Results
from a Study of the
Soil Dynamics, Inc.
EssentialSoil™ Formulation:

Runoff Characteristics and Sediment Retention
Under Simulated Rainfall Conditions

Prepared for

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1.0 THE SAN DIEGO STATE UNIVERSITY SOIL EROSION RESEARCH LABORATORY (SDSU/SERL)

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, the 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 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:

Design Features of Soil Erosion Laboratories

Design 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
Suction chamber to speed up drying of soil between runs	UWRL
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

These and other important design features of the SDSU Laboratory are described below.

1.1 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. The Norton simulator is reliable and is documented as giving reproducible results.

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 long, 0.32 meters wide, and 0.25 meters deep. Each frame is a self-contained unit, which 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 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 median drop size, a nozzle exit velocity of 6.8 m/s, 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 rain storms when the nozzle is at least 2.4 meters 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 above the soil surface. Rainfall intensity can be changed instantaneously with the simulator in operation, and the maximum intensity produced is 135 mm/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 interval within the 2 meter x 8 meter 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.

1.2 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 of 30.5 cm is sufficient to allow placement and compaction of soil and the implementation of the various surface roughness practices to evaluate their effect on erosion rates.

The sides and ends of the soil test bed were constructed of steel frame-supported 1.0-cm thick Plexiglas which 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 wide by 10 meters long, but during testing only a portion of the treated bed, 2 meters wide by 8 meters 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 flume.

Drainage grates have been installed in the floor to the front and sides 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.

1.3 Hydraulic System

The soil test bed has been 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 505 lbs a piece, have a 20.3-cm (8-inch) diameter as the largest moving stage.

The complete hydraulic system consists of the cylinders, a 60 gallon hydraulic fluid reservoir, a 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.

1.4 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.

1.5 Water Treatment and Storage

In order to obtain accurate results from the rainfall simulation/erosion rate evaluations, the municipal water supply is reverse osmosis treated 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 300-600 gallons per day (1,140-2,270 liters 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 U.S. Filter.

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

2.0 EssentialSoil™ Formulation Study

2.1 Introduction

Soil Dynamics, a Division of Hendrikus Schraven Landscape Construction & Design, Inc. located in Issaquah, WA, has developed a patent pending process of organic soil formulation and application. Marketed as a "living soil" Soil Dynamics' EssentialSoil™ is a blended product that is purported to be "strong and resistant to surface erosion caused by rainfall". In previous laboratory tests (Shannon & Wilson, Inc.) the saturated EssentialSoil™ has maintained stability during tilt table testing for slopes over 70 degrees from horizontal. In the field, a landslide with sections of its slope exceeding 70 degrees was restored with EssentialSoil™ Hydroseeded late in the Pacific Northwest growing season, the slope is reported to have "withstood several weeks of continuous wet Seattle, WA weather, including downpours before the seed even began to germinate" (Soil Dynamics report, October 2000).

The custom-blended EssentialSoil™ is typically applied to steep slopes using air placement or teleconveyors that can deliver the organic soil formulation to sites as much as 450 feet distant. Some of the benefits reported from the combined process include:

- Augmentation of soil bonding ability
- Addition of water to the mix as it is applied aids in adherence of the EssentialSoil to the subsurface as well as to itself
- Water in the mix enhances immediate vegetative growth
- Increased oxygen content in the soil, which is beneficial to soil microbes and plant health.

For the purposes of this study, a standard application of EssentialSoil™ was applied to the SDSU/SERL soil test bed at a depth of 12 inches. The EssentialSoil™ was then subjected to the erosive forces of three successive, standard 10-year storm events for the Los Angeles, CA basin. During each storm event, runoff water and sediment were collected at the bottom of the test plot and compared against values obtained for an untreated bare soil, or "control" condition. By comparing the differences in runoff and sediment production between bare soil and the EssentialSoil™ test conditions, differential performance and/or effectiveness of the EssentialSoil™ in reducing runoff and off-site sediment impacts can was quantified.

2.2 Study Objectives

There were two main objectives for the OSF study:

1) To provide scientific, reproducible and defensible data on the effectiveness of this custom-blended organic soil formulation to reduce runoff and control erosion.
2) To present the results of the testing in a format useful to field engineers in the design and specification of this organic soil formulation application on steep slopes.

