Gravel Admix, Vegetation, and Soil Water Interactions in Protective Barriers: Experimental Design, Construction, and Initial Conditions

W. J. Waugh

May 1989

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EXECUTIVE SUMMARY

Pacific Northwest Laboratory (PNL) and Westinghouse Hanford Company (WHC) are working jointly to develop protective barriers to isolate radioactive defense waste that may be disposed of near surface at the U.S. Department of Energy's (DOE) Hanford Site. The conceptual barrier design includes a fine-textured topsoil that stores rainwater until it can be cycled back into the atmosphere by evaporation and plant transpiration. However, because significant erosion of the topsoil may cause unacceptable levels of drainage through buried waste and subsequent transport of contaminants into the ground water, PNL and WHC scientists have proposed mixing gravel into the surface layer of the topsoil to create a self-healing veneer, analogous to desert pavements that have preserved underlying soils intact for thousands of years. The purpose of this study is to measure the interactive effects of gravel admix and greater precipitation on soil water storage and plant abundance. The study is one of many tasks in the Protective Barrier Development Program for the disposal of Hanford defense waste.

A factorial field-plot experiment was set up at the site selected as the borrow area for barrier topsoil. Gravel admix, vegetation, and enhanced precipitation treatments were randomly assigned to the plots using a split-split plot design structure. Changes in soil water storage and plant cover were monitored using neutron probe and point intercept methods, respectively.

The first-year results suggest that water extraction by plants will offset gravel-caused increases in soil water storage. Near-surface soil water contents were much lower in graveled plots with plants than in nongraveled plots without plants. Large inherent variability in deep soil water storage masked any effects gravel may have had on water content below the root zone. In the future, this source of variation will be removed by differencing monthly data series and testing for changes in soil water storage. Tests of the effects of greater precipitation on soil water storage were inconclusive. A telling test will be possible in the spring of 1988, following the first wet season during which normal precipitation is doubled.

Unexpectedly, plants were not more abundant on graveled plots, even though there was more plant-available water. Also, of the mixture of shrubs and grasses seeded, no shrubs emerged during this initial growing season. Soil cultivation at the site in the past may have eliminated populations of symbiotic root fungi that certain shrub species depend on for uptake of water and nutrients. Sagebrush will be transplanted on the plots in 1988 from adjacent stands.

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1.0 INTRODUCTION

The Final Environmental Impact Statement, Disposal of Hanford Defense High-Level, Transuranic, and Tanks Wastes presents a description of a conceptual protective barrier that would be placed over wastes disposed of near-surface (DOE 1987). The intent of the protective barrier would be to isolate effectively these wastes from infiltrating precipitation, biointrusion, and surficial erosion for up to 10,000 years (EPA 1985). Pacific Northwest Laboratory (PNL) and Westinghouse Hanford Company (WHC) are working jointly on a project funded by the U.S. Department of Energy (DOE) to develop such a barrier. The conceptual protective barrier consists of coarse rock and sand layers covered with a fine-textured soil, which stores rainwater until it can be cycled back into the atmosphere by evaporation and plant transpiration (Figure 1.1). The coarse rock layer also serves as an impediment to burrowing animals.

Because erosion of the fine soil layer and/or a reduction in plant transpiration could cause drainage through the barrier, it may be necessary to incorporate a gravel mulch to control erosion, much like desert pavements that have protected underlying soils for thousands of years. Several questions must be answered, however, before the use of gravel for controlling erosion on barriers can be adequately defended:

- What is the optimum gravel size, shape, and volume?
- How will plants respond? Will plant transpiration compensate for gravel-induced changes in infiltration and evaporation?
- Will freeze-thaw and shrink-swell cycles alter the engineered gravel design?
- How sensitive is the system to climatic variability?

This document reports the first-year results of a factorial experiment designed to help resolve these issues. The experiment was designed to measure the effects of erosion control practices on soil water storage and plant cover. Other studies will measure the erosivity of different types of gravel

FIGURE 1.1. Water Balance Parameters and Associated Potential Transport Pathways Acting on the Hanford Conceptual Barrier

mulch (Ligotke 1988) and the effects of gravel on drainage and evapotranspiration (Waugh and Link 1987; Kirkham and Gee 1987). The test plan for this project (Waugh and Link 1988) contains discussions of the rationale, experimental approach, costs, schedules, and the interaction between this study and other barrier development tasks. Adams and Wing (1987) prepared the baseline document for the Barrier Development Program.

Section 2.0 of this report includes conclusions and recommendations. Section 3.0 describes the study area, the experimental design and associated statistical models, and a rationale for treatment selection. A record of the construction sequence is included in Section 4.0. Sampling methods and first-year data are provided in Section 5.0 with a discussion of preliminary findings.

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2.0 CONCLUSIONS AND RECOMMENDATIONS

The following conclusions and recommendations are provided based on the experience and preliminary data obtained in FY 1987 from the gravel admix field plots at Hanford:

- Incorporating pea gravel into the barrier topsoil layer, as an erosion control measure, elevated near-surface soil water content when vegetation was excluded. Plant transpiration, however, from a first-year stand of cheatgrass and wheatgrass seedlings, offset gravel-induced higher moisture and, for all treatments combined, reduced volumetric water content at a depth of 30 cm by 3.5%.
- Between October 1986 and June 1987, mean soil water profiles for all plots varied little below 80 cm, indicating that the zone of soil water extraction was above this depth. Any treatment effects below this depth, however, were masked by a large initial variation in water content among plots, attributable either to heterogeneity in soil hydraulic properties, or possibly to the presence in some plots of residual water from past irrigation. In the future, this source of variation will be removed by differencing monthly data series and testing for changes in soil water storage. Differencing the data will also remove some of the error associated with the hydroprobe calibration.
- Hydroprobe calibration curves were calculated for each depth with the goal of reducing inaccuracies arising from heterogeneity in soil hydraulic properties. Measurements of wet-plot water content and changes in bulk density, with depth, are needed to improve the accuracy and precision of separate field calibration functions. If spatial variability in field conditions are negligible, a laboratory calibration of the hydroprobe, using large, containerized, homogeneous bodies of soil, and carefully controlled water content and density, will yield more accurate calibration curves.
- Of the nine species seeded, only four grasses and no shrubs emerged during the initial growing season. The old field soils may be

unsuited for shrub establishment because of the absence of host-specific vesicular-arbuscular mycorrhizae (VAM). Years of cultivation may have eliminated VAM in the old field. Shrubs dependent on VAM for uptake of water and nutrients are poor competitors in depleted soils. Transplanting sagebrush and hopsage seedlings from adjacent stands, which are likely infected with VAM, would accelerate the establishment of a shrub canopy on the plots.

- The gravel treatments appeared to have no effect on plant cover or species composition after one growing season. Although plant cover provided a useful measure of seedling abundance, measurements of phenology, leaf-area index, and gas exchange are needed for seasonal estimates of plant transpiration, a key parameter for testing the effects of gravel on soil water balance. These response variables will be measured as equipment becomes available and adapted to field-plot conditions.
- Calculations of the volumes of gravel needed to produce the 15 and 30% by weight admix treatments were based on unverified estimates of compaction and gravel bulk density. The gravel plots will be randomly sampled to obtain accurate measures of the actual admix depths and gravel/soil ratios attained.
- Variability in collection-can irrigation measurements among whole plots was small. However, during one breezy irrigation session, the system produced inordinately large differences in the amount of water received at the center and at the perimeter of a plot. To prevent spray drift, the plots should not be irrigated when wind velocities exceed 5 mph.

3.0 EXPERIMENTAL DESIGN

3.1 STUDY AREA

The gravel admix field experiment was conducted at McGee Ranch, the site of the barrier topsoil quarry. McGee Ranch lies directly northwest of the Yakima Barricade at Hanford, in Section 20, Township 13 North, Range 25 East, and is bordered on the south and east by Washington State Highways 24 and 240, respectively, as shown in Figure 3.1.

The study area is part of an abandoned agricultural field that was flood irrigated 40 years ago. Irrigation rills transecting the area from the northwest to the southeast are still visible. The plant canopy of an adjacent untilled tract consists primarily of sagebrush (Artemisia tridentata) and hopsage (Grayia spinosa). The old field remains dominated by cheatgrass (Bromus tectorum). This evidence contradicts a common assumption that the plant community inhabiting the barrier will eventually resemble that found on the undisturbed soil quarry. The introduction of cheatgrass, a naturalized Eurasian annual, has apparently caused plant communities once dominated by sagebrush to be less resilient to disturbance (Rickard 1985).

Hajek (1966) classified the McGee Ranch soil type as Warden silt loam. It consists of dry, grayish-brown, wind-laid silt mixed with small amounts of volcanic ash, with a very weak eluvial clay layer and often a calcareous layer at about 50 cm. Silt loam soils may contain 50 to 80% silt, up to 50% sand and up to 25% clay fractions. Warden silt loam grades into Ritzville silt loam at higher elevations.

3.2 HYPOTHESES

The field-plot experiment was designed to test the following four hypotheses as to the effects of gravel admix, denudation, and enhanced precipitation on soil water storage, plant abundance, and evapotranspiration:

- H1: Gravel admix volume will not affect soil water storage below the root zone.

FIGURE 3.1. Locations of the Gravel Admix Field-Plot Experiment

- H2: Denudation will not affect soil water storage or evapotranspiration.
- H3: Twice the annual precipitation will not increase soil water storage.
- H4: Gravel will not affect plant species composition, abundance, or evapotranspiration.

A useful approach in designing manipulative, comparative experiments such as this is to define four basic components of the design: 1) the treatment structure, 2) design structure, 3) method of assigning treatments to experimental units in the design structure, and 4) statistical model dictated by the total design (Milliken and Johnson 1984). These components are described in the following sections.

3.3 TREATMENT STRUCTURE

A three-way factorial treatment structure that encompasses all possible combinations of three types of treatments, or factors, was selected for this experiment: three levels of gravel admix, two levels of vegetation, and two levels of irrigation.

3.3.1 Gravel Admix

The three gravel admix treatment levels shown in Table 3.1 were selected for the following reasons:

- The balance of pedoturbation (freeze-thaw action, shrink-swell action, and soil mixing by burrowing animals), and erosional and depositional processes operating on a gravel mulch over the long term may result in an equilibrium gravel mix morphology, regardless of how the gravel was initially applied. Therefore, a clean surface gravel layer may eventually resemble an admix after years of soil deposition and mixing. Also, like a desert pavement, below which stones remain dispersed in the soil, an admix greater than one or two stones in thickness can be described as self-healing following disturbances of the surface veneer. (The long-term morphology of

TABLE 3.1. Treatment Structure for the Gravel Admix Field Experiment^(a)

<u>Factor</u>	<u>Levels</u>	<u>Treatment Description</u>
Gravel	3	1. 15% by wt gravel admix to a depth of 20 cm 2. 30% by wt gravel admix to a depth of 20 cm 3. Control: no gravel
Vegetation	2	1. Native and exotic grass/shrub seed mix 2. Control: nonselective herbicide
Water	2	1. 2x normal monthly precipitation 2. Control: no supplemental water

(a) 12 treatment combinations x 3 control replications = 36 experimental units.

an engineered gravel mulch will be inferred from the results of an investigation of natural gravel-armored soils at Hanford. See Task NAT-4 in Adams and Wing 1987).

- Pea gravel has a higher surface area to volume ratio than larger gravel or cobble and thus may provide greater soil protection with less impact on soil hydraulic properties. Wind erosion essentially ceases on desert pavements as the surface area covered by stones approaches 50% (Mabbutt 1977). However, adding gravel to denuded soils increases infiltration, reduces evaporation, and lowers the storage capacity, potentially increasing drainage (Nichols, Brown, and Grant 1984). The experiment estimated the effects of a range of gravel volumes on soil water storage and movement.
- A 15% pea gravel admix was used by Fayer et al. (1985) in a computer model simulation of the effects of gravel on recharge. In Ritzville silt loam without vegetation, 15% gravel mixed to depths of 7.5 cm or deeper will cause 1.7 cm drainage during an average precipitation year, according to the model. Also, no drainage will occur with vegetation present, according to the model, regardless of soil type. Fifteen percent gravel admix was included in this experiment for comparison with these model predictions.

3.3.2 Vegetation

A stable and lasting plant community cannot be engineered, unlike other components of the protective barrier system. Plant communities are dynamic and, to a large degree, unpredictable. Over time, regardless of what is initially seeded, a plant community will likely converge with that which would have developed naturally.

The natural development or succession of a plant community leads to greater biomass, slowed biogeochemical cycling, a buffering of macroenvironmental impacts (such as the effect of precipitation on soil water movement) and greater site stability (Odum 1969). With this in mind, the objective of the revegetation treatment was to accelerate succession--to establish a plant community with attributes similar to those of the community that would develop naturally, over time.

The two vegetation treatment levels comprised a mixture of native and exotic plant species and bare soil. The following types of species were selected: 1) indigenous species found in mature plant communities at McGee Ranch and surrounding the 200 areas, 2) commercially available cultivars similar to native species for which cultivars were not available, and 3) relatively easy to establish cultivars similar to more difficult to establish native species.

3.3.3 Precipitation Enhancement

The purpose of the precipitation enhancement treatment was to simulate the combined effects of a wet climate and gravel admix on soil water storage and plant abundance. Increased precipitation is only one of several changes associated with a wetter climate. Cloud cover, for example, plays an important role in energy exchange at the earth's surface. Clouds absorb and reflect solar radiation, thus reducing the amount received and, consequently, the evaporative demand at the surface. Conversely, clouds reradiate infrared radiation emitted from the earth's surface that otherwise would escape through the atmosphere into space. Also, in wetter climates, more energy is removed from or added to the surface environment as latent heat of evaporation and condensation, respectively. The overall result is a moderation of temperature extremes both diurnally and seasonally. Furthermore, a wetter climate would

increase the abundance and diversity of plants and animals and modify their adaptive strategies and behavior.

For comparative experiments, simulating a wetter climate is generally limited to water applications. The amount, frequency, timing, rate, duration, and uniformity of applications were all considered in the precipitation enhancement treatment for this study.

The historical annual precipitation at Hanford ranges from 8 to 27 cm with a mean of 16.0 cm (Stone et al. 1983). Using extreme value statistics, Kinnison (1983) estimated the maximum 100-year annual precipitation to be 30.1 cm. This value has been used in performance assessment calculations and in all wet year model simulations of drainage through protective barriers (Fayer et al. 1985). Although not defensible as a 10,000-year worst case condition, a more prudent value, 32 cm, or double the mean annual precipitation, was selected as one of two water treatment levels. No supplemental water is the control. These values are consistent with treatments in the Barrier Development Program lysimeter experiments (Kirkham and Gee 1987; Waugh and Link 1987).

3.4 DESIGN STRUCTURE

The design structure of an experiment consists of experimental units grouped so that treatments are observed under as uniform of conditions as possible. Each of the twelve treatment combinations described above were replicated three times, totaling 36 field plots, in a classic split-split-plot (SSP) design structure (Figure 3.1). Each of six large 10 x 15 m whole plots were divided into six 5 x 5 m subplots in a 2 x 3 grid. Treatments were assigned to these plots in the following hierarchy: Each whole plot received a precipitation enhancement level, a vegetation level was randomly assigned to half of a whole plot (the split-plot treatment), and the levels of gravel were randomly assigned to the subplots within the split plots (the SSP treatments). Table 3.2 outlines the random assignment of treatments to field plots.

