Vegetation Establishment and Maintenance Experiments

Performance of Erosion Control Treatments on Reapplied Topsoil

State of California
Department of Transportation

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Introduction

Roadside revegetation projects present substantial challenges to successful development of desired plant associations and vegetation structure. Cut or fill slopes are often steeply inclined, highly compacted, and lacking topsoil. Excavated topsoil is sometimes stockpiled for reapplication of pre-existing organic matter, soil microbes, and seed as both an inexpensive means of erosion control, and as a method to re-establish vegetation consistent with the surrounding context. However, stockpiled seedbanks may include undesirable, weedy species that inhibit establishment of desired native species.

During 2003-2004, two experiments were performed that have direct relevance to projected revegetation during phases of the Route 46 Corridor Improvement Project scheduled to begin construction in summer 2007. The goals of these experiments were to find effective erosion control treatments in conjunction with topsoil reapplication to:

- Establish vegetation for immediate soil surface stabilization;
- Statistically evaluate treatments to reduce soil loss and maintain water quality;
- Test the effectiveness of incorporating native seed with an existing competitive seedbank;
- Ascertain the effects of compost soil amendment on water quality and vegetation.

The first experiment, identified as RS5, sought to compare the effects of physical erosion control treatments (soil roughening, jute netting, jute netting over compost, straw crimped into compost, straw crimped into soil) on clay loam and fine sandy loam topsoils *with existing soil seedbanks*, and to ascertain how these treatments and vegetation from the seedbank affect runoff, sediment loss, and water quality during natural rainfall events.

The second experiment, identified as RS6, attempted to ascertain the affects of various rates of fiber and compost in a hydroseed mix on germination of existing soil seedbanks and germination of added California native seed on clay loam and fine sandy loam topsoils, and how these factors affect runoff, sediment loss, water quality, and vegetation cover under simulated rainfall.

Methods

Experiments were conducted using test boxes measuring 2.0 m (6.6 ft) x 0.6 m (2 ft) x 0.3 m (1 ft) constructed of pressure treated wood. Two types of topsoil, a clay loam and a fine sandy loam, were collected by Caltrans District 5 personnel from along SR 46 east of Paso Robles in San Luis Obispo County. Runoff from natural rainfall events, or from designed storms produced by two ladder-type boom oscillating rainfall simulators, was collected and analysed for total runoff, total sediment, and sediment concentration. Aerial live cover of vegetation, litter, and bare soil, were estimated using a modified Daubenmire method.

Data were analyzed via ANOVA models or by Logistic Regression. Treatment effects were compared with Tukey's HSD post-hoc procedure.

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No Added Seed Experiment (RS5)

Twelve test boxes were filled with clay loam (S1), and twelve with fine sandy loam (S2). Six erosion control treatments were replicated twice for each soil type. Boxes were randomly numbered and positioned to assure unbiased assignment of each treatment.

Experimental Design

Test Boxes	**24**			
Treatments	**12**			
Replicates	**2**			
Factor	**Soil Type**		**EC Treatment**	
Level	*1*	Clay Loam	*1*	None (Control)
	2	Fine Sandy Loam	*2*	Soil roughening
			3	Jute only
			4	Jute over Compost
			5	Crimped Straw
			6	Crimped Straw over Compost
Seed	Existing Soil Seed Bank (*no added seed*)			
Water Regime	Natural Rainfall			
Response Variables	Total Runoff Total Sediment Sediment Concentration Plant Cover			

Results Summary

Considering combined effects on total runoff, sediment concentration in runoff, and vegetation production, Crimped Straw Over Compost seems to be the best EC treatment over both soil types. If water quality is the highest priority on a site, and total runoff amount is lesser, Jute Over Compost is the suggested treatment, as it received the lowest rating in sediment concentration with a high amount of vegetation cover. Jute Without Compost also performed well in plant cover production, but water quality is not as good as when Jute is used in conjunction with Compost. Compost in combination with Straw also performed better than Straw alone in producing vegetation cover. Of course, sources of compost vary and results may vary from those of this experiment. Although No Treatment boxes did produce seemingly ample plant cover of either grasses or legumes, sediment concentration was also very high. Soil Roughening also performed poorly overall, and even worse than No Treatment.

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Ranked Evaluation of EC Treatment Effects on Each Soil Type.

A ranked evaluation (Good = 3, Fair = 2, Poor = 1) of the six treatments over both soil types follows. Bear in mind that these are qualitative assessments based on the statistical output. These ranking also reflect response trends in these data concordant with past experiments.

	CLAY LOAM					FINE SANDY LOAM					
	Runoff		Vegetation		*Sub*	Runoff		Vegetation		*Sub*	*Total*
	Total	Sed Conc	Grass	Legume	*Score*	Total	Sed Conc	Grass	Legume	*Score*	Score
No Treatment	***3***	*1*	*1*	***3***	**8**	*1*	*1*	***3***	*1*	**6**	**14**
Soil Roughening	*2*	*1*	*2*	*1*	**6**	*1*	*1*	*1*	*1*	**4**	**10**
Jute Only	*2*	*2*	***3***	*1*	**8**	*2*	*2*	***3***	*1*	**8**	**16**
Jute over Compost	*1*	***3***	*2*	*2*	**8**	*1*	***3***	*1*	***3***	**8**	**16**
Crimped Straw	***3***	*2*	*1*	*1*	**7**	*2*	*2*	***3***	*1*	**8**	**15**
Crimped Straw over Compost	***3***	*2*	*2*	*2*	**9**	***3***	*2*	***3***	*1*	**9**	**18**

Below, sediment concentration (Sed Conc) is transferred from the above table, and plant cover categories (Grass and Legume) are added for a total (Plant Cover) score.

	CLAY LOAM			FINE SANDY LOAM		
	Sed Conc	Plant Cover	*Score*	Sed Conc	Plant Cover	*Score*
No Treatment	*1*	*4*	**5**	*1*	*4*	**5**
Soil Roughening	*1*	*3*	**4**	*1*	*2*	**3**
Jute Only	*2*	*4*	**6**	*2*	*4*	**6**
Jute over Compost	***3***	***4***	**7**	***3***	***4***	**7**
Crimped Straw	*2*	*2*	**4**	*2*	*4*	**6**
Crimped Straw over Compost	*2*	*4*	**6**	*2*	*4*	**6**

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Added Seed – Seed Depth Experiment (RS6)

Twelve test boxes were filled with clay loam (S1), and twelve with fine sandy loam (S2). Six erosion control treatments were replicated twice for each soil type. Boxes were randomly numbered and positioned to assure unbiased assignment of each treatment.

Experimental Design.

Test Boxes	**24**			
Treatments	**12**			
Replicates	**2**			
Factor	**Soil Type**		**EC Treatment**	
Level	*1*	Clay Loam	*1*	None (Control)
	2	Fine Sandy Loam	*2*	Seed in Low Fiber, No Compost
			3	Seed in Low Fiber and High Compost
			4	Seed in Low Fiber and Low Compost
			5	Seed over High Fiber and Low Compost
			6	Seed under High Fiber and Low Compost
Seed	Existing Soil Seed Bank			
	Hydroseeded Species			
	Achillea millefolium L.		Common Yarrow	
	Bromus carinatus Hook & Arn.		California Brome	
Water Regime	Natural Rainfall			
Response Variables	Total Runoff			
	Total Sediment			
	Sediment Concentration			
	Plant Cover			

Results Summary

Considering combined effects on runoff, sediment concentration, and vegetation production, Seed *Over* 3920 Kg/Ha (3500 Lb/Ac) Fiber With 560 Kg/Ha (500 Lb/Ac) Compost seems to be the best EC treatment over both soil types, followed closely by Seed *Under* 3920 kg/ha (3500 lb/ac) Fiber With 560 kg/ha (500 lb/ac) Compost. Again, the predominant influence is likely the higher rate of Fiber and Compost rather than seed position, but seed position over or under a thicker layer of Fiber and Compost does matter to individual species germination and subsequent abundance in developing vegetation. No Treatment boxes again performed poorly, yielding high sediment concentrations and producing poor plant cover. The Seed *In* 1680 kg/ha (1500 lb/ac) Fiber with No Compost was only marginally better than No Treatment.

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Ranked Evaluation of EC Treatment Effects on Each Soil Type.

A ranked evaluation (Good = 3, Fair = 2, Poor = 1) of the six treatments over both soil types follows. Bear in mind that these are qualitative assessments based on the statistical output. These rankings also reflect response trends in these data concordant with past experiments.

			CLAY LOAM					FINE SANDY LOAM					
			Runoff		Vegetation		*Sub*	Runoff		Vegetation		*Sub*	*Total*
Seed	**Fiber**	**Compost**	Total	Sed Conc	Grass	Legume	*Score*	Total	Sed Conc	Grass	Legume	*Score*	Score
None	*None*	*None*	*1*	*1*	*1*	*1*	***4***	*1*	*1*	*1*	*1*	***4***	***8***
Mixed In	1680 kg/ha 1500 lb/ac	*None*	*1*	*1*	*2*	*2*	***6***	*1*	*1*	*1*	*2*	***5***	***11***
Mixed In	1680 kg/ha 1500 lb/ac	1680 kg/ha 1500 lb/ac	*1*	*2*	***3***	*2*	***8***	*1*	*2*	*2*	*2*	***7***	***15***
Mixed In	1680 kg/ha 1500 lb/ac	560 kg/ha 500 lb/ac	*1*	*2*	*2*	*2*	***7***	*1*	*2*	*2*	*2*	***7***	***14***
Over seeded	3920 kg/ha 3500 lb/ac	560 kg/ha 500 lb/ac	***3***	***2***	*1*	*3*	***9***	***3***	***2***	*3*	*3*	***11***	***20***
Under seeded	3920 kg/ha 3500 lb/ac	560 kg/ha 500 lb/ac	*2*	***3***	***3***	*1*	***9***	*2*	***3***	*3*	*1*	***9***	***18***

Below, total runoff (Total) and sediment concentration (Sed Conc) ranking were added for Water Quality and plant cover categories (Grass and Legume) were added for a total cover score.

			CLAY LOAM			FINE SANDY LOAM		
Seed	**Fiber**	**Compost**	Runoff	Plant Cover	*Score*	Runoff	Plant Cover	*Score*
None	*None*	*None*	*2*	*2*	***4***	*2*	*2*	***4***
Mixed In	1680 kg/ha 1500 lb/ac	*None*	*2*	*4*	***6***	*2*	*3*	***5***
Mixed In	1680 kg/ha 1500 lb/ac	1680 kg/ha 1500 lb/ac	*3*	*5*	***8***	*3*	*4*	***7***
Mixed In	1680 kg/ha 1500 lb/ac	560 kg/ha 500 lb/ac	*3*	*4*	***7***	*3*	*4*	***7***
Over seeded	**3920 kg/ha 3500 lb/ac**	**560 kg/ha 500 lb/ac**	*5*	*4*	***9***	*5*	*6*	***11***
Under seeded	3920 kg/ha 3500 lb/ac	560 kg/ha 500 lb/ac	*5*	*4*	***9***	*5*	*4*	***9***

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Implications and Recommendations

Although extrapolations from specific experimental results to general management practices are always perilous, recommendations drawn from the implications of these and past experiments are needed regarding erosion control measures for the Route 46 Corridor Improvement Project. The following is offered with a caveat that the climate of eastern San Luis Obispo County is extremely varied and unpredictable. Rainfall is unreliable, and 30- to 60-day episodes with no measurable precipitation are possible during the only season of reliable rainfall from December through March. Therefore, the "Expected Results" that follow assume near average rain seasons with no dry periods longer than 21 days.

The following recommendations refer to sites where stockpiled topsoil may be reapplied along the Route 46 Corridor. A **general recommendation** is also made here **to develop procedures to routinely sample and test soil seedbanks prior to construction** to ascertain what quantities of native and naturalized grasses and forbs exist in the soil. If high quantities of viable seed from naturalized species exist in reapplied topsoil, addition of purchased seed of non-local "native" species may be wholly ineffective at establishing against aggressive competition for water from naturalized species. In a landscape context dominated by naturalized alien species, re-establishment of native plants should focus on sites where specific management objectives necessitate promotion of local native genotypes, especially if local native plant genotypes are known to be host plants or food sources for locally important wildlife species.

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Where Re-establishment of Native Species Is NOT A Primary Objective

Under this objective, it is recommended that topsoil be reapplied and the following Temporary Soil Stabilization Treatment (SS-3 or SS-4) be used on final graded slopes.

	"Type D" EC Treatment — Application Rates lb / ac	kg / ha	Additional Recommended EC Measures	
Fiber ≥	4000	4485	**Jute Netting**	
Compost ≥	1000	1120	**Toe Treatment**[2]	
Fertilizer	NONE	NONE	*Physical:*	**EC Blanket (SS-7)**
Tackifier	0—5	0—5.5	*or Live Plants:*	**See Table 4.5**
Added Seed [1]	0—45	0—50		

[1] rapid cover native or naturalized species; if existing seedbank is adequate, then no added seed is necessary.

[2] protection of the toe of a slope, considered to be a critical area for erosion control (physical or vegetation).

	EXPECTED RESULTS: Without Jute, Without Toe Treatment	**WITH** Jute, Without Toe Treatment	**WITH** Jute, **WITH** Toe Treatment
Water Quality			
Runoff	High to Moderate	Moderate to Low	**Low**
Sediment Concentration	High	Low	**Very Low**
Vegetation			
Structure			
Dominants	Annual Grasses	Annual Grasses	Annual Grasses
Subordinates	Annual Forbs	Annual Forbs	Annual Forbs
Composition			
Dominants	Naturalized Aliens	Naturalized Aliens	Naturalized Aliens
Subordinates	Naturalized Aliens	Naturalized Aliens	Naturalized Aliens
Cover			
Overstory	High	High	High
Understory	Low	Low	Low
Persistence	Indefinite	Indefinite	Indefinite

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Where Re-establishment of Native Species IS A Primary Objective

Under this objective, it is recommended that topsoil be reapplied and the following Temporary Soil Stabilization Treatment (SS-4) is applied in two phases:

- *Phase 1* Seed of Burial Tolerant Species shall be applied UNDER a fiber and compost layer at least 10mm thick to maintain viability if applied at the time of highway construction during periods unfavorable for germination. In the SR46 Corridor, high temperatures exceeding 38C (100F) can occur anytime from April through June, and highs over 43C (110F) are not uncommon from June through October.
- *Phase 2* Seed of Burial Intolerant Species shall be applied OVER the fiber and compost layer applied during *Phase 1*. This is recommended December to March, depending on rainfall, in order to establish the best understory of native perennial forbs, e.g., Common Yarrow, and native annual grasses, e.g., Small Fescue, or to establish subshrubs such as Interior California Buckwheat or Golden Yarrow.

Phase 1: Post-Construction

	"Type D" EC Treatment	
	Application Rates	
	lb / ac	kg / ha
Fiber ≥	4000	4485
Compost ≥	1000	1120
Fertilizer	NONE	NONE
Tackifier	0—5	0—5.5
Added Seed	40—45	45—50
Burial TOLERANT Species ONLY; see Table 4.4		

Additional Recommended EC Measures	
Jute Netting	
Toe Treatment	
Physical:	**EC Blanket**
or Live Plants:	**See Table 4.6**

Phase 2: December Just Prior To Reliable Rain Season

	"Type D" EC Treatment	
	Application Rates	
	lb / ac	kg / ha
Fiber	2000	2242
Compost ≥	500	560
Fertilizer	NONE	NONE
Tackifier	0—5	0—5.5
Added Seed	40—45	45—50
Burial INTOLERANT Species ONLY; see Table 4.5		

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	EXPECTED RESULTS		
	Phase 1 ONLY **WITH** Jute Without Toe Treatment	Phase 1 and Phase 2 **WITH** Jute Without Toe Treatment	Phase 1 and Phase 2 **WITH** Jute **WITH** Toe Treatment
Water Quality			
Runoff	Moderate to Low	Moderate to Low	**Low**
Sediment Concentration	Low	Low	**Very Low**
Vegetation			
Structure			
Dominants	Annual Grasses Annual Legumes Some Perennial Grasses	Perennial Grasses Annual Grasses Annual Legumes	Perennial Grasses Annual Grasses Annual Legumes
Subordinates	Annual Forbs	Perennial Forbs Annual Grasses	Perennial Forbs Annual Grasses
Composition			
Dominants	~ 70 – 80% Naturalized ~ 10 – 20% Native	~ 50 – 70% Native ~ 30 – 50% Naturalized	~ 50 – 70% Native ~ 30 – 50% Naturalized
Subordinates	~ 70 – 80% Naturalized ~ 10 – 20% Native	~ 60 – 70% Native ~ 30 – 40% Naturalized	~ 60 – 70% Native ~ 30 – 40% Naturalized
Cover			
Overstory	High	High	High
Understory	Low to Moderate	High	High
Persistence	Indefinite	Indefinite	Indefinite

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1.1 Experiment Topic

Roadside revegetation projects present substantial challenges to successful development of desired plant associations and vegetation structure. Cut or fill slopes are often steeply inclined, highly compacted, and lacking topsoil (Montalvo et al. 2002). Excavated topsoil is sometimes stockpiled and reapplied due to benefits such as containing local organic matter, soil microbes, and seed. This is both an inexpensive means of erosion control and a method to re-establish vegetation consistent with the surrounding context. However, stockpiled seedbanks may include undesirable, weedy species that inhibit establishment of desired native species (D'Antonio and Meyerson 2002).

As a surrogate for soil, typical surface application of organic matter (e.g., "hydromulch") provides both physical protection from raindrop erosion and a favorable seedbed for some desired natives. However, composition, source, and cost issues, as well as the initial nutrient imbalances and absence of beneficial soil microbes, may present problems with individual products. Although topsoil replacement alone may provide ample plant cover through germination of an existing seedbank, the plant cover that does establish is typically naturalized grasses and forbs. This is especially true along roadsides throughout most of the lower elevations of California now dominated by naturalized alien species. Most of these species grow and die rapidly and produce or retain few basal leaves. Thus, little plant cover may exist at or near the soil surface to filter sediment from runoff during more intense rainfall events.

1.2 Experiment Relevence

From November 2003 through August 2004 two experiments were conducted that have direct relevance to projected revegetation during phases of the **Route 46 Corridor Improvement Project** scheduled to begin construction during summer 2007. This project will expand approximately 38.5 km (24 mi) of State Route 46 in San Luis Obispo County from a two-lane highway to a four-lane divided expressway from Airport Road, just east of Paso Robles, to the Highway 46/41 interchange (see **Figure 1.1**).

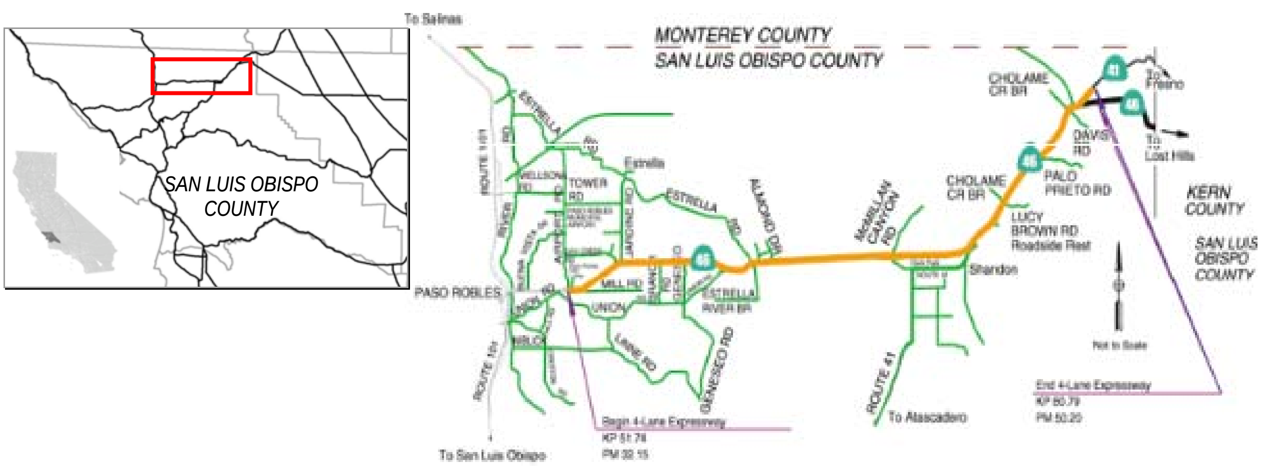

Figure 1.1. Location of Route 46 Corridor Improvement Project (from FHWA & Caltrans 2003).

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Photo 1.1. State Route 46 East of Paso Robles (from FHWA & Caltrans 2003).

State Route 46 traverses old river terraces and rolling hills that support mostly open upland grasslands now dominated by naturalized annual grasses and forbs, with occasional stands of native perennial grasses, especially in swales near the many seasonal streambeds. Oak woodlands of Blue Oak and Valley Oak occur along watercourses and where sufficient soil moisture is retained through the summer. Riparian Woodlands form along the Estrella River and elsewhere. Landuse is primarily rangeland or dryland grain farming, with ongoing conversion to vineyards, olive orchards, or urban (see **Photo 1.1**).

Climate is hot-summer, arid Mediterranean. Paso Robles averages over 90 days annually above 32C (90F) and highs above 43C (110F) are not uncommon. Winter averages over 65 nights below 0C (32F), with extremes ranging to -14C (7F). Annual precipitation averages about 375 mm (14.75 in), with extremes from 741 mm (29.19 in) to 108mm (4.24 in). January through March is the only season of reliable precipitation, but totals can be meager (all climate data obtained from the Western Regional Climate Center, http://www.wrcc.dri.edu).

Soils along the corridor vary considerably in basic properties of texture, structure, and erosivity. The Natural Resources Conservation Service (NRCS) has listed 35 different soil types in the area, several of which are considered unsuitable as fill material (FHWA and Caltrans 2003).

Given the arid climate and contracted season of favorable growing temperatures in conjunction with adequate rainfall, planned revegetation is inherently precarious at best. The Route 46 Corridor Improvement Project will necessitate erosion control and revegetation measures on several challenging cut and fill slopes in this unpredictable environment. Existing topsoil may or may not be reapplied to some slopes. The project Environmental Assessment/Draft Environmental Impact Report (FHWA & Caltrans 2003, p. 42) states the following with regard to erosion control:

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> All of the build alternatives for the project would result in exposed cut and fill slopes that would be subject to erosion. These areas would be treated with appropriate erosion control material: erosion control blankets installed with fiber, compost, seed, fertilizer, and stabilizing emulsion in a hydroseed application, with fiber rolls installed on the slopes to stabilize the soil. Additional soil amendments may also be used as needed to stabilize the soil. Seeds of plants indigenous to the area would be used to re-vegetate the exposed cut slopes. Duff[11] may be collected and used in some areas.
>
> [11] "Duff" is material containing organic matter and plant seeds. It is used to control soil erosion and to reestablish native ground cover.

Along the Route 46 corridor, "duff" primarily refers to topsoil with litter and fruits/seed from naturalized (non-native) annual grasses and forbs. Questions remain regarding the effectiveness of using reapplied topsoil and duff to both reduce erosion and to hasten revegetation. The experiments discussed in this report were designed to address some of these basic questions.

1.3 Experiment Goals

The goals of these experiments were to find effective erosion control treatments in conjunction with topsoil reapplication to:

- Establish vegetation for immediate soil surface stabilization;
- Statistically evaluate treatments to reduce soil loss and maintain water quality;
- Test the effectiveness of incorporating native seed with an existing competitive seedbank;
- Ascertain the effects of compost soil amendment on water quality and vegetation.

1.4 Experiment Objectives

1.4.1 No Added Seed Experiment (RS5)

To compare the effects of physical erosion control treatments (soil roughening, jute netting, jute netting over compost, straw crimped into compost, straw crimped into soil) on clay loam and fine sandy loam topsoils *with existing soil seedbanks*, and to ascertain how these treatments and vegetation from the seedbank affect runoff, sediment loss, and water quality during natural rainfall events.

1.4.2 Added Seed-Seed Depth Experiment (RS6)

To ascertain the affects of various rates of fiber and compost in a hydroseed mix on germination of existing soil seedbanks and germination of added California native seed on clay loam and fine sandy loam topsoils, and how these factors affect runoff, sediment loss, water quality, and vegetation cover under simulated rainfall.

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2.1 Elements Common to Both Experiments

This section provides a synopsis of the experimental design elements that are common to both experiments. Elements unique to each experiment are detailed in sections that follow.

2.1.1 Site Set-Up

Test boxes were positioned in rows on a concrete slab 21.3 m (70 ft) long by 10.6 m (35 ft) wide, and oriented such that soil surfaces faced about 165 south for adequate sun exposure (see **Photo 2.1**) at right. Rainfall simulators are positioned at the north end of this concrete slab.

Photo 2.1. Site and Test Box Setup

2.1.2 Rainfall Simulators

Two Norton Ladder-type boom oscillating, variable sweep rainfall simulators were used to produce designed storms for each experiment. Details on rainfall simulation, on the design of these simulators, and on their operation and calibration are provided in **Appendix D**.

2.1.3 Test Boxes

Test boxes measuring 2.0 m (6.6 ft) x 0.6 m (2 ft) x 0.3 m (1 ft) were constructed of pressure treated wood. The size conforms to field plot tests conducted by Pearce et al. (1998). A metal mesh grate formed the base of these boxes, and silt fabric lined the inside to minimize soil loss. Each box was positioned at a 2H:1V slope on a support composed of pressure treated wood and a galvanized metal pipe. A one-ton chain hoist was used to move boxes when necessary.

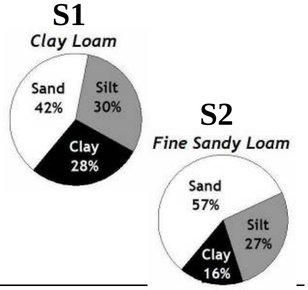
A length of vinyl gutter was used to collect runoff from the base of each erosion test box and channel it into a 7.6 L (8 qt) plastic collection container. A rectangular piece of synthetic pond liner was cut and riveted to the vinyl gutter to prevent simulated rainfall from entering the erosion collection system. For further details about these test boxes see **Appendix D Section D-2.**

2.1.4 Test Soils

Two types of topsoil were collected by Caltrans District 5 personnel from along SR 46 east of Paso Robles in San Luis Obispo County (see **Figure 2.1**). Soil was compacted in the loaded test boxes to at least 95% (calculated from bulk density), as typically required for construction fill (Caltrans 2002). Soils were labeled S1 and S2; properties are listed in **Table 2.1**.

Table 2.1. Test Soil Properties.

Label	Collection Site	Type	%Sand	%Silt	%Clay	Small Gravels
S1	SR 46 East, PM 39.9	Clay Loam	42	30	27	5% < 2.54 cm
S2	SR 46 East, PM 37.9	Fine Sandy Loam	57	27	16	< 2% < 1.27 cm



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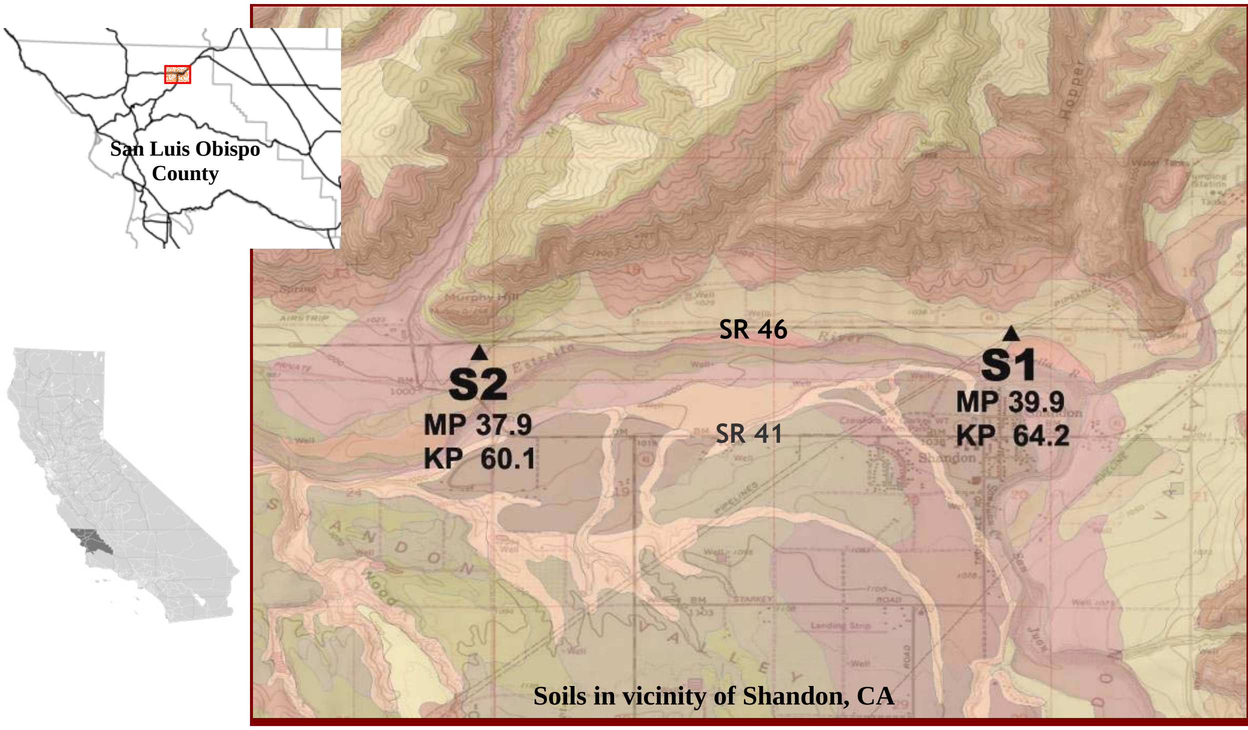

Figure 2.1. Soil Collection Sites Along SR 46 East of Paso Robles Near Shandon.

2.1.5 Runoff Data Collection and Analyses

Total runoff was weighed and converted from grams to liters. The pH was measured using a Corning pH 240 with a Fisher Accumet electrode. Runoff was analyzed for sediment load, pH, and salt concentration (electrical conductivity). Salt concentration and pH were measured for each runoff collection using a pH/EC/TDS/Temperature meter.

Total solids were analyzed using a procedure that combined methods described by ASTM D3977-97 (ASTM 2002) and EPA Method 160.2 (EPA 2001). After collection of each weighed runoff sample, samples received 10-20 ml 1 M $AlCl_3$, a common water treatment flocculent. Any remaining sediment on the walls or bottom of the storage container was rinsed into an evaporating dish to be oven dried. The container with sediment was oven dried at 115^0 C (239°F) for 24-48 hours and then weighed.

Total water runoff was calculated by subtracting the sediment and container weight from the original total collection weight. The total sediment included the evaporated sediment weight. Sediment concentration (mg/L) was calculated from the total runoff and total sediment values.

Total runoff, total sediment, and sediment concentration were analyzed via ANOVA models, after necessary variance stabilizing transformations were applied to achieve normality. Treatment effects were compared with Tukey's HSD post-hoc procedure (Devore 2003). For further details on runoff collection and water quality analysis methods see **Appendix E**.

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2.1.6 Vegetation Data Collection and Analyses

After 30 days, counts were made on seedling density. By 60 days, seedling density was too high for accurate counting. After 60 days, aerial live cover was estimated using a modified Daubenmire method (Daubenmire 1959, Interagency Technical Team 1996). Each test box was conceptually divided into an upper and lower half and a 25 cm x 25 cm quadrat was randomly positioned within each half. Plant identifications and nomenclature follow Hickman (1993).

Cover ranks were analyzed via ANOVA models and by Logistic Regression. For further details on vegetation data collection and analysis methods see **Appendix F**.

2.1.7 Weather Data Collection

Natural rainfall was measured and recorded by a weather station computer (**Photo 2.2**), and by backup rain gauges onsite. Additional data was available from a California Irrigation Management Information System (CIMIS) station and a National Oceanic and Atmospheric Administration (NOAA) station.

Photo 2.2. Weather Station

Chart 2.1 shows the monthly precipitation totals for the duration of both experiments. Note the sharp decline to zero after an above average February 2004. **Chart 2.2** shows the fifty-six year average monthly precipitation totals. Average precipitation values can be misleading because plants do not establish in one growing season.

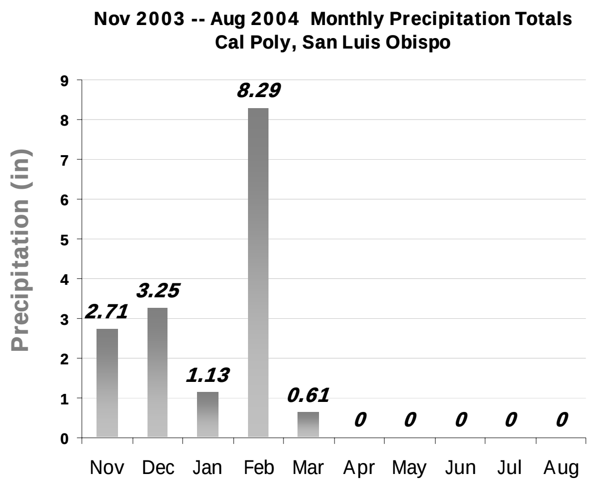

Chart 2.1. Monthly Precipitation Totals During Experiment Duration

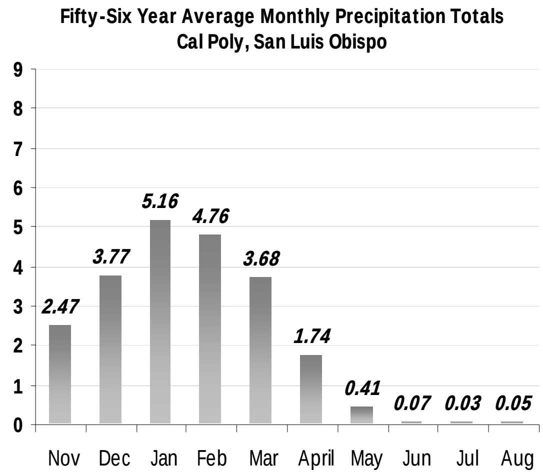

Chart 2.2. Fifty-Six Year Average Monthly Precipitation Totals

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2.2 Design: No Added Seed Experiment (RS5)

Twelve test boxes were filled with clay loam (S1), and twelve with fine sandy loam (S2). Six erosion control treatments were replicated twice for each soil type (see **Table 2.2** for the design matrix, and **Table 2.3** for treatment details). Boxes were randomly numbered and positioned to assure unbiased assignment of each treatment.

Table 2.2. RS 5 Experimental Design.

Test Boxes	**24**			
Treatments	**12**			
Replicates	**2**			
Factor	**Soil Type**			**EC Treatment**
Level	*1*	Clay Loam	*1*	None (Control)
	2	Fine Sandy Loam	*2*	Soil roughening
			3	Jute only
			4	Jute over Compost
			5	Crimped Straw
			6	Crimped Straw over Compost
Seed	Existing Soil Seed Bank (*no added seed*)			
Water Regime	Natural Rainfall			
Response Variables	Total Runoff Total Sediment Sediment Concentration Plant Cover			

Table 2.3. RS 5 Treatments.

Label	Treatment	Method
EC1	None (Control)	None
EC2	Soil roughening	The edge of a soil tamp was pressed into the soil at 20.32- to 25.4-cm (8- to 10-in) intervals to simulate texturing the soil surface.
EC3	Jute only	2.54 cm (1 in) Jute netting cut to box size, placed on soil surface, and fastened with jute hooks.
EC4	Jute over Compost	Hydropost®, a humified, fine, rich compost product was topically applied at recommended rate of 0.6 cm (0.25 in) (Caltrans 2003); 2.54 cm (1 in) Jute netting cut to box size, placed on soil surface, and fastened with jute hooks.
EC5	Crimped Straw	A 3.175 cm (1 ¼ in) rounded metal bar was used to press straw into the soil to simulate crimping.
EC6	Crimped Straw over Compost	Hydropost®, a humified, fine, rich compost product was topically applied at recommended rate of 0.6 cm (0.25 in) (Caltrans 2003); A rounded metal bar was used to press straw into the soil to simulate crimping.

2.2.1 Seed

The purpose of this experiment was to evaluate response by the seed existing in the soil samples. Thus, no additional seed was added to any treatment.

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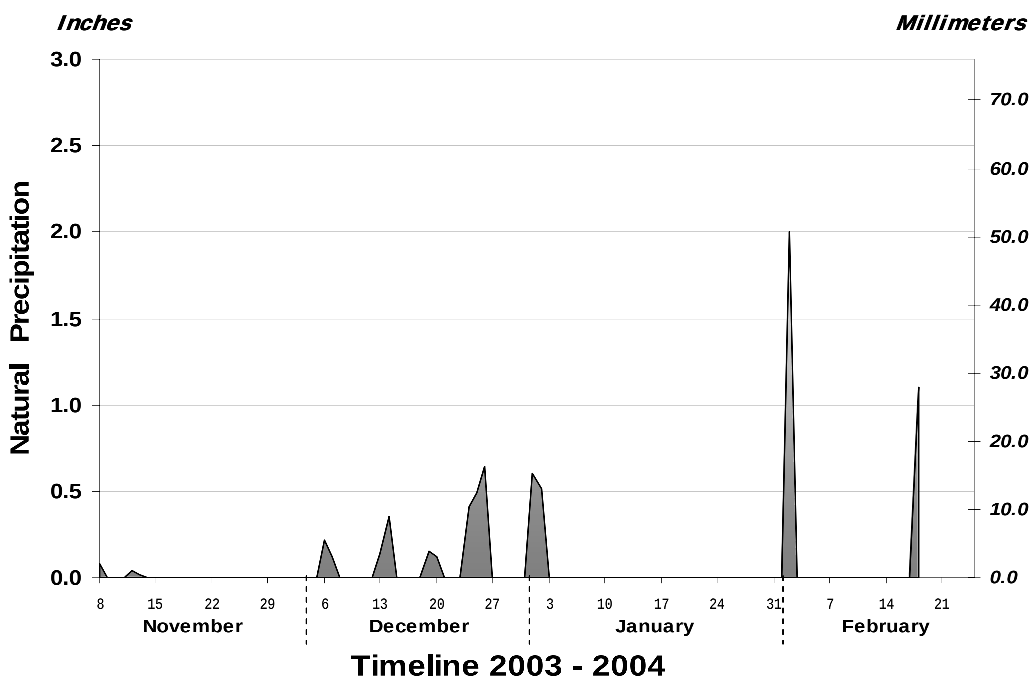
2.2.2 Rainfall Regime

Throughout the experiment, natural rainfall was permitted to fall on the boxes. In total, data for nine natural storms and one simulated storm were collected. Precipitation fell as rain because the average high temperature was 18.1C (64.5F) and the average low temperature was 5.4C (41.8F). Rainfall was collected from November to mid-February. The highest amount of rainfall, 50.8 mm (2.0 in), was collected 2 February 2004. Rainfall data are listed in **Table 2.4**.

Table 2.4. Natural Rainfall Data for the Duration of Experiment RS5.

			Rainfall	
Storm	Day	Year	mm	in
1	8-Nov	2003	2.0	0.08
2	12-Nov	2003	1.5	0.06
3	6-Dec	2003	5.6	0.22
3	7-Dec	2003	3.0	0.12
4	12-Dec	2003	3.4	0.13
4	13-Dec	2003	4.0	0.16
4	14-Dec	2003	5.0	0.20
5	19-Dec	2003	3.9	0.15
5	20-Dec	2003	3.0	0.12
6	24-Dec	2003	10.3	0.41
6	25-Dec	2003	12.3	0.48
6	26-Dec	2003	16.4	0.65
7	1-Jan	2004	15.2	0.60
7	2-Jan	2004	13.0	0.51
8	2-Feb	2004	50.8	2.00
9	18-Feb	2004	27.9	1.10
			177.3	**6.98**



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2.3 Design: Added Seed – Seed Depth Experiment (RS6)

Twelve test boxes were filled with clay loam (S1), and twelve with fine sandy loam (S2). Six erosion control treatments were replicated twice for each soil type. **Table 2.5** shows the design matrix; **Table 2.6** lists treatment details; **Table 2.7** provides fiber calculations; and **Table 2.8** lists materials loaded per hydroseeder tankfull. Boxes were randomly numbered and positioned to assure unbiased assignment of each treatment.