2.3 Test Procedures

The test procedures followed for the EssentialSoil™ organic soil formulation study 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).

Test Conditions

- The soil used for the bare soil or "control" condition was classified as a clayey sand (SC) The test area was 2 meters wide x 8 meter in length
- The storm event selected for all tests was a 10-year storm as predicted for the Los Angeles Basin (5 millimeter per hour for 30 minutes/40 millimeter per hour for 40 minutes and 5 millimeter per hour for 30 minutes)
- The slope selected for all tests was 1V:2H
- Three successive rainfall events for the bare soil (control) were conducted
- Three successive rainfall events for the EssentialSoil™ treatment were performed, yielding a total of six (6) tests at a 10-year storm level of intensity.
- At the end of the testing period for both the EssentialSoil™ treatment and the control, one 50-year storm event was applied to the each test plot. The intensity and duration of the 50-year storm was 5 millimeter per hour for 30 minutes/50 millimeter per hour for 30 minutes/5 millimeter per hour for 30 minutes.

Bed Preparation – Bare Soil "Control"

- Prior to the three successive 10-year and the one 50-year rainfall events, new soil was placed in the bed (on top of an already-compacted 12 inch layer of soil) and compacted in 4 inch lifts until a depth of 12 inches was achieved.
- The top 3-4 inches of the 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 testing, the surface of the compacted soil was loosely raked to a depth of ½ - ¾ inches.
- The test bed was raised to a 1V:2H slope prior to rainfall.

Bed Preparation - EssentialSoil Organic Soil Formulation

- Prior to installation of EssentialSoil™, the control soil (clayey sand) was excavated to a depth of approximately 12 inches over an area 2 meters wide by 8 meters in length.
- The manufacturer installed the organic soil formulation utilizing a 4 inch pneumatic hose equipped with a water jet.
- The EssentialSoil was applied with the bed inclined on a 1V:2H slope
- The application proceeded from the toe of the slope upwards for the bulk of the installation, and was applied from the top downwards to achieve final depth consistency and to confirm the ability to apply from either direction.

- A uniform 12 inch depth of application was maintained within the 2 x 8 meter plot
- Following the EssentialSoil™ installation, edging and flumes were installed
- A compost "tea" was applied prior to rainfall.

Rainfall events

It is important to note that for both the bare soil "control" and for the EssentialSoil™ application, three successive storm events were conducted. This procedure is somewhat different from the normal "replication testing" conducted at the SDSU/SERL for most surficial erosion control materials, such as rolled erosion control products (RECPs) or hydraulic soil stabilizers. However, both Soil Dynamics and SDSU/SERL personnel agreed that for the EssentialSoil™ system, three successive tests were more indicative of actual field conditions. For both the treated (EssentialSoil™) and untreated (control) condition, the three successive storms were conducted within a 24-hour time period.

All rainfall events 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 were 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.

At the end of the testing period for both the EssentialSoil™ treatment and the control, one 50-year storm event was applied to the each test plot. The intensity and duration of the 50-year storm is as follows:

- Period 1: 5 millimeters per hour of rain for 30 minutes
- Period 2: 40 millimeters per hour of rain for 50 minutes
- Period 3: 5 millimeters per hour of rain for 30 minutes

Sample Collection and Analysis

- Water and sediment were collected at the downstream (toe) end of the flume in polyethylene lined, 35 gallon containers.
- The samples are 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.

3.0 RESULTS

Table 1 and Table 2 present the results of the laboratory analysis of sediment weight and runoff volumes for both the bare soil "control" and EssentialSoil™ organic soil formulation respectively.

Soil losses from EssentialSoil™ (2.50 kilograms) were 98% less than the bare soil control (135.57 kilograms). The data also illustrate that under the same test conditions of slope and rainfall event, the Soil Dynamics EssentialSoil™ organic soil formulation produced around 32% less runoff (953.59 liters) than the bare soil control (1404.51 liters).