Split-plot and split-split-plot designs are often used when physical conditions make it difficult to completely randomize a factorial experimental

FIGURE 3.2. Split-Split-Plot Design Structure for the Gravel Admix Field Experiment

TABLE 3.2. Gravel Admix Experiment Treatment Assignment

Plot Number	Water		Vegetation		Gravel Admix Volume		
	N (a)	32 cm (b)	Bare	Seeded	Control	15%	30%
1A		X		X		X	
B		X		X			X
C		X		X	X		
D		X	X			X	
E		X	X				X
F		X	X		X		
2A	X			X			X
B	X			X		X	
C	X			X	X		
D	X		X		X		
E	X		X			X	
F	X		X				X
3A		X	X				X
B		X	X			X	
C		X	X		X		
D		X		X		X	
E		X		X			X
F		X		X	X		
4A	X			X		X	
B	X			X			X
C	X			X	X		
D	X		X				X
E	X		X		X		
F	X		X			X	
5A		X	X			X	
B		X	X		X		
C		X	X				X
D		X		X		X	
E		X		X			X
F		X		X	X		
6A	X			X	X		
B	X			X		X	
C	X			X			X
D	X		X		X		
E	X		X				X
F	X		X			X	

(a) Natural rainfall.

(b) Twice the average annual precipitation recorded at the Hanford Meteorological Station.

design. These special designs were chosen for the gravel admix experiment because of logistical problems associated with randomly irrigating and drill-seeding small plots. These designs are also used when more than one factor is of interest. For this experiment, the effects of gravel admix can be estimated more accurately than the effects of vegetation or enhanced precipitation.

3.5 ANALYSIS OF VARIANCE MODELS

Soil water storage and plant cover have been sampled from the start of the experiment. Evapotranspiration indices will be measured as instrumentation becomes available and adapted to the conditions of the experiment. An analysis of variance (ANOVA) procedure will be applied to these data, and the decision to reject or accept a hypothesis will be based on an F-test. ANOVA involves partitioning the sum of squares of deviations of the response measurements about their mean. ANOVA statistically judges the significance of the variation among sample means by comparing it with a measure of the random variation within the population data (the variation within sample means).

Five ANOVA models are specified for hypothesis testing: full and reduced versions of split-plot (SP) and split-split-plot (SSP) models and an expanded model for subsampling. Full and reduced SSP ANOVA models are used to analyze the response of soil water and evapotranspiration to all three factors in the treatment structure (enhanced precipitation, vegetation, and gravel admix). The effects of enhanced precipitation and gravel admix on plant abundance are compared using full and reduced SP ANOVA models because vegetation is eliminated as a treatment.

The most desirable statistical model would produce exact F-tests with many degrees of freedom in the denominator. Because this is not possible for SSP and SP designs, full models, which give exact F-tests with small numbers of degrees of freedom, and reduced models, which give approximate F-tests with many more degrees of freedom, will both be used. The full model includes all possible treatment interactions. The reduced model excludes treatment replication interaction effects. The expanded, full SSP model will be used

for analyses involving subsamples of plant abundance within the 5 x 5 m subplots. Table 3.3 lists the critical values of the F-test for each of the four hypotheses. If the F-statistic calculated for a given test is greater than or equal to these critical values, the hypothesis is rejected. Appendix A contains the ANOVA models and tables for all analyses.

TABLE 3.3. Critical Values of F-Tests for Hypotheses in the Gravel Admix Field Experiment

Hypothesis ^(a)	Design ^(b)	Full Model ^(c)	Reduced Model ^(d)
H1	SSP	$F(2,4) = 6.94$	$F^*(2,16) = 3.63$
H2	SSP	$F(2,4) = 6.84$	$F^*(2,16) = 3.63$
H3	SSP	$F(1,2) = 18.5$	$F(1,2) = 18.5$
H4	Sp	$F(2,4) = 6.94$	$F^*(2,8) = 4.46$

(a) Hypotheses defined within the text.

(b) SSP = split-split-plot analysis of variance; SP = split-plot analysis of variance.

(c) $F(a,b)$ denotes an F-value with "a" degrees of freedom in the numerator and "b" degrees of freedom in the denominator.

(d) * denotes an approximate F-statistic.

4.0 CONSTRUCTION SEQUENCE

This section documents construction activities associated with the gravel admix field experiment with sufficient detail to repeat the experiment or to repeat the setup for additional comparative tests of other erosion control practices, if warranted.

4.1 SITE PREPARATION

Before the study area (a 50 x 45 m rectangular plot oriented north to south) was bladed, plot corners were marked with 2-m steel stakes, and the area was surveyed with a conductivity meter for buried objects that could disrupt the operation of heavy equipment. (No significant deflections in conductivity were registered while traversing the area.) Heavy equipment operators bladed the top 5 to 10 cm of soil and vegetation, feathered the berm approximately 8 m beyond the plot perimeter, and ripped the soil to a depth of 1 m with a D-8 Caterpillar bulldozer.

Soils were ripped approximately 100-cm deep with the objective of severely disturbing the soil structure, as will occur when the soil is scraped, hauled, spread, and releveled during barrier construction. Plots were ripped in 50- to 60-cm swaths in an east-west direction. The soil structure disturbance was found to be uniform in test trenches excavated across the swaths. As a second check, the operator pulled the ripper perpendicular to the original direction and felt no corrugated or washboard resistance, further evidence that the first pass had adequately mixed the soil. Plots were then smoothed with a chisel plow to break up clods and compacted with the D-8 Caterpillar bulldozer, completing preparation of the site for treatment applications.

4.2 GRAVEL ADMIX APPLICATIONS

Whole plots and split plots were surveyed, their corners marked with steel posts and wooden stakes, and the gravel admix treatments applied to split-split plots as follows. The bucket of a small front-end loader was calibrated and equivalent volumes of 1.0- to 2.0-cm pea gravel hauled to and

spread evenly over the subplots. Plots assigned 15 and 30% by weight admix levels received 0.58 m^3 and 1.18 m^3 pea gravel, respectively. Calculations of gravel volume were based on a bulk density of 1.4 g/cm^3 for McGee soil, 1.7 g/cm^3 for basalt pea gravel, and 15% compaction. Gravel piles were spread evenly over the plot surfaces with a hand rake, rototilled in orthogonal directions, and compacted with a water-laden cultipacker to form admix layers approximately 20 cm thick.

4.3 SEEDING AND FERTILIZER APPLICATIONS

Designated split plots were seeded on September 19 and 20, 1986, as outlined in Table 4.1. To minimize initial interspecific competition and to provide an optimum seedbed ecology, some species were seeded with a tractor-drawn "Truax" drill while others were broadcasted with a hand-operated cyclone spreader. Wheatgrass seeding and fertilizer applications were conducted concurrently. Siberian wheatgrass (Agropyron sibericum) and thickspike wheatgrass (A. dasystachyum) were drilled simultaneously in alternating rows using partitions in the middle box of the drill. Indian ricegrass (Oryzopsis hymenoides) was drilled separately using the small box. All other species were premixed and broadcasted with the cyclone seeder. Fertilizer (16-20-0) was broadcasted, with boot hoses disconnected, from the small box on the drill. Following the seeding operation, plots were compacted and pitted with a cultipacker. The benefits of this practice include fertilizer incorporation, seedbed water conservation, improved seed-to-soil contact, and variable seed-depth placement. Placement of seed at variable depths helps balance the germination of a diverse species mixture.

4.4 HYDROPROBE WELL INSTALLATION

Access wells for a neutron moisture depth probe (hydroprobe) were installed in the center of each 5 x 5-m subplot. A 5-cm-diameter, hand-operated bucket auger was used to form holes for installation of 3-m long sections of 5.7-cm-diameter, seamless, thin-walled (0.32 cm) aluminum tubing (ASTM 1986a; Klute 1986). Graduated depths were marked on auger extension handles. The auger was advanced into the soil a desired distance, removed,

TABLE 4.1. Composition of Seed Mixture Sown and Fertilizer Spread
on Gravel Admix Test Plots at McGee Ranch

<u>Species</u>	<u>Cultivar or Subspecies</u>	<u>Source</u>	<u>% PLS^(a)</u>	<u>Date Tested</u>	<u>PLS Kg/ha</u>
<u>Drill-Seeded</u>					
Siberian wheatgrass (<u>Agropyron sibericum</u>)	P-27	Idaho	86	2/86	31.0
Thickspike wheatgrass (<u>Agropyron dasystachyum</u>)	Critana	Idaho	84	6/86	10.1
Indian ricegrass (<u>Oryzopsis hymenoides</u>)	Nezpas	Idaho	59	7/81	8.3
<u>Broadcast-Seeded</u>					
Big sagebrush (<u>Artemisia tridentata</u>)	Tridentata	Colorado	9	1/80	0.7
Rabbitbrush (<u>Chrysothamnus nauseosus</u>)	Albicaulis	?	9	1/86	0.8
Antelope bitterbush (<u>Purshia tridentata</u>)	-	Oregon	90	7/81	9.7
Spiny hopsage (<u>Grayia spinosa</u>)	-	Idaho	40	-	2.9
Canby bluegrass (<u>Poa canbyi</u>)	Canbar	Idaho	84	4/86	6.1
Sheep fescue (<u>Festuca ovina</u>)	Covar	Idaho	84	6/85	9.1
<u>Fertilizer (16-20-0)</u>					
N	-	-	-	-	26.8
P	-	-	-	-	33.0

(a) Pure live seed = purity x germination.

and the sample retrieved for gravimetric moisture analysis (see Section 5.1). Aluminum tubing was inserted into the bore hole to serve as well casing, and dry soil was carefully sifted into the annulus as a seal. Gaps between the well casing and surrounding soil can influence thermalized neutron distribution and, consequently, the neutron count. The well casings, protruding about 5 cm above the soil surface, were plugged with rubber stoppers to keep water and debris out of the holes between hydroprobe readings.

4.5 IRRIGATION SYSTEM

A sprinkler irrigation system with conventional spray heads was installed to enhance precipitation on three of the six whole plots. An 8-hp, gasoline-powered Berkeley centrifugal pump delivers water from a 9465-1 (2500-gal) tank at a rate of up to 300 L per minute (80 gpm) through aboveground polyvinyl chloride (PVC) piping to 36 Rainbird 1804-15 heads. Spray heads were positioned on the plots to provide a uniform spray pattern (Figure 4.1). With hose bibs and gate valves in the system, whole plots can be irrigated singularly or in pairs, as well as all at once, and the tank can be drained and the pipes blown out with an air compressor to prevent ice-induced cracking during the winter months. The system also has a y-strainer to trap exfoliated rust and other tank debris, an in-line flow meter to measure output, and an in-line pressure gage.

4.6 PESTICIDE APPLICATIONS

The nonselective herbicide Ureabor was applied on split plots assigned the vegetation control treatment with a hand-held cyclonic spreader at a rate of approximately 16 g/m^3 (1.1 lbs/100 ft^2) dry granules. The treated surface was wetted immediately to activate the chemical and to prevent migration of the chemical onto adjacent seeded plots.

Seeded plots were treated in May 1987 with the insecticide Dursban L.O. to control an infestation of grasshoppers. Sixty L of Dursban in a 1% solution were applied over approximately 600 m^2 using a backpack sprayer.

FIGURE 4.1. Sprinkler Irrigation System for the Gravel Admix Field Experiment

FIGURE 1. Plan view of the proposed high energy electron beam source.

5.0 METHODS AND PRELIMINARY FINDINGS

5.1 SOIL MOISTURE PROFILES

Two methods were used to determine soil water content: neutron thermalization and gravimetry. The neutron thermalization method, which requires using a neutron moisture depth probe (hydroprobe) containing radioactive materials, was the primary method for measuring treatment effects. Gravimetric measurements of water content were used to construct a calibration curve for the neutron probe.

5.1.1 Gravimetric Water Content

Field calibration of the hydroprobe required measurements of water content by gravimetric methods (ASTM 1986b). Soil samples (100-200 g wet wt) were extracted from bore holes with a bucket auger and transferred into corrosion-resistant containers from the bottom of the auger by tapping the bucket cylinder with a wooden mallet. The containers were sealed with tight-fitting lids and plastic tape. Samples were weighed (balance precision = ± 0.1 g), dried for at least 20 hours at 110°C with the lid removed, and reweighed with the lid replaced. Water content was computed using the following formula:

$$w = (W_1 - W_2) / (W_2 - W_c)$$

where w = dry-mass water content

W_1 = mass of moist specimen + container

W_2 = mass of oven-dried specimen + container

W_c = mass of container.

Two patterns observed in the initial soil water profile (Figure 5.1) could potentially confound interpretations of treatment effects: 1) soil water content increases with depth and 2) variation in water content increases with depth. These patterns may reflect variability in soil hydraulic properties among plots and possibly the presence of residual water from past irrigation of the old field. It may be possible to overcome the impact of

FIGURE 5.1. Volumetric Water Content Profile for all Admix Field Plots, October 1986. Estimated from Gravimetric Data. Error Bars = 2 standard error.

inherent variability in water content on treatment comparisons by differencing monthly data series and testing for changes in soil water storage. Appendix B contains the gravimetric water content data.

5.1.2 Nuclear Method

A Campbell Pacific Nuclear Corp. Model 503 hydroprobe (Serial Number H38092510) was used for monthly measurements of volumetric soil water content. The probe consists of a fast neutron source (Am-241/Be), a thermalized neutron detector, and a lead and paraffin protective shield for absorbing harmful gamma rays and neutrons. High-energy neutrons emitted by the probe source are thermalized (slowed and scattered) by hydrogen nuclei in the surrounding soil. Because most of the hydrogen in these arid soils is associated with water, the density of thermalized or slowed neutrons, as counted by the probe detector, can be calibrated to provide a measure of water content on a volume basis.

Variable soil organic matter content, soil mineralogical composition, and discontinuity in the soil-water profile, particularly at the soil-air interface, can introduce error in determining the distribution of water content in a soil profile. However, if the instrument is adequately calibrated, and standard measurements are routinely taken before each sampling session, relatively accurate measurements of changes in water content can be obtained (Gardner 1986).

A field calibration of the hydroprobe was performed in September 1986 by measuring the gravimetric water content of samples taken during the installation of access wells (Section 4.3), multiplying these values by soil bulk density (1.30 g/cm^3) to convert the data to volumetric units, and constructing a linear regression model of the relationship between volumetric water content and hydroprobe counts taken immediately following the installation of an access well. Soil samples for gravimetric water analysis and hydroprobe counts (counts/30 sec) were both taken at depths of 30, 45, 80, 125, 175, 225, and 275 cm. Hydroprobe counts have been recorded monthly at these depths since September 1986. Ten standard counts (counts/30 sec) were taken with the shielded probe during the installation of each access well and before and after each monthly sampling session. The measurement used for calculating water content was the ratio of the count for a particular depth to the average standard count. This count ratio corrects for temperature-induced electronic variability in the counting circuits for the probe.

With the ultimate goal of increasing the accuracy of hydroprobe measurements of soil water content, calibration functions were calculated for each depth, and for all depths combined (Table 5.1). Variation in linear regression parameters among depths, and associated error, may be attributed to 1) narrow water content ranges at each depth and 2) field variation in soil bulk density and texture. The calibration function for all depths combined will be used until gravimetric water content and hydroprobe data from wet profiles and depth measurements of bulk density are obtained. Appendix C contains volumetric moisture estimates and corresponding count ratios for all field plots.

