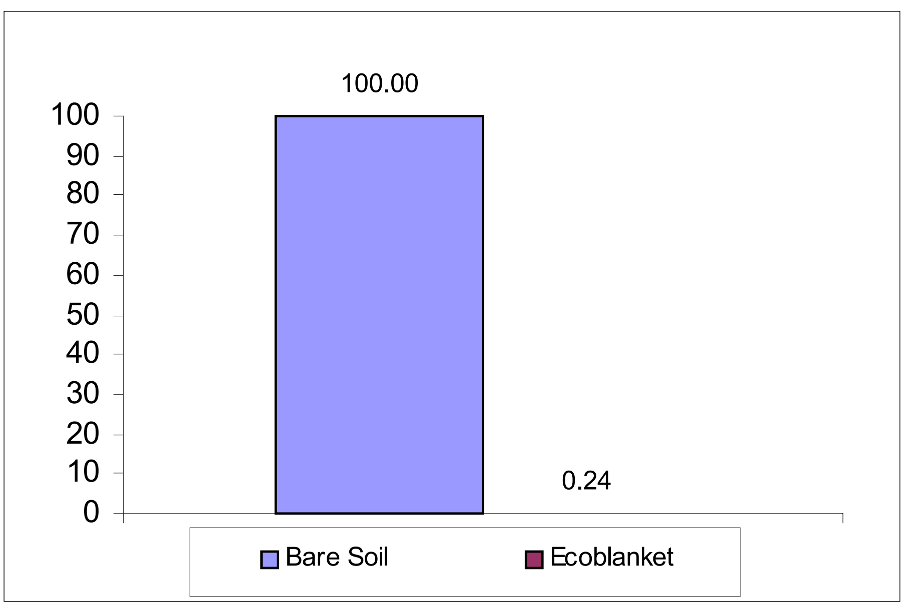


Figure 3.9
Cumulative Runoff for EcoBlanket™ Over Time

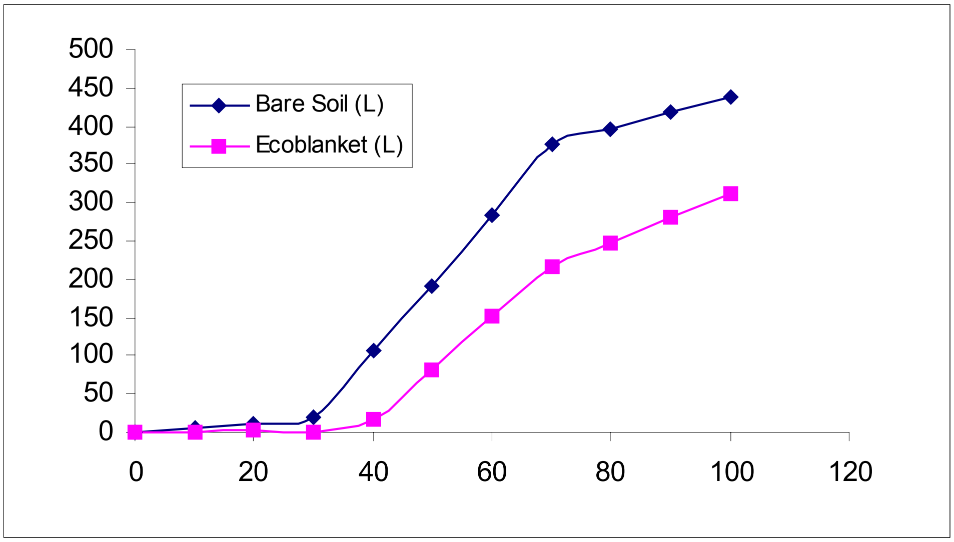


Figure 3.10
Cumulative Sediment Delivery for EcoBlanket™ Over Time