Table 1
Sediment Weight / Runoff Volume from Control Plot
(10-year storm)

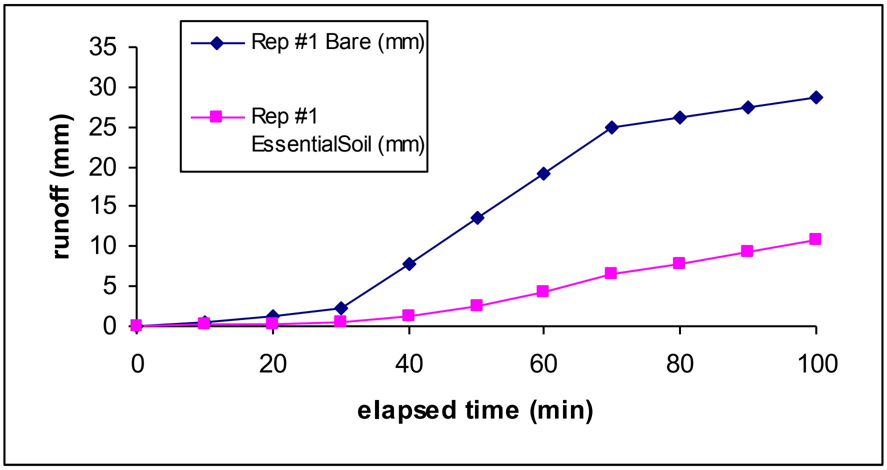
Soil Loss(kg)	Rep #1	Rep #2	Rep #3	Total(Kg)
Period 1	0.47	0.47	0.47	1.41
Period 2	52.54	31.33	26.96	110.83
Period 3	7.07	8.28	7.98	23.33
Total (Rep 1,2,3)				**135.57**
Runoff(L)	Rep #1	Rep #2	Rep #3	Total(L)
Period 1	18.19	52.25	54.14	124.58
Period 2	360.72	363.85	359.79	1084.36
Period 3	62.06	61.29	72.22	195.57
Total (Rep 1,2,3)				**1404.51**

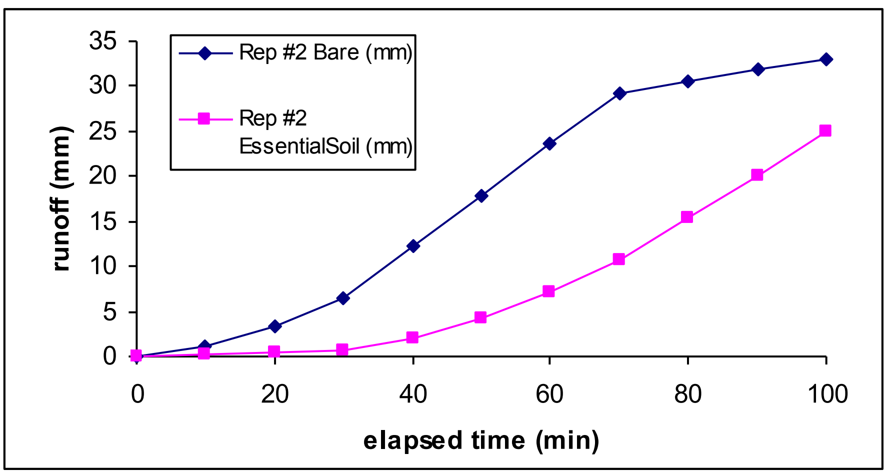
Table 2
Sediment Weight / Runoff Volumes
from EssentialSoil™ Organic Soil Formulation
(10-year storm)

Soil loss(kg)	Rep #1	Rep #2	Rep #3	Total(Kg)
Period 1	0.00	0.00	0.00	0.00
Period 2	0.00	0.00	2.08	2.08
Period 3	0.00	0.00	0.42	0.42
Total (Rep 1,2,3)				**2.50**
Runoff(L)	Rep #1	Rep #2	Rep #3	Total(L)
Period 1	6.62	9.46	13.25	29.33
Period 2	96.52	161.24	193.65	451.41
Period 3	68.13	227.10	177.62	472.85
Total (Rep 1,2,3)				**953.59**

Figures 1 and 2 illustrate the cumulative sediment delivery and runoff rate of both the bare soil and EssentialSoil™ organic soil formulation over time. As can be seen, most erosion and runoff occurs in the middle portion of each storm event as would be expected. The rate of sediment delivery and runoff appear to be relatively constant, particularly on the EssentialSoil™ slope. Figures 5 and 6 also provide a visual illustration of the difference in sediment weights and runoff volumes between the control and EssentialSoil™ test condition during different portions of the storm event.