TABLE 5.1. Linear Regression Analysis for Hydroprobe Calibration at Each Depth and for all Depths Combined Using Initial Gravimetric Water Contents, Count Ratios, and a Soil Bulk Density Estimate of 1.30 g/cm³

Depth	(a) β_0	(b) β_1	(c) $SE(\beta_1)$	(d) $SE(\hat{y})$	(e) r^2
30	-3.70	33.50	5.44	0.75	0.53
45	-2.74	29.62	3.77	0.55	0.64
80	-2.10	26.95	4.35	0.97	0.53
125	-1.21	22.65	5.26	1.51	0.35
175	-5.18	33.40	3.98	1.81	0.67
225	-0.76	21.22	4.39	3.23	0.41
275	-4.46	27.27	4.32	4.25	0.54
All Depths	-0.71	21.87	0.95	2.28	0.68

(a) Intercept of the regression line.

(b) Slope of the regression line.

(c) SE = standard error.

(d) $\hat{y}$ = estimated regression function.

(e) r^2 = coefficient of determination.

Appendix D contains percent volumetric moisture data for the field plots from November 1986 through June 1987. Changes in mean soil water content and associated standard errors for each depth and all field plots combined are shown in Figure 5.2. The data indicate that the initial October observation of greater water content with depth, and greater variation in water content with depth, persisted through June. Furthermore, during this 9-month period, no significant changes in soil water content were measured below 80 cm, indicating that the zone of water extraction was above this depth.

Although ANOVA tests of hypotheses using these first few months of data have not been completed, the influence of gravel on soil water content is readily illustrated in two comparisons of soil moisture profiles. No salient treatment effects were observed during the winter months. In May, following 2 weeks of abnormally hot weather, water content at 30 cm was noticeably higher in denuded gravel plots than in control plots with no gravel admix (Figure 5.3). This indicates that the evaporation rate was lower from the graveled

FIGURE 5.2. Soil Water Content Profiles for January, April, and June, and for all Admix Field Plots. Estimated from Hydroprobe Count Ratios. Error Bars = 2 standard error.

FIGURE 5.3. Soil Water Content Profiles for Gravel/no Vegetation Treatments in May 1987. Error Bars = 2 standard error.

surface than from bare soil. The difference appeared negligible, however, in seeded plots (Figure 5.4)--plant transpiration offset gravel-induced increases in soil water, even for a stand of first-year seedlings. Similar water profile patterns were observed in June and July.

The monthly irrigation treatment, which began in March, had a negligible influence on measured soil water content (30 cm and below). A more telling test of enhanced precipitation will be possible in the spring of 1988, following the first wet season during which the normal precipitation is doubled.

5.2 PLANT ABUNDANCE

For an evaluation of seedling establishment, the percent canopy cover of major species was estimated using a point-intercept sighting instrument. Canopy cover is considered a better index of the importance of a species in a community than density (no./unit area) because it permits less biased comparisons of different growth forms (Mueller-Dombois and Ellenberg 1974). The ocular point-intercept method provides less biased, more precise, and less time-consuming

FIGURE 5.4. Soil Water Content Profiles Comparing no Gravel/Vegetation, Gravel/Vegetation, and Gravel/no Vegetation Treatments in May 1987. Error Bars = 2 standard error.

estimates of percent canopy cover in sagebrush-grass vegetation than line-intercept or the Daubenmire (1959) cover class method (Floyd and Anderson 1983).

The sighting frame consists of two 50- x 100-cm frames (inside dimensions) constructed with 5- x 2-cm maple lumber and superimposed 10-cm apart with metal tubing. The frames were strung with white line in holes drilled at 10-cm intervals to produce a 36-point sighting grid. This unit was mounted on three adjustable camera tripod legs with large rubber clasps. Percent cover was estimated as the proportion of point interceptions for a species and for the other surface components of interest (gravel and bare soil).

5.2.1 Sample Size Estimation and Sighting Frame Placement

Percent canopy cover was recorded for 20 frame positions each in plots 1A, 1B, and 1C using a systematic placement of the frame and multiple random starting points. This preliminary data was entered into the following sample size estimator (n_0):

$$n_0 = (z^2 s^2 / d^2) 1.10$$

where z^2 is 1.960 in the standard normal distribution for a 95% confidence level, s^2 is the sample variance, and d^2 is the predetermined absolute precision level (the sample mean should be within $\pm d$ of the population mean).

Sample size estimates for percent cover of gravel, bare soil and prevalent plant species are shown in Table 5.2. Using this analysis, 20 quadrats per split-split plot were considered adequate to approach a 95% confidence

TABLE 5.2. Estimates of Adequate Numbers of Sighting Frame Locations for Sampling Percent Cover at a 95% Confidence Level and an Absolute Precision of 5%

<u>Media</u>	<u>Field Plot</u>		
	<u>1A</u>	<u>1B</u>	<u>1C</u>
Soil	12.19	14.99	9.72
Gravel	2.37	6.19	0.42
Cheatgrass	13.57	20.27	22.89
Wheatgrass	4.29	5.54	6.58

level that the sample mean percent cover for these surface components will be within $\pm 5\%$ of the population mean. Using the 36-point frame, this represents a sampling intensity of 720 points per field plot or a total of 12,960 points.

Field plots were systematically sampled using random starting points for selecting the first transect in each plot and for selecting the first sighting frame position on each transect. Four transects with five sample locations each were positioned so as to create a 25-cm buffer around the inside perimeter of a field plot. Sample means and variances were approximated using standard formulas for simple random sampling.

5.2.2 Seedling Establishment

Point-interception cover data, obtained in early June 1987, are tabulated in Appendix E. Table 5.3 shows sample means and standard errors, by plot, for percent cover of soil, gravel, cheatgrass, wheatgrass, and all plants combined.

Of the nine species seeded, four species (all grasses) established in an observable abundance: thickspike wheatgrass (*A. dasystachyum*), Siberian wheatgrass (*A. sibericum*), canby bluegrass (*Poa canbyi*), and sheep fescue (*Festuca ovina*). The fifth grass, Indian ricegrass (*Oryzopsis hymenoides*), characterized by extreme embryo dormancy and sporadic germination because of inhibited embryo gas exchange (McDonald and Kah 1977), was probably not observed because of the abnormally mild winter. Cold-moist stratification greatly improves *Oryzopsis* germination (Young and Evans 1984).

The absence of seeded shrubs in the plots may be tied to soil microorganism succession. Sagebrush (*Artemisia tridentata*) and other desert shrubs typically benefit from infection with endomycorrhizae (Williams and Aldon 1976), which form a mutualistic symbiosis with plant roots. Mycorrhizal fungi aid in water and nutrient uptake by host plants, particularly phosphorus uptake, and may play a major deterministic role in plant community development on disturbed land (Loree and Williams 1984). These fungi may also accelerate the establishment of perennial grasses.

Years of cultivation may have eliminated mycorrhizae populations in the McGee Ranch old field, thus inhibiting shrub establishment. Species dependent on vesicular-arbuscular mycorrhizae (VAM) for uptake of water and nutrients

TABLE 5.3. Mean Percent Cover and Standard Error^(a) for Soil, Gravel, Cheatgrass, Wheatgrass, and all Plants in Gravel Admix Fields Plots, June 1987

Plot Number ^(b)	Soil		Gravel		Total Plant		BRTE ^(c)		AGspp ^(c)	
	$\bar{x}$	2(SE)	$\bar{x}$	2(SE)	$\bar{x}$	2(SE)	$\bar{x}$	2(SE)	$\bar{x}$	2(SE)
1A	17.7	1.4	4.5	0.6	14.1	1.8	8.8	1.5	3.5	0.8
1B	13.1	1.5	8.5	1.0	14.1	1.7	7.9	1.7	5.8	0.9
1C	20.1	1.2	0.7	0.3	15.6	1.0	7.5	1.9	6.5	1.0
2A	11.5	1.1	9.6	0.8	14.3	1.6	7.6	1.6	6.1	1.3
2B	15.8	1.2	4.6	0.7	15.0	1.5	8.3	1.6	6.2	1.1
2C	18.3	0.8	0.2	0.2	16.9	1.1	9.7	1.6	6.9	1.1
3D	16.1	1.2	4.4	0.5	14.7	1.2	7.6	1.4	6.6	1.2
3E	11.2	1.0	9.9	0.8	15.2	1.3	6.4	1.0	7.6	1.1
3F	21.7	1.8	0.5	0.3	13.2	1.6	5.4	1.3	7.9	1.3
4A	19.6	1.2	5.2	0.7	11.6	1.1	4.6	1.0	6.1	0.7
4B	12.0	0.9	9.4	0.7	14.6	1.2	6.7	1.2	7.0	0.8
4C	19.9	0.9	0.5	0.3	15.4	0.9	7.9	0.9	7.2	0.9
5D	17.0	1.0	7.8	0.8	11.3	0.7	3.5	0.8	6.8	0.8
5E	13.2	1.3	11.6	0.9	11.2	1.3	3.4	1.2	6.8	0.8
5F	25.1	1.6	0.4	0.3	10.8	1.8	3.1	1.2	7.1	1.1
6A	22.8	1.5	0.2	0.2	13.1	1.7	5.4	1.5	6.8	1.4
6B	14.6	1.2	7.1	0.9	14.0	1.8	5.7	1.9	7.2	0.8
6C	12.5	0.8	10.7	0.8	13.4	1.3	4.1	1.2	7.9	1.4

(a) n = 20.

(b) Treatment assignments are shown in Table 3.2.

(c) BRTE = Bromus tectorum (cheatgrass); AGspp = Agropyron species (wheatgrass).

may be poor competitors with nonmycorrhizal species when seeded concurrently on depleted soils (Loree and Williams 1984). Furthermore, succession to a mycotrophic (literally, nourished by fungi) plant community may be retarded on disturbed areas by the combination of low mycorrhizal inoculum and an abundance of nonmycorrhizal annuals such as Russian thistle.

5.2.3 Plant Cover Comparisons

As with the soil water content data, ANOVA tests of hypotheses regarding the effects of gravel admix on plant abundance have not been completed. However, some descriptive statistics illustrate a couple of interesting observations. Recall that, with vegetation absent, near-surface soil moisture was consistently higher in gravel admix plots than in bare soil plots (Figure 5.3). Also recall that near-surface soil moisture was much lower in seeded plots than in denuded plots and that, with vegetation present, the effects of gravel were negligible (Figure 5.4). One would attribute these findings to plant water extraction. Because carbon fixation and plant transpiration are closely coupled, one might also expect more abundant vegetation in the gravel admix plots. Figure 5.5 shows evidence to the contrary. Figure 5.5 also shows that wheatgrass and cheatgrass cover varied little among gravel treatments and was nearly equivalent--neither species appeared to be particularly better adapted to either condition (gravel or no gravel).

FIGURE 5.5. Percent Cover of Vascular Plants on the Gravel Admix Field Plots in June 1987. Error Bars = 2 standard error.

5.3 PRECIPITATION ENHANCEMENT

Ideally, to simulate natural conditions, the experimental setup would permit close control of the frequency, timing, intensity, and uniformity of artificial rainfall, as well as the amount. Such a setup would require, at a considerable cost, automated rainfall simulators and mobile plot "umbrellas" linked by computer to a real-time, meteorological data logger. A conventional sprinkler system designed with as uniform a spray pattern as possible was constructed instead. Irrigation amount was calculated as the difference between twice the Hanford Meteorological Station (HMS) monthly average rainfall and that measured with a tipping bucket rain gage at McGee Ranch during the same month.

Conventional irrigation deviate from natural rainfall patterns in some important ways. Depending on the frequency of water applications, the lag time between the period during which natural precipitation is recorded and the following catch-up irrigation session may force a seasonally artificial delay in plant growth and animal behavior responses. Applying water significantly out of synchrony with the phenology and seasonal behavior of plants and animals could confound interpretations of the effects of a wetter climate on the soil water balance. For example, water applied in July, to double the April average rainfall, might percolate past dead cheatgrass roots that in April would have returned it to the atmosphere. Water was applied at McGee Ranch as soon as possible the following month to minimize ecophysiological perturbations.

Simulation of seasonal rainfall distribution patterns and labor requirements were also considered in selecting the irrigation frequency. Daily, quarterly, or yearly watering, too far removed from natural rainfall distribution patterns, were not considered. Although a weekly or biweekly interval would come close to winter storm frequencies, as well as reduce the catch-up lag time, it would have been too labor intensive under FY 1987 funding levels. Monthly watering, more representative of summer storm frequencies, was feasible in FY 1987 and is consistent with the Barrier Development Program lysimeter experiments.

Irrigation rate (intensity) and daily timing are also important variables. Runoff will occur if irrigation rates exceed the saturated soil conductivity. Even the slightest runoff on a plot can result in nonuniform infiltration. Watering in the evening or early in the morning comes closer to simulating the surface energy balance of a cloudy, rainy day than watering at midday when the solar elevation, and thus insolation, are greatest. The gravel admix plots are irrigated early in the morning and, to prevent excessive runoff, the system is shut off at the first sign of ponding.

5.3.1 Monthly Irrigation Volume

The irrigation system became operable in late March. It was not used to double the April normal rainfall, however, until May because the total rainfall received at McGee Ranch in March was more than twice the normal. July rainfall at McGee Ranch was also more than twice the normal. The system was turned on briefly in August anyway, however, to reduce the balance remaining from June when the water delivery truck was in the shop for repairs. The HMS monthly normal precipitation, McGee Ranch tipping-bucket measurements, monthly balances needed to obtain twice the HMS normal, and the actual amount of water applied are shown in Table 5.4.

5.3.2 Irrigation Uniformity

Because this study is first a comparative experiment, and second a model validation experiment (lysimeter experiments will provide the principal model validation data), irrigation uniformity, both within and among plots, is perhaps the most critical irrigation control variable. A high variability among plots in the volume of water applied would increase the probability of Type-I error in the analysis. In other words, the hypothesis that gravel and vegetation have no effect on soil water content could be erroneously rejected in a situation where measured differences are actually attributable to non-uniform irrigation. An irrigation specialist was consulted before the McGee system was designed to attain as uniform a spray pattern as possible with conventional sprinklers.

Collection cans (vol = 3.76 liters) were set out on whole plots 1, 3, and 5 in a stratified random manner, on May 21, with the goal of estimating irrigation amount and variability. Two cans were positioned on each of the six

TABLE 5.4. McGee Ranch Precipitation, Irrigation Schedule, and Water Metered onto the Gravel Admix Field Plots

Month	HMS ^(a) Normal (mm)	McGee Rainfall (mm)	Irrigation Balance (mm)	Volume Needed (m ³)	Equivalent Time ^(b) (min)	Volume Applied ^(c) (m ³)	Time Elapsed (min)	Balance (m ³)
Jan	23.4	14.3						
Feb	15.2	4.9						
Mar	9.4	20.2	-1.4	-0.64	-2.5			
Apr	9.9	2.5	17.3	7.80	30.9	7.81	30.0	0.01
May	12.2	5.9	18.5	8.31	32.9	8.32	33.0	0.02
Jun	13.7	1.5	26.0	11.67	46.3	10.58	42.0	-1.12
Jul	3.8	9.9	-2.2	-1.01	-4.0	0.09	0.4	0.02
Aug	6.1	1.0	11.2	5.04	20.0	5.04	18.5	0.02
Sep	7.9							
Oct	14.2							
Nov	21.6							
Dec	22.6							

(a) Hanford Meteorological Station.

(b) Equivalent time to apply needed volume given a maximum sprinkler system output of 0.25 m³/min at ≥30 psi as measured on an in-line pressure gauge.