Table 2.5. RS 6 Experimental Design.

Test Boxes	**24**			
Treatments	**12**			
Replicates	**2**			
Factor	**Soil Type**		**EC Treatment**	
Level	*1* Clay Loam		*1* None (Control)	
	2 Fine Sandy Loam		*2* Seed in Low Fiber, No Compost	
			3 Seed in Low Fiber and High Compost	
			4 Seed in Low Fiber and Low Compost	
			5 Seed over High Fiber and Low Compost	
			6 Seed under High Fiber and Low Compost	
Seed	Existing Soil Seed Bank			
	Hydroseeded Species			
	Achillea millefolium L.		Common Yarrow	
	Bromus carinatus Hook & Arn.		California Brome	
Water Regime	Natural Rainfall			
Response Variables	Total Runoff			
	Total Sediment			
	Sediment Concentration			
	Plant Cover			

Table 2.6. RS 6 Treatments.

Label	Treatment	Method
EC1	None (Control)	None
EC2	Seed *in* 1680 kg/ha (1500 lb/ac) fiber, with no compost	Hydroseed
EC3	Seed *in* 1680 kg/ha (1500 lb/ac) fiber with 1680 kg/ha(1500 lb/ac) compost	Hydroseed
EC4	Seed *in* 1680 kg/ha (1500 lb/ac) fiber with 560 kg/ha (500 lb/ac) compost	Hydroseed
EC5	Seed *over* 3920 kg/ha fiber (3500 lb/ac) with 560 kg/ha (500 lb/ac)compost	Hydroseed
EC6	Seed *under* 3920 kg/ha (3500 lb/ac) fiber with 560 kg/ha (500 lb/ac) compost	Hydroseed

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Table 2.7. RS 6 Fiber Calculations.

	RATES			
	SI Measures		US Measures	
Fiber Calculations	**Quantity**	**Units**	**Quantity**	**Units**
Mass rate of fiber per area	3923.00	kg/ha	3500.00	lb/ac
Mass per bale	22.68	kg	50.00	lb
Volume per bale	0.06	m^3	2.00	ft^3
Mass per unit volume	400.46	kg/m^3	25.00	lb/ft^3
Mass per unit volume applied	100.12	kg/m^3	6.25	lb/ft^3
Volume per plot area	39.185	m^3/ha	560.00	ft^3/ac
Depth of topical layer	3.00	mm	0.125	in

Table 2.8. RS 6 Materials Used Per Hydroseeder Tankfull.

	RATES			
	SI Measures		US Measures	
Materials Per Tankfull	**Quantity**	**Units**	**Quantity**	**Units**
Fiber	22.70	kg	50.00	lb
Compost	2.83	kg	6.25	lb
Water	432.60	L	114.00	gal

Boxes were hydroseeded with seed, fiber, compost (if part of treatment), and water. Boxes not receiving treatment were covered with a waterproof plastic tarp (**Photo 2.3** and **Photo 2.4**).

Photo 2.3. Hydroseeding 19 March 2004.

Photo 2.4. Boxes After Hydroseeding.

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2.3.1 Seed

The purpose of this experiment was to evaluate response by two hydroseeded native plant species in potential competition with species from seed existing in the soil samples. Thus, additional seed was added to treatments EC2 through EC6. **Table 2.9** shows the calculations used to scale a typical application rate of pure live seed to quantities proportional to the amount of water in the small tank (1500 L / 400 gal) of the hydroseeder used to apply these seeds.

Table 2.9. RS 6 Calculations for Hydroseeded Species.

	BASE RATE PLS				SCALED RATE PLS PER TANKFULL			
	SI Measures		US Measures		SI Measures		US Measures	
Species	Qty	Units	Qty	Units	Qty	Units	Qty	Units
Bromus carinatus Hook & Arn. California Brome	33.6	kg/ha	30.0	lb/ac	0.194	kg	0.4300	lb
Achillea millefolium L Common Yarrow	0.907	kg/ha	2.0	lb/ac	0.013	kg	0.0286	lb

2.3.2 Rainfall Regime

Although consistent fall and winter storm events in RS5 alleviated the need for irrigation, RS6, received no rainfall during the late spring and summer months. Light irrigation was applied three times per day for two minutes to provide adequate soil moisture while preventing runoff from occurring. NOAA rated March and April 2004 temperatures as “much above normal”. The average high temperature was 26.9C (75F), reaching 39.5C (103F), and the average low temperature was 8.3C (47F). May and June temperatures were rated as “above normal”, with the average high temperature at 26.6C (79.8F) and the average lows at 10.0C (50F) (NOAA 2004). **Table 2.10** provides the schedule of simulations performed during this experiment.

Table 2.10. RS 6 Simulation Schedule.

Simulation Date	Box	Treatment	Simulation Date	Box	Treatment
5/18/2004	12	S1EC1	6/9/2004	20	S1EC3
5/18/2004	18	S2EC1	6/9/2004	21	S1EC4
5/19/2004	17	S1EC2	6/11/2004	23	S2EC1
5/19/2004	19	S2EC2	6/13/2004	22	S1EC6
5/20/2004	4	S1EC3	6/13/2004	9	S2EC6
5/20/2004	2	S2EC3	6/14/2004	10	S2EC3
5/25/2004	14	S1EC4	6/15/2004	16	S1EC2
5/25/2004	24	S2EC4	6/15/2004	8	S1EC5
5/26/2004	11	S1EC5	6/15/2004	7	S2EC4
5/26/2004	3	S2EC5	6/15/2004	15	S2EC5
5/27/2004	1	S1EC6	6/16/2004	6	S1EC1
5/27/2004	13	S2EC6	6/16/2004	5	S2EC2

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3.1 Runoff and Sediment Analyses

3.1.1 Runoff Data Analyses

There appeared to be an effect of EC treatment on the amount of water in the runoff and that effect was different by soil type.

3.1.1.1 S1: Clay Loam Soil

EC4 had the highest total runoff, followed by EC2, EC3, EC5, EC1 and EC6, in order. EC4 had runoff significantly higher than all others. EC2 and EC3 could not be said to differ, but they were both significantly higher than EC5, EC1 and EC6. EC5, EC1 and EC6 could not be said to differ.

Statistically Significant Groupings

Most Runoff	Group 1	EC4 (Jute over Compost)
	Group 2	EC2 (Soil Roughening) EC3 (Jute)
Least Runoff	Group 3	EC5 (Crimped Straw) EC1 (Control) EC6 (Crimped Straw over Compost)

3.1.1.2 S2: Fine Sandy Loam Soil

EC2 had the highest total runoff, followed by EC1, EC4, EC3, EC5 and EC6, in order. EC3 and EC5 were not statistically different, but all other pairs were noticeably different.

Statistically Significant Groupings

Most Runoff	Group 1	EC2 (Soil Roughening) EC1 (Control) EC4 (Jute over Compost)
	Group 2	EC3 (Jute) EC5 (Crimped Straw)
Least Runoff	Group 3	EC6 (Crimped Straw over Compost)

Photo 3.1 and **Photo 3.2** show visible differences in runoff between EC3 (Jute only) and EC1 (Control) applied to Fine Sandy Loam. Vegetation is certainly influencing the lesser sediment quantity in the runoff from EC3 (Jute only).

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Photo 3.1. Fine sandy loam with EC3 (Jute only): high runoff, but great water quality (container bottom is visible)

Photo 3.2. Fine sandy loam with EC1 (Control): high runoff and very poor water quality

Table 3.1. Ranked Evaluation of EC Treatment Effect on Total Runoff.

EC Treatment	Clay Loam	Fine Sandy Loam
EC1 (Control)	Good	Poor
EC2 (Soil Roughening)	Fair	Poor
EC3 (Jute)	Fair	Fair
EC4 (Jute over Compost)	Poor	Poor
EC5 (Crimped Straw)	**Good**	Fair
EC6 (Crimped Straw over Compost)	**Good**	**Good**

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3.1.2 Total Sediment Analyses

Total sediment is the total amount of sediment (g) in the runoff solution, regardless of the amount of total water. Sediment *concentration* (discussed in the next section) is the ratio of total sediment (mg) *per* volume of water (L) in the runoff solution, and is often considered a measure of water quality. Although the fine sandy loam produced higher *total* sediment loads across all treatments compared to the clay loam, the treatments had the same comparative effects on both soils.

3.1.2.1 S1: Clay Loam Soil

EC1 and EC2 had the highest amounts of total sediment, on average, and all other EC methods were significantly lower.

Statistically Significant Groupings

Most Sediment	Group 1	EC1 (Control) EC2 (Soil Roughening)
Least Sediment	Group 2	EC3 (Jute) EC4 (Jute over Compost) EC5 (Crimped Straw) EC6 (Crimped Straw over Compost)

3.1.2.2 S2: Fine Sandy Loam Soil

EC1 and EC2 produced the highest amounts of sediment, on average, and all other EC methods were significantly lower.

Statistically Significant Groupings

Most Sediment	Group 1	EC1 (Control) EC2 (Soil Roughening)
Least Sediment	Group 2	EC3 (Jute) EC4 (Jute over Compost) EC5 (Crimped Straw) EC6 (Crimped Straw over Compost)

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Table 3.2. Ranked Evaluation of EC Treatment Effect on Total Sediment.

EC Treatment	Clay Loam	Fine Sandy Loam
EC1 (Control)	Poor	Poor
EC2 (Soil Roughening)	Poor	Poor
EC3 (Jute)	**Good**	**Good**
EC4 (Jute over Compost)	**Good**	**Good**
EC5 (Crimped Straw)	**Good**	**Good**
EC6 (Crimped Straw over Compost)	**Good**	**Good**

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3.1.3 Sediment Concentration Analyses

Sediment *concentration* is the amount of total sediment (mg) *per* volume of water (L) in the runoff solution. The EC treatments affected sediment concentration. However, the two soils produced similar sediment concentrations. The amount of *total* sediment produced by the fine sandy loam was proportionally higher with *total* runoff, yielding the same *ratio* of total sediment to water.

Statistically Significant Groupings

Highest Sediment Concentration	Group 1	EC1 (Control)
	Group 2	EC2 (Soil Roughening)
	Group 3	EC5 (Crimped Straw) EC3 (Jute) EC6 (Crimped Straw over Compost)
Lowest Sediment Concentration	Group 4	EC4 (Jute over Compost)

Table 3.3. Ranked Evaluation of EC Treatment Effect on Sediment Concentration.

EC Treatment	Clay Loam	Fine Sandy Loam
EC1 (Control)	Poor	Poor
EC2 (Soil Roughening)	Poor	Poor
EC3 (Jute)	Fair	Fair
EC4 (Jute over Compost)	**Good**	**Good**
EC5 (Crimped Straw)	Fair	Fair
EC6 (Crimped Straw over Compost)	Fair	Fair

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3.1.4 pH Data Analyses

There was an effect of soil type on pH (p=.033)[1]. Clay loam resulted in pH values in runoff that were about 0.17 higher than fine sandy loam (on average, across all treatments). The clay loam median and mean were approximately pH of 7.5, with a range from 7.0 to 8.2. The fine sandy loam median was 7.5, while the mean was 7.3. The pH range was from 6.8 to 7.3. There was an effect of EC on pH (p<.001) and that effect depended on soil type (p=.011).

[1]p-values, represented by (p=) or (p<), are the levels of statistical significance at the 95% confidence level.

3.1.4.1 S1: Clay Loam Soil

EC1 and EC2 had the highest pH values (7.9 average), but were not noticeably different from one another. EC3, EC4, EC5 and EC6 had lower pH values. Again, no significant difference was found among them.

Statistically Significant Groupings

Highest pH	Group 1	EC1 (Control) EC2 (Soil Roughening)
Lowest pH	Group 2	EC3 (Jute) EC4 (Jute over Compost) EC5 (Crimped Straw) EC6 (Crimped Straw over Compost)

3.1.4.2 S2: Fine Sandy Loam Soil

EC1 had the highest pH values and EC2 the next highest (average of 7.2 pH over both). EC3, EC4, EC5 and EC6 are all similar, but EC5 had pH that was higher than EC6. No other differences between these treatments were statistically significant.

Statistically Significant Groupings

Highest pH	Group 1	EC1 (Control)
	Group 2	EC2 (Soil Roughening)
Lowest pH	Group 3	EC3 (Jute) EC4 (Jute over Compost) EC5 (Crimped Straw) EC6 (Crimped Straw over Compost)

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Table 3.4. Average pH values for runoff of each soil type and EC Treatment.

EC Treatment	Clay Loam	Fine Sandy Loam
EC1 (Control)	**8.1**	**7.2**
EC2 (Soil Roughening)	**7.6**	**7.1**
EC3 (Jute)	7.3	7.0
EC4 (Jute over Compost)	7.2	7.1
EC5 (Crimped Straw)	7.3	7.0
EC6 (Crimped Straw over Compost)	7.5	6.9

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3.2 Vegetation Analyses

Germination began within 14 days after treatment applications. There was no significant difference in cover between "upper" and "lower" quadrants of the box (p=.171). A higher amount of vegetation established on all treatments compared to the control (see **Photo 3.3** and **Photo 3.4** for examples).

Photo 3.3. S1 (Clay loam)
EC1 (Control)

Photo 3.4. S1 (Clay loam)
EC5 (Crimped Straw)

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3.2.1 Grass Cover

There was an effect of EC on grass cover, and the effect of EC depended on the soil type.

3.2.1.1 S1: Clay Loam Soil

EC3 produced the greatest cover from grass. EC4, EC2 and EC6 could not be said to differ. EC5 and EC1, which had the lowest overall rates of grass cover. Certified weed-free *Hordeum vulgare* (cultivated barley) straw was used for EC5 (Crimped Straw) and EC6 (Crimped Straw over Compost). This grass was identified in the vegetation cover. Presumably, the straw contained viable seed and added to total grass cover.

Statistically Significant Groupings

Greatest Cover	Group 1	EC3 (Jute)
	Group 2	EC2 (Soil Roughening) EC4 (Jute over Compost) EC6 (Crimped Straw over Compost)
Least Cover	Group 3	EC5 (Crimped Straw) EC1 (Control)

3.2.1.2 S2: Fine Sandy Loam Soil

In summary, for fine sandy loam (S2), grass cover was lowest in EC4, which was significantly lower than all others except EC2. EC6 had the highest grass cover, but the grass cover in EC 6 was not significantly higher than EC1 EC3 and EC5.

Statistically Significant Groupings

Greatest Cover	Group 1	EC6 (Crimped Straw over Compost) EC1 (Control) EC3 (Jute) EC5 (Crimped Straw)
Least Cover	Group 2	EC2 (Soil Roughening) EC4 (Jute over Compost)

Table 3.5. Ranked Evaluation of EC Treatment Effect on Greater Grass Cover.

EC Treatment	Clay Loam	Fine Sandy Loam
EC1 (Control)	Poor	**Good**
EC2 (Soil Roughening)	Fair	Poor
EC3 (Jute)	**Good**	**Good**
EC4 (Jute over Compost)	Fair	Poor
EC5 (Crimped Straw)	Poor	**Good**
EC6 (Crimped Straw over Compost)	Fair	**Good**

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3.2.2 Legume Cover

There was an effect of EC on legume cover, and the effect of EC depended on the soil type.

3.2.2.1 S1: Clay Loam Soil

EC1 had the significantly highest rate of legume cover. No other significant differences were observed, but EC6 had a higher rate of legume cover than EC2 and EC3.

Statistically Significant Groupings

Greatest Cover	Group 1	EC1 (Control)
Least Cover	Group 2	EC6 (Crimped Straw over Compost) EC4 (Jute over Compost) EC5 (Crimped Straw) EC2 (Soil Roughening) EC3 (Jute)

3.2.2.2 S2: Fine Sandy Loam Soil

EC4 had the highest rate of legume cover. No other significant differences were observed.

Statistically Significant Groupings

Greatest Cover	Group 1	EC4 (Jute over Compost)
Least Cover	Group 2	EC2 (Soil Roughening) EC5 (Crimped Straw) EC6 (Crimped Straw over Compost) EC3 (Jute) EC1 (Control)

Table 3.6. Ranked Evaluation of EC Treatment Effect on Greater Legume Cover.

EC Treatment	Clay Loam	Fine Sandy Loam
EC1 (Control)	**Good**	Poor
EC2 (Soil Roughening)	Poor	Poor
EC3 (Jute)	Poor	Poor
EC4 (Jute over Compost)	Fair	**Good**
EC5 (Crimped Straw)	Poor	Poor
EC6 (Crimped Straw over Compost)	Fair	Poor

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3.3 Runoff and Sediment Analyses

Clay loam and fine sandy loam produced similar results in total runoff (L), *total* sediment (g of sediment weighed after sample dehydration), and sediment *concentration* (mg of sediment per L of runoff). EC1 produced the highest *total* sediment load (g), as well as sediment *concentration* in runoff (L). EC5 and EC6 yielded sediment *concentrations* similar to EC2, EC3 and EC4, but due to lower total runoff and *total* sediment production, EC5 and EC6 appeared to be the best treatments. Although EC5 produced lower total runoff and *total* sediment than EC6, the difference was not statistically significant. **Photos 3.5** and **3.6** show visible sediment in runoff from EC1 (Control) applied to both soils, and **Photos 3.7** and **3.8** show relatively clear runoff from EC5 (Seed OVER Fiber @ 1500 lb/ac & Compost @ 500 lb /ac) applied to both soils.

3.3.1 Runoff Data Analyses

EC treatment affected the log of total runoff. EC5 total runoff was 2.18 statistical units below the average (p=.007) and EC6 total runoff was 1.56 units below the average (p=.039).

Statistically Significant Groupings

			Seed	Fiber	Compost
Most Runoff	Group 1	EC1	*None*	*None*	*None*
		EC2	Mixed In	1680 kg/ha = 1500 lb/ac	*None*
		EC3	Mixed In	1680 kg/ha = 1500 lb/ac	1680 kg/ha = 1500 lb/ac
		EC4	Mixed In	1680 kg/ha = 1500 lb/ac	560 kg/ha = 500 lb/ac
	Group 2	EC6	Underseeded	3920 kg/ha = 3500 lb/ac	560 kg/ha = 500 lb/ac
Least Runoff	Group 3	EC5	Overseeded	3920 kg/ha = 3500 lb/ac	560 kg/ha = 500 lb/ac

3.3.2 Total Sediment Analyses

EC treatment had an effect on *total* sediment. EC1 yielded total sediment loads 3.61 units *higher* than the average (p<.001). EC5 yielded total sediment loads 2.64 units *lower* than the average (p=.003) and EC6 yielded total sediment loads 2.03 *lower* than the average (p=.013).

Statistically Significant Groupings

			Seed	Fiber	Compost
Most Sediment	Group 1	EC1	*None*	*None*	*None*
		EC2	Mixed In	1680 kg/ha = 1500 lb/ac	*None*
		EC3	Mixed In	1680 kg/ha = 1500 lb/ac	1680 kg/ha = 1500 lb/ac
		EC4	Mixed In	1680 kg/ha = 1500 lb/ac	560 kg/ha = 500 lb/ac
	Group 2	EC6	Underseeded	3920 kg/ha = 3500 lb/ac	560 kg/ha = 500 lb/ac
Least Sediment	Group 3	EC5	Overseeded	3920 kg/ha = 3500 lb/ac	560 kg/ha = 500 lb/ac

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Photo 3.5. S1 (Clay Loam)

EC1 (Control)

Photo 3.6. S2 (Fine Sandy Loam)

EC1 (Control)

Photo 3.7. S1 (Clay Loam)

EC5 (Seed OVER Fiber @ 1500 lb/ac & Compost @ 500 lb /ac)

Photo 3.8. S2 (Fine Sandy Loam)

EC5 (Seed OVER Fiber @ 1500 lb/ac & Compost @ 500 lb /ac)

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3.3.3 Sediment Concentration Analyses

No significant interaction was noted between Soil and EC. EC1 differed from all other levels of EC treatment. On average, sediment concentration was 2.16 units higher than the sediment concentrations for the other treatments ($p<.001$), but none of the other levels had significantly different sediment concentrations.

Statistically Significant Groupings

			Seed	Fiber	Compost
Highest Sediment Concentration	Group 1	EC1	*None*	*None*	*None*
Lowest Sediment Concentration	Group 2	EC2	Mixed In	1680 kg/ha = 1500 lb/ac	*None*
		EC3	Mixed In	1680 kg/ha = 1500 lb/ac	1680 kg/ha = 1500 lb/ac
		EC4	Mixed In	1680 kg/ha = 1500 lb/ac	560 kg/ha = 500 lb/ac
		EC5	Overseeded	3920 kg/ha = 3500 lb/ac	560 kg/ha = 500 lb/ac
		EC6	Underseeded	3920 kg/ha = 3500 lb/ac	560 kg/ha = 500 lb/ac

3.3.4 pH Data Analyses

There were no significant effects of Soil or EC on pH of runoff.

3.3.5 Fiber Rate Analyses

The mean difference in total runoff between fiber rates of 3920 kg/ha (3500 lb/ac) and of 1680 kg/ha (1500 lb/ac) was not significantly different.

3.3.6 Compost Rate Analyses

The mean difference in total runoff between compost rates of 1680 kg/ha (1500 lb/ac) and of 560 kg/ha (500 lb/ac) was not significantly different.

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3.4 Vegetation Analyses

Germination began approximately one week after hydroseeding, but was slow and sparse, likely due to higher than average spring temperatures. Species present were mostly the naturalized aliens typical of arid San Luis Obispo County, such as *Brassica* spp./*Hirschfeldia* spp. (Mustard), *Centaurea melitensis* (Tocalote), *Erodium cicutarium* (Red-Stem Filaree), *Melilotus officinalis* (Yellow Sweetclover), and *Bromus* spp. **Table 3.7** lists the species observed at least once over the 24 test boxes and the seed source for each.

Table 3.7. Plant Species Observed in Test Boxes of RS6.

Scientific Name	Common Name	Seed Bank	Added Seed
Native Perennial Forbs			
Achillea millefolium	Common Yarrow		✓
Native Annual Forbs			
Amsinckia sp.	Fiddleneck	✓	
Vicia sp.	Vetch	✓	
Lotus spp.	Lotus	✓	
Lupinus spp.	Lupine	✓	
Naturalized Perennial Forbs			
Hirschfeldia incana	Mustard	✓	
Medicago polymorpha	Bur Clover	✓	
Naturalized Annual Forbs			
Anagallis arevensis	Scarlet Pimpernel	✓	
Brassica nigra	Mustard	✓	
Centaurea melitensis	Tocalote	✓	
Erodium cicutarium	Red Stem Filaree	✓	
Euphorbia sp.	Euphorbia	✓	
Lactuca serriola	Prickly Lettuce	✓	
Malva spp.	Mallow	✓	
Melilotus officinalis	Yellow Sweetclover	✓	
Picris echioides	Bristly Ox-Tongue	✓	
Polygonum arenastrum	Oval-Leaf Knotweed	✓	
Portulaca oleracea	Common Purslane	✓	
Sonchus asper	Prickly Sow Thistle	✓	
Stellaria pallida	Common Chickweed	✓	
Veronica persica	Blue Speedwell	✓	
Native Perennial Grasses			
Bromus carinatus	California Brome		✓
Melica californica	California Melic Grass	✓	
Native Annual Grasses			
Festuca / Vulpia microstachys	Small Fescue	✓	
Naturalized Annual Grasses			
Avena fatua	Common Wild Oat	✓	
Bromus diandrus	Ripgut Brome	✓	
Bromus madritensis ssp. rubens	Red Brome	✓	
Bromus hordeaceus	Soft Chess	✓	
Festuca / Vulpia myuros	Rattail Fescue	✓	
Lolium multiflorum	Annual Ryegrass	✓	

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3.4.1 Grass Cover

There was a statistically significant effect of EC, a statistically significant effect of soil type (S) and an interaction between EC method (EC) and soil type (S) that differs by soil type. Overall, S1 (Clay Loam) provided lower rates of grass cover than did S2 (Fine Sandy Loam). Percentage cover estimates by soil type for each treatment method were separately presented due to the interaction. **Chart 3.1** compares Grass cover among EC treatments on both soils.

3.4.1.1 S1: Clay Loam Soil

EC1 and EC5 had the lowest percentage of grass cover. EC2 had grass cover lower than EC3 and EC6, but not significantly lower than EC4, which also was not significantly different from EC3 and EC6.

Statistically Significant Groupings

			Seed	Fiber	Compost
Most Cover	Group 1	EC3	Mixed In	1680 kg/ha = 1500 lb/ac	1680 kg/ha = 1500 lb/ac
		EC6	Underseeded	3920 kg/ha = 3500 lb/ac	560 kg/ha = 500 lb/ac
		EC4	Mixed In	1680 kg/ha = 1500 lb/ac	560 kg/ha = 500 lb/ac
		EC2	Mixed In	1680 kg/ha = 1500 lb/ac	*None*
Least Cover	Group 2	EC5	Overseeded	3920 kg/ha = 3500 lb/ac	560 kg/ha = 500 lb/ac
		EC1	*None*	*None*	*None*

3.4.1.2 S2: Fine Sandy Loam Soil

EC5 produced the highest grass cover. EC 1 comprised the lowest grass cover. All other EC methods (EC2, EC3, EC4 and EC6) produced cover rates that were not significantly different.

Statistically Significant Groupings

			Seed	Fiber	Compost
Most Cover	Group 1	EC5	Overseeded	3920 kg/ha = 3500 lb/ac	560 kg/ha = 500 lb/ac
Least Cover	Group 2	EC6	Underseeded	3920 kg/ha = 3500 lb/ac	560 kg/ha = 500 lb/ac
		EC4	Mixed In	1680 kg/ha = 1500 lb/ac	560 kg/ha = 500 lb/ac
		EC3	Mixed In	1680 kg/ha = 1500 lb/ac	1680 kg/ha = 1500 lb/ac
		EC2	Mixed In	1680 kg/ha = 1500 lb/ac	*None*
		EC1	*None*	*None*	*None*

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3.4.2 Legume Cover

Soil type and EC each had a significant effect on percent cover, but there did not appear to be an interaction. S1 (Clay Loam) had a significantly higher percent cover at 47.6% than the 5.1% for S2 (Fine Sandy Loam) ($p>0.001$), but the trend in the EC treatment by Soil interaction was the same. The legumes *Lupinus* spp. (Lupine) and *Lotus* spp. (Lotus) were California native species from the existing seedbank that germinated. *Lupinus* spp. was found on S1 (Clay Loam) only, and a small amount of *Lotus* spp. was found on the S2 (Fine Sandy Loam) only. On S1 (Clay Loam), EC1 (Control) rated lowest in legume cover, followed by EC6. **Chart 3.2** compares Legume cover among EC treatments on both soils.

Statistically Significant Groupings

			Seed	Fiber	Compost
Most Cover	Group 1	EC5	Overseeded	3920 kg/ha = 3500 lb/ac	560 kg/ha = 500 lb/ac
	Group 2	EC4	Mixed In	1680 kg/ha = 1500 lb/ac	560 kg/ha = 500 lb/ac
		EC2	Mixed In	1680 kg/ha = 1500 lb/ac	*None*
		EC3	Mixed In	1680 kg/ha = 1500 lb/ac	1680 kg/ha = 1500 lb/ac
Least Cover	Group 3	EC6	Underseeded	3920 kg/ha = 3500 lb/ac	560 kg/ha = 500 lb/ac
		EC1	*None*	*None*	*None*

3.4.3 Common Yarrow Cover

Soil type and EC both affected the percent cover of Common Yarrow (*Achillea millefolium*). Furthermore, the interaction between soil type and EC method asserted that the effects of EC on Common Yarrow cover depended on the soil type. S1 (Clay Loam) had lower percent Common Yarrow cover than did S2 (Fine Sandy Loam). Relatively few Common Yarrow or California Brome (*Bromus carinatus*) seeds germinated. Lower overall Common Yarrow cover was found on S1 (Clay Loam) than on S2 (Fine Sandy Loam). Common Yarrow cover was highest on S1 (Clay Loam) with seed *in* 1680 kg/ha fiber with 1680 kg/ha compost and highest on S2 (Fine Sandy Loam) with seed *over* 3920 kg/ha fiber with 560 kg/ha compost. **Chart 3.3** compares Common Yarrow cover among EC treatments on both soils.

On S1 (Clay Loam), there may have been more Common Yarrow germination on the lighter fiber and compost treatments due to lesser shading by other vegetation. Since Common Yarrow seeds are extremely small, seeding *under* 3920 kg/ha of fiber with 560 kg/ha of compost may have hindered germination by burying the seeds too deeply. Seeding *over* fiber seemed to encourage germination on S2 (Fine Sandy Loam). This effect was also noted in a previous experiment (Caltrans 2004). Common Yarrow presence is important because previous results (Caltrans 2004) indicate that the fine, mat-like foliage is an excellent sediment filter.

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3.4.3.1 S1: Clay Loam Soil

EC3 produced more Common Yarrow cover than did other treatments. EC1, EC2, EC3, EC4, EC5, and EC6 did not differ significantly.

Statistically Significant Groupings

			Seed	Fiber	Compost
Most Cover	Group 1	EC3	Mixed In	1680 kg/ha = 1500 lb/ac	1680 kg/ha = 1500 lb/ac
Least Cover	Group 2	EC6	Underseeded	3920 kg/ha = 3500 lb/ac	560 kg/ha = 500 lb/ac
		EC2	Mixed In	1680 kg/ha = 1500 lb/ac	*None*
		EC4	Mixed In	1680 kg/ha = 1500 lb/ac	560 kg/ha = 500 lb/ac
		EC5	Overseeded	3920 kg/ha = 3500 lb/ac	560 kg/ha = 500 lb/ac
		EC1	*None*	*None*	*None*

3.4.3.2 S2: Fine Sandy Loam Soil

EC5 produced more Common Yarrow cover than did other treatments. EC1, EC2, EC3, EC4, and EC6 did not differ significantly.

Statistically Significant Groupings

			Seed	Fiber	Compost
Most Cover	Group 1	EC5	Overseeded	3920 kg/ha = 3500 lb/ac	560 kg/ha = 500 lb/ac
Least Cover	Group 2	EC4	Mixed In	1680 kg/ha = 1500 lb/ac	560 kg/ha = 500 lb/ac
		EC3	Mixed In	1680 kg/ha = 1500 lb/ac	1680 kg/ha = 1500 lb/ac
		EC2	Mixed In	1680 kg/ha = 1500 lb/ac	*None*
		EC1	*None*	*None*	*None*
		EC6	Underseeded	3920 kg/ha = 3500 lb/ac	560 kg/ha = 500 lb/ac

3.4.4 Other Forb Cover

There was not a statistically significant effect of EC on Other Forb cover. Averaging across treatment groups (where there was no difference) and quadrat (upper versus lower), the following average estimated rank for Other Forb cover (and associated percent Other Forb cover) for each soil type. S1 (Clay Loam) produced lower rates of Other Forb cover than did S2 (Fine Sandy Loam), but no effect of EC treatment was found on Other Forb cover. **Chart 3.4** compares Other Forb cover among EC treatments on both soils.

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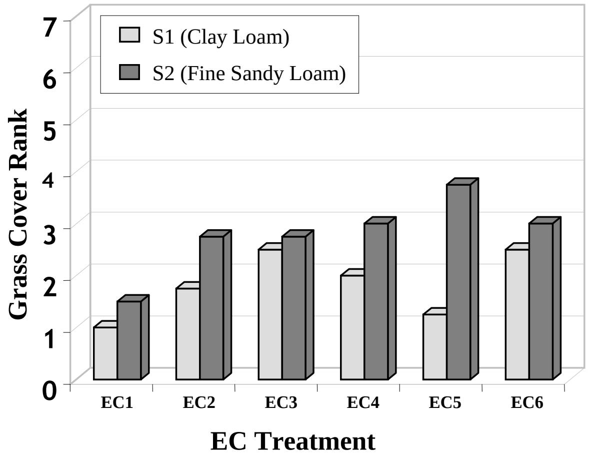

Chart 3.1. RS6 Grass Cover

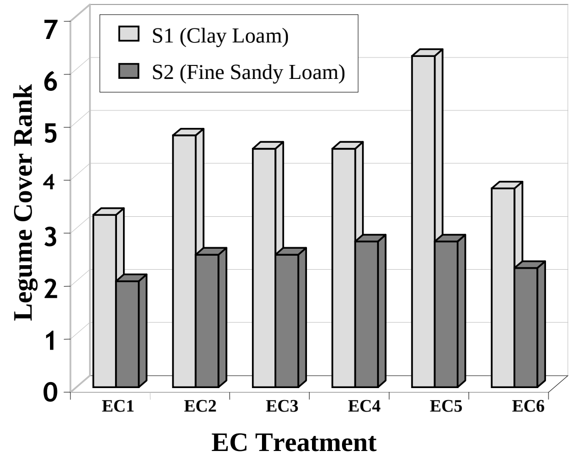

Chart 3.2. RS 6 Legume Cover

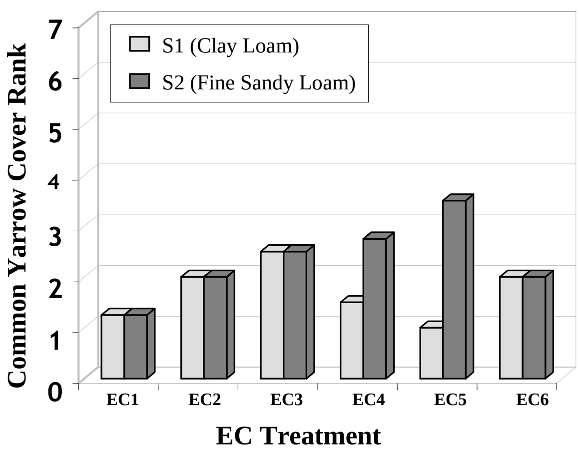

Chart 3.3. RS6 Yarrow Cover

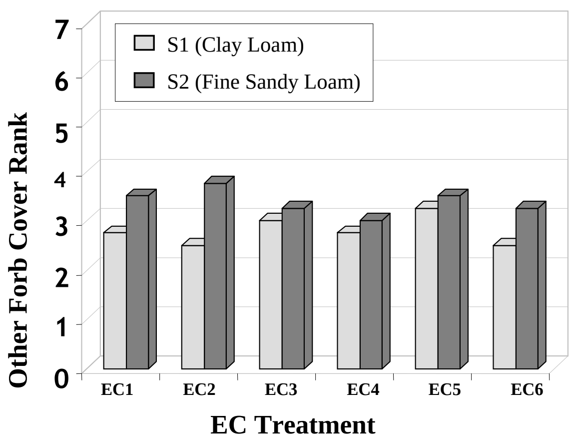

Chart 3.4. RS6 Other Forb Cover

Legend: EC Treatments

Label	Treatment
EC1	Control
EC2	Seed *in* 1680 kg/ha (1500 lb/ac) fiber, with no compost
EC3	Seed *in* 1680 kg/ha (1500 lb/ac) fiber with 1680 kg/ha(1500 lb/ac) compost
EC4	Seed *in* 1680 kg/ha (1500 lb/ac) fiber with 560 kg/ha (500 lb/ac) compost
EC5	Seed *over* 3920 kg/ha fiber (3500 lb/ac) with 560 kg/ha (500 lb/ac)compost
EC6	Seed *under* 3920 kg/ha (3500 lb/ac) fiber with 560 kg/ha (500 lb/ac) compost

Legend: Cover Ranking Percentages

Rank	Estimated Cover %
7	98.0
6	85.5
5	63.0
4	38.0
3	15.5
2	3.0
1	0.5

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4.1 RS 5: No Added Seed Experiment

4.1.1 Runoff and Sediment

There were noticeable improvements in total runoff, total sediment load, and water quality when Compost was used in conjunction with Jute or Crimped Straw. It is possible that an applied layer thicker than 0.6 cm (0.25 in) would further enhance these factors, as found in an earlier experiment (Caltrans 2004).

4.1.1.1 Effects Common to Both Soil Types

- Jute over Compost produced the lowest total sediment loads and sediment concentrations.
- Crimped Straw over Compost yielded the lowest amount of total runoff.
- Soil roughening and No Treatment produced the highest total sediment loads.

4.1.1.2 Effects Specific to Clay Loam

- Crimped Straw alone and Crimped Straw over Compost yielded lesser total runoff, and fairly low sediment concentrations.
- No Treatment yielded lesser total runoff, but sediment concentrations were high.

4.1.1.3 Effects Specific to Fine Sandy Loam

- Crimped Straw over Compost yielded lesser total runoff, and fairly low sediment concentrations.
- No Treatment yielded high total runoff with high sediment concentrations.

4.1.2 Vegetation

There was high heterogeneity in plant species and lifeform composition among boxes. Within each box, vegetation consisted of *either* grasses *or* legumes depending on EC treatment.

4.1.2.1 Effects Common to Both Soil Types

- Jute alone produced the most grass cover and the least legume cover.
- Crimped Straw alone yielded poor legume cover.
- Soil roughening produced poor grass and poor legume cover.

4.1.2.2 Effects Specific to Clay Loam

- No Treatment produced the most legume cover.
- Crimped Straw alone and Crimped Straw over Compost produced poor grass and poor legume cover.

4.1.2.3 Effects Specific to Fine Sandy Loam

- No Treatment produced the most grass cover.
- Crimped Straw alone and Crimped Straw over Compost produced good grass cover, but poor legume cover.
- Jute over Compost produced the most legume cover, but poor grass cover.

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4.1.3 Summary

Considering combined effects on total runoff, sediment concentration, and vegetation production, Jute over Compost seems to be the best EC treatment over both soil types. Jute Without Compost also performed well in plant cover production, but water quality is not as good as when Jute is used in conjunction with Compost. Of course, sources of compost vary and results may vary from those of this experiment. Although No Treatment boxes did produce seemingly ample plant cover of either grasses or legumes, sediment concentration was also very high. Soil Roughening also performed poorly overall, and even worse than No Treatment. **Table 4.1** provides a ranked evaluation of the six treatments over both soil types. Bear in mind that these are qualitative assessments based on the statistical output. These ranking also reflect response trends in these data concordant with past experiments.

Table 4.1. Ranked Evaluation of RS5 EC Treatment Effects on Each Soil Type.

A ranked evaluation (Good = 3, Fair = 2, Poor = 1) of the six treatments over both soil types follows. Bear in mind that these are qualitative assessments based on the statistical output. These ranking also reflect response trends in these data concordant with past experiments.

	CLAY LOAM					FINE SANDY LOAM					
	Runoff		Vegetation			Runoff		Vegetation			
	Total	Sed Conc	Grass	Legume	*Sub Score*	Total	Sed Conc	Grass	Legume	*Sub Score*	*Total* Score
No Treatment	***3***	*1*	*1*	***3***	**8**	*1*	*1*	***3***	*1*	**6**	**14**
Soil Roughening	*2*	*1*	*2*	*1*	**6**	*1*	*1*	*1*	*1*	**4**	**10**
Jute Only	*2*	*2*	***3***	*1*	**8**	*2*	*2*	***3***	*1*	**8**	**16**
Jute over Compost	*1*	***3***	*2*	*2*	**8**	*1*	***3***	*1*	***3***	**8**	**16**
Crimped Straw	***3***	*2*	*1*	*1*	**7**	*2*	*2*	***3***	*1*	**8**	**15**
Crimped Straw over Compost	***3***	*2*	*2*	*2*	**9**	***3***	*2*	***3***	*1*	**9**	**18**

Below, sediment concentration (Sed Conc) is transferred from the above table, and plant cover categories (Grass and Legume) are added for a total (Plant Cover) score.

	CLAY LOAM			FINE SANDY LOAM		
	Sed Conc	Plant Cover	*Score*	Sed Conc	Plant Cover	*Score*
No Treatment	*1*	*4*	**5**	*1*	*4*	**5**
Soil Roughening	*1*	*3*	**4**	*1*	*2*	**3**
Jute Only	*2*	*4*	**6**	*2*	*4*	**6**
Jute over Compost	***3***	***4***	**7**	***3***	***4***	**7**
Crimped Straw	*2*	*2*	**4**	*2*	*4*	**6**
Crimped Straw over Compost	*2*	*4*	**6**	*2*	*4*	**6**

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4.2 RS 6: Added Seed – Seed Depth Experiment

4.2.1 Runoff and Sediment

In this experiment, there were no significant differences in performance of erosion control treatments on each soil type. The driving factor in all differences among EC treatments seems to be the greater application rate of fiber. Treatments using rates of 3920 kg/ha (3500 lb/ac) Fiber yielded lower total runoff and total sediment than treatments using rates of 1680 kg/ha (1500 lb/ac) Fiber even when the lower Fiber rate was combined with the higher Compost rate of 1680 kg/ha (1500 lb/ac).