Figure 1
Comparison of Cumulative Runoff Between
Bare Soil Control and EssentialSoil™





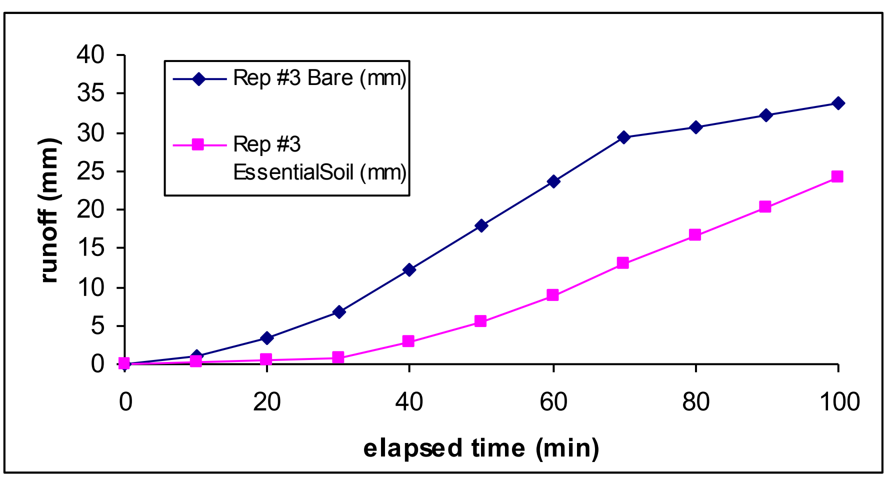
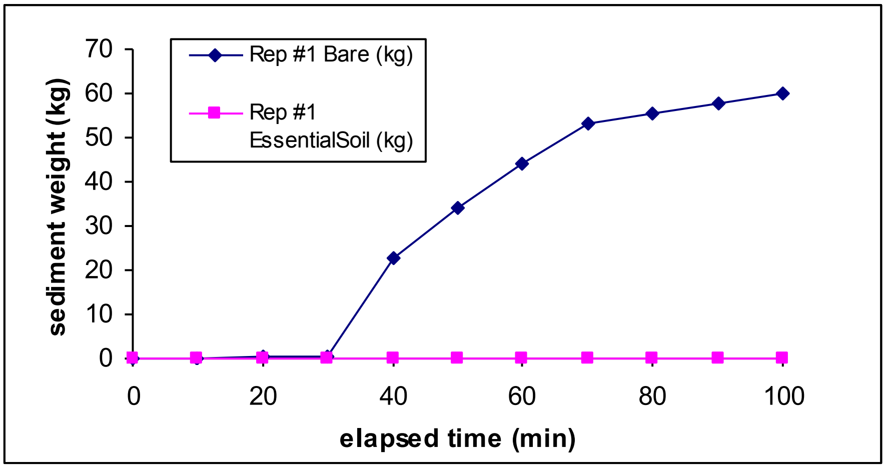
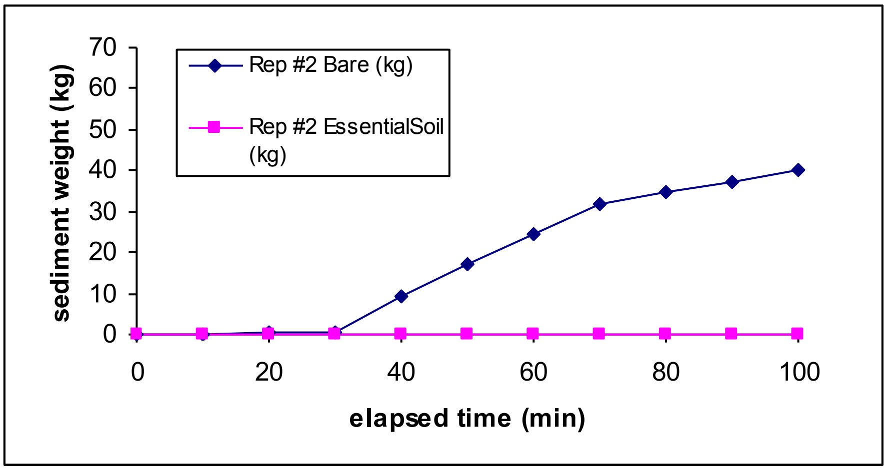
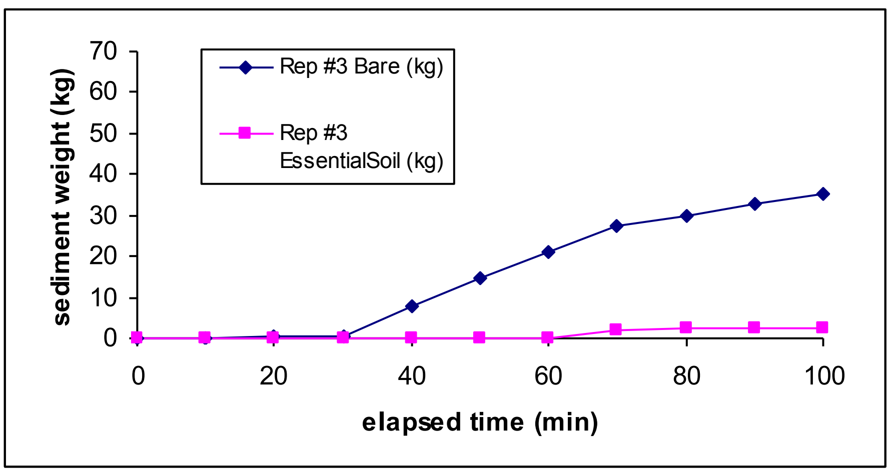