(c) Volume passing through in-line flow meter.

subplots composing a whole plot using randomly selected coordinates. The catch-up irrigation volume needed to double the April normal rainfall, as measured at the HMS, was 7.80 m^3 or 17.3 mm equivalent rainfall (Table 5.4). Table 5.5 gives collection can volumes in equivalent rainfall, whole plot means, and standard errors. The mean volume of water received over all plots was approximately 1 mm less than that measured through the flow meter, possibly because of spray evaporation or drift. Table 5.5 also shows that the variability among whole plots was not inordinately large. However, an undesirably high dispersion was measured within whole plots. Collection cans positioned close to plot perimeters consistently received one-fourth to one-half as much water as cans placed close to the center of a plot.

TABLE 5.5. Irrigation Collection Can Data, Mean Volume (mm water), and Standard Errors for Whole Plots

Plot Number(a)	Sample 1	Sample 2	$\bar{x}$	SE($\bar{x}$)
1A	6.4	20.5	15.8	4.1
B	23.5	15.3		
C	23.0	7.0		
D	19.6	7.3		
E	21.9	25.5		
F	9.5	9.8		
3A	21.5	14.6	17.3	2.9
B	22.3	23.5		
C	12.1	12.2		
D	8.3	13.7		
E	23.7	17.3		
F	21.3	17.7		
5A	8.7	11.8	15.8	3.5
B	21.6	15.7		
C	12.3	15.0		
D	13.5	8.5		
E	9.1	24.4		
F	26.5	22.3		
All Plots			16.3	2.0

(a) Treatment assignments are shown in Table 3.2.

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APPENDIX A

ANALYSIS OF VARIANCE MODELS AND TABLES

TABLE A.1. Full SSP ANOVA (Split-Split-Plot Analysis of Variance) Model for Tests of Gravel Admix, Vegetation and Irrigation Effects on Soil Water Storage and Evapotranspiration

Y_{ijkm}	=	$\mu + R_i + P_j + (RP)_{ij} + V_k + (RV)_{ik} + (PV)_{jk} + (RPV)_{ijk} + G_m + (RG)_{im} + (PG)_{jm} + (RPG)_{ijm} + (VG)_{km} + (RVG)_{ikm} + (PVG)_{jkm} + (RPVG)_{ijkm} + e(ijkm)$
Y_{ijkm}	=	Water storage or plant measurement taken on a plot that has assigned to it replication i, irrigation method j, revegetation method k and gravel volume m.
μ	=	Overall mean
R_i	=	Replication effect for level i, where i = 1, 2, 3
P_j	=	Irrigation effect for method j, where j = 1, 2
V_k	=	Revegetation effect for method k, where k = 1, 2
G_m	=	Gravel effect for volume m, where m = 1, 2, 3
$(PV)_{jk}$	=	Interaction effect of irrigation method j and vegetation method k
$(PG)_{jm}$	=	etc.

NOTATION USED FOR EXPECTED MEAN SQUARE (EMS)

σ_{RP}^2	=	Random error due to R x P interaction
ϕ_p	=	Component of EMS due to fixed effects of irrigation, P

In general,

σ_{factor}^2	=	Random error due to "factor"
ϕ_{factor}	=	Component of EMS due to fixed effects of "factor"

TABLE A.2. Full SSP ANOVA Table for Tests of Gravel Admix, Vegetation and Irrigation Effects on Soil Water Storage and Evapotranspiration

Effects	Source	Degrees of Freedom	ID Code	EMS Expected Mean Square	F-Test	(df ₁ ,df ₂)	F-Statistic 0.05 Level
Whole Plot	R _j	2	A	$\sigma_e^2 + 12\sigma_R^2$	A/E	(2,0)*	----
	P _j	1	P	$\sigma_e^2 + 6\sigma_{RP}^2 + 18\phi_P$	P/E1	(1,2)	18.5
	(RP) _{ij}	2	E1	$\sigma_e^2 + 6\sigma_{RP}^2$	E1/E	(2,0)*	----
Split-plot	V _k	1	V	$\sigma_e^2 + 6\sigma_{RV}^2 + 18\phi_V$	V/RV	(1,2)	18.5
	(RV) _{ik}	2	RV	$\sigma_e^2 + 6\sigma_{RV}^2$	RV/E	(2,0)	----
	(PV) _{jk}	1	PV	$\sigma_e^2 + 3\sigma_{RPV}^2 + 9\phi_{PV}$	PV/E2	(1,2)	18.5
	(RPV) _{ijk}	2	E2	$\sigma_e^2 + 3\sigma_{RPV}^2$	E2/E	(2,0)*	----

*Test cannot be computed.

TABLE A.2. (contd)

Effects	Source	Degrees of Freedom	ID Code	EMS Expected Mean Square	F-Test	(df ₁ ,df ₂)	F-Statistic 0.05 Level
Split-Split plot	G _m	2	G	$\sigma_e^2 + 4\sigma_{RG}^2 + 12\phi_G$	G/RG	(2,4)	6.94
	(RG) _{im}	4	RG	$\sigma_e^2 + 4\sigma_{RG}^2$	RG/E	(4,0)*	----
	(PG) _{jm}	2	PG	$\sigma_e^2 + 2\sigma_{RPG}^2 + 6\phi_{PG}$	PG/RPG	(2,4)	6.94
	(RPG) _{ijm}	4	RPG	$\sigma_e^2 + 2\sigma_{RPG}^2$	RPG/E	(4,0)*	----
	(VG) _{km}	2	VG	$\sigma_e^2 + 2\sigma_{RVG}^2 + 6\phi_{VG}$	VG/RVG	(2,4)	6.94
	(RVG) _{ikm}	4	RVG	$\sigma_e^2 + 2\sigma_{RVG}^2$	RVG/E	(4,0)*	----
	(PVG) _{jkm}	2	PVG	$\sigma_e^2 + \sigma_{RPVG}^2 + 3\phi_{PVG}$	PVG/RPVG	(2,4)	6.94
	(RPVG) _{ijkm}	4	RPVG	$\sigma_e^2 + \sigma_{RPVG}^2$	RPVG/E	(4,0)*	----
	e(ijkm)	0	E	σ_e^2 (not retrievable)	----	----	----

*Test cannot be computed.

TABLE A.3. Reduced SSP ANOVA Model for Tests of Gravel Admix Vegetation and Irrigation Effects on Soil Water Storage and Evapotranspiration

$$Y_{ijklm} = \mu + R_i + P_j + e(ij) + V_k + (PV)_{jk} + e(ijk) + G_m + (PG)_{jm} + (VG)_{km} + (PVG)_{jkm} + e(ijkm)$$

$e(ij)$ = Error for whole plot effects

$e(ijk)$ = Error for split-plot effects

$e(ijkm)$ = Error for split-split plot effects

(All other notation was previously defined in Table A-1.)

Effects	Source	Degrees of Freedom	ID Code	EMS Expected Mean Square	F-Test	(df ₁ ,df ₂)	F-Statistic 0.05 Level
Whole plot	R_i	2	A	$\sigma_e^2 + 3\sigma_2^2 + 6\sigma_1^2 + 12\sigma_R^2$	A/W	(2,2)	19.0
	P_j	1	P	$\sigma_e^2 + 3\sigma_2^2 + 6\sigma_1^2 + 18\phi_P$	P/W1	(1,2)	18.5
	$e(ij)$	2	W1	$\sigma_e^2 + 3\sigma_2^2 + 6\sigma_1^2$	W1/W	(2,4)	6.94
Split-plot	V_k	1	V	$\sigma_e^2 + 3\sigma_2^2 + 18\phi_V$	V/W2	(1,4)	7.71
	$(PV)_{jk}$	1	PV	$\sigma_e^2 + 3\sigma_2^2 + 9\phi_{PV}$	PV/W2	(1,4)	7.71
	$e(ijk)$	4	W2	$\sigma_e^2 + 3\sigma_2^2$	W2/W	(4,16)	3.01

TABLE A.3. (contd)

Effects	Source	Degrees of Freedom	ID Code	EMS Expected Mean Square	F-Test	(df ₁ ,df ₂)	F-Statistic 0.05 Level
Split-Split plot	G _m	2	G	$\sigma_e^2 + 12\phi_G$	G/W	(2,16)	3.63
	(PG) _{jm}	2	PG	$\sigma_e^2 + 6\phi_{PG}$	PG/W	(2,16)	3.63
	(VG) _{km}	2	VG	$\sigma_e^2 + 6\phi_{VG}$	VG/W	(2,16)	3.63
	(PVG) _{jkm}	2	PVG	$\sigma_e^2 + 3\phi_{PVG}$	PVG/W	(2,16)	3.63
	e(ijkm)	16	W	σ_e^2	----	----	----

TABLE A.4. Full SP ANOVA Model and Table for Testing Gravel Admix and Irrigation Effects on Plant Abundance (Notation defined in Table A.1.)

$$Y_{ijm} = \mu + R_i + P_j + (RP)_{ij} + G_m + (RG)_{im} + (PG)_{jm} + (RPG)_{ijm} + e(ijm)$$

Effects	Source	Degrees of Freedom	ID Code	EMS Expected Mean Square	F-Test	(df ₁ ,df ₂)	F-Statistic 0.05 Level
Whole Plot	R_i	2	A	$\sigma_e^2 + 6\sigma_R^2$	A/E	(2,0)*	----
	P_j	1	P	$\sigma_e^2 + 3\sigma_{RP}^2 + 9\phi_P$	P/E1	(1,2)	18.5
	$(RP)_{ij}$	2	E1	$\sigma_e^2 + 3\sigma_{RP}^2$	E1/E	(2,0)*	----
Split-plot	G_m	2	G	$\sigma_e^2 + 2\sigma_{RG}^2 + 6\phi_G$	G/RG	(2,4)	6.94
	$(RG)_{im}$	4	RG	$\sigma_e^2 + 2\sigma_{RG}^2$	RG/E	(4,0)*	----
	$(PG)_{jm}$	2	PG	$\sigma_e^2 + 1\sigma_{RPP}^2 + 3\phi_{PG}$	PG/RPG	(2,4)	6.94
	$(RPG)_{ijm}$	4	RPG	$\sigma_e^2 + 1\sigma_{RPG}^2$	RPG/E	(4,0)*	----
	$e(ijm)$	0	E	σ_e^2 (not retrievable)	----	----	----

*Test cannot be computed.

TABLE A.5. Reduced SP ANOVA Model and Table for Testing Gravel Admix and Irrigation Effects on Plant Abundance (Notation defined in Table A.1.)

$$Y_{ijm} = \mu + R_i + P_j + e(ij) + G_m + (PG)_{jm} + e(ijm)$$

$e(ij)$ = Error for whole plot effects

$e(ijm)$ = Error for split-plot effects

All other notation was previously defined in Table A-1.

Effects	Source	Degrees of Freedom	ID Code	EMS Expected Mean Square	F-Test	(df ₁ ,df ₂)	F-Statistic 0.05 Level
Whole plot	R_i	2	A	$\sigma_e^2 + 3\sigma_1^2 + 6\sigma_R^2$	A/W	(2,2)	19.0
	P_j	1	P	$\sigma_e^2 + 3\sigma_1^2 + 9\phi_P$	P/W1	(1,2)	18.5
	$e(ij)$	2	W1	$\sigma_e^2 + 3\sigma_1^2$	W1/W	(2,4)	6.94
Split-plot	G_m	2	G	$\sigma_e^2 + 6\phi_G$	G/W	(2,8)	4.46
	$(PG)_{jm}$	2	PG	$\sigma_e^2 + 3\phi_{PG}$	PG/W	(2,8)	4.46
	$e(ijm)$	8	W	σ_e^2	----	----	----

TABLE A.6. Full SSP ANOVA Model for Tests Involving Subsampling for Plant Abundance

$$Y_{ijklmq} = \mu + R_i + P_j + (RP)_{ij} + V_k + (RV)_{ik} + (PV)_{jk} + (RPV)_{ijk} + G_m + (RG)_{im} + (PG)_{jm} + (RPG)_{ijm} \\ + (VG)_{km} + (RVG)_{ikm} + (PVG)_{jkm} + (RPVG)_{ijkm} + e_{ijklm} + e_q(ijkm)$$

$\uparrow \quad \quad \quad \uparrow$
 $\quad \quad \quad e_{ijklmq} \quad \quad \quad$

Y_{ijklmq} = Water storage or plant measurement q taken on a plot that has assigned to it replication i , irrigation method j , revegetation method k and gravel volume m .

e_{ijklm} = Experimental error (not retrievable)

$e_q(ijkm)$ = Observational error

e_{ijklmq} = $e_{ijklm} + e_q(ijkm)$ (the combined errors are notationally simpler to use)

(All other notation defined in Table A-1)

TABLE A.7. Full SSP ANOVA Table for Tests Involving Subsampling for Plant Abundance

Effects	Source	Degrees of Freedom	ID Code	EMS Expected Mean Square	F-Test	(df ₁ ,df ₂)	F-Statistic 0.05 Level
Whole plot	R_i	2	A	$\sigma_e^2 + 12\sigma_R^2$	A/E	(2,D)	----
	P_j	1	P	$\sigma_e^2 + 6\sigma_{RP}^2 + 18\phi_P$	P/E1	(1,2)	18.5
	$(RP)_{ij}$	2	E1	$\sigma_e^2 + 6\sigma_{RP}^2$	E1/E	(2,D)	----
Split-plot	V_k	1	V	$\sigma_e^2 + 6\sigma_{RV}^2 + 18\phi_V$	V/RV	(1,2)	18.5
	$(RV)_{ik}$	2	RV	$\sigma_e^2 + 6\sigma_{RV}^2$	RV/E	(2,D)	----
	$(PV)_{jk}$	1	PV	$\sigma_e^2 + 3\sigma_{RPV}^2 + 9\phi_{PV}$	PV/E2	(1,2)	18.5
	$(RPV)_{ijk}$	2	E2	$\sigma_e^2 + 3\sigma_{RPV}^2$	E2/E	(2,D)	----

TABLE A.7. (contd)

Effects	Source	Degrees of Freedom	ID Code	EMS Expected Mean Square	F-Test	(df ₁ ,df ₂)	F-Statistic 0.05 Level
Split-Split plot	G _m	2	G	$\sigma_e^2 + 4\sigma_{RG}^2 + 12\phi_G$	G/RG	(2,4)	6.94
	(RG) _{im}	4	RG	$\sigma_e^2 + 4\sigma_{RG}^2$	RG/E	(4,0)	----
	(PG) _{jm}	2	PG	$\sigma_e^2 + 2\sigma_{RPG}^2 + 6\phi_{PG}$	PG/RPG	(2,4)	6.94
	(RPG) _{ijm}	4	RPG	$\sigma_e^2 + 2\sigma_{RPG}^2$	RPG/E	(4,D)	----
	(VG) _{km}	2	VG	$\sigma_e^2 + 2\sigma_{RVG}^2 + 6\phi_{VG}$	VG/RVG	(2,4)	6.94
	(RVG) _{ikm}	4	RVG	$\sigma_e^2 + 2\sigma_{RVG}^2$	RVG/E	(4,D)	----
	(PVG) _{jkm}	2	PVG	$\sigma_e^2 + \sigma_{RPVG}^2 + 3\phi_{PVG}$	PVG/RPVG	(2,4)	6.94
	(RPVG) _{ijkm}	4	RPVG	$\sigma_e^2 + \sigma_{RPVG}^2$	RPVG/E	(4,D)	----
	e _{ijklmq}	D=36(q-1)	E	σ_e^2	----	----	----

*Test cannot be computed.