4.2.2 Vegetation

Clay Loam produced greater vegetation cover overall, and greater grass cover. This may be due to either a higher number of seeds in the seedbank originally or due to the higher fertility and water-holding capacity of Clay Loam compared to Fine Sandy Loam. More non-legume forb cover was found on Fine Sandy Loam.

4.2.2.1 Effects Common to Both Soil Types

- Seed *Under* 3920 kg/ha (3500 lb/ac) Fiber With 560 kg/ha (500 lb/ac) Compost produced the most grass cover with the least legume cover.
- Seed *Over* 3920 Kg/Ha (3500 Lb/Ac) Fiber With 560 Kg/Ha (500 Lb/Ac) Compost produced the most legume cover.
- Seed In 1680 kg/ha (1500 lb/ac) Fiber With No Compost, and No Treatment produced poor grass and poor legume cover.

4.2.2.2 Effects Specific to Clay Loam

- Seed *Over* 3920 Kg/Ha (3500 Lb/Ac) Fiber With 560 Kg/Ha (500 Lb/Ac) Compost produced poor grass cover.

4.2.2.3 Effects Specific to Fine Sandy Loam

- Seed *Over* 3920 Kg/Ha (3500 Lb/Ac) Fiber With 560 Kg/Ha (500 Lb/Ac) Compost produced good grass cover.

4.2.3 Summary

Considering combined effects on runoff, sediment concentration, and vegetation production, Seed *Over* 3920 Kg/Ha (3500 Lb/Ac) Fiber With 560 Kg/Ha (500 Lb/Ac) Compost seems to be the best EC treatment over both soil types, followed closely by Seed *Under* 3920 kg/ha (3500 lb/ac) Fiber With 560 kg/ha (500 lb/ac) Compost. Again, the predominant influence is likely the higher rate of Fiber and Compost rather than seed position, but seed position over or under a thicker layer of Fiber and Compost does matter to individual species germination and subsequent abundance in developing vegetation. No Treatment boxes again performed poorly, yielding high sediment concentrations and producing poor plant cover. The Seed *In* 1680 kg/ha (1500 lb/ac) Fiber with No Compost was only marginally better than No Treatment.

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Table 4.2 provides a ranked evaluation of the six EC treatments over both soil types (S). Bear in mind that these are qualitative assessments based on the statistical output. These ranking also reflect response trends in these data concordant with past experiments.

Table 4.2. Ranked Evaluation of RS6 EC Treatment Effects on Each Soil Type.

A ranked evaluation (Good = 3, Fair = 2, Poor = 1) of the six treatments over both soil types follows. Bear in mind that these are qualitative assessments based on the statistical output. These rankings also reflect response trends in these data concordant with past experiments.

			CLAY LOAM					FINE SANDY LOAM					
			Runoff		Vegetation		*Sub Score*	Runoff		Vegetation		*Sub Score*	*Total* Score
Seed	**Fiber**	**Compost**	Total	Sed Conc	Grass	Legume		Total	Sed Conc	Grass	Legume		
None	*None*	*None*	*1*	*1*	*1*	*1*	***4***	*1*	*1*	*1*	*1*	***4***	***8***
Mixed In	1680 kg/ha 1500 lb/ac	*None*	*1*	*1*	*2*	*2*	***6***	*1*	*1*	*1*	*2*	***5***	***11***
Mixed In	1680 kg/ha 1500 lb/ac	1680 kg/ha 1500 lb/ac	*1*	*2*	***3***	*2*	***8***	*1*	*2*	*2*	*2*	***7***	***15***
Mixed In	1680 kg/ha 1500 lb/ac	560 kg/ha 500 lb/ac	*1*	*2*	*2*	*2*	***7***	*1*	*2*	*2*	*2*	***7***	***14***
Over seeded	3920 kg/ha 3500 lb/ac	560 kg/ha 500 lb/ac	***3***	***2***	*1*	*3*	***9***	***3***	***2***	*3*	*3*	***11***	***20***
Under seeded	3920 kg/ha 3500 lb/ac	560 kg/ha 500 lb/ac	*2*	***3***	***3***	*1*	***9***	*2*	***3***	*3*	*1*	***9***	***18***

Below, total runoff (Total) and sediment concentration (Sed Conc) ranking were added for Water Quality and plant cover categories (Grass and Legume) were added for a total cover score.

			CLAY LOAM			FINE SANDY LOAM		
Seed	**Fiber**	**Compost**	Runoff	Plant Cover	*Score*	Runoff	Plant Cover	*Score*
None	*None*	*None*	*2*	*2*	***4***	*2*	*2*	***4***
Mixed In	1680 kg/ha 1500 lb/ac	*None*	*2*	*4*	***6***	*2*	*3*	***5***
Mixed In	1680 kg/ha 1500 lb/ac	1680 kg/ha 1500 lb/ac	*3*	*5*	***8***	*3*	*4*	***7***
Mixed In	1680 kg/ha 1500 lb/ac	560 kg/ha 500 lb/ac	*3*	*4*	***7***	*3*	*4*	***7***
Over seeded	**3920 kg/ha 3500 lb/ac**	**560 kg/ha 500 lb/ac**	*5*	*4*	***9***	*5*	*6*	***11***
Under seeded	3920 kg/ha 3500 lb/ac	560 kg/ha 500 lb/ac	*5*	*4*	***9***	*5*	*4*	***9***

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4.3 Combined Summary

Results from both experiments indicate that use of Compost as a topical temporary erosion control treatment significantly reduces *total* sediment and sediment *concentration* in runoff. Use of Compost in conjunction with Jute Netting or Crimped Straw may provide additional slope protection, depending on soil type and situation, without hindering seed germination and plant cover development. **Table 4.3** lists the overall positive and negative attributes of the temporary erosion control treatments tested.

Table 4.3. Overall Positive and Negative Attributes of EC Treatments Tested.

Physical EC Treatment	Positive Attributes	Negative Attributes
Topsoil Replacement	▪ Quick cover given water and moderate temperature regime ▪ Soil microbes present ▪ Native seeds may be present ▪ Best visual and compositional similarity with context vegetation ▪ May be only alternative if site is dominated by alien plant species	▪ Seedbank typically dominated by naturalized alien plant species more competitive than seeded natives ▪ Need to test soil seedbank or conduct thorough vegetation inventory prior to reapplication to anticipate species likely to germinate and re-establish
Jute	▪ Low total sediment and sediment concentration ▪ Low initial soil disturbance	▪ Possible high runoff
Straw	▪ Low runoff, increased infiltration ▪ Low sediment over time	▪ Possible seed contamination from straw seedbank ▪ Initial soil disturbance
Compost	▪ Low total sediment and sediment concentration ▪ Thick layer may inhibit germination by naturalized alien plant species in the seedbank ▪ Possible benefits to developing vegetation on low-fertility soils	▪ May need additional physical erosion control treatment, e.g., jute netting, to maintain on slope
Hydroapplied Fiber & Seed	▪ Rate of 3920 kg/ha (3500 lb/ac) yielded low runoff and sediment; greater native seed germination on Fine Sandy Loam when seed applied Over Fiber	▪ Thin layers do not inhibit germination by naturalized alien plant species in the seedbank

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4.4 Implications and Recommendations

Although extrapolations from specific experimental results to general management practices are always perilous, recommendations drawn from the implications of these and past experiments are needed regarding erosion control measures for the Route 46 Corridor Improvement Project. The following is offered with a caveat that the climate of eastern San Luis Obispo County is extremely varied and unpredictable. Rainfall is unreliable, and 30- to 60-day episodes with no measurable precipitation are possible during the only season of reliable rainfall from December through March. Therefore, the "Expected Results" that follow assume near average rain seasons with no dry periods longer than 21 days.

The following recommendations refer to sites where stockpiled topsoil may be reapplied along the Route 46 Corridor. A **general recommendation** is also made here **to develop specifications to routinely sample and test soil seedbanks prior to construction** to ascertain what quantities of native and naturalized grasses and forbs exist in the soil. If high quantities of viable seed from naturalized species exist in reapplied topsoil, additional commercial seed of non-local "native" species may have difficulty competing with aggressive naturalized species for water. In a landscape context dominated by naturalized alien species, re-establishment of native plants should focus on sites where specific management objectives necessitate promotion of local native genotypes, especially if local native plant genotypes are known to be host plants or food sources for locally important wildlife species.

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4.3.1 Where Re-establishment of Native Species Is NOT A Primary Objective

Topsoil is reapplied and the following Temporary Soil Stabilization Treatment (SS-3 or SS-4) be used on final graded slopes.

	"Type D" EC Treatment		Additional Recommended EC Measures	
	Application Rates			
	lb / ac	kg / ha		
Fiber ≥	4000	4485	**Jute Netting**	
Compost ≥	1000	1120	**Toe Treatment**	
Fertilizer	NONE	NONE	*Physical:*	**EC Blanket (SS-7)**
Stabilizing Emulsion	0—5	0—5.5	*or Live Plants:*	**See Table 4.5**
Added Seed [1]	0—45	0—50		

[1] rapid cover native or naturalized species; if existing seedbank is adequate, then no added seed is necessary.

	EXPECTED RESULTS		
	Without Jute Without Toe Treatment	**WITH** Jute Without Toe Treatment	**WITH** Jute **WITH** Toe Treatment
Water Quality			
Runoff	High to Moderate	Moderate to Low	**Low**
Sediment Concentration	High	Low	**Very Low**
Vegetation			
Structure			
Dominants	Annual Grasses	Annual Grasses	Annual Grasses
Subordinates	Annual Forbs	Annual Forbs	Annual Forbs
Composition			
Dominants	Naturalized Aliens	Naturalized Aliens	Naturalized Aliens
Subordinates	Naturalized Aliens	Naturalized Aliens	Naturalized Aliens
Cover			
Overstory	High	High	High
Understory	Low	Low	Low
Persistence	Indefinite	Indefinite	Indefinite

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4.3.2 Where Re-establishment of Native Species IS A Primary Objective

Topsoil is reapplied and the following Temporary Soil Stabilization Treatment (SS-4) is applied in two phases:

- *Phase 1* applies seed of Burial Tolerant Species UNDER a fiber and compost layer at least 10mm thick to maintain viability if applied post-construction during periods unfavorable for germination. In the SR46 Corridor, high temperatures exceeding 38C (100F) can occur anytime from April through June, and highs over 43C (110F) are not uncommon from June through October.
- *Phase 2* applies seed of Burial Intolerant Species OVER the fiber and compost layer applied during *Phase 1*. This is necessary to establish the best understory of native perennial forbs, e.g., Common Yarrow, and native annual grasses, e.g., Small Fescue, or to establish subshrubs such as Interior California Buckwheat or Golden Yarrow.

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Phase 1: Post-Construction

	"Type D" EC Treatment		Additional Recommended EC Measures	
	Application Rates			
	lb / ac	kg / ha		
Fiber ≥	4000	4485	**Jute Netting**	
Compost ≥	1000	1120	**Toe Treatment**	
Fertilizer	NONE	NONE	*Physical:*	**EC Blanket**
Stabilizing Emulsion	0—5	0—5.5	*or Live Plants:*	**See Table 4.6**
Added Seed	40—45	45—50		
Burial TOLERANT Species ONLY; see Table 4.4				

Phase 2: December Just Prior To Reliable Rain Season

	"Type D" EC Treatment	
	Application Rates	
	lb / ac	kg / ha
Fiber	2000	2242
Compost ≥	500	560
Fertilizer	NONE	NONE
Stabilizing Emulsion	0—5	0—5.5
Added Seed	40—45	45—50
Burial INTOLERANT Species ONLY; see Table 4.5		

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	EXPECTED RESULTS		
	Phase 1 ONLY **WITH** Jute Without Toe Treatment	Phase 1 and Phase 2 **WITH** Jute Without Toe Treatment	Phase 1 and Phase 2 **WITH** Jute **WITH** Toe Treatment
Water Quality			
Runoff	Moderate to Low	Moderate to Low	**Low**
Sediment Concentration	Low	Low	**Very Low**
Vegetation			
Structure			
Dominants	Annual Grasses Annual Legumes Some Perennial Grasses	Perennial Grasses Annual Grasses Annual Legumes	Perennial Grasses Annual Grasses Annual Legumes
Subordinates	Annual Forbs	Perennial Forbs Annual Grasses	Perennial Forbs Annual Grasses
Composition			
Dominants	~ 70 – 80% Naturalized ~ 10 – 20% Native	~ 50 – 70% Native ~ 30 – 50% Naturalized	~ 50 – 70% Native ~ 30 – 50% Naturalized
Subordinates	~ 70 – 80% Naturalized ~ 10 – 20% Native	~ 60 – 70% Native ~ 30 – 40% Naturalized	~ 60 – 70% Native ~ 30 – 40% Naturalized
Cover			
Overstory	High	High	High
Understory	Low to Moderate	High	High
Persistence	Indefinite	Indefinite	Indefinite

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Table 4.4. SR 46 Native Species Best Seeded UNDER EC Layer 10—15 mm Thick.

NATIVE	PERENNIAL	ANNUAL	LEGUME	GRASS_GRAMINOID	FORB	SHRUB	SCIENTIFIC NAME	COMMON NAME	SOURCE
▸	▸			▸			*Bromus carinatus* H.&A. var. carinatus	California Brome	SR46* or C
▸	▸			▸			*Elymus elymoides* (Raf.) Swezey	Squirreltail	SR46* or C
▸	▸			▸			*Melica californica* Scribner	California Melic	! SR 46*
▸	▸			▸			*Melica imperfecta* Trin.	Coast Range Melic	SR46* or C
▸	▸			▸			*Nassella cernua* (Stebb. & Love) Barkworth	Nodding Needlegrass	SR46* or C
▸	▸			▸			*Nassella pulchra* (A.S. Hitchc.) Barkworth	Purple Needlegrass	SR46* or C
▸	▸			▸			*Poa scabrella* (Thunb.) Benth.	Malpais Bluegrass	! SR 46*
▸	▸				▸		*Eschscholzia californica* Cham.	California Poppy	SR46* or C
▸		▸	▸		▸		*Lupinus bicolor* Lindley	Miniature Lupine	SR46* or C
▸		▸	▸		▸		*Lupinus nanus* Douglas ex Benth.	Sky Lupine	SR46* or C
▸	▸	▸	▸	▸	▸		*Lupinus succulentus* Douglas ex Koch	Arroyo Lupine	SR46* or C

SR46* = Seed collected from native stands within SR46 Corridor   ! **SR 46*** = Use SR46* seed sources only   **C** = Commercial seed sources.

Table 4.5. SR 46 Native Species Best Seeded OVER EC Layer Greater Than 10 mm Thick.

NATIVE	PERENNIAL	ANNUAL	LEGUME	GRASS_GRAMINOID	FORB	SHRUB	SCIENTIFIC NAME	COMMON NAME	SOURCE
▸		▸		▸			*Bromus arizonicus* (Shear) Stebbins	Arizona Brome	SR46* or C
▸		▸		▸			*Vulpia microstachys* (Nutt.) Benth.	Small Fescue	SR46* or C
▸	▸				▸		*Achillea millefolium* L.	Common Yarrow	SR46* or C
▸	▸				▸		*Eschscholzia californica* Cham.	California Poppy	! SR 46*
▸		▸			▸		*Lasthenia californica* DC. ex Lindley	Dwarf Goldfields	SR46* or C
▸		▸			▸		*Layia platyglossa* (Fischer & C. Meyer) A. Gray	Tidy Tips	SR46* or C
▸		▸	▸		▸		*Lotus purshianus* (Benth.) Clem. & Clem.	Spanish Lotus	SR46* or C
▸	▸					▸	*Eriogonum fasciculatum* Benth. var. foliolosum (Nutt.) Abrams	Interior California Buckwheat	SR46* or C
▸	▸					▸	*Eriophyllum confertiflorum* (DC.) A. Gray var. confertiflorum	Golden Yarrow	SR46* or C

SR46* = Seed collected from native stands within SR46 Corridor   ! **SR 46*** = Use SR46* seed sources only   **C** = Commercial seed sources.

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Table 4.6. SR 46 Native Species Best Suited For Use As Living Toe Treatment.

Toe Treatment		
Live Plants		
Best	Sod Strips	
Next Best	Plugs 2 inch to 4 inch size at 6 inch to 8 inch centers	
Suitable Species	Native Perennial Grasses	
	Bromus carinatus H.&A. var. carinatus	California Brome
	Hordeum californicum Covas & Stebb.	California Barley
	Leymus triticoides Buckley	Creeping Wild Rye
	Melica californica Scribner	California Melic
	Melica imperfecta Trin.	Coast Range Melic
	Nassella cernua (Stebb. & Love) Barkworth	Nodding Needlegrass
	Nassella pulchra (A.S. Hitchc.) Barkworth	Purple Needlegrass
	Poa scabrella (Thunb.) Benth.	Malpais Bluegrass
	Native Perennial Forbs	
	Achillea millefolium L.	Common Yarrow

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A.1 Abbreviations

ac	acre	**m**	meter
°C	degrees Celsius	**mg**	milligram
cm	centimeter	**mg/l**	milligrams per liter
cm/hr	centimeters per hour	**meq**	milliequivalents
CO_2	Carbon Dioxide	**min**	minute
°F	degrees Fahrenheit	**mm**	millimeter
ft	feet	**m/s**	meters per second
ft^2	square feet	**m^3**	cubic meters
ft^3	cubic feet	**m^3/yr**	cubic meters/year
g	gram	**N**	Nitrogen (elemental)
ha	hectares	**N_2**	Nitrogen (molecular) or Nitrogen gas
in	inches	**NH_3**	Ammonia
in/hr	inches per hour	**NH_4^+**	Ammonium ion
hr(s)	hour(s)	**NO_3^-**	Nitrate ion
°K	degrees Kelvin	**O_2**	Oxygen
kg/ha	kilograms per hectare	**pH**	"power of Hydrogen" $-\log_{10}[H^+]$
kPa	kilo pascals (force)	**ppm**	parts per million
kg/m^2	kilograms per square meter	**psi**	pounds (force) per square inch
km	kilometer	**s**	second
l	liter	**v:h**	vertical : horizontal
lb	pound (US)	**yd^3**	cubic yard
lb/ac	pounds per acre	**yr(s)**	year(s)

$>$	greater than
$\geq$	greater than or equal to
$<$	less than
$\leq$	less than or equal to

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A.2 Acronyms

ANOVA	Analysis of Variance
ASTM	American Society for Testing and Materials International
BFM	Bonded Fiber Matrix
BMP	Best Management Practice
Caltrans	California Department of Transportation
CEC	Cation Exchange Capacity (soil property)
CEQA	California Environmental Quality Act
CIMIS	California Irrigation Management Information System
CWA	Clean Water Act
DWR	California Department of Water Resources
EA	Expenditure Authorization
EC	Electrical Conductivity; Erosion Control (context-dependent)
EPA	U.S. Environmental Protection Agency
FHWA	Federal Highway Administration
GW	Groundwater
HSD	Honestly Significant Difference (statistical sense)
HSG	Hydrologic Soil Group
KP	Kilometer Post
MCL	Maximum Contaminant Level
NEPA	National Environmental Policy Act
NOAA	National Oceanic and Atmospheric Administration
NRCS	Natural Resources Conservation Service (USDA)
NTU	Nephelometric Turbidity Unit
OC	Organic Content
PLS	Pure Live Seed
RECP	Rolled Erosion Control Products
RO	Runoff
RS	Rainfall Simulator
RSP	Rock Slope Protection
RWQCB	Regional Water Quality Control Board
SW	Storm Water
SWMP	Storm Water Management Plan
SWPPP	Storm Water Pollution Prevention Plan
SWQA	Storm Water Quality Assessment
SWRCB	California State Water Resources Control Board
TDS	Total Dissolved Solids or Sediment
TKN	Total Kjeldahl Nitrogen
TMDL	Total Maximum Daily Load
TSS	Total Suspended Solids
USDA	United States Department of Agriculture
USGS	United States Geological Survey
UV	Ultraviolet
VEMS	Vegetation Establishment and Maintenance Study
WQ	Water Quality

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A.3 Terms

Analysis of Variance (ANOVA)

A suite of univariate statistical methods that test a null hypothesis that population means are equal by analysing group variances.

Best Management Practice (BMP)

A BMP is a measure that is implemented to protect water quality and reduce potential for pollution associated with storm water **runoff**. Any program, technology, process, siting criteria, operating method, or device that controls, prevents, removes, or reduces pollution. There are four categories of BMPs: Maintenance, Design Pollution Prevention, Construction Site, and Treatment

Maintenance BMPs are water quality controls used to reduce pollutant discharges during highway maintenance activities and activities conducted at maintenance facilities. These BMPs are technology-based controls that attain MEP pollutant control. This category of BMPs includes litter pickup, toxics control, street sweeping, etc.

Design Pollution Prevention BMPs are permanent water quality controls used to reduce pollutant discharges by preventing **erosion**. These BMPs are standard technology-based, non-treatment controls selected to reduce pollutant discharges to the **MEP** requirements. They are applicable to all projects. This category of BMPs includes preservation of existing vegetation; concentrated flow conveyance systems, such as ditches, berms, dikes, swales, overside drains, outlet protection/velocity dissipation devices; and slope/surface protection systems such as vegetated surfaces and hard surfaces.

Construction site BMPs are temporary controls used to reduce pollutant discharges during construction. These controls are best conventional technology/best available technology **BCT/BAT** based BMPs that may include **soil stabilization**, sediment control, wind **erosion** control, tracking control, non-storm water management and waste management.

Treatment BMPs are permanent water quality controls used to remove pollutants from storm water **runoff** prior to being discharged from Caltrans right-of-way. These controls are used to meet **MEP** requirements and are considered for projects discharging directly or indirectly to **receiving waters**. This category of BMPs includes: traction sand traps, infiltration basins, detention devices, biofiltration strips/swales, dry weather flow diversion, and **GSRDs**.

California Environmental Quality Act (CEQA)

The CEQA of 1970 requires public agencies to prevent significant, avoidable damage to the environment by regulating activities that may affect the quality of the environment. Public agencies accomplish this by requiring projects to consider the use of alternatives or mitigation measures. Regulations for the implementation of CEQA are found in the CEQA Guidelines and are available online by the California Resources Agency at http://ceres.ca.gov/ceqa.

Caltrans Permit

Caltrans Permit refers to the **NPDES** Statewide Storm Water Permit issued to Caltrans in 1999 (Order No. 99-06-DWQ) (CAS000003), to regulate storm water discharges from Caltrans facilities.

Categorical Exemption (CE)

A CE is a list of classes of projects that have been determined not to have a significant effect on the environment and which shall, therefore, be exempt from the provisions of **CEQA**. For a list of classes of projects and further information see the web site
http://ceres.ca.gov/topic/env_law/ceqa/guidelines/art19.html

Clean Water Act (CWA)

The CWA, originally enacted by Congress in 1972, is a federal law that requires states to protect, restore, and maintain the quality of the waters of the United States, including lakes, rivers, aquifers and coastal areas. The CWA, as amended in 1987, is the enabling legislation for the **NPDES** permitting process.

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Code of Federal Regulations (CFR)

The CFR is a document that codifies all rules of the executive departments and agencies of the federal government. It is divided into 50 volumes, known as titles. Title 40 of the CFR (referenced as 40 CFR) contains all environmental regulations. 40 CFR is available from bookstores operated by the Government Printing Office and online at: http://www.epa.gov/epahome/cfr40.htm.

Construction Site

The term "construction site" should apply to all areas both within the construction limits on state right-of-way and areas that are directly related to the construction activity, including but not limited to staging areas, storage yards, material borrow areas and storage areas, access roads, barges or platforms, etc., whether or not they reside within the Caltrans right-of-way.

Construction Site Best Management Practices Manual

The Construction Site Best Management Practices Manual provides instructions for the selection and implementation of Construction Site **BMPs**. Caltrans requires contractors to identify and utilize these BMPs in preparation of their **SWPPP** or **WPCP**.

Department of Water Resources (DWR)

The California DWR (http://wwwdwr.water.ca.gov/) is a State Government department created to manage the water resources of California in cooperation with other agencies in such a way as to benefit the State's people, and to protect, restore, and enhance the natural and human environments. The DWR is a source for hydrology data, **groundwater** information, water maps, etc.

Electrical Conductivity (EC)

Measure of the ability of water to carry an electric current. This ability depends on the presence of ions, their concentration, valence, mobility and temperature. EC measurements can give an estimate of the variations in the dissolved mineral content of storm water in relation to receiving waters.

Erosion

Wearing away of land surfaces by water, wind, ice, or kinetics causing detachment of soil or rock.

Existing Vegetation

Existing vegetation is any plant material within the project limits that is present prior to the beginning of construction.

Geographic Information System (GIS)

GIS is a system of hardware and software used for storage, retrieval, mapping, and spatial analysis of geographic data.

Groundwater (GW)

GW is defined as the water that is naturally occurring under the earth's surface. It is situated below the surface of the land, irrespective of its source and transient status. Subterranean streams are flows of GW parallel to and adjoining stream waters, and usually determined to be integral parts of the visible streams. GW is considered a jurisdictional water of the State under the Porter-Cologne Water Quality Act (California Water Code, Division 7).

Highway Planting

Vegetation placed for aesthetic, safety, environmental mitigation, or erosion control purposes, including necessary irrigation systems, inert materials, mulches, and appurtenances. Highway planting provides for a level of planting that is compatible with the surrounding environment.

Holding Time

Holding time is specified by the analytical method and is the elapsed time between the time the sample is collected and the time the analysis must be initiated.

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Metals (Total and Dissolved)

Metals, both total and dissolved, are commonly monitored constituents and, next to **TSS** and **nutrients**, are the most common constituents cited in the literature as being present in storm water **runoff.**

Trace quantities of many metals are necessary for biological growth and may naturally occur in runoff. Most metals, however, have numeric water quality standards because of their toxicity to aquatic organisms at high concentrations. Toxicity of some metals is inversely related to water hardness. The numeric water quality standards for cadmium, chromium, copper, lead, nickel, silver and zinc are hardness-dependent. Copper, lead and zinc are the metals most commonly found in highway runoff.

National Environmental Policy Act (NEPA)

The NEPA of 1969 establishes policies and procedures to bring environmental considerations into the planning process for federal projects. NEPA requires all federal agencies to identify and assess reasonable alternatives to proposed actions that will restore and enhance the quality of the human environment and avoid or minimize adverse environmental impacts. The NEPA process is an overall framework for the environmental evaluation of federal actions.

Natural Resources Conservation Service (NRCS)

As part of the USDA, the NRCS provides leadership in a partnership effort to help people conserve, maintain, and improve natural resources and the environment. Soil types and local soil survey data can be obtained from the NRCS soil maps. The soil type and soil survey data are used during the desktop screening of potential infiltration basin sites.

Nephelometric Turbidity Units (NTU)

Unit that measures water quality based on "cloudiness" using a **nephelometer** (Greek: *nephele*, cloud) that assesses turbidity directly by comparing the amount of light transmitted straight through a water sample with the amount scattered at an angle of 90° to one side; this **unitless ratio** determines the turbidity in NTU's. The instrument is calibrated using samples of a standard solution such as **formazin**, a synthetic polymer. Drinking water should not exhibit turbidity above 1 NTU, although values up to 5 NTU are usually considered safe. Outside the U.S., this unit is usually called the **FNU** (**F**ormazin **N**ephelometric **U**nit), specified in standard ISO 7027 by the International Organization for Standardization.

New Construction/Major Reconstruction

New construction and major reconstruction includes new routes, route alignments, route upgrades (i.e., from two-lane conventional highway to four-lane expressway or freeway), and right-of-way acquisitions for whole parcels or wide swaths. New construction activity does not include routine maintenance to maintain original line and grade, hydraulic capacity, or original purpose of the facility, nor does it include emergency construction activities required to protect public health and safety.

Nutrients

Nutrients are nutritive substances such as phosphorous and nitrogen whose excessive input into **receiving waters** can over-stimulate the growth of aquatic plants.

Algae and vascular plants can cause numerous deleterious effects. Algae and vascular aquatic plants produce oxygen during the day via photosynthesis and consume oxygen during the night via respiration. The pH of the water is linked to this phenomenon through the carbonate cycle: the pH rises during the day when carbon dioxide (CO_2) is consumed for the photosynthetic production of plant tissue and falls at night when CO_2 is released by respiration. Algal blooms due to inputs of nitrogen or phosphorus can cause wide fluctuations in this dissolved oxygen and pH cycle during a 24-hour period, which can cause fish kills and mass mortality of benthic organisms. In addition, excessive algal and vascular plant growth can accelerate eutrophication, interfere with navigation, and cause unsightly conditions with reduced water clarity, odors, and diminished habitat for fish and shellfish.

Other trace nutrients, such as iron, are also needed for plant growth. In general, however, phosphorus and nitrogen are the nutrients of importance in aquatic environments.

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Phosphorus. Phosphorus is taken up by algae and vascular aquatic plants and, when available in excess of the plant's immediate needs for metabolism and reproduction, can be stored in the cells. With bacterial decomposition of plant materials, relatively labile pools of phosphorus are later released and recycled within the biotic community. The refractory portion (i.e., compounds relatively resistant to biodegradation) tends to sink to the bottom, where it degrades slowly over time.

Analytical tests for the minimum constituent list include TP, which is the sum of the dissolved and particulate orthophosphate, polyphosphate and organic phosphorus; and Total Ortho-P, which is the sum of the dissolved and particulate orthophosphate.

Nitrogen. Transformation of nitrogen compounds can occur through several key mechanisms: fixation, ammonification, synthesis, nitrification, and denitrification. Nitrogen fixation is the conversion of nitrogen gas into nitrogen compounds that can be assimilated by plants; biological fixation is the most common, but fixation can also occur by lightning and through industrial processes. Ammonification is the biochemical degradation of organic-N into NH_3 or NH_4^+ by heterotrophic bacteria under aerobic or anaerobic conditions. Synthesis is the biochemical mechanism in which NH_4^+-N or NO_3^--N is converted into plant protein (Organic-N); nitrogen fixation is also a unique form of synthesis that can be performed only by nitrogen-fixing bacteria. Nitrification is the biological oxidation of NH_4^+ to NO_3^- through a two-step autotrophic process by the bacteria *Nitrosomonas* and *Nitrobacter*; the two-step reactions are usually very rapid, and hence it is rare to find nitrite levels higher than 1.0 mg/l in water. The nitrate formed by nitrification is, in the nitrogen cycle, used by plants as a nitrogen source (synthesis) or reduced to N_2 gas through the process of denitrification; NO_3^- can be reduced, under anoxic conditions, to N_2 gas through heterotrophic biological denitrification.

Analytical tests for the minimum constituent list include NH_3/NH_4^+-N, NO_3^--N, and Total TKN. TKN is a measure of NH_3/NH_4^+-N plus organic-N; the concentration of organic-N is thus obtained by subtracting the concentration of NH_3/NH_4^+-N found in the sample from that of the TKN value.

pH

The pH scale is based on $-\log_{10}[H^+]$ in a sample and literally translates as the "power of Hydrogen" and expresses the intensity of an acid or base (alkaline) condition. The pH scale ranges from extreme acids of 1 to extreme bases of 14, with neutral being 7. Units are moles of hydrogen per liter. Extremes of pH can have deleterious effects on biological systems.

Planting Restoration

The renovation or rehabilitation of planting areas and irrigation systems to improve access and working conditions, incorporate "design for safety" features, reduce maintenance expenditures, reduce water consumption or utilize nonpotable water. Restoration is justified when capital costs can be recovered through maintenance savings within 12 years. Improvement of access and working conditions, incorporation of safety features, installation of Remote Irrigation Control System (RICS), and conversion to nonpotable water (see "Nonpotable Water" in Chapter 29, Section 2, Article 1 – General Policy) do not require a 12-year payback.

Regional Water Quality Control Board (RWQCB)

The RWQCB means any California RWQCB for a region as specified in Section 13200 of the California Water Code. There are nine RWQCBs that serve under the **SWRCB.** These nine RWQCBs are located in California and are responsible for enforcing water quality standards within their boundaries. A map of these boundaries is located in Section 2, Figure 2-1.

Replacement Planting

Planting to replace planting (installed by Caltrans or others) that is damaged or removed as a result of highway construction activity, including irrigation modification and/or replacement.

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Revegetation

Planting of indigenous plants to replace natural vegetation that is damaged or removed as a result of highway construction projects or permits requirements. This work may include irrigation systems.

Runoff (RO)

Surface waters that exceed the soil's infiltration rate and depression storage. It includes that portion of precipitation that appears as flow in streams, and also includes drainage or flood discharges that leave an area as surface flow or as pipeline flow, having reached a channel or pipeline by either surface or subsurface routes.

Sediment

Solid particulate matter, both mineral and organic, that is in suspension, is being transported, or has been moved from its site of origin by air, water, gravity, or ice and has come to rest on the earth's surface either above or below sea level.

Sedimentation/Siltation

The process of sediment/silt deposition.

Settleable Solids

The settleable solids (SS) tests measures the solid material that can be settled within a water column during a specified time frame. This typically is tested by placing a water sample into an Imhoff settling cone and allowing the solids to settle by gravity. Results are reported either as a volume (mL/L) or a weight (mg/L).

Silt

Soil particles between 0.05mm and 0.002mm in size. (For the purposes of its use here, it also includes clay, which is categorized by a particle size less than 0.002mm.)

Slope/Soil Stabilization

Soil stabilization is described as vegetation, such as grasses and wildflowers, and other materials, such as straw, fiber, stabilizing emulsion, protective blankets, etc. Soil stabilization is placed to stabilize areas disturbed by grading operations, to reduce loss of soil due to the action of water or wind, and to prevent water pollution.

Soil Amendment

Any material that is added to the soil to change its chemical properties, engineering properties, or erosion resistance that could become mobilized by storm water and would be not visible in the runoff. Soil amendments include lime, cementitious binders, chlorides, emulsions, polymers, soil stabilizers, and tackifiers applied as a stand-alone treatment (i.e., without mulch). Plant fibers (such as straw or hay), wood and recycled paper fibers (such as mulches and matrices), bark or wood chips, green waste or composted organic materials, and biodegradable or synthetic blanket fibers would not be included as soil amendments in this context because they would be visible in storm water runoff.

State Water Resources Control Board (SWRCB)

As delegated by the **EPA**, the SWRCB is a California agency that implements and enforces the **CWA** Section 401 (p) **NPDES** permit requirements, and is the issuer and administrator of the **Caltrans Permit**. The SWRCB's mission is to preserve, enhance and restore the quality of California's water resources, and ensure their proper allocation and efficient use for the benefit of present and future generations.

Statewide Storm Water Quality Practice Guidelines (Guidelines)

The Caltrans Guidelines describe each approved **BMP** included in the **SWMP** for Statewide application,. with instructions on implementing each approved storm water management practice or BMP.

Storm Water Management Plan (SWMP)

The SWMP is the Caltrans policy document that describes how Caltrans conducts its storm water management activities (i.e., procedures and practices). The SWMP provides descriptions of each of the major management program elements, discusses the processes used to evaluate and select appropriate

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BMPs, and presents key implementation responsibilities and schedules.

Storm Water Quality Assessment (SWQA)

The SWQA is a technical report prepared by the Caltrans Environmental Unit staff during the PA/ED process, for inclusion into the **CEQA/NEPA** documents. The SWQA provides input to the PE for completing the **SWDR**.

Suspended Sediment Concentration (SSC)

The suspended sediment concentration (SSC) test measures the concentration of suspended solid material in a water sample by measuring the dry weight of all of the solid material from a known volume of a collected water sample. Results are reported in mg/L. A high suspended solids level impacts the clarity of the water which may decrease the depth to which sunlight can penetrate the water and adversely impact aquatic plant growth. It also reduces the concentration of oxygen in the water, potentially affecting the ability of aquatic animals and plants to survive and flourish due to oxygen deprivation.

Total Dissolved Solids (TDS)

TDS refers to the sum of all cations or anions (sometimes measured in parts per million as calcium carbonate). TDS comprise inorganic salts (principally calcium, magnesium, potassium, sodium, bicarbonates, chlorides and sulfates) and small amounts of organic matter that are dissolved in water.

In fresh water the total dissolved solids concentration typically ranges from 20 to 1,000 mg/l; in seawater it ranges from 30,000 to 35,000 mg/l. High levels of dissolved solids concentrations can adversely affect drinking water quality.

Total Maximum Daily Load (TMDL)

TMDLs are pollutant load allocations for all point sources and nonpoint sources, and are intended to achieve a pollutant reduction goal along with a safety factor. TMDLs are developed in response to identification of **pollutants** as impairing a specific body of water identified in the 303(d) list.

Total Suspended Solids (TSS)

TSS is the weight of particles that are suspended in water. The total suspended solids test (TSS) test measures the concentration of suspended solids in water by measuring the dry weight of a solid material contained in a known volume of a sub-sample of a collected water sample. Results are reported in mg/L. A high suspended solids level impacts the clarity of the water which may decrease the depth to which sunlight can penetrate the water and adversely impact aquatic plant growth. It also reduces the concentration of oxygen in the water, potentially affecting the ability of aquatic animals and plants to survive and flourish due to oxygen deprivation. Suspended solids in a water sample include inorganic substances, such as soil particles and organic substances, such as algae, aquatic plant/animal waste, particles related to industrial/sewage waste, etc.

Turbidity

Cloudiness of water quantified by the degree to which light traveling through a water column is scattered by the suspended organic and inorganic particles it contains. The scattering of light increases with a greater suspended load. Turbidity is commonly measured in Nephelometric Turbidity Units (NTU), *q.v.*

United States Environmental Protection Agency (EPA)

The EPA (http://www.epa.gov/) provides leadership in the nation's environmental science, research, education and assessment efforts. The EPA works closely with other federal agencies, state and local governments, and Indian tribes to develop and enforce regulations under existing environmental laws. The EPA is responsible for researching and setting national standards for a variety of environmental programs and delegates to states and tribes responsible for issuing permits, and monitoring and enforcing compliance. The EPA issued regulations to control pollutants in storm water **runoff discharges**, such as the **CWA**. (The CWA and **NPDES** permit requirement.)

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Vegetative Erosion Control

Vegetation (grasses and wildflowers, and other materials like straw, fiber, stabilizing emulsion, protective blankets, etc.) placed to stabilize areas disturbed by grading operations, to reduce loss of soil due to the action of water or wind, and to prevent water pollution.

Water Quality Volume (WQV)

The WQV is the volume of flows associated with the frequent storm events that must be treated. The WQV of treatment **BMPs** is based upon, where established, the sizing criteria from the **RWQCB** or local agency (whichever is more stringent). If no sizing criterion has been established, Caltrans will do one of the following: maximize detention volume determined by the 85th percentile **runoff** capture ratio or; use volume of annual runoff based on unit basin storage WQV to achieve 80 percent or more volume of treatment. For further detail, refer to Section 2.4.2.2.

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Appendix B UNITS and CONVERSIONS

B.1 Basic SI Units

The International System of Units (SI) derives from the French *Le Systeme International d'Unites* that was formally adopted during October 1960 and has been officially recognised and adopted by nearly all countries. The System is based upon 7 principal units, 1 in each of 7 different categories (adapted from Tapson 2004).

Basic Unit	Unit Name	Definition
Length	**metre [m]**	The distance light travels, in a vacuum, in 1/299792458*th* of a second.
Mass	**kilogram [kg]**	The mass of an international prototype in the form of a platinum-iridium cylinder kept at Sevres in France. *It is now the only basic unit still defined in terms of a material object, and also the only one with a prefix [kilo] already in place.*
Time	**second [s]**	The length of time taken for 9192631770 periods of vibration of the caesium-133 atom to occur.
Temperature	**kelvin [K]**	It is 1/273.16*th* of the thermodynamic temperature of the triple point of water. *It is named after the Scottish mathematician and physicist William Thomson 1st Lord Kelvin (1824-1907).*
Electric Current	**ampere [A]**	That constant current which, if maintained in two straight parallel conductors of infinite length, of negligible circular cross-section, and placed 1 metre apart in vacuum, would produce between these conductors a force equal to 2 x 10-7 newton per metre of length. *It is named after the French physicist Andre Ampere (1775-1836).*
Matter	**mole [mol]**	The amount of substance that contains as many elementary units as there are atoms in 0.012 kg of carbon-12.
Light Intensity	**candela [cd]**	The luminous intensity, in a given direction, of a source that emits monochromatic radiation of frequency 540 ´ 1012 hertz and that has a radiant intensity in that direction of 1/683 watt per steradian.