Figure 2
Comparison of Cumulative Sediment Between Bare Soil Control and EssentialSoil™







Figures 3 and 4 graphically illustrate the reduction in erosion/sediment delivery and runoff afforded by the slope constructed of Soil Dynamics' EssentialSoil™ organic soil formulation. Erosion and sediment delivery on the EssentialSoil™ test area was roughly 2% of the bare soil control condition (Figure 3). This can be interpreted as 98% erosion control effectiveness. Similarly, the EssentialSoil™ yielded a runoff volume that was 69% of the control plot (Figure 4). This can be interpreted as a 31% reduction in runoff volume.

Figure 3
Comparison of Total Relative Sediment Weight Between Bare Soil Control and EssentialSoil™

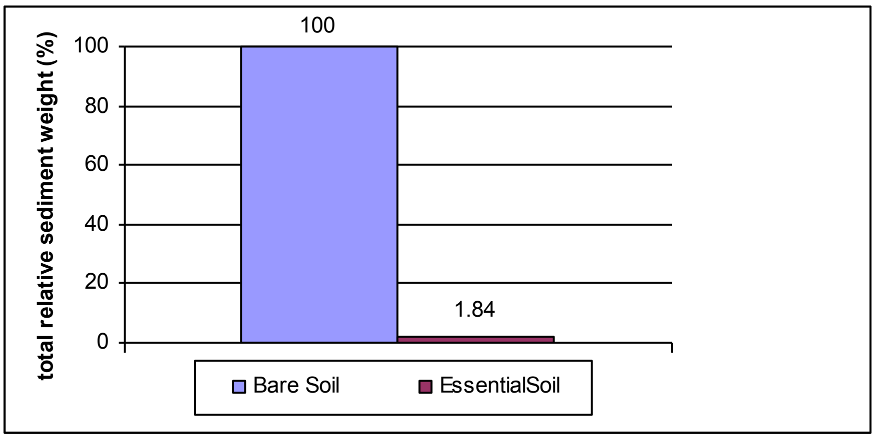
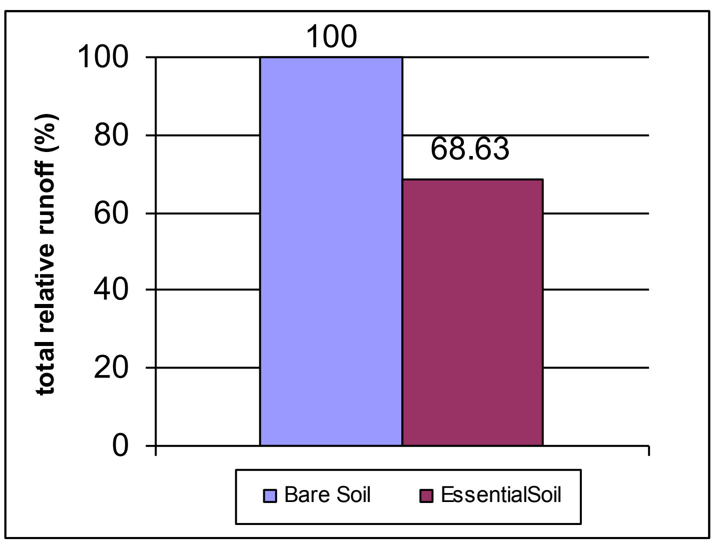