APPENDIX B

GRAVIMETRIC WATER PROFILE CONTENT DATA

APPENDIX B

GRAVIMETRIC WATER PROFILE CONTENT DATA

TABLE B.1. Gravel Admix Experiment Gravimetric Water (dry weight) Profile Content Data For Surface and 15 Centimeter Samples.

Plot ¹ Number	0 cm				15 cm			
	Wet Wt.	Dry Wt.	Tare Wt.	H ₂ O(dw) ²	Wet wt.	Dry Wt.	Tare Wt.	H ₂ O(dw) ²
1A	230.9	217.5	44.5	0.078	157.8	152.7	45.5	0.048
1B	225.2	215.5	45.0	0.057	213.3	206.6	44.9	0.041
1C	204.7	193.5	45.7	0.076	224.1	218.5	45.5	0.032
1D	183.7	172.3	45.7	0.090	221.7	213.2	45.4	0.051
1E	224.4	210.2	43.9	0.085	203.5	195.2	45.6	0.056
1F	218.0	205.7	44.9	0.077	213.0	207.2	45.7	0.036
2A	246.5	236.1	45.7	0.055	219.8	214.1	43.4	0.033
2B	215.6	202.9	45.6	0.081	239.4	234.3	46.4	0.027
2C	209.7	195.7	45.5	0.093	218.2	210.1	45.6	0.049
2D	200.6	189.2	44.2	0.079	205.8	199.8	45.4	0.039
2E	208.8	197.2	45.4	0.076	221.4	211.5	45.0	0.060
2F	228.1	214.7	43.6	0.078	221.8	214.3	45.2	0.044
3A	276.2	257.2	44.7	0.089				
3B	216.7	198.5	44.5	0.118				
3C	191.4	178.3	45.0	0.098				
3D	198.8	186.6	45.2	0.086	205.8	201.2	44.9	0.029
3E	180.9	169.0	45.5	0.096	200.2	196.0	45.5	0.028
3F	199.7	186.3	45.3	0.095	167.1	162.7	44.5	0.037
4A	212.8	201.6	45.5	0.072	215.9	208.8	46.0	0.044
4B	223.1	210.5	43.0	0.075	211.2	205.5	45.0	0.036
4C	170.4	160.5	45.6	0.086	203.4	194.9	45.5	0.057
4D	248.8	237.1	44.9	0.061	236.6	232.1	45.9	0.024
4E	198.9	187.2	46.1	0.083	233.8	229.7	43.7	0.022
4F	230.7	219.5	45.0	0.064	162.4	158.0	45.5	0.039
5A	211.7	201.9	46.1	0.063	194.3	187.5	45.5	0.048
5B	204.9	193.7	45.4	0.076	214.6	207.8	43.5	0.041
5C	137.1	134.1	45.4	0.034	196.4	187.8	45.1	0.060
5D	236.6	225.7	44.3	0.060	203.8	194.6	45.7	0.062
5E	254.4	245.2	46.6	0.046	174.7	168.8	45.7	0.048
5F	218.7	207.2	44.9	0.071	222.0	213.8	45.0	0.049
6A	174.6	165.4	45.3	0.077	195.5	190.0	45.1	0.038
6B	230.6	219.8	45.5	0.062	225.5	218.4	43.4	0.041
6C	209.6	202.6	45.5	0.045	147.8	141.5	45.1	0.065
6D	216.0	205.1	45.6	0.068	204.4	199.0	45.1	0.035
6E	212.1	203.5	45.5	0.054	180.6	170.9	46.3	0.078
6F	169.6	161.8	43.3	0.066	200.3	193.5	43.7	0.045

1 Treatment assignments are given in Table 3.2.

2 Dry-weight water content = g water/g dry soil.

TABLE B.2. Gravel Admix Experiment Gravimetric Water Profile Content Data
30 and 45 Centimeter Samples.

Plot ¹ Number	30 cm				45 cm			
	Wet Wt.	Dry Wt.	Tare Wt.	H ₂ O(dw) ²	Wet wt.	Dry Wt.	Tare Wt.	H ₂ O(dw) ²
1A	222.0	215.3	45.6	0.040	178.3	172.0	45.5	0.050
1B	190.3	181.5	44.3	0.064	229.5	221.7	44.7	0.044
1C	210.7	201.5	45.3	0.059	222.3	213.9	45.4	0.050
1D	213.3	206.7	45.1	0.041	215.0	207.8	44.5	0.044
1E	207.3	198.5	44.7	0.057	196.8	187.4	45.6	0.066
1F	208.3	202.5	45.4	0.037	201.7	194.4	43.6	0.048
2A	220.0	213.8	46.3	0.037	206.4	199.4	45.3	0.045
2B	189.0	181.2	45.3	0.057	183.0	175.3	45.7	0.059
2C	230.9	222.7	45.7	0.046	211.2	202.9	46.2	0.053
2D	193.0	186.3	43.3	0.047	189.2	182.6	45.5	0.048
2E	196.2	188.7	45.0	0.052	194.7	187.9	45.2	0.048
2F	193.3	186.6	45.7	0.048	208.9	202.3	45.9	0.042
3A	166.8	160.8	45.0	0.052	172.8	167.8	44.9	0.041
3B	187.9	181.9	44.5	0.044	235.0	227.9	45.5	0.039
3C	240.6	235.1	45.4	0.029	243.0	236.5	45.2	0.034
3D	187.7	182.0	45.5	0.042	197.5	191.2	45.8	0.043
3E	174.1	170.2	46.1	0.031	187.7	182.1	43.6	0.040
3F	170.4	165.2	45.6	0.044	161.5	156.8	45.2	0.042
4A	172.3	166.5	45.6	0.048	196.2	190.9	45.9	0.037
4B	193.9	187.9	45.5	0.042	198.7	191.5	44.6	0.049
4C	222.8	214.8	45.3	0.047	211.2	205.0	46.1	0.039
4D	213.2	207.3	45.9	0.037	190.9	183.9	44.7	0.050
4E	211.7	205.8	44.7	0.037	191.0	185.3	45.1	0.041
4F	166.1	161.5	45.4	0.040	204.7	197.3	44.7	0.049
5A	218.7	211.7	45.4	0.042	188.2	181.2	45.6	0.052
5B	190.2	185.1	45.9	0.037	213.9	207.8	45.0	0.038
5C	216.3	208.5	45.5	0.048	233.7	226.0	45.0	0.043
5D	223.3	215.0	45.3	0.049	193.4	188.2	45.5	0.036
5E	216.5	209.8	44.9	0.041	207.6	201.0	45.3	0.042
5F	192.6	185.2	45.9	0.053	170.8	165.2	45.7	0.047
6A	152.4	147.9	45.5	0.044	217.0	208.6	46.4	0.052
6B	185.9	177.5	45.7	0.064	215.4	205.8	45.7	0.060
6C	168.8	163.1	46.4	0.049	208.9	200.5	42.4	0.053
6D	210.5	204.1	45.0	0.040	219.1	212.1	45.8	0.042
6E	215.9	207.6	43.3	0.051	206.6	199.4	44.9	0.047
6F	218.0	210.2	43.7	0.047	213.0	205.0	45.7	0.050

1 Treatment assignments are given in Table 3.2.

2 Dry-weight water content = g water/g dry soil.

TABLE B.3. Gravel Admix Experiment Gravimetric Water Profile Content Data For 80 and 125 Centimeter Samples.

Plot ¹ Number	80 cm				125 cm			
	Wet Wt.	Dry Wt.	Tare Wt.	H ₂ O(dw) ²	Wet wt.	Dry Wt.	Tare Wt.	H ₂ O(dw) ²
1A	202.6	195.8	44.9	0.045	204.1	196.5	44.9	0.050
1B	196.2	188.9	46.3	0.051	210.4	204.3	45.4	0.038
1C	202.5	193.8	44.6	0.058	206.6	195.4	45.6	0.075
1D	215.4	207.8	45.5	0.047	220.6	213.0	45.5	0.045
1E	197.5	189.8	45.5	0.053	206.8	200.6	45.3	0.040
1F	203.5	195.6	45.8	0.053	193.6	184.8	44.8	0.063
2A	170.6	163.8	44.8	0.057	199.6	192.2	44.8	0.050
2B	220.1	208.0	45.4	0.074	199.5	189.9	45.5	0.067
2C	219.1	211.9	44.8	0.043	189.0	178.9	45.7	0.076
2D	208.6	201.4	45.7	0.046	200.8	194.1	45.6	0.045
2E	178.4	172.0	44.9	0.050	198.0	190.2	45.2	0.054
2F	180.1	171.3	45.5	0.070	189.9	183.5	44.9	0.046
3A	200.8	193.3	45.4	0.051	200.7	194.2	44.9	0.044
3B	186.0	179.9	45.6	0.045	207.6	201.0	45.4	0.042
3C	191.6	185.1	45.1	0.046	194.6	189.3	45.5	0.037
3D	207.1	201.5	45.2	0.036	193.2	183.6	46.0	0.070
3E	200.0	193.9	45.0	0.041	172.9	168.7	45.2	0.034
3F	198.6	192.3	45.9	0.043	213.0	206.0	45.2	0.044
4A	214.7	207.2	45.1	0.046	186.2	179.4	45.0	0.051
4B	199.8	192.7	45.0	0.048	206.6	198.0	45.8	0.057
4C	198.9	191.4	45.2	0.051	188.3	182.3	45.0	0.044
4D	177.9	170.4	43.7	0.059	211.5	198.1	43.6	0.087
4E	210.8	203.2	45.6	0.048	199.5	191.9	44.8	0.052
4F	190.2	183.2	45.6	0.051	173.1	164.8	44.3	0.069
5A	176.0	169.8	44.9	0.050	193.8	188.9	45.8	0.034
5B	210.3	202.9	45.6	0.047	201.7	195.9	44.7	0.038
5C	211.5	206.2	44.7	0.033	180.7	172.4	44.7	0.065
5D	177.2	171.1	46.3	0.049	207.0	201.3	45.6	0.037
5E	213.9	207.0	45.8	0.043	188.2	182.3	43.8	0.043
5F	179.6	171.5	43.6	0.063	170.3	161.9	45.2	0.072
6A	196.8	191.5	44.8	0.036	165.0	158.1	45.3	0.061
6B	215.4	207.4	45.9	0.050	179.3	169.6	43.0	0.077
6C	235.7	228.9	45.1	0.037	178.0	169.1	45.4	0.072
6D	188.7	183.4	43.5	0.038	181.1	175.2	43.1	0.045
6E	191.3	186.8	45.6	0.032	196.8	190.0	45.3	0.047
6F	224.5	211.2	46.2	0.081	192.0	184.1	44.6	0.057

¹ Treatment assignments are given in Table 3.2.

² Dry-weight water content = g water/g dry soil.

TABLE B.4. Gravel Admix Experiment Gravimetric Water Profile Content Data For 175 and 225 Centimeter Samples.

Plot ¹ Number	175 cm				225 cm			
	Wet Wt.	Dry Wt.	Tare Wt.	H ₂ O(dw) ²	Wet wt.	Dry Wt.	Tare Wt.	H ₂ O(dw) ²
1A	196.0	186.2	45.5	0.070	199.4	177.2	46.6	0.170
1B	199.1	186.7	43.4	0.087	183.0	175.5	45.5	0.058
1C	170.6	156.9	45.5	0.123	190.5	183.5	45.7	0.051
1D	183.0	176.6	43.5	0.048	180.6	167.3	45.4	0.109
1E	183.5	171.2	44.7	0.097	204.8	184.1	45.9	0.150
1F	202.6	197.2	45.5	0.036	205.1	188.5	45.6	0.116
2A	190.5	182.2	42.4	0.059	215.5	192.2	45.1	0.158
2B	203.4	192.3	45.3	0.076	189.6	179.3	44.9	0.077
2C	189.2	183.2	45.1	0.043	177.6	172.6	44.5	0.039
2D	184.2	174.9	44.5	0.071	191.6	178.3	45.6	0.100
2E	201.0	188.2	46.0	0.090	185.8	175.4	44.5	0.079
2F	196.8	188.8	46.1	0.056	208.4	193.6	46.1	0.100
3A	207.6	201.0	45.3	0.042	210.6	198.4	45.6	0.080
3B	195.9	186.3	44.3	0.068	207.7	191.2	45.7	0.113
3C	168.3	160.8	45.0	0.065	165.2	157.1	43.3	0.071
3D	200.1	185.4	45.7	0.105	200.8	185.8	45.5	0.107
3E	167.8	162.2	46.1	0.048	192.7	175.2	45.7	0.135
3F	176.5	162.8	44.9	0.116	204.9	191.7	45.6	0.090
4A	170.7	160.5	46.4	0.089	190.4	183.5	45.5	0.050
4B	172.9	164.2	44.9	0.073	184.8	175.0	45.4	0.076
4C	179.0	170.8	45.5	0.065	178.9	166.9	43.1	0.097
4D	198.7	189.3	45.9	0.066	193.1	181.5	43.5	0.084
4E	189.1	182.1	45.6	0.051	201.8	190.3	45.7	0.080
4F	181.4	172.5	45.5	0.070	170.6	163.3	45.3	0.062
5A	187.4	177.7	45.0	0.073	197.1	185.6	44.9	0.082
5B	179.7	172.9	45.9	0.054	180.8	172.6	43.9	0.064
5C	182.2	178.9	45.4	0.025	171.7	164.7	45.5	0.059
5D	197.0	191.5	45.5	0.038	198.0	189.4	43.4	0.059
5E	206.2	196.5	45.6	0.064	204.5	193.2	45.5	0.077
5F	198.0	186.8	45.2	0.079	204.8	194.2	46.1	0.072
6A	175.4	170.8	45.3	0.037	176.8	171.3	45.5	0.044
6B	219.1	212.3	45.5	0.041	195.1	185.6	45.7	0.068
6C	165.1	159.8	45.6	0.046	202.4	192.9	44.2	0.064
6D	204.1	199.5	44.2	0.030	203.1	188.7	45.6	0.101
6E	152.4	147.2	45.6	0.051	155.1	150.2	43.6	0.046
6F	206.2	201.1	46.1	0.033	180.0	171.1	45.7	0.071

1 Treatment assignments are given in Table 3.2.

2 Dry-weight water content = g water/g dry soil.

TABLE B.5. Gravel Admix Experiment Gravimetric Water Profile Content Data
For 275 and 300 Centimeter Samples.