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B.2 Derived SI Units

From the 7 basic SI units other units are derived. A few of the most common are listed here (adapted from Tapson 2004).

Derived Unit	Unit Name	Definition
Work	**joule [J]**	The joule is the SI unit of work or energy. One joule is the amount of work done when an applied force of 1 **newton** moves through a distance of 1 **metre** in the direction of the force. It is named after the English physicist James Prescott Joule (1818-89).
Power	**watt [W]**	The watt is used to measure power or the rate of doing work. One **watt** is a power of 1 **joule** per second. It is named after the Scottish engineer James Watt (1736-1819).
Force	**newton [N]**	The newton is the SI unit of force. One newton is the force required to give a mass of 1 kilogram an acceleration of 1 metre per second per second. It is named after the English mathematician and physicist Sir Isaac Newton (1642-1727).
Pressure	**pascal [Pa]**	The pascal is the SI unit of pressure. One pascal is the pressure generated by a force of 1 **newton** acting on an area of 1 square **metre**. It is a rather small unit as defined and is more often used as a **kilopascal** [**kPa**]. It is named after the French mathematician, *physicist and philosopher Blaise Pascal (1623-62).*
Period Frequency	**hertz [Hz]**	The hertz is the SI unit of the frequency of a periodic phenomenon. One hertz indicates that **1 cycle** of the phenomenon occurs **every second**. For most work much higher frequencies are needed such as the **kilohertz** [**kHz**] and **megahertz** [**MHz**]. It is named after the German physicist Heinrich Rudolph Hertz (1857-94).
Electrical Capacitance	**farad [F]**	The farad is the SI unit of the capacitance of an electrical system, that is, its capacity to store electricity. It is a rather large unit as defined and is more often used as a **microfarad**. *It is named after the English chemist and physicist Michael Faraday (1791-1867).*
Electrical Resistance	**ohm [Ω]**	The ohm is the SI unit of resistance of an electrical conductor. Its symbol, is the capital Greek letter 'omega'. It is named after the German physicist Georg Simon Ohm (1789-1854).
Electrical Potential	**volt [V]**	The volt is the SI unit of electric potential. One volt is the difference of potential between two points of an electical conductor when a current of 1 **ampere** flowing between those points dissipates a power of 1 **watt**. It is named after the Italian physicist Count Alessandro Giuseppe Anastasio Volta (1745-1827).

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B.3 Common Conversion Factors

FROM	Operation		TO	FROM	Operation		TO
acres	**x 0.4047**	=	hectares	kilograms	**x 35.3**	=	ounces
acres	**/ 247**	=	sq. kilometres	kilograms	**x 2.2046**	=	pounds
acres	**x 4047**	=	sq. metres	kilograms	**/ 1000**	=	tonnes
acres	**/ 640**	=	sq. miles	kilograms	**/ 1016**	=	tons (UK/long)
barrels (oil)	**/ 6.29**	=	cu.metres	kilograms	**/ 907**	=	tons (US/short)
barrels (oil)	**x 34.97**	=	gallons (UK)	kilometres	**x 1000**	=	metres
barrels (oil)	**x 42**	=	gallons (US)	kilometres	**x 0.6214**	=	miles
barrels (oil)	**x 159**	=	litres	litres	**x 61.02**	=	cu.inches
centimetres	**/ 30.48**	=	feet	litres	**x 0.2200**	=	gallons (UK)
centimetres	**/ 2.54**	=	inches	litres	**x 0.2642**	=	gallons (US)
centimetres	**/ 100**	=	metres	litres	**x 1.760**	=	pints (UK)
centimetres	**x 10**	=	millimetres	litres	**x 2.113**	=	pints (US liquid)
cubic cm	**x 0.06102**	=	cubic inches	metres	**/ 0.9144**	=	yards
cubic cm	**/ 1000**	=	litres	metres	**x 100**	=	centimetres
cubic cm	**x 1**	=	millilitres	miles	**x 1.609**	=	kilometres
cubic feet	**x 1728**	=	cubic inches	millimetres	**/ 25.4**	=	inches
cubic feet	**x 0.0283**	=	cubic metres	ounces	**x 28.35**	=	grams
cubic feet	**/ 27**	=	cubic yards	pints (UK)	**x 0.5683**	=	litres
cubic feet	**x 6.229**	=	gallons (UK)	pints (UK)	**x 1.201**	=	pints (US liquid)
cubic feet	**x 7.481**	=	gallons (US)	pints (US liquid)	**x 0.4732**	=	litres
cubic feet	**x 28.32**	=	litres	pints (US liquid)	**x 0.8327**	=	pints (UK)
cubic inches	**x 16.39**	=	cubic cm	pounds	**x 0.4536**	=	kilograms
cubic inches	**x 0.01639**	=	litres	pounds	**x 16**	=	ounces
cubic metres	**x 35.31**	=	cubic feet	square cm	**x 0.1550**	=	sq. inches
feet	**x 30.48**	=	centimetres	square feet	**x 144**	=	sq. inches
feet	**x 0.3048**	=	metres	square feet	**x 0.0929**	=	sq. metres
feet	**/ 3**	=	yards	square inches	**x 6.4516**	=	square cm
fl.ounces (UK)	**x 0.961**	=	fl.ounces (US)	square inches	**/ 144**	=	square feet
fl.ounces (UK)	**x 28.41**	=	millilitres	square km	**x 247**	=	acres
fl.ounces (US)	**x 1.041**	=	fl.ounces (UK)	square km	**x 100**	=	hectares
fl.ounces (US)	**x 29.57**	=	millilitres	square km	**x 0.3861**	=	square miles
gallons	**x 8**	=	pints	square metres	**/ 4047**	=	acres
gallons (UK)	**x 0.1605**	=	cubic feet	square metres	**/ 10 000**	=	hectares
gallons (UK)	**x 1.2009**	=	gallons (US)	square metres	**x 10.76**	=	square feet
gallons (UK)	**x 4.54609**	=	litres	square metres	**x 1.196**	=	square yards
gallons (US)	**x 0.1337**	=	cubic feet	square miles	**x 640**	=	acres
gallons (US)	**x 0.8327**	=	gallons (UK)	square miles	**x 259**	=	hectares
gallons (US)	**x 3.785**	=	litres	square miles	**x 2.590**	=	square km
grams	**/ 1000**	=	kilograms	square yards	**/ 1.196**	=	square metres
grams	**/ 28.35**	=	ounces	tonnes	**x 1000**	=	kilograms
hectares	**x 2.471**	=	acres	tonnes	**x 0.9842**	=	tons (UK/long)
hectares	**/ 100**	=	square km	tonnes	**x 1.1023**	=	tons (US/short)
hectares	**x 10000**	=	square metres	tons (UK/long)	**x 1016**	=	kilograms
hectares	**/ 259**	=	square miles	tons (UK/long)	**x 1.016**	=	tonnes
hectares	**x 11 960**	=	square yards	tons (US/short)	**x 907.2**	=	kilograms
inches	**x 2.54**	=	centimetres	tons (US/short)	**x 0.9072**	=	tonnes
inches	**/ 12**	=	feet	yards	**x 0.9144**	=	metres

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C.1 Need For Project

During 2000, Caltrans Storm Water, in cooperation with the California State University Sacramento Office of Water Programs and the Earth and Soil Sciences Department of Cal Poly State University, San Luis Obispo, initiated a research program to statistically test for significant differences in water quality and vegetation establishment among existing soil stabilization specifications used by Caltrans to better reduce runoff and sediment transport in compliance with regulatory requirements.

In general, this project seeks to:

- Measure the effectiveness of a hydroseeded plant species in controlling runoff under varying rainfall regimes and hydroseed application methods;
- Identify and select plant species for hydroseeding that demonstrate initially fast growth and long-term erosion control under a variety of rainfall regimes;
- Characterize how various rainfall regimes affect seed germination and plant establishment;
- Characterize how various hydroseeding techniques affect seed germination and plant establishment;
- Compare the effects of plugs, flats (sod strips), and hydroseed planting techniques on minimizing erosion and improving water quality;
- Ascertain the effects of compost soil amendment on native vegetation cover, species composition, and weedy annual species suppression.

The following pages provide synopses of the experimental designs and results of experiments conducted to date involving modifications to existing soil stabilization specifications, as well as some promising innovative methods previously untested.

Design elements common to all experiments are listed or discussed in other appendices.

DESIGN ELEMENT	DETAILS
Terminology	**Appendix A**
Units And Conversions	**Appendix B**
Rainfall Simulators And Test Boxes	**Appendix D**
Runoff Collection And Analysis	**Appendix E**
Vegetation Sampling And Analysis	**Appendix F**

Because natural rainfall governed results to a large degree, **Chart C.1** shows the monthly average rainfall amounts from September 2000 through February 2005 and the 55 year monthly averages for comparison.

Section C.6 provides a list of products and services generated by this project to date.

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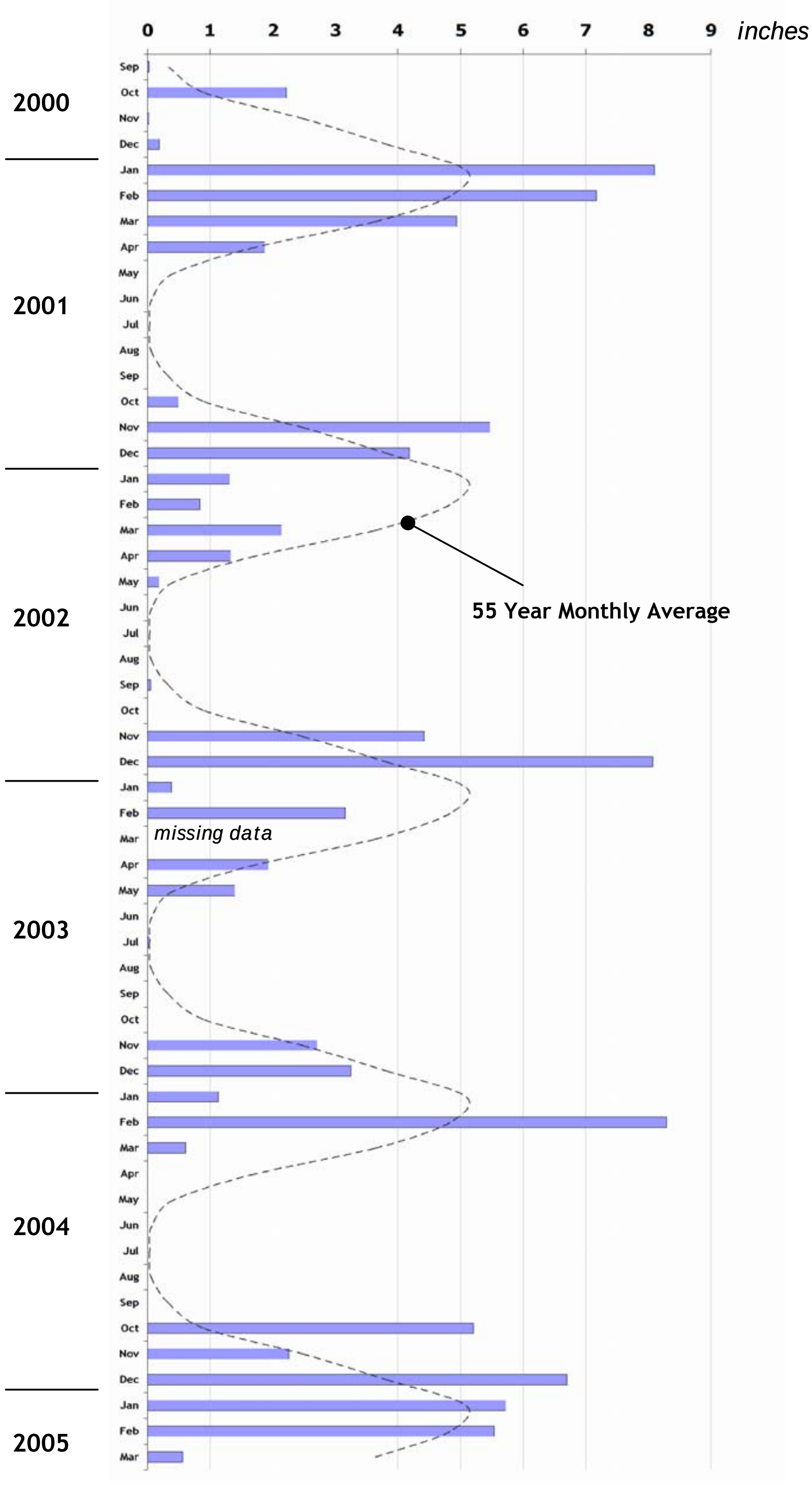

Chart C.1. Monthly Precipitation From September 2000 Through February 2005

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C.2 Exploratory Modifications to Existing Soil Stabilization Methods.

RS1 Experiment November 2000 - June 2001

Performance of standard erosion control measures and of a District 5 native seed mix on reapplied topsoil under simulated rainfall.

California Department of Transportation (Caltrans). 2001. Vegetation Establishment For Erosion Control Under Simulated Rainfall. **CTSW-RT-01-078**.

C.2.1 Research Problem

Problems with germination and establishment by burial intolerant native species or races are common to hydroseeding applications throughout California. Such problems are related to present erosion control specifications (Soil Stabilization BMP SS-4) designed to apply burial tolerant species, typically cereal grains or naturalized alien grasses, beneath layers of fiber, bonded fiber matrix, straw, erosion control blankets, used with or without tackifiers. Most cereal grains, naturalized alien grasses, and some native species used in seed mixes, are capable of emerging through such layers to provide additional aerial plant cover for soil stabilization. However, many native species are intolerant of such burial as they require diurnal fluctuations in light, temperature, moisture, or combinations thereof, to break dormancy. Existing specifications need modification to improve germination and establishment by burial intolerant native species. RS1 was designed to be an initial exploratory experiment using modifications to typical District 5 hydroseeding specifications and applications.

C.2.2 RS1 Experimental Design

The RS1 experiment was designed to test:

- whether present specifications of crimped straw or tackifier are effective at minimizing erosion;
- whether germination and establishment by a District 5 native species mix is inhibited by existing standard specifications for rates of crimped straw or tackifier;
- whether adequate plant cover can be established by 60 days or by 150 days to mollify erosion during modal or extreme precipitation events, respectively.

Table C.1 provides a synopsis of the experimental design; **Table C.2** lists the experimental treatments; and **Table C.3** lists the native species of the District 5 seed mix applied to all boxes.

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Table C.1. RS1 Experimental Design.

Test Boxes	**36**		
Treatments	**16** combinations of EC Treatment and Precipitation		
Replicates	**2** each		
Control	**4** (no EC treatment)		
Soil	Commercial "topsoil"; medium sandy loam		
Factor	**Level**	**Amount**	**Application**
Rainfall	High	840 mm (33 in)	Every 7–10 days
	Medium	560 mm (22 in)	Every 14–21 days
	Low	280 mm (11 in)	Every 21–28 days
	Natural	Natural [584mm (23 in)]	As seasonal rain fell
EC Treatment			
Straw	None	0	
	Straw	2240 kg/ha (2000 lb/ac)	Experiment Initiation
Tackifier (Psyllium)	None	0	
	Tackifier	168 kg/ha (150 lb/ac)	Experiment Initiation
Fertilizer (15:15:15)	None	0	
	Fertilizer	45 kg/ha (40 lb/ac)	Experiment Initiation
Seed Application			
Fiber	Fiber	897 kg/ha (800 lb/ac)	Experiment Initiation
Seed Mix	D5 natives	45 kg/ha (40 lb/ac)	Experiment Initiation
Response Variables	**Variable**	**Data Collection**	**Data Analysis**
	Total Runoff	see **Appx E**	see **Appx E**
	Total Sediment	see **Appx E**	see **Appx E**
	Sediment Concentration	see **Appx E**	see **Appx E**
	Plant Cover	see **Appx F.3**	see **Appx F.6.2**

Table C.2. RS1 Treatments.

Box	Trtmnt	EC Combination				PPT
2	1	Straw	~	~	D5 Mix	Low
30	1	Straw	~	~	D5 Mix	Low
11	2	Straw	~	~	D5 Mix	Medium
13	2	Straw	~	~	D5 Mix	Medium
17	3	Straw	~	~	D5 Mix	High
20	3	Straw	~	~	D5 Mix	High
22	4	Straw	~	~	D5 Mix	Natural
24	4	Straw	~	~	D5 Mix	Natural
1	5	~	~	Tackifier	D5 Mix	Low
28	5	~	~	Tackifier	D5 Mix	Low
4	6	~	~	Tackifier	D5 Mix	Medium
6	6	~	~	Tackifier	D5 Mix	Medium
9	7	~	~	Tackifier	D5 Mix	High
15	7	~	~	Tackifier	D5 Mix	High
19	8	~	~	Tackifier	D5 Mix	Natural
25	8	~	~	Tackifier	D5 Mix	Natural

Box	Trtmnt	EC Combination				PPT
10	9	Straw	Fertilizer	~	D5 Mix	Low
12	9	Straw	Fertilizer	~	D5 Mix	Low
8	10	Straw	Fertilizer	~	D5 Mix	Medium
31	10	Straw	Fertilizer	~	D5 Mix	Medium
3	11	Straw	Fertilizer	~	D5 Mix	High
29	11	Straw	Fertilizer	~	D5 Mix	High
21	12	Straw	Fertilizer	~	D5 Mix	Natural
26	12	Straw	Fertilizer	~	D5 Mix	Natural
23	13	~	Fertilizer	Tackifier	D5 Mix	Low
27	13	~	Fertilizer	Tackifier	D5 Mix	Low
16	14	~	Fertilizer	Tackifier	D5 Mix	Medium
18	14	~	Fertilizer	Tackifier	D5 Mix	Medium
7	15	~	Fertilizer	Tackifier	D5 Mix	High
14	15	~	Fertilizer	Tackifier	D5 Mix	High
5	16	~	Fertilizer	Tackifier	D5 Mix	Natural
32	16	~	Fertilizer	Tackifier	D5 Mix	Natural

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Table C.3. RS1 D5 Native Seed Mix.

Scientific Name	Vernacular Name	%PLS	Rate PLS lb/ ac	Rate PLS kg/ ha
Shrub				
Artemisia californica	California Sagebrush	2.5	1.0	1.2
Baccharis pilularis	Coyote Bush	2.5	1.0	1.2
Eriogonum fasiculatum	California Buckwheat	12.5	5.0	5.6
Lotus scoparius	Deer Lotus	5.0	2.0	2.2
Salvia mellifera	Black Sage	2.5	1.0	1.2
Perennial Grass				
Bromus carinatus	California Brome	25.0	10.0	11.2
Elymus glaucus	Blue Wild Rye	12.5	5.0	5.6
Nassella lepida	Foothill Needlegrass	5.0	2.0	2.2
Nassella pulchra	Purple Needlegrass	5.0	2.0	2.2
Annual Grass				
Festuca microstachys	Small Fescue	2.5	1.0	1.2
Perennal Forb				
Achillea millefolium	Common Yarrow	2.5	1.0	1.2
Annual Forb				
Eschscholzia californica	California Poppy	5.0	2.0	2.2
Lupinus succulentus	Arroyo Lupine	5.0	2.0	2.2
Trifolium gracilentum	Pin-Point Clover	12.5	5.0	5.6
		100.0	**40.0**	**44.8**

C.2.3 Results Summary

Straw treatments decreased both Sediment and SSC overall for all treatments. As expected, HIGH rainfall treatments generated the most amount of sediment.

C.2.3.1 Suspended Sediment Concentration (SSC)

Statistically Significant Groupings

Highest Sediment Concentration	Group 1	Tackifier with Fertilizer under HIGH or NATURAL Straw with Fertilizer under LOW ALL LOW rainfall treatments (least vegetation)
	Group 2	ALL other treatment combinations
Lowest Sediment Concentration	Group 3	Straw with Fertilizer under HIGH or NATURAL

C.2.3.2 Vegetation

Rainfall consistency matters more in the production of plant cover than does seasonal total. The LOW treatments that received 280 mm (11 in) of seasonal rainfall at 1 inch every 3 weeks produced more cover than did the NATURAL treatment that received the annual average of 584 mm (23 in), but with a 6 week gap where no rain fell. Rainfall consistency produced more understory plants, thus greater protection from raindrop impact on soil surfaces. Fertilizer produced significantly more understory and more overstory, but alien grasses benefited most.

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Statistically Significant Groupings

Most Overstory Cover	Group 1	ALL Fertilizer treatments under HIGH or MEDIUM ALL MEDIUM rainfall treatments
	Group 2	ALL other treatment combinations
Least Overstory Cover	Group 3	ALL LOW rainfall treatments
Most Understory Cover	Group 1	ALL Straw treatments under HIGH, MEDIUM, or LOW
	Group 2	ALL other treatment combinations
Least Understory Cover	Group 3	ALL LOW rainfall treatments ALL NATURAL rainfall treatments

Vegetation Composition

Over all 36 boxes, 45 species were observed: 10 were members of the seed mix, 35 were not Annual Ryegrass (*Lolium multiflorum*), a naturalized alien species present in the soil seedbank, constituted 64% absolute cover (plants + non-vegetated soil) and 70% relative cover (plants only) overall. Of the seeded species, grasses and forbs exhibited greater establishment than di d shrubs. California Sagebrush (*Artemisia californica*) was the only seeded shrub to emerge with any success at about 1.4% cover and 216 total seedlings counted, mostly under MEDIUM to HIGH rainfall treatments. No sagebrush seedlings were observed among any of the boxes that received NATURAL rainfall even though the total precipitation for the season was just above the 50-year average. **Table C.4** shows percent cover after 150 days for species in the seed mix.

Table C.4. Percent Cover Recorded For RS1 D5 Native Seed Mix After 150 Days.

				Percent Cover			
				Overstory		Understory	
Scientific Name	Vernacular Name	%PLS/Mix	PLS/ft2	Absolute	Relative	Absolute	Relative
Bromus carinatus	**California Brome**	25	24	**14.97**	**16.46**	**0.22**	**0.45**
Lupinus succulentus	Arroyo Lupine	5	1	**5.41**	**5.95**	**1.28**	**2.63**
Achillea millefolium	**White Yarrow**	2.5	63	**0.22**	**0.24**	**8.00**	**16.40**
Eschscholzia californica	California Poppy	5	13	**0.09**	**0.10**	**14.03**	**28.76**
Trifolium gracilentum	Pin-Point Clover	12.5	58	**0.06**	**0.07**	**2.00**	**4.10**
Festuca microstachys	Small Fescue	2.5	23	nd	nd	**4.41**	**9.03**
Artemisia californica	California Sagebrush	2.5	127	nd	nd	**0.66**	**1.35**
Baccharis pilularis	Coyote Bush	2.5	116	nd	nd	**0.09**	**0.19**
Nassella pulchra	Purple Needlegrass	2.5	5	nd	nd	**0.06**	**0.13**
Salvia mellifera	Black Sage	2.5	14	nd	nd	**0.03**	**0.06**
Elymus glaucus	Blue Wild Rye	12.5	15	nd	nd	nd	nd
Nassella lepida	Foothill Needlegrass	5	15	nd	nd	nd	nd
Eriogonum fasiculatum	California Buckwheat	12.5	52	nd	nd	nd	nd
Lotus scoparius	Deer Lotus	5	21	nd	nd	nd	nd

nd = non detectable; no hits recorded, but species may have been present in very low numbers

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C.2.4 Conclusions

Considering combined effects on runoff, sediment concentration, and vegetation production, Crimped Straw performed best. The addition of Fertilizer generally produced more plant cover, but more of the cover produced was naturalized alien annual grass, not native species in the seed mix. **Table C.5** provides a ranked evaluation of the treatments follows. Bear in mind that these are qualitative assessments based on the statistical output.

Table C.5. Ranked Evaluation of RS1 EC Treatment Effects.

Performance Rank : 1 = Poor 2 = Fair 3 = Good

Sed Conc = Sediment Concentration in Runoff

			Runoff		Vegetation: Overstory		Vegetation: Understory		
EC Treatment	**Fertilizer**	**PPT**	Total	Sed Conc	Native	Non-Native	Native	Non-Native	Score
No Treatment	**No**	High	*1*	*1*	*1*	*2*	*1*	*1*	**7**
		Med	*1*	*1*	*1*	*2*	*1*	*1*	**7**
		Low	*1*	*1*	*1*	*1*	*1*	*1*	**6**
		Nat	*1*	*1*	*1*	*1*	*1*	*1*	**6**
Straw	**No**	High	***3***	***3***	***2***	***2***	***3***	***3***	**16**
		Med	***3***	***2***	***3***	***2***	***2***	***2***	**14**
		Low	*2*	*2*	*2*	*2*	*2*	*2*	**12**
		Nat	*3*	*3*	*2*	*2*	*1*	*1*	**12**
	Yes	High	*2*	*3*	*1*	*2*	*2*	*2*	**12**
		Med	***2***	***2***	***2***	***2***	***3***	***2***	**13**
		Low	*3*	*1*	*2*	*2*	*2*	*2*	**12**
		Nat	*3*	*3*	*1*	*2*	*1*	*1*	**11**
Tackifier	**No**	High	*2*	*2*	*1*	*2*	*2*	*2*	**11**
		Med	*2*	*2*	*2*	*2*	*2*	*1*	**11**
		Low	*2*	*2*	*2*	*2*	*1*	*1*	**10**
		Nat	*3*	*3*	*1*	*2*	*1*	*1*	**11**
	Yes	High	*1*	*1*	*1*	*3*	*1*	*1*	**8**
		Med	*2*	*2*	*1*	*3*	*2*	*1*	**11**
		Low	*1*	*1*	*1*	*3*	*1*	*1*	**8**
		Nat	*1*	*1*	*1*	*3*	*1*	*1*	**8**

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C.3 Comparison of an Existing Seedbank with Native or Naturalized Rapid Cover Seed Mixes.

RS2 Experiment October 2001 – February 2002

Establishment from seed by native and non-native plants relative to standard soil stabilization treatments on reapplied topsoil under simulated rainfall.

California Department of Transportation (Caltrans). 2002. Evaluating Hydroseeding & Plug Planting Techniques For Erosion Control & Improved Water Quality. **CTSW-RT-02-052**.

C.3.1 Research Problem

Based on results from RS1 where Crimped Straw treatments provided the best compromise between soil stabilization and plant cover production, further exploration of standard Soil Stabilization BMPs resulted from the RS2 experiment.

C.3.2 RS2 Experimental Design

The RS2 experiment was designed to test:

- whether germination and establishment by an existing seedbank, by a District 5 native species mix, or by a rapid cover alien annual mix, is inhibited by existing standard specifications for rates of Crimped Straw, Gypsum, Bonded Fiber Matrix (BFM), or *Psyllium* Tackifier;
- whether plant cover produced by an existing seedbank provides adequate protection to soil surfaces during extremely intense precipitation events, thus negating need for additional seed
- whether adequate plant cover can be established by 45 days, or by 70 days, to mollify soil erosion during extreme precipitation events.

Table C.6 provides a synopsis of the experimental design; **Table C.7** lists the experimental treatments; **Table C.3** lists the native species of the District 5 seed mix; and **Table C.8** lists the alien annual species of the rapid cover seed mix.

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Table C.6. RS2 Experimental Design.

Test Boxes	**32**		
Treatments	**15** combinations of EC Treatment and Simulated Precipitation		
Replicates	**2** each		
Control	**2** (no EC treatment)		
Soil	Commercial "topsoil"; medium sandy loam		
Factor	**Level**	**Amount**	**Application**
Rainfall	Natural	Natural [312mm (12.3 in)]	As seasonal rain fell
Simulated	100 yr storm	51 mm (2 in) per hr	@ 45 days only
	100 yr storm	51 mm (2 in) per hr	@ 45 days & 70 days
EC Treatment			
Straw	None	0	
	Straw	2240 kg/ha (2000 lb/ac)	Experiment Initiation
Jute	None	0	
	Jute	2.5 cm net	Experiment Initiation
Gypsum	None	0	
	Gypsum	4483 kg/ha (4000 lb/ac)	Experiment Initiation
BFM	None	0	
	BFM	4483 kg/ha (4000 lb/ac)	Experiment Initiation
Tackifier(Psyllium)	None	0	
	Tackifier	269 kg/ha (240 lb/ac)	Experiment Initiation
Seed Application			
Fiber	Fiber	1793 kg/ha (1600 lb/ac)	
Seed Mix	None	0	
	D5 natives	45 kg/ha (40 lb/ac)	Experiment Initiation
	EC mix (alien annuals)	45 kg/ha (40 lb/ac)	Experiment Initiation
Response Variables	**Variable**	**Data Collection**	**Data Analysis**
	Total Runoff	see **Appx E**	see **Appx E**
	Total Sediment	see **Appx E**	see **Appx E**
	Sediment Concentration	see **Appx E**	see **Appx E**
	Plant Cover	see **Appx F.3**	see **Appx F.6.2**

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Table C.7. RS2 Treatments.

BOX	EC	SEED	Sim PPT
17	Straw	Existing	45
20	Straw	Existing	45 & 70
41	Straw	Existing+D5Natives	45
25	Straw	Existing+D5Natives	45 & 70
43	Straw	Existing+EC Mix	45
34	Straw	Existing+EC Mix	45 & 70
12	Jute	Existing	45
14	Jute	Existing	45 & 70
22	Jute	Existing+D5Natives	45
32	Jute	Existing+D5Natives	45 & 70
5	Jute	Existing+EC Mix	45
39	Jute	Existing+EC Mix	45 & 70
10	Gypsum	Existing	45
42	Gypsum	Existing	45 & 70
40	Gypsum	Existing+D5Natives	45
2	Gypsum	Existing+D5Natives	45 & 70
24	Gypsum	Existing+EC Mix	45
29	Gypsum	Existing+EC Mix	45 & 70

BOX	EC	SEED	Sim PPT
9	BFM	Existing	45
33	BFM	Existing	45 & 70
27	BFM	Existing+D5Natives	45
21	BFM	Existing+D5Natives	45 & 70
38	BFM	Existing+EC Mix	45
30	BFM	Existing+EC Mix	45 & 70
19	Tackifier	Existing	45
37	Tackifier	Existing	45 & 70
28	Tackifier	Existing+D5Natives	45
26	Tackifier	Existing+D5Natives	45 & 70
23	Tackifier	Existing+EC Mix	45
1	Tackifier	Existing+EC Mix	45 & 70

Table C.8. RS2 Rapid Cover Seed Mix of Alien Annual Grasses and Forbs.

Scientific Name	Vernacular Name	%PLS	Rate PLS lb/ ac	Rate PLS kg/ ha
Annual Grass				
Lolium multiflorum	Annual Ryegrass	95.0	28.0	31.3
Hordeum vulgare	Cereal Barley	99.0	4.0	4.5
Annual Legume Forb				
Trifolium hirtum	Rose Clover	50.0	4.0	4.5
Trifolium incarnatum	Crimson Clover	45.0	4.0	4.5
		100.0	**40.0**	**44.8**

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C.3.3 Results Summary

The BFM Treatment had the best overall water quality with 438 g of total runoff, the lowest amount of sediment with 0.4 g and the lowest sediment concentration with 1,144 g/ml. The Jute Treatment and the Crimped Straw Treatment followed closely producing greater runoff, sediment, and sediment concentration. The Gypsum Treatment and the Tackifier Treatment produced greater than 60 times the total runoff, over 200 times the total sediment and over 4 times the sediment concentration of the Jute Treatment and the Crimped Straw Treatment. No Treatment produced the worst overall water quality including the most runoff at 965,360 g, the most sediment load at 14,406 g and the highest sediment concentration at 14,944 g/ml.

C.3.3.1 Suspended Sediment Concentration (SSC)

Statistically Significant Groupings

Highest Sediment Concentration	Group 1	No Treatment (nearly five times worse)
	Group 2	Tackifier Treatment with Existing Seed Bank Gypsum Treatment with Existing Seed Bank
	Group 3	Crimped Straw Treatment with D5 Native Mix Jute Treatment with D5 Native Mix
Lowest Sediment Concentration	Group 4	BFM Treatment with D5 Native Mix

C.3.3.2 Vegetation

At 45 days seedling cover was poor, thus vegetation had no significant affect on runoff. No statistically significant difference was detected between grass cover (p=.253) and forb cover (p=.060) across the five EC treatments. At 70 days, both the commercial Rapid Cover Mix and the D5 Native Seed Mix produced significantly greater cover over the Existing Seed Bank (p<.001). The Crimped Straw, BFM, Jute, and Tackifier Treatments all produced significantly (p<.001) more plant cover than the Gypsum Treatment or No Treatment. Shrubs were so scarce that they were eliminated from the analysis (only 19 shrubs occurred in 3000 data points) because no relationships between treatments and shrub cover could be estimated with any reliability. See **Table C.9** for percent cover values by vegetation class.

Table C.9. Percent Cover Recorded For RS2 After 45 and 70 Days.

	AFTER 45 DAYS		AFTER 70 DAYS	
Class	Absolute %	Relative %	Absolute %	Relative %
Grasses	6.30	53.80	20.50	38.80
All Forbs	5.40	46.20	31.80	60.10
Legume Forbs			*24.50*	*46.30*
Other Forbs			*7.30*	*13.70*
Shrubs			0.60	1.20
All Veg	**11.70**	**100.00**	**52.90**	**100.00**
No Veg	**88.30**		**47.10**	

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Statistically Significant Groupings

Most Grass Cover	Group 1	Crimped Straw Treatment with Existing Seed Bank Crimped Straw Treatment with D5 Native Mix Tackifier Treatment with existing seed bank
	Group 2	Gypsum Treatment with Existing Seed Bank Jute Treatment with Existing Seed Bank
Least Grass Cover	Group 3	No Treatment with Existing Seed Bank BFM Treatment with Existing Seed Bank
Most Legume Cover	Group 1	BFM treatments with Rapid Cover Mix Jute Treatment with Rapid Cover Mix
	Group 2	Gypsum Treatment with Rapid Cover Mix Crimped Straw Treatment with Rapid Cover Mix
Least Legume Cover	Group 3	ALL No Treatment combinations

C.3.4 Conclusions

Considering combined effects on runoff, sediment concentration, and vegetation production, Crimped Straw performed best for grass from an Existing Seedbank or from the D5 Native Mix. BFM provided the best water quality overall, and best legume cover. However, BFM negatively affects grass cover from both native and naturalized species. **Table C.10** provides a ranked evaluation of the treatments follows. Bear in mind that these are qualitative assessments based on the statistical output.

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Table C.10. Ranked Evaluation of RS2 EC Treatment Effects.

Performance Rank : 1 = Poor 2 = Fair 3 = Good

Sed Conc = Sediment Concentration in Runoff

EC Treatment	Seed	Runoff		Vegetation					
				Grasses			Legumes		
		Total	Sed Conc	Native	Non-Native	Score	Native	Non-Native	Score
No Treatment	Existing	1	1	1	1	**4**	1	1	**10**
	Rapid Cover	1	1	1	1	**4**	1	1	**10**
	D5 Natives	1	1	1	1	**4**	1	1	**10**
Crimped Straw	Existing	2	2	1	3	**8**	1	1	**18**
	Rapid Cover	2	2	1	2	**7**	2	2	**18**
	D5 Natives	3	3	1	3	**10**	1	1	**22**
Jute	Existing	2	2	1	2	**7**	1	1	**16**
	Rapid Cover	2	2	1	2	**7**	3	3	**20**
	D5 Natives	3	3	1	1	**8**	1	1	**18**
Gypsum	Existing	1	1	1	2	**5**	1	1	**12**
	Rapid Cover	1	1	1	2	**5**	2	2	**14**
	D5 Natives	1	1	1	1	**4**	1	1	**10**
BFM	Existing	3	3	1	1	**8**	2	2	**20**
	Rapid Cover	3	3	1	1	**8**	3	3	**22**
	D5 Natives	3	3	1	1	**8**	3	3	**22**
Tackifier (*Psyllium*)	Existing	1	1	1	3	**6**	1	1	**14**
	Rapid Cover	1	1	1	2	**5**	1	1	**12**
	D5 Natives	1	1	1	1	**4**	1	1	**10**

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C.4 Establishment by California Brome From Seed or Live Plugs.

RS3 Experiment March 2002 – June 2002

Performance of standard erosion control measures and of California Brome from live plugs or from seed on reapplied topsoil under simulated rainfall.

California Department of Transportation (Caltrans). 2002. Evaluating Hydroseeding & Plug Planting Techniques For Erosion Control & Improved Water Quality. **CTSW-RT-02-052**.

C.4.1 Research Problem

Results from RS1 and RS2, as well as from other revegetation work in California, indicate that California Brome is one of the best native perennial grasses for establishment of rapid cover from seed. The RS3 experiment sought to evaluate whether accelerated establishment of California Brome through the use of live plugs versus seed offers significant short-term advantages to water quality of runoff from more the rapid development of desired vegetation cover.

C.4.2 RS3 Experimental Design

The RS3 experiment was designed:

- to compare hydroseeded versus plug-planted California Brome (*Bromus carinatus* H.& A. *sensu stricto*) in respective effectiveness at controlling sediment transport under intense simulated rainfall at 70 days;
- to test whether germination and establishment of California Brome from seed or plugs is positively or negatively affected by topical soil treatments using Jute netting, Bonded Fiber Matrix (BFM), Wood Fiber with *Psyllium* Tackifier, or soil imprinting to simulate a track-walk;
- to compare whether water quality of runoff is significantly better when California Brome is planted at 44/m^2 (4/ft^2) versus 22/m^2 (2/ft^2).

Table C.11 provides a synopsis of the experimental design; **Table C.12** lists the experimental treatments.

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Table C.11. RS3 Experimental Design.

Test Boxes	**32**		
Treatments	**15** combinations of EC Treatment and Simulated Precipitation		
Replicates	**2** each		
Control	**2** (no EC treatment)		
Soil	Commercial "topsoil"; medium sandy loam		
Factor	**Level**	**Amount**	**Application**
Rainfall	Natural	Natural [93mm (3.65 in)]	As seasonal rain fell
Simulated	100 yr storm	51 mm (2 in) per hr	@ 45 days only
	100 yr storm	51 mm (2 in) per hr	@ 45 days & 70 days
EC Treatment			
Jute	None	0	
	Jute	2.5 cm net	Experiment Initiation
BFM	None	0	
	BFM	4483 kg/ha (4000 lb/ac)	Experiment Initiation
Fiber & Tackifier(Psyllium)	None	0	
	Fiber &	4483 kg/ha (4000 lb/ac)	Experiment Initiation
	Tackifier	160 kg/ha (143 lb/ac)	Experiment Initiation
Imprint	None		
	Imprint		Experiment Initiation
Brome Installation			
Seed	California Brome	520 PLS/m^2 (40 PLS/ft^2)	Experiment Initiation
	Fiber	1793 kg/ha (1600 lb/ac)	
Plugs	@ 22/m^2 (2/ft^2)		Experiment Initiation
	@ 44/m^2 (4/ft^2)		Experiment Initiation
Response Variables	**Variable**	**Data Collection**	**Data Analysis**
	Total Runoff	see **Appx E**	see **Appx E**
	Total Sediment	see **Appx E**	see **Appx E**
	Sediment Concentration	see **Appx E**	see **Appx E**
	Plant Cover	see **Appx F.3**	see **Appx F.6.2**

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Table C.12. RS3 Treatments.