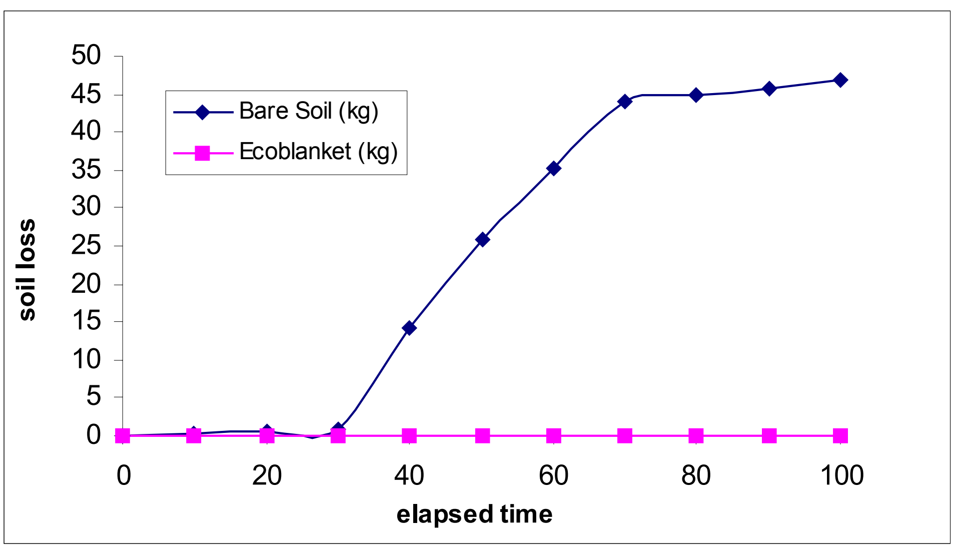


Figure 3.11
Cumulative Runoff for EcoBerm™ Over Time

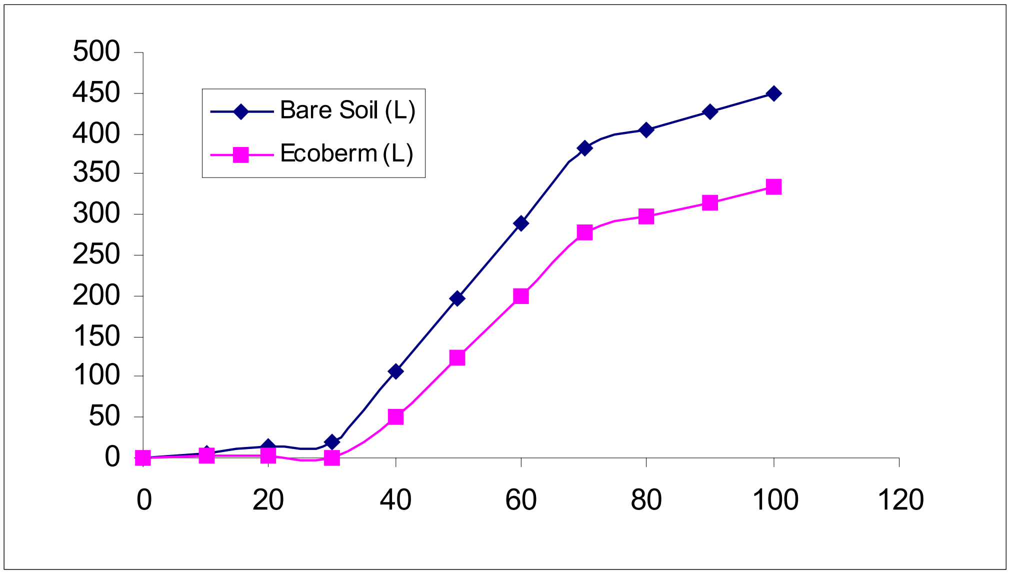
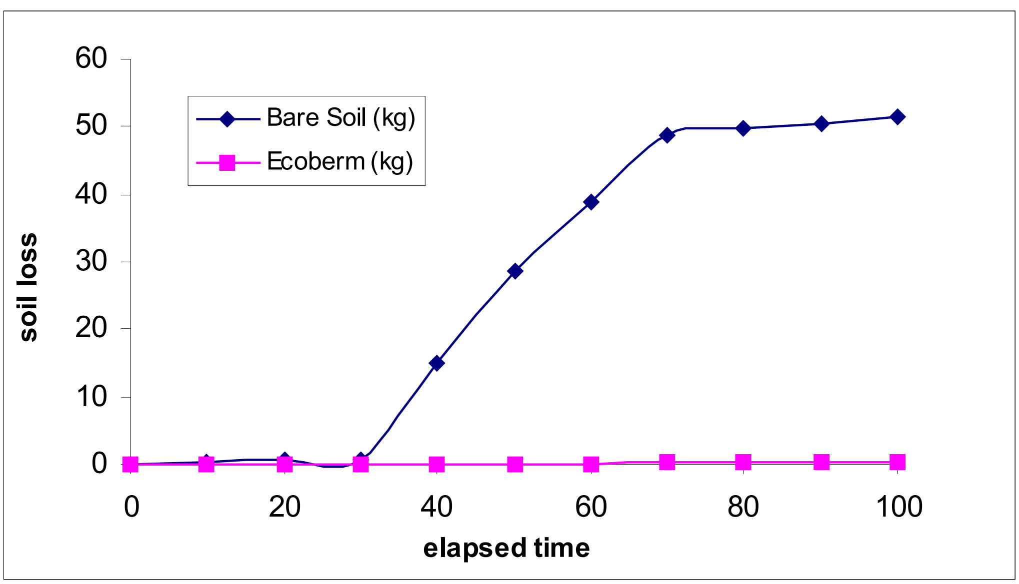