Plot ¹ Number	275 cm				300 cm			
	Wet Wt.	Dry Wt.	Tare Wt.	H ₂ O(dw) ²	Wet wt.	Dry Wt.	Tare Wt.	H ₂ O(dw) ²
1A	193.8	184.2	45.8	0.069	211.9	190.4	45.3	0.148
1B	177.4	169.1	44.2	0.067	197.6	178.2	45.9	0.147
1C	205.4	198.0	45.6	0.049	210.0	193.8	45.6	0.109
1D	214.2	205.1	45.7	0.057	213.9	194.8	45.0	0.128
1E	185.1	174.4	45.0	0.083	197.0	179.2	45.5	0.133
1F	171.2	165.8	44.8	0.045	189.2	169.6	45.0	0.157
2A	206.5	189.3	45.4	0.120	161.9	146.3	43.6	0.152
2B	168.5	163.1	45.7	0.046	158.1	145.0	45.8	0.132
2C	203.1	183.0	45.8	0.147	193.4	174.6	45.5	0.146
2D	186.7	179.8	44.9	0.051	185.2	169.5	45.4	0.127
2E	205.8	185.2	45.6	0.148	193.0	182.5	45.5	0.077
2F	215.3	203.5	43.8	0.074	246.4	214.2	45.7	0.191
3A	203.7	190.7	44.2	0.089				
3B	221.0	209.6	46.3	0.070	218.6	199.1	45.4	0.127
3C	216.9	201.8	45.5	0.097	211.6	188.8	45.6	0.159
3D	185.5	177.9	43.8	0.057	203.9	178.3	43.5	0.190
3E	184.7	177.4	45.8	0.056	200.1	181.8	45.5	0.134
3F	234.5	199.5	46.6	0.229	208.8	177.7	44.9	0.234
4A	205.4	187.5	45.5	0.126	185.8	180.4	45.3	0.040
4B	173.3	164.2	44.2	0.076	188.8	175.5	45.6	0.102
4C	170.8	165.2	43.3	0.046	211.2	199.5	44.2	0.075
4D	200.7	182.8	45.3	0.130	204.5	183.2	43.9	0.153
4E	167.2	160.8	45.6	0.056	199.7	189.4	45.5	0.072
4F	180.6	168.9	45.1	0.095	182.7	177.3	46.3	0.041
5A	200.0	181.2	45.5	0.139	165.4	158.6	44.5	0.060
5B	192.0	180.6	45.6	0.084	178.8	167.1	44.5	0.095
5C	155.9	145.7	45.6	0.102	180.6	172.2	45.5	0.066
5D	195.7	185.4	45.3	0.074	192.0	179.2	45.6	0.096
5E	220.7	209.6	46.0	0.068	220.5	209.8	46.1	0.065
5F	199.6	183.5	45.5	0.117	175.8	165.7	45.5	0.084
6A	171.4	149.7	45.8	0.209	162.3	157.2	44.5	0.045
6B	215.6	191.9	45.6	0.162	191.1	184.9	45.4	0.044
6C	162.3	157.5	45.8	0.043	176.3	169.1	44.9	0.058
6D	179.8	166.5	46.0	0.110	193.8	170.8	45.3	0.183
6E	200.5	176.6	44.8	0.181	191.8	184.6	45.5	0.052
6F	187.1	171.6	45.9	0.123	169.8	160.4	45.9	0.082

1 Treatment assignments are given in Table 3.2.

2 Dry-weight water content = g water/g dry soil.

APPENDIX C

HYDROPROBE CALIBRATION DATA

APPENDIX C

HYDROPROBE CALIBRATION DATA

TABLE C.1. Count Ratios (counts/30 seconds) and Volumetric Moisture Estimates for Soils Sampled at Depths of 30, 45, 80, and 125 Centimeters During Installation of Hydroprobe Ports.

Plot Number ¹	30 cm		45 cm		80 cm		125 cm	
	Count Ratio	Water (% Vol)	Count Ratio	Water (% Vol)	Count Ratio	Water (% Vol)	Count Ratio	Water (% Vol)
1A	0.256	5.14	0.284	6.47	0.264	5.86	0.328	6.51
1B	0.310	8.33	0.287	5.73	0.292	6.66	0.334	4.99
1C	0.290	7.66	0.304	6.49	0.350	7.58	0.414	9.72
1D	0.270	5.30	0.286	5.73	0.317	6.08	0.323	5.90
1E	0.340	7.44	0.355	8.62	0.346	6.94	0.331	5.19
1F	0.259	4.80	0.286	6.29	0.298	6.85	0.330	8.18
2A	0.302	4.81	0.301	5.90	0.342	7.42	0.305	6.53
2B	0.315	7.46	0.372	7.72	0.457	9.67	0.440	8.65
2C	0.317	6.02	0.319	6.89	0.334	5.60	0.456	9.85
2D	0.276	6.10	0.283	6.25	0.317	6.01	0.314	5.86
2E	0.305	6.79	0.319	6.20	0.331	6.55	0.411	6.99
2F	0.301	6.19	0.280	5.49	0.367	9.10	0.329	6.01
3A	0.287	6.73	0.266	5.29	0.326	6.59	0.332	5.66
3B	0.268	5.68	0.264	5.06	0.321	5.90	0.333	5.51
3C	0.249	3.77	0.268	4.42	0.268	6.03	0.278	4.80
3D	0.269	5.43	0.270	5.63	0.286	4.65	0.377	9.07
3E	0.252	4.08	0.280	5.25	0.314	5.33	0.411	4.42
3F	0.295	5.66	0.285	5.47	0.282	5.59	0.324	5.66
4A	0.288	6.24	0.276	4.76	0.319	6.02	0.343	6.58
4B	0.291	5.47	0.327	6.37	0.317	6.25	0.389	7.35
4C	0.307	6.14	0.304	5.07	0.344	6.67	0.340	5.68
4D	0.264	4.76	0.295	6.54	0.318	7.70	0.444	11.27
4E	0.255	4.76	0.285	5.29	0.320	6.27	0.326	6.72
4F	0.261	5.15	0.279	6.31	0.305	6.62	0.343	8.96
5A	0.308	5.47	0.300	6.71	0.323	6.45	0.325	4.45
5B	0.263	4.76	0.277	4.88	0.298	6.11	0.342	4.99
5C	0.304	6.23	0.290	5.53	0.287	4.26	0.376	8.45
5D	0.305	6.36	0.264	4.73	0.288	6.36	0.309	4.76
5E	0.286	5.28	0.284	5.51	0.285	5.56	0.437	5.54
5F	0.280	6.90	0.288	6.10	0.343	8.23	0.367	9.36
6A	0.307	5.71	0.331	6.73	0.341	4.69	0.418	7.96
6B	0.320	8.28	0.317	7.80	0.279	6.44	0.381	9.96
6C	0.292	6.34	0.304	6.90	0.260	4.81	0.391	9.35
6D	0.249	5.23	0.290	5.47	0.288	4.93	0.315	5.81
6E	0.300	6.57	0.282	6.06	0.265	4.15	0.303	6.11
6F	0.301	6.08	0.325	6.53	0.364	10.48	0.447	7.36

¹ Treatment assignments are given in Table 3.2.

TABLE C.2. Count Ratios and Volumetric Moisture Estimates for Soils Sampled at Depths of 175, 225 and 275 Centimeters During Installation of Hydroprobe Ports.

Plot Number ¹	175 cm		225 cm		275 cm	
	Count Ratio	Water (% Vol)	Count Ratio	Water (% Vol)	Count Ratio	Water (% Vol)
1A	0.423	9.06	0.616	22.10	0.448	9.02
1B	0.443	11.25	0.624	7.50	0.491	8.65
1C	0.537	15.99	0.624	6.60	0.413	6.32
1D	0.330	6.25	0.620	14.18	0.459	7.42
1E	0.431	12.64	0.743	19.47	0.514	10.75
1F	0.363	4.63	0.672	15.11	0.465	5.80
2A	0.395	7.72	0.937	20.59	0.759	15.54
2B	0.432	9.82	0.592	9.96	0.490	5.98
2C	0.322	5.64	0.377	5.07	0.748	19.05
2D	0.437	9.27	0.477	13.03	0.471	6.64
2E	0.534	11.70	0.664	10.32	0.806	19.19
2F	0.445	7.29	0.662	13.04	0.615	9.61
3A	0.373	5.51	0.735	10.37	0.656	11.53
3B	0.450	8.79	0.502	14.74	0.651	9.07
3C	0.405	8.42	0.591	9.26	0.522	12.56
3D	0.550	13.68	0.596	13.90	0.428	7.37
3E	0.451	6.27	0.820	17.56	0.608	7.22
3F	0.585	15.11	0.543	11.74	0.847	29.76
4A	0.428	11.62	0.472	6.50	0.674	16.39
4B	0.412	9.48	0.441	9.83	0.496	9.85
4C	0.443	8.50	0.499	12.60	0.421	5.97
4D	0.464	8.53	0.510	10.93	0.757	16.93
4E	0.353	6.67	0.475	10.34	0.401	7.23
4F	0.384	9.11	0.486	8.05	0.572	12.29
5A	0.396	9.50	0.558	10.62	0.734	18.01
5B	0.337	6.96	0.480	8.28	0.494	10.97
5C	0.250	3.21	0.346	7.63	0.596	13.25
5D	0.295	4.90	0.367	7.66	0.478	9.56
5E	0.368	8.36	0.463	9.95	0.572	8.81
5F	0.403	10.28	0.492	9.31	0.643	15.17
6A	0.328	4.77	0.449	5.68	0.921	27.16
6B	0.331	5.30	0.506	8.83	0.927	21.06
6C	0.317	6.03	0.504	8.31	0.960	5.59
6D	0.276	3.85	0.467	13.08	0.846	14.35
6E	0.333	6.66	0.582	5.98	0.802	23.57
6F	0.450	4.28	0.521	9.23	0.831	16.03

¹ Treatment assignments are given in Table 3.2.

APPENDIX D

MONTHLY VOLUMETRIC MOISTURE DATA OERIVED FROM HYDROPROBE
COUNT RATIOS

APPENDIX D

MONTHLY VOLUMETRIC MOISTURE DATA DERIVED FROM HYDROPROBECOUNT RATIOSTABLE D.1. Percent Volumetric Moisture in Gravel Admix Experiment Soil Profiles for November 4, 1986.

Plot Number ¹	Depth (cm)						
	30	45	80	125	175	225	275
1A	5.3	5.5	5.7	6.8	9.0	13.4	10.0
1B	6.2	5.5	5.8	6.6	9.3	12.7	10.3
1C	6.0	5.8	7.4	8.6	11.7	13.7	8.3
1D	5.3	5.7	6.3	5.9	6.4	12.8	9.0
1E	6.4	7.0	6.9	6.4	8.9	15.8	10.3
1F	5.1	5.7	5.9	6.5	7.9	14.1	9.7
2A	5.5	5.6	6.8	5.9	7.8	19.7	15.3
2B	6.6	7.3	8.7	8.6	9.1	11.9	9.8
2C	6.1	6.0	6.7	8.9	6.5	7.7	15.8
2D	5.1	5.4	6.2	6.5	9.0	10.0	9.6
2E	6.1	6.3	7.1	8.6	11.1	13.1	16.7
2F	5.8	5.5	7.5	6.6	9.4	14.7	13.6
3A	5.2	5.2	6.4	6.6	8.1	15.3	15.7
3B	4.9	5.0	6.5	6.6	9.5	10.0	13.2
3C	4.6	4.9	5.0	5.0	8.3	12.2	10.7
3D	5.0	5.2	5.5	7.4	10.9	12.2	8.9
3E	4.8	5.2	6.2	8.0	9.0	17.2	12.6
3F	5.8	5.6	5.8	6.1	12.4	11.5	17.7
4A	5.7	5.4	6.2	6.8	9.0	9.6	14.3
4B	5.7	6.1	6.2	7.8	8.5	9.4	10.3
4C	5.8	5.8	6.8	6.6	9.0	10.2	8.9
4D	5.2	5.5	6.3	9.4	9.4	10.6	16.2
4E	5.0	5.2	6.2	6.2	7.0	10.0	7.9
4F	5.1	5.4	6.0	6.8	7.5	10.0	11.5
5A	6.0	5.9	6.5	6.7	8.0	11.3	15.3
5B	5.2	5.0	5.7	6.8	6.6	9.5	10.0
5C	6.0	5.5	5.8	7.9	5.3	7.0	12.7
5D	5.9	5.1	5.6	6.2	5.6	7.6	9.4
5E	5.4	5.4	5.6	8.4	7.7	9.6	11.6
5F	5.6	5.4	6.9	7.6	8.4	10.5	13.4
6A	6.5	6.6	6.8	8.4	6.5	9.3	19.7
6B	6.2	6.2	5.9	7.3	6.6	10.6	19.0
6C	5.7	5.7	5.2	7.7	6.1	10.5	20.2
6D	4.8	5.2	5.4	6.0	5.5	9.9	18.1
6E	5.6	5.4	5.2	5.8	6.4	11.7	17.0
6F	6.1	6.7	6.9	9.2	9.2	11.1	17.0

¹ Treatment assignments are given in Table 3.2.

TABLE D.2. Percent Volumetric Moisture in Gravel Admix Experiment Soil Profiles for December 3, 1986.

Plot Number ¹	Depth (cm)						
	30	45	80	125	175	225	275
1A	5.4	5.5	6.1	6.6	9.3	13.7	9.9
1B	6.4	5.5	5.7	6.2	9.6	12.4	10.1
1C	5.9	5.7	7.3	8.6	11.4	13.2	8.2
1D	5.5	5.4	6.2	6.1	6.5	12.7	9.1
1E	6.9	6.7	7.3	6.4	9.1	15.4	10.4
1F	5.1	5.6	5.8	6.9	7.7	14.0	9.3
2A	5.8	5.7	6.9	5.8	7.6	18.9	15.2
2B	7.0	7.5	8.7	8.6	8.5	12.0	9.9
2C	6.2	6.2	6.9	8.6	6.6	7.2	15.3
2D	5.3	5.2	6.3	6.3	8.9	10.0	9.2
2E	6.1	6.3	7.1	8.5	10.8	13.4	16.8
2F	6.0	5.5	7.5	6.7	9.5	14.7	13.2
3A	5.7	5.0	6.4	6.9	7.7	15.3	13.6
3B	5.0	5.0	6.2	6.4	9.5	10.0	13.1
3C	4.5	4.8	5.1	5.2	8.5	11.7	10.4
3D	5.3	5.0	5.4	7.4	10.7	11.9	8.3
3E	5.0	5.2	6.4	8.5	9.0	16.9	12.8
3F	5.6	5.2	5.6	6.0	12.4	11.0	17.7
4A	5.7	5.2	6.2	7.0	8.7	9.1	14.1
4B	6.1	6.1	6.3	7.8	8.3	9.3	10.4
4C	5.9	4.5	6.8	6.3	9.0	9.9	8.8
4D	5.2	5.5	6.3	8.9	9.8	10.6	16.1
4E	5.1	5.3	6.8	6.5	6.9	10.0	7.9
4F	5.2	5.4	5.8	7.1	7.7	9.7	11.7
5A	6.1	5.7	6.4	6.6	8.3	10.9	15.4
5B	5.0	5.2	5.9	6.6	6.6	9.7	9.9
5C	6.1	5.4	5.8	7.3	5.0	6.8	12.1
5D	6.0	5.1	5.5	6.1	5.9	7.9	9.6
5E	5.6	5.3	6.0	8.6	7.6	9.4	11.7
5F	5.7	5.3	6.9	7.4	8.4	10.1	13.3
6A	6.1	6.5	6.9	8.6	6.4	9.2	19.5
6B	6.4	6.2	5.6	7.5	6.5	10.3	19.1
6C	5.8	5.6	5.0	7.9	6.3	10.2	20.1
6D	4.9	5.4	5.3	6.1	5.3	10.0	18.0
6E	6.1	5.4	5.1	5.9	6.2	12.0	16.9
6F	6.2	6.5	7.2	9.0	9.0	10.7	17.1

¹ Treatment assignments are given in Table 3.2.

TABLE D.3. Percent Volumetric Moisture in Gravel Admix Experiment Soil Profiles for January 9, 1987.