EC Treatment		Seed/Plug Treatment	
EC1	**Jute** (2.5 cm or 1 in mesh)	**S1**	**Seed** @ 520 PLS/m^2
		S2	**Plugs** @ 22/m^2 (2/ft^2)
		S3	**Plugs** @ 44/m^2 (4/ft^2)
EC2	**BFM** @ 4483 kg/ha (4000 lb/ac)	**S1**	**Seed** @ 520 PLS/m^2
		S2	**Plugs** @ 22/m^2 (2/ft^2)
		S3	**Plugs** @ 44/m^2 (4/ft^2)
EC3	**Fiber** @ 4483 kg/ha (4000 lb/ac) & **Tackifier** @ 160 kg/ha (143 lb/ac)	**S1**	**Seed** @ 520 PLS/m^2
		S2	**Plugs** @ 22/m^2 (2/ft^2)
		S3	**Plugs** @ 44/m^2 (4/ft^2)
EC4	**Imprint** to simulate track-walk	**S1**	**Seed** @ 520 PLS/m^2
		S2	**Plugs** @ 22/m^2 (2/ft^2)
		S3	**Plugs** @ 44/m^2 (4/ft^2)
EC5	**None**	**S1**	**Seed** @ 520 PLS/m^2
		S2	**Plugs** @ 22/m^2 (2/ft^2)
		S3	**Plugs** @ 44/m^2 (4/ft^2)
		S4	**No Seed / No Plugs**

C.4.3 Results Summary

Hydroseeded California Brome treatments initially resulted in lesser sediment loads over plug planting owing to roughly twice the amount of weedy annual plant cover in the understory that arose from the existing soil seedbank and provided more surface protection. Although California Brome plugs at 44 / m^2 produced more California Brome cover than plugs at 22 / m^2, there was no statistically significant difference in sediment load, suggesting that planting at the greater density did not provide more protection to soil surfaces. See **Table C.13** for percent cover values by vegetation class.

Statistically Significant Groupings

Highest Sediment Concentration	Group 1	No Treatment
	Group 2	All other treatment combinations
Lowest Sediment Concentration	Group 3	Jute Treatment with CA Brome Seed BFM Treatment with CA Brome Seed

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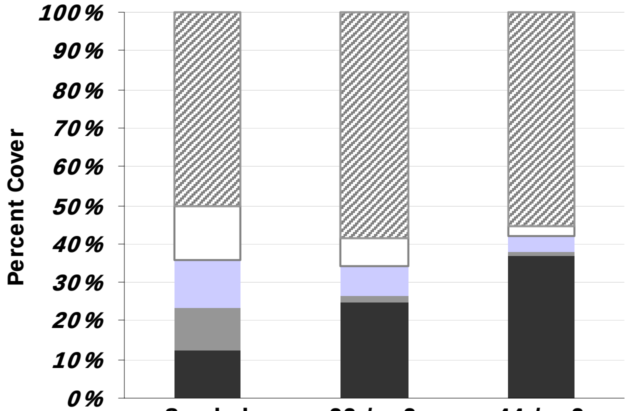
Table C.13. Percent Cover Recorded For RS3 After 70 Days.



	Seeded	22 / m2	44 / m2
No Veg	50.20	58.70	55.20
Other Forb	14.10	7.10	2.60
Legume Forb	12.20	7.70	4.20
Other Grass	10.60	1.60	0.90
California Brome	12.60	24.90	36.90

California Brome Installation

C.4.4 Conclusions

Considering combined effects on runoff, sediment concentration, and vegetation production, Hydroseeded California Brome Treatments performed better than either Plug Planted California Brome Treatment. Plug Planted California Brome Treatments produced two to three times more California Brome cover, but Hydroseeded California Brome Treatments produced more understory and other grass cover that combined to offer greater protection to soil surfaces. If a specific management goal is to establish the greatest California Brome cover with the fewest naturalized weeds as well, then establishment from plugs is much more effective than from seed. However, the physical act of plug planting does cause more initial soil surface disruption that causes increased sediment loads over hydroseeding during the first rains after installation. BFM provided the best water quality overall, and best legume cover. However, BFM negatively affects grass cover from both native and naturalized species.

Table C.14 provides a ranked evaluation of the treatments follows. Bear in mind that these are qualitative assessments based on the statistical output.

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Table C.14. Ranked Evaluation of RS3 EC Treatment Effects.

Performance Rank : 1 = Poor 2 = Fair 3 = Good

Sed Conc = Sediment Concentration in Runoff

		Runoff		Vegetation				
				Grasses		Forbs		
EC Treatment	Seed	Total	Sed Conc	CA Brome	Non-Native	Legume	Other	Score
Jute	Seed	3	3	1	3	3	2	**15**
	Plugs 22 / m^2	2	2	2	1	2	1	**10**
	Plugs 44 / m^2	2	2	3	1	2	2	**12**
BFM	Seed	3	3	2	1	3	2	**14**
	Plugs 22 / m^2	2	2	3	1	2	2	**12**
	Plugs 44 / m^2	2	2	3	1	2	2	**12**
Fiber & Tackifier (*Psyllium*)	Seed	3	3	2	3	3	3	**17**
	Plugs 22 / m^2	2	2	2	2	2	3	**13**
	Plugs 44 / m^2	2	2	2	2	2	2	**12**
Imprint	Seed	1	1	1	1	1	1	**6**
	Plugs 22 / m^2	1	1	1	1	2	2	**8**
	Plugs 44 / m^2	1	1	1	1	1	1	**6**
No Treatment	Seed	2	2	1	2	2	2	**11**
	Plugs 22 / m^2	1	1	1	1	2	2	**8**
	Plugs 44 / m^2	1	1	1	1	2	2	**8**

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C.5 Comparisons Among Seed, Live Plug, And Live Flat Treatments.

RS4 Experiment November 2002 – May 2003

Performance of standard erosion control measures and of native seed, live plugs, and live flats on reapplied topsoil under simulated rainfall.

California Department of Transportation (Caltrans). 2004. Effectiveness of Planting Techniques for Minimizing Erosion. **CTSW-RT-04-004.69.01**.

C.5.1 Research Problem

Expanding on results from RS1 and RS2 regarding native seed mixes, and from RS3 results using plugs of California Brome, the RS4 experiment was designed to maximize germination and establishment by a native seed mix, and to test whether flats container live plants grown from the same seed mix, or plugs of California Brome or Common Yarrow, provided significantly more slope protection if applied at the toe, or at the top and toe, of treatment boxes. To promote native seed germination over existing naturalized aliens in the soil seed bank, a thick layer [5.08 cm (2.0in)] was applied topically to both suppress germination by more aggressive aliens, and to promote germination by Common Yarrow and Small Fescue, two species shown in RS1 and RS2 to produce significantly more cover when seeded on top of, rather than beneath, a layer of wood fiber or bonded fiber matrix.

C.5.2 RS4 Experimental Design

The RS4 experiment was designed to test:

- whether a topical layer of compost 5.08 cm (2.0in) thick significantly suppresses germination by naturalized aliens in the soil seedbank;
- whether a topical layer of compost 5.08 cm (2.0in) thick significantly promotes germination by native species in an applied seed mix;
- whether water quality of runoff is significantly better when California Brome and Common Yarrow are planted from plugs at the toe, or at the top and toe, of treatment boxes.
- whether water quality of runoff is significantly better when California Brome and Common Yarrow are planted from flats at the toe, or at the top and toe, of treatment boxes.

Table C.15 provides a synopsis of the experimental design; **Table C.16** lists the experimental treatments; **Table C.17** lists the native species used in the seed mix; and **Figure C.1** shows the configuration of live plant treatments.

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Table C.15. RS4 Experimental Design.

Test Boxes	**32**		
Treatments	**30** combinations of EC Treatment and Simulated Precipitation		
Replicates	**1** each		
Control	**2** (no EC treatment)		
Soil	Commercial "topsoil"; medium sandy loam		
Factor	**Level**	**Amount**	**Application**
Rainfall	Natural	Natural [93mm (3.65 in)]	As seasonal rain fell
Simulated	100 yr storm	51 mm (2 in) per hr	13 May 2003
EC Treatment			
Jute	None	0	
	Jute	2.5 cm net	Experiment Initiation
Compost	None	0	
	Compost	5.08 cm (2.0 in) Topical	Experiment Initiation
Seed			
Native Seed	None		
	Under Compost		Experiment Initiation
	Over Compost		Experiment Initiation
	Over Soil		Experiment Initiation
Live Plants	None		
	Plugs at Toe Only	20 / 0.125 m2 (1.35 ft2)	Experiment Initiation
	Plugs at Top & Toe	20 / 0.125 m2 (1.35 ft2)	Experiment Initiation
	Flats at Toe Only	2 @ 0.125 m2 (1.35 ft2)	Experiment Initiation
	Flats at Top & Toe	1 @ 0.125 m2 (1.35 ft2)	Experiment Initiation
Response Variables	**Variable**	**Data Collection**	**Data Analysis**
	Total Runoff	see **Appx E**	see **Appx E**
	Total Sediment	see **Appx E**	see **Appx E**
	Sediment Concentration	see **Appx E**	see **Appx E**
	Plant Cover	see **Appx F.3**	see **Appx F.6.2**

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Table C.16. RS4 Treatments.

Physical Treatments			Vegetation Treatments				
			Seed		Live		
	Jute	Compost				Plugs	Flats
EC1	Yes	5.08 cm (2.0 in) Topical	S1	UNDER Compost	T1	Toe	—
					T2	Top & Toe	—
					T3	—	Toe
					T4	—	Top & Toe
					T5	—	—
			S2	OVER Compost	T1	Toe	—
					T2	Top & Toe	—
					T3	—	Toe
					T4	—	Top & Toe
					T5	—	—
EC2	Yes	NONE Added	S3	OVER Soil	T1	Toe	—
					T2	Top & Toe	—
					T3	—	Toe
					T4	—	Top & Toe
					T5	—	—
			S4	NONE Added	T1	Toe	—
					T2	Top & Toe	—
					T3	—	Toe
					T4	—	Top & Toe
					T5	—	—
EC3	No	NONE Added	S3	OVER Soil	T1	Toe	—
					T2	Top & Toe	—
					T3	—	Toe
					T4	—	Top & Toe
					T5	—	—
			S4	NONE Added	T1	Toe	—
					T2	Top & Toe	—
					T3	—	Toe
					T4	—	Top & Toe
					T5	—	—

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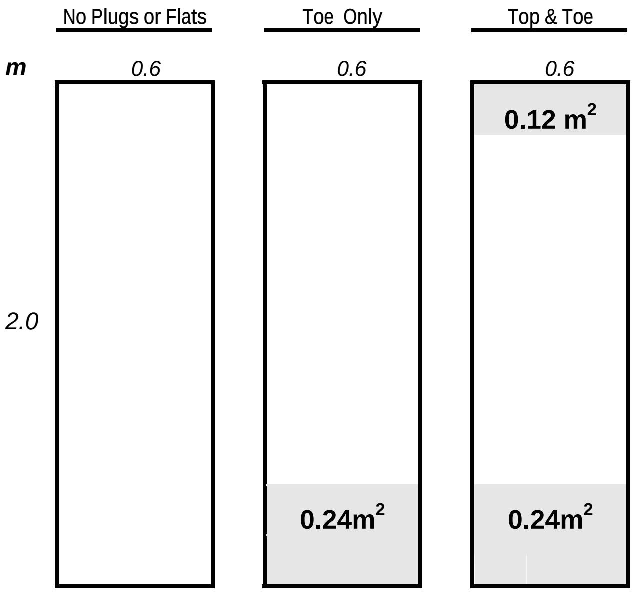
Table C.17. RS4 Native Seed Mix.

Duration	Lifeform	Scientific Name	Common Name	PLS	PLS/ft^2	lb PLS/ac	PLS/m^2	kg PLS/ha
Per	Gr	*Bromus carinatus* Hook. & Arn.	California Brome	95%	27	12.0	290	13.45
Per	Gr	*Festuca microstachys* Nuttall	Small Fescue	90%	54	3.0	581	3.35
Per	F	*Achillea millefolium* L.	Common Yarrow	69%	27	0.5	291	0.56
Ann	F_L	*Lupinus succulentus* Douglas ex Koch	Arroyo Lupine	83%	3	9.0	32	10.08
					111	**24.5**	**1194.0**	**27.4**

Ann = Annual
Per = Perennial

Gr = Grass
F = Forb
F_L = Legume Forb

Figure C.1. RS4 Configuration of Live Plant Treatments.



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C.5.3 Results Summary

Results from this multifactorial experiment are complex, but expectedly follow trends observed in prior experiments. No Treatment results in extremely high sediment loads over 1000 times worse than the best combination of Flats Top & Toe of a Seed Over Compost Treatment covered by Jute. The combination of Jute with Seed Over Compost resulted in significantly less runoff and significantly lower sediment concentrations. Adding Flats Top & Toe to Jute with Seed Over Compost resulted in nearly no sediment loss at all (0.2g) after simulation of a 50-year storm event. The relatively thick layer of compost did significantly reduce germination and cover produced by naturalized alien species, and did produce significantly more germination. See **Table C.18** for percent cover values by vegetation class.

Statistically Significant Groupings

			Physical		Vegetation		
		Combination	Jute	Compost	Seed	Plugs	Flats
Highest Sediment Concentration	**Group 1**	EC3 S4 T5	None	None	None	None	None
	Group 2	EC* S1 S2 S3 T5	All Combinations			None	None
	Group 3	EC* S* T1	All Combinations			Top	None
		EC* S* T2	All Combinations			Top & Toe	None
Lowest Sediment Concentration	**Group 4**	EC1 S2 T2	Yes	Yes	OVER	None	Top
		EC1 S2 T3	Yes	Yes	OVER	None	Top & Toe

Table C.18. Percent Cover Recorded For RS4 After 120 Days.

		T1	T2	T3	T4	T5	*avg*
EC1	S1	48%	65%	44%	65%	63%	*57%*
EC2	S2	64%	75%	68%	76%	63%	*69%*
EC2	S3	73%	84%	70%	69%	58%	*71%*
EC2	S4	66%	63%	57%	53%	47%	*57%*
EC3	S3	71%	83%	62%	92%	69%	*75%*
	avg	*64%*	*74%*	*60%*	*71%*	*60%*	

C.5.4 Conclusions

Considering combined effects on runoff, sediment concentration, and vegetation production, any erosion control treatment that uses Jute with Seed Over Compost should result in significantly more native cover, less runoff and significantly lower sediment concentrations. Addition of Flats at the toe of slopes should provide the best overall slope protection.

Table C.19 provides a ranked evaluation of the treatments follows. Bear in mind that these are qualitative assessments based on the statistical output.

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Table C.19. Ranked Evaluation of RS4 EC Treatment Effects.

Performance Rank : 1 = Poor 2 = Fair 3 = Good

Sed Conc = Sediment Concentration in Runoff

Physical Treatments			Vegetation Treatments							Vegetation				
			Seed			Live		Runoff		Overstory		Understory		
	Jute	Compost				Plugs	Flats	Total	Sed Conc	Native	Non-Native	Native	Non-Native	Score
EC1	Yes	5.08 cm (2.0 in) Topical	S1	UNDER Compost	T1	Toe	—	2	2	2	2	2	1	11
					T2	Top & Toe	—	2	2	2	2	2	1	11
					T3	—	Toe	3	3	2	2	2	1	13
					T4	—	Top & Toe	3	3	2	2	2	1	13
					T5	—	—	2	2	2	2	2	1	11
			S2	OVER Compost	T1	Toe	—	2	2	3	2	3	1	13
					T2	Top & Toe	—	2	2	3	2	3	1	13
					T3	—	Toe	3	3	3	2	3	1	15
					T4	—	Top & Toe	3	3	3	2	3	1	15
					T5	—	—	2	2	2	2	3	1	12
EC2	Yes	NONE Added	S3	OVER Soil	T1	Toe	—	2	2	3	2	1	2	12
					T2	Top & Toe	—	2	2	3	2	1	2	12
					T3	—	Toe	2	2	3	2	1	2	12
					T4	—	Top & Toe	2	2	3	2	1	2	12
					T5	—	—	2	2	3	2	1	2	12
			S4	NONE Added	T1	Toe	—	2	2	3	2	1	2	12
					T2	Top & Toe	—	2	2	3	2	1	2	12
					T3	—	Toe	2	2	3	2	1	2	12
					T4	—	Top & Toe	2	2	3	2	1	2	12
					T5	—	—	1	1	3	2	1	2	10
EC3	No	NONE Added	S3	OVER Soil	T1	Toe	—	1	1	1	3	1	2	9
					T2	Top & Toe	—	1	1	1	3	1	2	9
					T3	—	Toe	2	2	1	3	1	2	11
					T4	—	Top & Toe	2	2	1	3	1	2	11
					T5	—	—	1	1	1	3	1	2	9
			S4	NONE Added	T1	Toe	—	1	1	1	2	1	1	7
					T2	Top & Toe	—	1	1	1	2	1	1	7
					T3	—	Toe	2	2	1	2	1	1	9
					T4	—	Top & Toe	2	2	1	2	1	1	9
					T5	—	—	1	1	1	2	1	1	7

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C.6 Products to Date

C.6.1 Erosion Control and Vegetation Establishment Research

C.6.1.1 Technical Reports

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C.6.1.2 Research Papers for Academic Degrees

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C.6.1.3 Conference Proceedings

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Hallock, B., M. Curto, S. Rein, and M. Scharff. 2002. Vegetation Establishment For Erosion Control Under Simulated Rainfall. Proceedings of the 33rd Annual Conference and Expo of the International Erosion Control Association, 25 February-1 March 2002, Orlando, FL.

C.6.1.4 Magazine Articles

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C.6.2 Seed and Live Plant Materials Specification and Calculation Tool

C.6.2.1 Technical Reports

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C.6.2.3 Training Workshops

2004. District 5: Training for Landscape Architect use of Seed and Plant Calculator.

2003. District 5: Training for Landscape Architect use of Seed and Plant Calculator.

C.6.3 Expert Assistance

C.6.3.1 Technical Reports

2004. Proposal: Guidance and Specifications for the Use of Compost and Mulch for Erosion Control and Stormwater Treatment (LAP-01).

2003. Simi and Piru Burn Visit: Meeting Observations and Recommendations.

2003. Old and Grand Prix Burn Visit: Meeting Observations and Recommendations.

2003. Revisions to Sections 2 and 3 of the Caltrans Erosion Control Manual.

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C.6.3.2 Training Workshops

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C.6.3.3 Technical Assistance

2004. Sacramento: Research Development Workshop Sponsored by the Caltrans Divisions of Design, Construction, Right-of-Way / Land Surveys.

2004. District 4 Landscape Architects. Recommendations regarding portable rainfall simulators.

2004. District 5: Plant species list and recommendations for planned post-construction revegetation along CA Hwy 41 and CA Hwy 46.

2004. District 12: Plant species list and recommendations for biofilters.

2003. District 5: Plant species list and recommendations for Coastal Scrub Revegetation.

2003. District 2: Plant species list and recommendations for biofilters.

2002. District 12: Comments on Orange County Bioretention Filter Planting Plan.

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D.1. Rainfall Simulation

The primary purpose of a rainfall simulator is to imitate natural rainfall patterns accurately and precisely. Rainfall is complex, with interactions among properties (drop size, drop velocity, etc.), and with large climatic variation based on topography, marine influences, and water vapor temperature.

Properly simulating rainfall requires several criteria:

1) Drop size distribution near to natural rainfall (Bubenzer 1979a);
2) Drop impact velocity near natural rainfall of terminal velocity (Gunn and Kinzer 1949; Laws 1941);
3) Uniform rainfall intensity and random drop size distribution (Laws and Parsons 1943);
4) Uniform rainfall application over the entire test plot;
5) Vertical angle of impact;
6) Reproducible storm patterns of significant duration and intensity (Meyer and Harmon 1979; Moore et. al. 1983).

Drop size distribution, impact velocity and reproducible storm patterns must be met to simulate the kinetic energy of rainfall. Kinetic energy (KE = mass •Velocity^2/2) is a single measure of the rainfall used to correlate natural storms and simulator settings. Drop size distribution depends on many storm characteristics, especially rainfall intensity. Drop size distribution varies with intensity from less than 1 mm to about 7 mm. Most design standards are based on a 2.25 mm median drop size arrived at through empirical studies by Laws and Parson (1943).

To date, most studies of natural rainfall characteristics have outside California (e.g., Washington, Illinois, Washington DC, or locations in the southeast). Proximity to marine influence together with orographic lifting over the mountains of California contributes to variation in rainfall characteristics (McCool 1979). Parameters can be approximated using the studies from other regions, but an accurate simulation of California rainfall is difficult without adequate research studies of California conditions.

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Drop velocity is important in designing a rainfall simulator. Drops from natural rainfall are at terminal velocity when they hit the soil surface (Meyer and McCune 1958). Therefore, a rainfall simulator must create drops of adequate size and velocity to simulate the same condition. A direct relationship exists between drop diameter and fall distance (Laws 1941). A reproducible storm pattern is easy to simulate when a simulator can be adjusted to the desired intensities and duration.

D.1.1. Types of Rainfall Simulators

Simulators can be separated into two large groups: drop-forming simulators and pressurized nozzle simulators (Thomas and El Swaify 1989). Drop-forming simulators are impractical for field use since they require such a huge distance (10 meters) to reach terminal velocity (Grierson and Oades 1977). The drop-forming simulators do not produce a distribution of drops unless a variety of drop-forming sized tubes are used. Another negative of the drop forming simulator is their limited application to small plots (Bubenzer 1979b). Several points of raindrop production must be closely packed to create an intense enough downpour of rain. Drop forming simulators

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use small pieces of yarn, glass capillary tubes, hypodermic needles, polyethylene tubing, or metal tubing to form drops (Bubenzer 1979b). Pressurized nozzle simulators are suited for a variety of uses. They can be used in the field and their intensities can be varied more than the drop forming type (Grierson and Oades 1977). Since drops exiting the nozzles have an initial velocity greater than zero due to the pressure driving them out, a shorter fall distance is required to reach terminal velocity. Nozzle intensities vary with orifice diameter, the hydraulic pressure on the nozzle, the spacing of the nozzle and nozzle movement (Meyer 1979). Pressurized nozzle simulators can produce variable storm intensities. A continuous spray from a nozzle creates an unnaturally intense storm. Thus, some method of starting or stopping the spray is needed. Tested solutions include: a rotating disc, a rotating boom, a solenoid-controlled simulator (Miller, 1987) or an elaborate sprinkler system (Sumner et al. 1996). The simplest to use is a rotating or oscillating boom (Bubenzer 1979b). The most popular nozzle is the Veejet 80100 nozzle run at 41 kPa (6psi). It was chosen because it most closely resembles the drop size distribution of erosive storm patterns in the Midwest (Bubenzer 1979a). Accurate testing of nozzles must be done to ensure adequate spray coverage and uniformity in the plot. Since computers are now relatively inexpensive, a simulator can be driven by specialized software controlling the intensity and duration of the storm.

D.1.2. Rainfall Simulators Selected For These Experiments

Two Norton Ladder-type variable sweep rainfall simulators were purchased for use in this study (see Photo 3.9 and 3.10). These pressurized nozzle type simulators were developed at the USDA Erosion Research Center at Purdue University and manufactured by Advanced Design and Machine, Clarks Hill, IN. Each simulator consists of a boom oscillating side-to-side by way of a cam (see Photo 3.11). A small motor drives the cam at one end of each simulator. Intensity of rainfall is determined by how many times the nozzles of the boom sweep past the box opening in a given amount of time. The boxes are configured to regulate spray pattern and return non-effective rainfall to the water supply system. Rainfall is simulated by industrial spray nozzles with an optimum pressure range of 35 to 2068 kPa (5 to 300 psi) set at 41 kPa (6 psi) for rainfall simulation purposes. At 41 kPa (6 psi), the drop size should be about 2.25 mm (0.09 in) in diameter, corresponding to the average drop size of erosive storms in the Midwestern United States. Drop size along the Pacific Coast is frequently smaller, but actual measurement data are lacking in the literature. Most nozzles tend to produce irregular spray when used at its capacity limits due to machining differences. Thus, any differences between nozzles are amplified by the weak pressure used, leading to reduced uniformity.

D.1.3. Designed Simulated Storms

Rainfall simulators used in this experimental program are computer controlled to produce “bell shaped” storm patterns simulating the intensity variation inherent in typical winter storm events where smaller drops fall with lighter intensity as storms begin and end. Larger drops falling with increased intensity often occur sometime in between. Two designed storms were written for the simulations of the erosion test boxes. One storm delivers of one inch of rain in two hours; the other delivers two inches of rain in three hours. The frequency and intensity pattern, simulating the west coast hydrograph model, delivers 15 minutes of low intensity rainfall (rising limb), followed by an hour of high intensity rainfall (peak), and again 15 minutes of low intensity rainfall (falling limb), totaling 3.81 cm (1.5 in) in 1.5 hrs (see **Chart D-1)**.

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Photo D-1

Photo D-2

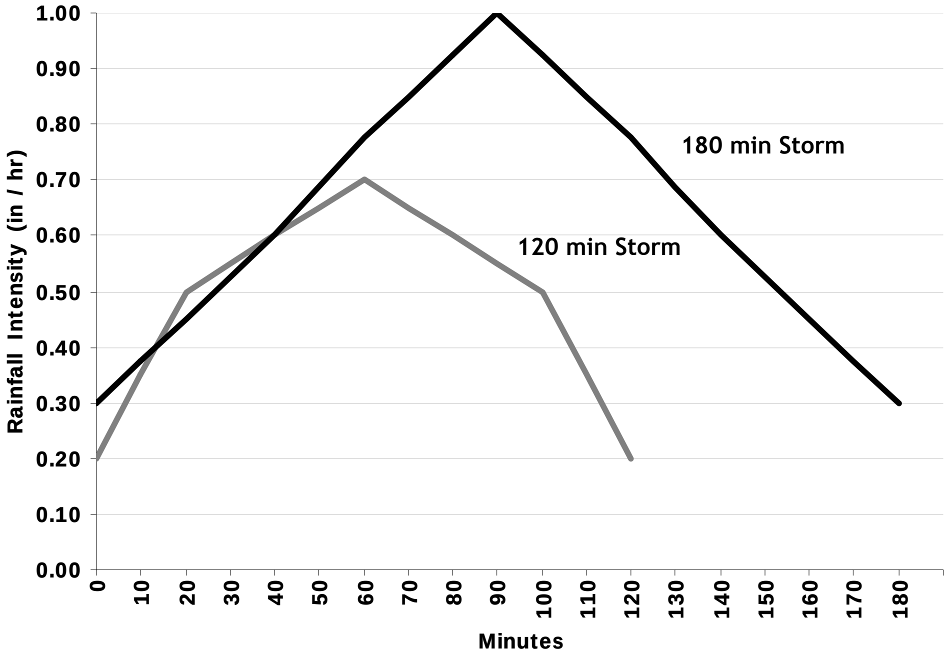

Chart D-1 Simulated Storm Event Patterns

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D.2. Test Box Design

Two criteria were used to determine the size of the erosion test boxes. First, box dimensions must relate to boxes used in experiments found in the soil erosion literature. Second, size, shape, and weight must be appropriate for easy handling by two people using a simple one-ton chain hoist. Pearce et al. (1998) utilized field micro-plots of 0.6 m (2 ft) by 2.0 m (6.6 ft) alongside standard plots of 3.0 m (9.9 ft) by 10 m (32.9 ft). A box having the same dimensions as the micro-plots and with a soil depth of 20 cm (7.8 in) weighs less than one ton when saturated and is easily moved by two people using a hoist.

During early 2000, a prototype erosion test box measuring 2.0m L x 0.6m W x 0.3m was designed and built. The design called for the use of standard pressure-treated lumber for outdoor applications. The lumber is treated with chromated copper arsenate and is considered safe to humans when proper safety guidelines are followed. Boxes constructed for the project differ slightly from the prototype. An extra pressure-treated cross-member was placed at the base of the box to support the soil load and to allow the steel mesh at the base of the box to remain more rigid under load. When necessary additional steel pipe supports are inserted through and mounted to the side rails to provide additional stability as boxes age and wood integrity diminishes. Boxes were assembled using a drill press, mitre box saw, and a variable speed hand drill. To facilitate runoff collection, one end of each box was cut to a height of 20 cm (7.8 inches) to coincide with the height of the added soil (see **Photo D-3**).

In addition to the erosion test boxes, support stands were specially designed. The supports are constructed of pressure treated lumber, and 2.5 cm OD, schedule 40, galvanized steel pipe to support the boxes at a 2:1 slope. These supports were used during rainfall simulations, and for positioning boxes throughout the experiment. Each box had a designated space under the box transport system. The erosion test boxes were aligned five to six boxes per row with a total of five rows (see **Photo D-4**).

Photo D-3

Photo D-4

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D.3. Runoff Collection Systems

D.3.1. Simulator Runoff

A length of vinyl gutter is used to collect runoff from the base of each erosion test box and channel it into a basin where it was collected. A rectangular piece of synthetic pond liner is cut and riveted to the vinyl gutter (see **Photo D-5**). This prevents simulated rainfall from entering the erosion collection system. The collection system is secured to the box with screws (see **Photo D-6**). The basin consists of a 7.6 L (8 qt) plastic container, trimmed to accept the curve of the gutter (see **Photo D-7**).

Photo D-5.

Photo D-6.

Photo D-7.

D.3.2. Natural Storm Runoff

For experiments including natural precipitation collection in the design, rainfall is allowed to flow along the surface of the boxes and runoff is collected in plastic containers at the base. Synthetic pond liner is attached to the bottom of the boxes above the runoff opening to prevent rain from directly entering the collection containers (see **Photo D-8**). After each storm, the samples are collected and analyzed.

Photo D-8

D.3. Test Box Arrangement

Test boxes are positioned in rows on a concrete slab 21.3 m (70 ft) long by 10.6 m (35 ft) wide. Boxes are oriented such that soil surfaces faces about 165 south for adequate sun exposure. Rainfall simulators are positioned at the north end of this concrete slab.

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D.4. Rainfall Simulator Operation

Each rainfall simulation follows the same protocol to ensure both repeatability and worker safety among simulation events. Prior to a simulation, two erosion test boxes are moved into place beneath the simulators. The I-beam of a one-ton hoist is positioned directly over the box to be moved. Three heavy-duty nylon straps, each with a capacity in excess of the weight of a saturated erosion test box, are used to cradle the box. The hoist lifts the box at the union of the straps. To position boxes for simulation, two box supports are utilized. Although the design of the box transport system allows each box to be moved by one person, this operation is best performed by two people for safety reasons. Workers are required to wear a properly fitting hard hat, gloves, and approved footwear.

After the boxes are set in place, the runoff collection systems are installed. Prior to a rainfall simulation event, the hoses supplying the deionized water to the simulators are attached from the manifold to each simulator. To start the flow of deionized water, the valve at the base of the water storage tank is opened prior to turning on the Jacuzzi pump. This ensures a long life for the pump. Using a ladder, fine-tune adjustments are made using the C-clamps on the supply hoses to ensure 6 psi at the nozzles.

A laptop computer is used to run rainfall simulation software. After each rainfall simulation, the two boxes are moved back to their respective locations within the box transport system using the same procedures used to move them into place.

D.5. Rainfall Simulator Quality Assurance/ Quality Control

Experimental repeatability of rainfall simulation is achieved by creating uniform rainfall across each test box during every simulation event. Lateral uniformity is achieved by selection of a nozzle with proper drop size distribution, and by spacing such nozzles in series with adequate spacing to allow sufficient overlap. When this laterally-uniform boom is swept back and forth across an area, the spray will be uniform. Properly designing and testing the boxes used for cutting off the spray is critical for creating uniform rainfall.

D.5.1. Drop-Size Tests

Proper drop size is critical for simulation of rainfall. The drop size distribution was tested using Eigel and Moore's (1983) oil method. This entails mixing 1 part STP oil treatment and 1 part Swan brand mineral oil. Drops with ranges from 0.5mm - 7 mm (0.02 in to 0.28 in) are caught in a petri dish of oil and held there for enough time to count and measure them (see **Photo D-9**). This approach was much simpler and easier to perform than methods that use flour and time-lapse photography. The found drop size distribution is that of natural rainfall.

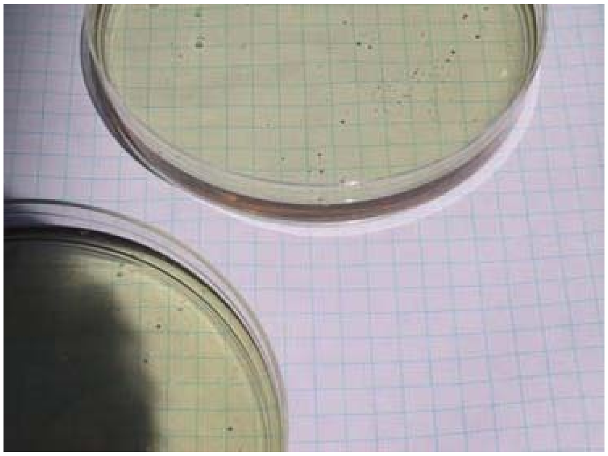

Photo D-9

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Drop size ranges from less than 1 mm to about 7 mm (0.04 in to 0.28 in) in diameter. The average drop size is 1.71 mm (0.067 in). The average drop size is smaller than the standard of 2.25 mm (0.089 in) used on previous simulators but, agrees with the literature for drop size for lower intensity storms [less than 50 mm, (2 in) per hour]. The drops were assumed to be at terminal velocity due to their size and the height of the boom. No tests were performed to find drop velocity or energy due to several previously conducted studies in the literature.

D.5.2. Lateral Uniformity Tests

In order to be sure the Norton rainfall simulators were consistently applying the proper amount of rainfall for a given storm event, uniformity is routinely tested about once each month. These tests are performed using two empty erosion test boxes each filled with 48 six-inch cans. After assuring the support stands and erosion test boxes filled with cans are properly placed, a typical two-hour storm is run.

Collected water amounts are measured in milliliters. Average values are calculated and the amount each value deviated from the average is added and used to determine the coefficient of uniformity for each simulator. Typical results from a two hour, one inch storm test are presented below. The mean for Simulator 1 was 428 ml. The mean for Simulator 2 was 452 ml. Coefficient of uniformity measured for simulator 1 was 93.9%, while uniformity for simulator 2 was 93.6%.

Table D-1. Typical Data From Lateral Uniformity Tests.

Avg	Simulator 1			
435	407	444	438	450
469	447	478	475	477
471	440	478	488	478
470	439	475	475	490
433	409	413	474	435
396	383	394	380	425
413	397	407	438	409
405	393	412	400	415
423	401	426	431	435
421	407	420	433	425
398	376	397	415	405
403	378	404	410	419
428	**406**	**429**	**438**	**439**

Uniformity 93.9 %

Avg	Simulator 2			
439	390	441	460	466
481	427	484	500	511
499	441	501	530	525
501	461	511	530	502
446	417	435	495	437
444	432	455	420	470
455	430	440	480	470
425	395	423	438	445
431	388	420	455	460
436	415	430	450	447
417	385	407	440	435
445	420	450	445	463
452	**417**	**450**	**470**	**469**

Uniformity 93.6 %

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D.6. Rainfall Simulation References

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E.1 Runoff Collection

Runoff contained in collection basins is carefully poured into 18.9 liter (5 gallon) or 4 liter runoff collection containers as required to accommodate the volume. Each container is labeled with unique container number, date of simulation, erosion test box #, simulator #, and total volume of deionized water used to rinse any sediment remaining in the collection gutter or basins. After collection of each runoff sample, samples receive 10-20 ml 1 M AlCl3, a common water treatment flocculant used to precipitate as much colloidal sediment as possible. **Photo E.1** shows runoff collected after a simulated storm ran for one hour on boxes containing California Brome seeded over jute netting as an erosion control method.

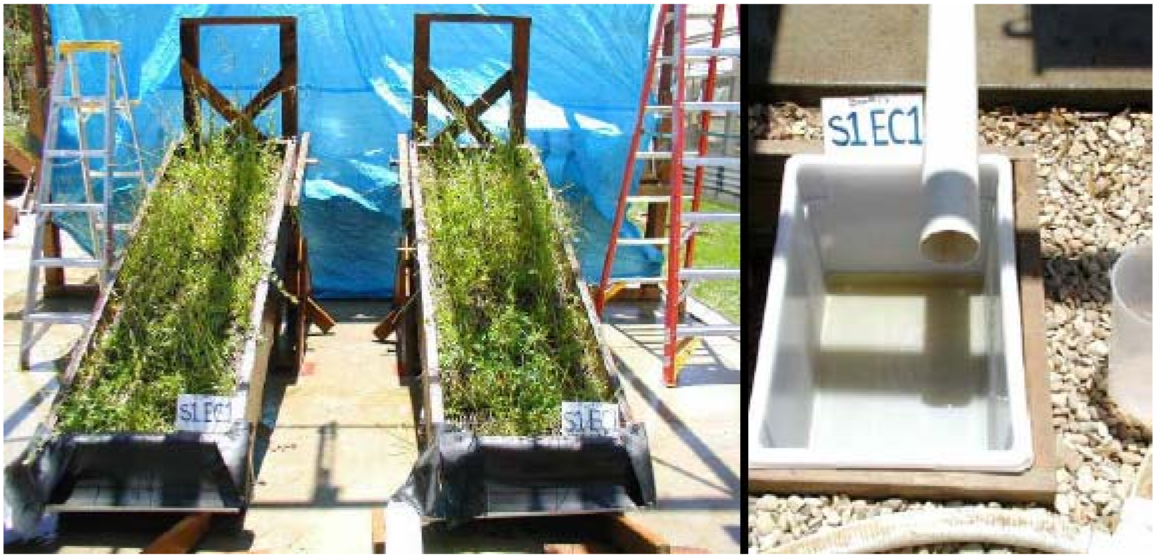

Photo E.1.

E.2 Water Quality Analyses

E.2.1 pH / EC / NTU Sampling

For each collected sample, pH, electrical conductivity (salt concentration), and total suspended sediment as NTU (Nephelometric Turbidity Unit) are measured directly using a handheld pH/EC/NTU/ meter.

E.2.2 Total Suspended Sediment

The two most common methods of measuring suspended sediment in water are Suspended Sediment Concentration (SSC) analysis (ASTM D3977-97) and Total Suspended Solids (TSS) analysis (EPA Method 160. 2). Section **E.4** below provides synopses for these standards. One major difference between these two methods is that SSC utilizes an entire sample for sediment analysis, whereas TSS utilizes a small portion (aliquot) of the original sample. Because TSS uses a smaller sample, it is often the preferred method due to time and money savings over SSC. Although TSS has been widely utilized as a replacement for SSC, there are fundamental

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problems associated with it. These problems lead to the production of data that are negatively biased from 25 to 34 percent when compared to SSC data from samples taken at the same time and same location as TSS samples (Gray and Glysson, 2000). The major problem with TSS is the inability to reliably extract an aliquot of suspended sediment from a water sample. Particles in suspension vary in size and settling time; therefore, it is inherently difficult to shake or suspend all sample particles evenly throughout the sample and then to pull an aliquot before any significant settling has occurred. This is especially true for sand-size particles in a sample (due to their high settling rate). Use of different methods of aliquot extraction and the individual techniques of laboratory personnel compound the difficulties associated with accurate TSS analysis. In order to avoid the problems associated with TSS and in order to obtain the most accurate measure of sediment concentration possible, a modified version of ASTM D3977-97 is used for water quality analyses conducted for this experiment series because of the relatively small box size (0. 6 m by 2. 0 m) used as compared with the standard plot size of 3. 0 m by 10 m for most simulated rainfall studies. Additionally, the rather small sizes of entire samples (~0. 5 L to 3. 5 L) lend themselves to analysis in their entirety.

E.2.2.1 Test Method A: Modified Evaporation

This method is utilized when most of the solid material in the liquid had settled down from suspension. Two measurements are obtained: final filter weight and final evaporation weight. The summation of these two measurements yielded the total sediment weight. This sediment weight is divided by total water volume (determined by the weight of water) to yield Suspended Sediment Concentration (SSC) for given sample. Supernatant water (clear, overlying water, which contains mainly fine sediment) is slowly filtered through a vacuum-filtration manifold. The supernatant water is decanted onto oven dried, pre-weighed Whatman 934AH filter paper. Filters are then oven dried for a minimum of eight hours at a temperature of 115 degrees Celsius. After oven drying, filters are placed into a desiccator. A desiccator prevented airborne moisture from collecting in the sediment specimens while the filters are cooling. After filters are at room temperature, an analytical balance is used to obtain the final filter weight. Once the supernatant water is filtered, the remaining water-sediment mixture is flushed from the storage container into a pre-weighed Nalgene evaporation beaker. The additional water amount used to flush the water-sediment mixture did not affect final calculations for any data analysis. Multiple evaporation beakers are required for most samples. Evaporation beakers are then oven dried at a temperature of 115 degrees Celsius until all water is evaporated. Since most of the evaporation beakers are over 2 liters in volume and too large for the desiccator, a desiccator is not used for the evaporation beakers. After the evaporation beakers are brought to room temperature, a digital balance is used to obtain the final evaporation weight of sediment.