Figure 3.12
Cumulative Sediment Delivery for EcoBerm™ Over Time



4.0 CONCLUSIONS

The data from this series of tests appear to support the use of EcoBlanket™ and EcoBerm™ to reduce runoff and off-site delivery of sediment from steep slopes. A modest reduction in runoff water volumes – approximately 26% for the EcoBerm™ and 31% for the EcoBlanket™ - illustrates that one of the beneficial functions of compost is to slow runoff water velocities and retain a certain amount of water within its organic matrix. Figures 3.9 and 3.11 appear to support a conclusion that once saturated, compost releases water at a steady rate. This is important because with some soils, total absorption of runoff water might not be beneficial for slope stability or establishment of vegetation.

The data also illustrate that the specified Rexius compost/mulch blend, as tested, reduced off-site sediment delivery by nearly 100% for both the EcoBerm™ and the EcoBlanket™. Figures 3.10 and 3.12 demonstrate that erosion rate/sediment delivery, like runoff volume, occurs at a relatively constant rate throughout the storm period.

Previous testing at the SDSU Soil Erosion Research Laboratory has demonstrated the effectiveness of various surface treatments – such as hydraulically-applied soil binders, bonded fiber matrices and rolled erosion control products - to control soil erosion. Recent tests have also shown that the installation of slope interrupter devices (SIDs) can provide highly effective means of soil erosion control and runoff reduction. The results of this study illustrate that a proper application of an EcoBlanket™ and/or the construction of an EcoBerm™ at the toe of slopes can accomplish the same level of erosion control performance as many of these other conventional erosion control technologies.

APPENDIX A: Compaction of Soil Within the Test Bed

Compaction Procedures:

The placement and preparation of soil in the test bed can be divided into two distinct activities: 1) the initial "filling" of the test bed with a base layer of compacted soil 30-40 cm (12-16 inches) in depth, and 2) the creation of a second 10 cm (4 inches) "testing" layer of soil on top of the fill layer.

1) The "fill layer" of soil is placed in the bed in 10 cm (4 inches) lifts. Each lift is moistened to optimum moisture content as determined by an initial series of Modified Proctor tests (ASTM D1557) for the soil being evaluated. A mechanical whacker is used to compact each lift. Following compaction, eight randomly positioned sand cone tests are performed (ASTM D1556) to verify 95% relative compaction of the fill layer.

2) After placement of the fill layer and compaction as described, the top 10 cm (4 inches) of compacted soil is loosened using a rotor-tiller. After tilling, the soil is then re-compacted by hand using an 20 cm x 20 cm (8 inch x 8 inch) hand tamp weighing 5 kg (11 pounds). Following hand-tamping, the soil is lightly raked perpendicular to the length of the test plot and is considered ready for testing.

Following each rainfall simulation test, the eroded soil is removed to a depth of 5-10 cm (2-4 inches) depending on saturation and replaced with new untested soil from storage bins located inside the laboratory. The rotor-tilling and hand compaction steps are then repeated in preparation for the next test.

Sand Cone Testing Procedures (ASTM D1556):

1. Prepare a level surface in the fill and dig a cylindrical hole about 5in. (125 mm) in diameter and about 5in. (125 mm) deep. Save all of the soil that comes out of the hole and determine its weight.
2. Fill the sand cone apparatus with a special free-flowing SP sand, of a known density, similar to that found in an hourglass. Then determine the weight of the cone and the sand.
3. Place the sand cone over the hole. Then open the valve and allow the sand to fill the hole and the cone.
4. Close the valve, remove the sand cone from the hole, and determine its new weight.
5. Through comparing the weight of the sand used in the test with the weight of the soil removed from the hole the density of the soil can be determined.

Nuclear Density Testing is performed in accordance with **ASTM D2922**.