Plot Number ¹	Depth (cm)						
	30	45	80	125	175	225	275
1A	8.9	5.9	5.8	7.1	9.4	13.5	9.9
1B	11.4	6.5	5.7	6.6	8.9	11.9	9.9
1C	8.4	6.1	7.4	8.6	11.6	13.1	8.4
1D	9.5	6.0	6.1	6.0	6.8	12.6	8.9
1E	11.0	7.3	6.7	6.7	9.8	15.5	10.2
1F	8.5	5.7	5.8	6.7	7.6	13.8	9.6
2A	9.4	6.3	6.5	5.9	7.9	19.2	15.9
2B	10.4	7.6	8.7	8.4	8.8	11.9	9.4
2C	8.3	6.2	7.0	8.4	6.8	7.1	15.3
2D	7.1	5.4	6.9	6.5	9.1	9.3	9.2
2E	9.0	6.6	7.1	8.7	10.8	13.7	17.3
2F	11.3	6.1	7.6	6.5	8.6	14.9	13.6
3A	10.4	5.4	6.5	6.7	7.9	15.5	13.4
3B	7.8	5.1	6.3	6.7	9.4	10.2	12.9
3C	7.6	5.1	5.1	5.1	8.7	12.3	10.7
3D	9.5	5.5	5.7	7.6	10.4	11.9	8.1
3E	7.5	5.6	6.6	8.2	8.7	17.4	12.7
3F	8.9	5.6	5.7	6.4	13.1	11.5	17.5
4A	9.1	5.5	6.4	7.1	9.0	9.7	13.6
4B	10.3	6.6	6.3	8.0	8.2	9.6	10.3
4C	8.2	6.3	7.0	6.5	8.7	10.0	8.6
4D	9.7	6.2	6.4	9.1	9.4	10.4	15.8
4E	8.5	5.5	6.4	6.1	6.6	10.1	7.7
4F	11.3	6.4	5.9	7.1	7.8	9.8	11.5
5A	9.9	6.0	6.4	6.5	8.2	11.2	14.7
5B	8.8	5.3	5.7	6.7	6.8	9.4	9.6
5C	9.4	5.7	5.9	7.4	5.2	7.4	12.4
5D	10.3	5.3	5.7	6.2	5.9	7.3	9.3
5E	9.9	5.7	5.7	8.5	8.0	9.3	11.7
5F	8.8	5.5	6.9	7.3	8.0	10.2	12.9
6A	8.6	6.7	7.1	8.6	6.6	9.4	19.2
6B	11.1	6.9	5.6	7.2	6.4	10.4	18.5
6C	10.0	6.0	5.2	7.5	6.4	10.5	19.5
6D	7.5	5.5	5.7	5.9	5.6	10.2	17.8
6E	10.2	5.8	5.2	5.6	6.2	12.1	17.1
6F	9.3	6.7	7.4	9.3	9.1	10.8	16.6

¹ Treatment assignments are given in Table 3.2.

TABLE D.4. Percent Volumetric Moisture in Gravel Admix Experiment Soil Profiles for February 12, 1987.

Plot Number ¹	Depth (cm)						
	30	45	80	125	175	225	275
1A	10.5	6.8	6.1	7.0	9.2	13.7	10.1
1B	13.5	8.3	5.7	6.8	9.2	13.0	9.8
1C	10.9	6.8	7.4	8.9	11.1	13.0	8.3
1D	11.7	6.9	6.3	6.3	7.2	12.4	9.1
1E	12.5	8.7	6.8	6.4	9.8	15.8	12.2
1F	10.8	7.3	5.9	6.7	8.2	13.9	9.7
2A	11.3	6.8	6.9	5.6	8.0	19.3	15.7
2B	13.4	9.0	8.9	8.9	8.7	11.9	9.6
2C	10.5	6.6	7.1	8.6	7.1	7.4	15.0
2D	9.0	5.7	6.7	6.5	9.4	9.4	8.9
2E	11.4	7.5	7.1	8.9	10.9	13.4	16.9
2F	12.7	6.6	7.5	6.7	9.6	15.0	14.6
3A	11.6	5.9	6.2	6.8	8.5	15.4	13.6
3B	9.3	5.1	6.3	6.5	9.7	10.1	13.0
3C	9.7	5.6	5.4	5.5	9.0	12.0	11.8
3D	10.6	6.0	5.4	7.7	10.2	11.8	8.1
3E	9.7	5.9	6.9	8.5	8.6	16.9	12.3
3F	11.3	5.9	5.9	6.2	13.7	11.8	18.2
4A	11.1	6.3	6.2	6.9	9.2	9.6	13.6
4B	13.2	8.0	6.6	7.9	8.5	9.7	9.9
4C	11.3	6.8	7.0	6.5	8.6	10.4	8.7
4D	11.5	7.7	6.2	9.6	9.4	10.8	16.4
4E	10.5	6.8	6.3	6.2	6.7	10.3	7.5
4F	13.4	8.0	6.0	7.2	7.5	10.1	10.9
5A	12.0	6.9	6.4	6.6	8.9	11.2	14.5
5B	10.7	6.0	5.5	7.0	7.0	9.5	9.6
5C	11.2	6.4	6.1	7.3	5.0	7.4	12.3
5D	11.9	5.6	5.7	6.0	6.3	7.7	9.3
5E	12.3	6.8	5.8	8.5	7.9	9.8	11.6
5F	11.2	6.5	6.8	7.4	8.5	9.6	12.7
6A	10.3	6.9	7.0	8.8	6.9	9.8	18.5
6B	13.6	7.7	5.8	7.3	6.7	10.6	18.4
6C	11.9	6.8	5.3	7.3	6.2	10.8	18.7
6D	9.6	6.3	5.6	6.0	5.7	10.3	17.7
6E	12.1	7.3	4.8	5.8	6.1	12.4	17.3
6F	9.8	7.8	7.4	9.6	9.5	11.5	16.5

¹ Treatment assignments are given in Table 3.2.

TABLE D.5. Percent Volumetric Moisture in Gravel Admix Experiment Soil Profiles for March 11, 1987.

Plot Number ¹	Depth (cm)						
	30	45	80	125	175	225	275
1A	10.2	7.5	6.1	7.2	9.5	13.9	9.8
1B	12.1	8.0	5.7	7.2	8.9	13.5	10.0
1C	11.1	7.4	7.3	8.7	11.8	12.9	8.2
1D	11.5	8.0	6.3	5.9	6.8	12.2	9.2
1E	11.9	10.1	6.9	6.6	9.9	16.2	10.0
1F	10.4	8.1	5.7	6.8	8.5	14.1	10.1
2A	10.6	7.3	6.9	5.7	8.0	19.9	16.2
2B	12.7	10.0	8.7	8.9	8.3	12.0	9.9
2C	10.3	6.9	7.2	8.3	7.1	7.5	15.1
2D	9.2	6.0	6.6	6.4	9.7	9.7	9.1
2E	11.3	8.7	7.2	8.9	10.7	13.7	17.1
2F	11.5	7.0	7.3	6.4	9.7	15.4	14.2
3A	11.3	6.2	6.7	6.9	8.3	15.7	13.6
3B	8.9	5.5	6.6	6.9	9.7	9.7	12.7
3C	9.3	5.9	5.3	5.2	9.5	12.7	11.9
3D	10.1	6.3	5.7	7.8	10.0	11.6	8.5
3E	9.9	6.7	6.5	8.5	8.3	17.6	12.6
3F	10.4	6.5	5.6	6.4	14.5	12.4	18.0
4A	10.7	6.7	6.2	7.5	9.4	9.8	13.5
4B	12.2	8.7	6.3	8.2	8.5	10.1	9.5
4C	11.0	7.1	6.8	6.3	8.5	10.2	13.4
4D	11.3	8.7	6.4	9.5	9.7	11.1	16.3
4E	10.8	8.0	6.2	6.0	6.4	10.7	7.5
4F	12.5	8.2	6.0	6.9	7.8	9.9	10.8
5A	11.2	7.4	6.6	6.6	9.4	11.3	14.3
5B	10.6	6.5	5.8	6.9	6.9	9.8	9.3
5C	11.2	7.4	6.2	7.2	5.4	7.7	12.7
5D	11.3	5.9	5.7	6.3	6.3	7.7	8.9
5E	11.5	7.3	5.9	8.7	8.2	9.8	11.6
5F	10.8	7.1	6.8	7.2	8.7	9.6	12.5
6A	10.1	7.7	7.0	9.2	7.0	10.1	18.3
6B	12.3	8.6	5.7	6.9	6.7	10.9	18.3
6C	11.4	7.9	5.2	7.1	6.8	11.1	18.5
6D	9.3	6.7	5.5	6.0	5.7	10.3	17.8
6E	12.4	8.6	5.1	5.7	6.4	12.8	17.4
6F	11.5	8.9	7.5	9.6	9.9	12.0	16.5

¹ Treatment assignments are given in Table 3.2.

TABLE D.6. Percent Volumetric Moisture in Gravel Admix Experiment Soil Profiles for April 9, 1987.

Plot Number ¹	Depth (cm)						
	30	45	80	125	175	225	275
1A	10.0	8.4	6.1	7.0	9.3	13.5	9.9
1B	12.0	8.7	5.9	7.2	8.7	13.5	9.6
1C	10.8	7.8	7.5	8.8	11.8	13.4	8.8
1D	12.4	8.9	6.2	6.2	6.9	12.1	9.6
1E	12.5	11.1	7.1	6.9	10.1	16.5	9.7
1F	10.7	9.6	5.8	6.9	8.4	14.3	10.4
2A	9.9	8.0	6.6	6.0	8.1	20.3	16.6
2B	11.7	10.6	8.7	9.1	8.7	11.9	9.6
2C	10.2	7.7	7.4	8.3	7.5	7.8	15.1
2D	9.8	6.3	6.7	6.5	10.0	9.5	8.8
2E	12.2	9.4	7.1	9.1	10.9	14.2	17.3
2F	11.7	7.8	7.8	6.2	10.1	15.6	14.7
3A	12.6	6.7	6.6	7.1	8.7	16.1	13.8
3B	9.4	6.3	6.3	6.9	9.9	9.8	12.6
3C	9.3	6.7	5.1	5.2	9.8	13.1	12.2
3D	9.6	6.9	5.4	8.0	10.2	11.6	8.2
3E	10.1	7.8	6.5	9.0	8.1	17.8	12.5
3F	10.0	6.7	5.9	6.6	14.9	12.9	18.2
4A	11.3	7.3	6.2	7.3	9.4	9.9	13.1
4B	11.2	10.0	6.5	8.1	8.5	10.1	9.7
4C	10.0	7.6	6.7	6.5	8.5	10.4	9.1
4D	11.6	10.7	6.2	9.4	9.8	11.0	16.6
4E	11.9	9.4	6.4	6.4	6.6	10.3	7.4
4F	13.2	9.1	6.0	6.8	7.9	10.3	10.8
5A	11.7	8.8	6.4	6.8	9.4	11.3	14.3
5B	10.9	7.3	6.0	6.9	7.2	9.3	9.2
5C	12.4	8.4	6.1	7.0	5.3	7.8	13.0
5D	11.4	6.4	5.6	6.3	6.4	7.6	9.1
5E	10.3	8.4	6.0	8.7	8.4	9.6	11.5
5F	11.5	7.6	7.0	7.2	8.7	9.4	12.5
6A	9.4	8.4	7.1	9.2	7.1	10.6	17.8
6B	12.2	9.6	5.8	7.0	6.7	11.1	17.7
6C	11.6	9.5	5.5	7.2	6.5	11.7	18.7
6D	10.0	8.0	5.5	5.9	5.9	10.7	18.4
6E	13.4	10.3	5.0	5.7	6.2	13.0	17.5
6F	12.7	10.4	7.8	9.8	10.0	12.6	16.1

¹ Treatment assignments are given in Table 3.2.

TABLE D.7. Percent Volumetric Moisture in Gravel Admix Experiment Soil Profiles for May 11, 1987.

Plot Number ¹	Depth (cm)						
	30	45	80	125	175	225	275
1A	6.9	7.4	6.3	7.3	9.8	13.4	9.6
1B	8.6	7.3	5.9	7.0	9.0	13.9	9.9
1C	7.0	6.3	7.4	9.4	11.8	13.3	9.3
1D	11.0	9.2	6.2	6.4	7.2	12.2	9.5
1E	11.2	10.7	7.4	6.9	10.0	16.6	9.8
1F	9.3	9.1	6.0	6.7	8.8	14.6	10.8
2A	6.5	6.7	7.2	5.9	8.3	20.6	17.0
2B	7.4	8.5	9.1	9.3	8.7	11.9	10.5
2C	7.5	7.2	7.4	8.5	7.8	8.1	15.0
2D	9.2	6.5	6.6	6.7	10.6	9.4	9.1
2E	11.1	9.4	7.4	9.3	11.0	14.3	18.1
2F	10.1	7.9	7.5	6.2	10.3	16.3	15.4
3A	10.6	7.0	6.7	7.2	9.0	16.6	13.9
3B	8.6	6.4	6.6	7.0	9.9	9.9	12.8
3C	8.1	6.8	5.2	5.2	10.3	13.6	12.7
3D	7.0	6.4	5.5	7.8	10.0	11.6	8.7
3E	6.5	6.9	6.9	9.3	8.2	18.0	13.6
3F	6.9	6.4	6.1	6.6	15.2	13.7	18.6
4A	7.7	6.7	6.7	7.9	9.8	10.4	13.2
4B	7.2	7.7	6.7	8.4	8.5	10.7	9.8
4C	6.7	7.2	7.1	6.4	8.6	10.5	8.9
4D	10.6	10.4	6.6	10.1	9.8	11.3	16.8
4E	10.4	8.9	6.6	5.9	6.7	11.0	7.5
4F	11.0	9.0	6.1	7.0	8.0	10.7	10.3
5A	10.4	8.5	6.7	7.0	10.1	11.5	13.8
5B	9.4	7.5	7.6	8.2	7.4	9.8	9.2
5C	11.4	8.4	6.1	7.1	5.4	8.2	13.5
5D	8.3	6.2	5.8	6.7	6.3	7.6	9.0
5E	6.9	7.0	6.1	8.7	8.8	10.0	11.6
5F	8.0	6.8	7.3	7.3	8.7	9.5	12.4
6A	6.3	6.6	7.3	9.4	7.6	11.5	17.8
6B	8.2	7.7	5.9	6.7	7.1	12.0	17.9
6C	8.1	7.9	5.6	7.1	7.1	12.4	18.0
6D	9.0	8.4	5.7	6.2	6.1	10.8	18.3
6E	11.6	10.2	5.4	5.6	6.5	13.8	17.1
6F	11.7	11.1	7.6	9.7	10.6	13.4	16.3

¹ Treatment assignments are given in Table 3.2.

TABLE D.8. Percent Volumetric Moisture in Gravel Admix Experiment Soil Profiles for June 16, 1987.