E.2.2.2 Test Method B: Evaporation

This method is utilized when most of the solid material in the liquid has not settled from suspension. An entire sample is poured into a pre-weighed Nalgene evaporation beaker. Multiple evaporation beakers are needed for most samples. Evaporation beakers are then oven dried at a temperature of 115 degrees Celsius until all water is evaporated. Since most of the evaporation beakers are over 2 liters in volume and too large for the desiccator, a desiccator is not used for the evaporation beakers. After evaporation beakers are at room temperature, a digital balance is used to obtain the final evaporation weight.

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E.2.2.3 Example Data and Example Calculations

Total Runoff

From the combined mass of all collection containers with respective runoff, the combined mass of all runoff containers used is subtracted to yield the mass of total runoff.

Sum Of Collection_Mass_Total_g — Sum Of Collection_Container_Mass_g = Runoff_Total_g

Box_ID	Collection_Event_ID	Collection_Container_ID	Collection_Mass_Total_g	Container_Mass_g	RunOff_Total_g
1	1	64	1711.7	200.9	1510.8
1	1	5	2476.3	197.3	2279.0
			4188.0	**398.2**	**3789.8**
1	2	234	9551.0	1067.2	8483.8
			9551.0	**1067.2**	**8483.8**
1	3	74	2354.0	199.8	2154.2
1	3	56	2437.9	199.4	2238.5
1	3	231	15751.0	1001.5	14749.5
			20542.9	**1400.7**	**19142.2**

Final formatted data.

Box_ID	Collection_Event_ID	Collection_Mass_Total_g	Container_Mass_g	RunOff_Total_g
1	1	**4188.0**	**398.2**	**3789.8**
1	2	**9551.0**	**1067.2**	**8483.8**
1	3	**20542.9**	**1400.7**	**19142.2**

Total Sediment

From the combined mass of all evaporation containers with respective runoff, the combined mass of all evaporation containers used is subtracted to yield the mass of total sediment.

Sum Of Evaporation_Mass_Total_g — Sum Of Evaporation_Container_Mass_g = Sediment_Total_g

Calculations and data format are similar to those for Total Runoff.

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Suspended Sediment Concentration

Suspended Sediment Concentration is calculated as follows:

$$\text{Suspended Sediment Concentration} = \frac{\text{Sediment\_Total\_g}}{\text{Runoff\_Total\_g}}$$

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E.3 Water Quality Data

To both facilitate and control data input to analyses, a small custom relational database is used that consists of a frontend forms and queries in Microsoft® Access®, and backend data tables in Microsoft® Excel®. Data can be entered either directly into Excel tables, or through the Access forms. The rationale for this design is that some project workers are more comfortable using Excel, but data queries are easier and faster using Access. Through a command button, a query is run to both calculate and format data for export to Excel for basic statistical analysis and charting, and further into dedicated statistical software.

Table E.1 lists the data tables, **Figure E.1** shows the relationships, and **Figure E.2** shows the Access interface. **Figure E.3** shows an example row/record/tuple of formatted data.

Table E.1. Data Tables of Custom Relational Database.

Date Table	Data Stored
tblCollectionEvents	Date, source, and amount of each rainfall event (may span > 1 day)
tblCollectionMass	Data for each unique collection of runoff water + sediment
tblEvaporationMass	Data for each unique evaporated sample
tblContainers	Unique ID and mass of each empty collection or evaporation container

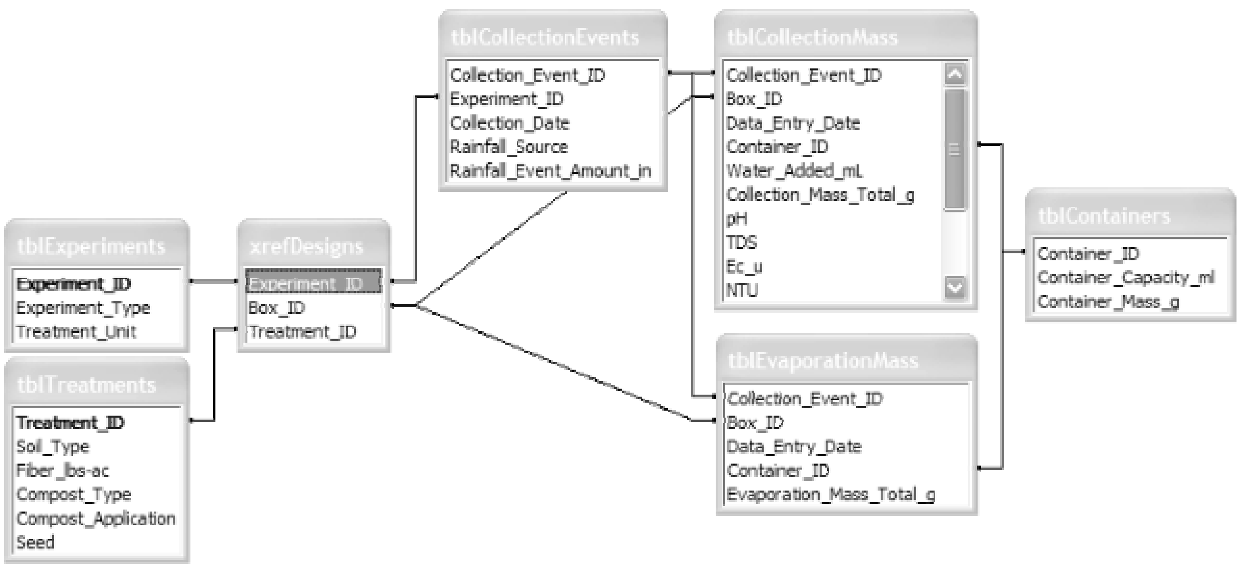

Figure E.1. Relationships of Custom Relational Database.

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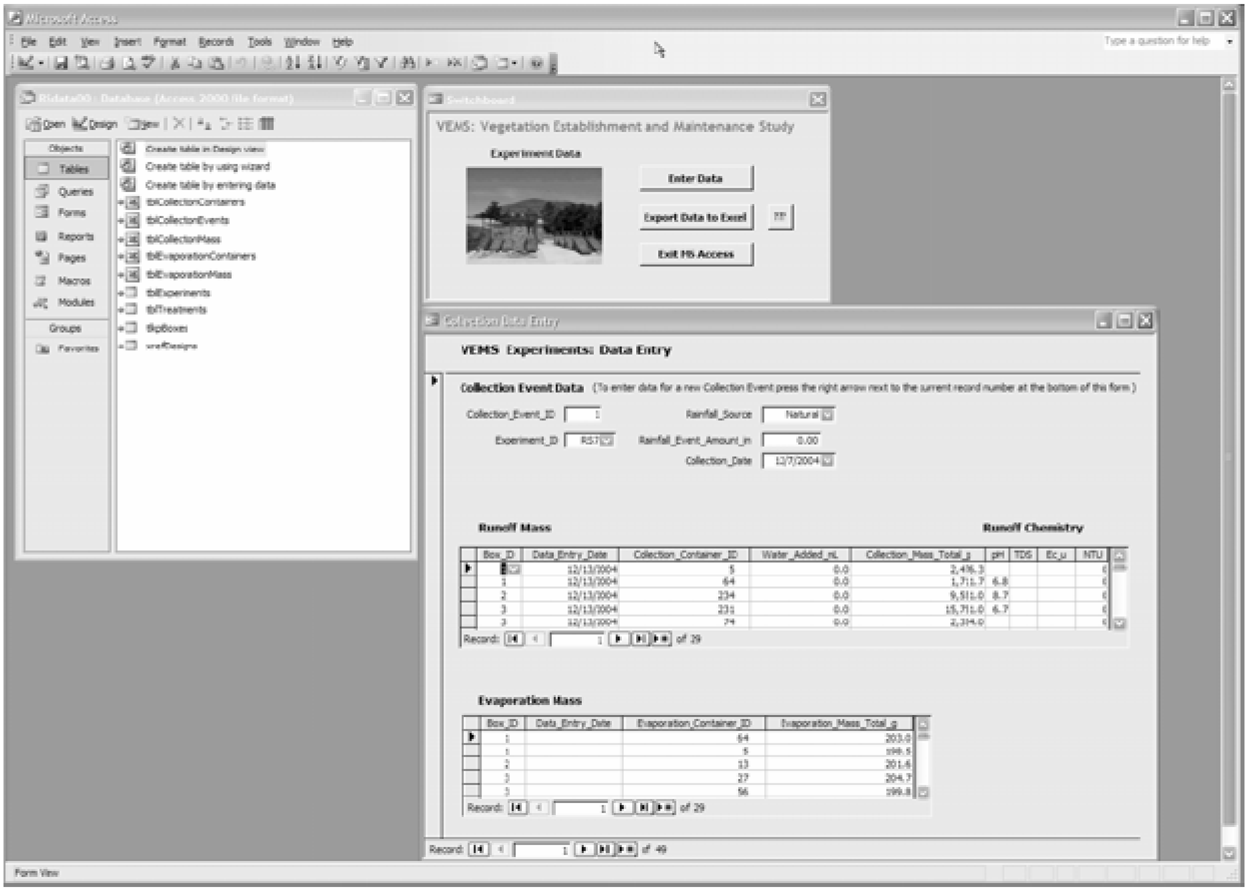

Figure E.2. Interface of Custom Relational Database.

Experiment_ID	Treatment_ID	Collection_Event_ID	Rainfall_Source	Rainfall_Event_Amount_in
RS7	2	1	Natural	1.54

Box_ID	Runoff_Total_g	Sediment_Total_g	pH	TDS_ppm	Ec_u	NTU
2	11245	232	7.9	58.4	29.1	602

Figure E.3. Example Record from Custom Relational Database.

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E.4 Standards

E.4.1 EPA Method 160. 2

TOTAL SUSPENDED SOLIDS (TSS)
Gravimetric, Dried at 103°-105°C

Follow the procedure outlined in EPA method 160. 2 for the analysis of samples for TSS. Weigh solid residue to a constant weight, defined as two consecutive weight measurements differing by less than 0. 5 mg, or less than 4%, whichever is smaller.

Data Calculations and Reporting Units:
Calculate the sample results according to Section 8 of EPA Method 160. 2. Report sample results in concentration units of milligram per liter (mg/L) as total suspended solids. Report TSS concentrations that are less than 100 mg/L to 2 significant figures, and TSS concentrations that are greater than or equal to 100 mg/L to 3 significant figures.

For rounding results, adhere to the following rules:

a) If the number following those to be retained is less than 5, round down;

b) If the number following those to be retained is greater than 5, round up; or

c) If the number following the last digit to be retained is equal to 5, round down if the digit is even, or round up if the digit is odd.

All records of analysis and calculations must be legible and sufficient to recalculate all sample concentrations and QC results. Include an example calculation in the data package.

Table E. 1. Summary of Sample Requirements for Total Suspended Solids (TSS).

Analytical Parameter	Contract Required Detection Limit (CRDL)	Technical and Contract Holding Times	Preservation
Total Suspended Solids (TSS)	10 mg/L	Technical: 7 days from collection; Contract: 5 days from receipt at laboratory	Cool to 4°C ±2°C

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Use sample aliquots of 100 mL. If the weight of captured residue is less than 1. 0 mg, increase the sample volume (up to 200 mL) to provide at least 1. 0 mg of residue and repeat the analysis.

Table E. 2. Summary of Internal Quality Control Procedures for EPA 160. 2.

QC Element	Frequency	Acceptance	Corrective Action
Analytical Balance Check: ***Weights of 100 mg, 1 g, and 100 g***	Daily	Difference < 0. 5 mg	1. Identify and document problem 2. Verify before sample analysis
Method Blank (MB)	One per Batch or SDG (1 per 20 samples minimum)	< CRDL	1. If lowest sample concentration is more than 10X the blank conc. , no action 2. If samples are non-detected, no action 3. If detected sample concentrations are less than 10X blank conc. , all associated samples must be prepared again with another method blank and reanalyzed
Duplicate Sample (DUP)	One per batch or SDG (1 per 20 samples minimum)	RPD <20% for samples >5X CRDL; ± CRDL for samples <5X CRDL	1. Flag associated data with an "*"
One set (two concentration levels) mineral reference samples	One set per batch or SDG (1 set per 20 samples minimum)	± 15% from expected concentration	1. Terminate analysis 2. Identify, document, and correct the problem 3. Reanalyze all associated samples

CRDL = Contract Required Detection Limit

SDG = Sample Delivery Group - each case of field samples received; or each 20 field samples within a case; or each 14 calendar day period during which field samples in a case are received.

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Appendix F VEGETATION SAMPLING and ANALYSES

F.1 Basic Variables

The primary measures of vegetation are: ***density***, the number of rooted individuals of a species, lifeform, or structural class per unit area; ***frequency***, the number of times that a species occurs over a series of sampling units; ***cover***, a two-dimensional perpendicular projection down onto the ground surface of the three-dimensional aerial vegetation above; and ***biomass***, the quantity of herbaceous or woody tissue produced by individuals of a species, lifeform, or structural class per unit area per unit time (Bonham 1989; Interagency Technical Team 1996; Kent and Coker 1992; Mueller-Dombois and Ellenberg 1974). Biomass measures require destructive sampling, intensive labor, and extensive time; thus are not typically performed because such measurements would likely not repay their costs nor provide additional information beyond cover estimates. A synopsis of the typically assessed vegetation attributes of density, frequency, and cover, is presented in **Table F.1.** The discussion that follows focuses primarily on estimates of aerial plant cover because cover is the most important vegetation attribute relative to any reduction of soil erosion owing to the ability for aerial plant parts to intercept a raindrop before it strikes the soil surface. Aerial plant cover percentages are typically used by regulatory agencies to determine adequate soil surface protection and compliance with environmental regulations.

Table F.1. Definitions of the Basic Vegetation Variables Typically Measured.

	Density	Frequency	Cover (aerial)
Definition	Number of rooted individuals per unit area	Number of times that a species occurs over a series of sampling units	Amount of ground surface "covered" by the perpendicular projection downward of aerial plant parts
Data required	Counts of the number of rooted individuals or aerial stems of each species	Recorded presence of each species	A quantitative or qualitative measure (ranked percentage) of the live aerial "cover" contributed by each species and by non-living ground litter
Attribute Calculation	Sum *n* rooted individuals/ total sampled area	Sum *n* occurrences/total sampled area	Sum *n* individual cover values/Sum *n* samples
Attribute Expression	Average # rooted individuals/ unit area	Average # occurrences/unit area	Average cover value/unit area

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F.2 Cover

Over the last several decades, vegetation cover has been evaluated using various methods based upon the three fundamental models of one- or two-dimensional spatial phenomena: points, lines, or areas (see Mueller-Dombois and Ellenberg 1974; Bonham 1989; or Interagency Technical Team 1996 for thorough reviews). Points, lines (transects), or areas (polygons) are used either alone or in combination with varying success at estimating canopy cover of one or more vegetation strata across both organismal and geographic scales.

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Even though vegetation is three-dimensional, methods employing volumetric measures are rarely used owing to both added complexity and added sampling time necessary to measure volume. Addition of time as a fourth dimension is also too infrequent, as the majority of vegetation sampling is effectively a temporal "snapshot" of a dynamic assemblage exhibiting both seasonal changes and longer term responses to climate, disturbance, interspecific interactions, and intraspecific demographic fluxes.

Cover is the most logical and time-efficient measure in that the interception of raindrops by aerial plant parts is fundamental in retarding water-driven soil erosion processes. Although plant density can provide important information about how many individuals of a given species in a seed mix germinated and established, obtaining plant counts are extremely labor intensive and time consuming, especially in a multi-species mix. Although ***cover*** is the most frequently employed vegetation measure, the term "cover" includes a multitude of possible measurement techniques, and connotes different meanings to different people (Bonham 1989). Therefore, an explicit discussion of the exact method(s) used to measure plant cover for any research project is imperative.

Valid estimates of plant cover are difficult owing to some complex and interacting factors:

- Plants are spatially three-dimensional, stratified, and interwoven;
- Plants are variable over space and time;
- Plant sizes and shapes influence the spatial dispersion of "hits" (i.e. the spacing of observation points must not be too closely or widely spaced for the vegetation).

F.3 Point Cover Estimates

The oldest, most objective, and most repeatable measure of plant cover is by *point intercept* whereby a theoretically infinitely small point projected from above down onto vegetation surfaces contacts individual plant structures, soil surface litter, rock, or bare soil. Each contact is termed a "hit" for each category scored. Rules must be established beforehand regarding exactly what constitutes a "hit" for each purpose-dependent investigation. For example, for studies of long-term plant cover "hits" upon inflorescences may not be counted owing to their ephemeral presence. However, other studies, such as this one, may choose to count "hits" upon inflorescences because such plant organs do intercept raindrops when present during the season of precipitation.

F.3.1 Pin Frame Method

Although the best point method for cover measurements is through an optical sighting device (a tube with lenses and cross-hairs analogous to a short-range telescope) mounted on a frame and directed along an axis perpendicular to the ground surface, the observer must sight through the device from directly above or to the side. Because the test boxes in these experiments are inclined at a 2:1 H:V (=50% = 26.6°∠) or greater slope, and not readily movable to a position flat on the ground, an optical sighting device is not used. Instead, a pin-frame, the next-best traditional method for measuring cover over small areas, is used for cover analyses.

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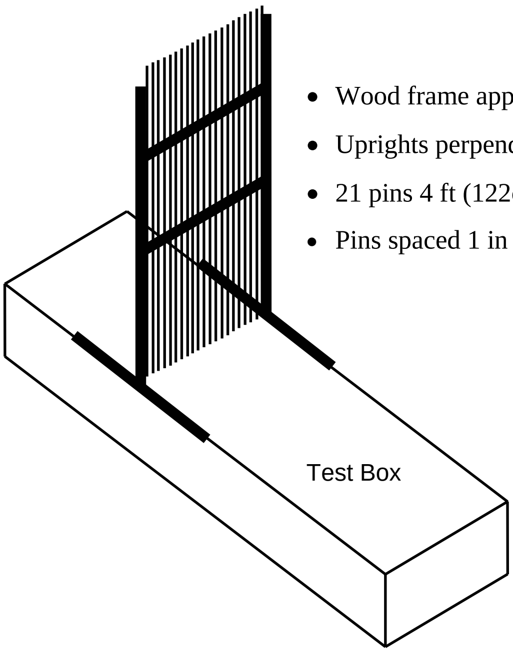
A custom pin-frame was designed and constructed for these experiments using wood and stainless steel rods as pins. The frame is designed such that the uprights are perpendicular to the actual ground surface, not to the soil in the box, because the vegetation in the boxes is growing perpendicular to the actual ground surface owing to phototropism. The frame contains 21 independently operated pins in a single row, each approximately 122 cm (4 ft) long and spaced 25.4 mm (1 in) apart (see **Figure F.1**). This length accommodates increasing plant height as plants grow through the season. Pin spacing reflects the finely textured, mostly grassy, nature of the vegetation growing in the soil test boxes, and the need to include as many potential sample points as possible in a randomized sampling scheme.



- Wood frame approximately 4 ft (122 cm) tall by 2 ft (61 cm) wide of 3/2 square stock
- Uprights perpendicular to the actual ground surface, not to the soil in the box
- 21 pins 4 ft (122cm) long of 5/32in (4 mm) diameter stainless-steel
- Pins spaced 1 in (25.4 mm) apart in a single row

Figure F.1. Details of the Custom Pin Frame Designed to Sample Plant Cover

The 21-pin design of the pin frame allows for two different sampling schemes. A standard method where 20 pin positions are sampled consecutively with the remaining pin position used to randomly select a starting position at pin 0 or 1. A second method randomly selects a subset of pins from the 21 positions possible. For this experiment series the latter method is used for cover estimates because it reduces the affect of spatial autocorrelation on the data set. Spatial autocorrelation is an important and complex issue in statistical analyses of spatial phenomena and too large of a topic for in-depth discussion here. In brief, the issue simplifies to this: spatial autocorrelation among observed values occurs where the value of a measured variable at one spatial location positively or negatively influences the value of that same variable at adjacent or nearby locations (Cliff and Ord 1973; Fortin et al. 1989; Legendre 1993).

F.3.2 Line-Point Method

For this modified line-point method a 600mm (24 in) length of 20mm (0.8 in) square wood stock is notched along the length of each angled face at 25mm (0.98 in) intervals. Along each face 10 positions are selected using random numbers to render four different point position arrays. The

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ends of the stock are affixed and allowed to rotate on uprights so that the bar is held approximately 25mm (0.98 in) above, and parallel to, the soil surface. A computer spreadsheet is used to assign randomly generated numbers to each of the 21 possible sample point positions, to sort the 21 positions, and to select the first 10 unique positions for each transect. Positions selected for the five transects in the upper half are used for lower half transects of the same box. The design renders 100 observations per box.

F.3.3 Point Cover Sampling Design

An outline of the sampling method devised to obtain plant cover estimates for the test boxes is as follows.

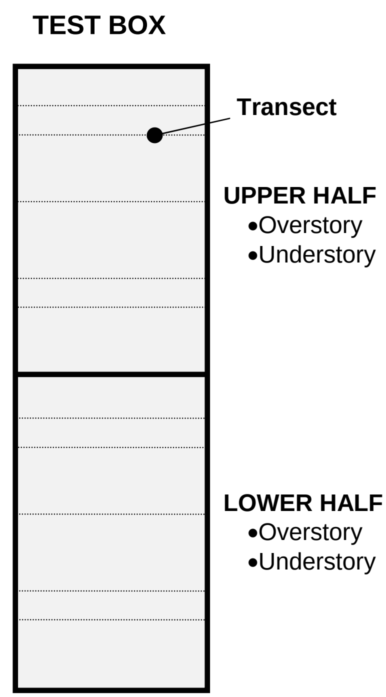
2 divisions per box

For sampling purposes, each test box is conceptually divided into an upper and a lower half to assess whether differences in plant cover exist between the two halves because of greater gravity water flow and retention in the lower end of each inclined box.

5 transects per box division (randomly spaced)

Positions are marked every decimeter along the rails of each box. This renders nine possible transect positions in each half of every box. A computer spreadsheet is used to assign randomly generated numbers to each of the nine possible positions, to sort the nine positions, and to select the first five unique positions for each box. Positions selected for the upper half are used for the lower half of the same box.

10 sample points per transect (randomly selected)



For Pin Frame Method Only

2 vegetation layers (overstory / understory) per transect

Vegetation within the test boxes is usually visibly stratified into two layers: an *overstory* consisting of mostly taller grasses, and an *understory* of shorter annuals, of first-year shoots of perennial forbs, or of shrub seedlings. To separate the treatment responses of these shorter plants from the faster growing and taller plants, "hits" are recorded in the overstory and understory separately. As each pin is pushed down into the vegetation, a single contact "hit" is recorded for any part of any plant in the overstory. The same pin is then pushed further down until a single contact "hit" is made with any part of a different plant occupying the lowest vegetation layer.

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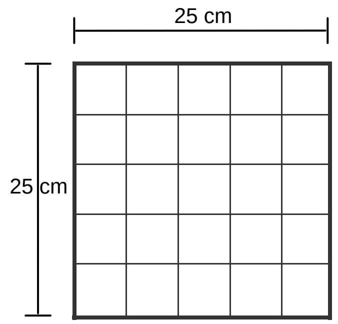
F.4 Area Cover Estimates

A long-standing method of estimating aerial plant cover within area plots uses portable squares or rectangles of wood, wire, or pipe, dubbed quadrats, to temporarily enclose a vegetation sample while an observer estimates canopy cover from above by class (forb, grass, litter, bare ground), or by species expressed ranked percentage ranges (Daubenmire 1959; Mueller-Dombois and Ellenberg 1974). Quadrat size and shape must be scaled appropriately for the vegetation at the time that observations are made to be accurate, precise, and statistically valid. This subject of quadrat size, shape, and placement has engendered much debate in the ecological literature with discussion much too lengthy for review here.

F.4.1 Quadrat Proportions and Cover Class

For this experiment series, a 25 cm x 25 cm square wire quadrat divided into twenty-five 5 cm x 5 cm squares is used as the basic sampling unit. Cover is estimated by cover class within each square and then averaged to obtain an estimate for the whole quadrat. The original six cover ranks devised by Daubenmire are expanded to seven by splitting the 0% – 5 % class into two ranks, < 1 % and 1 – 5% to ensure better resolution of species at very low cover values during the initial stages of revegetation. Midpoint values of these cover class ranks are then used to calculate absolute and relative percentages. Cover classes typically assessed are legume shrub seedlings, non-legume shrub seedlings, legume forbs, non-legume forbs, grasses, litter, and bare ground. Classes may vary with each experimental design, and may estimate cover for species rather than live cover classes.

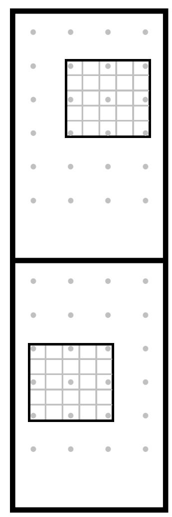


Class	% CoverRange	Midpoint
1	<=1	0.5
2	1 to 5	2.5
3	5 to 25	15.0
4	25 to 50	37.5
5	50 to 75	62.5
6	75 to 95	85.0
7	95 to 100	97.5

F.4.2 Quadrat Proportions and Cover Class

An outline of the sampling method devised to obtain plant cover estimates for the test boxes is as follows.

TEST BOX



2 divisions per box

For sampling purposes, each test box is conceptually divided into an upper and a lower half to assess whether differences in plant cover exist between the two halves because of greater gravity water flow and retention in the lower end of each inclined box.

2 quadrats per box division (randomly placed)

Within each box half, 24 anchor positions spaced one decimeter apart are possible locations for placement of the top-right or top-left corner of the quadrat. A computer spreadsheet is used to randomly assign a quadrat to an anchor position.

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F.5 Plant Identification

Species identification, taxonomy and nomenclature follow the most recent comprehensive flora for California, *The Jepson Manual: Higher Plants of California* (Hickman 1993) and subsequent updates available over the internet. Other pertinent floristic references (e.g., Hitchcock 1951; Munz 1974; Munz and Keck 1959) are consulted, as needed.

F.6 Analytical Methods

F.6.1 Descriptive Statistics

From point or quadrat data, the sample size, mean, min, max, standard deviation, variance, range, sum, standard error of the mean, kurtosis and skewness with their standard errors, and frequencies are calculated for cover, and, when sampled, for counts of individual species or lifeforms within quadrats.

F.6.2 Analyses of Point Cover Data

Proportion cover can be analyzed using three methods: logistic regression, a weighted analysis of variance (ANOVA) and ANOVA on arcsine root transformed data. Although the conceptual model of how treatments and other factors affect each of these response variables is the same with each of these three methods, different sets of assumptions must be satisfied for each method before the results can be trusted. If all three methods produce largely similar estimates of cover, and of treatment effects, then this can be viewed as confirmation of the conceptual model. While proportion cover estimates are informative and perhaps the easiest method for comparison between treatments (light versus heavy rainfall, etc.) they do not allow for formal conclusions. Thus, formal statistical tests appropriate to each method are used to overtly test null hypotheses. What follows is an attempt to provide a brief description of each of these methods, but the fine points of using each method for estimation or testing should are best described in any of the standard reference books (e.g., Agresti 1996; Montgomery 1991). The conceptual model relating various experimental factors to the observed proportion cover in the context of each method is described by logistic regression and ANOVA.

F.6.2.1 Logistic Regression

Percent cover is measured in each box-half by determining cover or no cover for each of 50 points. If the presence or absence of plant matter at each sampled location is considered as the response variable of interest, then logistic regression is a method by which the presence of plant matter at any point in the box is modeled as a function of treatment and other factors. For example, for any location with a fixed rainfall regime, fertilizer level, treatment (straw versus tackifier) and box-half (upper versus lower) a probability exists that there is live plant cover at that location, i.e. the probability of cover at a location in the l^{th} box division with the i^{th} rainfall level, j^{th} level of fertilizer, k^{th} level of treatment (straw or tackifier) is π_{ijkl} which is modeled as:

$$
\begin{aligned}
\operatorname{logit}(\pi_{kjkl}) = \log(\pi_{kjkl}/(1-\pi_{kjkl})) \quad &= \quad \mu + \alpha_i + \beta_j + \gamma_k + \delta_l + \\
&\alpha\beta_{ij} + \alpha\gamma_{ik} + \alpha\delta_{il} + \beta\gamma_{jk} + \beta\delta_{jl} + \gamma\delta_{kl}
\end{aligned}
$$

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where

α_i	Effect of rainfall level *i*
β_j	Effect of fertilizer level *j*
γ_k	Effect of treatment level *k*
δ_l	Effect of Box-division *l*
$\alpha\beta_{ij}$	Interaction between rainfall level *i* and fertilizer level *j*
$\alpha\gamma_{ik}$	Interaction between rainfall level *i* and treatment level *k*
$\alpha\delta_{il}$	Interaction between rainfall level *i* and box-division level *l*
$\beta\gamma_{jk}$	Interaction between fertilizer level *j* and treatment level *k*
$\beta\delta_{jl}$	Interaction between fertilizer level *j* and box-division *l*
$\gamma\delta_{kl}$	Interaction between treatment level *k* and box-division *l*

Note that an interaction, e.g., between rainfall level and box-division, would imply that the effect of rainfall level on proportion cover differs between the two box-divisions. Thus, logistic regression attempts to model the proportion of "successes" (e.g., percent cover) as a function of these other factors.

F.6.2.2 Analysis of Variance (ANOVA)

Next is the same model described in the ANOVA context. Two ANOVA methods for analyzing these proportion cover data are used. The first method is to model the proportion cover directly with a weighted ANOVA and the second approach is to use a transformation of the proportion cover data, which is then modeled with a straightforward ANOVA.

For the weighted ANOVA, the following model was used to describe the relationship between experimental factors and proportion cover:

$$\begin{aligned} y_{kjklm} = \; & \mu + \alpha_i + \beta_j + \gamma_k + \delta_l + \\ & \alpha\beta_{ij} + \alpha\gamma_{ik} + \alpha\delta_{il} + \beta\gamma_{jk} + \beta\delta_{jl} + \gamma\delta_{kl} + \\ & \varepsilon_{ijklm} \end{aligned}$$

where y_{ijklm} is the proportion cover for the l^{th} box division of the m^{th} box with the i^{th} rainfall level, j^{th} level of fertilizer, k^{th} level of treatment (straw or tackifier) and the main effects and interactions are exactly analogous to the terms defined in the discussion of the model in the previous paragraph. According to these models, percent cover is affected by the rainfall level, fertilizer, treatment (straw versus tackifier) and box division. The two-way interaction terms allow for the affect of fertilizer on percent cover to depend on the rainfall level (etc). The ε_{ijklm} terms are assumed to be normally distributed and independent of each other. Due to the fact that the response variable plant cover is proportion data, the variance of the ε_{ijklm} terms is assumed to equal $p_{ijkl}(1 - p_{ijkl})$ where $p_{kjkl} = \mu + \alpha_i + \beta_j + \gamma_k + \delta_l + \alpha\beta_{ij} + \alpha\gamma_{ik} + \alpha\delta_{il} + \beta\gamma_{jk} + \beta\delta_{jl} + \gamma\delta_{kl}$ is the theoretical proportion cover.

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F.6.2.3 Weighted Analysis of Variance (ANOVA)

A weighted ANOVA is performed when the analysis weights depend on estimated sample variances based on the nature of how data were collected. Thus, if the sample proportion of cover in any box-half is estimated to be $\hat{p}$, the analysis weights for that box-half would be proportional to $\frac{1}{\hat{p}(1-\hat{p})}$.

However, because in some cases 100% of the sampled points show vegetation cover , two successes and two failures are added to such data for the purpose of estimating sample weights, as suggested by Agresti and Coull (1998). Thus the sample weights for a box-half are proportional to $\frac{1}{\tilde{p}(1-\tilde{p})}$ where $\tilde{p}$ equals the number of sample points with vegetation plus two over the number of sampled points plus four. [Note: other ways to consider for sensitivity analysis would be byes or shrinkage estimated weights or weights that are based on the fitted estimated values (starting with no weighs) in the previous iteration and iterate until stable.]

Another approach could be to transform the response variable so that we have approximate normality of the disturbance terms. One common transformation is the arcsine root transform. The model remains:

$$
\begin{aligned}
y_{kjklm} \quad = \quad & \mu + \alpha_i + \beta_j + \gamma_k + \delta_l + \\
& \alpha\beta_{ij} + \alpha\gamma_{ik} + \alpha\delta_{il} + \beta\gamma_{jk} + \beta\delta_{jl} + \gamma\delta_{kl} + \\
& \varepsilon_{ijklm}
\end{aligned}
$$

but y_{ijklm} is the arcsine of the square root of proportion cover for the l^{th} box division of the m^{th} box with the i^{th} rainfall level, j^{th} level of fertilizer, k^{th} level of treatment (straw or tackifier) and the main effects and interactions are exactly analogous to the terms defined in the discussion of this model above. The ε_{ijklm} terms are assumed to be independent of each other, normally distributed and with constant variance.

A benefit of the weighted ANOVA over the arcsine root transformed response data ANOVA is that the interpretation of the parameter estimates is natural (i.e., parameter estimates may be thought of as the estimated difference in proportion cover between, say, high rainfall level and natural rainfall, all other things being held equal). A drawback of the weighted ANOVA is that there is no guarantee that the estimated proportion cover will fall in the zero to one range. Two benefits of the arcsine root transformation are that the estimated proportion cover will always be in the zero to one range and that post-hoc comparisons of treatments are straightforward. A drawback of the arcsine root transformation is that the parameter estimates do not have a natural interpretation.

Among the three methods, logistic regression should be thought of as most appropriate for estimating the effects of each factor on the proportion cover. However, arcsine root ANOVA is used for making comparisons across the various treatments within each rainfall regime. For the post-hoc comparisons Bonferroni based methods are used because they are conservative and thus are unlikely to announces difference among treatments if, in fact, no difference exists.

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F.6.3 Analyses of Quadrat Cover Data

There are three reasonable methods for analyzing cover based on ranked estimates, such as the Daubenmire Method:

1. **Ordinal logistic regression** where the **chance** that a quadrat would receive any particular rank value is a function of explanatory variables. A benefit of this method is that it is reasonable with rank data. The drawback is that with such an analysis, only the effect of treatment conditions on the chance of cover for the cover rank categories (zero to 1%, 1% to 5%, 5% to 25%, etc.) could be determined;

2. **ANOVA using the midpoints of the each rank class** as the response variable (i.e., a rank of 1 corresponds to a midpoint of 0.5%, a rank of 2 corresponded to a midpoint of 2.5%, a rank of 3 corresponds to a midpoint of 15%, etc.). A benefit of this method is that it provides a direct estimate of the effects of treatment variables on percent cover. The drawback is that the ANOVA assumption of equality of variance is not satisfied. The only solution is to use a transformation of the midpoints. In fact, the best transformation appears to be something akin to using the original ranks themselves;

3. ANOVA **using the rank data** as the response variable. The benefit of this method is that there are no problems with the ANOVA assumptions. The drawback is that there is no direct estimate of the effects of treatment on percent cover. However, this can be finessed.

Because there are only ranks to work with, a method of transforming from an average of ranks back to percentage is necessary to estimate percentages. **Chart F.1** shows the relationship between ranks and percentages. If the original percentage cover for a location is 32%, it receives a rank of 4. In fact, any cover percentage in the range from 25% to 50% receives a rank of 4. Traditionally one might use midpoints for analysis, i.e. treat any observation with a rank of 4 as if it were 37.5% cover.

The relationship between rank and midpoint is approximately logistic. Because $\log\left(\frac{\text{midpoint}}{100\% - \text{midpoint}}\right) \approx -6.38 + 1.41 \times \text{rank}$, estimated ranks associated with particular treatment conditions are converted back to percentages via:

$$\text{estimated percentage} = \frac{e^{-6.38+1.41\times\text{rank}}}{1+e^{-6.38+1.41\times\text{rank}}} \times 100\%.$$

As an example, if for a particular set of treatment conditions, an average rank is 3.32, the estimated percentage is:

$$\text{estimated percentage} = \frac{e^{-6.38+1.41\times 3.32}}{1+e^{-6.38+1.41\times 3.32}} \times 100\% = 15.5\%.$$

The solid line in **Chart F.1** shows this relationship. ANOVA is used on the ranks themselves, then, as necessary, ANOVA results are transformed back to a percentage scale.

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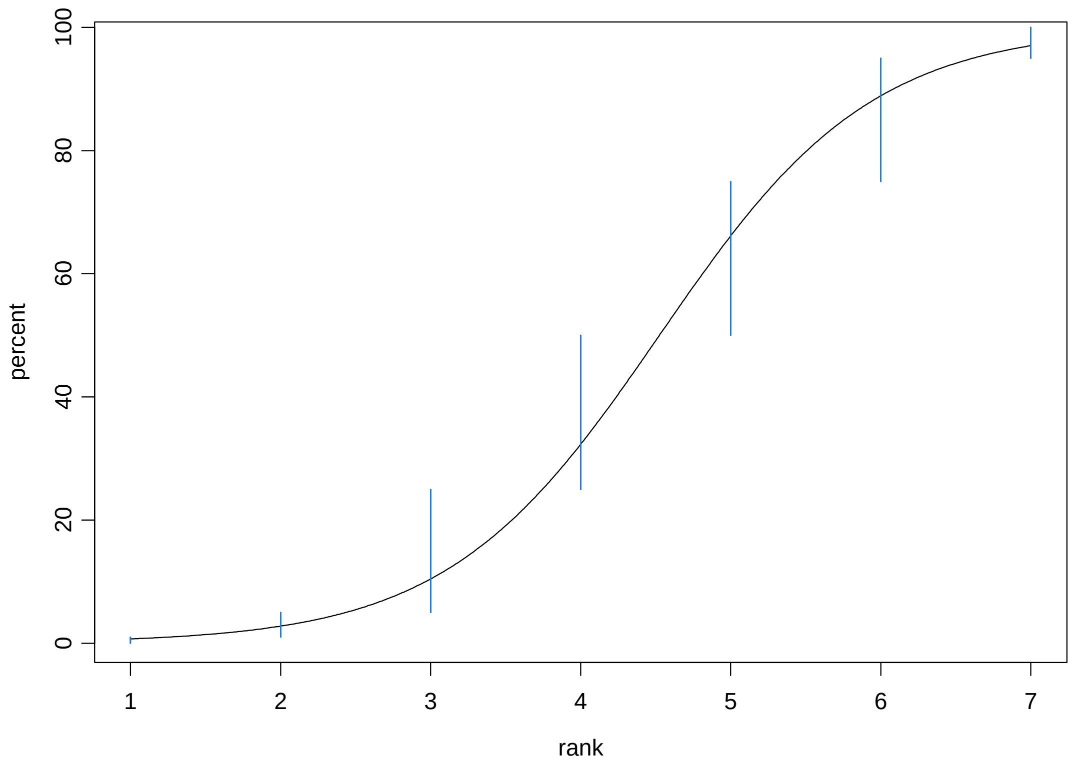

Chart F.1. Relationship Between Cover Ranks and Percentages.

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F.7 Vegetation Sampling References

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G.1 Experiment RS5 Water Quality Analyses

The variables that could be used to predict the various aspects of water quality were soil type, EC method, date, and rainfall amount. Because the rainfall pattern during the November 2003 through February 2004 period was moderately correlated (r=0.724), any time-trend in the water quality could not be differentiated from an effect of rainfall amount. If there were differing rainfall patterns, perhaps storms that alternated large and small rainfall amounts, a time trend may have been noticeable. However, this is not the case. See **Chart G.1** below.