Figure 4
Comparison of Total Relative Runoff Between Bare Soil Control and EssentialSoil™



Figures 5 and 6 present a comparison of runoff for test replicates numbers 1, 2 and 3 of the 10-year storm event. As can be seen from the bar charts, soil erosion was reduced dramatically – 100% for Rep 1, 100% for Rep 2. Only in the final and third successive storm event (Rep 3) was any sediment detected in the runoff water (7%). Runoff from the EssentialSoil™ plots was reduced somewhat - 63% for Rep 1, 25% for Rep 2 and 29% for Rep 3.

Figure 5
Dry Sediment Weight from EssentialSoil™ Treatment
Expressed as Percentage of Bare Soil Control
(10-year storm, three replicates)

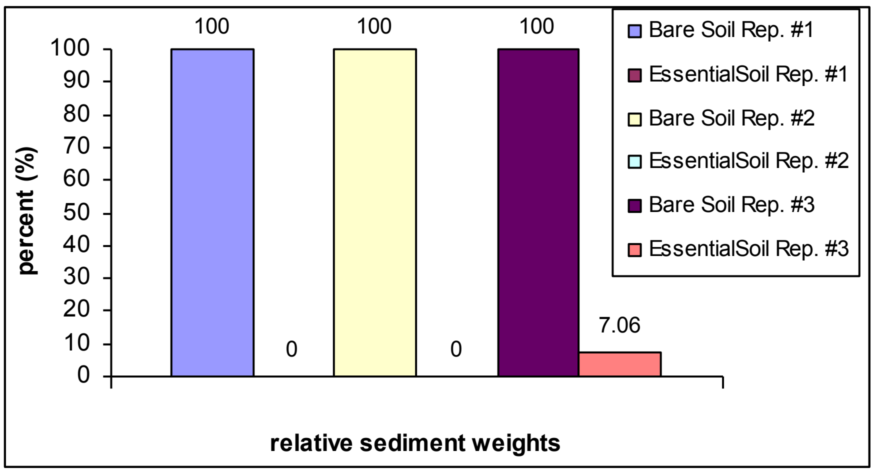
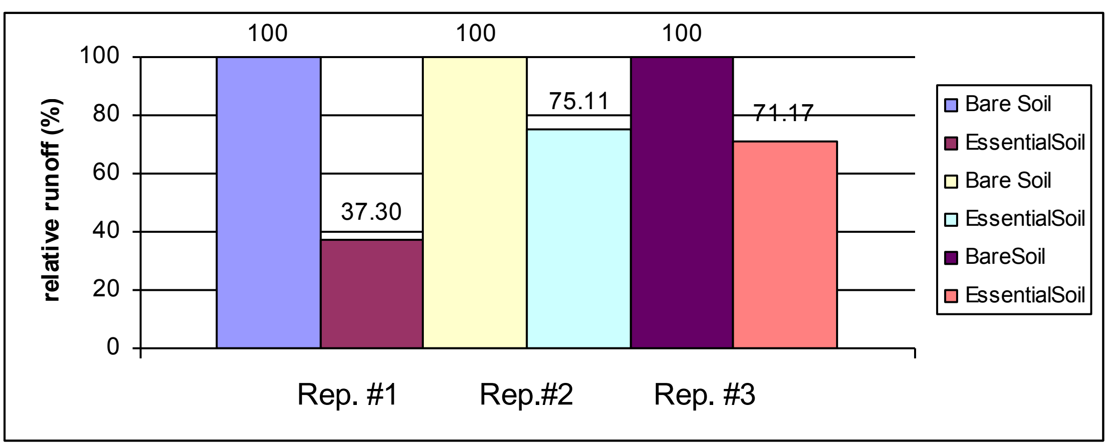