Plot Number ¹	Depth (cm)					
	30	45	80	125	175	275
1A	6.9	6.5	6.5	7.4	9.6	13.9
1B	7.3	6.6	5.6	7.3	8.6	14.2
1C	6.0	5.9	7.6	9.6	11.3	13.4
1D	9.9	8.9	6.7	6.1	6.8	11.8
1E	10.4	9.9	7.3	7.1	10.1	16.3
1F	8.9	8.7	5.9	6.7	9.3	14.7
2A	5.8	6.2	7.0	5.7	8.4	20.6
2B	6.9	7.3	9.4	9.4	8.3	12.0
2C	7.0	6.5	7.5	8.4	8.0	8.0
2D	8.7	6.7	6.9	6.6	10.6	9.2
2E	10.1	8.9	7.8	9.6	10.9	14.2
2F	9.0	7.5	7.9	6.0	11.0	16.6
3A	9.6	7.1	6.8	7.3	9.1	16.6
3B	8.5	6.6	6.5	7.1	10.1	9.7
3C	7.5	6.8	5.6	5.3	11.1	14.1
3D	5.9	5.6	5.7	8.2	9.4	11.9
3E	6.3	6.0	6.8	9.3	7.9	18.0
3F	6.7	6.1	5.9	6.9	15.7	14.1
4A	6.3	5.7	6.8	8.0	9.9	10.1
4B	6.8	6.9	6.5	8.7	8.6	10.9
4C	6.0	6.6	7.2	6.4	8.3	10.7
4D	9.8	9.6	6.8	9.9	10.1	12.0
4E	9.2	7.8	6.8	6.4	6.1	10.9
4F	10.1	8.2	6.3	7.2	7.7	10.5
5A	9.7	8.0	6.6	7.1	10.4	11.7
5B	9.4	7.4	5.7	7.5	7.6	10.1
5C	10.1	8.4	6.2	7.1	5.4	8.5
5D	6.9	6.0	5.9	6.7	6.4	7.8
5E	6.3	6.1	6.2	9.3	8.7	9.7
5F	6.6	6.2	7.2	7.2	8.8	9.7
6A	5.9	6.1	7.1	9.8	7.7	11.8
6B	7.6	7.2	6.0	7.0	7.1	12.0
6C	6.5	6.3	5.3	7.2	7.0	12.4
6D	8.0	8.5	5.8	6.2	6.5	11.0
6E	10.4	9.4	5.4	5.4	6.4	13.5
6F	10.5	10.5	8.1	10.4	10.8	13.5

¹ Treatment assignments are given in Table 3.2.

APPENDIX E

POINT INTERCEPTION DATA

APPENDIX E

POINT INTERCEPTION DATA

TABLE E.1. Point-Interception Data (Hits Per Frame Position) for Soil, Gravel and Plants on the Gravel Admix Field Plots Using a 36-point Sighting Frame and 20 Frame Positions Per Plot.

PLOT NUMBER																	
1A	1B	1C	2A	2B	2C	3D	3E	3F	4A	4B	4C	5D	5E	5F	6A	6B	6C
SOIL																	
18	12	26	12	15	18	12	12	23	19	10	20	17	14	26	22	14	12
22	8	21	11	11	20	18	10	15	19	11	18	13	14	23	24	14	14
14	14	20	9	15	19	12	15	17	24	11	20	16	15	25	21	15	14
20	13	21	9	14	21	18	13	17	20	11	18	14	15	23	24	14	10
25	17	19	14	19	20	23	8	22	20	18	19	13	13	25	25	20	12
17	13	19	11	13	19	14	12	27	23	11	21	14	8	26	17	14	14
21	9	22	10	14	19	15	9	17	15	10	22	16	17	31	26	15	12
18	17	21	8	13	19	17	12	18	16	11	21	17	18	26	19	14	13
15	12	19	10	16	16	16	12	25	19	12	16	20	11	19	21	12	11
16	13	17	12	19	20	18	12	22	18	13	22	18	12	29	25	17	13
20	15	25	11	18	17	12	14	31	22	14	23	18	9	27	19	13	15
16	7	19	11	16	17	15	10	25	19	11	18	21	10	31	23	14	16
18	18	17	11	18	18	15	11	18	19	14	15	16	11	23	25	14	11
16	12	21	12	14	16	13	9	22	18	10	21	18	10	21	20	16	13
18	11	13	19	17	22	20	15	19	22	11	21	17	13	25	28	20	11
18	20	20	11	17	18	17	9	26	21	16	23	18	14	26	23	7	14
14	9	20	14	15	16	16	9	22	16	13	19	18	14	26	28	13	13
21	10	22	9	18	16	17	10	21	24	10	19	21	18	27	19	14	12
14	14	21	11	12	19	18	8	26	15	11	21	16	11	16	18	14	11
12	15	18	14	22	16	16	14	21	23	11	20	18	16	26	28	17	9
GRAVEL																	
5	8	0	9	4	1	5	12	0	6	11	0	10	14	1	0	6	12
5	7	1	11	5	0	4	8	2	7	9	0	10	12	0	0	8	9
4	10	1	10	4	0	4	9	1	7	11	1	10	11	1	0	9	12
3	6	1	8	5	1	4	14	0	6	11	1	10	8	0	0	7	11
3	6	1	14	6	0	4	11	0	5	8	0	6	10	3	0	9	9
6	8	0	10	2	0	3	12	0	4	6	1	12	16	0	0	8	12
8	10	0	9	6	0	7	11	1	5	9	0	9	9	0	0	9	11
5	9	1	9	3	1	5	10	0	7	11	1	6	10	0	0	4	11
3	5	1	10	5	0	2	6	1	3	8	0	6	10	1	0	9	14
3	9	0	13	6	0	3	11	0	3	9	1	7	11	1	1	8	12
5	8	0	9	5	0	5	9	0	6	9	0	7	15	0	0	4	13
5	9	0	6	3	0	4	13	1	8	8	0	6	11	0	0	7	8
5	8	1	8	3	0	5	10	0	6	9	1	8	10	0	1	10	8

TABLE E.1. (contd)

PLOT NUMBER																	
1A	1B	1C	2A	2B	2C	3D	3E	3F	4A	4B	4C	5D	5E	5F	6A	6B	6C
GRAVEL (contd)																	
4	6	1	10	7	0	4	9	0	5	8	2	8	10	0	0	5	11
3	8	2	10	8	0	4	8	1	4	13	0	7	13	1	0	7	11
7	8	0	9	1	0	5	9	0	4	12	0	8	14	0	0	3	13
5	14	1	7	5	0	7	8	0	6	8	0	7	14	0	0	6	9
5	10	1	10	5	0	5	9	0	2	9	0	4	12	0	0	10	10
4	7	1	10	5	0	4	9	1	6	9	0	8	11	0	1	6	10
2	13	0	10	3	0	4	9	1	4	10	1	6	10	0	0	7	7
TOTAL PLANT																	
12	16	14	18	17	14	14	9	18	10	14	17	12	12	13	12	15	15
8	13	16	8	11	15	9	17	14	11	9	17	17	13	8	11	8	15
12	15	17	15	21	17	19	12	9	9	19	14	10	12	10	19	13	10
7	16	14	17	15	17	13	16	18	16	16	14	11	10	5	10	12	13
12	10	14	18	20	16	14	14	18	13	14	14	13	8	10	17	17	12
18	19	16	16	15	20	18	17	10	14	16	19	10	15	16	14	15	11
16	14	18	7	10	16	11	12	13	15	14	13	11	13	6	10	11	11
11	13	11	16	13	19	19	13	5	8	13	13	10	12	9	17	19	7
15	19	17	19	17	19	16	13	10	9	17	17	9	15	5	13	14	12
13	10	18	17	15	18	15	14	18	11	13	20	11	13	12	10	12	17
20	18	14	14	15	20	19	18	14	13	18	13	10	16	15	16	15	12
15	22	21	7	11	14	12	13	16	10	12	16	12	10	10	7	9	14
11	7	16	15	18	18	14	18	10	11	8	12	10	8	9	13	26	9
17	13	15	14	16	20	13	19	14	14	15	17	11	7	10	8	17	14
9	16	13	17	13	18	14	17	15	10	17	17	11	6	9	17	11	14
18	14	14	14	19	17	14	19	9	15	15	15	12	14	20	17	16	15
20	8	18	11	11	12	16	13	14	9	15	14	11	10	10	8	11	19
9	16	13	17	13	18	14	17	15	10	17	17	11	6	9	17	11	14
18	14	14	14	19	17	14	19	9	15	15	15	12	14	20	17	16	15
20	8	18	11	11	12	16	13	14	9	15	14	11	10	10	8	11	19
Bromus tectorum (cheatgrass)																	
12	8	4	15	16	14	11	7	7	4	7	12	2	0	4	8	8	7
8	13	8	6	15	9	5	10	11	6	8	11	7	4	5	4	7	7
11	2	1	6	7	10	12	2	9	0	6	5	1	0	0	2	3	0
10	12	8	10	9	7	6	3	9	5	1	11	3	3	4	4	7	2
6	8	10	3	2	6	8	6	4	5	4	10	7	5	2	3	1	2
6	9	10	11	14	11	12	9	7	6	12	8	3	5	2	10	6	5
1	12	8	11	7	11	4	7	9	7	8	8	6	2	0	6	6	8
6	1	2	5	8	5	4	6	7	1	6	7	3	1	1	1	3	1
13	11	8	6	9	12	7	6	2	8	11	9	3	8	5	6	8	1
10	8	11	3	4	3	7	4	5	7	4	8	4	2	1	3	2	6
8	4	7	11	7	16	12	7	3	1	7	7	2	4	2	12	11	3
10	12	8	8	9	9	6	4	1	4	9	8	3	8	2	4	5	5

TABLE E.1. (contd)

PLOT NUMBER																	
1A	1B	1C	2A	2B	2C	3D	3E	3F	4A	4B	4C	5D	5E	5F	6A	6B	6C
<u>Bromus tectorum</u> (cheatgrass) (contd)																	
5	2	2	5	4	14	5	8	5	5	5	7	3	0	1	2	1	2
12	12	6	6	10	13	12	7	6	5	11	5	4	8	5	10	7	4
12	14	19	3	5	5	10	6	6	5	6	8	7	3	6	0	2	4
6	4	7	12	11	12	10	10	2	2	3	5	1	2	2	8	20	3
12	7	9	12	8	12	4	8	7	8	8	8	3	1	3	3	7	3
4	8	1	9	4	7	2	4	1	3	6	5	2	0	0	5	2	2
12	6	7	6	11	12	5	8	1	7	5	7	3	8	11	10	6	5
11	5	13	3	6	5	9	5	6	3	7	8	3	4	5	6	2	11

<u>Agropyron</u> species (wheatgrasses)																	
1	5	6	0	0	2	8	4	6	7	7	3	6	7	5	4	6	5
0	3	5	7	1	6	9	7	7	4	7	7	5	6	8	7	7	5
6	8	9	10	9	7	8	9	9	5	7	10	8	7	10	11	8	9
2	3	6	8	8	7	7	6	7	5	10	6	6	9	8	7	8	10
2	5	6	4	7	8	1	10	10	5	5	6	8	7	6	8	6	12
4	4	6	4	7	5	6	3	1	3	6	6	6	7	8	8	6	4
6	4	6	6	7	6	7	8	9	7	6	6	5	6	5	3	4	4
5	8	10	11	11	10	8	7	10	10	8	6	9	5	9	16	12	9
4	7	7	9	6	8	9	9	7	6	5	9	7	6	10	8	7	9
2	5	5	3	5	10	2	6	7	8	9	5	5	11	3	4	9	5
2	8	3	5	5	3	6	6	2	7	6	6	7	6	6	4	7	3
4	7	7	8	6	9	8	8	9	5	8	8	5	7	3	8	6	6
6	8	12	9	9	4	8	6	13	6	6	12	8	12	11	7	10	15
5	6	7	7	5	7	7	8	8	6	7	8	6	7	9	6	7	8
2	8	2	4	6	9	1	6	9	4	5	7	5	6	3	7	5	10
2	2	8	3	6	6	3	7	8	8	4	7	8	6	7	3	6	6
2	5	5	2	8	8	8	11	6	6	6	9	8	5	7	5	8	9
4	8	8	7	7	11	10	13	14	7	10	11	7	5	9	11	8	12
5	8	7	6	8	4	9	11	7	8	10	7	8	6	9	7	5	8
6	3	4	8	3	7	6	6	8	5	8	5	8	4	5	2	9	8

<u>Sisymbrium altissimum</u> (Jim Hill mustard)																	
0	2	0	0	1	1	0	0	0	0	0	0	0	0	0	1	2	0
0	4	1	1	2	0	0	1	1	0	1	0	0	0	0	0	0	0
1	0	0	0	1	0	0	0	0	0	0	0	1	1	0	0	0	0
0	0	0	0	0	0	0	0	1	0	3	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	1
0	1	0	0	0	1	1	0	0	0	1	0	0	0	0	0	1	1
0	0	0	0	1	0	2	1	0	1	2	0	0	2	0	0	1	1
0	0	0	1	1	0	0	0	0	1	0	1	0	0	0	0	0	0
1	0	1	0	0	0	0	1	1	0	0	1	0	1	0	0	0	0
2	0	2	0	0	1	1	1	1	0	0	0	0	0	0	1	0	0
0	0	0	0	1	0	0	0	0	0	0	0	0	1	0	1	1	0

TABLE E.1. (contd)

PLOT NUMBER																	
1A	1B	1C	2A	2B	2C	3D	3E	3F	4A	4B	4C	5D	5E	5F	6A	6B	6C
<u>Sisymbrium altissimum</u> (Jim Hill mustard) (contd)																	
1	0	1	2	2	1	2	0	0	0	0	0	0	0	0	0	2	1
1	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	3	0	1	0	0	1	0	0	0	0
1	0	0	0	0	0	0	0	0	1	0	0	1	0	1	0	0	0
0	1	0	0	1	0	1	1	0	0	0	0	1	0	0	1	0	0
1	0	1	0	0	0	0	0	0	0	1	0	0	0	0	0	2	0
0	0	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0
1	0	0	1	0	1	0	0	1	0	0	1	0	0	0	0	0	0
2	0	1	0	1	0	1	2	0	0	0	0	0	0	0	0	0	0
<u>Festuca ovina/Poa canbyi</u> (Sheep fescue/Canby bluegrass)																	
0	1	0	0	0	0	0	0	0	0	1	1	1	1	0	0	0	0
1	0	0	0	0	1	0	0	0	0	0	0	0	0	0	1	0	1
0	1	1	1	0	0	0	1	0	0	1	0	0	1	0	1	1	1
0	1	0	0	0	0	1	0	1	0	0	0	0	0	1	1	0	2
0	0	0	1	2	1	0	1	0	1	0	0	1	0	0	0	1	0
0	0	1	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0
1	1	2	1	0	1	2	1	1	1	0	0	1	2	0	0	1	2
0	1	0	1	0	0	2	0	0	0	0	0	0	0	1	0	0	1
2	1	0	1	1	2	1	1	0	0	1	0	2	0	1	1	0	0
0	1	1	0	0	0	1	0	0	0	0	0	1	1	1	0	0	1
0	0	1	0	0	0	0	1	0	0	0	0	0	0	0	1	0	0
1	0	4	3	2	0	2	0	0	0	1	1	0	1	0	1	1	0
2	0	1	1	0	0	0	0	0	1	0	0	0	0	1	0	1	0
0	0	0	0	0	0	1	1	0	1	1	0	0	0	1	0	2	0
0	0	0	0	0	0	0	0	0	1	1	0	0	0	0	1	0	0
1	0	0	0	0	0	1	0	1	0	0	0	0	1	0	0	0	2
1	0	3	0	1	0	2	0	0	0	1	1	1	0	0	1	1	0
0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	4	0
1	0	0	0	1	0	0	0	0	1	0	1	0	1	0	0	0	0
<u>Secale cereale</u> (Cereal rye)																	
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0
0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0
2	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

TABLE E.1. (contd)

PLOT NUMBER																	
1A	1B	1C	2A	2B	2C	3D	3E	3F	4A	4B	4C	5D	5E	5F	6A	6B	6C
<u>Secale cereale</u> (Cereal rye) (contd)																	
1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	1	0	0	0	0	0	0	0	1	1	0	0	0	1	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
3	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
<u>Salsola kali</u> (Russian thistle)																	
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0
0	1	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	1	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0
0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	1	1	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	1	0
0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0

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