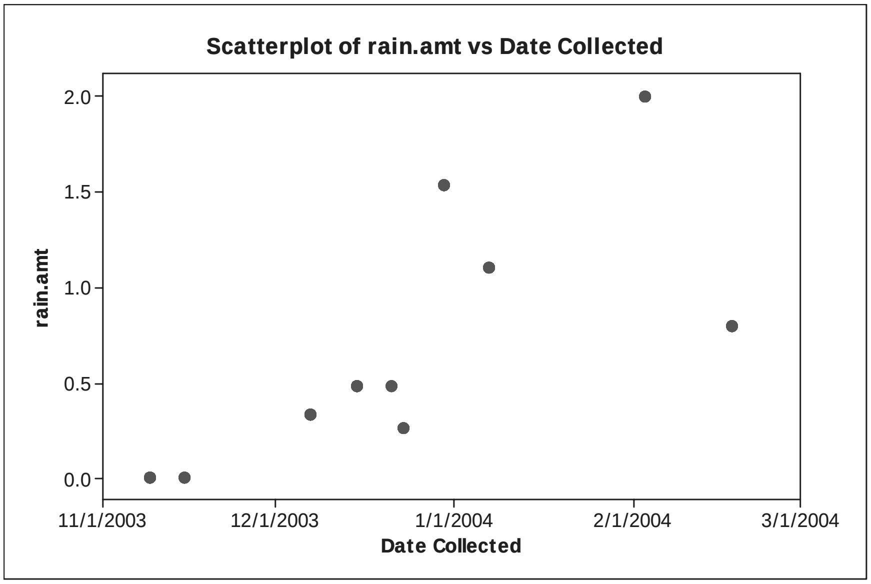

Chart G.1. Rainfall Amount By Date Collected.

Because of this positive correlation between date and rainfall amount, there were three choices of variables which could have been included.

1. Date, but not rainfall amount. This would give a biased estimate of the effect of date, however the level of the bias would be unknown. If this model was used, it would state that the concentration decreased with time, as would be expected. For such an analysis, the adjusted R square for the concentration analysis is 23% (i.e. 27% of the variability of the response variable was considered "explained" by the explanatory variables).
2. Rainfall amount, but not date. This would give a biased estimate of rainfall amount. Again, the amount of the bias would be unknown. If this model was used, it would state that higher rainfall was related to **lower** concentration. This would not have been realistic if taken at face value. (In fact, this was likely because the low rainfall storms were at the beginning of the time period, but the high rainfall storms were toward the end of this period.) The adjusted R square for concentration is 27%.
3. Both date and rainfall. Neither estimate would have been biased, but the two estimates would have been substantially correlated nor would both have had large standard errors. Furthermore, the pattern was somewhat counter-intuitive for early dates and small rainfall amounts. The adjusted R square for concentration is 27%.

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Model 1 with "Date, but not rainfall amount" was used because the real question is the effect of EC treatment and soil type on water quality. All three choices gave similar answers to this question. Furthermore, two of the three analyses (for total water and total sediment) had higher adjusted R square values when using date instead of rainfall amount. Note, however, that this produced estimates of the effect of date that are confounded with the effect of rainfall amount.

G.1.1 RS5 Runoff Analysis

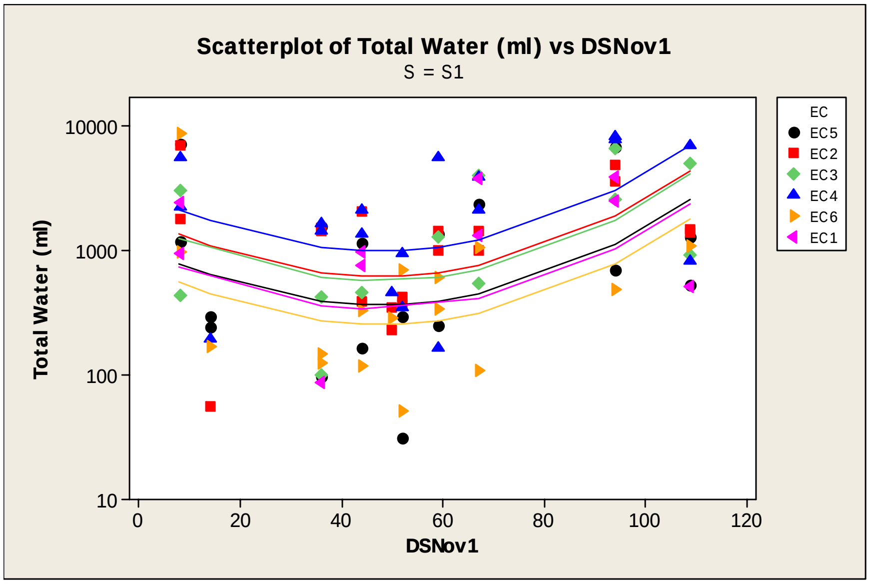
G.1.1.1 Total Runoff ANOVA:

```
Analysis of Variance for log.water, using Adjusted SS for Tests
Source           DF    Seq SS    Adj SS   Adj MS       F      P
S                 1     1.833     0.001    0.001    0.00  0.982
EC                5    74.654    82.747   16.549    9.05  0.000
S*EC              5    36.439    36.989    7.398    4.05  0.002
DSNov1            1    22.432    28.820   28.820   15.76  0.000
DSNov1*DSNov1     1    47.975    47.975   47.975   26.24  0.000
Error           165   301.708   301.708    1.829
Total           178   485.041

S = 1.35223   R-Sq = 37.80%   R-Sq(adj) = 32.90%
```

There appeared to be an effect of EC on the amount of water in the runoff and that effect was different by soil type.

- On clay loam (S1), EC4 had the highest total runoff, followed by EC2, EC3, EC5, EC1 and EC6, in order. EC4 had runoff significantly higher than all others. EC2 and EC3 could not be said to differ, but they were both significantly higher than EC5, EC1 and EC6. EC5, EC1 and EC6 could not be said to differ.
- On fine sandy loam (S2), EC2 had the highest total runoff, followed by EC1, EC4, EC3, EC5 and EC6, in order. EC3 and EC5 were not statistically different, but all other pairs were noticeably different.



RS 5 EC Treatments	
Abbr	**Treatment**
EC1	Control
EC2	Soil Roughening
EC3	Jute only
EC4	Jute over Compost
EC5	Crimped straw only
EC6	Crimped Straw over Compost

Chart G.2. RS5 Clay Loam (S1) Runoff Scatterplot.

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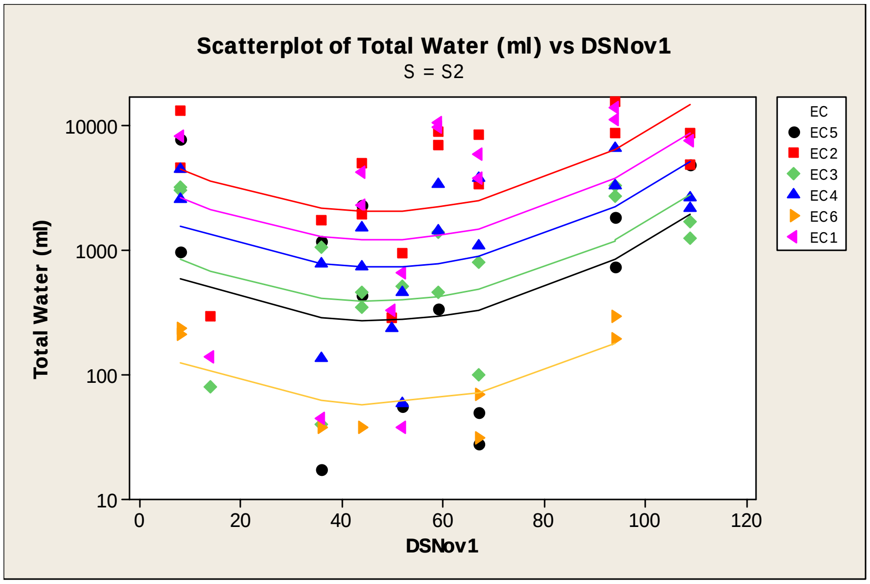

RS 5 EC Treatments

Abbr	Treatment
EC1	Control
EC2	Soil Roughening
EC3	Jute only
EC4	Jute over Compost
EC5	Crimped straw only
EC6	Crimped Straw over Compost

Chart G.3. RS5 Fine Sandy Loam (S2) Runoff Scatterplot.

G.1.2 RS5 Sediment Analysis

G.1.2.1 Total Sediment ANOVA:

```
Analysis of Variance for log.sediment, using Adjusted SS for Tests

Source          DF    Seq SS    Adj SS    Adj MS      F      P
S                1    8.2272    6.1406    6.1406  13.41  0.000
EC               5   85.1899   88.7770   17.7554  38.78  0.000
S*EC             5    5.4828    5.3209    1.0642   2.32  0.045
DSNov1           1   10.6959   21.3544   21.3544  46.65  0.000
DSNov1*DSNov1    1   14.9154   14.9154   14.9154  32.58  0.000
Error          171   78.2841   78.2841    0.4578
Total          184  202.7953

S = 0.676611   R-Sq = 61.40%   R-Sq(adj) = 58.46%
```

There was an effect of soil type and EC method on the sediment in the runoff. Furthermore, the effect of EC on sediment in the runoff differed by soil type.

- On clay loam (S1), EC1 and EC2 had the highest amounts of sediment, on average, and all other EC methods were significantly lower.
- On fine sandy loam (S2), EC1 and EC2 had the highest amounts of sediment, on average, and all other EC methods were significantly lower.

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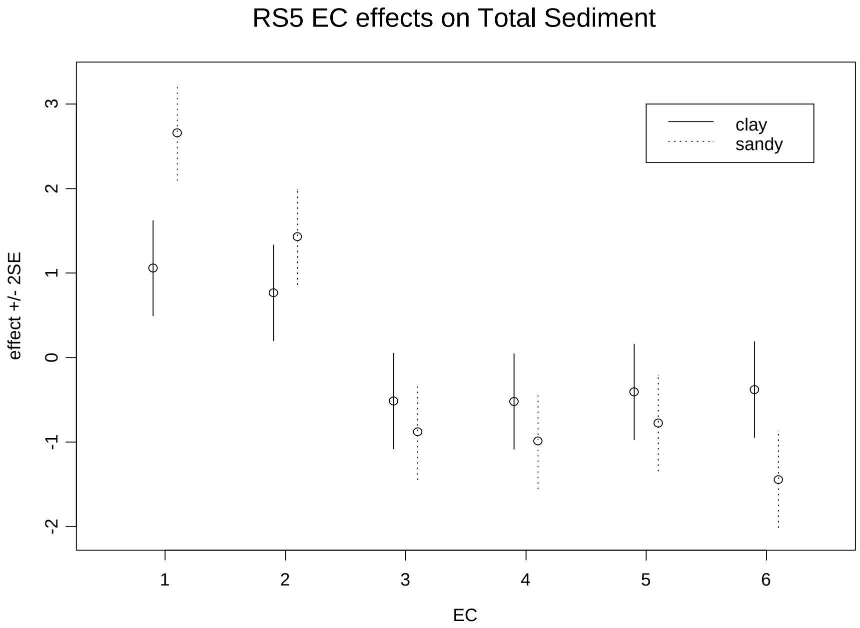
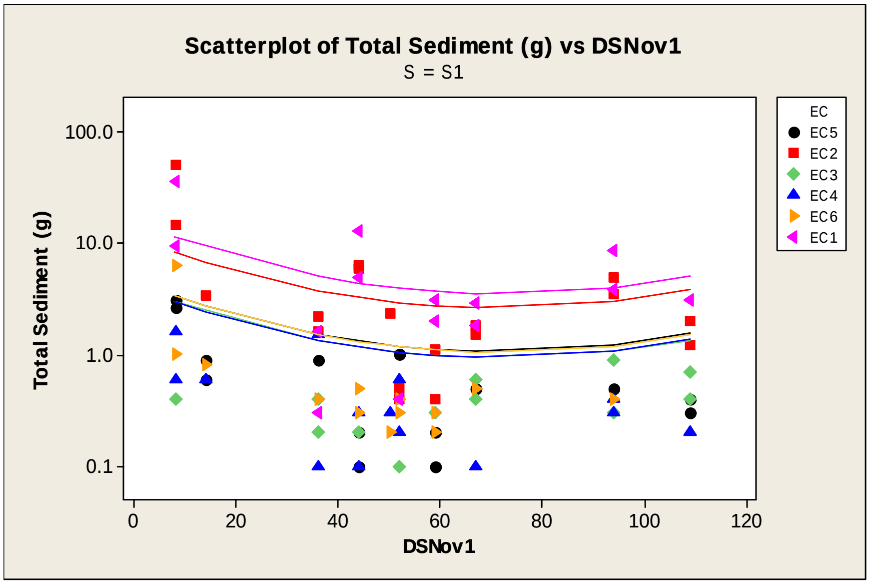


RS 5 EC Treatments	
Abbr	**Treatment**
EC1	Control
EC2	Soil Roughening
EC3	Jute only
EC4	Jute over Compost
EC5	Crimped straw only
EC6	Crimped Straw over Compost

Chart G.4. RS5 EC Treatment Effects on Total Sediment.



RS 5 EC Treatments	
Abbr	**Treatment**
EC1	Control
EC2	Soil Roughening
EC3	Jute only
EC4	Jute over Compost
EC5	Crimped straw only
EC6	Crimped Straw over Compost

Chart G.5. RS5 Clay Loam (S1) Total Sediment Scatterplot.

Note: blue and green lines for EC3 and EC4 are overlapping, as are orange and black lines for EC6 and EC5.

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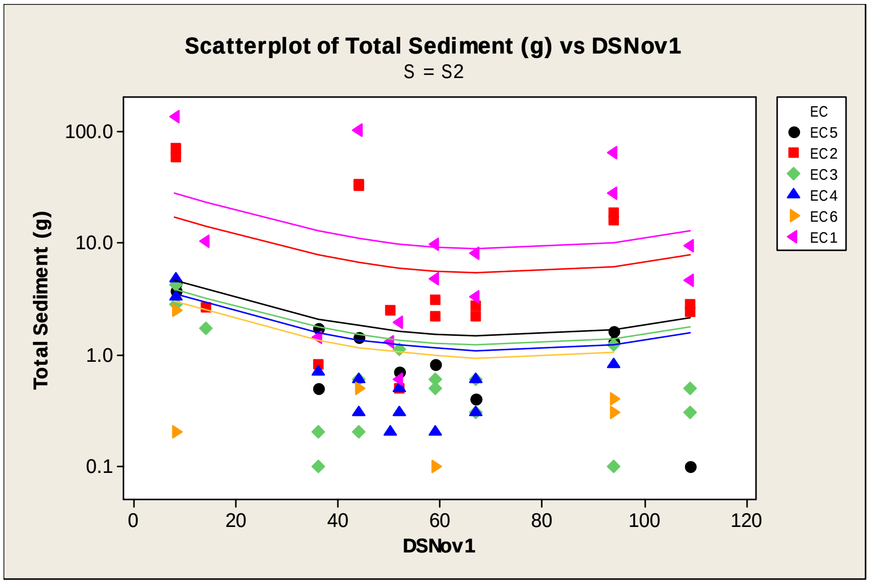

RS 5 EC Treatments	
Abbr	**Treatment**
EC1	Control
EC2	Soil Roughening
EC3	Jute only
EC4	Jute over Compost
EC5	Crimped straw only
EC6	Crimped Straw over Compost

Chart G.6. RS5 Fine Sandy Loam (S2) Total Sediment Scatterplot.

Note: blue and green lines for EC3 and EC4 are overlapping, as are orange and black lines for EC6 and EC5.

G.1.3 RS5 Sediment Concentration Analysis

G.1.3.1 Sediment Concentration ANOVA:

```
Analysis of Variance for log.conc, using Adjusted SS for Tests

Source    DF    Seq SS   Adj SS   Adj MS      F      P
S          1    17.394    4.914    4.914   1.01  0.316
EC         5   200.716  219.619   43.924   9.05  0.000
S*EC       5    40.631   35.239    7.048   1.45  0.208
DSNov1     1    72.544   72.544   72.544  14.95  0.000
Error    161   781.306  781.306    4.853
Total    173  1112.591

S = 2.20291   R-Sq = 29.78%   R-Sq(adj) = 24.54%
```

There was an effect of EC on sediment concentration in the runoff. This effect did not differ by soil type.

- EC1 had the highest concentration in the runoff, followed by EC2, EC5, EC3, EC6 and EC4.
- EC1 was significantly higher than all other EC methods.
- EC2 was significantly higher than EC5, EC3 and EC6, which were not noticeably different.
- EC4 had significantly lower concentration in the runoff than all other EC methods.

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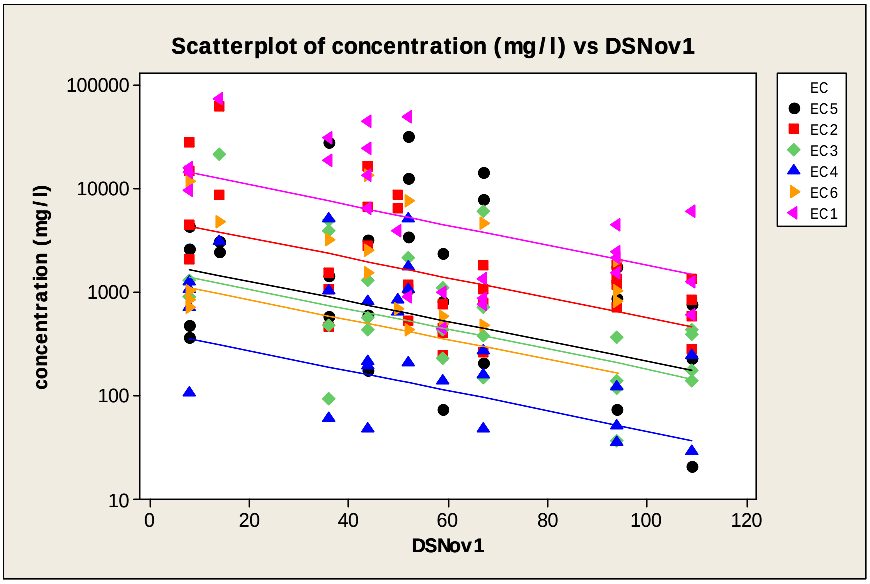

RS 5 EC Treatments

Abbr	Treatment
EC1	Control
EC2	Soil Roughening
EC3	Jute only
EC4	Jute over Compost
EC5	Crimped straw only
EC6	Crimped Straw over Compost

Chart G.7. RS5 Sediment Concentration Scatterplot.

G.1.4 RS5 pH Analysis

G.1.4.1 pH ANOVA:

```
Analysis of Variance for pH, using Adjusted SS for Tests

Source             DF    Seq SS    Adj SS   Adj MS       F
P
S                   1    1.7705    1.0716   1.0716    4.63
0.033
EC                  5    6.7199    7.3477   1.4695    6.35
0.000
S*EC                5    3.2454    3.5600   0.7120    3.08
0.011
DSNov1              1    0.1921    8.5679   8.5679   37.01
0.000
DSNov1*DSNov1       1    1.6391    8.3029   8.3029   35.86
0.000
rain.amt            1    0.3532    6.8983   6.8983   29.80
0.000
DSNov1*rain.amt     1    6.6357    6.6357   6.6357   28.66
0.000
Error             142   32.8745   32.8745   0.2315
Total             157   53.4303


S = 0.481155   R-Sq = 38.47%   R-Sq(adj) = 31.97%
```

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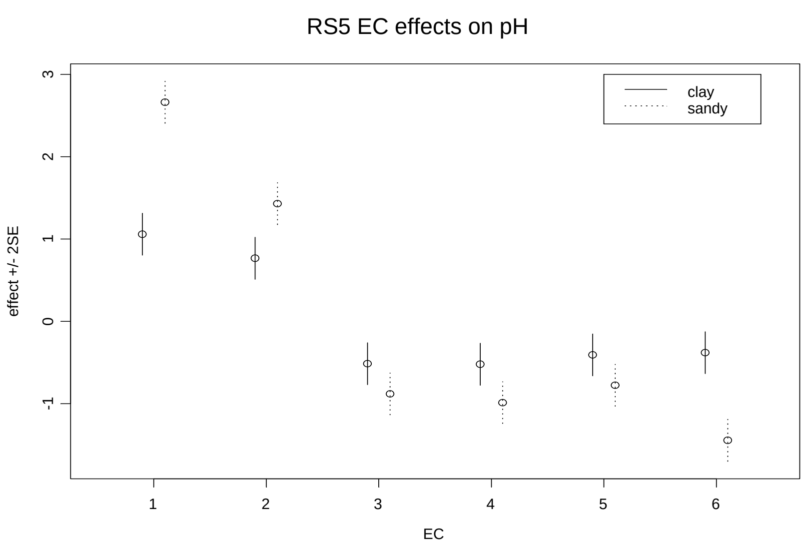
```
Term                     Coef    SE Coef      T      P
Constant               6.7602     0.1444  46.83  0.000
S
S1                    0.08406    0.03907   2.15  0.033
EC
EC5                  -0.03911    0.08756  -0.45  0.656
EC2                  -0.06310    0.08101  -0.78  0.437
EC3                  -0.17081    0.08973  -1.90  0.059
EC4                  -0.28562    0.08358  -3.42  0.001
EC6                   0.45166    0.09718   4.65  0.000
S*EC
S1 EC5                0.07013    0.08730   0.80  0.423
S1 EC2                0.14621    0.08098   1.81  0.073
S1 EC3               -0.07346    0.08955  -0.82  0.413
S1 EC4               -0.07703    0.08373  -0.92  0.359
S1 EC6               -0.26961    0.09764  -2.76  0.007
DSNov1                0.06693    0.01100   6.08  0.000
DSNov1*DSNov1       -0.000850   0.000142  -5.99  0.000
rain.amt               -5.548      1.016  -5.46  0.000
DSNov1*rain.amt       0.08849    0.01653   5.35  0.000
```

There was an effect of S (soil type) on pH ($p=.033$). Clay loam resulted in pH values in runoff that were about 0.17 higher than fine sandy loam (on average, across all treatments). There was an effect of EC on pH ($p<.001$) and that effect depended on S ($p=.011$).

- Clay loam (S1):
    - EC1 and EC2 have the highest pH values. They are not noticeably different.
    - EC3, EC4, EC5 and EC6 have lower pH values. Again, no difference can be spotted.
- Fine sandy loam (S2):
    - EC1 has the highest pH values.
    - EC2 has the next highest pH values.
    - EC3, EC4, EC5 and EC6 are all similar, but EC5 has pH that is higher than EC6. No other differences between these treatments can be said to be statistically significant.



RS 5 EC Treatments

Abbr	Treatment
EC1	Control
EC2	Soil Roughening
EC3	Jute only
EC4	Jute over Compost
EC5	Crimped straw only
EC6	Crimped Straw over Compost

Chart G.8. RS5 Treatment Effects on pH.

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G.2 Experiment RS5 Vegetation Analyses

G.2.1 RS5 Cover Analysis

Average of ranks for each cover class and associated % cover:

Bare	Compost	EC	Grass	Legume	Other
2.54	1.61	2.69	3.43	2.18	2.25
5.7%	1.6%	7.0%	17.5%	3.5%	3.9%

For each cover class, the relationship between treatment conditions was investigated: soil type (S), EC method (EC) and location (Top/Toe, lower versus upper) on the average rank for cover.

G.2.1.1 Bare Ground ANOVA:

```
Analysis of Variance for Average, using Adjusted SS for Tests

Source    DF  Seq SS  Adj SS  Adj MS     F      P
S          1   3.478   3.478   3.478  2.11  0.155
EC         5   7.022   7.022   1.404  0.85  0.523
S*EC       5   6.554   6.554   1.311  0.80  0.560
Top/Toe    1   0.002   0.002   0.002  0.00  0.975
Error     35  57.684  57.684   1.648
Total     47  74.739
```

There was no apparent effect of soil type, EC or Top/Toe on the percent bare soil.

G.2.1.2 Compost ANOVA:

```
Analysis of Variance for Average, using Adjusted SS for Tests

Source    DF   Seq SS   Adj SS  Adj MS      F      P
S          1   6.2785   6.2785  6.2785  10.27  0.003
EC         5   2.8295   2.8295  0.5659   0.93  0.476
S*EC       5   7.0759   7.0759  1.4152   2.31  0.065
Top/Toe    1   0.2581   0.2581  0.2581   0.42  0.520
Error     35  21.4075  21.4075  0.6116
Total     47  37.8495
```

The only factor which had a statistically significant effect on compost cover was soil type. The estimated average rank for compost with clay loam (S1) was 1.25 and with fine sandy loam (S2) was 1.97. These average ranks converted to percentages of 1.0% and 2.7%, respectively.

G.2.1.3 EC ANOVA:

```
Analysis of Variance for Average, using Adjusted SS for Tests

Source    DF  Seq SS  Adj SS  Adj MS     F      P
S          1   4.154   4.154   4.154  2.25  0.142
EC         5  10.485  10.485   2.097  1.14  0.359
S*EC       5   7.965   7.965   1.593  0.86  0.514
Top/Toe    1   0.663   0.663   0.663  0.36  0.553
Error     35  64.480  64.480   1.842
Total     47  87.747
```

The percent cover due to EC was not affected by soil type, EC method or location.

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G.2.1.4 Grass Cover ANOVA:

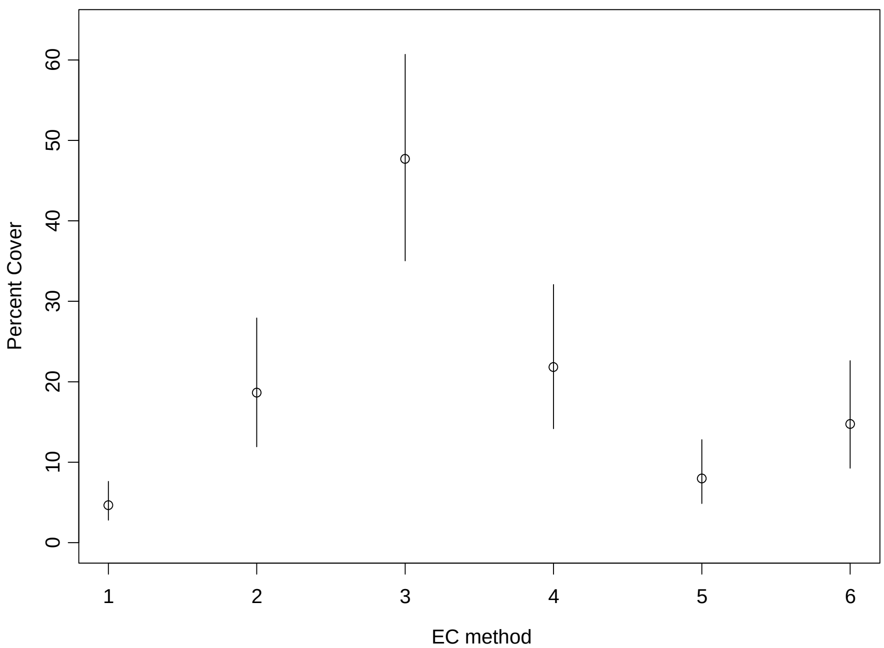
```
Analysis of Variance for Average, using Adjusted SS for Tests

Source    DF    Seq SS    Adj SS   Adj MS     F      P
S          1    0.4033    0.4033   0.4033  1.21  0.279
EC         5    5.7251    5.7251   1.1450  3.43  0.013
S*EC       5    9.2159    9.2159   1.8432  5.52  0.001
Top/Toe    1    0.6533    0.6533   0.6533  1.96  0.171
Error     35   11.6771   11.6771   0.3336
Total     47   27.6747
```

There was an effect of EC on grass cover, and the effect of EC depended on the soil type.

- **Clay loam (S1) grass cover:**

EC	Avg Rank	Confidence Interval for Rank	Estimated Percentage	Confidence Interval for Percentage
1	2.38	(2.007 , 2.753)	4.6	(2.8 , 7.6)
2	3.48	(3.107 , 3.853)	18.6	(11.9 , 27.9)
3	4.46	(4.087 , 4.833)	47.7	(35 , 60.7)
4	3.62	(3.247 , 3.993)	21.8	(14.2 , 32.1)
5	2.79	(2.417 , 3.163)	8.0	(4.9 , 12.8)
6	3.28	(2.907 , 3.653)	14.7	(9.3 , 22.6)



RS 5 EC Treatments

Abbr	Treatment
EC1	Control
EC2	Soil Roughening
EC3	Jute only
EC4	Jute over Compost
EC5	Crimped straw only
EC6	Crimped Straw over Compost

On clay loam (S1), EC3 produced the greatest cover from grass. EC4, EC2 and EC6 could not be said to differ. EC4 and EC3, however, had higher cover than EC5 and EC1, which had the lowest overall rates of grass cover.

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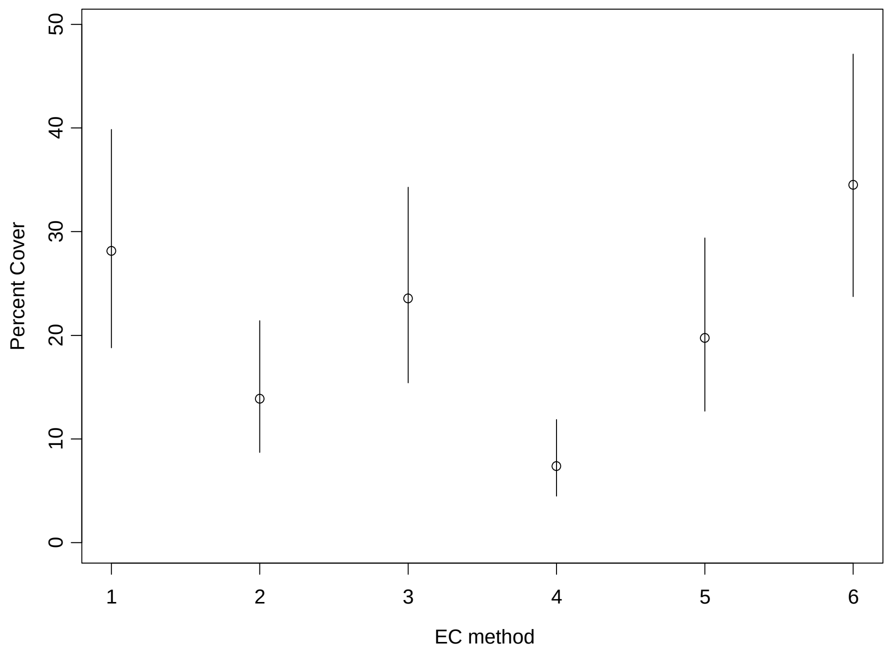
- **Fine sandy loam (S2) grass cover:**

EC	Avg Rank	Confidence Interval for Rank	Estimated Percentage	Confidence Interval for Percentage
1	3.86	(3.487 , 4.233)	28.1	(18.8 , 39.8)
2	3.23	(2.857 , 3.603)	13.9	(8.7 , 21.4)
3	3.69	(3.317 , 4.063)	23.6	(15.4 , 34.3)
4	2.73	(2.357 , 3.103)	7.4	(4.5 , 11.9)
5	3.53	(3.157 , 3.903)	19.7	(12.7 , 29.4)
6	4.07	(3.697 , 4.443)	34.5	(23.7 , 47.1)



RS 5 EC Treatments

Abbr	Treatment
EC1	Control
EC2	Soil Roughening
EC3	Jute only
EC4	Jute over Compost
EC5	Crimped straw only
EC6	Crimped Straw over Compost

In summary, for fine sandy loam (S2), grass cover was lowest in EC4, which was significantly lower than all others except EC2. EC6 had the highest grass cover, but the grass cover in EC 6 was not significantly higher than EC1 EC3 and EC5. EC1, EC3 and EC5 were not significantly different from each other or from EC2.

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G.2.1.5 Legume Cover ANOVA:

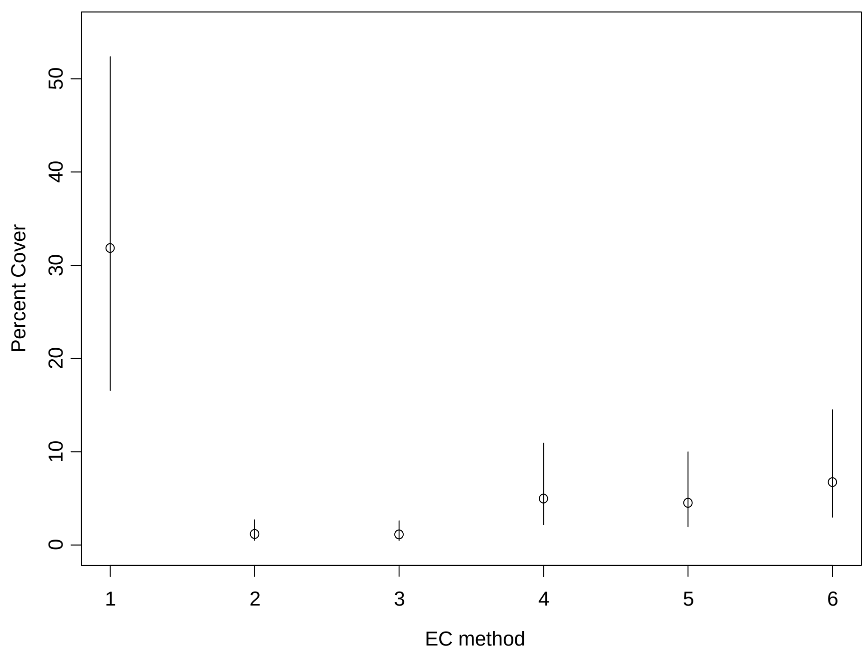
```
Analysis of Variance for Average, using Adjusted SS for Tests

Source    DF   Seq SS   Adj SS  Adj MS     F      P
S          1   1.5769   1.5769  1.5769  1.79  0.190
EC         5  12.1036  12.1036  2.4207  2.74  0.034
S*EC       5  18.8144  18.8144  3.7629  4.26  0.004
Top/Toe    1   0.6960   0.6960  0.6960  0.79  0.381
Error     35  30.9143  30.9143  0.8833
Total     47  64.1052
```

There was an effect of EC on legume cover and that effect depends on soil type.

- **Clay loam (S1) legume cover:**

EC	Avg Rank	Confidence Interval for Rank	Estimated Percentage	Confidence Interval for Percentage
1	3.985	(3.378 , 4.592)	31.8	(16.6 , 52.4)
2	1.38	(0.773 , 1.987)	1.2	(0.5 , 2.7)
3	1.35	(0.743 , 1.957)	1.1	(0.5 , 2.6)
4	2.43	(1.823 , 3.037)	5.0	(2.2 , 10.9)
5	2.36	(1.753 , 2.967)	4.5	(2 , 10)
6	2.66	(2.053 , 3.267)	6.7	(3 , 14.5)



RS 5 EC Treatments

Abbr	Treatment
EC1	Control
EC2	Soil Roughening
EC3	Jute only
EC4	Jute over Compost
EC5	Crimped straw only
EC6	Crimped Straw over Compost

For clay loam (S1), EC1 had the highest rate of legume cover. EC6 had a higher rate of legume cover than EC2 and EC3. No other significant differences were observed.

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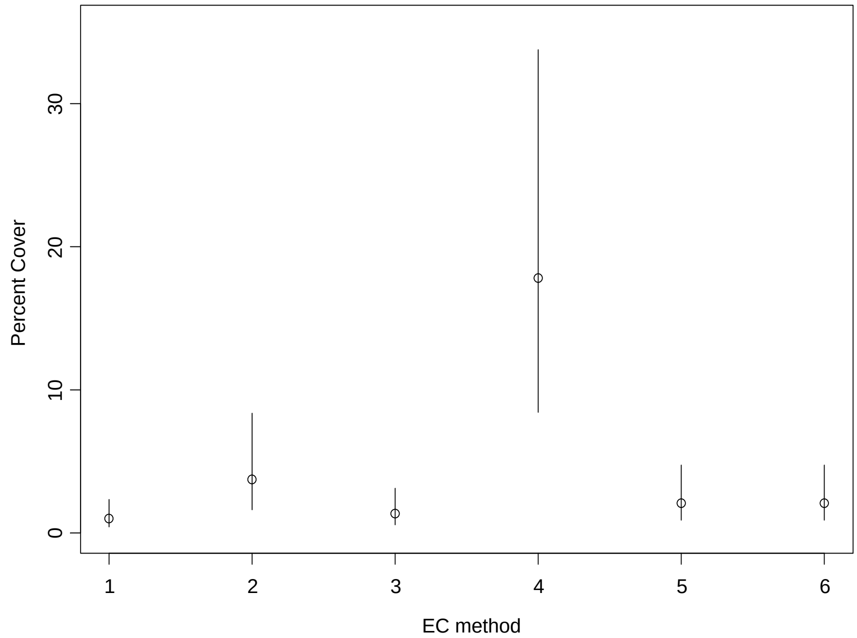
- **Fine sandy loam (S2) legume cover:**

EC	Avg Rank	Confidence Interval for Rank	Estimated Percentage	Confidence Interval for Percentage
1	1.27	(0.663 , 1.877)	1.0	(0.4 , 2.3)
2	2.22	(1.613 , 2.827)	3.7	(1.6 , 8.4)
3	1.48	(0.873 , 2.087)	1.3	(0.6 , 3.1)
4	3.44	(2.833 , 4.047)	17.8	(8.4 , 33.8)
5	1.79	(1.183 , 2.397)	2.1	(0.9 , 4.7)
6	1.79	(1.183 , 2.397)	2.1	(0.9 , 4.7)



RS 5 EC Treatments

Abbr	Treatment
EC1	Control
EC2	Soil Roughening
EC3	Jute only
EC4	Jute over Compost
EC5	Crimped straw only
EC6	Crimped Straw over Compost

For fine sandy loam (S2), EC4 had the highest rate of legume cover. No other significant differences were observed.

G.2.1.6 "Other Forb" Cover ANOVA

```
Analysis of Variance for Average, using Adjusted SS for Tests

Source    DF    Seq SS    Adj SS    Adj MS      F       P
S          1    0.0199    0.0199    0.0199   0.07   0.798
EC         5    2.4397    2.4397    0.4879   1.64   0.176
S*EC       5    1.7600    1.7600    0.3520   1.18   0.338
Top/Toe    1    0.0155    0.0155    0.0155   0.05   0.821
Error     35   10.4364   10.4364    0.2982
Total     47   14.6714
```

No effects of soil type or EC were found on the percentage cover due to "other forb".

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H.1 Experiment RS6 Water Quality Analyses

For this data, the log-concentration, log-total water and log-total sediment were used as response variables. A transformation of these variables was necessary. While a log transformation of these response variables was slightly better than a root transformation, both were sufficiently appropriate.

Log-concentration: the log of the sediment concentration was analyzed as dependent on S (1 or 2) and EC (1, 2, 3, 4, 5 or 6).

```
Analysis of Variance for log.conc, using Adjusted SS for Tests

Source     DF     Seq SS     Adj SS     Adj MS       F      P
S           1     0.2819     0.2819     0.2819    0.48  0.501
EC          5    22.9357    22.9357     4.5871    7.84  0.002
S*EC        5     2.2206     2.2206     0.4441    0.76  0.596
Error      12     7.0211     7.0211     0.5851
```

No significant interaction was noted between S and EC. Furthermore, there was no significant effect of S on log concentration. A Tukey-Kramer post-hoc analysis of the effects of the EC levels showed that EC treatment level 1 differed from all other levels of EC treatment. On average, the log of sediment concentration was 2.16 units higher than the log of sediment concentrations for the other treatments, p<.001, but none of the other levels had significantly different log sediment concentrations.

H.1.1 RS6 Runoff Analysis

H.1.1.1 Total Runoff ANOVA:

The log of total water was used as a response variable, and S and EC were treatment factors.

```
Analysis of Variance for log.water, using Adjusted SS for Tests

Source     DF     Seq SS     Adj SS     Adj MS       F      P
S           1      1.136      1.136      1.136    0.52  0.485
EC          5     46.743     46.743      9.349    4.27  0.018
S*EC        5      2.523      2.523      0.505    0.23  0.942
Error      12     26.253     26.253      2.188
Total      23     76.655
```

It appeared that only EC had an effect on log of total water in runoff. EC treatment level 5 had log of total water 2.18 units below the average log of total water (p=.007). EC treatment level 6 had a log of total water 1.56 below the average log of total water (p=.039).