Figure 6
Runoff Volume from EssentialSoil™ Treatment
Expressed as Percentage of Bare Soil Control
(10-year storm, three replicates)



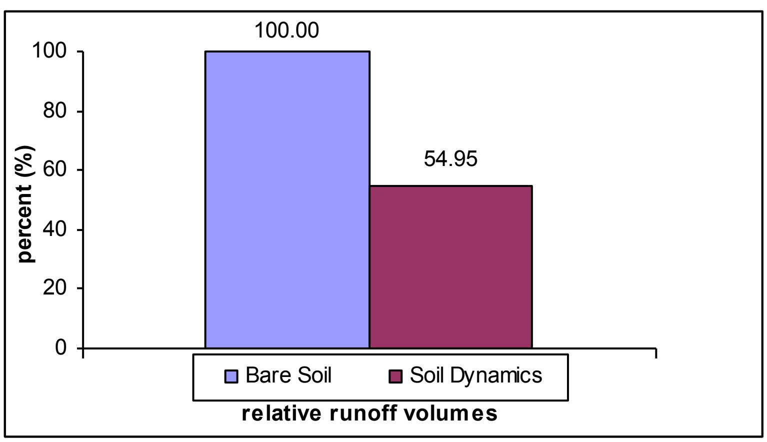
Following the three consecutive 10-year storm events on both the bare soil control and the EssentialSoil™ treatment, a 50-year storm was introduced to both plots, respectively. The results are reported in Table 3. There was no appreciable sediment delivered from the

EssentialSoil™ plot (0.00). Additionally, Figure 7 reflects a relatively strong reduction in runoff (45%) for the EssentialSoil™ treatrment.

Table 3
Comparison of Sediment Weight / Runoff Volumes
from Bare Soil and EssentialSoil™ Organic Soil Formulation
(50-year storm)

Soil loss(kg)		EssentialSoil	Bare soil
Period 1		0.00	1.17
Period 2		0.00	52.48
Period 3		0.00	2.20
Total (1,2,3 periods)		**0.00**	**55.85**
Runoff(L)		EssentialSoil	Bare soil
Period 1		9.46	52.25
Period 2		183.33	565.19
Period 3		185.61	71.15
Total (1,2,3 periods)		**378.40**	**688.59**

Figure 7
Comparison of Relative Runoff Between
Bare Soil Control and EssentialSoil™
(50-year storm)



4.0 CONCLUSIONS

The data from this series of tests appear to support the use of Soil Dynamics EssentialSoil™ organic soil formulation to reduce runoff and off-site delivery of sediment from steep slopes. A modest reduction in runoff water volumes (31%) coupled with a high reduction in erosion (98%) appears to indicate that EssentialSoil™ can retain water within its matrix without creating instability.

Water within the saturated EssentialSoil™ matrix appears to be released at a steady rate (Figure 1). It was interesting to note that when a 50-year storm event was applied to the EssentialSoil™ test plot (after three successive 10-year storm events) there was no resultant soil erosion and water was retained in the soil at a high rate (45%). These phenomena would appear to support the plant-enhancing claims of the manufacturer

Finally, previous testing at the SDSU Soil Erosion Research Laboratory has demonstrated a high level of effectiveness of various surface treatments – such as hydraulically-applied soil binders, bonded fiber matrices and rolled erosion control products - to control soil erosion. Where site conditions support the use of an organic soil formulation, it appears that Soil Dynamics' EssentialSoil™ organic soil formulation, particularly when used in combination with complementary plant establishment techniques, is another highly effective tool for soil stabilization.