RS 6 EC Treatments

Abbr.	Treatment
EC1	Control
EC2	Seed *in* 1680 kg/ha (1500 lb/ac) fiber, with no compost
EC3	Seed *in* 1680 kg/ha (1500 lb/ac) fiber with 1680 kg/ha(1500 lb/ac) compost
EC4	Seed *in* 1680 kg/ha (1500 lb/ac) fiber with 560 kg/ha (500 lb/ac) compost
EC5	Seed *over* 3920 kg/ha fiber (3500 lb/ac) with 560 kg/ha (500 lb/ac)compost
EC6	Seed *under* 3920 kg/ha (3500 lb/ac) fiber with 560 kg/ha (500 lb/ac) compost

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H.1.1.2 Seed Versus No Seed ANOVA:

```
Variable  seeds    N  N*    Mean  SE Mean   StDev  Minimum      Q1  Median
FITS9     n        4   0  3.9829   0.0400  0.0799   3.8850  3.9086  3.9829
          y       20   0  2.8594   0.0237  0.1062   2.6619  2.7579  2.8491

Variable  seeds       Q3  Maximum
FITS9     n       4.0572   4.0807
          y       2.9445   3.0956

ANOVA for log.conc, using Adjusted SS for Tests

Source          DF  Seq SS  Adj SS  Adj MS     F      P
Toe Treatment    1  0.0618  0.0618  0.0618  0.59  0.454
Soil Type        1  0.0532  0.0532  0.0532  0.51  0.487
EC               5  4.3259  4.3259  0.8652  8.23  0.001 <- Significant
Error           16  1.6813  1.6813  0.1051
Total           23  6.1222
```

EC was significant. Contrasting the mean values of EC1 (the control) with EC2-EC6 (hydroseeding treatment) showed that seeding reduced runoff by 1.12356. At the 95% confidence level, when adjusting for effects of toe treatment and soil type, the effect of the seeding to reduce runoff was between .8 and 1.44.

RS 6 EC Treatments

Abbr.	Treatment
EC1	Control
EC2	Seed *in* 1680 kg/ha (1500 lb/ac) fiber, with no compost
EC3	Seed *in* 1680 kg/ha (1500 lb/ac) fiber with 1680 kg/ha(1500 lb/ac) compost
EC4	Seed *in* 1680 kg/ha (1500 lb/ac) fiber with 560 kg/ha (500 lb/ac) compost
EC5	Seed *over* 3920 kg/ha fiber (3500 lb/ac) with 560 kg/ha (500 lb/ac)compost
EC6	Seed *under* 3920 kg/ha (3500 lb/ac) fiber with 560 kg/ha (500 lb/ac) compost

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H.1.1.3 Seed Over, Seed In, or Seed Under Compost ANOVA:

```
Variable  IOU      N  N*    Mean  SE Mean   StDev  Minimum      Q1  Median
FITS9     cont     4   0  3.9829   0.0400  0.0799   3.8850  3.9086  3.9829
          in      12   0  2.8687   0.0362  0.1255   2.6619  2.7579  2.8549
          over     4   0  2.8480   0.0400  0.0799   2.7502  2.7737  2.8480
          under    4   0  2.8428   0.0400  0.0799   2.7449  2.7685  2.8428

Variable  IOU         Q3  Maximum
FITS9     cont    4.0572   4.0807
          in      2.9822   3.0956
          over    2.9223   2.9458
          under   2.9171   2.9406
```

The mean difference between in and over was 2.8687-2.848 = .0207. The mean difference between in and under was 2.8687 – 2.8428 = .0259. The mean difference between over and under was 2.848 – 2.8428 = .0052. There was no significant difference in the mean values between the in, over, and under rate. There was no significant difference in seeding Over, In, or Under Compost.

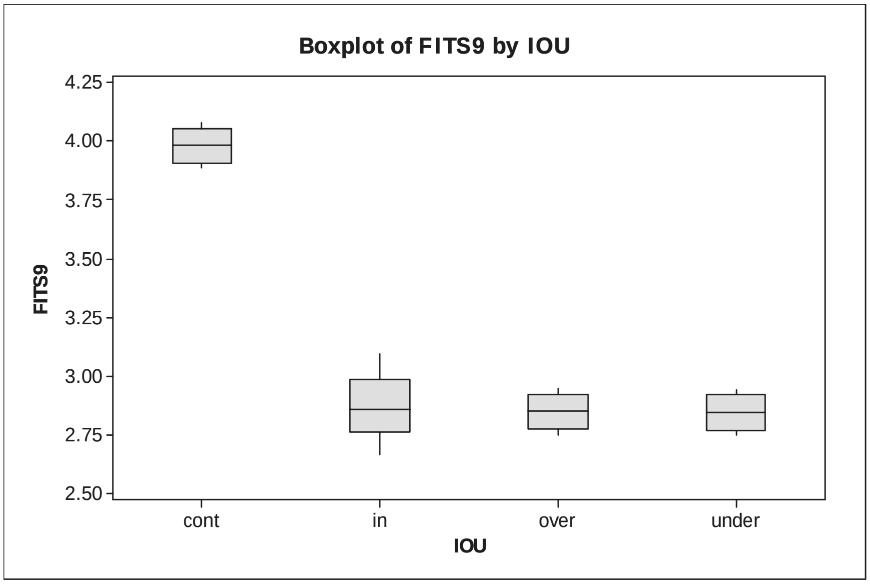

Chart H.1. Boxplot of RS6 Seed Treatment Effects on Runoff.

RS 6 EC Treatments	
Abbr.	**Treatment**
EC1	Control
EC2	Seed *in* 1680 kg/ha (1500 lb/ac) fiber, with no compost
EC3	Seed *in* 1680 kg/ha (1500 lb/ac) fiber with 1680 kg/ha(1500 lb/ac) compost
EC4	Seed *in* 1680 kg/ha (1500 lb/ac) fiber with 560 kg/ha (500 lb/ac) compost
EC5	Seed *over* 3920 kg/ha fiber (3500 lb/ac) with 560 kg/ha (500 lb/ac)compost
EC6	Seed *under* 3920 kg/ha (3500 lb/ac) fiber with 560 kg/ha (500 lb/ac) compost

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H.1.1.4 Fiber rate 1500 lb/ac vs. 3500 lb/ac ANOVA:

```
Variable  amt      N  N*    Mean  SE Mean   StDev  Minimum       Q1  Median
FITS9        0     4   0  3.9829   0.0400  0.0799   3.8850  3.9086  3.9829
          1500    12   0  2.8687   0.0362  0.1255   2.6619  2.7579  2.8549
          3500     8   0  2.8454   0.0262  0.0741   2.7449  2.7724  2.8454

          fiber
Variable  amt         Q3  Maximum
FITS9        0    4.0572   4.0807
          1500    2.9822   3.0956
          3500    2.9184   2.9458
```

The mean difference between fiber rates of 1500 lb/ac and 3500 lb/ac was .0233, which was not significantly different. There was no significant difference between fiber amounts of 1500 lb/ac and 3500 lb/ac.

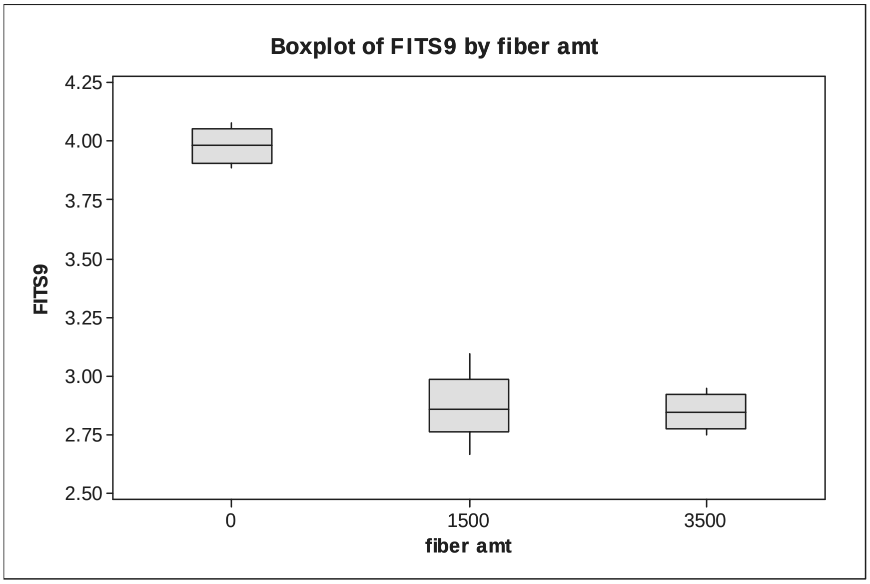

Chart H.2. Boxplot of RS6 Fiber Treatment Effects on Runoff.

RS 6 EC Treatments	
Abbr.	**Treatment**
EC1	Control
EC2	Seed *in* 1680 kg/ha (1500 lb/ac) fiber, with no compost
EC3	Seed *in* 1680 kg/ha (1500 lb/ac) fiber with 1680 kg/ha(1500 lb/ac) compost
EC4	Seed *in* 1680 kg/ha (1500 lb/ac) fiber with 560 kg/ha (500 lb/ac) compost
EC5	Seed *over* 3920 kg/ha fiber (3500 lb/ac) with 560 kg/ha (500 lb/ac)compost
EC6	Seed *under* 3920 kg/ha (3500 lb/ac) fiber with 560 kg/ha (500 lb/ac) compost

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H.1.1.5 Compost Rate 500 lb/ac vs. 1500 lb/ac ANOVA:

```
Variable  comp amt   N  N*    Mean  SE Mean   StDev  Minimum      Q1  Median
FITS9            0   8   0   3.416    0.216   0.611    2.751   2.847   3.416
               500  12   0  2.8962   0.0301  0.1042   2.7449  2.8404  2.8758
              1500   4   0  2.7597   0.0400  0.0799   2.6619  2.6854  2.7597

Variable  comp amt      Q3  Maximum
FITS9            0   3.985    4.081
               500  2.9820   3.0956
              1500  2.8340   2.8575


2.8962-2.7597 = .1365
```

The mean difference between compost rates of 500 lb/ac and 1500 lb/ac was .1365, which was not significantly different.

H.1.1.6 pH Analysis

There was no observed relationship between S or EC and pH of runoff.

H.1.2 RS6 Sediment Analysis

H.1.2.1 Total Sediment ANOVA:

The log of sediment levels was analyzed as dependent on S (1 or 2) and EC (1, 2, 3, 4, 5 or 6).

```
Analysis of Variance for log.sediment, using Adjusted SS for Tests

Source     DF   Seq SS    Adj SS    Adj MS      F      P
S           1    2.549     2.549     2.549   1.10  0.316
EC          5  103.044   103.044    20.609   8.85  0.001
S*EC        5    2.273     2.273     0.455   0.20  0.958
Error      12   27.930    27.930     2.328
Total      23  135.797
```

Only EC has an effect on total sediment. EC level 1 has log sediment levels 3.61 higher than the average sediment level (p<.001), EC level 5 has log sediment levels 2.64 lower than the average sediment level (p=.003) and EC level 6 has log sediment levels 2.03 lower than the average sediment level (p=.013).

H.1.3 RS6 Summary

Soil type (S) had no significant effect on runoff. EC1 increased sediment and sediment concentration in runoff. EC 5 and EC6 had sediment concentrations similar to EC2, EC3 and EC4, but because they had lower water and lower total sediment, EC5 and EC6 appeared to be the best. Although EC5 appeared better than EC6 in terms of total sediment and total water, the difference was not statistically significant.

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H.2 Experiment RS6 Vegetation Analyses

H.2.1 RS6 Cover Analysis

Average of ranks for each cover class and associated % cover:

Bare Soil	Grass	Legume	Litter	Other Forb	Yarrow
2.92	2.31	3.46	2.85	3.10	1.98
9.4%	4.2%	18.2%	8.7%	11.9%	2.7%

For each cover class, the relationship between treatment conditions was investigated: soil type (S), EC method (EC) and location (quadrant, upper versus lower versus) on the average rank for cover.

H.2.1.1 Bare Ground ANOVA:

```
Analysis of Variance for Rank, using Adjusted SS for Tests

Source  DF   Seq SS   Adj SS   Adj MS      F      P
S        1    1.333    1.333    1.333   1.21  0.278
EC       5   59.667   59.667   11.933  10.85  0.000
S*EC     5    2.167    2.167    0.433   0.39  0.850
Qdrt     1    0.000    0.000    0.000   0.00  1.000
Error   35   38.500   38.500    1.100
Total   47  101.667
```

There was not a statistically significant effect of soil type on bare ground rates. There was a statistically significant effect of EC on bare ground rates. Averaging across soil types (which were not related to bare ground rates) and quadrat (upper versus lower), the following average estimated rank for Bare Ground (and associated percent Bare Ground) for each EC method was found:

EC	Avg Rank	Confidence Interval for Rank	Estimated Percentage	Confidence Interval for Percentage
1	4.750	(4.073 , 5.427)	57.9	(34.6 , 78.1)
2	2.375	(1.698 , 3.052)	4.6	(1.8 , 11.1)
3	3.375	(2.698 , 4.052)	16.5	(7.1 , 33.9)
4	3.375	(2.698 , 4.052)	16.5	(7.1 , 33.9)
5	1.125	(0.448 , 1.802)	0.8	(0.3 , 2.1)
6	2.500	(1.823 , 3.177)	5.4	(2.2 , 13)

RS 6 EC Treatments

Abbr.	Treatment
EC1	Control
EC2	Seed *in* 1680 kg/ha (1500 lb/ac) fiber, with no compost
EC3	Seed *in* 1680 kg/ha (1500 lb/ac) fiber with 1680 kg/ha(1500 lb/ac) compost
EC4	Seed *in* 1680 kg/ha (1500 lb/ac) fiber with 560 kg/ha (500 lb/ac) compost
EC5	Seed *over* 3920 kg/ha fiber (3500 lb/ac) with 560 kg/ha (500 lb/ac)compost
EC6	Seed *under* 3920 kg/ha (3500 lb/ac) fiber with 560 kg/ha (500 lb/ac) compost

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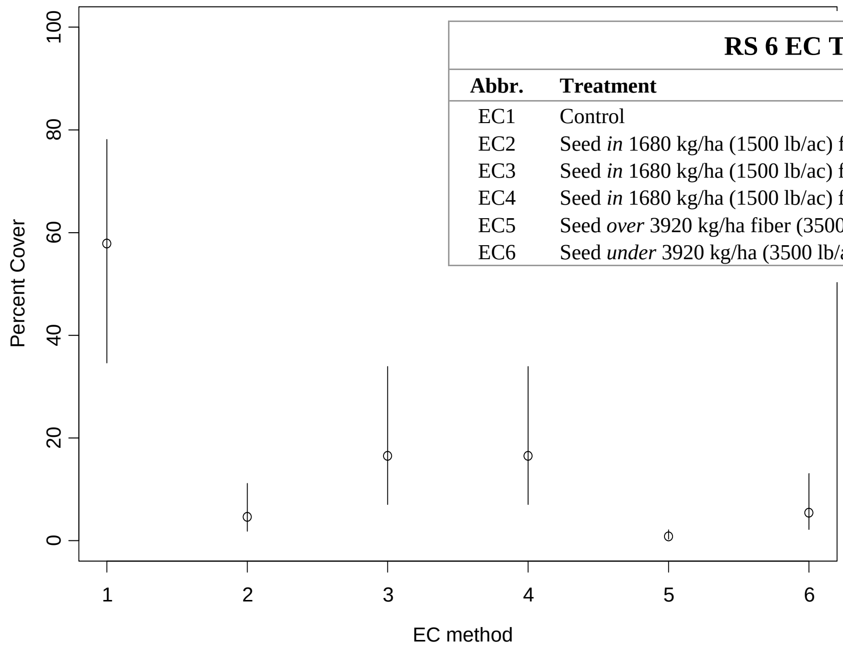

RS 6 EC Treatments

Abbr.	Treatment
EC1	Control
EC2	Seed *in* 1680 kg/ha (1500 lb/ac) fiber, with no compost
EC3	Seed *in* 1680 kg/ha (1500 lb/ac) fiber with 1680 kg/ha(1500 lb/ac) compost
EC4	Seed *in* 1680 kg/ha (1500 lb/ac) fiber with 560 kg/ha (500 lb/ac) compost
EC5	Seed *over* 3920 kg/ha fiber (3500 lb/ac) with 560 kg/ha (500 lb/ac)compost
EC6	Seed *under* 3920 kg/ha (3500 lb/ac) fiber with 560 kg/ha (500 lb/ac) compost

To summarize, EC1 provided the highest percent bare ground and EC5 had the lowest percentage bare ground. EC2 and EC6 were not noticeably different from one another, or from EC3 and EC4.

H.2.1.2 Grass Cover ANOVA:

```
Analysis of Variance for Rank, using Adjusted SS for Tests

Source  DF   Seq SS   Adj SS   Adj MS      F      P
S        1  11.0208  11.0208  11.0208  35.95  0.000
EC       5  11.9375  11.9375   2.3875   7.79  0.000
S*EC     5   6.6042   6.6042   1.3208   4.31  0.004
Qdrt     1   0.0208   0.0208   0.0208   0.07  0.796
Error   35  10.7292  10.7292   0.3065
Total   47  40.3125
```

There was a statistically significant effect of EC, a statistically significant effect of soil type (S) and an interaction between EC method (EC) and soil type (S) (i.e., the effect of EC differs by soil type). Overall, clay loam (S1) provided lower rates of grass cover than did fine sandy loam (S2). Percentage cover estimates by soil type for each treatment method were separately presented due to the interaction:

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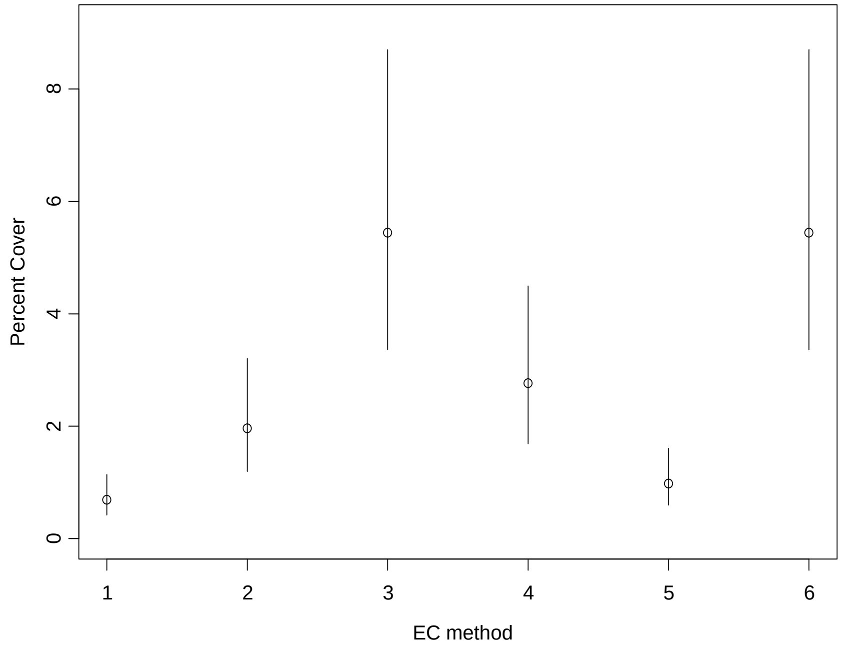
- **Clay loam (S1) grass cover:**

EC	Avg Rank	Confidence Interval for Rank	Estimated Percentage	Confidence Interval for Percentage
1	1.000	(0.643 , 1.357)	0.7	(0.4 , 1.1)
2	1.750	(1.393 , 2.107)	2.0	(1.2 , 3.2)
3	2.500	(2.143 , 2.857)	5.4	(3.4 , 8.7)
4	2.000	(1.643 , 2.357)	2.8	(1.7 , 4.5)
5	1.250	(0.893 , 1.607)	1.0	(0.6 , 1.6)
6	2.500	(2.143 , 2.857)	5.4	(3.4 , 8.7)



RS 6 EC Treatments	
Abbr.	**Treatment**
EC1	Control
EC2	Seed *in* 1680 kg/ha (1500 lb/ac) fiber, with no compost
EC3	Seed *in* 1680 kg/ha (1500 lb/ac) fiber with 1680 kg/ha(1500 lb/ac) compost
EC4	Seed *in* 1680 kg/ha (1500 lb/ac) fiber with 560 kg/ha (500 lb/ac) compost
EC5	Seed *over* 3920 kg/ha fiber (3500 lb/ac) with 560 kg/ha (500 lb/ac)compost
EC6	Seed *under* 3920 kg/ha (3500 lb/ac) fiber with 560 kg/ha (500 lb/ac) compost

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To summarize, for clay loam (S1), EC1 and EC5 had the lowest percentage of grass cover. EC2 had a grass cover which was lower than EC3 and EC6, but not significantly lower than EC4 which also was not significantly different from EC3 and EC6.

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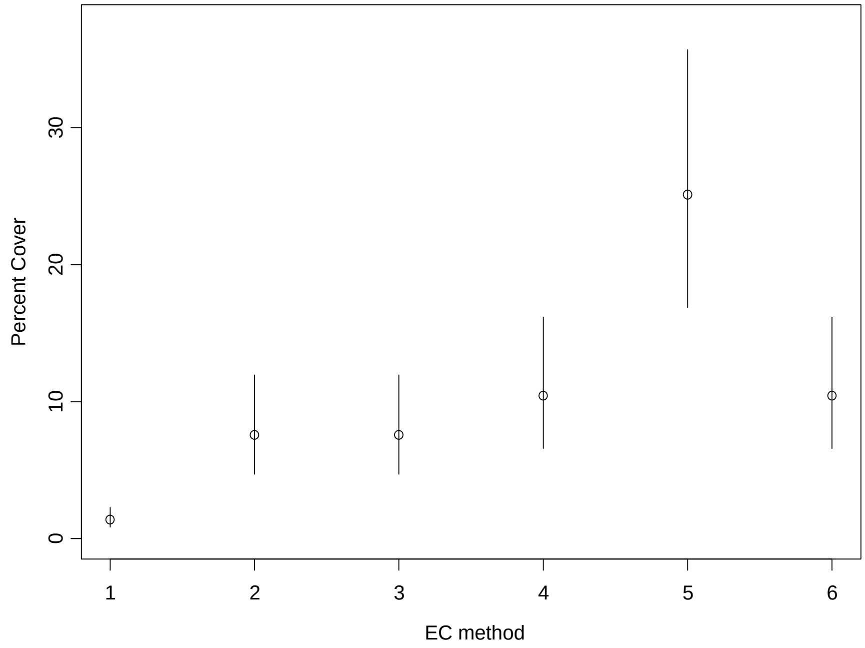
- **Fine sandy loam (S2) grass cover:**

EC	Avg Rank	Confidence Interval for Rank	Estimated Percentage	Confidence Interval for Percentage
1	1.500	(1.143 , 1.857)	1.4	(0.8 , 2.3)
2	2.750	(2.393 , 3.107)	7.6	(4.7 , 11.9)
3	2.750	(2.393 , 3.107)	7.6	(4.7 , 11.9)
4	3.000	(2.643 , 3.357)	10.4	(6.6 , 16.2)
5	3.750	(3.393 , 4.107)	25.1	(16.8 , 35.7)
6	3.000	(2.643 , 3.357)	10.4	(6.6 , 16.2)



RS 6 EC Treatments	
Abbr.	**Treatment**
EC1	Control
EC2	Seed *in* 1680 kg/ha (1500 lb/ac) fiber, with no compost
EC3	Seed *in* 1680 kg/ha (1500 lb/ac) fiber with 1680 kg/ha(1500 lb/ac) compost
EC4	Seed *in* 1680 kg/ha (1500 lb/ac) fiber with 560 kg/ha (500 lb/ac) compost
EC5	Seed *over* 3920 kg/ha fiber (3500 lb/ac) with 560 kg/ha (500 lb/ac)compost
EC6	Seed *under* 3920 kg/ha (3500 lb/ac) fiber with 560 kg/ha (500 lb/ac) compost

To summarize grass cover for fine sandy loam (S2), EC5 produced the highest grass cover. EC 1 had the lowest grass cover. All other EC methods (EC2, EC3, EC4 and EC6) produced cover rates which were not significantly different.

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H.2.1.3 Legume Cover ANOVA:

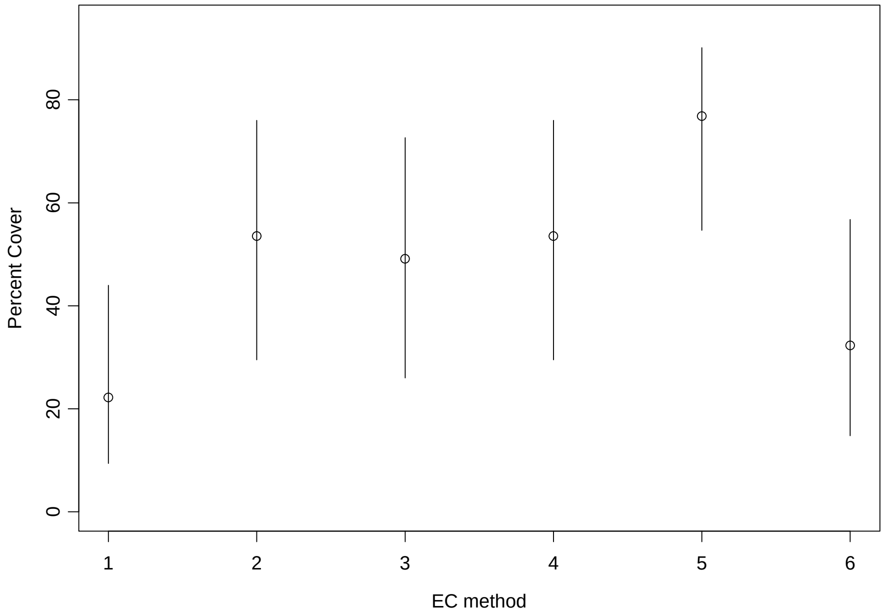
```
Analysis of Variance for Rank, using Adjusted SS for Tests

Source   DF    Seq SS   Adj SS   Adj MS       F      P
S         1    49.938   49.193   49.193   39.77  0.000
EC        5    15.472   16.763    3.353    2.71  0.036
S*EC      5     4.957    4.499    0.900    0.73  0.608
Qdrt      1     8.259    8.259    8.259    6.68  0.014
Error    35    43.291   43.291    1.237
Total    47   121.917
```

Soil type and EC each had a significant effect on percent cover, but there did not appear to be an interaction. The effect of EC method on the rank given to legume cover appeared to be similar across both soil types. Clay loam (S1) had a significantly higher percent cover than fine sandy loam (S2) (47.6% as opposed to 5.1%).

- **Clay loam (S1) legume cover:**

EC	Avg Rank	Confidence Interval for Rank	Estimated Percentage	Confidence Interval for Percentage
1	3.635	(2.918 , 4.352)	22.2	(9.4 , 44)
2	4.625	(3.908 , 5.342)	53.5	(29.5 , 76)
3	4.500	(3.783 , 5.217)	49.1	(26 , 72.6)
4	4.625	(3.908 , 5.342)	53.5	(29.5 , 76)
5	5.375	(4.658 , 6.092)	76.8	(54.7 , 90.1)
6	4.000	(3.283 , 4.717)	32.3	(14.8 , 56.7)



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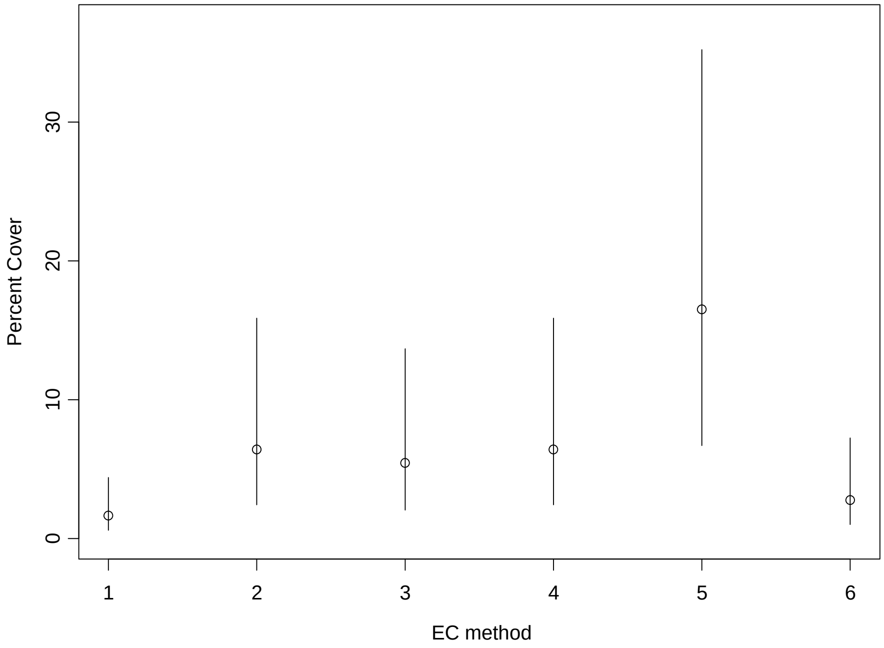
- **Fine sandy loam (S2) legume cover:**

EC	Avg Rank	Confidence Interval for Rank	Estimated Percentage	Confidence Interval for Percentage
1	1.625	(0.908 , 2.342)	1.6	(0.6 , 4.4)
2	2.625	(1.908 , 3.342)	6.4	(2.4 , 15.9)
3	2.500	(1.783 , 3.217)	5.4	(2.1 , 13.7)
4	2.625	(1.908 , 3.342)	6.4	(2.4 , 15.9)
5	3.375	(2.658 , 4.092)	16.5	(6.7 , 35.2)
6	2.000	(1.283 , 2.717)	2.8	(1 , 7.3)



RS 6 EC Treatments	
Abbr.	**Treatment**
EC1	Control
EC2	Seed *in* 1680 kg/ha (1500 lb/ac) fiber, with no compost
EC3	Seed *in* 1680 kg/ha (1500 lb/ac) fiber with 1680 kg/ha(1500 lb/ac) compost
EC4	Seed *in* 1680 kg/ha (1500 lb/ac) fiber with 560 kg/ha (500 lb/ac) compost
EC5	Seed *over* 3920 kg/ha fiber (3500 lb/ac) with 560 kg/ha (500 lb/ac)compost
EC6	Seed *under* 3920 kg/ha (3500 lb/ac) fiber with 560 kg/ha (500 lb/ac) compost

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To summarize the effects of EC on percent legume cover, EC5 had higher legume cover than did EC1 or EC6. EC2, EC3 and EC4 had legume cover rates which did not differ significantly from any of the other EC cover rates.

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H.2.1.4 "Other Forb" Cover ANOVA

```
Analysis of Variance for Rank, using Adjusted SS for Tests

Source  DF   Seq SS   Adj SS  Adj MS     F      P
S        1   3.5208   3.5208  3.5208  6.95  0.012
EC       5   1.6042   1.6042  0.3208  0.63  0.676
S*EC     5   1.1042   1.1042  0.2208  0.44  0.820
Qdrt     1   2.5208   2.5208  2.5208  4.98  0.032
Error   35  17.7292  17.7292  0.5065
Total   47  26.4792
```

There was not a statistically significant effect of EC on Other Forb cover. Averaging across treatment groups (where there was no difference) and quadrat (upper versus lower), the following average estimated rank for Other Forb cover (and associated percent Other Forb cover) for each soil type:

EC	Avg Rank	Confidence Interval for Rank	Estimated Percentage	Confidence Interval for Percentage
1	2.833	(2.628,3.038)	8.4	(6.4%,10.9%)
2	3.375	(3.170,3.580)	16.5	(12.9%,20.9%)

RS 6 EC Treatments	
Abbr.	**Treatment**
EC1	Control
EC2	Seed *in* 1680 kg/ha (1500 lb/ac) fiber, with no compost
EC3	Seed *in* 1680 kg/ha (1500 lb/ac) fiber with 1680 kg/ha(1500 lb/ac) compost
EC4	Seed *in* 1680 kg/ha (1500 lb/ac) fiber with 560 kg/ha (500 lb/ac) compost
EC5	Seed *over* 3920 kg/ha fiber (3500 lb/ac) with 560 kg/ha (500 lb/ac)compost
EC6	Seed *under* 3920 kg/ha (3500 lb/ac) fiber with 560 kg/ha (500 lb/ac) compost

To summarize these results, clay loam (S1) had lower rates of "Other Forb" cover than did fine sandy loam (S2), but no effect of EC treatment was found on "Other Forb" cover.

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H.2.1.5 Common Yarrow (Achillea millefolium) Cover ANOVA

```
Analysis of Variance for Rank, using Adjusted SS for Tests

Source   DF    Seq SS    Adj SS   Adj MS       F      P
S         1    3.5208    3.5208   3.5208    8.46  0.006
EC        5    6.6042    6.6042   1.3208    3.17  0.018
S*EC      5    7.6042    7.6042   1.5208    3.66  0.009
Qdrt      1    4.6875    4.6875   4.6875   11.27  0.002
Error    35   14.5625   14.5625   0.4161
Total    47   36.9792
```

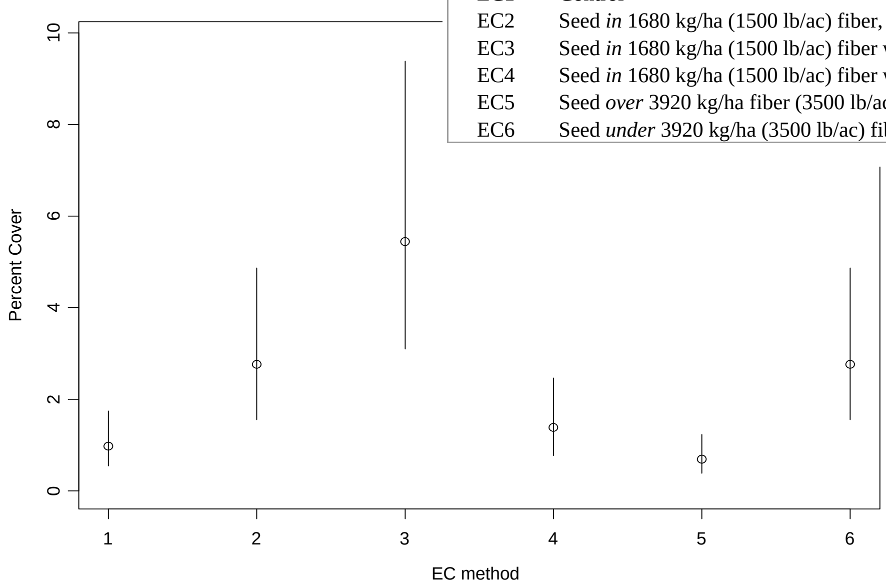
Soil type and EC both affected the percent cover due to Common Yarrow. Furthermore, the interaction between soil type and EC method asserted that the effects of EC on Common Yarrow cover depended on the soil type. Clay loam (S1) had lower percent Common Yarrow cover than fine sandy loam (S2).

- **Clay loam (S1) Common Yarrow cover:**

EC	Avg Rank	Confidence Interval for Rank	Estimated Percentage	Confidence Interval for Percentage
1	1.25	(0.834 , 1.666)	1.0	(0.5 , 1.7)
2	2.00	(1.584 , 2.416)	2.8	(1.6 , 4.9)
3	2.50	(2.084 , 2.916)	5.4	(3.1 , 9.4)
4	1.50	(1.084 , 1.916)	1.4	(0.8 , 2.5)
5	1.00	(0.584 , 1.416)	0.7	(0.4 , 1.2)
6	2.00	(1.584 , 2.416)	2.8	(1.6 , 4.9)

RS 6 EC Treatments

Abbr.	Treatment
EC1	Control
EC2	Seed *in* 1680 kg/ha (1500 lb/ac) fiber, with no compost
EC3	Seed *in* 1680 kg/ha (1500 lb/ac) fiber with 1680 kg/ha(1500 lb/ac) compost
EC4	Seed *in* 1680 kg/ha (1500 lb/ac) fiber with 560 kg/ha (500 lb/ac) compost
EC5	Seed *over* 3920 kg/ha fiber (3500 lb/ac) with 560 kg/ha (500 lb/ac)compost
EC6	Seed *under* 3920 kg/ha (3500 lb/ac) fiber with 560 kg/ha (500 lb/ac) compost



To summarize, for clay loam (S1), EC3 produced more Common Yarrow cover than did EC1, EC4, or EC5. EC2 and EC6 were not significantly different from EC4. EC4 did not significantly differ from EC1 or EC5.

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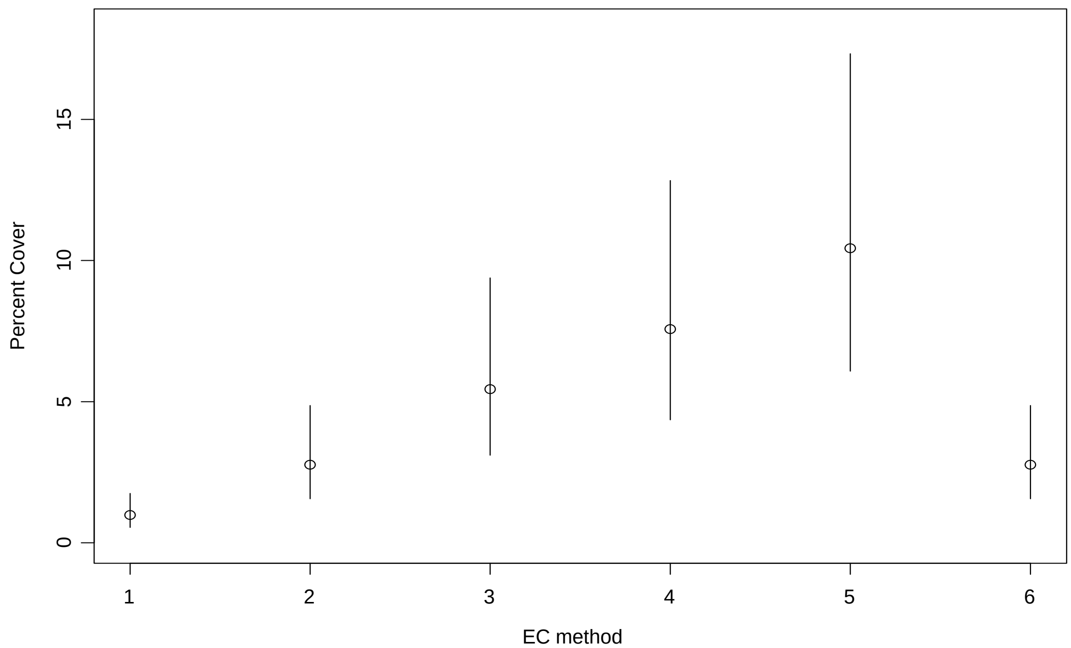
- **Fine sandy loam (S2) Common Yarrow cover:**

EC	Avg Rank	Confidence Interval for Rank	Estimated Percentage	Confidence Interval for Percentage
1	1.25	(0.834 , 1.666)	1.0	(0.5 , 1.7)
2	2.00	(1.584 , 2.416)	2.8	(1.6 , 4.9)
3	2.50	(2.084 , 2.916)	5.4	(3.1 , 9.4)
4	2.75	(2.334 , 3.166)	7.6	(4.4 , 12.8)
5	3.00	(2.584 , 3.416)	10.4	(6.1 , 17.3)
6	2.00	(1.584 , 2.416)	2.8	(1.6 , 4.9)



RS 6 EC Treatments	
Abbr.	**Treatment**
EC1	Control
EC2	Seed *in* 1680 kg/ha (1500 lb/ac) fiber, with no compost
EC3	Seed *in* 1680 kg/ha (1500 lb/ac) fiber with 1680 kg/ha(1500 lb/ac) compost
EC4	Seed *in* 1680 kg/ha (1500 lb/ac) fiber with 560 kg/ha (500 lb/ac) compost
EC5	Seed *over* 3920 kg/ha fiber (3500 lb/ac) with 560 kg/ha (500 lb/ac)compost
EC6	Seed *under* 3920 kg/ha (3500 lb/ac) fiber with 560 kg/ha (500 lb/ac) compost

To summarize, EC1 had lower Common Yarrow cover than any of the other EC treatments. EC5 had higher Common Yarrow cover than EC1, EC2 and EC6. EC4 had higher Common Yarrow cover than EC1 and EC6, but not significantly higher than EC3 or EC2.

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